Enabling world-class food innovation and sustainable food production

- with interdisciplinary research solutions from Aarhus University

AARHUS UNIVERSITY

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Introduction

An increasing population and changing consumer behaviours requires that we produce and secure more food that delivers on consumption and lifestyle needs. However, food production systems put pressure on the environment and the climate as well as on scarce resources. These global challenges demand the need for innovative solutions in the food chain that lead to more responsible, resource-efficient and green food production systems.

The challenges and suggested enablers formulated by the Danish Food Industry in the "World-Class Food Innovation towards 2030" will successfully be delivered on by bringing together interdisciplinary teams involving both industry and research expertise. This approach will ensure the needed context, scientific expertise and infrastructure and an ability to apply the new innovation into a business context.

Aarhus University is very strong within food research and education and has a long tradition for identifying and building the necessary collaborations across disciplines, national borders and institutions together with industrial partners. Aarhus University acknowledges the importance of a close dialogue and partnership with the food industry in order to ensure the relevance and impact of its research outcomes.

A new location for excellence in food research will strengthen this close collaboration with the industry

A close ongoing collaboration with the food industry and health sector with a view to identifying future solutions within the food area is just one of the reasons why the Department of Food Science at Aarhus University moves into a new building at Agro Food Park in Skejby. The department will contribute to the food ecosystem through open collaboration with its research and development based experts and young talent, supported by its state-of-the-art research infrastructure. The department will be physically positioned to act as a key contact point for the food related talent across Aarhus University and specifically in developing a strong bridge to health research at the Aarhus University Hospital. It also looks forward to an active role in connecting students to the food industry through its teaching activities, student projects and research projects.

Agro Food Park is the leading food innovation park in Denmark and it is the home to the ever strengthening Danish food cluster. Currently, Agro Food Park houses ca. 80 companies, both large and small, that together underpin a world leading profile within food innovation. Therefore Agro Food Park is well positioned to significantly contribute to delivering new solutions to the global challenges related to foods, food quality, food supply, food waste, sustainable food production

under changing climatic conditions, and to address the increased occurrence of lifestyle diseases.

Complex problems require complex solutions

One of the interdisciplinary centres of Aarhus University– Centre for Innovative Food Research (iFOOD) – is led by Department of Food Science, but brings together the relevant expertise and knowledge from a wide range of departments across Aarhus University. The iFOOD Centre was established to address the food related challenges associated with changing consumer behavior and food consumption patterns due to new lifestyle needs as expressed by an increasing consumption of convenience foods both inside and outside the home. The iFOOD center is focused on delivering innovative food solutions and deliver healthy and natural convenience foods, with priorities in new processing technologies, raw material quality, novel packaging solutions, innovative production systems and validating health attributes of the food and ingredient solutions.

Agricultural and food sciences at Aarhus University are among the elite according to international rankings within these fields. In 2017, Aarhus University ranked as no. 10 in the National Taiwan University Ranking and was placed as no. 12 in the U.S. News Best Universities ranking.

Reader's guide

In the following document the capabilities and facilities of Aarhus University within food research and innovation are mapped against the key innovation enablers identified and described in the strategy "World-Class Food Innovation towards 2030." presented in 2017 by the Danish Food Industry. The needs and key outcomes mentioned under each topic are directly from the industry strategy.

The seven key innovation enablers are:

1. Sustainable production through circular economy
2. Food design – from molecular interaction to excellent eating
3. Food analytics – ensuring and documenting safe foods
4. Omics technologies – from molecules to understanding
5. Foods contributing to health and well-being
6. Agile and intelligent automation
7. Connected and competitive through smart use of big data

In each of the seven chapters, the relevant competences and facilities at Aarhus University are listed, along with case studies describing current interdisciplinary research and innovation activities.

Furthermore, a description of two interdisciplinary research centres; iFOOD, Centre for Innovative Food Research and CBIO, Centre for Circular Bioeconomy, are presented as these are the most relevant interdisciplinary centres aligned to the food industry strategy.

Abbreviations used in the document

Direct contact details for each of the departments and faculty are provided at the back of this document.

Enabler 1

Sustainable production through circular economy

Needs

- Valorize raw materials, waste and side streams
- Delivery of natural ingredients
- Ensure a supply of safe, high quality raw materials
- Solve the supply of protein
- Optimize the use of raw materials, ingredients, energy, water and packaging
- Develop and implement tools to validate sustainability

Key Outcomes

- A more sustainable production; producing more with less
- Enhanced cascade utilization of all raw materials
- Improved documentation of environmental impact

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Sustainable production through circular economy', we have taken a food chain approach by aligning the relevant competences and facilities at Aarhus University to three sub-topics along the value chain:

- Production of sustainable and natural food and ingredients
- Valorization and validation
- Supply chain and acceptance in the market

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

PRODUCTION OF SUSTAINABLE AND NATURAL FOOD AND INGREDIENTS

- Pre-breeding and phenotyping (FOOD)
- Improving mineral micronutrients in the cereal grain through molecular manipulation, i.e. in transgenic plants and in plants modified by genome-editing tools (MBG)
- Utilization of genetic resources (FOOD)
- Sustainable production strategies for different raw materials (FOOD+AGRO+ ENG)
- Utilization of seasonal and applied variation (FOOD)
- Organic plant based food production systems in open field and greenhouse (FOOD+AGRO+ENG)
- Expertise in fruit, vegetable and plant based foods (FOOD)
- Local primary food production (FOOD+AGRO)
- Local processed food production (FOOD)
- Primary production of plant based foods and ingredients in innovative, closed systems e.g. urban farming (FOOD)
- Resilient plant production systems (FOOD+AGRO)
- Innovative strategies in nature based solutions in landscape development and land-use (ARTS)
- Resource minimization in primary food production (FOOD+AGRO+ENG)
- Optimize resource utilization (FOOD+AGRO+ENG)
- Optimized nutrient use efficiency of plant crops (N, P) (FOOD+AGRO)
- Expertise in lighting, humidity and nutrition to optimize plant growth and minimize resource inputs (FOOD)
- Bio-based compost and growing media for plant foods (FOOD)
- Plant-based fertilizers from waste (FOOD)
- Green manure (FOOD)
- Agro-ecological service crops (FOOD)
- Reduced tillage food production systems (FOOD+AGRO+ENG)
- New protein food crops (FOOD+AGRO)
- Enabling meat production from dairy cows through finish-feeding (FOOD-ANIS)
- Improving feed conversion and meat quality through compensatory-feeding strategies (FOOD+ANIS)
- Exploiting use of bull calves/steers from Jersey (milking breed) for meat production (FOOD+ANIS)
- Reduce food waste (FOOD+ENG)
- Use diversity in raw materials resources (FOOD)

VALORIZATION AND VALIDATION

- Utilization of side streams (FOOD+ANIS)
- Breeding resources for plants bioplastics (MBG)
- Producing bioplastics from plants (MBG)
- Evaluation of new packaging formats in relation to food quality (FOOD)
- New ingredients (FOOD+ANIS)
- Analyse the ingredients in food (FOOD+ANIS)
- Fractionation technologies (FOOD)
- Analysis of food structure and sensory assessment (FOOD)
- Exploitation/utilization of new protein sources (FOOD+ANIS+ENG)
- Protein quality of new protein sources (FOOD+ANIS)
- Evaluation of anti-nutritional factors in plant materials e.g polyphenol oxidase, trypsin inhibitor and chlorophyll (FOOD+ANIS)
- Evaluation of oxidative changes in plant proteins and identification of redox enzymes (FOOD)
- Raw material quality in relation to production factors (FOOD)
- Exploitation of seasonal and other variation (FOOD+ANIS)
- Exploiting superior cuts (muscles) for high-value meat products (FOOD)
- Design and develop integrated processes for enhanced cascade utilization of all raw materials (ENG)
- Digitalization /auto-control of the parameterization of the plant oil refining process and waste stream utilization (access to the Multi-Purpose Vessel pilot plant) (ENG)

SUPPLY CHAIN AND ACCEPTANCE IN THE MARKET

- Reduce food waste in the supply chain (FOOD+ENG)
- Reduce food waste at the consumers (FOOD)
- Quality and sensory perception of new food and ingredients (FOOD)
- Analysis of determinants of sustainable behaviors, including sustainable food choices, and avoidance of food waste at the consumers (MAPP)
- Analysis of consumer acceptance of sustainable alternatives, for example alternative protein sources, meat substitutes and products based on side streams (MAPP)
- Consumer acceptance of alternative food processing technologies, new packaging materials (MAPP)
- Determinants of demand for organic food (MAPP)
- Reconfiguration of value chains for a more sustainable food production (MAPP)
- Acceptance of sustainability branding (MAPP)
- Environmental and economic cost benefit analysis (ENVS+ENG)
- Life Cycle Sustainability (LCA) Assessment of food products, production systems and value chains (AGRO)
- Environmental life cycle assessment including impacts on climate, soil carbon sequestration, biodiversity, eutrophication, land and energy use etc. (AGRO)
- Identification of environmental hotspots and improvement options using LCA (AGRO)
- Document and validate environmental impact and sustainability in the value chains using LCA (AGRO)

PRODUCTION OF SUSTAINABLE AND NATURAL FOOD AND INGREDIENTS

- State-of-the-art glasshouse facility (FOOD+AGRO)
- State-of-the-art walk in climate chambers (FOOD+AGRO)
- Urban farming facility for multi-layer growing of plants (FOOD)
- 285 ha organic and conventional land for grain, seed and grass production (AGRO)
- 75 ha organic and conventional land for fruit and vegetables production (FOOD)
- Field equipment and machines for organic and conventional fruit and vegetable production (FOOD+ENG)
- Semi-field confined growth facilities (FOOD+AGRO)
- Meat quality lab (FOOD)
- Dairy pilot plant (FOOD)
- Minirhizotrones for in-field root studies (FOOD)
- Fruit and vegetable quality lab (FOOD)
- Non-invasive analytical equipment to measure plant responses (FOOD+AGRO)
- Development of methods to extract and clean white protein from green biomass (FOOD)
- Extraction and characterization of secondary metabolites and active ingredients (FOOD+AGRO+ANIS)
- Lab scale filtration technologies for purification (ultra- and microfiltration) and profiling of proteins (size exclusion) (FOOD)
- Platform for testing bioactivity and functionality (FOOD+ANIS)
- Lab phenotyping of milk and food in relation to genetic background, including components and functional/technological properties (FOOD)
- Pretreatment and lab-scale double screw extractor (FOOD)
- ISO approved expert sensory profiling lab and associated facilities (FOOD)
- Objective expert sensory reference panels in different product categories (FOOD)
- Pilot plant for extraction of protein from green biomasses (legumes & grasses) (ENG+AGRO)
- Biological evaluation of digestibility and nutritive value with laboratory animals (ANIS)
- Digestibility and balance experiments with pigs, poultry and cattle (ANIS)
- Large scale feeding experiments with pigs, poultry and cattle (ANIS)

VALORIZATION AND VALIDATION

- Development of methods to extract and clean white protein from green biomass (FOOD)
- Extraction and characterization of secondary metabolites and active ingredients (FOOD+AGRO+ANIS)
- Platform for quantitative analysis using advanced equipment for food profiling, incl. mass spectrometry based (LC-ESI-MS, 2D-LC-IM-Q ToF MS/MS, GC-MSD, LC-MS QQQ) and spectroscopic techniques (VIS/UV, FT-IR, ESR, fluorescence, DLS, and SLS, zeta-sizer, NMR) (FOOD)
- Platform for analyzing bioactive components by non-targeted and targeted LC-MS/MS (ANIS)
- FPLC-gel filtration technologies for profiling of proteins (FOOD)
- Platform for testing bioactivity (e.g. in vitro cell based assays, primary cells and RT-PCR) and functionality (FOOD+ANIS)
- Lab phenotyping of milk and food in relation to genetic background, including components and functional/technological properties (FOOD)
- Pretreatment and lab-scale double screw press (FOOD)
- Meat quality lab (including texture, fibre typing, histochemistry and metabolite profiling) (FOOD)
- Pressured fluid extraction system, short path distillation (ENG)
- Multi-Purpose Vessel pilot plant (MPV pilot plant). The MPV is able to perform plant / animal oil / fat refining with fully auto-control and digitalization of parameters (ENG)
- Lab equipment, including GC-MS, HPLC, NMR, DSC, TLC-FID, FTIR-NIR, etc (analysis equipment for lipids analysis and characterization) (ENG+ANIS)
- Full range of facilities to support protein production, isolation / fractionation, analysis and characterization. For example, UPLC, Nano UPLC/QTOF MS, 1D/2D gel apparatus and fermenters for yeast based enzyme production (MBG)
- Genome editing for crops and edible plants. Genotyping. Gene expression analysis in edible plants. Tissue culture for development of genome editing techniques (MBG)

SUPPLY CHAIN AND ACCEPTANCE IN THE MARKET

- ISO Approved Expert Sensory Profiling Lab and associated facilities (FOOD)
- Objective Expert Sensory Reference Panels in different product categories (FOOD)
- Consumer behaviour lab for experimental studies including eye-tracking technology, physiological measures of arousal, face reader for online measure of emotional response (MAPP)

Coloring agents from juice press residues may be used in food production

Within the framework of the COLARO project, researchers, producers, and the ingredient company Chr. Hansen A/S collaborated to identify the potential of extracting natural coloring agents from press residues in juice production. Today, the press residues are of little value and may constitute a waste problem for the juice producer. Thus, from an economic as well as an environmental desire to utilize all resources, there is an increased focus on utilization of side streams from berry and juice production.

