



AARHUS
UNIVERSITY

DC - ISH CENTRE FOR FOOD AND AGRICULTURE

PERSPECTIVE

ANNUAL REPORT 2019

DCA – DANISH CENTRE FOR FOOD AND AGRICULTURE

Food and agricultural science
Research-based policy support
Knowledge exchange and industrial collaboration
National and international research alliances

Publisher

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Cover photo

Morten Ambye-Jensen carries out research in biorefining technologies, and the new biorefining plant at AU Foulum will play an important role in the transition towards circular and more environmental and climate-friendly agriculture. Read more on page 16.

Photo: Lars Kruse, AU Photo.

DCA – Danish Centre for Food and Agriculture publishes the annual report Perspective. The report contains information about the work that underpins Aarhus University's research-based policy support in food and agriculture.

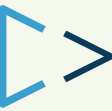
The publication provides examples of new projects and recent research results including collaborations with commercial companies and organizations.

It is our vision that Perspective will generate interest and understanding – in research as well as policy support – and illustrate how these efforts help strengthen the foundation for important societal decision-making.





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We will increase **quality** and **transparency** in research and communication

Like previous years, 2019 was a busy year for research, policy support, education, industrial collaboration, international collaboration, communication and various other tasks. This annual report provides examples of the many different activities within the DCA focus areas.

As always, the aim of our activities is to create knowledge and insight into the complicated problems often associated with agriculture and food production.

This new knowledge should contribute an improved basis in order for society as a whole, i.e. authorities, organizations, companies and farmers to make knowledge-based decisions.

The need for knowledge was as significant as ever in 2019. Society faces huge challenges in relation to reducing climate impact, and the food sector is one of the most important areas.

Credibility and integrity

In other words, we strongly need trustworthy and reliable research-based knowledge. It is aggravating as well as unfortunate, when our policy support and/or communication of research results do not meet our expectations.

In 2019, we noticed an error in relation to a study of peatlands. The error dates back to 2015 and was caused by a wrong layout/ reading of a table, which resulted in an incorrect estimate being used for future peatland notes. The CO₂ emissions from peatlands are considerable, and the incorrect study led to a change in the national Danish estimate for GHG emissions, but obviously no changes in the actual emissions.

The so-called "climate impact of beef" case gave rise to significant criticism in the media as an interest group had contributed to a report without this being explicitly stated. In addition, we made the mistake of giving the same organization the opportunity to influence the press release in relation to the said report.

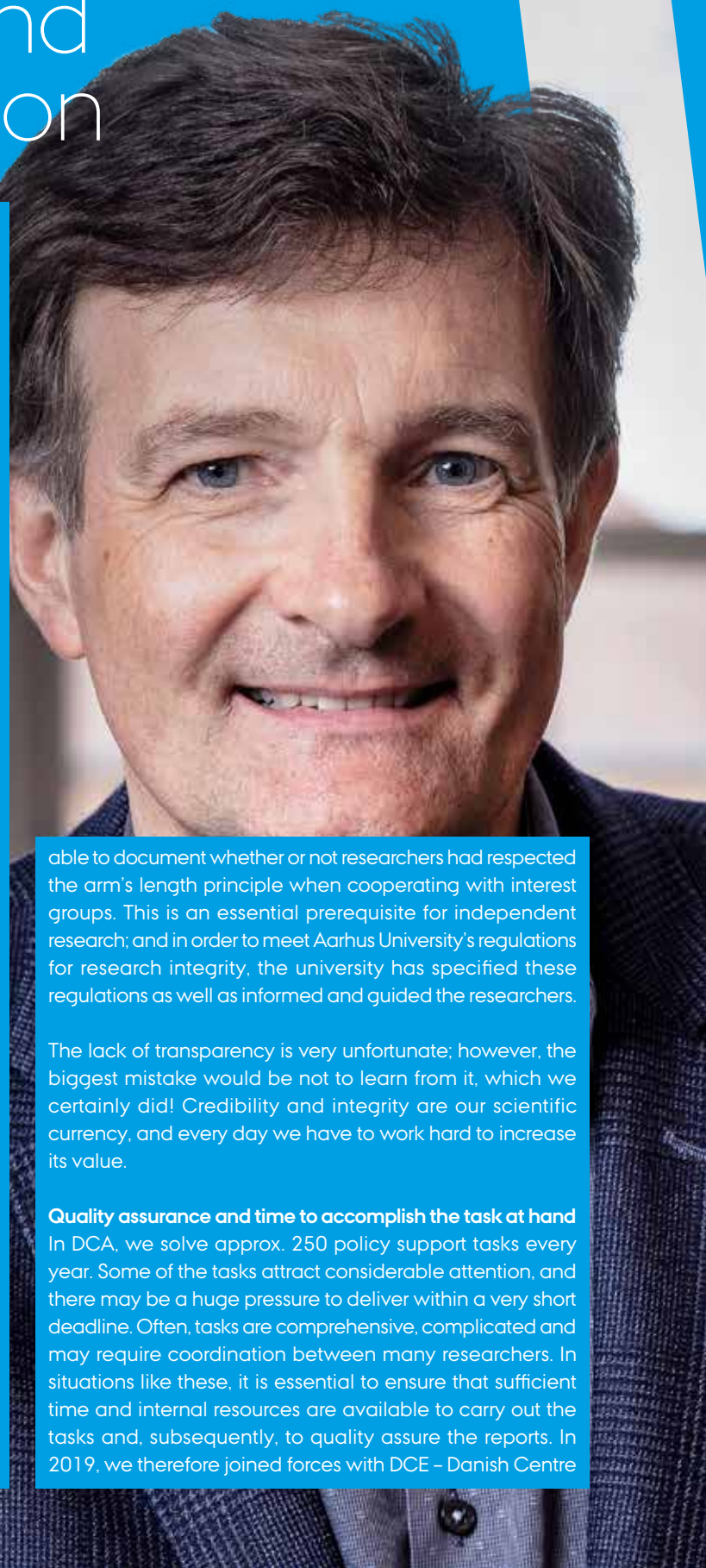
As a result of the criticism expressed, the university withdrew the report; not because there were any scientific errors in the report, but because – due to unclear cooperation contracts and insufficient work processes – we were not

able to document whether or not researchers had respected the arm's length principle when cooperating with interest groups. This is an essential prerequisite for independent research; and in order to meet Aarhus University's regulations for research integrity, the university has specified these regulations as well as informed and guided the researchers.

The lack of transparency is very unfortunate; however, the biggest mistake would be not to learn from it, which we certainly did! Credibility and integrity are our scientific currency, and every day we have to work hard to increase its value.

Quality assurance and time to accomplish the task at hand

In DCA, we solve approx. 250 policy support tasks every year. Some of the tasks attract considerable attention, and there may be a huge pressure to deliver within a very short deadline. Often, tasks are comprehensive, complicated and may require coordination between many researchers. In situations like these, it is essential to ensure that sufficient time and internal resources are available to carry out the tasks and, subsequently, to quality assure the reports. In 2019, we therefore joined forces with DCE – Danish Centre



for Environment and Energy and Aarhus University's Faculty of Technical Sciences in order to strengthen our quality assurance systems. We introduced e.g. improved procedures for examination and peer review to support researchers in maintaining the quality of research-based policy support efforts. In addition, our quality management system is currently being certified.

We want our answers and reports to be based on a solid and reliable scientific foundation – also if pressed for time to meet a deadline.

Increased transparency

We further recognize the need to be more specific when stating our collaboration relations with organizations and companies. Research efforts within the DCA focus areas originally spring from sector research. Many of us are steeped in a tradition of strategic and application-oriented research focusing on relevance, often in cooperation with the agricultural industry, and wanting to communicate research results as soon as possible. This has contributed to a rapid and effective implementation of new technologies in the agricultural and food industries. This is also one of the reasons why Danish agriculture is in the lead, paving the way for the implementation of new environmentally friendly technologies, as well as the reason why organic farming plays a significant role in Denmark. However, we strongly need a new approach to interpret and communicate research results, when it comes to complicated and much debated societal challenges such as e.g. climate and environment.

Every year, researchers within the DCA focus areas publish approx. 500 peer reviewed scientific articles in recognized journals. Our communication should be based on these articles; e.g. by communicating research results in newsletters etc.

When needed, we publish DCA reports that gather and communicate research knowledge. The reports mainly contain research that has already been published in international journals.

In other words, we continue to do our best in order to inform you about research and its results, just as researchers are free to discuss their research and use their knowledge to provide policy support to authorities and cooperation partners.

Improved information as to cooperation

At the same time, we will explicitly state the participants in any given collaboration project, together with information on who funded the research, and who were given the opportunity to comment the results achieved etc.

We also continue our efforts to ensure transparency in relation to research-

based policy support to the authorities. All answers and reports are available for download at our website, and – if it seems relevant – we will publish DCA reports communicating the knowledge foundation for our policy support to the authorities.

Regarding this – as well as all other areas – we aim to do our best to specify the work efforts. We should always be able to document that we respect the arm's length principle to funders and other interested parties.

It is never wrong to learn

Bearing this in mind, it should be mentioned that we work with biological systems that vary with time in accordance with a huge number of factors in agriculture and the surrounding nature, such as soils, precipitation, climate, diseases, farm management etc.

For instance, we are not able to measure the nitrate leaching from all fields continuously, nor the methane emissions from all cows. This means that policy advice within our focus areas is mostly based on estimates and models based on experimental data as well as a relatively limited number of measurements of a given factor. Our policy advice is based on the available foundation and we always aim to indicate the margin of uncertainty in relation to the actual estimate. The more data we have, the better and more precise our models will be. Therefore, our estimates and the specific policy advice will be subject to change with time as a result of more and improved measurements.

It is depressing to witness researchers being criticized for being wrong or making mistakes simply because an improved model may generate results that vary from previous results.

Improved documentation

The major part of our research and policy advice efforts includes a rather fruitful cooperation with companies, organizations and authorities. However, it is obvious that in some cases our policy support contributes to establishing a framework for production, some will find this framework too narrow and others too loose.

We will be exposed to criticism and our policy support will be challenged. This is, however, part of the job and our response will be a more explicit presentation of research documentation with the inherent uncertainty in relation to figures and results, increased transparency as to collaboration with external parties and improved indication of third party contributions.

We will do our very best to minimize errors and increase the quality in our research and policy support. Yet, we are not afraid of admitting errors and learning from them. This is actually the purpose of our work efforts.

We hope you will enjoy reading this report.

Niels Halberg, Director DCA – Danish Centre for Food and Agriculture

Research-based policy support

One of a university's core tasks is to provide research and ensure communication of new knowledge. This is accomplished by publication and dissemination of research results, student education and research-based policy support to authorities.

Aarhus University (AU) has entered into an agreement with the Ministry of Environment and Food of Denmark (MFVM) on the provision of research-based policy support in areas relating to nature and the aquatic environment, arctic conditions, air, emissions and risk assessment, food quality and consumer behavior, crop production, and livestock production. The agreement comprises a framework agreement ensuring that AU carries out research to support the Ministry's administrative tasks. In addition, the agreement ensures that AU has the necessary knowledge and competence required to provide research-based policy support within the scientific areas comprised by the framework agreement.

About DCA – Danish Centre for Food and Agriculture

Providing policy support in relation to complex questions often requires interdisciplinary collaboration. In order to ensure this within the areas of food and agricultural science, Aarhus University has established DCA – Danish Centre for Food and Agriculture. The centre coordinates cooperation with the Ministry within the following areas: Crop production, Livestock production, and Food Quality and Consumer Behaviour.

A centre unit supports DCA activities, which – in addition to policy support – further comprise industrial collaboration, international collaboration and communication.

Similarly, AU established DCE – Danish Centre for Environment and Energy to support activities within environment and energy. DCA departments cooperate with DCE departments as to interdisciplinary policy support. Activities within DCE focus areas are not included in this report.

DCA – Danish Centre for Food and Agriculture comprises AU departments with food and agricultural science activities:

- Department of Agroecology
- Department of Animal Science
- Department of Food Science
- Centre for Quantitative Genetics and Genomics
- Department of Engineering





What is research-based policy support?

In order to provide qualified advice and support to authorities, the university must possess scientific competence within the area as well as observe the authorities' expectations as to relevance, form and punctuality in the support provided. In other words, research provides the necessary foundation for highly qualified policy support, and the term "research-based policy support" thus comprises both research-based advice and the underlying research.

All public research and policy support should be freely available, and the universities are entitled – and obligated – to publish the results. Researchers' freedom of speech and research are fundamental principles that the universities cherish and protect, also in relation to research-based policy support.

The agreement with the Ministry respects the arm's length principle, and DCA's policy support is based solely on the scientific contributions provided by the researchers. The authorities are responsible for the subsequent political and administrative considerations.

Research-based policy support comprises four types of support:

- Research-based advice
- Research-based surveillance and scientific data centres
- Research-based readiness
- Research and general competence building

Financing food and agricultural research

Different sources fund food and agricultural research, and DCA's contract with the Ministry of Environment and Food of Denmark is the main income source. According to the agreement, DCA received 269 million DKK in 2019.

The grant from the Ministry of Environment and Food of Denmark allows DCA to attract and carry out research projects in collaboration with organizations and companies. This collaboration, together with grants from national funds and research programmes, was the main reason why the total research and development funding within the agricultural and food area amounted to 573 million DKK in 2019.

International collaboration in DCA

Researchers from the DCA focus areas often participate in international collaboration. Collaboration highlights are presented in the following.

