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DCA - DANISH CENTRE FOR FOOD AND AGRICULTURE

PERSPECTIVE

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DCA – DANISH CENTRE FOR FOOD AND AGRICULTURE

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National and international research alliances

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Cover photo
Stig Purup carries out research in cell-based agriculture for a more sustainable meat and milk production in the future. Among other projects, this is accomplished within the framework of the CleanPro project. Read more on page 52. Photo: Lars Kruse, AU Photo

2020

Targeted research and policy advice provides opportunities for a green transition in agriculture and food production

Denmark has an extensive and strong food sector, which – through the years – has developed innovative methods for the production of foods. In recent years, we have witnessed an increasing focus on the reduction of resource consumption as well as climate and environmental impact. In cooperation with research environments and the policy advice service, the agricultural sector and companies have developed e.g. methods for increased recirculation of nutrients and value creation of by-products.

Most recently, the agricultural industry is implementing the use of concentrated feed protein extracted from grass by means of biorefining; an innovation process with the potential of reducing soya imports, reducing nitrogen leaching and pesticide use, as well as building soil carbon stocks etc.

To this should be added the fact that Danish agriculture leads the way when it comes to developing organic farming concurrently with increasing demand and increasing social interest. By means of targeted cooperation with research environments, the organic sector has developed a comprehensive production of new, innovative products made with improved methods focusing on animal welfare and environment.

Other exciting initiatives are in the pipeline within the development of the agricultural sector as well as the processing industries. These initiatives e.g. include Conservation Agriculture, cellular agriculture, sustainable textiles based on biorefining, plant-based food ingredients, reduction of food waste etc.

So, what is the actual problem in relation to a green transition?

The problem is that our current production methods still have a negative impact on the environment as we use too many nutrients. Our livestock production entails a significant loss of climate gases, and biodiversity suffers as the major part of the Danish land use area is used for intensive agriculture, which has huge consequences for biodiversity.

Denmark is committed to meeting both national and international goals in relation to climate neutrality and the protection of environment and biodiversity. As an example, climate gas emissions must be reduced by 70 percent in 2030 according to the Danish Climate Act, and we aim at full climate neutrality in 2050. According to the EU biodiversity strategy, 30 percent of the land use area must be designated as protected natural areas in 2030. According to the EU Water Framework Directive, a significant reduction in the leaching of nutrients to lakes, streams and the sea must be accomplished in order to ensure healthy, organic conditions for the aquatic environment. To these should be added the recent EU goal of 25 percent organic farming in 2030 and – suggestions for – goals to ensure a significant reduction in food waste. The challenges are plentiful – and whatever the size of the agricultural sector will be in the future, a strong need exists to develop and adapt production methods and products to future markets and consumer demands.

Research targeted at green transition

Luckily, we have excellent opportunities to establish a knowledge-based foundation for a green transition in agriculture and food production. Such a transition will address climate and environmental challenges as well as ensure that the agricultural sector, companies and authorities will be market leaders within systems and technologies in both a European and a global green transition. By means of timely and focused investments in research and innovation, the green transition may entail global competitive advantages.

An excellent example of these advantages is the development of protein based on green biomasses, which may reduce – and in the longer term even eliminate – the need for importing soya protein from areas in which the

cultivation of soya results in clearcutting of rainforests and natural areas. At Aarhus University (AU), comprehensive research and innovation efforts have demonstrated how to produce high-quality protein (similar to soya) by biorefining of grass.

Such a protein production possesses a huge potential in relation to both increasing the total biological production per hectare – as the pulp may be a replacement for fresh grass in cow feed – and at the same time help minimize nitrogen leaching to vulnerable water areas and increase carbon soil stocks.

Companies and farmers are currently implementing this knowledge. At the same time, we witness an increased focus on the development of other alternative protein sources, especially in future cultivation and processing of a variety of crops such as legumes and new sorts of vegetables.

Another long-term example is the need to research and develop environmental and climate friendly alternatives to traditional animal products in order to reduce the need for farmland areas, and to utilize competences and capacities in the Danish food industry. We have to do research in and develop new plant-based foods based on Danish high-quality raw materials, and – in the longer run – develop the production of animal products via cell cultures and biorefining. This research will enable radical innovation; however, it is a prerequisite that the basic funding allows for a long-term building of research competences and capacity.

Contributions to the solving of global problems

Danish research in a green transition will contribute to solving a series of global problems.

In the coming years, increasing affluence and global

Roadmap for Research

Based on political aims, the Ministry of Environment of Denmark and the Ministry of Food, Agriculture and Fisheries of Denmark have prepared a Roadmap for research for the coming decade. This roadmap focuses on green transitions and, among other issues, the goals are:

- Minimized climate impact from agriculture, food production and dietary habits via the development of production systems and environmental technologies for low climate impact
- Methods for setting aside wetlands, which will reduce climate emissions and environmental impact as well as increase biodiversity
- A 40-percent reduction in the environmental and climate impact from pesticides compared to 2011 via a reduction in the application of pesticides as well as pesticide alternatives
- Ensuring a healthy aquatic environment by 2027, e.g. by developing tools to prioritize land use and effects of various types and locations of wetlands
- Contribute to UN goals as to stop the decline in biodiversity by developing cost-effective methods to monitor biodiversity as well as methods to implement biodiversity considerations in areas with agricultural production
- Reduced agricultural impact on nature and biodiversity, including an increased transition to organic farming
- Sustainable and resource-efficient agricultural and food production, a 50-percent reduction in food waste and an optimized utilization of by-products and side-streams in circular bioeconomy
- Development of plant-based foods and cell-based products as alternatives to e.g. meat
- Development and up-scaling of new protein sources, including locally produced plant-based protein sources for feeds and foods as well as processes/technologies for processing and biorefining and in vitro production of functional proteins
- Sustainable animal production with a reduced impact on humans, nature and climate, increased animal welfare and a reduced use of antibiotics
- Several of these knowledge areas and technologies may only be achieved by improving research methods, including methods to measure emissions as well as the characterization of new protein sources at physical-chemical and molecular levels as well as a basic understanding of the importance of both the gastrointestinal tract's microbiome and the soil-plant system's microbiome to health and resistance

population growth will result in a soaring global demand for foods, animal foods in particular. This means that the impact on natural resources will increase unless we develop production methods that are much more friendly to the climate and the environment.

At the same time, climate changes and scarcity of water may complicate food production in large areas of the world and result in huge variations in yields and food prices. Therefore, a need exists to develop robust food systems that are able to ensure a stable food production under changing cultivation conditions – this concerns considerable parts of the world, including Denmark. There is a need to protect natural areas and consider biodiversity, and at the same time to hand over valuable cultivation land for roads, facilities and cities. Therefore, we are faced with the need to develop new production methods that require less farmland areas.

Roadmap for Research

Generally, in Denmark and globally speaking, there is a need for knowledge that will enable an increased food production, but at a reduced area per consumer and with reduced climate and environmental impact. These are the exact goals in the "Roadmap for Research" prepared in cooperation by the Ministry of Environment of Denmark and the Ministry of Food, Agriculture and Fisheries of Denmark.

Roadmap for Research illustrates that a huge need for knowledge exists in order to facilitate a green transition in society. However, the roadmap also demonstrates how research can contribute the necessary solutions to meet the goals that require a transition of our food production. Naturally, this involves a wide range of actors and knowledge institutions.

For more than a decade, the Ministry of Environment of Denmark and the Ministry of Food, Agriculture and Fisheries of Denmark have entered into framework agreements with Aarhus University and DCA – Danish Centre for Food and Agriculture as well as DCE – Danish Centre for Environment and Energy on the provision of research-based policy advice.

As a result of this agreement, internationally leading research environments have been established at Aarhus University; research environments that focus on establishing the knowledge that is essentially necessary for a green transition. Research efforts carried out at AU TECH, DCA and DCE play a key role in relation to most of the areas mentioned in the Roadmap for Research.

The research base is a prerequisite for targeted research

AU is expected to build and maintain the necessary research basis that will allow the implementation of major parts of this Roadmap as well as research focusing on green transition in general. We are ready to do this and our researchers look forward to continuing these very important research efforts.

The departments at AU Tech are currently recruiting the next generation of accomplished researchers to provide results in the years to come.

The research basis consists of infrastructures and competences in the form of world-leading researchers, laboratory technicians and experimental technicians working in laboratories, livestock farms, experimental fields and technical plants as well as in private farms. At the same time, the research basis constitutes the foundation for attracting and utilizing funding from targeted research and innovation programs and from Danish and international funds.

The research base is financed primarily via the framework grant (basic grant) for research-based policy support. Researchers build their research environments according to this framework grant. The framework grant helps finance the departments' buildings, laboratories, IT equipment, accounting and lots more – all this is known as overheads. Thus, the framework grant is a decisive factor when it comes to building and maintaining infrastructures and research competences – also in a long-term perspective.

Therefore, it is a major problem that the framework agreement has been reduced by 138 million DKK during the period 2009-2021; from 498 million per year to 360 million per year. Considering the full inflation, the reduction is even larger. The reason for this is the fact that the framework grant from the ministries is cut by 2 percent per year as a result of the reprioritization contribution. In addition, approx. 25 million DKK from the framework grant have been used for other purposes. To this should be added the fact that the development in salaries and prices is only partly compensated for.

Initially, the researchers were able to compensate for the reduced funding by applying for additional grants from external funds etc., just as the university financed a significant part of the reduced income. In 2016, however, the reductions reached a level where it was no longer possible to find the sufficient external funding, and the total amount allocated to the area was reduced. At the same time, the co-financing from other university departments and faculties reached an untenable level, and this internal financing should be balanced.

The reduction in the framework grant can no longer be replaced by other funding or new research packages from e.g. the Research Reserve Fund, as these grants generally do not allow for sufficient overhead costs. This means that it will reduce the basic grant even further to apply for such funding.

The basic framework grant has now been reduced to the extent where it is no longer possible to sustain all the research environments that constitute the foundation for the policy support and that also ought to support the green transition.

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 of Denmark (MIM) and the Ministry of Food, Agriculture and Fisheries of Denmark (MFLF) on the provision of research-based policy support in areas relating to crop production, livestock production and food quality and consumer behavior. The agreement comprises a framework agreement ensuring that AU carries out research to support the administrative tasks in the respective ministries. 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 of Food, Agriculture and Fisheries.

DCA comprises AU departments and research environments with activities within the food and agricultural areas, and these are as follows:

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

* From the end of 2020, Aarhus University has closed Department of Engineering as well as the Aarhus University School of Engineering. Four new engineering departments have been established instead:

- Department of Biological and Chemical Engineering
- Department of Civil and Architectural Engineering
- Department of Electrical and Computer Engineering
- Department of Mechanical and Production Engineering

A centre unit supports DCA activities, which – in addition to policy support – further comprise industrial collaboration, international collaboration and communication. In addition, the Centre Unit ensures the involvement of other relevant research environments at AU in order to solve specific tasks in relation to the framework agreement:

- MAPP Centre – Research on Value Creation in the Food Sector for Consumers, Industry and Society, Department of Management
- DPU – Danish School of Education

Similarly, AU established DCE – Danish Centre for Environment and Energy to support activities within environment and energy. The DCA Centre Unit and the DCA departments cooperate with DCE's Department of Bioscience and Department of Environmental Science as to interdisciplinary policy support, including the cross field between agriculture, climate, nutrient loss and biodiversity as well as tasks in relation to health hazards of harvesting mussels from Danish waters. Activities within DCE focus areas are not included in this report.

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 order 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 of Food, Agriculture and Fisheries of Denmark 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.

Financing food and agricultural research

Different sources fund food and agricultural research, and DCA's contract with the Ministry of Food, Agriculture and Fisheries of Denmark is the main income source. According to the agreement, DCA received 269.1 million DKK in 2020 to cover expenses in relation to the research-based policy support. Of these, 13.1 million DKK were special grants and 1.9 million DKK were acquisitions.