The colour remaining in the residue from e.g. Aronia berries may be used in foods. Aronia berries have intense colours, and also contain beneficial substances such as antioxidants and polyphenols, which makes the species interesting. Colouring agents are expensive, and consumers are increasingly interested in authentic and natural ingredients as an alternative to artificial colourants. The method used to extract the colourant from the press residue as well as the method used for juice production are of vital importance. Usually, more than half of the colouring agents are left in the press residue. Project experiments have demonstrated that careful cold pressing will provide residues that are richer in colourants than the traditional, industrial juice production, which includes heating and the addition of enzymes. Fruit colour stability remains a challenge, as results demonstrated that colour properties depend on both pH and temperature during storage. The experiments included Aronia berries, blackcurrants, sour cherries and elderberries. Research including concentrates – liquid colorants instead of colour powder – seemed especially promising. Concentrates demonstrated the ability to maintain the berry taste as well as the colour, and they were excellent in products with low pH values such as yogurt and other sour milk products. A consumer test demonstrated a preference for fruit-based colourants instead of the standard coloring agent Carmine Red. The AU part of the project that was led by Senior Scientist Martin Jensen, Department of Food Science, Aarhus University, ended on 30 June 2018, and based on the promising results a research and industry consortium has been developed and a follow-up project PROBIOFA has been granted.

Contact

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This case study is also aligned to enablers 2 and 3

Residual product from potato production may be a sustainable alternative to animal protein in foods

Within the project ProPotato Aarhus University collaborates with the University of Copenhagen, KMC, AKV Langholt and DuPont Industrial Biosciences to develop new and healthy protein-based ingredients. The project is led by Carsten Scavenius, Department of Molecular Biology and Genetics, and includes expertise from the Department of Food Science and the MAPP Centre at Aarhus University. Research includes method development, partly to remove natural, inherent potato toxins (found especially in green potatoes), and partly to inhibit the enzyme that turns potato products brown. In relation to the browning enzyme (polyphenol oxidase), Andreas Møller Stokbro, an AU-FOOD Master's student affiliated with the project, has carried out a number of experiments using natural inhibitors that stop enzyme activity. Among other items, he tested chili, coriander, beetroot and liquorice root. Liquorice root and liquorice root extract were particularly effective when it came to stopping enzyme activity.
Concurrently, the MAPP Centre, carried out a series of consumer studies on consumer attitudes in relation to replacing protein from meat with potato protein in various products; and generally, consumer attitudes towards plant-based potato alternatives are positive. At the Aarhus Food Festival, ProPotato representatives will introduce consumers to a plant-milk, based on potatoes, and will carry out a consumer study in relation to this.

Contact

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This case study is also aligned to enablers 2 and 3.

Enabler

2.

Food design – from molecular interaction to excellent eating

Needs

- Understand the molecular properties of ingredients and the interactions in the food matrix during processing, storage and consumption
- Design new sustainable, healthy, high quality foods, both fresh and preserved with extended shelf life to fulfill consumer and customer demands
- Improved understanding on how processing and storage affect product quality in order to improve existing products
- Bring together relevant capabilities in order to characterize structure, interactions, matrices in food and how these are influenced by processing approaches and storage conditions in order to deliver new products

Key Outcomes

- Improved understanding of the impact of tailored food design
- Development of new eating experiences
- New technologies that can keep food products fresh for a longer period of time

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Food design – from molecular interaction to excellent eating', we have aligned the relevant competences and facilities at Aarhus University to the following three logical sub-topics along the value chain:

- Design of new and adding value to existing food and ingredients
- Characterization and technologies for future food and ingredients
- New eating experiences

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

DESIGN OF NEW AND ADDING VALUE TO EXISTING FOOD AND INGREDIENTS

- Securing and exploiting local food production (FOOD)
- Organically based food and ingredients (FOOD+AGRO)
- Adjust food production to local environment and cultivation conditions (FOOD+AGRO)
- Handling, processing and storage solutions for fresh fruit and vegetables (FOOD)
- Natural preservatives (FOOD)
- Production of induced and required quality properties (FOOD)
- Differentiated sensory properties of fruit and vegetables (FOOD)
- Improving stability of natural colorants (FOOD)
- Designing new plant carbohydrates (MBG)
- High-resistant starches (MBG+ANIS)
- Production of amylose-only starches (MBG)

CHARACTERIZATION AND TECHNOLOGIES FOR FUTURE FOOD AND INGREDIENTS

- Novel packaging materials (FOOD)
- Postharvest and storage technology expertise (FOOD+ENG)
- Chemical, structural and sensory changes in the food under differentiated storage conditions (FOOD)
- New ingredients with differentiated properties (stability, functional, bioactive) (FOOD)
- Relations between processing, microstructure and functionality (FOOD)
- Novel formulation of natural colorants using biotechnology approaches or complexation with e.g. proteins and sugars (FOOD)
- Structural and functional characterization of milk components (MBG)
- Protein biophysics: Key interactions between aggregates (milk proteins), food-modifying enzymes and lipids (iNANO)
- Quantification and whereabouts of vitamin B12 in raw complex fluids and soft solids, during processing and in the ingredients (MBG)
- Characterization of molecular interactions governing vitamin B12 binding in the food matrix (MBG)
- Understanding starch biosynthesis and starch digestion (MBG+ANIS)
- Soft matter physics: Determination of structures and structural development in foods and different phases of micro-emulsions, including phase separation kinetics (iNANO)

NEW EATING EXPERIENCES

- Influence of the food matrix on vitamin B12 bioavailability in the elderly population (MBG)
- Influence of food matrix and protein complexation on vitamin D3 stability and availability (FOOD+HEALTH)
- Analysis of consumer preferences across generations (FOOD)
- Ultra precise profiling of food sensory properties (FOOD)
- Developing food in synergy with the industry for the future consumer (FOOD)
- Securing food quality in export markets (FOOD)
- Understand the opportunities and risks in changing export markets (FOOD)
- Cross-cultural new food design and development, e.g. future key export markets e.g. Asia (FOOD)
- Food consumption / eating patterns of the future, lifestyle and food products (FOOD)
- Multicultural studies to support export markets (FOOD)
- Measuring and sensing flavours and aromas in beer to develop new beers (iNANO)
- Culture and design of meals (ARTS)
- Technologies in the development of food services (experiences from studies in telemedicine) (ARTS)
- Development of apps to register food consumption by patients (ARTS)
- Use of consumer insights in consumer-oriented new product development (MAPP)
- Management of new product development projects (MAPP)
- Methodologies for idea generation and screening, concept tests, prototype tests and market tests (MAPP)
- Analysis of value chain configurations for improved market orientation (MAPP)

DESIGN OF NEW AND ADDING VALUE TO EXISTING FOOD AND INGREDIENTS

- State-of-the-art glasshouse facility for new crop production (FOOD)
- State-of-the-art walk in climate chambers (FOOD)
- Urban farming facility for multi-layer growing of plants and upregulation of bioactive compounds (FOOD)
- 75 ha organic and conventional land for fruit and vegetables production for manipulation of production factors and exploitation of germplasm (FOOD)
- Semi-field confined growth facilities (FOOD)
- Postharvest facilities for storage and shelf life assessment (FOOD)
- Dairy pilot plant (FOOD)

CHARACTERIZATION AND TECHNOLOGIES FOR FUTURE FOOD AND INGREDIENTS

- Texture analysis (FOOD)
- Aroma and volatile analysis (FOOD)
- GC-MS and LC-MS for bioactive components and metabolites (FOOD+ANIS)
- Advanced equipment for food constituent profiling, including mass spectrometry based analysis (FOOD)
- Instruments for analyzing microstructure and material properties of food (FOOD)
- Lab and pilot scale food processing and fractionation (FOOD+ANIS)
- Platform for quantitative analysis using advanced equipment for food profiling, including mass spectrometry based techniques (LC-ESI-MS, 2D-LC-IM-Q ToF MS/MS, GC-MSD, LC-MS QQQ) and spectroscopic techniques (VIS/UV, FT-IR, ESR, fluorescence, DLS, and SLS, zeta-sizer, NMR) (FOOD)

NEW EATING EXPERIENCES

- Genome editing for crops and edible plants (MBG)
- Genotyping (MBG)
- Biochemical and molecular characterization techniques (MBG)
- Cell culture intestinal models (MBG+ANIS)
- Animal and clinical studies (MBG+ANIS)
- Genome editing for crops and edible plants (MBG)
- Genotyping (MBG)
- Gene expression analysis in edible plants (MBG)
- Tissue culture for development of genome editing techniques (MBG)
- SAXS, SANS, light scattering (iNANO)
- Spectroscopic techniques (fluorescence, CD, stopped-flow, FTIR, scanning and isothermal calorimetry, NMR, quartz crystal microbalances, atomic force microscopy and dynamic and static light scattering) (iNANO)
- Sensors for beer taste identification (iNANO)

- ISO approved expert sensory profiling lab and associated facilities (FOOD)
- Objective expert sensory reference panels in different product categories (FOOD)
- Consumer measurement capabilities for different demographic groups, children, adolescents, elderly (FOOD)
- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Multisensory perception and interactions in food quality and eating experiences (FOOD)
- Multivariate data analysis tools and expertise (FOOD)
- Centre for Food Culture Studies (ARTS)
- Centre for STS (Science Technology Society) studies (ARTS)
- Consumer behaviour lab for experimental studies including eye-tracking technology, physiological measures of arousal and face reader for online measure of emotional response (MAPP)

The perfect packing of fresh fruit and vegetables must meet many demands

Within the framework of the Quality Packaging (Kvalipak) project, Aarhus University collaborates with a number of companies and the Danish Technological Institute to develop new types of packaging that may increase the shelf life of fresh fruit and vegetables.

The packaging of fresh fruit and vegetables constitutes a challenge as these are living products that continue to change quality, even after harvest. On one hand, packaging is necessary to avoid dehydration and product weight loss and to keep products crisp and appetizing on their journey from harvest until they are available in the shops. On the other hand, using inappropriate packaging may "suffocate" the products or enhance the microbial development.

Project leader and Associate Professor Merete Edelenbos represents the Department of Food Science at Aarhus University in the project, and she explains:

- In the project we study two aspects of packaging; alternatives to the existing conventional plastic materials, as well as solutions that are able to change the microclimate inside the packages and thus influence the microbial load.