European Union Reference Centre for Animal Welfare

Department of Animal Science holds a leading position within European livestock research, and together with two research institutions in Germany and The Netherlands, the department has been designated to establish the first European Union Reference Centre for Animal Welfare (EURCAW). This assignment was won in competition with other European consortia. During the next five years, the Danish researchers will contribute to improving animal welfare control in European livestock herds and provide advice to authorities in the 28 member countries.

Global Rust Reference Center

Researchers from Department of Agroecology at AU Flakkebjerg lead the Global Rust Reference Center (GRRRC), which carries out phenotyping and genotyping of virulence in both yellow rust and wheat stem rust – devastating plant diseases in e.g. grains. In addition, the center is in charge of training students and researchers as well as data management, storage (databases) and data reporting.

Climate cooperation

DCA researchers participate in the Global Research Alliance on Green House Gases (GSP). This cooperation mainly consists of network activities, but collaboration efforts have resulted in method development, articles and new project collaboration.

Similarly, DCA participates in FACCE JPI – the European research collaboration in relation to climate and food safety. DCA acts as an initiative leader and participates in research activities established in relation to FACCE JPI.

EIT Food

Aarhus University is a core partner in EIT Food, which is Europe's leading initiative within food innovation. EIT FOOD consists of a consortium of key actors from the industry, newly established companies, research centres and universities from all over Europe. Work efforts are supposed to result in a healthier, more sustainable and more reliable food system. The DCA departments – Department of Food Science in particular – applied for, and was granted, several EIT FOOD projects starting in 2020. Other departments will follow in 2020 and apply for innovation projects with the participation of companies.

EU cooperation

DCA researchers participate in a wide range of European research programmes, primarily Horizon 2020. In addition, the centre unit carries out tasks within international research and policy support:

The permanent Subgroup on Innovation for agricultural productivity and sustainability under European Innovation Partnership on Agricultural Sustainability and Productivity (EIP-AGRI). The group identifies problem areas as well as good practices and supports innovation.

SCAR (Standing Committee on Agricultural Research) Collaborative Working Group on Sustainable Animal Production, the purpose of which is to improve the coordination of research priorities and collaboration concerning funding within sustainable animal production.

SCAR (Standing Committee on Agricultural Research) Foresight Group, the main activity of which is the initiation of Foresight studies, currently the 5th Foresight Exercise: Natural resources and Food Systems: Transitions towards a "safe and just" operating space.

Animal Task Force (ATF) is a Public-Private-Partnership working for a sustainable and competitive European animal production by generating knowledge and innovation in the entire chain. DCA holds the position of Vice President for knowledge institutions in 20 European countries.

Interdisciplinary collaboration

Aarhus University has established a number of interdisciplinary, thematic centres to ensure collaboration across different scientific disciplines and create synergies between departments and other units.

The centres act as the entrance for cooperation partners from industry and trade, nationally as well as internationally. Via cooperation in the form of joint research projects, the centres focus on the development of research-based technologies and solutions to societal challenges.

The four following centres are of major importance to the DCA focus areas:

- iFOOD – Centre for Innovative Food Research
- CBIO – Centre for Circular Bioeconomy
- iCLIMATE – Interdisciplinary Centre for Climate Change
- WATEC – Aarhus University Centre for Water Technology



Read more about the centres at
dca.au.dk



Climate conference: Foods in a changing climate

Agriculture, companies, consumers and society as a whole share the responsibility for the environmental impact of foods. Aarhus University Interdisciplinary Centre for Climate Change, iClimate, gathered actors within the focus area to discuss solutions. This conference took place at Eigtveds Pakhus in Copenhagen on 18 March 2019.

At the meeting, researchers and other participants first pointed out problems and development opportunities within the food area. Next, representatives from companies and organizations presented their solutions for a climate friendly food production as well as for the role of Danish agriculture in a future with climate changes.

Circular Bioeconomy Days

In connection with the opening of the new biorefining plant in June 2019, AU Foulum hosted the Circular Bioeconomy Days 2019, bringing together the most important Danish and international actors to discuss the development of sustainable protein of the future, and how circular bioeconomy can be a tool to implement the UN Sustainable Development Goals. Agenda issues further included how companies and agriculture may enter into circular bioeconomy, and how to ensure that its further development will be of value to industry and society.



Conference organizers were Aarhus University Centre for Circular Bioeconomy (CBIO), SEGES, Agro Business Park, Central Denmark Region, Viborg Municipality, Climate KIC and the EU project Green Valleys.

European food innovation competition in Aarhus

The first Nordic event within the framework of EIT Food took place in September 2019, i.e. the award of the EIT FOOD Innovation Prize – a major competition for startups within the agrifood sector – giving entrepreneurs and early start-up companies the chance of winning 10,000 Euros based on the presentation of their business plans to an expert jury.

Sector collaboration

Collaboration with companies and organizations

A number of research projects entail significant collaboration with companies and industrial organizations etc. Further, we collaborate as to professorships, industrial PhD's as well as investments in infrastructure such as a huge, new biorefining demo plant.

Via its centre unit, DCA is a member of the Biobased Innovation Consortium (BIC). BIC is a European organization consisting of companies and universities working within bioeconomy. The DCA centre unit is the BIC contact body and coordinates participation in partnering events in relation to the Horizon 2020 program BBI – Biobased Innovation – according to which grants are given to support the creation of consortia with the participation of European companies in order to prepare BBI applications.

Together with Agro Business Park and SEGES, the DCA centre unit is a main actor in Central Denmark Region's bioeconomy programme 2016-2020. DCA departments participate in a major part of the many projects initiated during the programme.

Further, the centre unit acts as project leader in relation to the PPS project – Partnership for Precision Spraying 2018-2021 – under the Ministry of Environment and Food of Denmark. Aarhus University researchers participate in a major part of the initiated projects – all in cooperation with Danish companies.

Within the DCA focus areas, 65 Green Technologies have been identified; all with the potential of evolving into new companies and cooperation relations. So far, four spin-outs have been established.

Advisory panel

The DCA advisory panel contributes to organizing cooperation with national users and collaborative partners. Advisory panel members include the Ministry of Environment and Food of Denmark and organizations and companies related to food and agricultural production.

The panel provides advice on the centre's overarching vision and strategy, including the relevance of research in relation to society's future needs for advisory services, national and international research topics, communication of knowledge to society and the framework of research-based policy support.

DCA

Department of **Animal Science**Department of **Food Science**Department of **Agroecology****DCA Centre Unit**Department of **Engineering**Center for **Quantitative Genetics and Genomics****MAPP**

DCA – Danish Centre for Food and Agriculture comprises AU departments with food and agricultural research activities:

Department of Food Science

Research and teaching activities in the Department of Food Science comprise the entire food chain from field to fork, as well as the health-promoting properties of foods and food constituents.

The Department of Food Science possesses leading capabilities and resources, as well as active national and international networks. Thus, the department is able to make significant contributions to current food-related global challenges: food supply, food wastage, sustainable food production under changed climatic conditions, and increased occurrence of lifestyle-related diseases. Additional focus areas include food quality, differentiation of foods, and novel, convenient and healthy foods.

Department of Agroecology

The Department of Agroecology carry out basic, strategic and applied research in agroecology, which means the interaction between climate, soil, plants, animals and people in agro-ecosystems with a focus on promoting health, sustainability and environmentally friendly production of food, feed, energy and bio-based products. We contribute to a sustainable production and growth through research, consulting and teaching.

The vision of the Department of Agroecology is to be among the elite of research institutions that work with agroecosystems and to create, develop and transfer groundbreaking knowledge that can promote society's bioeconomy nationally and internationally.

Department of Engineering

The research and development activities in Department of Engineering broadly cover the engineering field and are organized in four fields: Biological and Chemical Engineering, Civil and Architectural Engineering, Electrical and Computer Engineering and Mechanical Engineering. In the interface between these four engineering research areas, the department regularly selects a number of interdisciplinary research initiatives that are either relevant to society or possess significant commercial perspectives. These include e.g. renewable energy, medical technologies, and food and agricultural technologies.

Department of Animal Science

The objective of the Department of Animal Science is to carry out basic, strategic and applied research in issues relating to the nutrition, health and welfare of livestock, companion animals and humans.

The staff have expertise in disciplines such as cell biology, physiology (digestion, reproduction, growth, lactation, stress, organ and production physiology), applied analytical chemistry and biochemistry, nutrition, microbiology, reproductive biology and technology, embryology, immunology, biomarkers in clinical chemistry and biomodelling, pathology, pain biology, ethology, veterinary epidemiology, herd diagnostics, production management and animal health economics. To this may be added the skills required for carrying out research work at the experimental facilities..

Center of Quantitative Genetics and Genomics

The Centre for Quantitative Genetics and Genomics' (QGG) research includes both basic and applied research. Research efforts focus on the genetic basis of complex traits in farm animals, cultivated plants and model organisms and comprise the development and implementation of advanced statistical and bioinformatic methods used to analyze genetics problems. QGG research efforts are characterized by a very close synergy between method development, basic analyses and the application of the developed methods in relation to practical problems across animal species.

MAPP Centre, Department of Management

Regarding research-based policy support, DCA has close cooperation relations with the MAPP Centre, Department of Management at Aarhus University's Faculty of Business and Social Sciences (BSS). MAPP's primary research area is consumer behavior with regard to food and drink, embedded in a value chain perspective. Therefore, MAPP also carries out research in relation to buyer behavior of retailers and food producers as well as how actors in the food chain cooperate to create value for the consumer. This focus area is complemented by research dealing with the implications of insight into consumer behavior and how this affects the industry as well as public policy-making.

AU Foulum

AU Foulum houses the major part of the university's agricultural research. Research topics comprise livestock, plants, foods, ecology, bioenergy, environment, climate, soils, genetics and technologies.

Part of the plant experiments are accomplished at Foulumgård, close to AU Foulum.

Department of
Agroecology

Center for
Quantitative Genetics and Genomics

Department of
Animal Science

Department of
Engineering

AU Skejby / Årslev

At the end of 2019, Department of Food Science moved its activities to new facilities in Agro Food Park in Skejby – together with most of the research facilities from Årslev. Now, a new 7500 m² building in Skejby houses analysis laboratories, sensory facilities, cultivation facilities, postharvest facilities and greenhouses.

Department of Food Science still carries out research activities at AU Årslev. These are primarily experiments in relation to the cultivation of fruits and vegetables.

Department of
Food Science

AU Askov

Askov Experimental Station is a part of Department of Agroecology, and the main task is to carry out trials with animal manure and soil carbon. Part of the land is occupied by long-term fertilization trials, which were established in 1894 and have continued without interruptions since then. The trials have achieved international status, as they are the only ones in the world, in which variable application of nutrients from commercial fertilizers and animal manure have been compared for a period of more than 120 years.

Department of
Agroecology

AU Flakkebjerg

Research areas at AU Flakkebjerg comprise crop protection, pollination and bee diseases as well as plant biological research with a specific focus on cereals, seeds and industrial crops. During the growth season, advisors, working groups, farmers and other specialists are often invited for walks in the fields. Many of the trials specifically relate to pesticides, crop varieties and seeds. Research activities are primarily embedded within Department of Agroecology.

Department of
Agroecology



Plant production

The Ministry of Environment and Food of Denmark (MFVM) and Aarhus University (AU) have entered into an agreement on the provision of research-based policy support within plant production.

The agreement specifies eight scientific focus areas in relation to which AU/DCA carries out research and policy support activities:

1. Plant breeding and pollination, plant health aspects, crop protection and Integrated Pest Management (IPM)
2. Climate-smart production systems
3. Fertilizers, standard values and nitrogen prognosis
4. Technology – agriculture and plant breeding
5. Soils and soil conditions, including digital data, maps and image analysis
6. Green transition and biomasses
7. Targeted area regulation and mitigating measures
8. Agricultural reform and public green goods

Research-based policy support within the area is primarily carried out by researchers from the departments of Agro ecology, Molecular Biology and Genetics, Food Science and Engineering.

However, researchers from other departments often contribute, especially researchers from the environmental areas comprised by DCE. Interdisciplinary research areas such as e.g. climate and bioeconomy involve cooperation with researchers from various disciplines.

In relation to interdisciplinary research areas such as climate and bioeconomy, researchers from many other areas contribute.

You can read more about our plant production activities in the following.



You can find the agreement at
dca.au.dk





125th anniversary celebrated at Askov Experimental Station

Aarhus University's long-term field experiments on manure and mineral fertilizers at Askov Experimental Station have provided soil, plants and data for a wide range of studies over the years. At the celebration of the 125th anniversary of the experiments on 11 June 2019, researchers from Oxford, Rothamsted, Newcastle, Jülich – and Denmark – presented some of the results.

The field experiments at Askov have been running without interruption since 1894. Together with archived samples of plants and soils, collected systematically since 1923, the experiments provide a unique research facility that supports research in widely different areas. In recent years, the experiments have been the launch pad for international collaboration in soil biology, soil physics, plant nutrition, environment and climate change, occurrence of antibiotic resistance, and prehistoric archaeology.

Plant Conference 2019

In keeping with tradition, researchers from Aarhus University participated in the plant conference in January 2019 contributing as many as 26 presentations within agriculture.

Recent research results within current topics such as climate, aftercrops, mitigating measures, pesticides, soil quality or biomass were presented; the titles of some of the presentations were:

"Consequences of banning glyphosates", "Triazoles – what is the problem?", "Climate change and droughts", "Reduction of nitrous oxides", "Adapting rotations to aftercrops and alternatives" and "Synergy between cereal types and feed enzymes".