The grant from the Ministry of Food, Agriculture and Fisheries of Denmark allows DCA to attract and carry out research projects in collaboration with organizations and companies. This collaboration, together with grants from national and international funds and research programmes, was the main reason why the total research and development funding within the agricultural and food area amounted to 610 million DKK in 2020. This amount includes AU co-funding to the amount of approx. 65 million DKK.

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**

International collaboration

Researchers from the DCA focus areas often participate in international collaboration. Activities accomplished in 2020 are presented in the following.

EJP SOIL: New European research collaboration on sustainable and climate-smart agricultural soil management

Fertile and productive soils are the prerequisite for a stable supply of food, fibre, animal feed, timber and other biomasses. Soils sustain a huge biodiversity, and as the largest store of minerals, water and carbon on land, soils play a major role in relation to limiting global climate challenges.

Sustaining soil functions
However, soil is a limited resource, and in many areas it is under increasing pressure. Soil degradation including erosion, loss of soil organic matter, soil contamination and soil sealing are threats to soil fertility and soil functions, and thus also to food production, biodiversity and carbon stocks. Intensified production due to a rising global demand for food and biomass will only amplify the challenges.

European efforts for sustainable soil management
A major European research programme, EJP SOIL – consisting of 24 European countries – will improve the knowledge foundation for sustainable agricultural soil management in the future.

The programme will develop solutions that contribute to food supply, biodiversity and climate as well as other important functions, and one of the aims is to provide farmers, advisors, companies, authorities and other interested parties with easy access to context-specific guidelines for sustainable soil management practices.

In addition, the collaboration will strengthen a multidisciplinary research community working on agricultural soils and soil management, and through a collaborative approach, EJP SOIL will initiate and support transnational projects, PhD training, educational training as well as dissemination and communication.

Finally, collaboration efforts will contribute to a scientific foundation for joint management of soil resources in Europe.

EJP SOIL facts
EJP SOIL comprises 26 partner organizations from 24 European countries. The programme has a 5-year duration and the total joint budget is 80 million Euro. The EU Commission funds approx. half of the budget, while the participating countries finance the other half of the budget.

DCA, including Department of Agroecology and the DCA Centre Unit, is an EJP SOIL partner. Soil fertility is an important element in research-based policy support and therefore the Danish participation is funded via the agreement on research-based policy support between the Ministry of Food, Agriculture and Fisheries of Denmark and Aarhus University.

Participation in partnerships and working groups

As agreed with the Ministry of Food, Agriculture and Fisheries of Denmark (MFLF), DCA participates in several international collaborations. Among others, these include:

- European Innovation Partnership on Agricultural Sustainability and Productivity (EIP-AGRI)
- Standing Committee on Agricultural Research (SCAR)
- Collaborative Working Group of Sustainable Animal Production
- Animal Task Force
- NordGen Council for Farm Animal Genetic Resources

DCA participates in a series of European research programmes; e.g. several European Research Area Networks (ERA-NETs), including SusCrop and ERA-NET SusAn, as well as initiatives within the framework of European Joint Programme (EJP). In addition, Aarhus University is an EIT Food core partner.

Green biorefining in a European perspective

In November, CBIO - Aarhus University Centre for Circular Bioeconomy held a webinar on green biorefining for European politicians.

The European Commission has launched the "European Green Deal", which aims to ensure that the EU will be climate neutral by 2050. In order to achieve this goal, a number of sectors, including agriculture, need innovative thinking. This is described in the Commission's "Farm to Fork" strategy, where the most important goals are to ensure the lowest possible climate and environmental impact from agriculture, and – at the same time – to support sustainable growth and development in rural areas within food production, including an ambitious increase in organic production.

- We need new and innovative solutions if we are to meet the visions presented in the Green Deal, says Senior Researcher Uffe Jørgensen, Head of CBIO. He further points out that green biorefining –supplying, among other things, high-quality protein from grass – has the potential of becoming an important element when creating a greener Europe.
Webinar on European perspectives

On this background – and in cooperation with members of the European Parliament as well as representatives from the European Commission – CBIO organized a webinar in November about the European perspectives in relation to green biorefining. About 150 researchers, decision-makers and stakeholders participated in the event.

Asger Christensen and Pernille Weiss, Danish members of the European Parliament, hosted the webinar. Together with member of the Cabinet of the Commissioner for Agriculture Jorge Pinto Antunes, they talked about the political framework. The EU is facing a modernization of the Common Agricultural Policy, and is about to enter a new programme period for the EU research and innovation program, Horizon Europe. In addition, a new European Climate Act is in preparation.

Researchers Uffe Jørgensen from CBIO, James Gaffey from the Irish Institute of Technology, Tralee, and Johan Sanders from the Netherlands agreed that research has demonstrated that the cultivation of perennial green biomass crops will help reduce the use of pesticides, reduce nitrogen leaching and contribute to soil carbon storage.

In cooperation with farmers and feed producers, all three researchers work with biorefining plants at a practical level, and the results from these efforts further demonstrate that plant protein extracted from green biomasses can replace imported soya and help establish local value chains and jobs in relation to the biorefining plants in rural areas.

A part of the Green Deal for Europe
There was general agreement that it is a very impressive effort to go from laboratory level to the first commercial plant in less than ten years. In addition, it was recognized and appreciated that if green biorefining is to succeed as a business model, then farmers need actual incentives to be part of this.

One of these incentives may be a form of carbon crediting system, which is known from other sectors. Specifically, the Commission will launch carbon farming initiatives under the new Farm-to-Fork strategy with a view to preparing the European Commission's Circular Economy Action Plan, which will introduce systems across sectors for carbon removal certification from 2023.

- We received major support from the webinar participants, and it is my impression that they really appreciated it. It is particularly interesting that the European Commission is right now in the process of developing a concept for carbon crediting. It is a very exciting project for us as it may help develop biorefining based on grass fields into an even better business case than it already is. This work area is obviously ready for development, although many uncertain factors exist, but it is in process and I find it very exciting to follow and hopefully also participate in these efforts", says Uffe Jørgensen.

Read more at cbio.au.dk/en

Technologies for green biorefining

In December, CBIO held a follow-up webinar, focusing on new technologies for green biorefining.

In December, the webinar targeting policymakers was followed by another webinar – this time targeting companies and experts in the field.

The webinar went in depth with the technical as well as the cultivation and environmental aspects of green biorefining with presentations for CBIO researchers, SEGES and Vestjyllands Andel, who is one of the partners behind Denmark's first farm for biorefining of grass, inaugurated in 2020.

Plant production

The Ministry of Food, Agriculture and Fisheries of Denmark (MFLF) and Aarhus University (AU) have entered into an agreement on the provision of research-based policy support within plant production. The agreement is one of 6 performance agreements under the framework agreement between the Ministry of Food, Agriculture and Fisheries of Denmark, the Danish Ministry of Environment and Aarhus University.

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 Agroecology, Food Science and Engineering as well as researchers from Center for Quantitative Genetics and Genomics.

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.

News in brief

New Section Manager for Climate and Water

As of March 2020, Professor of Crop Science and Water Management Mathias Neumann Andersen was appointed Head of Section for Climate and Water in the Department of Agroecology.

Immediately after completing his agronomic education at the Royal Veterinary and Agricultural University in 1984, Mathias Neumann Andersen started his career as a Research Assistant at Statens Planteavlsforsøg's research station in Jyndevad.

At that time, the research station in Jyndevad was the hub of Denmark's field irrigation research. Mathias Neumann Andersen worked here until 1992, when he moved to the research center in Foulum near Viborg. Here he has accomplished extensive work efforts - first as an Associate Professor and since August 2013 as Professor of Crop Science and Water Management. Mathias is strongly committed to the department's education of PhD students.

Citizens' Council on green transition

As part of the Danish government's new climate legislation, a Citizens' Council is to be set up with 99 randomly selected Danish citizens. The purpose of the Council is to debate relevant dilemmas and solutions related to the green transition. In order to ensure a solid academic foundation for the Citizens' Council debate, an expert panel has been set up as a central part of the preparatory work prior to council meetings.

Professor Jørgen E. Olesen is part of the expert panel:

- I see it as highly relevant to involve citizens and to hear their reflections on these issues. Hearing about what problems and opportunities ordinary Danes see in relation to the green transition is extremely valuable. I'm pleased to have been invited to join the expert panel.

New Head of Department in Agroecology

As of March 2020, Professor Jørgen E. Olesen was appointed Head of Department at the Department of Agroecology, where he was previously Section Manager and most recently acting Head of Department

As one of Denmark's most recognized climate scientists, Jørgen E. Olesen has been concerned with the interaction between agriculture and climate throughout his career; and in particular how we manage climate change. He has been a member of the UN Climate Panel, the IPCC, and was part of the research team that received the Nobel Peace Prize in 2007. He is a former member of the Climate Commission, the Natur- og Landbrugskommisionen (Danish Nature and Agricultural Commission) and the Danish Council on Ethics. He is an Honorary Professor at the University of Copenhagen, China Agricultural University and Ganzu Agricultural University (China) – and a Research Fellow at the Sino-Danish Center for Education and Research (Beijing, China) and the Global Change Research Institute (Brno, Czech Republic).

Drones will reduce agricultural CO_2 emissions

The Department of Agroecology develops methods and technology for mapping and analysing peatlands - a major source of CO_2 emissions in agriculture.

The national target of reducing CO_2 emissions by 70 % by 2030 in Denmark is hardly news to anyone anymore. But such an ambitious goal requires focus on and research into new technologies. One of the means to help us on the way to a 70 % reduction is the removal of peatlands from farming. Peatlands in agricultural production emit a lot of CO2 when drained and cultivated. Removal of peatlands in agricultural production is a highly prioritized goal in order to achieve the reduction target within the next 10 years.

ReDoCO2 is a new Danish development project, supported by Innovation Fund Denmark. In collaboration with Aalborg University, RegionMidt, SkyTEM, and I • GIS, researchers from the Department of Agroecology will develop methods and technology for mapping and analyzing peatlands. The project will develop methods for a more accurate determination of the distribution of peat soils as well as carbon stocks here.

- Detailed knowledge about the distribution of these soils is sparse, and that is why this project is so important. It can help us map the areas that can generate the biggest reduction in CO_2 emissions in Denmark, says Mogens H. Greve from the Department of Agroecology.

The project develops advanced hardware and software in order to map areas in unprecedented detail, thus enabling much more accurate estimates of carbon stocks and current CO_2 emissions.

Drones and 3D

- We are working with a combination of ground-breaking drone-mounted geophysical sensors, field data, machine learning, 3D visualization software, cloud-based data, and computing platforms. It will revolutionise the mapping of peatlands both nationally and globally, because it can be done in unprecedented detail, which allows us to make accurate estimates of carbon stocks and current CO_2 emissions from here, says Mogens H. Greve.

At national level, the main goal is to help reduce CO_2 emissions and ensure maximum effect of the strategies that focus on the extraction of agricultural land.

In addition, the result may have an economic, social, and environmental impact allowing Denmark to maintain its position as a green pioneer internationally. The project will also create new export opportunities for Danish green technology and for the project's business partners in particular.

Plant genomes reveal the basis for climate adaptation

In the face of rapid climate change, it is important that plants can survive by adapting quickly to new conditions to ensure their survival.

Researchers from Center for Quantitative Genetics and Genomics (QGG), among others, have thus studied the plant Lotus japonicus, which – with relatively limited genomic changes – has been able to adapt to diverse Japanese climates ranging from subtropical to temperate.

Using a combination of field experiments and genome sequencing, the researchers were able to infer the colonisation history of L. japonicus in Japan and identify areas in the genome where plant populations adapted to warm and cold climates, respectively, showed extreme genetic differentiation. At the same time, they showed that some of these genomic regions were strongly associated with plants' abilities as to winter survival and flowering.

This is the first time researchers have identified specific genomic regions that have changed in response to natural selection to allow the plant species to adapt to new climatic conditions.