- Within the framework of the project, we examined whether plant extracts that are similar or related to the products – such as e.g. thyme oil – might be able to reduce the microbial load on carrots, but this solution didn't work, as one could taste the thyme oil in the carrots and the oil didn't have any effect.

Bioplastics as a potential alternative

The most promising research results include alternative types of packaging materials. Bioplastics are based on renewable resources and are also bio-degradable, and they hold potential in relation to controlling bacterial growth due to higher water vapor transmission rates. Project experiments included packaging of root vegetables and strawberries in conventional plastic material (oil-based BOPP film) as well as more environmentally friendly bioplastics (polylactate film (PLA) and starch-based bioplastics).

- Bioplastics demonstrate promising properties as to moisture regulation; however, the materials need further development as certain technical challenges exist in relation to the strength and sealing of bioplastics as well as material transparency, but these challenges can be solved, says Merete Edelenbos.

Consumers prefer alternatives to plastics

- Finding alternatives to plastic materials is a hot topic, globally speaking. Consumer resistance to plastic packaging of fresh fruit and vegetables is increasing, but the problem is not as simple as that, says Merete Edelenbos. She further emphasizes that appropriate packaging is necessary if we want fresh and crisp vegetables and less food waste.

- The perfect packaging for fruit and vegetables does not yet exist. Our current research efforts with bioplastic packaging are not yet fully developed.

Department of Food Science at AU wants to be part of this development process as our knowledge of fresh fruit and vegetables may contribute to finding the best solutions, says Merete Edelenbos. The Kvalipak project received funding of 3.5 million DKK from the Ministry of Environment and Food of Denmark's Green Development and Demonstration Programme (GUDP), and runs until the end of 2018.

Contact

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This case study is also aligned to enablers 1 and 3.

Milk protein may help improve vitamin D uptake

Within the framework of the DFORT project, funded by Innovation Fund Denmark with an amount of 13 million DKK, researchers from Aarhus University cooperate with a number of Danish and international partners to improve vitamin D availability. During the winter period, vitamin D deficiency is a common problem in the northern part of the world, affecting up to 1 billion people. There is every indication that vitamin D has a substantial impact on our health. One way of ensuring that we take up sufficient vitamin D is to fortify foods with the vitamin, which is mainly produced in our skin when exposed to sunlight. However, vitamin D fortification is complicated as the vitamin is fat-soluble and prone to degradation in foods.

Professor Daniel Otzen from the iNANO Centre at Aarhus University, together with his PhD student Jannik Nedergaard Pedersen (now a Postdoc at iNANO) used model systems to study how selected milk proteins are able to form vitamin D complexes and thus protect the vitamin against degradation long enough to ensure that vitamin D is absorbed into our digestive system.

- Our hypothesis was that a complex consisting of the milk protein α-lactalbumin and a fatty acid might form a protective membrane around the vitamin. However, these complexes quickly disintegrated because of the acidic stomach environment. We then discovered that the pure protein, α-lactalbumin, is able to bind vitamin D – very efficiently. It is a flexible protein which quickly looses its structure and thus forms a larger surface on which to bind the vitamin. This was a bit of an eye-opener, says Daniel Otzen.

The α-lactalbumin whey protein is a natural component in milk, and occurs in large quantities. Usually, another whey protein, β-lactoglobulin, is used to bind vitamin D in fortified milk products. However, in this case α-lactalbumin demonstrated the best effect at a low pH value, i.e. in an acidic environment.

Next, Project Leader Trine Kastrup Dalsgaard, Department of Food Science, studied the stability of vitamin D3 in food systems. It has been demonstrated that milk and juice are able to significantly improve solubility and stability of vitamin D3, but that milk may provide further protection of the vitamin. At Department of Food Science and Department of Clinical Medicine, a long-term intervention study – in rats and in humans – is currently planned in order to study vitamin bioavailability and the effect of complex formation using milk proteins. It is hypothesized that protein-bound vitamin D will degrade less than normally in the acidic stomach environment resulting in increased vitamin uptake. This will allow an increased vitamin uptake and help reduce uptake rate as well as the utilization of the vitamin.

Partners in this interdisciplinary project include researchers from Aarhus University Hospital, iNANO and Departments of Food Science and Clinical Medicine at Aarhus University, Leida University in Spain, Groningen University in the Netherlands as well as the companies Arla Foods Amba, Arla Foods Ingredients, DSM and Rynkeby. The project ends by 30 August 2020.

Contact

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This case study is also aligned to enablers 4 and 5.

Enabler

3

Food analytics, ensuring and documenting safe foods

Needs

- Qualitative measurement of food components and contaminants,
- On-line and in-line tools for early assessment of quality and safety aspects
- Validation of food with new formulations (changes in: ingredients, raw materials, temperature, pH)
- Predict changes in foods during transport and shelf life
- Describe how food quality is impacted by raw materials, ingredients, processing and packaging
- Develop new solutions to overcome antibiotic resistance and ensure a One Health approach
- Establish track and trace to provide traceability and increased trustworthiness in food products
- Develop early warning systems to manage risk

Key Outcomes

- Improved documentation of safety and quality
- Advanced quantitative and analytical methods
- Methods for risk prediction

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Food analytics, ensuring and documenting safe foods', we have taken a food chain approach and aligned the relevant competences and facilities at Aarhus University to three sub-topics along the value chain:

- Safe production of food and novel ingredients
- Validation of new formulations and quality of foods
- Consumer validation of new formulations and quality of foods

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

SAFE PRODUCTION OF FOOD AND NOVEL INGREDIENTS

- Sustainable production systems (FOOD)
- Organic production systems (FOOD)
- Raw material quality in relation to further processing (FOOD)
- Exploitation of seasonal- and other variation (FOOD)
- Utilization of genetic resources and food quality in relation to genetic background (FOOD)
- Handling, processing and storage solutions for fresh fruit and vegetables (FOOD)
- Natural preservatives (FOOD)
- Production of induced and required quality properties (FOOD)
- Emerging technologies' impact on and implications for food quality and function (FOOD)
- Development and utilization of natural ingredients (FOOD)

VALIDATION OF NEW FORMULATIONS AND QUALITY OF FOODS

- Exploitation and optimization of structural and functional properties of foods (FOOD)
- Biochemical analysis of food components (fat, protein, carbohydrate, peptides, vitamins, metabolites and aroma components) (FOOD+ANIS)
- Fractionation technologies (FOOD)
- Analysis of food structures (FOOD)
- Oxidative changes in proteins and lipids in food and aqua feed (FOOD)
- Stability of vitamins and colorants (FOOD)
- Quantitative determination of food components using NMR technologies (FOOD)

CONSUMER VALIDATION OF NEW FORMULATIONS AND QUALITY OF FOODS

- Analysis of consumer preferences (FOOD)
- Ultra precise profiling of food sensory properties (FOOD)
- Consumer measurement capabilities for different demographic groups, children, adolescents and elderly (FOOD)
- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Cross-cultural new food design and development, e.g. future key export markets e.g. Asia (FOOD)

SAFE PRODUCTION OF FOOD AND NOVEL INGREDIENTS

- State-of-the-art glasshouse facility for new crop production (FOOD)
- State-of-the-art walk in climate chambers (FOOD)
- Urban farming facility for multi-layer growing of plants and upregulation of bioactive compounds (FOOD)
- 75 ha organic and conventional land for fruit and vegetables production for manipulation of production factors and exploitation of germplasm (FOOD)
- Semi-field confined growth facilities (FOOD)
- Postharvest facilities for storage and shelf life assessment (FOOD)
- Dairy pilot plant (FOOD)

VALIDATION OF NEW FORMULATIONS AND QUALITY OF FOODS

- Texture analysis (FOOD)
- NMR platform – foods, saliva, blood, intestinal content/ faeces (FOOD)
- GC- and LC-MS/MS platform – food, saliva, blood and intestinal content/faeces and tissues (FOOD+ANIS)
- Real time RT-PCR for gene regulation analysis (FOOD+ANIS)

CONSUMER VALIDATION OF NEW FORMULATIONS AND QUALITY OF FOODS

- ISO approved expert sensory profiling lab and associated facilities (FOOD)
- Objective expert sensory reference panels in different product categories (FOOD)
- Consumer measurement capabilities for different demographic groups, children, adolescents and elderly (FOOD)
- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Consumer behaviour lab for experimental studies, including eye-tracking technology, physiological measures of arousal and face reader for online measure of emotional response (MAPP)

Development of “wooden breast” in slaughter chickens

The phenomena “wooden breast” is a muscle abnormality where the breast muscle appear bulgy and hard and can lead to degradation of the meat or even discarding of the affected breast filet, at a huge cost for the slaughter plant.

The etiology of wooden breast development is unknown, and both genetic and environmental factors have been suggested in the literature. Under conditions of Danish poultry production we have registered development of wooden breast already from day 21of the slaughter chicken production i.e. 10-14 days prior to slaughter. A subjective palpation method correlated to a biochemical profile of wooden breast tissue has led to robust objective determination of wooden breast. In order to identify single/few biological markers for faster and easier detection of wooden breast, small chickens have been followed until the time of slaughter in order to identify early predictors of wooden breast development. This work is ongoing.

The hypothesis is that capillarisation of the breast muscle is at the limit of sustaining oxygen demands to the tissue and removal of carbon dioxide and waste products from the breast muscle tissue. If the environment is sub-optimal i.e. slight changes in oxygen/carbon dioxide levels this may initiate development of wooden breast as there seem to be similar defects upon experimentally induced oxygen deficiency of muscle tissue.

The analytical developments assist in screening flocks for factors affecting the wooden breast frequencies i.e. flocks in different housing conditions and originating from eggs from hens at different ages (difference in robustness). These investigations have indicated that both oxygen/carbon dioxide levels in the stable and hen age may have an impact on the frequencies but this need to be investigated in more controlled environments before any solid recommendations can be given to the farmers.

These results have been obtained in collaboration with DMRI, TI, Danpo and a poultry farmer. The ultimate aim is to be able to advise farmers on how to minimize the frequency of wooden breast in the flocks.

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This case study is also aligned to enabler 1.

Reduced spraying of apples is possible

Consumers are concerned about pesticide residues in fruit and vegetables. A previous research project at Department of Food Science, Aarhus University, has shown that the number of sprays in apple orchards can be significantly reduced if spraying is optimized between early spring and fruit set. This avoids spraying on the fruit itself, so there are no pesticide residues on the actual apple. Three growers tested this new spraying strategy, by growing 'Aroma' apples and a cultivar of own choice as a comparison.

Project Leader, Senior Researcher at Department of Food Science, Marianne Bertelsen, says: - The results have exceeded all expectations. The growers have completely avoided apple scab, and by using this new spraying strategy they have reduced the number of applications by six sprays and have produced 90% apples free of pesticide residues.

Even though it is possible to reduce spraying, there are challenges: the individual grower is at greater risk and the incentive is small because the effort is "invisible" to the consumers.

- The growers compete with organic products, but, in contrast to the organic producers, they don't have a sticker to label it and therefore there is no premium for the effort, says Marianne Bertelsen.

Rots remain a challenge

Regarding the occurrence of storage rots, the situation is less clear when the new spraying strategy is introduced and the results vary between years and orchards. Part of the project is therefore to develop warning systems.

- We study if there are any indicators of rot before it is visible on the apples. In the future, it might be possible to take air samples in the storage rooms and analyze them for volatiles that are early indicators of rot. However, we still do not know much about the causality for rot. However, we know that apples are often infected in the period right before harvest, says Marianne Bertelsen.

Contact

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This case study is also aligned to enabler 1.