Climate change induced drought threatens the world's wheat production

In the coming years, a growing portion of the global wheat growing areas will be affected by drought and this will have serious consequences for the global food supply.

Wheat is the most cultivated crop in the world and it is a basic food in virtually all cultures. Wheat represents approx. 20 % of the calories consumed by people worldwide. Unlike many other crops, wheat is mostly rainfed, and thus cultivated without irrigation. In other words, the wheat depends on the water naturally present in the soil and supplied by rainfall. This means that wheat is one of the crops most threatened by increased temperatures and changing drought conditions.

A significant reduction of the wheat harvest seems unavoidable. Even if global warming is limited to the 2 degrees as stipulated in the Paris Agreement of 2015, a doubling of the severely drought-affected area cannot be avoided. This is revealed in a new study just published. Professor of climate change and agriculture Jørgen E. Olesen from the Department of Agroecology at Aarhus University is a part of the international research group behind the study.

- We have looked at the growth periods from past to present and calculated an index for drought. From there, we could see how much of the wheat growing area has been affected by severe drought each year," Jørgen E. Olesen explains.

The calculations are based on the observed climate, and if you look at the time from 1900 and onwards, the drought-affected area has remained fairly stable, until 20 years ago when the drought affected area suddenly began to expand – and it is still expanding.

- We have looked at how it will develop in the future under different scenarios. Among other things, the research team has looked at the goal of the 2015 Paris Agreement to limit the global temperature rise to below two degrees Celsius, as well as two scenarios with even higher rises in temperature", says Jørgen E. Olesen.

The research group's study shows that approx. 15 % of the cultivated wheat area is affected by severe drought at present, but up to 30 % will be affected in the future, even if the climate efforts of the Paris Agreement is respected.

- The situation is very serious. We cannot avoid the fact that water scarcity will have very serious consequences for wheat. Therefore, we need to adapt the world's food production to increased droughts and water scarcity", Jørgen E. Olesen states.



Collaboration partners:

15 partners from 9 countries, including Department of Agroecology and iCLIMATE, Aarhus University.

New research on climate and plants

Aarhus University's research in plants and climate creates new knowledge that may contribute to reduce the climate impact from agriculture and help climate-proof the crops of the future.

Crops for the future climate

A flood can ruin a potato harvest in just 24 hours. However, by understanding the plants' defence mechanisms, it is possible to create crops that are more resistant and able to withstand flooding. An international research team with the participation of Department of Agroecology, Aarhus University, is working to make plants "waterproof".



Wild plants as climate change resistant crops of the future

Climate changes and an increasing population make it imperative to find alternatives to the crops that feed the world's population today. Together with colleagues from the University of Copenhagen, researchers from Department of Agroecology, Aarhus University, will make new crops out of wild plants.

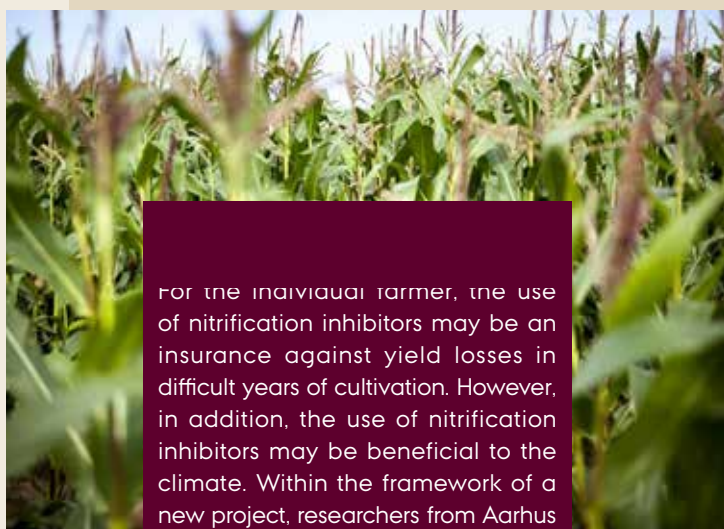
Grassland in crop rotation is beneficial to the climate

Crop rotations play an important role in climate change mitigation as it may increase soil carbon storage. Within the framework of a new project, researchers from Department of Agroecology, Aarhus University, will examine how farmers may use grassland-arable crop rotations with an increased proportion of grassland as a measure to increase carbon storage and thus reduce climate impact. The project is carried out in collaboration between Aarhus University, University of Copenhagen and SEGES, and the Ministry of Environment and Food of Denmark financially supports the project with an amount of almost 9 million DKK.

Aftercrops for the sake of our environment

For several years, aftercrops have been used as a mitigating measure to reduce nitrogen leaching in Danish agriculture. Together with colleagues from University of Copenhagen and SEGES, researchers from Department of Agroecology at Aarhus University work to quantify the potential of using aftercrops and green fertilizers as climate mitigation measures.

For the individual farmer, the use of nitrification inhibitors may be an insurance against yield losses in difficult years of cultivation. However, in addition, the use of nitrification inhibitors may be beneficial to the climate. Within the framework of a new project, researchers from Aarhus University, University of Copenhagen and SEGES cooperate to examine the effect of nitrification inhibitors on nitrous oxide emissions under Danish conditions as well as the effect of nitrification inhibitors on soil organisms.



New biorefinery plant at AU Foulum

In June 2019, a new demonstration-scale biorefinery plant for the extraction of protein from grass was inaugurated. The plant is established with a view to further developing the technology and providing new knowledge as to the establishment of a full-scale plant.

Cultivation of perennial crops, such as grass and clover grass, has many benefits for the environment and climate. Grass can be cultivated without the use of pesticides, and trials at AU Foulum have shown that nitrogen leaching to the aquatic environment is significantly reduced when perennial grass crops are grown.

In Denmark, several areas have a particularly high risk of nitrogen loss. In these areas, leaching can be avoided by cultivating sustained grass instead of grain. Similarly, grass cultivation without the use of pesticides may be an option in water extraction areas.

How to use all that grass?

This grass can be used for cattle feed, but there are many other options. Fresh grass contains about 20 % protein, and research at AU Foulum has shown that protein extracted from green biomass can be used as protein feed for pigs and poultry.

If the protein is further refined, it may be used as food ingredients. In addition, by-products from the production may be used as cattle feed, bioenergy and as a basis to produce chemicals and other biobased products.

In order to support a commercial development and the establishment of a full-scale biorefinery plant, additional knowledge is required as to the design of a full-scale plant, the costs and energy consumption associated with the production, as well as which product qualities we expect to achieve in full scale production.

Demonstration plant at AU Foulum

So far, research efforts have been carried out in laboratories and at a small experimental plant. However, in 2018 a number of agricultural organizations and foundations allocated the money required to establish a new demonstration-scale biorefinery plant at Aarhus University in Foulum. The plant was inaugurated in June 2019.

- The new biorefinery plant will allow us to work with the optimization of biorefining processes, almost in full scale, and provide new opportunities for further development and tests of new products in larger quantities, says project manager and Associate Professor Morten Ambye-Jensen, Department of Engineering.

The new plant can process 10-20 tons of fresh green biomass per hour. This means that researchers at AU Foulum will have sufficient feed to carry out extensive feed experiments.



Moderate nitrous oxide **emissions** from perennial grass for future **bio-refineries**

Cultivation of perennial crops, such as grass and clover grass, has many benefits for the environment and climate. Grass can be cultivated without the use of pesticides, and trials at AU Foulum have shown that nitrogen leaching to the aquatic environment is significantly reduced when perennial grass crops are grown.

Researchers from Department of Agroecology at Aarhus University have documented the annual emissions of the greenhouse gas nitrous oxide (N₂O) in crops, for biorefining purposes, with different levels of nitrogen input (N). As a reference, the N₂O emission from annual maize was determined.

- The objective of our study was to quantify nitrous oxide emissions, if we were to cultivate perennial crops such as festulolium, tall fescue and grass clover for the production of green protein to replace imported soya protein. The challenge is that high-yielding perennial grass requires high N fertilization. Without measurements of the actual emissions, Denmark has to follow guidelines from IPCC (International Panel on Climate Change) and assume that 1% of applied N ends up as N₂O, and this may offset the climate benefits of using biomass as a renewable resource, explains Søren O. Petersen.

Documented for the first time

This long-term experiment was established in 2012, but it is the first time that annual N₂O emissions have been measured rather than calculated.

- We found that annual emission factors (loss of N input in percentage) for both perennial grasses and annual maize, included as reference, were well below the 1 % default value set by IPCC. However, this result is in agreement with several other Danish studies of N₂O emission from arable soil, and it indicates that this level of emissions is typical for the local climate and soil conditions, Søren O. Petersen explains.

Effective use of fertilizer N

The results therefore indicate that intensively managed perennial crops can be used for biomass production under Danish conditions without excessive N₂O emissions compared to annual crops. The study further indicated why N₂O emissions were moderate:

- We found that when the crops are actively growing, they can take up most of the fertilizer N from the soil within a few days. Thus, the nitrogen becomes inaccessible for the soil microorganisms responsible for N₂O production. Therefore, if the N fertilizer is given in the right amount, and at the right time, this will reduce the risk of N₂O emission, Søren O. Petersen explains.



Collaboration partners:
**Department of Agroecology and
iCLIMATE, Aarhus University**

New calculation model for the prediction of nitrogen leaching

Researchers from Aarhus University have developed a new version of the empirical model for the prediction of nitrogen leaching from arable lands.

NLES5 is an updated and extended model for the calculation of nitrogen leaching, thus improving the basis for determining nitrogen leaching and consolidating the estimated marginal leaching. The model is a continuation of the previous models, NLES3 and NLES4.

NLES5 is a so-called empirical model for predicting the annual nitrogen leaching (nitrate-N) from the root zone of arable lands. The model takes into account the impact of nitrogen inputs, crop sequences, autumn and winter soil cover, and soil and weather conditions.

Being empirical means that the model is based on actual measurements of nitrate leaching from the root zone. The measurements included are from both experimental fields and farmers' fields, and a total of 2053 field observations are included in NLES5, which is far more than the previous models. The model is validated by means of cross validation as well as an actual validation test using data from 856 independent observations with a good result. In addition, an uncertainty analysis as to the NLES5 model's parameters is included. The analysis includes data from all fields in Denmark, gathered in the year 2011, and demonstrates a model parameter uncertainty of approx. 10 % for Denmark.

More data and a new structure

Senior Researcher Christen Duus Børgesen, Department of Agroecology, contributed his efforts to the development of the new model.

NLES5 is based on an updated and modern data set. While previous NLES models included older data sets dating as far back as the 1970's, NLES5 is based on data from a limited period ranging from 1991 to 2017. This means that the model includes a better reflection and representation of the actual cultivation practice compared to the previous models, Christen Duus Børgesen explains.

In addition, the NLES5 model includes a new and improved structure for crops and crop sequences, which allows for improved estimated effects of crop combinations and preceding crops etc.



Læs mere i DCA-rapporten

„NLES5 – An empirical model for predicting nitrate leaching from the root zone of agricultural land in Denmark“



Samarbejdspartnere

Institut for Agroøkologi og iCLIMATE, Aarhus Universitet samt Miljø- og Fødevarerministeriet.

Nutrient balance in agriculture

Every year, DCA provides an update of the nutrient balances for the last 20 years at national level for the agricultural use of nitrogen (N), phosphorus (P) and potassium (K), including a calculation of the surplus and nutrient use efficiency of the three nutrients.

The most recent calculation covering the years from

1997/98 to 2017/18 shows an increase in nutrient surpluses when compared to the average of the last five years. The increases correspond to 5 kg N/ha, 0.6 kg P/ha and 1 kg K/ha, respectively.

The nutrient surplus is the difference between agricultural input and output, and the total surpluses have seen steady

decreases over the last 20 years, during which time surpluses have been reduced by 25-29 % for nitrogen, 55 % for phosphorus and 43 % for potassium. These figures correspond to reductions of 44-49 kg N/ha, 8 kg P/ha and 16 kg K/ha, respectively.



Read the DCA report **„Næringsstofbalancer og næringsstofoverskud i landbruget 1997/98-2017/18“** (in Danish)



Use of mineral and organic fertilizers **according to the Phosphorus ceiling**

In 2017, an amendment to the Danish Livestock Act introduced phosphorous ceilings, and recent research accounts for the problems that P ceilings cause for the use of fertilizers.

The Livestock Act was amended in 2017 implementing restrictions on the annual amount of phosphorus (P) applicable to agricultural land in mineral and organic fertilizers. These restrictions are termed P ceilings and their purpose is to prevent the accumulation of phosphorus in agricultural soils. At a request from the Ministry of Environment and Food of Denmark, researchers from Department of Agroecology have prepared a report accounting for the problems that the P ceilings pose to the use of fertilizers.

Evaluation of the P ceilings

Senior Researcher Peter Sørensen is one of the researchers behind the report, and he explains that P ceilings cause problems for Danish cattle farms – especially cattle farms that use biogas plants to degas the slurry:

- The digested slurry returned to the farm often has a lower N/P ratio than untreated cattle slurry, and contains a relatively high amount of phosphorus and a relatively low amount of nitrogen. This means that dairy farms can apply less nitrogen in digested slurry than could be applied in untreated slurry. However, biogas plants may potentially play an important role in a wider redistribution of nutrients in livestock manure as they act as an exchange station for livestock manure.