Danish plant species to prevent drought loss for billions

The drought in 2018 cost Danish farmers 4 billion DKK. Fortunately, it is rare that Denmark experiences a drought as the one in 2018. However, in five of the past six years, farmers across Europe have suffered spring droughts in the order of billions. According to climate models, this kind of phenomenon will be the rule rather than the exception in the future.

In cooperation with Danish plant improvement companies and researchers from Aalborg University and Copenhagen University, researchers from Center for Quantitative Genetics and Genomics are developing new wheat, grass and potato species that are able to produce up to 10 percent higher yield than traditional species during spring and summer droughts.

The project aims at breeding crops with deeper roots, which will assure that the plants can continue their growth longer when the drought sets in.

New research in organic farming

Significant differences in greenhouse gas balances in organic cultivation systems

The impact of agriculture on the climate and the environment has helped strengthen the popularity of organic produce. The impact of organic farming on nitrate leaching and on the climate via nitrous oxide emissions and carbon storage in the soil has previously been studied, but so far, there has been a lack of studies from long-term field trials, but that is no longer the case.

Together with researchers from Switzerland and France, researchers from the Department of Agroecology have found that the greenhouse gas balance varies significantly between different organic cultivation systems.

Comparisons between organic and conventional agriculture should be improved

The environmental impact of agriculture and food production is a highly topical issue and frequently discussed worldwide. However, researchers from Aarhus University, Chalmers University of Technology and INRAE point out that the comparison method most widely applied (LCA) often lacks some rather crucial factors.

Often, the LCA method does not include factors such as biodiversity, soil quality and pesticide impacts, factors of major importance in relation to agricultural impact on the environment.

In a scientific paper in the journal Nature Sustainability, the researchers describe – based on an exhaustive analysis – their concern that the current application of the method may result in incorrect conclusions concerning comparisons of intensive specialized farming and agroecological agriculture such as organic farming.

Converting to organic farming reduces agricultural climate gas emissions in Denmark

In a report to the Danish Agricultural Agency, researchers from Aarhus University have estimated the impact of conversion to organic farming on climate gas emissions for selected conventional and organic farms in Denmark.

They demonstrated a reduction in emissions per hectare of 775 kg CO_2 equivalents in relation to crop production, 3,600 kg CO_2 equivalents in cattle production and 3,700 kg CO_2 equivalents in pig production, when including changes in soil carbon stocks.

Taking into account the current area distribution of agricultural branches within both organic and conventional production, the researchers estimate generally reduced emissions from organic areas – between 1.2 and 2.0 tons CO_2 equivalents per hectare, depending on the method used to determine area distribution – when including changes in soil carbon stocks. indregnes.

Read more on dca.au.dk/en

Great opportunities **for Denmark to secure self-sufficiency in protein**

Grass protein can replace imported soy protein in compound feed for livestock. A complete transition will require an optimization of grass cultivation and the extraction technology applied.

Every year, Denmark imports between 1.5 and 1.7 million tons of soy, corresponding to 700,000 tons of pure soy protein. Cultivation of this soy takes up an area of approx. 760,000 hectares, primarily in South America. An increasing concern exists as to the environmental and socio-economic problems caused by soy bean production, and also that an increasing global demand for soy will result in further clearing of the rainforest.

At a request from the Danish Agricultural Agency, researchers from Aarhus University thus examined "how much of the current agricultural land in Denmark should be used for grass production in order to replace imported soy for feed by using protein extracted from Danish grassland areas?"

Higher yields expected

Today, Danish grass production yields approx. 10 tons of dry matter per hectare. Green grass and clover contain 15–25 percent protein in dry matter, and biorefining experiments show that about 40 percent of the protein is extracted. All in all, this means that it is possible to produce 0.72 tons "pure protein" per hectare, which in turn means that a total area of 979,000 hectares should be used for grass production in order to replace the current import of soy.

However, neither the current cultivation practice nor the grass varieties used are optimized in relation to biorefining, just as the biorefining technology is not yet fully developed. Targeted research and development efforts will increase the yields as well as the amount of protein extracted.

Different scenarios

The researchers set up four scenarios within the framework of which they estimate the effect of various improvements in the grass production system. One scenario optimizes both cultivation systems, grass varieties and technology, and expects to produce an average of 14 tons of grass dry matter per hectare with a protein content of 20 percent. Adding an improved biorefining technology allows for the production of 1400 kg extracted protein per hectare per year.

- We are aware that significant opportunities exist for optimizing both cultivation practice and biorefining technologies. However, it will require huge research and development efforts to facilitate this within the foreseeable future, says Senior Researcher and Head of Centre Uffe Jørgensen, Aarhus University Centre for Circular Bioeconomy (CBIO).

He further points to the challenge of maintaining the high yields in longer rotations as well as the risk of soil compaction in perennial fields.

We borrow grass from the cows

According to the optimized scenario, it will require an area of 500,000 hectares of grasslands in order to substitute imported soy protein with locally produced grass protein. Today, the Danish grasslands constitute approx. 300,000 hectares.

This grass is used as feed for ruminants, primarily dairy cows. However, the grass may still be used for feed after extracting the protein.

By means of biorefining, protein is extracted from the grass, but the pulp – which constitutes the major part – may still be used as cattle feed. Experiments even demonstrate increased milk yield when dairy cows are fed the pulp.

Analysis of climate and environmental effects of biogas production

What should future biogas production look like in order to be as sustainable as possible?

At the request of the Danish Energy Agency, researchers from the Department of Agroecology and the Department of Engineering have investigated this. Five model plants with five different forms of biogas production were studied.

Professor Jørgen E. Olesen, Head of Department at the Department of Agroecology and one of the researchers behind the study, says:

- The quantification of the environmental impact in relation to biogas production constitutes an important basis for designing and targeting future biogas funding in order to optimize the climate and environmental benefits of the production. Our report presents an analysis of the effects of biogas production based on livestock manure and other relevant types of waste biomasses, agricultural residues and energy crops. The report sheds light on how different types of biomasses affect the sustainability of biogas.

The DCA report, entitled "Sustainable biogas - climate and environmental effects of biogas production", describes and quantifies the impact of relevant biogas productions, including energy production, greenhouse gas emissions, nitrate leaching, ammonia volatilization, nutrient use, and odour from field application of the digested slurry.

Seaweeds may contribute to a sustainable transition

At CBIO - Aarhus University Centre for Circular Bioeconomy – significant research efforts are carried out as to how we best establish a sustainable food system ensuring the inclusion of the biological resources of the planet and minimize waste. And here, seaweeds may play an important role.

CBIO is part of a project within the framework of which researchers – in collaboration with Hjarnø Havbrug (Hjarnø Aquaculture) – examine how to optimize the cultivation of sugar kelp which can be used in food production.

The SeaSusProtein project aims at identifying the best way to extract high-quality protein from seaweed and use it in veggie-mince and cheese. At the same time, harvesting seaweeds is good for the environment as nutrients are removed from the aquatic environment, which reduces the risk of oxygen depletion.

Researchers from Aarhus University also participate in another research project, Climate Feed, to examine how various Nordic types of seaweed may help reduce the emission of methane from dairy cows.

Finally, the Tang.nu project is currently examining ways in which seaweeds may contribute to improve the marine environment. This is a cooperation between a huge number of seaweed actors in Denmark.

From Danish hemp fields to sustainable textiles

A new project, supported by Innovation Fund Denmark, aims to develop a method that will make hemp textiles a sustainable alternative to cotton.

Hemp is a very sustainable plant; it may be grown almost anywhere, it has a very low demand for manure and water, and it can easily be cultivated organically and without the use of pesticides.

A funding of DKK 10.2 million (EUR 1.4 million) from Innovation Fund Denmark, allows a large number of Danish companies and knowledge centres as well as Aarhus University to cooperate to develop a method enabling Danish agriculture and the textile industry to produce sustainable textiles from Danish-grown hemp.

The goal of the project, known as Hemp4Tex, is to develop a finished concept ranging from cultivation, harvesting, processing and extraction of hemp fibres to the practical production, spinning, weaving and knitting of sustainable fabrics.

From lab to pilot scale

Aarhus University's research group "Green Biorefining Technologies", headed by Assistant Professor Morten Ambye-Jensen, will participate in the project.

The aim is to develop a technology to pre-treat hemp stalks to make high-quality hemp fibres that can be spun.

Normally, hemp stalks are pre-treated in the field, where the stalks are left after the harvest. Natural biological processes ensure that it is possible to peel off the fibres from the stems and process them further separately:

"We're going to automate this process through efficient and reproducible hydrothermal treatment of bundles of hemp stems 1.5 metres long. The project will take us from laboratory scale to pilot scale, using the technology in a completely integrated, automatic pre-treatment facility that will ensure uniform and optimal treatment of the stems for further processing of the fibres," says Morten Ambye-Jensen.

The pilot-scale facility is part of the development of Aarhus University's demonstration platform for green biorefining at Foulum, which also conducts research into proteins from grass.

New research in nutrients

Aarhus University research efforts in nutrients provide new knowledge contributing to increased yields and utilization of nutrients as well as to help reduce the environmental impact and agricultural emissions.

A closer look at cover crops' release of nitrogen

The mineralisation of cover crops releases nitrogen for future crops, but it may also cause leaching of nitrate, which can be harmful to the aquatic environment. Researchers from Aarhus University have investigated different cover crops and how they are turned over in the soil and how this may release nitrogen to the subsequent crops.

Acidified cattle slurry's effect on springtails

Acidification of cattle slurry increases the fertilizer value and reduces the environmental impact. However, what about the impact on soil organisms? Researchers from Department of Agroecology examined the impact of acidified slurry on springtails. The researchers demonstrated that the springtails were little affected at normal slurry volumes; however, they actually thrived well also with acidified slurry, even at the high slurry rates

Long-term experiments show low levels of uranium in soil supplied with phosphorus fertilizers

It is possible to maintain a low and harmless concentration of uranium in agricultural soil, but only if phosphorus fertilizers from raw phosphorate with a low content of phosphorus are used. This was demonstrated with the help of the long-term fertilizer experiment at Aaskov Research Station as well as German field trials.

Row-injected cattle slurry is a promising fertilizer strategy for silage maize

According to researchers from Aarhus University, row-injected cattle slurry has the potential to replace mineral phosphorus fertilizers in silage maize production. This fertilizer strategy will also reduce phosphorus surplus while maintaining the crop yields.

Measures to reduce nitrogen impact on the aquatic environment

In a new report on mitigating measures, researchers from Aarhus University and the University of Copenhagen describe 32 measures to reduce the nitrogen impact on the aquatic environment. The report is an update of well-known measures like the use of cover crops and set-aside farmland, as well as a number of new measures such as e.g. nitrification inhibitors in slurry and paludiculture.

Biochar as a source of phosphorus

Pyrolysis is not only a source of sustainable and climate-friendly energy, but the residual product from pyrolysis, known as biochar, can – in addition to carbon binding – also act as phosphorus fertilizer in agricultural fields.

Biochar is the new black – its degradation in soil is very slow and it may thus help increase soil carbon storage. In addition, biochar contains several important plant nutrients. Together with colleagues from the Technical University of Denmark and the University of Copenhagen, researchers from Aarhus University have investigated whether phosphorus in biochars may be used as plant fertilizer.

From residue to nutrients in the soil

Biochar is the charred residue from plant or animal biomass exposed to pyrolysis or thermal gasification in a pyrolysis plant. Unlike carbon from plant material that has not undergone so-called gasification, carbon in biochar is very stable and does not convert to CO2 until many years after being returned back into the soil. It simply binds the carbon and thereby provides a significant climate effect.

- Therefore, we use surplus straw in pyrolysis plants and convert it into gas, energy and biochar for fertilizer and soil improvement in the fields. It is a way of reducing climate emissions from agriculture. Biochar as a product entails more benefits, but the interesting thing for us in this project was to find out whether phosphorus in biochar is available to the plants, allowing it to act as a fertilizer, says Senior Researcher Peter Sørensen, Department of Agroecology.

Phosphorus availability in different types of biochars

Biochar can be made from a wide variety of biomasses, and differences exist from one biomass to another. Therefore, the researchers examined phosphorus availability in different types of biomasses in the form of straw, chicken manure, sheanut shells as well as two types of sludge.