4

Enabler

Omics technologies – from molecules to understanding

Needs

- Take a 'foodomics' approach; exploit food in relation to human nutrition
- Deliver food to optimise human health and well-being
- Develop advanced plant and animal breeding omics technologies
- Explore how breeding and genetics can deliver better raw materials eg nutrients, quality, functionality, processability
- Use omics to elucidate the links between raw materials / ingredients and functionality of the final food product
- Use omics to elucidate the relationship between food intake, the microbiota and health status, in order to deliver new diet solutions and to document existing products

Key Outcomes

- Decipher the "why" through the use of omics technologies
- Better linkage of genetics to product functionality
- Increased understanding of the relation between food, microbiota and health

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of "Omics technologies – from molecules to understanding", we have aligned the relevant competences and facilities at Aarhus University to three sub-topics within this area:

- Omics in relation to food
- Expertise in omic technologies
- Omics in relation to physiology and health

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

OMICS IN RELATION TO FOOD

- Profiling and analyses for validation of food and ingredient components using omics technologies (FOOD+ANIS)
- Detection of protein modifications – natural or process induced (FOOD)
- Milk genomics (FOOD+MBG)
- Food-metabolomics (metabolic changes within the food and ingredients) (FOOD+ANIS)

EXPERTISE IN OMICS TECHNOLOGIES

- Generation and interpretation of large-scale sequence data to underpin animal and human studies within genetics and genomics, including nutrigenomics, metagenomics, epigenetics, transcriptomics, and systems biology (MBG+ANIS)
- Investigation of different types of genetic variation and their functional consequences with respect to the regulation of gene expression, including interpretation of specific gene profiles in the context of product development and functionality (e.g. milk proteins) (MBG)
- Expertise in lipidomics, metabonomics, metabolomics and proteomics (iNANO+ANIS)
- Linking cow genes to milk properties, functionality and health attributes (MBG+FOOD)
- Omics methods for qualitative and quantitative characterizations of food (FOOD+ANIS)

OMICS IN RELATION TO PHYSIOLOGY AND HEALTH

- Metabolomics – impact of foods on human metabolism and microbiota metabolism (FOOD+ANIS)
- Short- and long-term intervention studies in humans, animals and cell cultures (HEALTH+ANIS)
- Human studies specifically in healthy subjects and subjects with obesity, pre-diabetes and type 2 diabetes as well as acute ill patients and the elderly population (HEALTH+ANIS)
- Epidemiologic studies in relation to the diet and health outcomes including large cohorts (HEALTH+ANIS)

OMICS IN RELATION TO FOOD

- LC-ESI-MS, LC-MS/MS ion trap, 2D-LC-IM-Q ToF MS/MS, GCMSD, GC-MS Q-ToF, MALDI ToF MS/MS, Triple Q MS equipment, 1 and 2 dimensional gels, documentation, staining and quantification for molecular characterizations (FOOD)
- Non-targeted and targeted LC-MS/MS methods (ANIS)
- Using genomics data in relation to proteomics, peptidomics and metabolomics (FOOD+MBG)
- Nuclear Magnetic Resonance (NMR) – foods (FOOD)
- Real time RT-PCR for gene regulation analysis (FOOD+ANIS)

EXPERTISE IN OMICS TECHNOLOGIES

- Laboratory facilities for molecular biology, genetics and genomics research (MBG)
- Access to high performance computing facilities for large-scale bioinformatics analysis and modelling (MBG)
- Solid- and Liquid-State Nuclear Magnetic Resonance (NMR) (iNANO)
- Spectroscopy (lipidomics and metabonomics) (iNANO+ANIS)
- HPLC, Mass Spectrometry techniques (metabolomics/proteomics) (iNANO)
- Using omics data to link genes to food characteristics – compositional, technological and health related (FOOD)
- Relative and absolute characterizations and quantifications of molecules and matrices (FOOD)

OMICS IN RELATION TO PHYSIOLOGY AND HEALTH

- Nuclear Magnetic Resonance (NMR) – saliva, blood, urine, intestinal content/faeces (FOOD)
- GC- and LC-MS/MS – saliva, blood, urine, intestinal content/faeces (FOOD+ANIS)
- Facilities for doing long-term diet intervention (HEALTH)
- Facilities for doing long-term diet interventions in animal models (ANIS)
- Laboratories for measurements of hormones, lipids, glucose metabolism, satiety scores, body composition, diurnal blood pressure, gene changes in fat and muscle tissue (HEALTH+ANIS)
- Invasive muscle balance/turnover studies (proteins, fat and carbohydrates) in humans (HEALTH)
- Studies using metabolomics and microbiota techniques (HEALTH+ANIS)
- Animal operation facilities and cell line lab facilities (HEALTH+ANIS)

Prestigious Elite Research Prize awarded to food scientist

How does the body respond to the intake of specific foods, and what does diet mean for our health? Professor Hanne Christine Bertram, Department of Food Science, Aarhus University, has been working on these questions for more than a decade.

In 2017, she was awarded the Elite Research Prize for her contribution to the development of advanced food analysis and in recognition of her position as a frontrunner in this field. The Danish Ministry of Higher Education and Science awards the prize to five outstanding researchers of international excellence.

- Apart from the personal recognition, I'm extremely happy that I can pave the way for an Elite Research Prize to Danish food research, which undoubtedly is in Europe's premier league, says Hanne C. Bertram.

Development of a new research method
The newly appointed elite researcher has received particular attention for her contribution to the development of metabolomics – an advanced method to studying how the body metabolises food. When the body metabolises nutrients, various molecules are formed and excreted into the blood or urine. By analysing and mapping the content of these molecules, researchers can study whether a particular food product is associated with a specific effect in the body.
The metabolomics method has been used for generating knowledge about why foods like cheese are healthy, and how milk proteins can influence weight control.

Better knowledge about meat and health
The prize includes 1 mill DKK in research funds. Professor Bertram is using the funding to conduct research in how healthier meat products can be developed.

- There is focus on how meat intake exerts impact on our health, but there are many unclarified factors. I have a great desire to contribute to improving our understanding of how meat is metabolised and affects us when we eat it, and I hope this can provide knowledge so that we can strategically design the meat products to achieve an overall healthier solution, says Hanne C. Bertram.

Focus on industrial collaboration
In addition to strengthening research with regard to generating knowledge that can lead to the development of healthier meat products, Hanne C. Bertram is using the Elite Research grant to study how we are affected by what we inherit from our parents.

- There is actually increasing evidence that our parents provide us with more than genes. The dietary pattern we get from our mothers seems to leave its mark on our health right up into adulthood, says Hanne C. Bertram.

Professor Bertram also hopes to use the attention associated with the prize to focus on the importance of strong collaboration between the universities and the Danish food industry.

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This case study is also aligned to enabler 5.

Pigs may help increase our knowledge on lifestyle diseases

Within the framework of the research project MERITS, it is the intention to study how diets rich in proteins and fibres may contribute to improved health for people with metabolic syndrome. Metabolic syndrome is a cluster of metabolic abnormalities that significantly increases the risk of cardiovascular diseases and type 2 diabetes. Approximately 20-25% of the adult population in affluent societies suffer from metabolic syndrome, and the problem is increasing due to the development of overweight in the population. One of the reasons for this is the consumption of energy dense and unhealthy foods. The project leader is Professor Knud Erik Bach Knudsen, Department of Animal Science, Aarhus University.

The project experiments are carried out in human subjects with metabolic syndrome, and in obese pigs raised on an energy dense diet. A separate objective is to develop a pig model with metabolic abnormalities corresponding to those seen in humans with metabolic syndrome.

The development of an obese pig model with metabolic syndrome will allow in-depth studies of molecular changes in body tissue and organs as a consequence of an unhealthy dietary lifestyle as well as the opportunities to mitigate – by means of diet intervention – the negative consequences of an unhealthy dietary lifestyles earlier in life. The information obtained with pigs is very useful also for humans, as the physiology of pigs and humans are very similar.

Knud Erik Bach Knudsen explains:
- The pig experiments have been concluded, and we observed that the pigs become very obese due to the energy dense diet. Based on the on-going studies, we are currently in the process of determining whether they actually suffer from metabolic syndrome. The experiments including humans have also been carried out, and we are currently in the process of analyzing the vast number of samples obtained from the studies with humans and pigs. As diet interventions in humans and pigs are identical, we will be able to compare the results obtained on the two species.

The diets studied consist of bioactive whey proteins and wheat bran fibres that have been modified with enzymes to increase its bioactivity. One of the long-term aims is to develop healthy foods that may counteract the development of obesity-related abnormalities in humans.

The project is a collaboration between Aarhus University Hospital, Rigshospitalet, University of California, Davis, Norwegian University of Life Science, Arla Food/Arla Food Ingredients, Lantmännen and DuPont. The total project budget is 23 million DKK. Innovation Fund Denmark provided funding to the amount of 17.5 million DKK.

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This case study is also aligned to enabler 5

Enabler

Foods contributing to health and well-being

Needs

- Understanding the relationship between food and health throughout life
- Understanding how diet and lifestyle affect non-communicable diseases
- Development of personal nutritional solutions
- Document health promoting properties of raw materials and processed foods
- Document the value of functional foods and health supplements
- Bring together knowledge on sensory, food structure and nutrition to deliver healthy meals
- Develop solutions to connect to consumers and customers – to provide and receive information
- Increased understand of food choices and consumer behaviours

Key Outcomes

- Evidence-based recommendations pertaining to the relation between food and health
- Improved understanding of personalized nutrition throughout life
- Getting the nutrition messages across

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Foods contributing to health and well-being', we have aligned the relevant competences and facilities at Aarhus University to three sub-topics within this area:

- Food in the context of health and nutrition
- Health and nutrition as influenced by food
- Consumer perception and behavior in relation to healthy food

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

FOOD IN THE CONTEXT OF HEALTH AND NUTRITION

- Ultra precise profiling of food sensory properties (FOOD)
- Food structure and functionality (FOOD)
- New products to support healthier choices, e.g. in sweet, sour, salt and bitter contexts (FOOD)
- Documentation of health effects of foodstuffs (FOOD+ANIS)
- Natural ingredients (FOOD+ANIS)
- Satiation optimised and focused food product production (FOOD)
- Optimized beneficial phytochemcials through fruit and vegetable cultivar choice and production methods (FOOD)
- Optimized beneficial phytochemcials in cereals production and processing methods (ANIS)
- Structural and functional characterization of milk components (MBG)
- Development and testing of protein ingredients for new and improved infant formulas from different species of ruminants (MBG)
- Identification of low-value byproducts suited for tailoring of a high-grade vitamin B12 ingredients (MBG)
- Compare the bioavailability of vitamin B12 in milk from cow and buffalo, and cow milk powder in a vitamin B12 deficient cohort (MBG)
- Characterization of milk fat globules in milk and their potential health beneficial effects in infants (MBG)
- Characterization of beta-casein peptides and their biological functions in milk and the consumer (MBG)

HEALTH AND NUTRITION AS INFLUENCED BY FOOD

- Metabolite profiles (metabolomics) of blood, urine and faeces (FOOD+ANIS)
- In vitro models for screening of bioactivity, including primary cultures of e.g. muscle and liver cells isolated from pigs (FOOD+ANIS)
- Children, adolescent, adult and elderly nutrition (FOOD)
- Food effects on microbiota (FOOD+ANIS)

- Food-drug interaction (food-components effect on detoxification capacity) (FOOD)
- Population-based studies of diet and health (HEALTH)
- Epidemiological and biostatistical methods (HEALTH)
- The mouth - the entrance of food, including orofacial function in relation to food intake with regard to health and disease, oral sensory function, oral motoric function (HEALTH)
- Taste, flavor and odor, - including salivation in relation to food intake and the texture, taste and temperature of food for optimal intake (HEALTH)
- Food supplements and exercise training - including cardiovascular physiology, and movement analyses (HEALTH)
- Aesthetics and food intake, including testing the influence of aesthetics of food products on intake using qualitative methods (HEALTH)
- Short- and long-term intervention studies in humans, animals and cell cultures. Human studies involve healthy subjects and subjects with obesity, pre-diabetes and type 2 diabetes as well as interventions in the elderly population and in patients with inflammatory diseases such as inflammatory bowel diseases (HEALTH+ANIS)
- Dietary recommendation to the Danish population (HEALTH)