The P ceilings are also a challenge to dairy farms under the current derogation rules. These farms – allowed to use more livestock manure than otherwise authorized by the EU nitrate directive – may apply up to 230 kg N/ha in livestock manure. For farms under the current derogation rules, the phosphorus content corresponds to the P ceiling. Therefore, these farms will no longer be able to use mineral phosphorus as starter fertilizer for maize without having to allocate a larger proportion of their livestock manure to other farms.

However, a solution seems available, says Peter Sørensen:

Recent results from field experiments in maize have shown that direct injection of slurry close to maize rows immediately before sowing may replace mineral P in starter fertilizer. In addition, the experiments demonstrate that slurry may have an improved effect on certain soils caused by soil acidification or by adding nitrification inhibitors. A relatively smooth implementation of this practice is expected when applying GPS and newly developed equipment for a precise placement of slurry in maize crops.

Crop removal of phosphorus

The report also contains an inventory of potential crop removal of phosphorus on different types of farms.

For cattle farms, an average removal of 19–26 kg P/ha is calculated, depending on soil type and crop rotation. For plant and pig farms, crop removal varies between 15–28 kg P/ha. Even if phosphorus is applied up to the P ceiling of 30–35 kg P/ha, there are significant differences in P surplus, i.e. the accumulation of P in the soil, among individual farms.



Read the DCA report

„Udredning om anvendelse af gødning i dansk landbrug i relation til indførslen af fosforlofter,, (in Danish).



Cooperation partners are
Department of Agroecology, Aarhus University,
and the Ministry of Environment and Food of Denmark.

Huge potential for new, small biotopes in agricultural landscapes

The up-coming reform of the EU Common Agricultural Policy paves the way for new possibilities for establishing small biotopes. Researchers have examined the potential in Denmark.

In connection with the up-coming reform of the EU common agricultural policy, it is expected that agriculture will have new and improved possibilities for establishing small biotopes in the agricultural land – small, uncultivated areas in fields that are not used for production purposes.

At a request from the Danish Agricultural Agency – and in order to create an overview of the consequences of the reform as to the allocation of new small biotopes – Aarhus University has examined the potential for small biotopes.

Major interest for agricultural areas that are not in rotation

Part of the study consists of interviews with farmers and advisors. According to the interviews, an exceptionally high potential exists in relation to fields that are currently used for permanent grass production as well as other fields not in rotation and/or in relation to peatland/lowland areas.

Generally, such areas already have a high biodiversity, but the establishment of new small biotopes may provide additional benefits to both biodiversity, environment and the

climate. For areas in rotation, i.e. fields with crops in rotation that are regularly converted, a certain interest in establishing new small biotopes seems to exist, particularly along hedges and less applicable areas.

An opportunity to double the area

The estimated potential actually corresponds to more than a doubling of the current area of small biotopes. We may thus expect the area with small biotopes to increase to 2-4 % of the total agricultural area, and significantly more regarding areas not in rotation. Research efforts have been initiated to evaluate the effects of establishing small biotopes.



Read more in the policy support response „**Potentiale for småbiotoper i Danmark**” (in Danish).



Cooperation partners are **Department of Agroecology, Department of Bioscience, Aarhus University, and Ministry of Environment and Food of Denmark.**

Several factors affect honeybee health

Honeybee populations are declining in Europe and North America. Various insecticides are suspected of causing the increased mortality rate, but often the pesticide amounts found on the bees are lower than the lethal dose. Thus, it remains unclear how much, or how little, the insecticides mean when compared to other factors that affect honeybee health and life cycle.

Together with other European research institutions, a research team from Aarhus University works to develop a digital tool that may create a realistic life cycle assessment of the harmful side effects of pesticides. In addition, the team examines the connection between agricultural landscapes and the prevalence of virus and parasites. The project is funded by the European Food Safety



Forest agriculture and its impact on environment, climate and biodiversity

Forest agriculture may have a number of positive effects on both environment, climate and biodiversity if it is developed and applied correctly.

Forest agriculture is not common in Denmark, which may be due to the fact that it is not possible to receive subsidies for forest agriculture. However, this seems to change with the reformed EU common agricultural policy.

At a request from the Danish Agricultural Agency, researchers from Department of Agroecology, Department of Food Science and Department of Bioscience, Aarhus University, have examined the impact of forest agriculture on environment, climate and biodiversity. Based on this, they suggest minimum criteria to be applied in relation to the subsidy regulations.

Effects depend on the actual cultivation system

The researchers state that forest agriculture is a broad concept covering various combinations of agriculture and horticulture with very different trees/bushes and different production purposes. Therefore, it seems rather difficult to evaluate the general impact on the ecosystem. Professor Tommy Dalgaard, Department of Agroecology at Aarhus University, explains:

“Generally, forest agriculture may have a positive impact on both environment, climate and biodiversity if it is optimally developed and tended to, and at the same time, we may expect improved animal welfare by combining forest agriculture and free-range livestock. However, the effects depend on the actual cultivation system, and this aspect is the main topic to be investigated within the framework of a huge EU project called MIXED (2020-2024).”

Regarding biodiversity, the researchers estimate that forest agriculture will increase the genetic, structural and functional variation in habitats in cultivation areas. With time, this will allow for an increased supply and diversity regarding feed, shelter, habitats, breeding locations as well as ensuring that animal species have the possibility of living their natural behavior. This will increase the fauna biodiversity for both mammals, birds and insects.

At the same time, forest agriculture will have an environmental impact by reducing erosion, increasing soil fertility and reducing nutrient losses. In addition, the researchers expect that forest agriculture will increase carbon sequestration in soils and e.g. tree trunks as well as improve the microclimate by providing shade for grazing animals. Finally, studies have demonstrated that, in some cases, the total production of biomasses may be increased.

Based on this, the researchers suggest a series of minimum criteria to be applied in relation to subsidy regulations.



Cooperation partners:

Department of Agroecology, Department of Food Science, Aarhus University, and the Ministry of Environment and Food of Denmark



Read more in the policy support responses:

„Effekt af skovlandbrug på miljø, klima og biodiversitet” and „Scenarier for skovlandbrug i Danmark - effekter på miljø, klima og biodiversitet” (both in Danish)

More opportunities to set aside wetlands

More than 25 % of the total agricultural climate gas emissions originate from the cultivation of drained wetlands with a high level of organic carbon; the so-called organogenic soils. In Denmark, we have approx. 170,000 ha of such soils with more than 6 % carbon.

The problem in relation to organogenic soils is that cultivation of crops such as grains, rapeseed and maize requires tillage. When soil is cultivated, the organic carbon is oxidized and degraded, which results in CO₂ emissions. This is demonstrated as the first scenario in figure 1.

When the soil is no longer cultivated, oxidation, and thus the degradation of organic carbon, is reduced. However, only anaerobic soils allow for a significant reduction in the degradation of organic carbon. This means that a major climate impact is achieved by raising the water level to just below the soil surface.

Setting aside land areas and letting them growing wild over time

- One way of raising the water level is by means of a so-called "passive setting aside of land", an option where the drainage system is degraded and the vegetation is allowed to develop naturally, says Senior Researcher Poul Erik Lærke, Department of Agroecology.

Until the drains are fully degraded, which may take many years, degradation of the soil carbon will continue and thus also a net emission of greenhouse gases. This is shown as the third scenario in figure 1.

When setting aside areas, the vegetation will develop depending on local conditions. At first, this may seem beneficial to biodiversity, but often, in very nutrient-rich wetland areas, it is not likely that the developing vegetation has a high nature value.

Extensive farming with controlled or no drainage

- Another option is to wet the areas by actively stopping or controlling drainage, thus raising the water level to just

below the soil surface, Poul Erik Lærke explains. This is shown as the middle scenario in figure 1.

Rewetting of the areas will allow for an extensive cultivation of crops that are tolerant to flooding, such as e.g. reed canary grass or common reed. This type of cultivation is known as paludiculture and, like passive setting-aside, it will contribute to the building of soil carbon content and thus to a significant reduction in CO₂ emissions.

Experiments at AU Foulum have demonstrated that paludiculture with a modified nutrient supply will allow a harvest of 13 tons of reeds per year. Via the biorefining process, this biomass may be used for feeds and biobased products. In addition, the harvest of biomasses contributes to the removal of surplus nutrients from the areas.

Challenges in relation to setting aside of wetlands

However, certain challenges exist as to the setting aside of organogenic wetlands. Even though nitrous oxide emissions, like CO₂ emissions, will be reduced in some areas after wetting, then the water saturation of the soil can result in increased methane emissions.

Only a few measurements exist of the total GHG balance, including all three primary greenhouse gases for set-aside land in Denmark. Thus, the climate impact of setting aside wetlands as a mitigating measure is subject to uncertainty, not least as we still lack important knowledge of the current water level of organogenic areas as well as the development of this when active draining is stopped.

Many of the organogenic farm lands have high nutrient contents, which prevents the vegetation growing forth after setting aside of farmland in achieving the desired nature value. Harvest of biomasses may remove the nutrients from the areas and also help to maintain the open countryside. However, rewetted soils will pose specific challenges due to the reduced bearing capacity of the soil, and there is a need to develop harvest machinery to be used in soft wetland areas.

Scenarios of extensive farming and setting aside of wetlands and the hypothetical GHG emissions

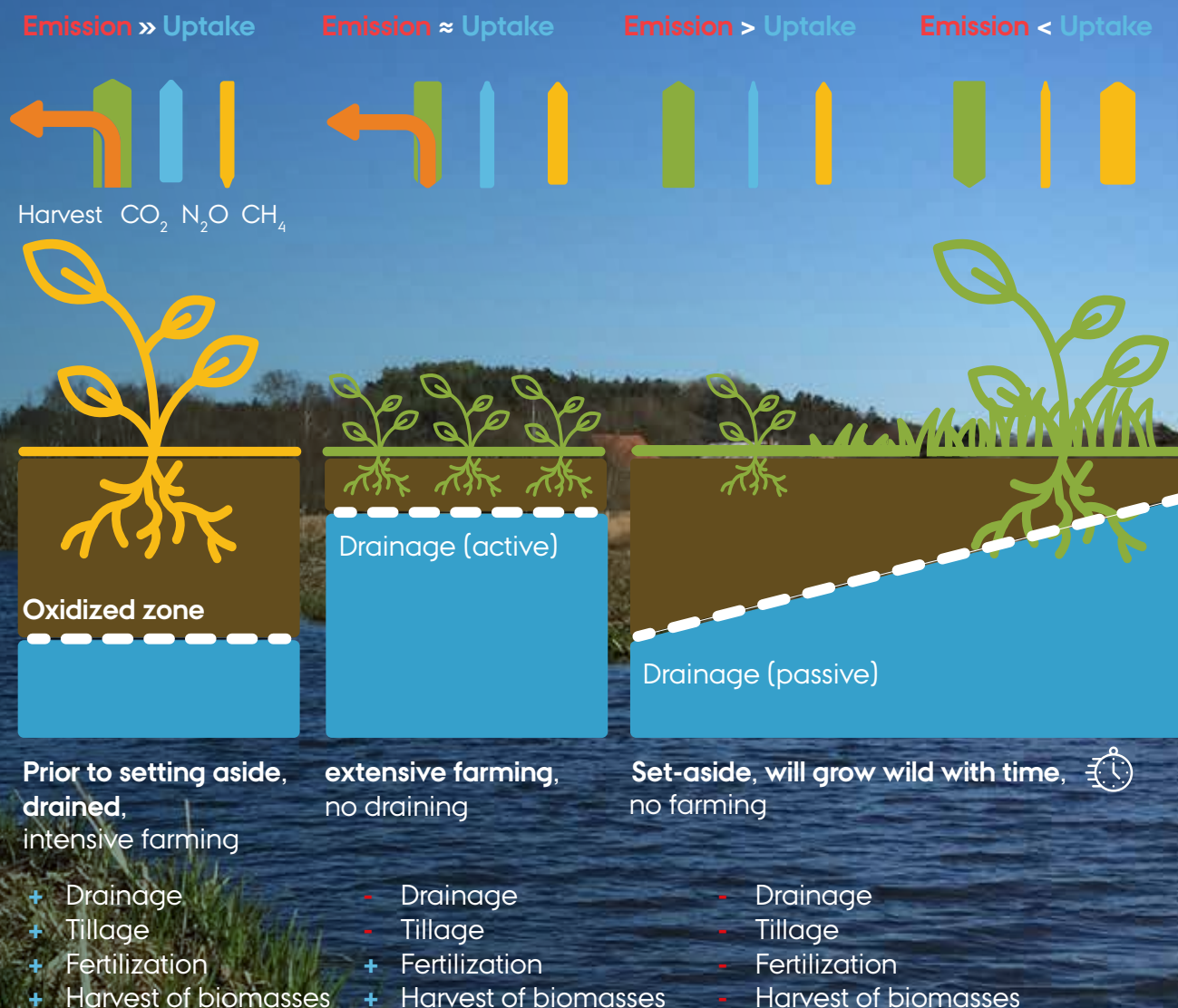


Figure 1. The first scenario shows drained peatland prior to being set aside and with traditional crop production. In the middle scenario, drainage is stopped or controlled, and crops that are tolerant to flooding are established with a view to harvesting huge yields of biomasses with a modified supply of nutrients. The last scenario shows a passive setting aside of the farmland area, in which the drainage system slowly degrades and the vegetation develops after natural succession.