- We have worked with five different biochars in this project, and it turns out that phosphorus is actually available to the plants in all of them, but in varying amounts, says Peter Sørensen.

pH in the soil plays a role

The experiments demonstrated that all biochar types increased the pH value of the soil, thus adding a calcium effect. However, the increase depends on the amount of biochar as well as the original soil pH.

- Changes in soil pH is important to the availability of phosphorus, and we demonstrated that a high pH value means more available phosphorus, says Peter Sørensen.

In addition to being a hot issue in the climate debate, the study showed that biochar is also important in relation to an improved recirculation of nutrients in agriculture.

60 million DKK to future-proof biodiversity

SustainScapes is a new 6-year-old centre that will work with solutions as to how biodiversity can be future-proofed in a changing climate and in a world with an ever-increasing need for resources.

How is it possible to rethink the agricultural landscape in order to develop agricultural production sustainably, while at the same time achieving the goal of a significantly increased biodiversity? SustainScapes, funded by the Novo Nordisk Foundation, will investigate this question.

Rethinking in the terms of biodiversity
SustainScapes research will help us understand how changes in land use and climate conditions have historically affected biodiversity across Denmark.

- Based on this new knowledge, we will develop tools to predict how and in which areas nature restoration and new methods of agricultural production will have the greatest effect on biodiversity in the future, says Professor and Head of Centre Tommy Dalgaard, Department of Agroecology.

- With SustainScapes, we rethink the use of the Danish landscape and explore nature-based solutions for the conservation of biodiversity and bio-based production. We will contribute new knowledge about where – and how quickly – we can expect biodiversity to be restored and use data obtained from space to follow the changes. By linking local and global models, we will put local choices in a global context. Thus, we aim to deliver local, sustainable solutions that benefit both biodiversity, climate and production. We want to make it easier for citizens and decision-makers to implement local initiatives for a sustainable future, explains Head of Centre Signe Normand, Department of Biology, who is very much looking forward to the interdisciplinary collaboration.

More plant species in the grasslands provide food for pollinating insects

Danish farmers can ensure a high and stable yield as well as increase the biodiversity and abundance of pollinating insects in grasslands with the right mix of different plant species and by adapting the frequency of cuttings.

A major proportion of global agricultural production is dependent on pollinating insects, as are most wild flowers. However, there has been a documented decline in the number of wild pollinating insects in both Europe and North America due to habitat loss, pesticide use, parasites, invasive species and climate change. According to recent research at Aarhus University, Danish farmers, however, can make a difference in Denmark and improve conditions for pollinating insects by increasing the diversity of plants in their grasslands.

- Traditional grasslands typically consist of few but high-yielding plant species, which – with 4 or 5 annual cuts – only provide very little floral food for insects, explains Professor Jørgen Eriksen, Department of Agroecology.

Increased biodiversity does not reduce yield
It is possible to mix plant species and increase plant diversity of grasslands to benefit the pollinating insects without reducing the yield of the grasslands. This will require cutting strategies or a mix of plant species like herbs, grass and legumes.

- Our conclusions can easily be fitted into a modern agricultural practice with 4-5 cuts per year by systematically leaving uncut strips of multi-species mixtures at each cut. These may be harvested in the subsequent cut. This will provide a significant increase in the food source for pollinating insects in cultivated areas, and it will only marginally reduce quality and yield, Jørgen Eriksen explains.

Natural enemies of pests and biodiversity in organic farming

Windbreaks, hedges, nature strips, buffer strips, flower strips and beetle areas are just some of the initiatives to make life difficult for the pests and – at the same time – help increase biodiversity in organic farms.

Researchers from Aarhus University have prepared a new report on initiatives to increase the natural enemies of pests and – at the same time – increase biodiversity in organic farms. The report was commissioned by the Danish Agricultural Agency and identifies 42 different initiatives.

- Pests have many enemies, including ladybirds, flower flies, net-winged insects, parasitic wasps, Campylomma bugs, ground beetles, rove beetles, spiders and starlings – and these provide protection in many ways, says Senior Researcher Gabor Lövei, Department of Agroecology.

42 different initiatives

The report comprises a total of 42 various initiatives. Out of these, six are beneficial to soil biodiversity, 13 are good for natural enemies, and 23 are beneficial to both.

The 23 initiatives that will help increase natural enemies as well as soil biodiversity, include the preservation of special habitats such as bogs, lark strips, insect areas and salt meadows.

A growth strategy for organic farming from the Ministry of Food, Agriculture and Fisheries of Denmark suggests the implementation of cultivation-related requirements of nature initiatives in farms of a certain size; the report is based on this strategy.

Ensuring biodiversity in agricultural and afforestation areas

Researchers from the universities in Aarhus and Copenhagen have prepared a report of measures to benefit biodiversity in Danish agricultural and afforestation areas.

Lark spots, flower strips, hedges, wetland areas, natural overgrowing etc. are just some of the measures that may help increase biodiversity. This appears from a report of measures commissioned by the Danish Agricultural Agency.

The report examines a number of existing and new measures, their adaptation in agriculture as well as the expected effect on biodiversity and economy.

Different from other reports on mitigating measures

- It is not possible to interpret biodiversity precisely in relation to a total, specific and quantitative goal. We cannot achieve a comparable effect of each of the different measures, and the point is that we need a wide range of initiatives in order to increase biodiversity, while protecting existing biotopes at the same time. The effect depends on whether the measure is a targeted field area, small biotopes or afforestation areas, Professor Tommy Dalgaard, Department of Agroecology, explains.

Therefore, the report contains recommendations on how to implement these measures and how to utilize existing biotopes in order to increase biodiversity in the best possible way, but the measures are not directly compared to each other.

The new EU agricultural reform (CAP2020+) opens up new possibilities of increasing biodiversity in interaction with agricultural production, including the opportunity of achieving financial support for field plots with no agricultural activities. This is the background for the study accomplished.

Climate and environmental impact of Conservation Agriculture

A new report gathers available knowledge on Conservation Agriculture and provides a survey of climate and environmental effects, weaknesses and challenges as well as how cropping systems may increase the sustainability in crop production

Minimum tillage, permanent soil cover with stubbles or crop residue, comprehensive crop rotations, intercropping and an extensive use of cover crops are some of the characteristics of Conservation Agriculture (CA).

Improved soil quality, increased soil carbon storage and biodiversity

CA provides the possibility of improving soil quality, increasing soil carbon storage and biodiversity just as it helps reduce the environmental impact of nitrogen and phosphorus when compared to long-term cereal-based ploughing systems with a limited use of cover crops.

Given that one of the principal cultivation elements in CA is minimum tillage, CA helps reduce work and machinery costs, not to mention fuel consumption, compared to the cultivation system mentioned above.

Pesticides and nitrous oxide

The report does not only list the advantages of CA, however. The weaknesses of the CA system include the dependence and consumption of herbicides, nitrous oxide emissions and crop establishment and growth. Due to the absence of ploughing, CA will depend on the use of herbicides in conventional crop production, just as it may be difficult to minimize nitrous oxide emissions in systems with an intensive use of cover crops.

High demands as to farm management

CA is not simple or straightforward – even though benefits are obvious, several challenges still exist. CA is especially challenging for organic farmers because of weed problems. In addition, it is not possible to grow potatoes in a no-tillage system.

CA places significant demands on farm management. CA success depends on a fruitful interaction between the cultivation system and the timing of the various cultivation elements.

Future development

The implementation of CA still entails challenges and weaknesses, but the system is very beneficial if you can strengthen the positive aspects and reduce the more negative ones.

- We need coordinated efforts that focus on the optimization of individual elements such as e.g. timing and intensity of tilling in relation to nitrous oxide emissions, as well as the total CA cultivation system, says Professor Lars Juhl Munkholm, Department of Agroecology.

Predicting functional properties in soil layers

Using new analytical methods, a PhD student from Department of Agroecology has made it easier to assess the risk that spraying a specific piece of land with pesticides will lead to contamination of the drinking water.

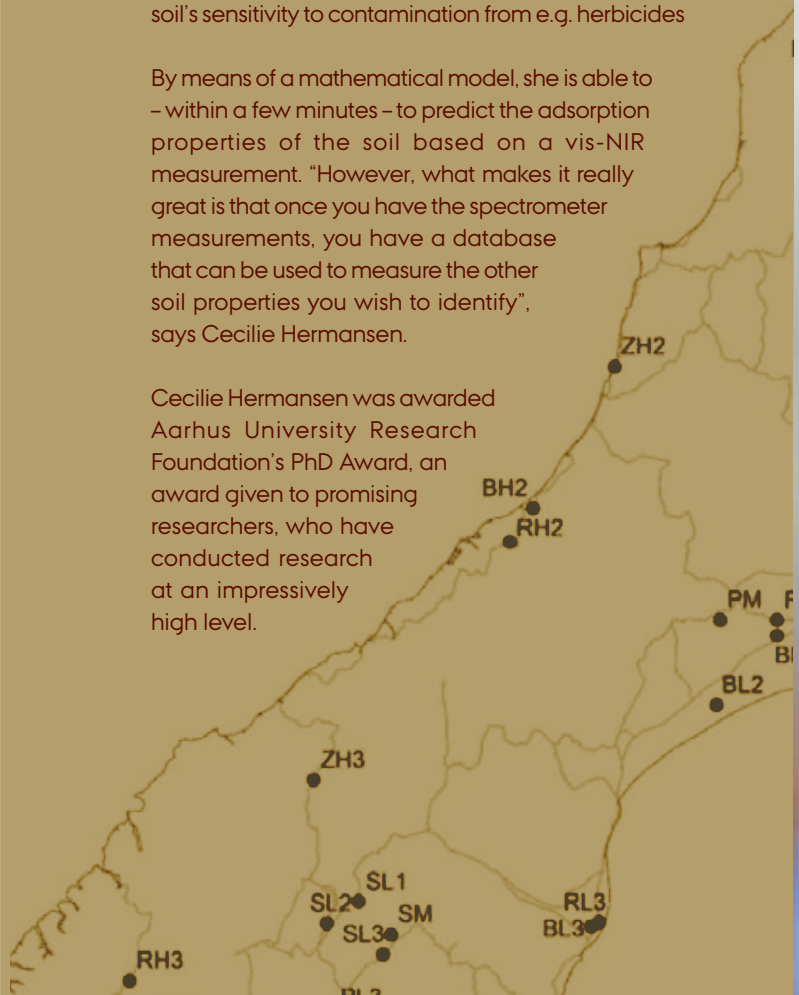
During her PhD studies at Department of Agroecology, Cecilie Hermansen has developed methods attracting international attention for results that show how the use of vis-NIR-spectroscopy may be expanded to assess the risk of contaminating drinking water.

PhD award

vis-NIR-spectroscopy is an established method for analysis of the composition of soil layers, but Cecilie Hermansen has discovered a shortcut to measuring the soil's sensitivity to contamination from e.g. herbicides

By means of a mathematical model, she is able to – within a few minutes – to predict the adsorption properties of the soil based on a vis-NIR measurement. "However, what makes it really great is that once you have the spectrometer measurements, you have a database that can be used to measure the other soil properties you wish to identify", says Cecilie Hermansen.

Cecilie Hermansen was awarded Aarhus University Research Foundation's PhD Award, an award given to promising researchers, who have conducted research at an impressively high level.



Carbon is still active after 20 years in the soil

A 20-year-old experiment at Askov research station has demonstrated that carbon, which has been fixed in the soil for many years, is still active and a part of the natural biological decomposition process in the soil.

The longer the organic carbon has been in the soil, the more difficult it will be to decompose for microorganisms such as fungi and bacteria. Microorganisms will first convert the easily decomposable parts of the carbon.

20-year-old feed for microorganisms

The researchers are surprised that the old soil carbon still forms a substantial part of the resource base of the food chains in the soil even after 20 years.