CONSUMER PERCEPTION AND BEHAVIOR IN RELATION TO HEALTHY FOOD

- Analysis of consumer preferences (FOOD)
- Ultra precise profiling of food sensory properties (FOOD)
- Healthier choices (FOOD)
- Research in the connection between well-being, health and social understanding (ARTS)
- Pedagogical approaches to nutritional diets and healthy living for school children (ARTS)
- Analysis of ways of promoting healthy consumer choices (MAPP)
- Impact of information (labelling, claims), of changes in product assortment, of changes in choice of environment (nudging) (MAPP)
- Methodologies for measuring impact of food on well-being (MAPP)

FOOD IN THE CONTEXT OF HEALTH AND NUTRITION

- Cell culture labs (FOOD+ANIS)
- Plant genetic resources (FOOD)
- LC-ESI-MS, LC-MS/MS ion trap, 2D-LC-IM-Q ToF MS/MS, GCMSD, GC-MS Q-ToF, MALDI ToF MS/MS, Triple Q MS equipment, 1 and 2 dimensional gels, documentation, staining, quantification (FOOD)
- Non-targeted and targeted LC-MS/MS platform (ANIS)
- NMR – food and ingredients (FOOD)
- Protein and peptide characterization (MBG)
- Phospholipid analysis (MBG)
- Milk fat analysis (MBG)
- Texture analysis (FOOD)
- Effect of composition, structure and texture on digestibility (FOOD)

HEALTH AND NUTRITION AS INFLUENCED BY FOOD

- NMR –saliva, blood and intestinal content/faeces (FOOD)
- LC-MS/MS –saliva, blood, intestinal content/faeces and tissues (ANIS)
- Real time RT-PCR for gene regulation analysis (FOOD+ANIS)
- In vitro gastro intestinal digestion models biochemical and molecular techniques (MBG+ANIS)
- Cell culture intestinal models (MBG+ANIS)
- Diet cancer and health cohort of 57,000 Danish citizens; detailed food, disease and lifestyle information, including stored biological samples (HEALTH)
- Facilities for clinical and experimental studies in dentistry and oral health (HEALTH)
- Flavour Institute (HEALTH)

- Facilities for human movement analysis, physiological analyses combined with measurements of muscle turnover, glucose and lipid metabolism (HEALTH)
- Long-term diet intervention studies in humans (HEALTH)
- Laboratories for measurements of hormones, lipids, glucose metabolism, satiety scores, body composition, diurnal blood pressure and gene changes in fat and muscle tissue, to determine the effects on gut flora and on biomarkers/metabolomics (HEALTH+ANIS)
- Animal operation facilities and cell line lab facilities (HEALTH+ANIS)
- Epidemiological dietary research (HEALTH)

CONSUMER PERCEPTION AND BEHAVIOR IN RELATION TO HEALTHY FOOD

- ISO approved expert sensory profiling lab and associated facilities (FOOD)
- Objective expert sensory reference panels in different product categories (FOOD)
- Consumer measurement capabilities for different demographic groups, children, adolescents and elderly (FOOD)
- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Consumer behaviour lab for experimental studies including eye-tracking technology, physiological measures of arousal and face reader for online measure of emotional response (MAPP)

InnoSweet

- Integrating perception, psychology, and physiology for maintaining sweetness perception via sugar replacement

Sugar intake, especially from beverages, is very high amongst specific consumer segments, e.g., adolescents, the target group of the InnoSweet project. From a food production perspective, there has been great emphasis on reducing the sugar content in beverages using alternative sweetness. However, these methods have been met with only partial success due to the drastic alteration in the sensory properties of the products. Perception and acceptance of sweetness differ between individuals due to sensory and psychological factors and brain-rewarding systems. They are also embedded in our culture and background. Hence, these factors can be exploited as active tools to model sweetness perception and acceptance of products with reduced sugar content.

The aim of the InnoSweet project is to apply an integrated scientifically based sensory perceptual-, psychological-, and physiological (PPP) approach to sugar-reduced or sugar-replaced (SRR) beverages enabling lowering the sugar content whilst maintaining acceptable sweetness perception, ensuring market success.

The InnoSweet project is led by Professor Derek Victor Byrne, Department of Food Sciences, Aarhus University and is a unique interdisciplinary collaboration between sensory scientists, psychologists, clinical researchers and economists from Aarhus University, DK, Oxford University, UK and Copenhagen University, DK and innovation experts from the three key ingredient and beverage companies, Carlsberg Breweries A/S, DK; DuPont Nutrition Biosciences ApS, DK and Rynkeby Foods A/S, DK.

InnoSweet is a four year project which started in 2017, and the project is funded by Innovation Fund Denmark.

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This case study is also aligned to enabler 2.

OmniSaM

- A multimodal metric for predicting the satiating effects of foods and drinks

Designing food and drink that maximizes satiety has long been an ambition of industry and public health. Foods that fill faster and for longer are desirable to consumers for weight management and for public health programs designed to prevent obesity.

In so far as satiety metrics have progressed, they have done so primarily along two frontiers. The first frontier employs subjective measures, quantified using standardized scales such as the visual analogue scale or category scales. The second frontier entails measuring biomarkers of satiety, either neural or hormonal. There is a wealth of evidence that several hormones and several brain regions correlate with, or causally affect appetite and food consumption. Such advances however are not yet at the stage of developing or validating explicit metrics. To date, no metric has explained more than 25% of the variance in next-meal energy consumption, and no metric has been shown to have predictive accuracy for real world consumption.

The main objective of the OmniSaM project is to develop a multi-modal based metric of satiety that is predictive of future energy consumption that surpasses the performance of existing benchmark metrics, and acts as a proof-of-concept for its use in industrial R&D. The project is led by Professor Derek Victor Byrne, Department of Food Science, Aarhus University, project partners are Aarhus University (AU-FOOD and AU CLIN) and Copenhagen University (KU HEALTH and KU DRCMR). The OmniSaM project is funded by the research and innovation centre Arla Food for Health. Ingredients for pre-loads are delivered by Arla Foods and Arla Ingredients.

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This case study is also aligned to enabler 2

FOODHAY

As mentioned in the Industry Strategy, World Class Food Innovation towards 2030, a key enabler to underpin research and innovation is to secure world leading research infrastructure. As part of this need, the food industry recommends the funding and establishment of FOODHAY – an open innovation food and health laboratory as described in the Danish roadmap for research infrastructure (2015). The consortium aims to establish a research infrastructure for food research with a view to extending innovation science and implementation for the benefit of the Danish food industry. The research infrastructure will consist of a food and health laboratory linked to Aarhus University at Agro Food Park in Aarhus, complemented by laboratories located at both Copenhagen University and the Danish Technology University to support infrastructure and knowledge sharing at a national level. The research infrastructure will be made up of five platforms:

1. a biomarker and screening platform for in vitro screening of biological responses from food components combined with specialised analysis facilities;
2. a proteomics and metabolomics research platform for analysis of foods and biofluids;
3. a food biophysics platform equipped with a range of scanners, spectroscopes, microscopes and more for analysing structural changes in food proteins and food lipids and their interactions;
4. a sensory and consumer platform for experimental and experiential human food perception analysis, with facilities for activities such as product development and behavioural spaces including video and eye-tracking instruments;
5. a platform for nutrition and health information, which will make data available to food industry and health sector stakeholders. ufm.dk/en/publications/2016/danish-roadmap-for-research-infrastructures-2015

Arla Food for Health

Established in 2015, Arla Food for Health is a public-private partnership between Arla Foods amba, Arla Food Ingredients, University of Copenhagen and Aarhus University. The centre initiates and funds research in dairy health and nutrition and is currently funding 10 projects. www.arla.com/company/arla-food-for-health (June 2018).

The Centre is founded in the spirit of exploring the competences between these four stakeholders to carry out best-in-class dairy health and nutrition research and become a platform for knowledge sharing, training and education.

Arla Food for Health sponsors science-based research on identification, isolation and characterization of health associated milk components, including validation, quality and up-scaling of such as well as the mechanisms behind the health benefits of dairy products and ingredients in-vitro, in-vivo and in clinical studies.

Research is aligned to 3 categories:

- Prevent/Remedy Metabolic Syndrome
- Prevent/Remedy Malnutrition
- Enhance Immune Defense/Response

6

Enabler

Agile and intelligent automation

Needs

- Development of intelligent, highly agile and (self-learning) robotic solutions
- Low cost sensor technologies for robotic control and advanced process control
- Establishment of twin models of main unit operation (to speed up process and product innovation)
- Integrated and intuitive man-machine-interfaces to deliver intelligent automation
- Redefining and development of packaging technologies with a digital link across the food chain
- Development of new and flexible logistic solution
- Increased sustainability and reduced footprint when developing new processing and preserving technologies

Key Outcomes

- More agile and sustainable production
- Hyper-flexible production technologies and processes
- Increased use of automation and intelligent robotics

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Agile and intelligent automation', we have taken a food chain approach by aligning the relevant competences and facilities at Aarhus University to three sub-topics along the value chain:

- Technologies in the food chain
- Automation of food systems
- Consumer relation to food technologies

This overview is followed by two case studies demonstrating how research and innovation at Aarhus University currently contributes to reaching the key outcomes as identified in the industry strategy.

TECHNOLOGIES IN THE FOOD CHAIN

- New minimal processing to determine impact on food quality of raw materials and foods (FOOD)
- Pilot scale processing to evaluate feasibility and sustainability (FOOD)
- Natural preservatives to increase sustainability (impact on quality and food waste) (FOOD)
- Alternative packaging materials (FOOD)
- Fast methods for food characterization (FT-IR) (FOOD)
- Low cost sensor technologies (ENG)
- Integrated and intuitive man-machine interfaces, e.g. Hardware Apps (HAPPs) for robots in manufacturing systems (ENG)

AUTOMATION OF FOOD SYSTEMS

- Ability to simulate shipping, transport and distribution chain (FOOD+ENG)
- Non-destructive methodologies for evaluation of food quality in the food chain (FOOD)
- Sensor technologies to monitor the food chain (FOOD+ENG)
- Digital twins in smart manufacturing processes connecting the physical (real) world with the digital (simulated) world (ENG)
- Automated and robotic systems for processing in the food chain (ENG)
- Post-harvesting (pre-processing, storage, etc.) (ENG)
- Optimising supply chains and logistics (ENG)
- ICT and IoT-based technologies aimed at traceability, smart logistics, and data/service platforms for food systems (ENG)

CONSUMER RELATION TO FOOD TECHNOLOGIES

- Research in the use of robots in the design and practice of eating in future health care and in the aging society (ARTS)
- Analysis of value chain configurations for more sustainable production and consumer perceptions of production methods (MAPP)

TECHNOLOGIES IN THE FOOD CHAIN

- Minimal processing facility (FOOD)
- Pilot scale processing facilities (FOOD)

AUTOMATION OF FOOD SYSTEMS

- Post-harvest facility for simulation of transport and distribution chain (FOOD+ENG)
- Greenhouse climate control for simulation studies (FOOD+ENG)
- Automation and Mechatronic Laboratory for integration of electronic devices in the food chain (ENG)
- Optimization and simulation tools for supply chains (CPLEX, TomLab, ExtentSIM) (ENG)

CONSUMER RELATION TO FOOD TECHNOLOGIES

- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Consumer behaviour lab for experimental studies including eye-tracking technology, physiological measures of arousal, face reader for online measure of emotional response access to online platform for online studies (MAPP)

Improving quality of bananas by optimizing post-harvest processes

Maersk Container Industry (MCI) have engaged Aarhus University in a 3 year project with the objectives of understanding and improving the reefer transportation of fruit and vegetables in particular bananas.

This approach will address different steps in the transportation and handling chain from farms to consumers and these types of partnerships are a reflection on the increased need to deliver new innovative improvements in products and processes.

The target of the MCI project is to be able to deliver better quality of bananas at the same or lower cost than today. Project Leader Associate Professor Merete Edelenbos of the Department of Food Science emphasizes that optimizing postharvest approaches and identifying novel solution and technologies not only increases the sustainability of our food chain but it also adds new knowledge needed to reduce food waste along the chain and therefore reduce the footprint of our transport and distribution systems.