Orange arrows: Carbon removed from the area together with the harvested biomasses.

Green arrows: Net CO₂ gas development from the eco system (difference between respiration and photosynthesis).

Blue and yellow arrows: Exchange of N₂O and CH₄, respectively. Arrow thickness indicates the balance in CO₂ equivalents.

Farmer: **know your soil**

Soil health is of major importance to crop growth

You can examine soil health by means of new and simple soil analyses, described in fact sheets and videos developed in cooperation between Department of Agroecology and Seges.

The new guidelines make it easy to examine your soil in order to find the reasons for poor crop growth. The methods

are simple and easy to apply, they do not require special equipment or access to a laboratory.



Read more at dca.au.dk

Nematode

protection mechanisms to be elucidated

Certain nematodes cause great damage to crops and can be difficult to control. An improved understanding of nematodes' modes of action can contribute to developing efficient methods of control.

Nematodes can be both beneficial and harmful. They are beneficial in that they help decompose dead plants and animals in the soil, and kill certain plant-pathogenic insects. However, nematodes also have a dark side: They cause 10 percent of crop losses globally. Nematodes that attack plant roots are particularly problematic.

Funded by the Independent Research Fund Denmark, researchers from the Department of Agroecology at Aarhus University will delve into nematode larvae's secrets to see if they can find efficient, environmentally friendly control methods.

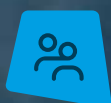
The nematodes that the researchers are investigating spend most of their life cycle within the plant roots, except during a single larval stage, J2, during which they live freely in the soil. This J2 larva moves around in the soil and infects plants despite the fact that the environment, which includes a range of pathogenic bacteria, is very tough for the young larva.

A shield of microorganisms for protection

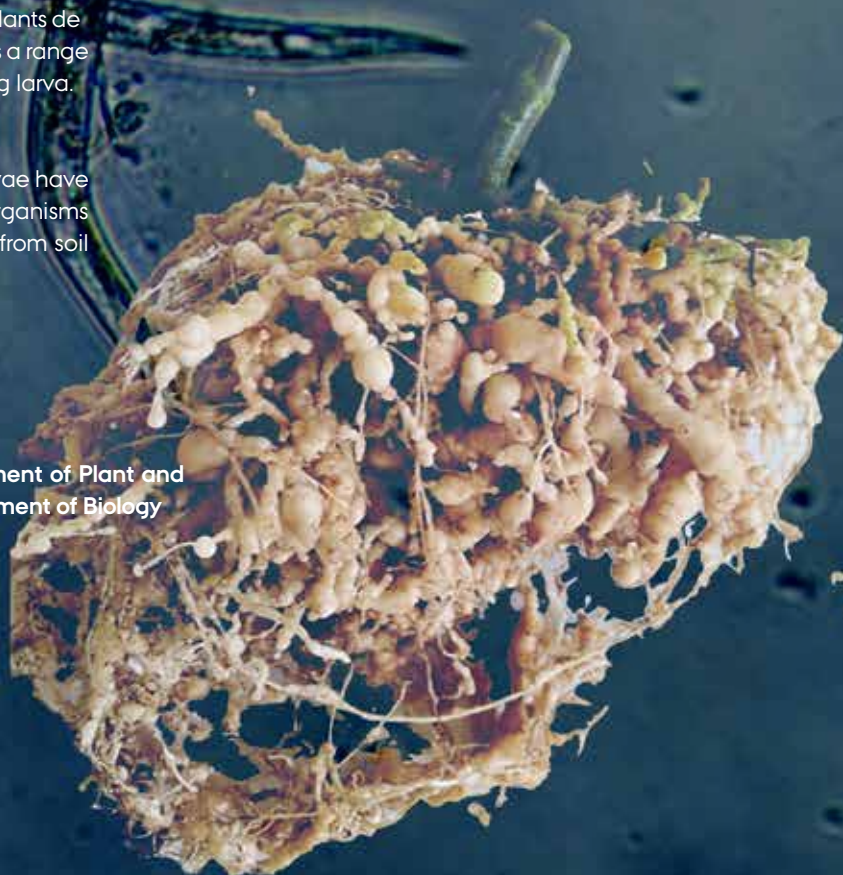
The researchers have a theory that nematode larvae have a microbiome – a special combination of microorganisms – on their cuticle that protects them from attacks from soil pathogenic microorganisms.

We want to investigate if there are specific key microorganisms on the surface of the nematodes that are independent of the soil that the larvae live in, and whether this microbiome protects the larvae or even helps them infect plant roots. We also want to investigate if this protection is reduced in soil environments with poor biological diversity, explains the leader of the new project, Researcher Mette Vestergård from the Department of Agroecology.

The researchers will use the Northern rootknot nematode as their research object. This is a nematode that attacks a very wide range of crops in greenhouses and fields all over the world. The aim is to find out which microorganisms play a key role in the larvae's survival and ability to infect plants, and if conditions in the soil can be controlled to minimize the problem.



Cooperation partners are
**University of Copenhagen, Department of Plant and
Environmental Sciences and Department of Biology**



Overview of crop protection

Which diseases occurred in wheat and barley in research trials in 2018 – and which fungicides demonstrated a good effect? What is the situation with regard to pesticide resistance in Denmark and Sweden? How well did the fungicides against potato blight work in 2018? And how was the weather in May 2018 – was it more dry or wet than normally?

You can find answers to these questions and more in the 2019 version of the report “Applied Crop Protection” published by DCA – Danish Centre for Food and Agriculture. The report provides an overview of the results from studies carried out in the Department of Agroecology regarding plant protection in agricultural crops with an emphasis on the effects of various pesticides.



Read the DCA report
„Applied Crop Protection 2018”

Risk assessment of new plant pests

All things equal, climate changes will affect Danish agriculture – and one thing to be aware of is potential new plant pests.

At a request from the Danish Agricultural Agency, researchers from Department of Agroecology have thus performed a risk assessment of new plant pests. This is an ongoing assignment, and the assessment list was published for the second time in the Summer of 2019. The first list comprised 18 potential plant pests, while the second list comprised 26.



Read the policy support response
„Horizon scanning. Risikovurdering af nye planteskadegørertrusler for Danmark – del 1 „Horizon scanning. Risikovurdering af nye planteskadegørertrusler for Danmark – del 2” (in Danish).

Updated list of pests in seed crops

In individual ways, certain fungi, insects, nematodes, plant and microorganisms may harm seeds that are exported from Denmark. Thus, it is very important to have a survey of their spreading.

At a request from the Danish Agricultural Agency, researchers from Department of Agroecology have prepared an updated status concerning specific pests in relation to seed exports. The survey comprises harmful fungi, insects, nematodes, plants, viruses and bacteria.



Read the policy support response
„Opdatering af skadegørerstatus i Danmark for specifikke skadegørere i relation til eksport af frø – del 1“ „Opdatering af skadegørerstatus i Danmark for specifikke skadegørere i relation til eksport af frø – del 2” (in Danish).

The best **fruits** and **berries** for the garden



A report from DCA – Danish Centre for Food and Agriculture provides a survey of the best fruit and berry varieties for private gardens – depending on the place where you live.

All fruits and berries – ranging from apples, pears, plums and cherry trees to berry bushes, nut bushes, chestnuts and exotic fruits are examined in the DCA report, and the individual characteristics of the varieties, time of maturing, pollination and risk of diseases are described in detail. The report is richly illustrated.

- We have emphasized that the varieties are easy to grow, that they are fertile, robust and taste good. Furthermore, we aim to inspire private garden owners to test new sorts and varieties, says Martin Jensen, Senior Researcher at Department of Food Science at Aarhus University and main author of the report.

Privathavebrugets Frugt- og Bærudvalg (a fruit and berry committee) has put together the selection presented in the report. The committee consists of advisors from the Danish Association of Allotment Gardens and HortiAdvice (an organization providing consultancy, research and development), teachers from Green Academy (offering a broad range of educations within green areas), garden consultants and researchers from Aarhus University and the University of Copenhagen.

Martin Jensen is the main author and organizer of work efforts.



Read the DCA report
„**Frugt og bær - gode sorter til haven**” (in Danish).

From chops to cabbage – the road to a greener food production

Replacing the meat by vegetables on our dinner plates will not only require new habits, but also new knowledge on sustainable cultivation methods.

Today's food production has a significant impact on climate and environment. This also applies to vegetable production where producers have to ensure that the plants have the sufficient amount of fertilizer right up to the time of harvest.

- When cultivating vegetables outdoors, it entails a huge risk of nitrogen leaching. Therefore, we focus our efforts on providing more knowledge to the producers as to how it may be possible to produce more vegetables without unnecessarily affecting the environment, says biologist and Associate Professor Hanne Lakkenborg Kristensen, Science Leader of the science team Plant, Food & Sustainability, Department of Food Science at Aarhus University.

Focus areas in research

The science team investigates aspects within the areas of environment, climate and biodiversity when growing vegetables outdoors. The researchers cooperate with international partners, e.g. within the SureVeg project (CORE organic COFUND programme). Currently, the team examines the advantages of intercropping – or strip-cropping – certain crops. If you grow alternating rows of beetroots and white cabbage, Hanne Lakkenborg Kristensen expects to identify more synergy effects. For instance, the cabbage roots can reach far below the soil surface and gather nutrients from under the beets' root zone.

Another focus area for the team is the identification of new types of fertilizer. Today, slurry from conventional farming constitutes an important source when it comes to ensuring a high yield of cabbage and root crops; also in organic production. However, research results from Department of

Food Science have demonstrated that clover and other legumes, which producers can grow themselves, may actually be great fertilizers. This will allow producers to limit the use of animal nutrients in the production (DoubleCrop and ClimateVeg projects, the RDD programme).

Greenhouses cannot replace outdoor cultivation

Hanne Lakkenborg Kristensen is sometimes asked if vegetable production will take place in greenhouses in the future, sheltered from climate changes. However, she does not believe in that scenario:

We need different cultivation methods as we will be eating more vegetables, but I cannot imagine that we will allow greenhouses to dominate the Danish landscapes. Besides, several of our green crops such as root crops and cabbage thrive best outdoors. Therefore, I expect that the increasing green food production in Denmark will take place in the fields as well in greenhouses, Hanne Lakkenborg Kristensen explains.

Listen to the podcast "From chops to cabbage – the road to a greener food production", available at podtail.com

Animal production

The Ministry of Environment and Food of Denmark (MFVM) and Aarhus University (AU) have entered into an agreement on the provision of research-based policy support within animal production.

The agreement specifies six scientific focus areas in relation to which AU/DCA carries out research and policy support activities:

1. Breeding and genetics of livestock breeds
2. Animal behaviour and welfare
3. Feed and nutrition
4. Nutrient cycle management and livestock manure
5. Production systems, management and advisory service
6. Animal production and mitigating measures

You can find the agreement at dca.au.dk

Research-based policy support within the area is primarily carried out by researchers from the departments of Animal Science, Molecular Biology and Genetics, and Engineering. However, researchers from other departments often contribute.

You can read more about our animal production activities in the following.





News in Brief

Climate and health on the agenda at international milk conference

Health challenges – and the dilemma between climate changes and an increasing demand for dairy products – were on the agenda when Aarhus hosted the "International Symposium on Milk Genomics and Human Health" on 12-14 November 2019.

The symposium was arranged in collaboration between the scientific association "International Milk Genomics Consortium", Aarhus University and a number of industrial partners.

The symposium brought together international researchers to present and discuss the latest knowledge within milk research. Senior Researcher Troels Kristensen, Department of Agroecology at Aarhus University, described the impact of primary production on the climate and discussed how we can increase milk production and, at the same time, consider sustainability and climate. Associate Professor Nina Aagaard Poulsen, Department of Food Science at Aarhus University, explained the connection between sustainable production and milk ingredients and its technological properties and health-related quality.

ViD conference in Aarhus attracted many attendees

Every year the Knowledge Centre for Animal Welfare (ViD) arranges a conference focusing on various topics related to animal welfare. In 2019, the major theme was "Transporting animals", and the event was held in November at Aarhus University.

The conference programme comprised presentations from research institutions and authorities. Senior Researcher Mette S. Herskin from Department of Animal Science, Aarhus University, presented her results from a major project focusing on animal fitness for transport. The animals considered are cull animals in cattle and pig production, and their clinical status was examined before, during and after transport. In addition to transporting the animals for slaughter, they are also moved around in the housing facilities. Three researchers from Department of Animal Science, Aarhus University, shared recent knowledge as to the advantages, disadvantages and recommendations within this particular field.

A new project to pave the way for **the climate-friendly dairy cow**

Aarhus University is in charge of a new research project to pave the way for a more climate-efficient dairy production.

In order to meet the national goals in relation to reducing the total emission of agricultural greenhouse gases, and in order to maintain a competitive agricultural production in Denmark, we need to make dairy production more climate-efficient. The loss of methane from cows' rumens currently accounts for up to 700 litres per cow per day.

The Ministry of Environment and Food of Denmark's climate fund supports a new project that aims at contributing to the reduction of the carbon footprint in Danish dairy production. Preliminary studies from Aarhus University have shown that methane emission from cows may be significantly affected via feeding.

Therefore, the new project, led by Department of Animal Science, Aarhus University, is based on a number of important focus areas, including for example feeding, rumen metabolism, phenotypes, measuring and assessment methods, and effect assessments.

Amount of roughage has a major influence on cows' methane production

Feeding experiments have demonstrated that cows' enteric methane emissions decrease considerably when the amount of roughage in feed rations is significantly reduced.