- By measuring the isotope composition in decomposing organisms, we can now detect the extent to which microorganisms are living from carbon that is more than 20 years old, says Mette Vestergård, Department of Agroecology:

- Older organic carbon is constantly active and under process, and it is decomposed especially by fungi and feeding nematodes. This is new and very exciting knowledge that we would like to investigate further.

Anti-resistance strategies are important in the fight against Septoria

Researchers from Aarhus University have found a pattern in the spread of fungicide resistance in Septoria in winter wheat.

Septoria is the most prevalent fungal disease in wheat in Northern Europe, and it causes major damage in wheat fields as well as negatively affects the farmer's yield. Control of the disease is highly dependent on fungicides, but due to the steady increase in the use of fungicides, more and more fungicides have become resistant.

From West to East

Experiments have demonstrated that resistance is travelling from Ireland in the West and slowly towards the East. According to the researchers, it is essential to implement anti-resistance strategies even in countries with low resistance problems.

- We simply need to think in terms of anti-resistance strategies from the very beginning to ensure that resistance to new fungicides is not quickly built up. We hope that our research may help shed some light on the importance of anti-resistance strategies, so we can continue to fight Septoria in wheat in the future, says Assistant Professor Thies Marten Heick, Department of Agroecology.

Plants may be able to defend each other

Within the framework of a new project, researchers from Aarhus University will investigate whether plants are able to defend each other.

Plants cannot run away or fight when faced with a threat. Instead, they have developed physical and chemical defence mechanisms. However, not all plants have the same, or equally effective, defence mechanisms.

In a project funded by the Villum Foundation, researchers from Aarhus University will examine how plants can absorb chemical defence substances – formed by other plant species – from the soil environment. This will help them investigate whether plants will be better equipped in the defence against pests.

Later sowing can help control herbicide resistant weeds

Resistance to herbicides in weeds may be at the expense of other plant properties, and may provide ideas for alternative control methods.

Ill weeds grow apace, as they say, and weeds do not perish easily, because plants have the ability to adapt to different cultivation conditions. Therefore, many farmers experience problems with herbicide-resistant weeds. However, research demonstrates that plant resistance to herbicides may be at the expense of other plant characteristics. Therefore, minor changes in cultivation techniques may help reduce the problems of herbicide-resistant weeds in the fields.

Two types of resistance

There are wo types of resistance. The most common type is known as "target-site" resistance, which is a single mutation in a major gene in the plant. This means that the plant is completely resistant to a certain herbicide.

The other type is "non-target-site" resistance, characterized by mutations in several less important genes, each of which contribute to reduce sensitivity, and the more mutations the plant has, the less sensitive it will be to herbicides. This means that the plant can resist a series of different herbicides.

- This means that it is often not possible to fight them chemically, which is why the issue of differences in fitness is very important for these biotypes, says Per Kudsk.

Plant fitness

If a plant has acquired resistance to a certain herbicide, it may be at the expense of other plant properties. In other words, they will have a reduced fitness level and will not be able to cope or be as strong as non-resistant plants.

Dormancy may be the solution

- Our experiments with Black-grass (Alopecurus myosuroides) demonstrated that resistant biotypes have shorter dormancy periods than herbicide-sensitive biotypes, says Per Kudsk.

Dormancy ensures that seeds do not germinate immediately after they hit the soil. Black-grass seeds are dropped during the month of July, and if they germinated immediately, they would be destroyed in the tillage that occurs in the fall before sowing the next crop.

- But it turns out that resistant biotypes have a shorter dormancy rest, so they may germinate earlier, says Per Kudsk.

Sow later and avoid weeds

If a farmer has problems with this type of resistance, the solution may be to postpone sowing until the major part of the seeds have germinated. In this way, the seeds will be destroyed in connection with the tillage before sowing.

- We found different fitness levels in the plants, and it turned out that this may be utilized when cultivating the fields. By slightly changing the cultivating technique, it is possible to favour the sensitive biotype at the expense of the resistant one. In the long run, this will allow us to reduce the proportion of resistant plants in the fields, says Per Kudsk.

Animal production

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

The agreement is one of 6 performance agreements under the framework agreement between the Ministry of Food, Agriculture and Fisheries of Denmark, the Danish Ministry of Environment and Aarhus University.

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

Dairy cows fed a low-energy diet around dry-off **show signs of hunger**

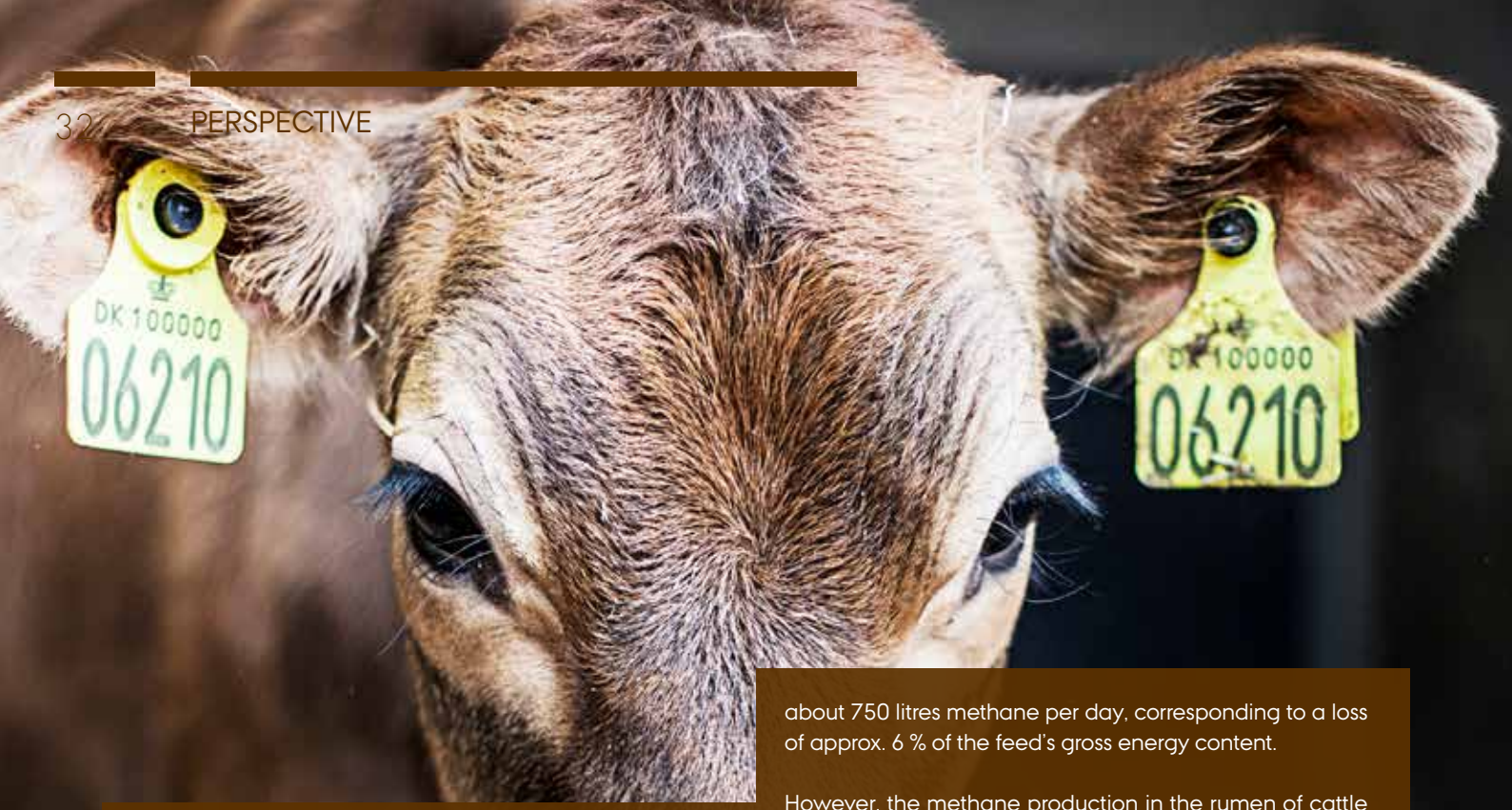
Researchers from AU have studied the extent to which the feed energy density affects dairy cows' feeding motivation during dry-off. A motivational test showed that using low energy diets to dry-off high-yielding dairy cows results in hunger despite ad libitum access.

Cows **favour natural over synthetic** vitamin E for the cow milk

When cows are fed grass with a high content of natural vitamin E, the milk's content of vitamin E is higher than when cows are primarily fed feed containing synthetic vitamin E. The explanation is that cows favour natural vitamin E over synthetic vitamin E. This is demonstrated in studies conducted by researchers at AU Foulum. The results have been published in the recognized journal FOOD Chemistry.

New project: **Feeding organic sows during winter**

In the future, organic pig producers must be able to feed their sows optimally during the winter period. AU researchers are in charge of a new project with the purpose of developing new feed mixtures for organic sows fed silage during winter. The nutrition should be better adapted to the sows' need, thus increasing the feed efficiency, reducing the loss of nitrogen and improving the farmer's economy.



What happens to hydrogen and carbon when the production of methane from cattle is reduced?

Methane consists of carbon and hydrogen, and the production of methane in the rumen of cattle may be significantly reduced by adding fat or feed additives to the feed. Researchers at AU Foulum will examine whether the reduced methane production will imply that more carbon and hydrogen is available for the animal's metabolism, and what happens to the carbon and hydrogen.

Methane (CH_4) consists of carbon (C) and hydrogen (H) and is a powerful greenhouse gas, the effect of which is 25-28 times higher than that of carbon dioxide. Methane is produced as a natural part of the microbial fermentation in the rumen from hydrogen and carbon dioxide, both of which are end products from the fermentation of carbohydrate in the rumen. A high-yielding Danish dairy cow produces about 750 litres methane per day, corresponding to a loss of approx. 6 % of the feed's gross energy content.

However, the methane production in the rumen of cattle may be reduced by adding fat or targeted feed additives to the feed rations. Yet, it is unclear whether the reduced methane production means that more carbon and hydrogen is lost in the exhalation of e.g. carbon dioxide, hydrogen and hydrogen sulphide, or if more carbon and hydrogen is actually available for the animal's metabolism, and where that carbon and hydrogen will subsequently end up.

Can cows benefit from surplus carbon and hydgrogen?
A new feeding experiment at Aarhus University in Foulum is to shed light on this.

- Carbon and hydrogen exhaled in the form of carbon dioxide and hydrogen, respectively, is of no value to the cow. If it is included in the formation of microbial protein and volatile fatty acids such as acetic acid, propionic acid and butyric acid, which the cow can subsequently utilize, this will be very positive for the animal's energy and nutrient supply. Therefore, we need more knowledge about the positive consequences, and negative if any, of a reduced methane production in the rumen in relation to the cow's supply of energy and nutrients, says head of the experiment Professor Peter Lund, Department of Animal Science at Aarhus University.

Previous experiments at AU Foulum have shown that increased fat contents in the feed may help reduce the release of methane from the cows' digestion by as much as 10%. Within the framework of the new feeding experiment, the researchers will further investigate how an additional fat allocation and feed additives will affect the animal's supply of nutrients.

The project is a part of the overall project "Reduced climate imprint at cow and farm level", funded by the Dairy Levy Foundation and headed by Professor Peter Lund, Department of Animal Science at Aarhus University (AU). Research results will be part of a PhD project at AU. The overall project will run during the period 2019-2022.

Sows utilize clover grass surprisingly well

An organic sow walks 2-3 kilometres a day and digests grass as well as a cow. These are some of the results from the EFFORT project, accomplished at Department of Animal Science at Aarhus University.

New research results from the EFFORT project demonstrate that sows utilize both protein and energy from fresh clover grass surprisingly well.

The experiments accomplished at Department of Animal Science, Aarhus University, demonstrate that the protein intake is increased by 60 % if half of the energy from cereal-based feed is replaced by fresh clover grass. So far, researchers have been concerned whether sows are capable of utilizing the nutrients in grass. It turns out, however, that organic sows are capable of digesting as much as 71 % of the protein from fresh clover grass.