The project involves the specialized postharvest facility at Department of Food Science , where it is possible to replicate, simulate and control microclimate conditions representative of postharvest handling systems. Merete adds that these industrial partnerships provide a very good example of how we can use our specialized research infrastructure in partnership and how this type of projects enables us to secure young international talent to the disciplines of food science and technology; talent development and technology development are critical for the future of both the Danish food industry and the university.

Contact

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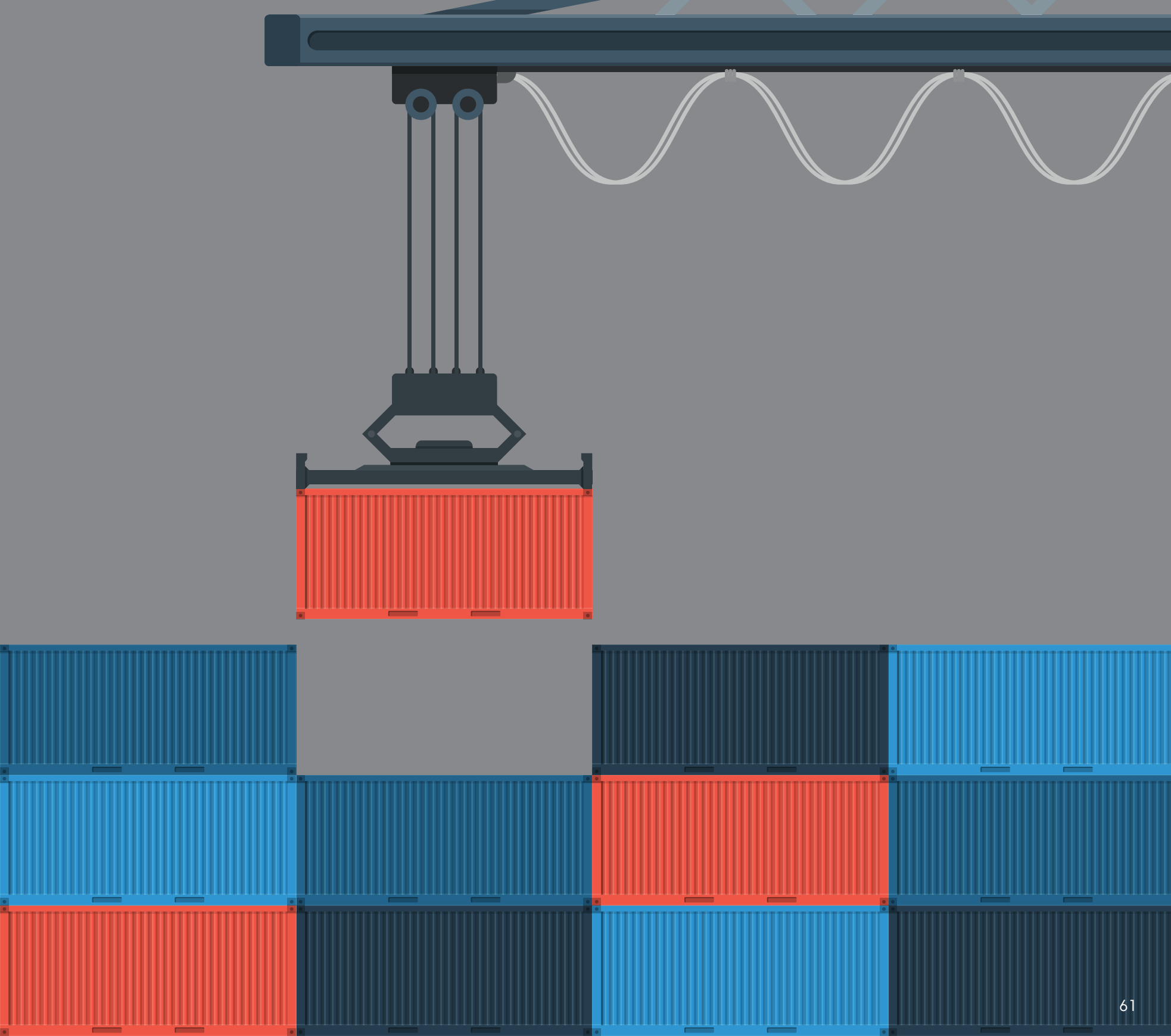
This case study is also aligned to enablers 2 and 3.



New technology to boost the biotechnology industry

The start-up-company Consibio has discovered a market niche for its intelligent management system for biological processes.

It can monitor microorganisms and regulate their growth conditions, and thus ensure these are always optimal. At the same time, the Monesco system, developed by the three Consibio founders, is easy to use and cheap to buy. The three founders all have a Bachelor degree in Engineering from Aarhus University, and came up with their business idea during one of the first semesters.

- It does not take much for a biological process to get out of control. It can be the temperature being a little too high, or a slightly too low humidity. And if you finally succeed in identifying optimum conditions, then these may be very difficult to recreate. We have been lacking a tool to control the processes in all our study projects, and this is the exact same challenge that many companies are faced with, says Emil Jakobsen, one of the Consibio founders.

The three fellow students founded Consibio in August 2017, and since then they have worked to further refine the technology for their project with a view to commercializing it in one of the start-up environments at the Aarhus University School of Engineering. Now – before they have even considered sales and marketing – the industry seems very interested.

More for less

In principle, the system is an assembly kit. It consists of a central unit with a small computer able to carry out complicated data processing via a set of special algorithms. You can connect sensor and actuator modules to the central unit, which allows you to register and influence the conditions that are important to an optimal biological process.

- These may include the inflow of light, humidity, oxygen content, CO_2 level, temperature, pH value or other conditions important to any given biological process. We can incorporate all kinds of sensors. The point is that this system makes it possible to automate monitoring and control and thus ensure that all decisions are based on data. At the same time, we have focused on user-friendliness right from the first prototype. It is important that our system is as easy to use as an iPhone and a box of Lego, says Johan Thomsen, one of the Consibio founders.

Technological equipment to monitor biological processes already exists, However, it is expensive and in most cases only major production companies can afford this.

- Our system is an intelligent solution as it allows for an easy combination of various modules, which makes it multifunctional. At the same time, it is based on a relatively inexpensive technology. We store sensor data in the cloud, and the design is very compact with a simple user interface. It is easy to apply and cheap to buy even for small companies, says Søren Kjær, one of the Consibio founders.

This system allows companies to produce more for less money, and he expects a significant international demand:

- To our customers, the value creation is huge. They can hire a person to check if the insects are okay or measure the temperature in a keg of beer. But they may also choose to invest in a system that is able to do the same much more precisely and thus increase production quality as well as quantity.

Oyster mushrooms, insects and artificial stomachs

The Copenhagen-based company Beyond Coffee was one of the first companies to apply the Consibio system. Beyond Coffee grows oyster mushrooms on a basis of coffee grounds. In order to achieve ideal growth conditions and the desired taste, precision is required as to monitoring of air quality.

- It is an excellent example of how our technology may benefit a small company that does not have the necessary capital to invest in monitoring equipment, says Søren Kjær.

Another customer has many research and development activities and uses the technology to build a kind of "artificial stomach". The system helps to recreate temperatures and pH values identical to those that characterize the human physiology and biochemistry in the stomach and intestines.

First, Consibio will contact food and production companies as well research and education institutions to present their product.

Consibio was awarded the prize for best engineering start-up at Aarhus University, recommended by a panel consisting of researchers and experts from industry and trade.

Contact

www.consibio.com

This case study is also aligned to enablers 2, 3 and 7

Enabler

Connected and competitive through smart use of big data

Needs

- Establishment of a common framework for data access and sharing to ensure a closer cooperation
- Aggregate and make available customer data
- Increase utilization and integration of consumer data to understand preferences; bring together social media, sales data, and data on market intelligence

Key Outcomes

- Connecting better with the consumers
- Optimized food systems and increased connectivity across the supply chain based on big data
- Shared framework for data use

Needs and Key Outcomes as described in the industry strategy "WORLD-CLASS FOOD INNOVATION TOWARDS 2030"

In the area of 'Connected and competitive through smart use of big data', we have taken a food chain approach by aligning the relevant competences at Aarhus University to to two subtopics along the food chain:

- Food and consumer related data
- Data handling and access strategies

This overview is followed by two case studies demonstrating how research and innovation activities with participation of Aarhus University contributes to reaching the key outcomes as identified in the industry strategy.

FOOD AND CONSUMER RELATED DATA

- Hedonic consumer mobile and online measurement capabilities – Compusense (FOOD)
- Consumer measurement capabilities for different demographic groups, children, adolescents, elderly (FOOD)
- Cross-cultural data across world markets regarding new food design and development (FOOD)
- Research data and communication strategies in the connection between producers and consumers (ARTS)
- Analysis of transaction data like consumer panel data or scanner data (MAPP)
- Analysis of data harvested from social media, sentiment analysis (MAPP)
- Analysis of data resulting from consumer engagement via mobile devices (MAPP)

DATA HANDLING AND ACCESS STRATEGIES

- Efficient data access using database technology and scalable search; collect, process, store and retrieve data (CS)
- Data analytics: machine learning and data mining for Big Data; analyze data for validation, optimization, and prediction; including social network data and sensor data (CS+ENG)
- Cloud technologies (ENG)
- IoT (Internet of Things) (ENG)
- Machine Learning (ENG)
- Security in data handling (ENG)
- Operability and semantic standardization for communication between stakeholders in the food chain (ENG)

Internet of Food and Farm 2020

Even though the agri-food sector has generally been willing to adopt technologies such as Big Data, Artificial Intelligence and IoT (Internet of Things), their use is currently still fragmented and the technologies are mainly used by early adopters.

This inadequate use of new technologies has an impact on both productivity and sustainability. The challenge is to nurture a development where farmers embrace these technologies – which are precisely tailored to farming.

An EU project of EUR 30 million with more than 70 partners from 14 EU countries will speed up this development. Nineteen use-cases organised around five sectors (arable, dairy, fruit, meat and vegetables) develop, test and demonstrate IoT technologies in an operational farm environment all over Europe and will show how IoT can drastically improve productivity and sustainability in Europe.

Senior Researcher Claus Grøn Sørensen Department of Engineering, Aarhus University (AU ENG) who coordinates one of the 19 cases on farm machine interoperability explains:
- Internet of Food and Farm 2020 is off to a good start, and during this first year the focus for us has been *"A digital gateway for seamless data transmission between field machinery and FMIS for supporting cross-over pilot machine communication and prescription farming".* We have worked with different data models (e.g. AgGateway), which can translate vendor specific data formats into one common format in "the cloud." This is then able to communicate with management systems and other actors in the value chain thus enhancing interoperability of farming equipment and a more effortless transfer of data between different actors.

AU-ENG focuses on system design, requirement analysis, development of decision support tools in regards to optimal operation of machinery taking all relevant factors into account.

Aarhus University is a project partner in the Internet of Food and Farm 2020. The project is led by Wageningen University and Research, Netherlands and runs from 2017-2020.

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This case study is also aligned to enabler 1.

PROSPECT FNH-RI underpins the design of our plate of the future

An application called PROSPECT FNH-RI will be submitted to ESFRI, European Strategy Forum on Research Infrastructures seeking the establishment of a European Research Infrastructure for Food, Nutrition and Health (FNH-RI). The FNH-RI will be a European overarching research infrastructure that is specific for studying food in relation to nutrition and (preventive) health within the planetary boundaries and that connects the currently fragmented data or research on the food system and the health system with the consumer as a linking pin. The plan is to make FNH-RI the leading European platform for top-level research in this domain. This will be achieved by bringing together innovative and inclusive communities by serving the pan-European research community to overcome fragmentation and to collate, connect and share innovative and existing research data, tools and labs and experimental facilities. The aim is to have an operational European Research Infrastructure on Food, Nutrition and Health up and running in 2024. From Denmark the intention is to link FOODHAY as a national research infrastructure and to contribute data and to access data for the benefit of both research and innovation.