Based on the drought in 2018, a previous project at AU Foulum examined the possibility of feeding dairy cows less or no roughage at all. Within the framework of a new project, researchers studied the effect of this on cows' methane production.

The results demonstrated a major reduction in methane emissions when the amount of roughage was reduced from

50 % to 0 %. The reduction of methane may be explained by the fact that removing roughage in feed rations will entail a reduced amount of fermentable fibres and the fermentation of fibres causes the methane production.

- Our results are interesting and constitute new knowledge in relation to reducing cows' production of greenhouse gases. However, it is not as simple as it may sound to implement such an extreme feeding. Firstly, we will not utilize the cow's potential of eating what other species cannot – roughage. And secondly, there is a risk of digestive disorders in the cow, and, last but not least, this type of feeding is rather expensive, says Senior Advisor Christian F. Børsting, Department of Animal Science at Aarhus University, who was in charge of the study.

Recent research in climate and livestock

Research in livestock and climate at Aarhus University generates new knowledge that contribute to reducing the climate impact of livestock farming.

Research to reduce the emission of greenhouse gases from livestock manure

Within the framework of the research project "INTEgreret Reduktion af METHan-emission fra husdyrgødning" (integrated reduction of methane emissions from livestock manure), researchers from Aarhus University will contribute their efforts to develop and document integrated strategies to reduce methane emissions from livestock manure in the entire chain ranging from animal excretion to ended storage. About one third of total agricultural methane emissions originates from livestock manure.

Researchers test a substance that may help reduce methane emissions from COWS

In laboratory tests at University of Copenhagen, researchers demonstrated that a new substance, "X", may help reduce methane production by as much as 99 %. The substance is now to be tested in cows at AU Foulum.

Less methane when seaweed is added to the feed

Within the framework of the Climate Feed research project, researchers from Aarhus University will contribute to the development of a cattle feed supplement based on seaweed that may be grown in Denmark. Seaweed may help inhibit the production of methane gas in the cows' rumens. Cows emit approx. 5 700 litres of methane per day when burping and breathing. Thus, they contribute a significant share of the agricultural greenhouse gas emissions.

7 scenarios for future cattle farms

What will Danish dairy cattle farms look like in 2040? With in the framework of the project „Fremtidens helhedsorienterede og balancerede kvægproduktion” (Holistic and balanced cattle production in the future), researchers from Department of Agroecology, Aarhus University, had a closer look at this topic.

- In the future, dairy cattle production will use both market developments and society's demands and expectations as its starting point. Market developments as the market will buy the increasing production; society's demands and expectations to the industry, partly as a part of socio-economics and partly because production may potentially affect nature and environment. Legislative changes, e.g. in relation to nitrogen with a more targeted local regulation, is expected to increase the need for different methods to carry out production at the individual farms in order to adapt to

local restrictions and, at the same time, ensuring a cost-effective production, says Troels Kristensen, Department of Agroecology.

The researchers have presented seven different future scenarios for individual farms. Each scenario should be considered as a proposed farm type associated with differences in farmer goals and values, the market for dairy products and different framework conditions for dairy production in 2040.

The seven scenarios are farm types that we expect will illustrate the total variation in farm types defining Danish dairy production in 2040.



Read the DCA report
„Fremtidens helhedsorienterede og balancerede kvægproduktion” (in Danish).

Is seaweed a potential feed for ruminants?

Traditionally, seaweed has been used as feed in areas close to water. The animals have either eaten the seaweed washed ashore themselves, or they have been fed with collected seaweed. Feeding seaweed has especially been used in cases of shortage of land-based feed.

Despite the fact that seaweed has been used as feed, knowledge about the nutritional value of seaweed for

production animals seems very limited. Thus, the use has been based on observations and traditions and the animals' search for seaweed washed ashore.

An international group of researchers, with the participation of Department of Animal Science at Aarhus University, has investigated this area. The results show that some seaweed species have a huge potential as feed for ruminants. However, the use of seaweed as cattle feed also entails many challenges. These comprise seaweed's content of water, ash and heavy metals as well as conservation and transport costs. In addition, the price of seaweed today is considerably above the price level of ordinary feedstuff in cattle farming.



Feed value and optimum harvest time for grasses

EA good and stable production of high-quality roughage is important in order to support a sustainable milk production with a high level of self-sufficiency. Grass crops increase soil carbon sequestration and reduce nitrate leaching. Increased cultivation of grass crops is crucial in an eco- and climate-friendly dairy production.

Refined protein from grassland crops may be used as nutrition for monogastric animals. As the technologies used to extract protein from grass crops are improved, the interest of growing grass crops will increase in other agricultural areas.

Therefore, researchers from Department of Animal Science, Aarhus University, now examine various grasses to acquire new knowledge on the optimum harvest time for each grass variety in relation to yield, feed value and nutrient content.

This knowledge will be used to optimize the combination and harvest time for new grass mixtures, where the optimal solution will depend on whether the purpose is production of roughage for high-yielding dairy cows, heifers, beef cattle or horses, production of green protein for monogastric animals or the production of green biomass.

Green protein is good for pigs

Within the framework of the project SuperGrassPork (funded by the Green Demonstration and Development Programme), researchers from Department of Animal Science at AU Foulum have carried out a feeding experiment in organic pigs, which were fed compound feed with protein extracted from clover grass.

The project purpose was to examine the effect achieved when part of the traditional protein – typically soya – was replaced by protein extracted from locally produced clover grass. The experiment was accomplished as a dosage-response trial, and the research results demonstrate that the pigs are doing fine with up to 15 percent grass protein in their feed rations.

- Our results are very positive, as the use of protein extracted from clover grass possesses a huge potential in several areas. Firstly, it will secure the supply of locally grown protein for the increasing production of organic pigs in Denmark; and secondly, the cultivation of grass will increase productivity in the fields and at the same time contribute to reducing nitrogen leaching and pesticide consumption", says Researcher Lene Stødtkilde, Department of Animal Science at Aarhus University.

The clover grass protein was extracted at a minor biorefining plant at AU Foulum. In 2019, a major demonstration plant was built for the extraction of grass protein, which makes it possible to supply feed for more extensive feeding experiments in the future.

New feeding concept for piglets in the pipeline

Researchers from Aarhus University are currently working to develop a feeding concept for weaning piglets without the use of medical zinc and with a low antibiotic consumption. These efforts are carried out in collaboration with SEGES and the industry.

The idea of the new concept is to introduce dry feed to the piglets by having a machine scattering it on the floor starting when the piglets are two days old. At the same time, the protein and starch in the feed is optimized to ensure high digestibility.

By feeding dry feed from day two, the piglets grow accustomed to eating it, and they will have a high feed intake

prior to weaning. At the same time, the enzyme system in the pig's gastrointestinal tract will be accustomed to digest dry feed after weaning. The optimized feed will ensure a high digestibility and thus reduce the excess nutrients in the gut as well as diarrhea that requires treatment, says Senior Researcher and project leader Mette Skou Hedemann, Department of Animal Science.

In many weaning systems, the protein amount in feed is reduced to avoid diarrhea, but this approach has a negative consequence, namely that pigs are not able to fully utilize their growth potential. Within the framework of this project, the researchers will develop a new feedstuff that better suit the piglets' needs and ensure optimum growth.

Can **garlic and berries** prevent weaning diarrhoea?

In both Danish and international pig production, weaning diarrhoea in piglets constitutes a problem – for animal welfare as well as economics. So far, antibiotics, zinc oxide and synthetic organic acids have been used to prevent and treat diarrhoea. However, the problem of antibiotic resistance and the environmental consequences of the accumulation of zinc in the soil has resulted in political and consumer demands for a reduction of the use of antibiotics and for phasing out the use of medical zinc oxide.

Led by researchers from Department of Food Science, Aarhus University and in cooperation with researchers from Department of Animal Science, the MAFFRA II research project builds on the hypothesis that garlic may constitute an alternative to antibiotics and zinc oxide; and now, together with the industry, they will try to document this.

Many plants produce defence substances, including antimicrobial substances, and the project builds on previous studies investigating a series of plant species and their contents of antibacterial substances. Project work efforts mainly concentrate on ramson and garlic, both of which contain the bioactive compound allicin; a compound that has been known for ages for its antimicrobial activity, however, it was never used as much as traditional antibiotics.

Allicin concentrations may vary between different garlic varieties, a fact also reflected in antimicrobial activity. The allicin content of garlic is significantly higher than that of ramson. In spite of this, the antimicrobial effect of ramson may often be better, which is due to interactions with other plant substances. However, ramsons are difficult to cultivate and produce and must be gathered in nature, and therefore, the project focuses on garlic, for practical and economic reasons. Within the framework of the project, garlic will be combined with sour berries, which seem to increase the antimicrobial effect and prevent diarrhea by reducing the pH value (acidity).



Opportunities for increasing the contact between the cow and her calf

Recent research points to the possibility of increasing the contact between a cow and her calf in the future.

In Denmark as well as in most other parts of the world, a cow and her calf are separated one or two days after calving. Research demonstrates that separation within the first 24 hours will result in reduced distress and restlessness in both the cow and her calf compared to a later separation. However, research also demonstrates that a prolonged cow-calf contact, e.g. couple of weeks, will have beneficial effects on the calf's social behaviour and learning abilities.

Thus, a dilemma exists between ensuring a gentle separation on one hand, and – on the other hand – considering the relation between the cow and her calf. Maybe we can avoid this dilemma if we are able to reduce the distress of a later separation.

Studies carried out at Aarhus University demonstrate that calves, when housed together with other calves, are less fearful, develop better social behaviour, have higher learning abilities and a higher solid feed intake than calves that are housed individually. Contrary to this, isolation is distressing to the calves.

Reduced amount of milk for sale, but it may be a long-term gain

One of the reasons for separating a cow and her calf only hours after calving is the harvest of milk, and farmers may want to deliver a huge amount of milk for sale to the dairy. When calves are together with the cows, they will drink more milk than they are typically offered after separation. A high intake of milk during the first five or six weeks of the calf's life will ensure a high growth rate, which – in turn – will result in a higher milk yield when the calf becomes a cow. Thus, it is not solely a disadvantage for calves to drink a lot of milk when they are together with the cows.

Unfortunately, most studies of the effect of cow-calf contact on the animals' welfare are short-term studies. However, a few studies indicate that calves raised by their mothers become better mothers themselves, and that they are better at avoiding aggressive confrontations with older cows, when they are introduced to the cow group as heifers.

Calves in day care

Cow-calf contact does not necessarily have to be full time. Studies have demonstrated positive effects as to social behavior, learning abilities and growth when calves are in contact with the cows for part of the day. If this practice is applied during the entire milk-feeding period, then separation may be more smoothly accomplished.

In addition, studies of beef cattle demonstrate that the distress of separating cow and calf, when the calf is five or six months old, is reduced if separation is accomplished gradually; first by preventing the calf from suckling and next separating it from the cow. Preliminary international studies indicate that this will also apply to dairy cow calves that are only a few weeks old.

Today, most cow housing systems are not suitable for letting cows and calves be together, and in many cases, significant investments are required in order to redesign present housing systems allowing prolonged cow-calf contact. However, a part of this investment will be worth it, as these animals will thrive in modern loose housing systems



Production of slaughter pigs without tail docking or tail biting

Within the framework of a GUDP project (Green Development and Demonstration Programme) and in cooperation with researchers from University of Copenhagen, researchers from Aarhus University have examined whether it is possible to predict tail biting in pigs. This was accomplished by observing the pigs' tail posture and applying data, which automatically measured the pigs' consumption of water and pen temperature at pen level by means of sensors.

In the project, the researchers contributed work efforts to develop and validate two different mathematical models to predict tail biting. Both models confirmed that it is actually possible to predict tail biting and inform the farmer.

- One model was able to predict approx. 80 % of the tail biting incidents registered at pen level, but as 20 % of incidents remain unpredicted, and because false alarms appeared, we need to develop the model further, and this develop-

ment may include information on tail posture. The study also confirmed that the occurrence of hanging/tucked tail posture was high in the days prior to an outbreak of tail biting, says Mona Lilian Vestbjerg Larsen, Department of Animal Science at Aarhus University.

Finally, the study showed that a combination of giving the pigs more space and more straw was just as efficient to avoid tail biting as tail docking.



How do cull sows respond to the transport to the slaughter plant?

In relation to transport, cull sows may be more vulnerable compared to other swine categories due to disorders or weaknesses after several reproductive cycles.

As the first of its kind, researchers from Department of Animal Science at Aarhus University have completed a study of sows' clinical condition before and after transport to the slaughter plant under commercial Danish conditions.

The results showed that transport in many cases involves a deterioration of the sows' physical condition compared to before they were loaded on the truck. For about half of the clinical measures examined before and after the transport, a significant deterioration had happened in, for example, number of superficial skin lesions and wounds, gait score and signs of dehydration.

The European regulation for transport of animals states that "all animals shall be transported in conditions guaranteed not to cause them injury or unnecessary suffering" (Transport Regulation, EU 1/2005). However, the regulation does not specify limits for "injury", which makes it difficult to determine whether or not the deterioration of the sows' condition in this study was inconsistent with EU regulations for animal transport.

- Our results highlight the need for more knowledge about the concept of fitness for transport and for further studies of the importance of transport for the welfare of cull sows, including the development of methods which can optimize transport of pigs", says Senior Researcher Mette S. Herskin.