The energy digestibility of fresh grass in sows is equally high and similar to that of ruminants, about 68 %. This means that organic and free-range farmers may reduce the protein contents of their gestation feed diets by 10-15 % during summer, if the grass cover is appropriate. This way, the protein contribution from pasture is included in the feed plan, which will reduce the need for organic soya and other expensive protein sources.

AU boosts its research in circular bio-economy with a new professorship

Søren Krogh Jensen has been appointed professor in "Animal food production in circular bio-economy" as of 1 June 2020. With this, the Department of Animal Science, AU, seriously positions itself as one of the leading research institutions in providing sustainable solutions for the future farm animal production – in Denmark as well as internationally.

New unique cattle research centre at AU Foulum

The new Danish Cattle Research Centre is now a reality. It is an impressive barn complex equipped with brand new and unique state-of-the-art research facilities. Three new cattle barns have been built, the forage barn has been expanded, and the staff facilities have been modernized. The new cattle facilities have already been put into service, and the research projects are running.

The building and renovation of the new Danish Cattle Research Centre (DKC) was completed in the end of 2020. Previously, DKC was found at two locations, but now cattle and staff have been gathered at Burrehøjvej, while the rental agreement in relation to the old research facilities at Blichers Allé at AU Foulum has been terminated.

- We are very satisfied with the result. It has been a long and intensive process to come this far. However, it was necessary in order to modernize and adapt our cattle research facilities for future requirements and because of an essential reduction of rent and important optimizations. I am very pleased that we have now reached our goals, and I am proud and happy to be able to present these modern research-focused settings to cattle research, which we have now built, says Klaus Lønne Ingvartsen, Head of Department in Department of Animal Science, Aarhus University.

Large and bright cubicle barn

Three new barns have been established. The biggest of these is a new cattle barn with cubicles and room for 96 cows. In the big cubicle barn, electronic feeding troughs have been installed as far as the eye can see — one feeding trough per cow, and there is a brand new milking system.
Intensive barn with methane chambers

Next in our new housing complex is the intensive barn, which is divided into different units. One of these units is equipped with four new respiration chambers. Here, the researchers can collect the cows' exhalation air and e.g. measure their methane emissions. This may be relevant in experiments where you look at the effect of different feeding initiatives or feeding strategies, the purpose of which is to reduce the methane emission from cattle.

Unique stalls

As the first place in the world, the remaining part of the new intensive barn is uniquely equipped with 20 stalls for individual animals. These stalls are specially designed and customized for experimental cows with so-called fistulas. These cows provide an opportunity for the researchers to collect analytical samples directly from the cows' digestive systems without the cows feeling anything. The new stalls allow the animals to move around freely, as opposed to the previous practice of being tied up in order to avoid damaging the fistulas.

The third new barn system is a so-called flexible barn. This barn is suitable for e.g. behavioural studies, which often demand an alternative barn design and sometimes a test arena.

Apart from the newly established housing systems, the forage barn has been expanded and is twice it previous size. Additionally, the staff building has been modernized.

Hoof trimming late in gestation **increases the risk of abortion**

A study from Aarhus University, based on a large data set from the Danish Cattle Database, demonstrates that hoof trimming late in gestation increases the risk of abortion in dairy cows.

Researchers from Aarhus University and University of Copenhagen have conducted a large-scale study evaluating whether hoof trimming late in gestation is a risk factor for abortion in dairy cows.

In the study, the researchers have retrieved recordings from the Danish Cattle Database on all pregnant cows from 2012 to 2018. The study included 1,476,013 pregnancies, during which the cow had been trimmed at least once during gestation.

Hoof trimming late in gestation increases the risk of abortion

The results showed that 1.24 percent of all pregnancies resulted in an abortion during the last third of gestation. Twin pregnancies had a higher risk of abortion compared to pregnancies with only one calf. In addition, Jersey cows had a significantly lower risk of abortion compared to other breeds. Approximately 29 percent of all cows included in the study had been trimmed within the last eight weeks before calving or abortion.

Finally, the analyses showed that the risk of abortion was significantly higher in cows trimmed late in gestation.

- Cows trimmed during the last four weeks before end of gestation had a 2.4 times higher risk of abortion compared to cows trimmed more than eight weeks before end of gestation, says Senior Researcher Peter T. Thomsen from Department of Animal Science, Aarhus University.

Be extra careful when trimming cows late in gestation

Even though the study design does not make it possible to conclude that hoof trimming is the direct cause of these abortions, Peter T. Thomsen states – based on the large and comprehensive data material – that there is reason to be extra careful when trimming cows in late gestation. Therefore, farmers and hoof trimmers are encouraged to keep this in mind and thoroughly consider pros and cons before deciding whether a cow in late gestation needs to be trimmed.

- Of course, situations exist where it is necessary to trim a cow late in gestation. In these situations, the cow should be handled as gently as possible, and we recommend that you only lift one leg at a time, in order to limit the external pressure on the uterus during trimming, says Peter T. Thomsen.

Why do sows die in the farrowing house?

Most sows dying spontaneously die in the farrowing house. A DCA report from Department of Animal Science, Aarhus University, shows that the predominant cause of death is torsion of the liver, followed by farrowing problems and infections.

In 2018, the mortality in Danish sows was 12.6 %. Approx. half of the sows die spontaneously and often without preceding symptoms. Most spontaneous deaths take place in the farrowing house. For practical reasons, there are often no subsequent diagnosis, which makes it difficult to implement targeted efforts.

As part of the agreement between Aarhus University and the Ministry of Food and Agriculture of Denmark on the provision of research-based policy support, researchers from Department of Animal Science have mapped the causes of spontaneous sow mortality in farrowing pens in Denmark. The results of the efforts have been published in the DCA report "Årsager til spontan sodødelighed i farestalden" (in Danish) – (Causes of spontaneous sow mortality in the farrowing pen).

Torsions of the liver is the predominant cause of death

Based on ten commercial sow herds, the researchers examined causes of death and conditions in relation to spontaneous sow deaths in the farrowing house in the period from April 2018 to June 2019. One single cause of death turned out to be the most frequent:

- The predominant cause of death was torsions of the liver. As many as 42 % of the pigs in the project died because a liver lobe had twisted about its axis causing venous congestion and necrosis. By comparison, and according to the autopsies performed, 17 % of the sows died from farrowing problems, mainly because of retention of dead piglets in the uterus. 17 % of the sows died from infections, explains Postdoc Hanne Kongsted, Department of Animal Science.

The study provided an increased insight into both the causes of death in the herds examined, as well as high-risk periods for spontaneous sow death. Two periods stood out in particular:

- 25 % of the dead sows in the study died in the period 0-5 days after farrowing, but also the late suckling period – i.e. approx. 3 weeks after farrowing – turns out to be a high-risk period. The most frequent cause of death, torsion of the liver, occurs during the entire suckling period; however, more sows seem to die in the late suckling period rather than around farrowing, Hanne Kongsted elaborates.

A new vaccine against piglet diarrhoea is on its way

Aarhus University takes part in a new and ground-breaking project to develop an effective vaccine against weaning diarrhoea in piglets. If the development of the vaccine goes like the researchers hope it will, we might prevent 90 % of the mortality caused by weaning diarrhoea seen today, and the use of antibiotics will be reduced accordingly.

In modern pig production, diarrhoea in piglets is a huge challenge, it is very expensive for the farmer due to the high mortality rate in the piglet pens and the considerable use of antibiotics. At the same time, the significant use of antibiotics is a serious problem as it increases the development of antibiotic-resistant bacteria.

With funding from the Ministry of Food and Agriculture of Denmark's Green Development and Demonstration Programme (GUDP), Statens Serum Institut SSI (project manager), Aarhus University and SEGES have joined forces to develop an effective vaccine against weaning diarrhoea. The diarrhoea, which is caused by E. coli bacteria, typically occurs shortly after the piglets have been separated from the sow. At this time, the piglets are no longer protected by antibodies from the sow and have not yet developed their own immune system. It is essential that this new vaccine, developed by Statens Serum Institut, is given to piglets at a very early stage in order to contribute to the activation of the piglets' own immune system prior to weaning.

Housing cull sows together may affect welfare

Temporary housing with unfamiliar sows is a common practice for cull sows in the days prior to transport to the slaughterhouse. A new study from Department of Animal Science, Aarhus University, demonstrates that this practice may have welfare consequences for the sows.

Before bringing the sows together, the clinical examinations showed that the cull sows had few superficial skin lesions, few wounds and a gait score close to normal. Twentyfour hours after bringing the sows together, the clinical conditions of the sows had deteriorated, e.g. demonstrated in an increased gait score, increased occurrences of superficial skin lesions and a tendency for more wounds per sow.

Culling of mink at AU Foulum

Due to the COVID-19 situation, all mink at AU Foulum's experimental farm were destroyed in 2020.

The political decision to destroy all mink in Denmark had major consequences for fur animal research at Aarhus University's research centre in Foulum.

Just like the animals in private farms, the mink at AU Foulum's mink farm were culled. The Department of Animal Science was in charge of the farm. AU Foulum's mink farm housed 6,350 mink.

In the Department of Animal Science, five researchers worked with fur animal research, and students and technical staff further participated in the experimental efforts. At the mink farm, three staff members were in charge of tending to the mink as well as assisting in experiments.

Long tradition for fur animal research

In the beginning of 1989, new research facilities for mink research were inaugurated at AU Foulum.

Fur animal research at AU Foulum has been an internationally leading hub for fur animal research, and Aarhus University has been one of few universities with full-scale research within this particular area.

In recent years, research efforts have focused on animal welfare, including the importance of breeding, housing and caring for animal welfare. Researchers have developed tools for fur animal breeders to apply in relation to production control focusing on health, welfare and production. Since 2017, animal welfare on all mink farms in Europe have been assessed according to the welfare assessment protocol WelFur-Mink, which was developed by researchers from AU.

Fear testing in foals may contribute to higher safety in equestrian sports

A new study at Aarhus University shows that it is possible to identify fearful horses at a very early age by means of an objective fear test. This provides a better opportunity of ensuring that especially sensitive horses are placed in capable hands from the beginning. This is very good news both for the rider's safety and the horse's welfare.

New results from the Department of Animal Science at Aarhus University have shown that it is possible to identify the most fearful horses, already as foals, by means of an objective fear test. This is important knowledge in relation to the future use of the horse in question. Associate Professor Janne Winther Christensen, Department of Animal Science at Aarhus University, is behind the study. She has accomplished research efforts in relation to horses since 2001. Her research has focused particularly on horses' stress sensitivity, fearfulness and learning ability, and she knows the importance of understanding horse behaviour and fear reactions.

- Some riding accidents are purely accidental, for instance when the horse stumbles and falls. This kind of accident are difficult to foresee. However, we can actually do something about the number of accidents that happen when the horse gets scared, says Janne W. Christensen.

Can avoid many accidents

According to numbers from Ulykkes Analyse Gruppen (Accident Analysis Group) at Odense University Hospital, riding is the most dangerous leisure activity in Denmark when considering the severity of personal injuries.

- If we can identify the most fearful horses early in life, we can place them in capable hands that can give them the correct training from the beginning. This way, it will likely be possible to avoid many of the serious accidents, says Janne W. Christensen.

Do rider weight and balance affect horse welfare?

It seems like the rider's weight does not affect the horse's welfare as much as previously expected. Neither the horse's stress hormone level, heart rate nor behaviour was affected during moderate work when the rider gained 25 % in weight. A project conducted by Aarhus University in cooperation with a veterinary consultant from the Danish Equestrian Federation demonstrated that horses showed signs of discomfort and stress if the rider's balance was poor.

Together with veterinarian Mette Uldahl, Associate Professor Janne W. Christensen, Department of Animal Science, Aarhus University, has conducted a study aiming at achieving increased knowledge as to how ordinary riding horses in Denmark are affected by an acute increase of the rider's weight. The experiment is the largest of its kind to date.