In December 2018 the final composition of the consortium will be decided. The Netherlands, together with Denmark, Slovakia, Italy and UK will coordinate the proposal, accompanied by at the associated countries; Sweden, Spain, Norway, Finland, Germany, Belgium, Greece, Slovenia and Macedonia.

In May 2020 the updated ESFRI Roadmap 2020 will be launched and the hope is that FNH-RI will be invited to write a preparatory proposal to develop FNH-RI towards implementation.

Aarhus University is a project partner in the PROSPECT FNH-RI application along with Aalborg University, Copenhagen University and Danish Technology University. The consortium is being led by Wageningen University and Research, The Netherlands.

For more info visit the link: www.wur.eu/fnhri
This case study is also aligned to enabler 5

Centre for Circular Bioeconomy (CBIO)

Going from a fossil based economy to a circular and bio-based economy holds significant societal and industrial potentials. In a bio-based economy fossil raw materials are replaced with renewable plant- and marine-based biomasses, and energy consumption is based on renewable sources, including sustainable biomasses and organic waste.

The possibilities include for example the production of new high-value products based on an innovative utilization of side streams and by-products as a means to avoid waste. At the same time, more resource-efficient production systems in agriculture and marine farming will ensure compliance with the EU Water Framework Directive as well as the climate policy.

However, the transition to a bio-based economy requires the development of biorefineries being able to utilize the new biomass types as a basis for producing high-value products.

In May 2017, Aarhus University, Science and Technology, established the Centre for Circular Bioeconomy (CBIO) to carry out research and to develop bio-economy production systems and recirculation concepts, e.g. biorefining methods and high-value products based on green crops, marine biomasses as well as residual and by-products from the agricultural and food sectors.

CBIO activities include research within the entire production chain ranging from cultivating and procuring biomass, logistics, management, refining, product development and tests, recirculation, impact on nature and environment as well as research in relation to society and economy.

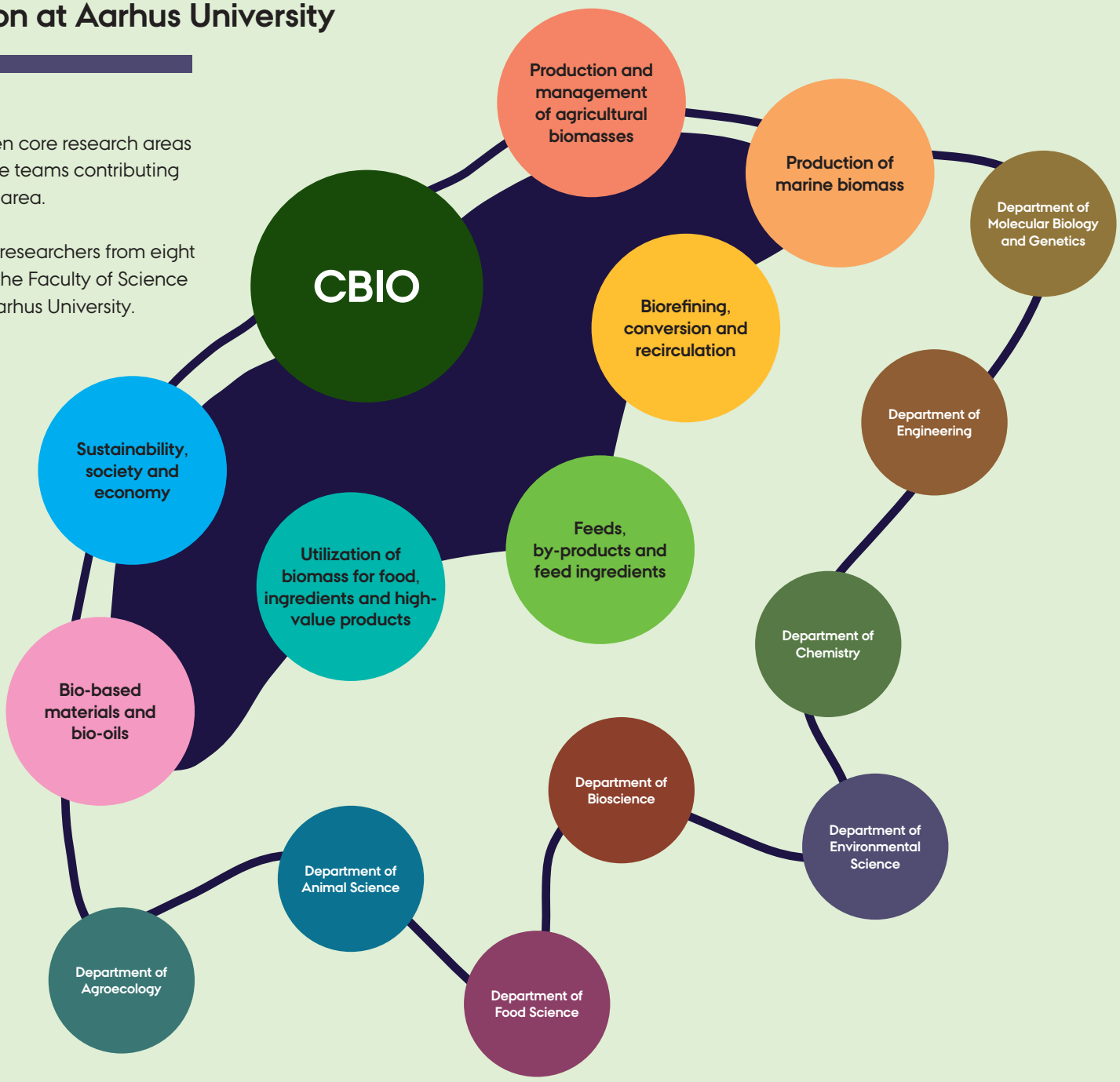
In addition, more basic research activities are carried out, e.g. in relation to the understanding of biomass conversion at molecular level, supported by advanced chemical analyses.

Product examples include high-quality feed protein and other types of feed, bio-based fibres for composite materials and chemical components such as bioplastic polymers. Furthermore, the extraction and production of ingredients and components for the food and pharmaceutical industries hold significant potential. →

An example of interdisciplinary research collaboration at Aarhus University

CBIO includes seven core research areas with related science teams contributing into each research area.

The teams include researchers from eight departments from the Faculty of Science & Technology at Aarhus University.



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Utilization of biomass for food, ingredients and high-value products in CBIO, techniques and technologies for extraction of high-value products for foods and ingredients are being developed. Primary focus is on the extraction and characterization of white protein, active compounds, prebiotics and natural colouring agents.

Strategic efforts in food and ingredients are focussed on the optimization of process parameters in relation to protein-chemical changes, functional properties, sensory preferences and bioavailability.

Food and ingredient focus areas include:

- Extraction, purification and characterization of white protein, natural colouring agents and active compounds
- Bioactivity in active compounds
- Characterization and strategic optimization of process parameters (antinutrients including polyphenols, heat and oxidative change in amino acids, D-amino acid)
- Functionality and sensory consumer preference
- Bioavailability and prebiotics

Contact

Centre Leader Senior Researcher Uffe Jørgensen:
uffe.jorgensen@agro.au.dk

Specific facilities connected with evaluation of green biomass components for foods:

- Development of different methods to extract and purify white protein from green biomasses (removing chlorophyll)
- Extraction of active compounds such as polyphenols and phytoestrogens
- Techniques for examining functional properties (solubility, gelation, foaming properties etc.)
- Sensory panel
- State-of-the-art mass spectrometry facilities (2D-LC-IM-QToF, LC-MS QQQ, LC-MS ion trap, Maldi-ToF-ToF, GC-QToF, GC-MSD) for omics techniques (proteomics, metabolomics and oxidomics) and quantitative analyses of bioactive compounds (peptides, polyphenols, mono- and oligo saccharides) as well as antinutrients (oxidative and heat-induced changes in proteins and amino acids, D amino acids, polyphenol oxidase), respectively
- FPLC gel filtering techniques for profiling soluble proteins
- Platform for bioactivity testing (e.g. antioxidative capacity, ACE, GLP1 etc.)
- Cell laboratory for initial in vitro testing of bioactive components
- Pig and rat models for bioavailability evaluation (DIAAS and PDCAAS), as well as a micro-biological laboratory

Centre for Innovative Food Research (iFOOD)

– interdisciplinary solutions for the complex challenges of tomorrow

Centre for Innovative Food Research (iFOOD) is a cross disciplinary research centre launched in September 2017. The centre is anchored in the Department of Food Science at Aarhus University. iFOOD carries out research, innovation and talent development within the fields of new innovative production systems and natural and convenience foods. The centre brings together leading competences through close corporation with the industry and involvement of a broad range of key departments across AU.

- The iFOOD centre aims to build up new knowledge and technologies that will underpin the production and development of natural and nutritional innovative foods (both home and out-of-home contexts). iFOOD aims to become a nationally leading and internationally prominent research centre integrating and building up excellent research and development on natural and convenient food solutions specifically addressing the grand societal challenges linked to lifestyle trends, changing behavioral patterns of the consumers and health and food.

The Danish food sector has a strong international brand for delivering quality and trustworthy foods, but it needs to maintain this brand, while expanding its export strength in existing and emerging markets. Danish food producers need to deliver novel solutions in adequate shelf life, timely delivery, high trustworthiness, sustainability, authenticity as well as a range of organic foods that are minimally processed to meet the increasing food lifestyle trends: health and convenience products.

The Danish food industry needs to deliver differentiated and high-value foods and products, that will secure a premium position, enable increased revenue, and that will underpin their brands, whilst meeting the increasing convenience and healthy needs of consumers in a sustainable setting. In order to address these many and complex challenges, Aarhus University will in the iFood Centre bring together existing but diverse capability, aligned to several AU departments and across Faculty; capabilities that span from excellent basic to applied research capabilities, with social sciences to technology based approaches, both specialized in and non-specialized in food research. Through the centre this capability will be focused on taking interdisciplinary initiatives to provide innovative solutions to these key challenges. This includes strategic recruitment of complementary competences within areas of vital importance, which are currently not present at the level needed to take a national leading and international prominent position in the area.