Communication may help reduce consumption of antibiotics

An increased level of communication is needed in order to reduce the consumption of antibiotics and medical zinc in Danish pig production.

At a request from the Ministry of Environment and Food of Denmark, researchers from Aarhus University have examined farmers' experience with and attitudes to the use of antibiotics and medical zinc as well as the attitudes of veterinarians to the prescription of antibiotics and the phasing out of zinc.

The study was based on qualitative interviews with owners and employees from pig farms as well as a group of veterinarians. In all participating herds, antibiotics were used for weaner pigs, and – with the exception of one – all herds used medical zinc as well for this group of pigs. Often, diarrhea was the reason for using antibiotics:

- It was generally agreed, that antibiotics should only be used as a cure against certain diseases. At the same time, the medicine was mentioned as an efficient "management tool" to ensure stability among the pigs during the growth period. Therefore, some of the participants feared that a reduced antibiotic consumption, together with the phasing out of medical zinc, would entail a risk of instability and reduced growth, explains Senior Advisor Inger Anneberg, Department of Animal Science at Aarhus University, who was in charge of the study.

Prevention requires more knowledge

Pig producers and veterinarians declared that communication with employees is of crucial importance if we are to reduce the consumption of antibiotics and zinc. It is necessary to provide employees with the sufficient knowledge to manage situations where changes in everyday practices occur. It is important that employees are able to identify animals that become sick and take preventive action.

- The farmers in the study described changes in feeding strategies and hygiene as methods to prevent diseases, which would otherwise require the use of antibiotics and medical zinc. In addition, vaccination programmes were mentioned as a potential area for future development, says Inger Anneberg.

Some veterinarians and pig producers emphasized that huge piglet litters might result in several disease problems. Therefore, it might be an advantage to reconsider the current breeding strategy and initiate a dialogue on the negative aspects of huge litters:

If employees working in the farrowing pens would share their experiences, this might encourage the motivation for still helping weak pigs, but also serve the purpose of ensuring that employees – in the best possible way – contribute to a production based on a reduced consumption of antibiotics in the entire system, says Inger Anneberg.



Read the DCA report
„Hvad fremmer og hvad hindrer landmænd og
dyrlæger i at reducere brugen af antibiotika og
medicinsk zink til svin?“ (in Danish).



Cooperation partners are
Department of Animal Science, Aarhus University, and
the Ministry of Environment and Food of Denmark.

New centre for research in welfare for companion animals

Extreme breeding, obesity or behavioural issues. Welfare problems also affect companion animals, and this may have major consequences for the animals and their owners. Now, a new centre – Danish Research Centre for Companion Animal Science – will carry out research in the extent of the problems and how they may be addressed.

Professor Peter Sandøe, University of Copenhagen, is head of the new centre, which is located in the Department of Veterinary and Animal Sciences at the University of Copenhagen. The centre is run in collaboration with two other departments at the University of Copenhagen and Department of Animal Science, Aarhus University. The centre will gather

Danish expertise within welfare research concerning dogs, cats and horses.

For many years, Associate Professor Janne W. Christensen from Department of Animal Science, Aarhus University has carried out research in behaviour and stress biology in horses, and she will be in charge of the work efforts comprising horses.

The Danish Research Centre for Companion Animal Science received a grant of DKK 1 million from "Skibsreder Per Henriksen, R. og Hustrus Fond" and was officially opened 2 January 2020.

Can interactions with companion animals affect our mental health?

The use of animals in animal-assisted therapy and support from e.g. service dogs has the potential of becoming an important supplement as an aid to vulnerable people, as well as in the treatment of patients with psychiatric diagnoses.

- Despite an increasing number of studies suggesting that animal-assisted therapy is an excellent treatment supplement in relation to several groups of patients, we still lack solid scientific evidence for the positive effect of animal interaction with humans, says one of the leading researchers within this area, Karen Thodberg from Department of Animal Science, Aarhus University.

Within the framework of a new project, "ANIMALCONTACT", led by Karen Thodberg and funded by TrygFonden, work efforts focus on the identification of basic responses in people when they are in contact with animals – more specifically, with dogs. Furthermore, efforts should be investigated as to which types of effect measures may be used in practice in connection with therapy sessions.

The project comprises two case studies, partly with nursing home residents and partly with war veterans.



Food quality and consumer behaviour

The Ministry of Environment and Food of Denmark (MFVM) and Aarhus University (AU) have entered into an agreement on the provision of research-based policy support within food quality and consumer behaviour.

The agreement specifies three scientific focus areas in relation to which AU/DCA carries out research and policy support activities:

1. Raw materials and food quality
2. Consumer behavior and food preferences
3. The importance of food and meal habits to health and sustainability

You can find the agreement at dca.au.dk

Research-based policy support within the area is primarily carried out by researchers from the Department of Food Science and the MAPP Centre, Department of Management.

You can read more about our activities in the following.





Michelin events in Aarhus

In the beginning of 2019, the MICHELIN Guide Nordic countries Awards was held in Aarhus. Headed by Assistant Professor Janice Wang, the science team of "Food Quality, Perception and Society", Department of Food Science, co-organized a series of events.

A MasterClass event was held at ARoS Aarhus Museum of Art, investigating how our senses interact, when we eat, and concluded by a unique taste experience in the Rainbow on top of ARoS. A chocolate tasting experience at three Aarhus hotels was accompanied by different soundtracks with the purpose of emphasizing various aspects of the chocolate taste. Finally, during the reception held in relation to the Awards show, two unique soundscapes allowed visitors to experience how sounds affect the taste, as they walked in and out of the soundscapes.



Aarhus University at the Food Festival

In the autumn of 2019, a wide range of Aarhus University's food research was presented at the annual Food Festival in Aarhus – and in keeping with tradition, researchers and students from Department of Food Science participated.

Visitors had the opportunity to learn more about how research contributes to healthier and more sustainable foods in the future via presentations of a huge number of the department's research activities, including work efforts to extract protein from green biomasses, development of robust crops for extreme climate conditions, optimization of our eating experiences and much more.

In addition, Department of Food Science arranged a MasterClass in winetasting, providing participants with an insight into the scientific and psychological basis for experiencing and describing wine when all senses are at play.



Culinary experiences at ARoS

In the spring of 2019, ARoS – Aarhus Museum of Art – and Department of Food Science, Aarhus University, arranged a dinner event combining art, light, sound and food.

The dinner was inspired by the special combination of psychology and sensory science – focus areas of the science team "Food Quality, Perception and Society" in Department of Food Science, Aarhus University. The various dishes were inspired by the ARoS exhibition "Far from Home", and emphasized the importance of the individual senses to our taste experiences. Food and drink were accompanied by soundscapes composed for this specific event as well as scents and lights.

- It is rather unique to be able to illustrate how food elements such as e.g. taste properties are combined with elements surrounding the food, in this particular case soundscapes, and together this will create a total perception of the food. It is very important to incorporate both elements, if you want to create healthy and memorable food experiences in the future, says Professor and science team leader Derek V. Byrne, Department of Food Science.

Arla Food for Health

Arla Food for Health was established in 2015 as a consortium between Arla Foods, Arla Foods Ingredients Group, Aarhus University and the University of Copenhagen. Within the framework of this cooperation, research and educational activities are carried out – all focusing on the health aspects of dairy products and milk-based ingredients.

In 2019, researchers from e.g. Department of Food Science, Aarhus University, have contributed work efforts to Arla for Health projects in relation to breast milk, satiety and food structure.

New center of excellence for food research

In November 2019, all research facilities of Department of Food Science moved to Agro Food Park, a world leading food cluster.

Previously, Department of Food Science was located in Foulum and Aarslev, but in November all facilities moved to Agro Food Park. Here, companies, research and education institutions as well as authorities are gathered to constitute a dynamic ecosystem of food innovation.

Michelle Williams, Head of Department of Food Science, is excited about the new opportunities:

- In Agro Food Park, we aim to create a unique research environment. The central location close to students and food companies is essential in order to ensure that research and education is productive and creates value in the food sector. For research to be relevant, it must be linked to current opportunities and challenges within the food sector. We have to cooperate and contribute to solving the global food challenges.

A new 7500 m² building now acts as the frame for the department's unique state-of-the-art research facilities that also include greenhouse facilities.

- Having all our analysis laboratories, sensory science facilities, cultivation facilities, postharvest facilities and much more just around the corner, allows us to act as a key contact point and to better create and communicate knowledge to the benefit of research, says Head of Department Michelle Williams.

The move to Agro Food Park does not only apply to existing facilities, but also brand new facilities. Among these are the "Human Sensory Food Perception & Design Lab (iSENSE Lab)" for sensory-oriented food development. The innovative laboratory will support the multi-disciplinary approach to food research already taking place at the department.

103 million DKK for future food research

A new high-tech laboratory centre, FOODHAY, will develop healthier and more sustainable foods and reduce food waste.

A group of Danish universities headed by Department of Food Science, Aarhus University, joined forces with a series of Danish companies to create a joint high-tech laboratory center, Open Innovation FOOD & Health Laboratory (FOODHAY), to develop healthier and more sustainable foods and reduce food waste.

In December 2019, FOODHAY received a grant of 51.5 million DKK from the Danish Ministry of Higher Education and Science. The consortium behind FOODHAY contributed a corresponding amount, which means a total investment of 103 million DKK. In addition to Aarhus University, the consortium consists of the Technological University of Denmark (DTU), University of Copenhagen, Arla and the Danish Technological Institute (DTI). The major part of the new research facilities will be located at Department of Food Science, Agro Food Park.

This investment significantly underpins the quality of our research and education initiatives, and will improve our ability to provide new knowledge, technologies and innovative solutions within the food and ingredients area. The new equipment will support the strong research cooperation between universities and the food industry. Together, we will contribute to deliver innovative, healthy and sustainable Danish foods to global consumers, says Michelle Williams, Head of Department of Food Science and head of the FOODHAY consortium.



Aarhus will have its food laboratory in 2020

Department of Food Science and iFOOD (Aarhus University Centre for Innovative Food Research) will be part of the EU-funded Food CityLab in 2020.

Department of Food Science and iFOOD (Aarhus University Centre for Innovative Food Research) were – together with the city of Aarhus, Agro Food Park and the Central Denmark Region – awarded as a Food CityLab under the Fit4Food2030 initiative. The purpose is to prepare food systems for the future by strengthening the connection with local communities.

Two workshops will be held in 2020 with consumer representatives, relevant NGOs and industrial actors. The workshops will focus on establishing an understanding of the links between foods and well-being, as well as how foods can deliver functionality beyond simple nutrition.

At Aarhus University, the NFORM network recently received funding to focus on finding new, sustainable food solutions by establishing partnerships between AU departments, public stakeholders, international collaboration partners, business and industry as well as private citizens.

Milena Corredig, Professor at Department of Food Science and director of iFOOD, explains:

- There is an increasingly large gap in our society between the upper middle class and the poor, while the high pace of urbanization is leaving the elderly and the marginalized groups behind. NFORM aims to establish a strong research-based foundation for the development of new foods that may contribute to maintaining our physical and mental health as well as preventing or improving chronic conditions at any stage of life.



Research network to contribute to the UN Sustainable Developments Goals

A new network project will help society meet the UN Sustainable Development Goals. In cooperation with a series of partners in e.g. New Zealand, France, Canada and Denmark – among these Aarhus Municipality – the project "New Foods For Physical and Mental well-being" will carry out research and develop a sustainable food production; one of the specific goals is to improve the well-being of marginalized citizens. The project is managed by Professor Milena Corredig, Head of the Aarhus University Centre for Innovative Food Research (iFood).

- In some cases, social inequality may be prevented by identifying how to provide practicable, available and appropriate nutrition and dietary habits. Our network will focus on the development of evidence-based food innovation with the purpose of ensuring physical and mental health for individuals of all ages, says Professor Milena Corredig.

Aarhus University's Committee for Research and External Cooperation funds the network with an amount of 1 million DKK.

Too little, too much and wrong types of food

Research in food and consumer behaviour at Aarhus University provides new knowledge on how much and how we eat – and especially why.

How do we avoid eating too much?

An increasing number of Danes are overweight or obese and this is related to overeating. Researchers from Aarhus University have examined how we can avoid eating too much. Based on a literature survey of accomplished research in this area, they have formulated a series of advice for Danes to use in their everyday lives. This advice relates to both food, our surroundings and ourselves.

vocational college students tend to eat less healthily compared to high-school students of the same age. By elucidating vocational college behavior, attitudes, motivation, social influence, knowledge, socio-demography and health, researchers from Aarhus University have examined how we best communicate healthier eating habits to vocational college students.

Too many children do not eat enough in school

Many pupils do not eat enough food in school, and this hinders their concentration, attention and learning abilities. This applies to children who bring their own lunch, but also children in schools with lunch arrangements or school kitchens. During a study on meals, researchers from Aarhus University discovered that many pupils feel hungry in school.

Which factors decide how much we eat?

Within the framework of the Omnisam project, headed by Aarhus University, researchers approach the satiety aspect from many different angles. One angle involves physiology and metabolism, where appetite hormones and blood metabolites are measured. A neurological approach studies the brain's reward centers, while a behavioral approach looks at the feeling of satiety and eating behavior. The development of a new method to measure satiety will allow us to develop foods that fill more and for longer.