Generally, the results from the experiment show that an increase in the rider's weight of up to 25 % of the normal weight does not affect the horse's stress level (stress hormones and heart rate). Rider weight did not have any impact on the horse's behavioural reactions, either.

Read the entire article "Do rider weight and balance affect horse welfare?" at dca.au.dk

Hatching broilers on-farm rather than in hatcheries increases animal welfare

A new study from the Department of Animal Science at Aarhus University shows that hatching broilers on-farm rather than in hatcheries has a number of benefits: The chicks rest more, eat more feed, have a higher weight and a reduced mortality.

Hatching on-farm is an alternative to the traditional hatching in a hatchery. Here, the incubated eggs are placed in the barn three days before hatching so that the actual phase of hatching takes place in the barn. Hence, some procedures at the hatchery and transport of day-old chicks are avoided. Furthermore, the chicks have access to feed and water immediately after hatching. But does it make any difference to the chicks' welfare whether they hatch on-farm or in the hatchery?

Increased animal welfare

Researchers at Aarhus University have examined this question more closely. In the study, the researchers found positive effects in relation to a number of welfare indicators for the chicks hatched on-farm compared to those hatched in the hatchery. In the chicks' early age, the researchers found increased resting behaviour, feeding behaviour and body weight as well as reduced fear of humans.

- Furthermore, applicable to the entire growth period, we found a lower mortality and a tendency to a lower level of general fear. Finally, the study indicated that hatchery chicks had been exposed to dehydration during the procedures in the hatchery and the following transport as they partly drank more frequently afterwards and partly lost weight during transport, says Project Manager and Senior Researcher Anja Brinch Riber, Department of Animal Science, Aarhus University.

However, she emphasizes that in order to achieve improved animal welfare by hatching on-farm, good management of the barn climate during the hatching phase is essential.

Read more on dca.au.dk/en

New research project on ceiling height in trucks transporting pigs

Danish as well as European legislation requires that piglet welfare be taken into account – also during transport. One of the elements is the ceiling height in the trucks during transport. However, no scientific documentation exists as to the importance of ceiling height in relation to piglets, nor what the optimum height should be to consider animal welfare. A new research project will aim at procuring new knowledge about this. At a request from the Danish Veterinary and Food Administration, the Department of Animal Science, Aarhus University, will investigate which inner floor-to-ceiling height in trucks transporting piglets up to 26 kg is necessary to meet the transport regulation.

Reflections on domestic animals

We love some domestic animals more than life itself, and others may be our favorite food. In a new publication in the "Reflections" series, Anthropologist Inger Anneberg, Department of Animal Science at Aarhus University, focuses on our relations to domestic animals. In order to understand the disagreements in the animal welfare debates, this book is a must-read.

Food quality and consumer behaviour

The Ministry of Food, Agriculture and Fisheries of Denmark (FVM) 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 is one of six performance agreements under the framework agreement between the Ministry of Food, Agriculture and Fisheries of Denmark, the Danish Ministry of Environment and Aarhus University.

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.

News in brief

Researcher receives Young Scientist Research Award

In October, Mario M. Martinez from the Department of Food Science received the prestigious Young Scientist Research Award from the Cereals & Grains Association for his outstanding work on food carbohydrate polymers that can be used for creating healthy and sustainable solutions.

The research of Mario M. Martinez focuses on the structure, hydrodynamics and interactions of carbohydrate polymers and their structural modification through process-intensifying technologies.

- In the future, we will urgently need affordable and safe foods that account for both the increase in diet-related chronic diseases as well as the environmental impact. My research is essentially about understanding plant foods and transforming food and agricultural polymeric streams into healthy and sustainable raw materials for the food and packaging industries, Mario M. Martinez says.

Inaugural lecture by Hildegarde Heymann

In august 2019, Professor Hildegarde Heymann, University of California, Davis, was appointed as Honorary Professor in "Advanced Sensory Methodologies for Innovation in Food Quality" at the Department of Food Science. In February 2020, she gave her inaugural lecture.

Professor Hildegarde Heymann is the world-leading expert in the field of key sensory science methodologies in relation to food quality. In particular, her research focuses on the use and optimization of the measurement methods that exist in sensory science and the way that we perceive and experience foods. This includes everything from food design to basic improvement of measurement methods as well as data analysis and research into the context in which human perception takes place. All in relation to food quality for a healthier diet.

Conference on novel eating experiences

In December, the digital conference ReThink Eating 2020 brought together food-loving researchers and practitioners from all over the world with the same purpose: to generate new research ideas, collaborations and ultimately novel food experiences.

Qian Janice Wang, Tenure-track Assistant Professor at the Department of Food Science, Aarhus University, hosted the conference as part of her Carlsberg Foundation Young Researcher Fellowship project "Virtual and augmented flavours", examining how technology can create novel eating experiences:

- ReThink Eating 2020 managed to unite more than 170 people from over 30 countries sharing a strong interest in food, but having a multitude of backgrounds - from computer science to anthropology - and this resulted in very interesting discussions highlighting many aspects of our eating experiences. By learning from each other and taking a more holistic view on what it means to eat, we can create innovative novel eating experiences, she says.

The conference began with a keynote talk by famed experimental psychologist Charles Spence on bringing magical experiences into the dining room. The conference furthermore included workshops and interviews with experts from different disciplines on the digitalization of eating experiences.

Corona-related research

Eating habits during the corona crisis

In many ways, the corona crisis has changed the way we live, but how has it changed the way we eat and shop? Researchers from ten European countries have taken a closer look at this within the framework of an EIT Food project.

Professor Klaus Grunert, Head of the MAPP Centre, has had the overall responsibility for the study:

- Lockdown, isolation and working from home are some of the factors that have influenced Europeans' consumer behavior during the corona crisis. Some have had more free time, but perhaps also less money on their hands. Such major changes in our lives will inevitably affect the way we shop and eat. In this study, we aimed to shed some light on this.

The results of the study show that European consumers, despite certain regional differences, actually have much in common during the corona crisis:

- We can see certain trends in the European consumers' shopping habits. Across the ten countries, consumers are starting to shop more online. They have also started bulk buying, and they generally consume more food in all food categories, especially fruit, vegetables and flour, says Klaus Grunert:

- The European consumers also answer that they have started planning their purchases more carefully, both to save money and because they are generally more mindful when it comes to shopping. For example, they have a more significant interest in buying local products than before the corona crisis, and they want to avoid additives to an increasing extent. They are also more interested in food packaging, and here we can see, among other things, that they feel trapped in a dilemma between hygiene and environmental considerations.

How does COVID-19 affect our appetite?

Researchers from the Department of Food Science, Aarhus University, are investigating how people affected by COVID-19 experience changes in appetite, sense of taste and smell as well as in the pleasure related to food intake. This is part of a new EIT Food-funded project, which also involves companies from Belgium and Spain.

Assistant Professor Barbara Vad Andersen is part of the science team Food Quality, Perception & Society at the Department of Food Science, which is responsible for the scientific part of the project:

- Enjoying food is an important part of people's appetite, and the expected pleasure greatly affects our motivation to eat. There is currently very limited knowledge about the effect of COVID-19 on appetite. By expanding this knowledge, we can gain an understanding of the opportunities and barriers to affect appetite among people affected by COVID-19, she explains.

The COVID-19 project is linked to a series of studies on appetite, which are conducted in the science team and serve to understand human eating behaviour - and use this knowledge to influence people's eating habits in a healthier direction without compromising well-being.

Read more on dca.au.dk/en

Sustainable packaging in focus

Aarhus University carries out research in packaging solutions that can reduce food waste and contribute to a sustainable development in the food industry.

New research network for sustainable food packaging

A new international research network with representatives from 36 countries, CIRCUL-A-BILITY, has been created within the framework of the European Cooperation in Science and Technology (COST). The network's purpose is to support knowledge sharing on sustainable food packaging solutions.

Professor Milena Corredig from the Department of Food Science is the main proposer of the network. She explains why it is so important to promote research within this field:

- Food packaging is designed to protect the food through its supply chain, communicate to customers, and to ensure food quality, safety and optimal shelf life. However, we need progress to secure its circularity, minimize food waste and improve sustainability, engage citizens and work with policy makers.

How do consumers respond to sustainable packaging?

In collaboration with the company KLS Pureprint and Food Innovation House – and with the support of Danish Food Innovation – Professor Polymeros Chrysochou, the MAPP Centre, tries to answer this question:

- Implementing sustainable packaging solutions for food will often lead to price increases and changes in product elements that can affect the market position of the brand. As a result, several food companies are reluctant to implement sustainable packaging solutions due to the risk of losing customers, he says.

- The project investigates two things: The consumer reactions, including perception, preferences and willingness to pay, when visual changes to the packaging are made (for instance, by changing the packaging from plastic to paper); and the consumer reactions when changes in the packaging are not visual and therefore must be communicated, e.g. through labelling.

New appointments strengthen research in sustainable packaging

This spring, the Department of Food Science has appointed two new and highly specialized tenure tracks, Mario M. Martinez and Ilke Uysal Unalan, who - with several years of international experience from leading research institutions - will contribute to strengthen the research in innovative, sustainable packaging.

- We have a strategic focus on research in innovative packaging solutions that can reduce food waste and contribute to a sustainable development in the food industry. With the appointments we will have an even stronger research environment in this area, says Lars Wiking, who is head of the Science Team Food Chemistry and Technology, which now includes the two new researchers.

Mapping food waste in the service sector

Some food waste is unavoidable - and some is avoidable because it might have ended up on a plate. In the Danish service sector, the proportion of avoidable food waste is bigger than unavoidable food waste.

Throughout 2018, the Danish service sector, including hotels, restaurants, institutions and canteens/catering, has created over 100,000 tons of food waste. Some food waste is unavoidable, such as banana peel, fish bones and tea bags, whereas some food waste may be characterized as avoidable. This applies, for example, to bread, whole fruits and leftovers from plates. The proportion of avoidable food waste is larger than that of unavoidable food waste – but there is a difference between hotels and institutions.

This is the result of a nationwide study prepared by the Department of Food Science at Aarhus University at the request of the Ministry of Environment and Food of Denmark. The study is based on data collected from about 600 companies in the Danish food-related service sector throughout 2018. Combined with figures from Statistics Denmark on the number of companies in each category, researchers have scaled up the amount of food waste in the sector to national level on an annual basis.

Avoidable food waste in different industries

Based on the study, the total amount of food waste in the categories studied was estimated at approx. 103,000 tons in 2018. This is distributed between hotels (10,500 tons), restaurants (64,500 tons), institutions (14,700 tons) and canteens/catering (13,300 tons).

- It can be concluded that restaurants constitute the category with the highest amount of food waste per year, while hotels have the lowest amount per year. In this context, it is important to point out that our study does not take into account the number of people that each category provides with meals. We have investigated absolute quantities, says Ulla Kidmose, Associate Professor at the Department of Food Science and one of the researchers behind the report.

Although hotels generate the lowest amount of unavoidable food waste in the service sector, they account for the highest proportion of avoidable food waste in the service sector, if restaurants are left out of account:

- We have made an analysis of the relationship between unavoidable food waste and avoidable food waste. The analysis included a total of approx. 420 kg of mixed food waste, which came from hotels, institutions and canteens/catering. By adding the figures from the analysis, we found that 62 % could be characterized as avoidable food waste, while 36 % of the 420 kg could be characterized as unavoidable food waste. The remaining 2 % was characterized as plastic or paper. This ratio of avoidable/unavoidable food waste - combined with the calculated national level of food waste - showed that the highest proportion of avoidable food waste is found in the hotel category, whereas the lowest proportion is found in the category of institutions covering hospitals, schools, children's institutions and nursing homes.

Healthier and more sustainable eating habits

Research in food and consumer behavior at Aarhus University creates knowledge that can help guide our eating habits in a healthier and more sustainable direction.

Sustainability is difficult in practice

We associate sustainability with food and we want to eat sustainably - but to a limited extent do we buy sustainable food.