Contact

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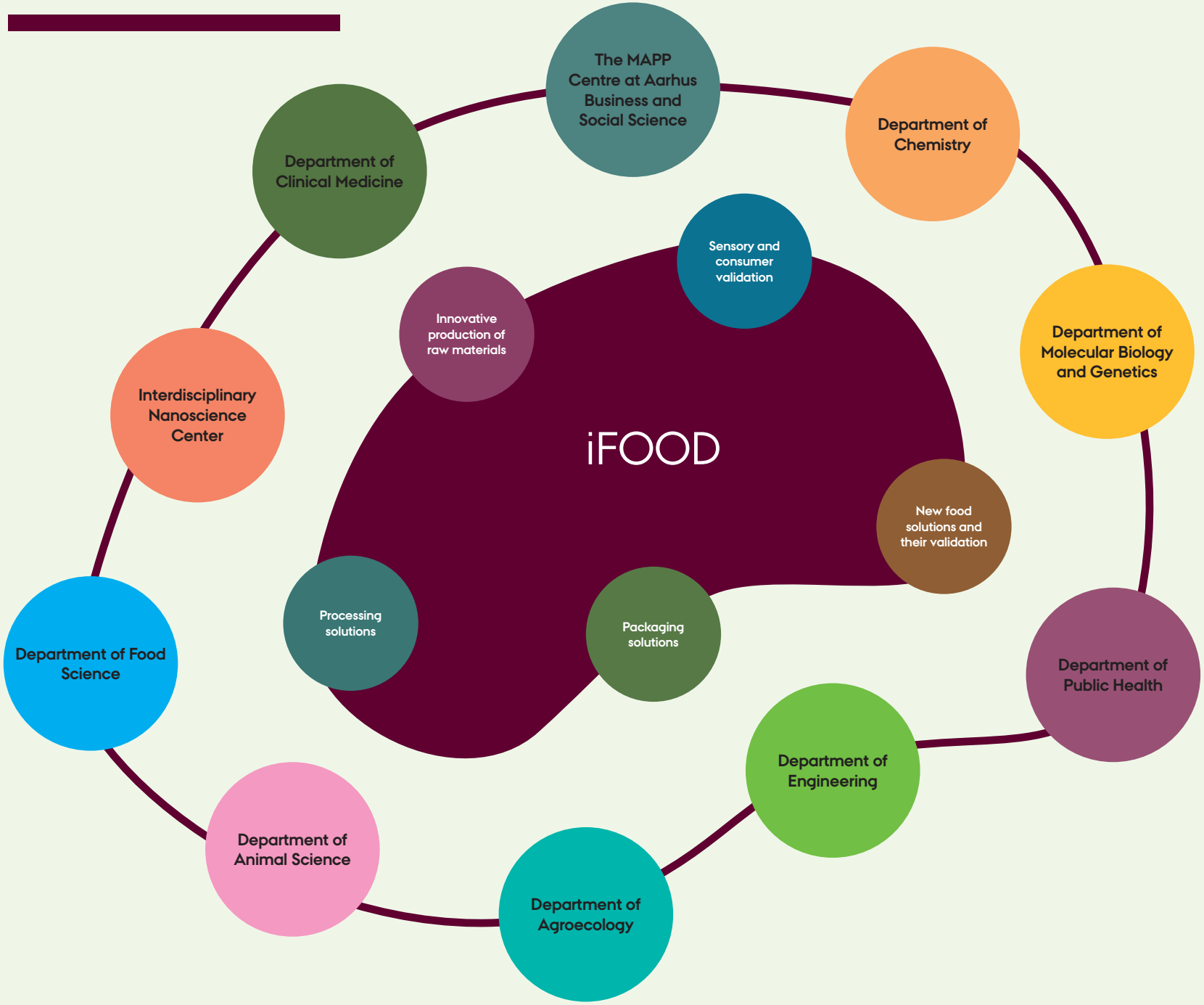
An example of interdisciplinary research collaboration at Aarhus University



Research based policy support

Aarhus University provides science based policy support to the Ministry of Environment and Food of Denmark. The support is provided within a broad range of thematic areas of food and agriculture, and in many cases in parallel to the seven research enablers of the strategy on World-Class Food Innovation Towards 2013.

According to the annual framework contract, the departments linked to the Danish Center for Food and Agriculture (DCA) will carry out research for the benefit of industry and society within animal husbandry and crop production including circular economy, climate and environmental impact, as well as within food science including raw materials, processing, food quality and consumer perceptions. These competences form the basis for providing advice to the Ministry responding to specific requests and questions following a formalised procedure and work plans.

The policy support is provided by scientists and research groups at Aarhus University. To ensure cross-disciplinary cooperation between the research environments within food and agriculture, Aarhus University has established DCA – Danish Centre for Food and Agriculture. The centre provides the framework for cooperation and a central unit supports and coordinates e.g. policy support and may serve as entry point for new, strategic collaboration with industry partners.

DCA delivers between 150-200 specific services to the Ministry's different departments annually.

The framework agreement and specific contracts with work programs are adjusted annually in a dialogue with the Ministry, but knowledge areas and thematic focus normally remain stable in order to facilitate long-term knowledge and capacity building (Table 1). The knowledge areas reflect decades of established collaboration with industry as well as international challenges and research agendas.

Policy support must be transparent, and in general, all deliverables are published at dca.au.dk.

Performance agreements	Knowledge areas and competences available for science based advice
Plant production	• Crop breeding and pollination, crop health aspects and crop protection, and Integrated Pest Management (IPM) • Climate-smart production systems • Fertilisers, standards and nitrogen prognosis • Technology – agriculture and plant production • Soil and soil conditions, including digital data, maps and image analysis • Green transition and biomass • Targeted (agro-environmental) regulation • Agricultural reform and public green benefits
Livestock production	• Animal breeding and genetics • Animal behaviour and welfare • Feeding and nutrition • Nutrient cycles and animal manure • Production systems, management and advisory service • Animal production and measures
Food quality and consumer behaviour	• The purpose is to build knowledge on food and food quality that meets the needs of industry, consumers and authorities for documentation and assessment of food suitability for further processing, sensory and health qualities and the correlation with the production characteristics, incl. packaging and storage. • The purpose is to build knowledge of consumer behaviour and food preferences, including developments in national and international consumer trends, behaviour, and preferences, etc. The knowledge forms a basis for healthy conversion and/or green conversion of production, product differentiation and product development. Furthermore, research should provide knowledge to authorities that can form the basis for targeted communication to specific consumer segments. • The purpose is to build knowledge about the importance of food and eating habits to health and sustainability, including demand and outlets for healthy nutritional purposes and, for example, organic foods, which at the same time meet consumer requirements for sensory and culinary quality.

Table 1: Areas of capacity building

Ensuring cross-disciplinary cooperation in science and policy advice and taking notice of global agendas.

There is a close linkage between a) the food and agricultural science of the DCA departments reflecting global challenges and agendas, b) the collaboration with industry in research and innovation activities and c) the science based policy advice (figure).

This opportunity for synergies between linked activities within the thematic focus areas secures optimal use of resources and co-funding of research with industry partners based on up-to date facilities and cutting-edge competences with respect to international partners. This enables the scientific groups to leverage the core funding from the Ministry to an annual turnover 2.6 times the contract with a majority of projects including direct collaboration with Industry.

What is research based policy advice

Policy making in the twenty first century requires robust evidence, impact assessment and adequate monitoring and evaluation.

Scientific advice needs to be independent of political or institutional interests, bring together evidence and insights from different disciplines and approaches, and ensure adequate transparency.

European Commission, 2015: Strengthening Evidence Based Policy Making through Scientific Advice

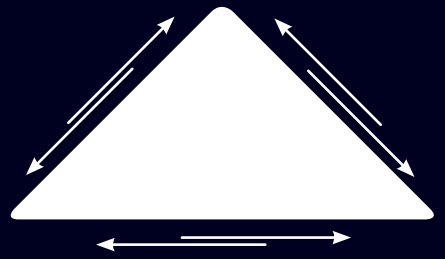
Evidence-based scientific policy advice gives weight to hard empirical facts and restrictions.

Klaus F. Zimmermann, 2014, IZA Policy Paper No. 90, Bonn University

Perspectives on DCA activities

Research based advise to government

Current problems in food and agriculture:
Environment, climate, productivity etc



Global agenda

Focus: sustainable/eco-functional
intensification, food security, climate change

Collaboration with sector/industry

Focus on inovation and solution of problems: Smart,
environmentally friendly growth, bioeconomy

Food related **educations** at Aarhus University

In the industry strategy, the importance of recruitment and talent development in a research based educational system in close contact with the industry is emphasized. Aarhus University offers a wide range of degrees looking at all aspects of the food sector and working closely with industry as well as international partners. The students learn to convert knowledge and theory into practical skills and problem solving.

Bachelor's degrees

Bachelor in Agrobiology
The education focuses on food production and bioenergy to develop the agriculture of the future. The food quality track of this degree focuses on health, nutrition and food and students work with the factors affecting food quality and the technologies that can be used to improve the level of quality and efficiency of food quality, nutrition and how food is absorbed and affects the body.

Bachelor in Chemical Engineering and Food Technology
Focuses on food of the future and technology-based food production. The degree gives the students an in-depth understanding of the food industry and its current innovation needs. The BEng programme is business-oriented, where students learn to use their growing knowledge about chemical and biotechnology engineering to solve real-life problems in the food industry – often in collaboration with businesses.

Master's degrees

Master's degree in Agrobiology
Climate change and population growth pose a huge, multifaceted, worldwide challenge to agricultural production. Food production needs to be increased in scale and efficiency, while at the same time animal welfare, the environment and natural resources need to be protected. A degree in agrobiology will equip students to play a part in finding solutions to these problems. Students choose one of three tracks: Animal health and welfare, Plant nutrition and health and Organic agriculture (single degree) or Organic Agriculture and Food Systems (double degree).

Master's degree in Molecular Biology
Students can choose to specialise within a more general field, including one of the five branches of molecular biology in which Aarhus University is particularly strong: molecular medicine, structural biology, systems biology, plant biology, and quantitative genetics.

Molecular Nutrition and Food Technology
With the Master's degree in Molecular Nutrition and Food Technology, students will acquire the tools and knowledge required to develop nutritious foods – foods designed to reduce the risk of developing the lifestyle diseases of obesity, diabetes, heart disease, allergy and cancer.

Summer School on Food and Ingredients

Each year, Aarhus University hosts an international summer school course on Food and Ingredients. The purpose of the summer school is to discuss some of the latest knowledge in food and ingredients, and to enable participants to apply their competencies in food sciences to the challenges and opportunities when developing novel, differentiated and sustainable foods and ingredients. The summer course is run at Agro Food Park and is organized in close collaboration with representatives from both small and large food companies in Denmark. This will lead to an insight into a highly innovative and leading food ecosystem in Europe, and demonstrate how to take ideas from science to the industry and from industry to science.

Master of Science in Biomedical Engineering
The two-year Master's degree programme in Biomedical engineering at Aarhus University is offered in collaboration with the Aarhus University Hospital, Skejby. The graduate engineer degree programme bridges the gap between the technical world and the health sector. In addition to engineering skills, students acquire medical insight and become qualified to work in interdisciplinary collaboration on developing medico-technical methodologies and instruments for monitoring, diagnosing and treating patients.

Master's degree in Nanoscience
The Master's degree in Nanoscience programme provides an opportunity to study subjects in the fields of physics, chemistry and molecular biology as well as in specific nanoscience subjects. Through their choice of courses and Master's project, students specialise in one of the disciplines of nanophysics, nanochemistry, or molecular biology.

Organic Agriculture and Food Systems (EUR-Organic) (Double-Degree)
A comprehensive and integrative education in all areas of organic farming, as well as the processing and commercialization of organic food. The EUR-Organic Master in Organic Agriculture and Food Systems is developed and offered by the following universities:

- University of Hohenheim (UHOH), Stuttgart, Germany
- University of Natural Resources and Life Sciences (BOKU), Vienna, Austria
- Warsaw University of Life Sciences (WULS-SGGW), Warsaw, Poland
- Aarhus University (AU), Aarhus, Denmark
- Institut supérieur d'agriculture et d'agroalimentaire Rhône-Alpes (ISARA-Lyon), Lyon, France

Students completing the Master's program will be awarded a double degree from two of these universities.

Master's degree in Molecular Medicine
Diabetes, cardio-vascular diseases, cancer, diseases of the brain and nervous system and arthritis affect a large proportion of the population. The Master's degree programme includes teaching in the molecular mechanisms that have an impact on the development of these diseases; as well as teaching in their diagnosis, treatment and possible prevention. Teaching also focuses on the changes in cells and tissues that occur during such diseases.

Master of Science in Biotechnology and Chemical Engineering
The theme of the degree programme is the development and optimisation of processes in the chemical and biotechnological industries and in the environmental sector.

Agro-Environmental Management
One of the greatest challenges of the twenty-first century is at the core of the Master's degree in Agro-Environmental Management programme. Nationally and globally there is a need for solutions that combine the increasing demand for food with sustainable management of nature, the climate and the environment.

Master's degree in Public Health Science
The Master's degree programme in public health science develops students' knowledge of political, social and economic approaches to improving the health of the population in general and of particular population groups.

Master's degree of Food and Health at the Sino Danish Centre (SDC), led by AU
This degree will be offered as from September 2019. The SDC Food and Health research area has been developed to meet Danish and Chinese food market challenges via a stakeholder chain driven research based collaboration to strengthen Denmark and China's position in the food market. The focus is on application-oriented food science for sustainable, healthy and high quality food supply and security.

Specific areas of interest under this theme include:
Food quality, processing and production, microbial food safety and hygiene, food business, marketing and the consumer, food sociology, economics and supply chain management and nutrition and health.

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