Read more here:
food.au.dk/omnisam



Read more in the DCA reports

"Rammer for mad og måltider i skolen" (in Danish)

"Råd til at lykkes med at undgå at spise for meget" (in Danish)

"Kommunikation om sunde spisevaner til erhvervsskoleelever" (in Danish)

The study identified a number of factors that may increase the probability of taking the vitamin D supplement. The probability is likely to increase:

1. If your doctor suggests that you should/ought to take vitamin D supplements
2. The more you feel that vitamin D is beneficial to your body
3. The higher knowledge you have of vitamin D, the better
4. The lower your negative attitude towards vitamin D is, and
5. The older you are

Read the DCA report „Anbefalinger om tilskud af D vitamin og calcium Vid en, accept og efterlevelse blandt de 55+-årige” (in Danish)

Many senior citizens are not aware **they should take dietary supplements**

Seniors over the age of 70 should take a daily supplement of vitamin D and calcium, but they are not always aware of this.

As we grow older, our ability to produce vitamin D in our skin is reduced. As it may be difficult to obtain sufficient vitamin D solely via diets, the Danish Veterinary and Food Administration recommends that seniors above the age of 70 take a daily supplement of vitamin D and calcium to protect their bones and muscles. However, recommendations are one thing, reality is quite another.

Researchers from Aarhus University have examined whether the target group knows the recommendations, if they comply with them, and what initiatives may be made to make them follow the official recommendations. This was accomplished by means of a questionnaire survey comprising 451 citizens between the ages of 55 and 90 years.

- Our results demonstrate that a little more than 50 % of the elderly take vitamin D supplements. The majority of these are women. In the study, we witness a similar gender imbalance in relation to calcium. Almost 50 % of the women over 70 years of age take supplements of both vitamin D and calcium, whereas the number for men is a little less than 25 %, says Research Assistant Claus Frantzen, Department of Food Science and co-author of the report.

Further, the results demonstrate that a little more than one third within the target group is familiar with the vitamin D recommendations, and only half of the 70+ year-old citizens think the recommendations apply to them; most of these are women.



Cooperation partners are:

Department of Food Science and MAPP Centre, Aarhus University as well as the Ministry of Environment and Food of Denmark.

Natural colours to replace artificial colours

Researchers from Aarhus University will make it possible to replace artificial colours in food with natural colours based on vegetables.

Consumers all over the world are increasingly demanding food without artificial additives, just as vegetarian and vegan food solutions are gaining momentum in both Denmark and the rest of the world. This increases the need for natural and purely vegetable food colours.

However, the transition to natural colours is limited by the fact that in many cases these colours are sensitive to light, heat and pH, as well as by limited shades of colour and high prices.

Within the framework of the research project NaFoCo, Department of Molecular Biology and Genetics applies classic plant breeding, new breeding techniques and cultivation techniques to develop and optimize the production of raw materials specifically aimed at the production of natural food colours. This is accomplished in cooperation with the company Chr. Hansen Natural Colors A/S.

Innovation Fund Denmark funds the project with an amount of almost 15 million DKK.

Sweetness happens in the mind as much as in the mouth

Researchers from Aarhus University investigate how the amount of sugar in sweet beverages may be reduced without compromising with the consumers' perception of sweetness.

When you have a sweet beverage, taste is not only in the fizzy drink. We eat and drink with all our senses. Within the framework of the InnoSweet project, researchers from Department of Food Science will examine how to reduce the sugar contents in sweet beverages without compromising with the consumers' perception of sweetness.

This is accomplished by considering factors, other than sugar and artificial sweeteners, which influence the taste experience. These factors may be divided into product related factors and include e.g. beverage aroma, viscosity and colour, as well as external factors such as packaging and music.

The researchers participating in the project have taken a unique multidisciplinary approach working with both food science, health and psychology, and in close collaboration with leading industrial partners to develop the sugar-reduced beverages of the future. Professor Derek V. Byrne, Department of Food Science, explains

- Our senses are interrelated and influence each other. We have a tendency to ignore this in food research because it seems difficult to manage this in an experiment. Instead, we look at the product. In the InnoSweet project we do not solely focus at the product, we try to include the situation, the setting and the surroundings. We want to have a closer look at the interaction between our senses in relation to the perception of sweetness.



The importance of food texture to nutrient uptake

Within the framework of the DairyMat project, researchers examine the importance of the texture and microstructure of foods to the uptake of nutrients.

Recent research indicates that the texture of a given food can influence our uptake of fat and nutrients from the food. This is the main topic of the DairyMat project.

Associate Professor Marianne Hammershøj, Department of Food Science at Aarhus University, is DairyMat project leader and she explains:

-In the project, we work with dairy products, our starting point being cheddar cheese, which has a solid texture. Thus, it is representative of a microstructure with a certain protein network and incorporating fat droplets. We created different samples incorporating the same nutrients, and using the same ratios, as that of the cheese but with different structures.

The samples were used in a meal study at the University of Copenhagen. A group of test persons was served a meal with one of the products. Subsequently, blood samples were taken:

- In the blood samples you examine specific markers that show when you take up fat from the products, how fast the uptake is, how much you take up, and finally, how long it may be traced in the blood, says Marianne Hammershøj.

The aim of the project was to be able to predict more precisely how the structures and texture of food affect fat uptake – a useful knowledge if you want both higher and reduced fat uptake in certain groups of the population.

The project received grants from the funding bodies; Arla Food for Health, University of Copenhagen and Aarhus University.

How does the infant make best use of human breast milk nutrients?

Within the framework of the MainHealth project, researchers study the composition of breast milk and its importance to the infant.

What is the function of breast milk, how does it change and how does the infant make best use of breast milk nutrients? By following 200 mothers – classified into three groups according to BMI – and their infants from pregnancy and until the children reach the age of five, researchers hope to elucidate the importance and role of breast milk to infant health.

Assistant Professor and MainHealth project leader Ulrik K. Sundekilde, Department of Food Science at Aarhus University, explains:

-We already have a significant knowledge on the composition of breast milk, but there is still a lot that we do not know. For instance, the interaction between the various constituents in breast milk – and how does the infant specifically use

these constituents? We do not know this yet. In particular, when it comes to the microorganisms in the infant's gut. This project is unique because of the repeated, systematic sample gathering as well as the five-year timeframe. The perspectives of such a long-term project, including more than 2000 samples, are huge:

- In other words and in relation to obesity, we may discover that if you need certain bacteria, we can dispense one drop of probiotics, which is beneficial to the infant – and this will be sufficient in order for the infant not to have an increased risk of obesity. This may be the result of this study, but we do not know. In the future, increased knowledge will help us act in relation to issues and problems that we cannot

How healthy and nutritious are insects?



Currently, alternative protein sources are in focus and insects in particular. Protein from insects for human nutrition holds significant potentials. Partly because it requires less space, water and energy than normal livestock production, and partly because protein production from insects, from an ethical point of view, may be more acceptable to consumers who would otherwise choose plant protein.

But how do we absorb nutrients from insects; and can insect protein help increase muscle building? During her PhD studies, PhD student Sofie Kaas Ovesen, Department of Food Science at Aarhus University, will examine this:

- Insect protein may constitute a compromise between plant protein and traditional protein from meat. Insect protein is of a high quality and considering amino acids and composition, it bears a close resemblance to meat protein; however insect protein production does not cause the same extent of environmental impact that livestock production does.

During her PhD project, Sofie Kaas Ovesen will examine whether it is possible to replace the dietary protein sources, which we know and use today by insect protein as well as its implications to our body and metabolism:

- Humans have eaten insects for thousands of years, but only few studies have examined the implications of eating insects. We know which amino acids, vitamins and minerals that the insects contain, but the absorption of these in the body, i.e. the bioavailability is rather interesting. A previous study demonstrated that amino acids from insects are absorbed more slowly, and we want to test this further in a human study, says Sofie Kaas Ovesen.

Major mapping of Danish dairy milk in process

In cooperation with Danish dairies, researchers from Aarhus University are currently mapping the variations in dairy milk composition.

Milk is not just milk. Factors such as season, geographical conditions, cattle race and feeding strategies influence the variations in the ingredients in Danish dairy milk. Within the framework of the DanMilk project, researchers from Department of Food Science at Aarhus University examine the variations in dairy milk composition. This is accomplished in cooperation with a series of Danish dairies.

Project efforts comprise a further development of the Milk Genomics project, in which the milk profiles of individual cows were mapped. A mapping of dairy milk composition as well as of the range of variation in milk has topped the dairies' priority list for a long time. But why is it important to know in which ways the milk varies as to levels of ingredients between regions or between seasons?

Professor and project manager Lotte Bach Larsen, Department of Food Science at Aarhus University explains:

-When working with individual milk components for ingredient production, e.g. by isolating a single substance in the milk and up-concentrating it, this means that existing variations will be increased. These might be variations in certain vitamins and minerals. Today, we lack a reference that may show – in case of this type of variation – whether this is a natural variation. Therefore, it is a way to create a reference as well as a tool for fault detection and process optimization. In addition, detailed knowledge on milk composition is an important tool for the industry to be used within quality assurance, product differentiation and utilization of raw materials.

Grass protein in foods

– just around the corner, or?

Can grass from Danish grasslands be a useful protein source for human food? Researchers from Aarhus University work hard to make this a suitable alternative.

Grass protein is a fine source of healthy protein, because the amino acid composition is excellent. In addition, we are good at growing grass in Denmark, and grass has a positive environmental impact due to the very low nutrient leaching from perennial grasslands, says Trine Kastrup Dalsgaard, Department of Food Science.

Grass is interesting for food purposes, and not merely as a protein source. Research efforts further focus on processing protein from grasses in order to achieve protein fractions with specific functional properties. This means that the protein can be used as ingredients in different types of foods.

The protein abilities to gel, foam or act as emulsifiers are crucial to which types of foods they may be added and help change e.g. the texture of a product. Grass proteins thus become a high-value product; and something to profit from, Trine Kastrup Dalsgaard explains.

Some way to go yet

However, challenges exist as to the use of grass protein for foods, and extracting proteins from grass for use in the food industry is not quite simple.

- We need to extract the chlorophyll (the green pigment), as it may cause challenges in relation to shelf life and quality. Another problem is enzymatic browning of the product, which we also know from cut apples or peeled potatoes. This browning will reduce the digestibility and the absorption of protein in our digestive systems. The browning may also imply that the functional properties of the protein are changed because you change the structure of the entire protein.

In cooperation with the Department of Animal Science, experiments were carried out that demonstrated promising results in relation to inhibiting the enzymes that cause enzymatic browning. Thus, protein digestibility is increased.

Foods are not just foods

Digestibility is a factor to be taken seriously; however, at the moment focus is on functionality. The protein is sup-

posed to be multifunctional, depending on the end product. This may be e.g. a protein drink or meal replacements for sick persons or the elderly, but it may also be muesli bars or meat alternatives. In these instances, protein solubility, amino acid composition, binding properties and product texture are of vital importance.

In addition, the researchers work to eliminate the green colour and the taste of grass in order to make the product more appealing to consumers.

It should be emphasized that we still have a way to go. We may start testing the proteins that we extract today, but they are nowhere near food quality yet. We will get there – we simply need to develop the techniques that we use already, says Trine Kastrup Dalsgaard.



Milk and meat to be grown in petri dishes

Can you produce milk without a cow – or meat without animals? Researchers from Aarhus University will investigate this in a new research project that will pave the way for a more sustainable food production.

The future of meat and milk production must both respond to rising global demand and take into account the climate and the environment. In the CleanPro project, researchers from Aarhus University will investigate whether growing milk and meat in laboratories may be part of the solution.

Researchers from the Department of Food, the Department of Animal Science, the Department of Agroecology, the Department of Clinical Medicine and Aarhus University School of Engineering are participating in the project.

Huge potential

Margrethe Therkildsen, Associate Professor at the Department of Food and project manager for CleanPro, does not doubt that there are great opportunities in the project:

- There is a huge potential in producing food of animal origin in a laboratory. CleanPro is taking a step towards fulfilling this potential. The project will establish and test cell cultures for the production of meat and milk, test the quality, and it will develop life-cycle models that will be used to assess the effects of products on the climate and the environment at a future scaling up of the production, she says and adds:

- Not just is the energy and resource consumption just a fraction of what the traditional production uses, but the production method also allows the "design" of milk and meat with a possible better nutritional composition. In addition, production-related health risks can be avoided, and the entire animal welfare debate becomes superfluous when our milk and meat have been created in a bioreactor instead of a stable and a slaughterhouse, says Margrethe Therkildsen.

CleanPro consists of two sub-projects, CleanMilk and CleanMeat, which will run until July 2022.



Cooperation partners

Comprise Department of Food Science, Department of Animal Science, Department of Agroecology, Department of Clinical Medicine and Aarhus University School of Engineering.

Colzacoli (rape buds) may become a new super vegetable

Together with the private plant breeding company Knold and Top, researchers from Aarhus University have developed a new super vegetable, the so-called Colzacoli. Colzacoli is a crossing between white rapeseed and the Italian cabbage "rapini". When raw, the rape buds have a spiced and rather sharp taste with a hint of mustard; when slightly boiled or fried, it tastes somewhat like white asparagus.

Genes from winter rapeseed provides the new vegetable with overwintering properties. It can be sown in early Autumn and harvested in early Spring, where fresh garden vegetables are few and far between. The development of the Colzacoli is also an attempt to make a new kind of super vegetable, as both cabbage and mustard contain healthy substances, the so-called glucosinolates that are able to prevent a series of diseases.

Information on DCA Research



DCA research results

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