Read more about this in the DCA report (Danish only): "Kvalitetsindeks 2019"

Can we get used to eating less sugar?

We eat far too much sugar, for example in the form of sweetened drinks, yogurt and cake. However, do we even like these foods if they no longer have the same high sugar content?

You can find the answer in the DCA report (Danish only): "Tilvænning til mindre sød smag og brug af sødemidler, samt præference for sød smag fra barndom"

Communities can motivate men to eat healthier

If men over the age of 55 are to eat healthier, the solution might be to spend time together around food, for instance by taking part in cooking and dining communities.

Read more in the DCA report (Danish only): "Hvordan motiveres og engageres mænd 55+ til sunde(re) spisevaner?"

Vocational school students want to eat healthier, but they lack the tools

Some of the Danish vocational school students want to eat healthier, but they lack knowledge and skills in relation to food - so-called "food literacy" - to reach the goal.

Read more in the DCA report (Danish only): "Målrettet kommunikation til unge på erhvervsuddannelser - Fokus på "Food Literacy" i en ny livssituation"

We underestimate our own consumption of candy and chips

We are well aware that our own consumption of candy and chips is too high - but still, each of us believe that our consumption is lower than that of other consumers.

Read more in the DCA report (Danish only): "Danskernes forbrug af slik og chips - en undersøgelse af portionsstørrelser"

Can sugar-reduced products be just as sweet?

It is essential that we reduce sugar consumption, but how can the industry create sugar-reduced food products without compromising on the sweet taste?

It is often argued that the consumption of sweet foods is one of the major contributors to the current obesity epidemic witnessed worldwide. Thus, it is of utmost importance to public health that we significantly reduce sugar consumption, but how can the food industry overcome the dilemma between reducing sugar levels and maintaining the sweet taste that is so appealing to consumers?

In cooperation with researchers from the Department of Experimental Psychology, University of Oxford, researchers from the Department of Food Science have looked into the matter as part of an extensive literature review. The answer is found in an understanding of our sensory perception involving not just the food itself, but also everything that surrounds our food. This calls for new ways of thinking in relation to product development and new approaches to food design in the industry.

All our senses matter

Professor Derek V. Byrne, from the Department of Food Science, Aarhus University, explains:

- An increasing share of the research conducted over the last decade or two demonstrates that all of our senses play a role in influencing flavor perception. This means that the perception of sweetness is not just a matter of the amount of sugar added to a food product. The experience of sweetness depends on a number of factors that have to do with the product itself as well as with the context in which the product is consumed.

The literature divides these factors into food-intrinsic factors, such as product colour, aroma, texture and viscosity, and food-extrinsic sensory factors, such as visual, auditory, olfactory (relating to the sense of smell) and tactile (relating to the sense of touch) properties of product packaging, tableware, background music, ambient lighting, temperature and aroma.

A sweet combination

The literature review has focused on how the different intrinsic and extrinsic factors may be combined in order to provide an enhanced perception of sweetness. This includes an understanding of the process of eating.

- Different senses are dominant in different parts of the eating process - and various brain mechanisms are involved. From the field of cognitive neuroscience, it is suggested that the major impact on our experiences and behaviours occur, when several sensory attributes are changed at once, and even more so when these changes complement one another, says Derek V. Byrne.

Industry implications

Changing multiple sensory stimuli to maximize the experience of sweetness is quite a challenge, as work efforts in relation to intrinsic and extrinsic factors are considered as belonging to different disciplines.

- R&D and the marketing department should work closely together in order to optimally balance product-intrinsic and extrinsic cues. Efficient collaboration relations are important and necessary; it will require significant efforts, but they are crucial in order to utilize the full potential of sweetness enhancement, says Derek V. Byrne.

Does our meat intake increase the risk of cardiovascular diseases?

Researchers from the Department of Food Science have come a step closer to understanding the connection between our meat intake and the possible risk of cardiovascular diseases.

The intake of red and processed meat has often been linked to an increased risk of cardiovascular diseases, but maybe it is not that simple?

Research results point in different directions, which may be explained by other factors in our lifestyle than our meat intake alone.

Researchers from the Department of Food Science and their colleagues from Ghent University in Belgium have come a step closer to understanding the connection between how we are affected by our meat intake and what else we put on our plate on a daily basis.

This has been accomplished by examining the effect of four dietary patterns on a compound called trimethylamine N-oxide (TMAO). TMAO is formed in the liver from trimethylamine (TMA), which is formed by intestinal bacteria from carnitine and choline – which is found especially in meat from four-legged animals.

Previous studies have indicated that TMAO can cause atherosclerosis, and therefore a low level of TMAO is thought to be desirable.

What else we eat matters

The researchers examined how the intake of either chicken or a combination of red and processed meat affects the TMAO level of pigs fed either a typical Western diet with a high fat content and a low vegetable content - or fed a somewhat healthier diet with a high fiber content and a high content of vegetables.

The feeding study took place over four weeks and comprised 32 pigs. The researchers examined the TMAO level in the pigs' urine and studied the TMAO-related gene expression in the liver – i.e. the processes in the liver, where specific genes are activated to affect the TMAO level. In addition, the researchers also investigated whether correlations exist between the TMAO level in the urine and various gut bacteria.

The results show that our dietary patterns have a significant impact on the TMAO level.

Hanne Christine Bertram, Professor at the Department of Food Science and one of the researchers behind the study, elaborates:

- We observed a lower TMAO level in the urine of pigs fed red and processed meat together with an otherwise high-fiber diet consisting of a high vegetable content compared to the pigs that were fed red and processed meat together with a diet consisting of higher fat content and a low vegetable content. This shows us that there is a relation between the amount of TMAO formed when we eat red and processed meat, and what we otherwise eat. On the other hand, we found no effect of the different dietary patterns of the pigs fed chicken instead of red and processed meat.

What is the composition of breast milk?

The milk that mothers produce during the first three days after birth is significantly different from the milk produced four months later. As a mother, you targetedly produce nutrients for your child and the child's intestinal bacteria. Researchers from the Department of Food Science investigate this in more detail in the research project MaInHealth.

- Among other things, we investigate how breast milk varies over time, and how you as a mother are able to influence it. At the same time, we want to examine how the baby uses breast milk to grow. The infant does not directly use everything, there is also a certain part that the infant's intestinal bacteria utilizes, says Assistant Professor Ulrik Sundekilde, Department of Food Science at Aarhus University, who is principal investigator in the research project.

The main purpose of the project is to increase our knowledge on the components and composition of breast milk as well as the influence of the mother's lifestyle and state of health on the milk.

Healthy intestines to strengthen bone structure

Within the framework of a new research project, researchers will develop a new and unique food concept that will add a highly effective calcium source and stimulate the intestines to improve calcium absorption and strengthen the bones.

With age, bone decalcification increases, and it is estimated that approx. 20 % of women aged 50+ in Europe suffer from osteoporosis. Taking the constant growth in the ageing population into account, this will constitute a major societal challenge as well as a financial burden. In Denmark alone, the costs covering treatments of injuries, rehabilitation and home care etc. amount to approx. 20 billion DKK per year.

Within the framework of the RENEW research project, funded by Innovation Fund Denmark, researchers from Aarhus University, University of Copenhagen, Zealand University Hospital and USDA Western Human Nutrition Center in USA will – together with the company Arla Foods Ingredients – develop a new type of ingredient that combines calcium from whey permeate, which is rich in lactose, and prebiotic dietary fibres. Prebiotics are known for their beneficial interaction with gut bacteria. This will help establish an intestinal environment that will improve calcium absorption.

If researchers succeed in developing this new ingredient solution, then the product may contribute to reducing the huge number of bone fractures, which entails countless hospitalizations and sick days each year, not to mention reduced quality of life for many people. At the same time, it will ensure an optimized resource utilization in the dairy industry as waste products from cheese production will be utilized for this product.

Will the food ingredients of the future be plant-based?

New research demonstrates that it is possible to use chickpea water in foods where we would typically use egg white.

What do aquafaba water and egg white have in common?
Researchers from the Department of Food Science and the company NEXUS A/S have come closer to an understanding of this, which could have a major impact on the composition of food ingredients in the future.

A few years ago, it was discovered that the residual products from the cooking and storage of canned chickpeas can be whipped, and that the whipped result is very similar to whipped egg white. The by-product was named "aquafaba" from the Latin word for water (aqua) and the Latin word for beans (faba), and it comprises both water from canned chickpeas and the water used to cook the chickpeas.

Chickpea water holds great potential, simply because there is so much of it and because its protein composition has special food-functional properties. In addition, production is sustainable, the price is low, and only to a minor degree are chickpeas associated with allergens.

Associate Professor Marianne Hammershøj, Department of Food Science, elaborates:

- Chickpea water is similar egg white in several ways. Both have the ability to bind fat, the ability to hold water, solubility, ability to form gels, and the ability to foam and to emulsify, i.e., to stabilize liquids that are by nature not mixable. Therefore, it is obviously a good idea to examine proteins from legumes and to compare them with known animal proteins. This knowledge may be used in a wide range of foods - from salad dressings to baked goods!

- All in all, our studies show that aquafaba has a number of functional properties, both as an emulsifier and as a foaming agent under pH values and salt conditions relevant to food. As a plant-based alternative to animal protein, aquafaba seems to be an interesting protein ingredient in foods where air and oil binding properties are important, concludes Marianne Hammershøj.

Milk and meat to be grown in petri dishes

Can you produce milk without a cow – or meat without animals? Researchers from Aarhus University are investigating this in a new research project. The meat and milk production of the future must accommodate both rising global demand and consider climate and environment. In the CleanPro project, researchers from Aarhus University investigate whether producing milk and meat in laboratories may be part of the solution. Researchers from the Department of Food Science, the Department of Animal Science, the Department of Agroecology, the Department of Clinical Medicine and Aarhus University School of Engineering participate in the project.

New Nordic network for cultivated meat

The Department of Food Science has initiated a new network that will accelerate the development of alternative meat based on Nordic ingredients.

A new network for cultured meat has been established at an initiative from the Department of Food Science. The network will accelerate the development of cultured meat based on local, Nordic ingredients as a sustainable alternative on the market.

Associate Professor Jette Feveile Young, Department of Food Science, initiated the two-year network under the auspices of the Nordic Joint Committee for Agricultural and Food Research (NKJ). The network mainly consists of researchers working with different aspects of the subject – ranging from food science to the life cycle analyzes that examine the environmental impact of a given product "from farm to fork".

- At the turn of the year 2019-2020, we really initiated our research in alternative meat at Aarhus University within the framework of the CleanPro project. We have now gained our first experiences, and we want to exchange knowledge with other partners to see if we can build something together, she says.

Companies need to get involved

A few companies also participate in the network, and during the network meeting and the subsequent workshop, it became clear that there is a significant need to involve the agrifood industry and other relevant companies.

- Researchers around the world are currently carrying out research in the development of cultured meat. It is important and essential for the Nordic countries to get started as well; there is no doubt these products will come on the market and cross our borders. We need to find the proper Nordic angle that will allow us to positively influence the production, as seen from our perspective. Internationally, researchers work with soy protein but why not replace this with pea protein or potato starch? These are sustainable alternatives and we can deliver, says Jette Feveile Young.

There are many potential ingredients in cultured meat, providing just as many opportunities for different companies to play a role in the production:

- To produce cultured meat, we first isolate muscle stem cells from the animal. These stem cells need a medium, a kind of soup, to multiply. The medium must supply nutrients to, and remove waste products from, the cells. The cells are not able to multiply if they do not have a place to adhere to, so we also need a scaffold. Many different companies can supply the medium and scaffold. Producers of both pea protein, potato starch and green algae may play an important role here, and the same applies to the meat industry, which can supply both ingredients for the medium and the scaffold from slaughterhouse waste, not to mention the pharmaceutical industry in relation to approved food growth factors, Jette Feveile Young points out.

Information on DCA Research

DCA reports

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DCA issues a newsletter with information on current agricultural and food research, including new research results, policy support, education, events, and other activities. You can subscribe for the free newsletter at dca.au.dk

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