



AARHUS  
UNIVERSITY

DCA - DANISH CENTRE FOR FOOD AND AGRICULTURE

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## PERSPECTIVE

ANNUAL REPORT 2015

DCA – DANISH CENTRE FOR FOOD AND AGRICULTURE

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

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Scientists at Aarhus University are cooperating with the Danish seed company DLF to develop the first grass varieties that are robust against root-feeding pests. Read more in the article on p. 14.

Photo: Jesper Rais.

Printed by Digisource

ISBN: 978-87-93398-33-7

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## EDITORIAL

# RESEARCH-BASED POLICY SUPPORT CREATES VALUES AND DEVELOPMENT OPPORTUNITIES

According to the contract between Aarhus University and the Ministry of Environment and Food of Denmark on research-based policy support, DCA must provide research-based policy support to the authorities within 13 thematic areas. These areas often have specific challenges; this may be in relation to the industry's productivity and income; and it may be in relation to balance intensive agricultural production and societal considerations to nature and environment, animal welfare or food quality.

DCA carries out about 150 policy support commissions annually, typically targeted towards very specific challenges within the 13 thematic areas. However, the superior aim of the DCA policy support and the underlying research efforts is to create solutions that provide long-term value for industry and society.

The researchers providing policy support build up extensive knowledge about agrifood issues. Collaboration with problem-oriented researchers facilitates development of technologies and processes by commercial businesses to solve the challenges.

The extent of collaboration with research foundations, private companies and organizations is considerable. The basic grant – and thus also research efforts – increased from 277m DKK to a remarkable 724m DKK in 2015.

Targeted land use regulation is an example of an area with significant challenges as well as major perspectives regarding technology development. The national parliament of Denmark has adopted an ambitious agricultural package, the purpose of which is to increase agricultural production and reduce environmental impact.

In order for this to succeed significant research and development efforts are needed. The agreement between the Ministry of Environment and Food of Denmark and DCA focuses on this important task. If the ambitions are satisfied, then Danish agriculture, Danish companies and Danish research will set completely new international standards within the agricultural and environmental areas.



Photo: Jesper Raas

Challenges in the tension areas between agriculture, food and society encourage research and innovation that can meet societal and industrial interests. DCA's problem-oriented research thus acts as a catalyst for innovation and new ways of thinking.

In this report you will find examples of how we solve the problems.

We hope you enjoy reading the report.

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

# POLICY SUPPORT IN THE AREA OF FOOD AND AGRICULTURE

DCA – Danish Centre for Food and Agriculture is the framework for the collaboration between the research environments within the agricultural and food areas at Aarhus University. DCA is supported by a central unit which coordinates the university's agreement with the Ministry of Environment and Food of Denmark on research-based policy support.

Making decisions on new legislation and social initiatives is often complicated. Significant amounts of knowledge form part of the basis for decision-making. New technologies emerge continuously and it may be difficult to get a general overview. Research-based policy support provides the authorities with the best and most recent knowledge available. The idea is that scientists working within specific areas gather knowledge and put it into perspective in relation to a given question.

Aarhus University is a world leader within the areas of food and agriculture. The Ministry of Environment and Food of Denmark has therefore entered into an agreement with the university on the provision of research-based policy support within these areas. To ensure cross-disciplinary cooperation between the research environments within food and agriculture, Aarhus University has established DCA – Danish Centre for Food and Agriculture. The centre provides the framework for cooperation and it is supported by a central unit that coordinates e.g. policy support.

According to the agreement with the ministry, DCA is obliged to carry out research in and sustain scientific support in 13 thematic research areas. These areas constitute the research basis for collaboration with companies and organizations as well as for transnational and international research cooperation.

On an annual basis, scientists from DCA-related departments carry out about 150 policy support tasks ranging from short memorandums to extensive evaluations, reports and knowledge syntheses. The agreement with the ministry respects the arm's length principle and DCA's policy support is solely based on scientific contributions provided by scientists. The authorities are responsible for subsequent political and administrative considerations.

DCA also has a duty to take initiatives; a duty that puts the university under the obligation to evaluate which areas may become topical for the policy support. The evaluation may initiate research tasks in areas within which there is a need for further or new knowledge.

In this connection DCA is supported by an advisory panel the main task of which is to provide advice on the superior vision and strategy, including the relevance of research in relation to society's future needs for advisory services. Members of the advisory panel include representatives from the Danish food and agricultural sector.



Photo: Søren Kjeldgaard

According to the agreement with the ministry, DCA is under an obligation to carry out research in and sustain scientific support in 13 thematic research areas.

### Collaboration makes us stronger

The total annual extent of agricultural and food research at Aarhus University is approximately 724m DKK. Different sources fund the research and a significant amount comes from DCA's contract with the Ministry of Environment and Food of Denmark. In 2015 DCA received 276.9m DKK from the ministry to fund research-based policy support.

The grant from the Ministry of Environment and Food of Denmark allows DCA to attract and carry out research projects in collaboration with organizations and companies. This collaboration, together with grants from national funds and research programmes, was the main reason why the total research and development funding in food and agriculture at Aarhus University increased to more than 700m DKK in 2015.

DCA also participates in a significant number of international research collaborations at the Scandinavian and EU levels and in major global research consortia. International funding ensures increased research activities and allows DCA to provide research-based policy support at the highest level possible.



### DCA – Danish Centre for Food and Agriculture

DCA – Danish Centre for Food and Agriculture comprises the departments at Aarhus University that carry out research activities directly related to development within the agricultural and food areas.

These departments include the Department of Agroecology, Department of Animal Science, Department of Food Science and parts of the Department of Molecular Biology and Genetics and Department of Engineering and the MAPP Centre. DCA activities are supported by a small central unit.



### Contact DCA

The DCA central unit is the specialist approach at Aarhus University for authorities, companies and organizations who are seeking advice and collaboration within the fields of food and agriculture.

You can find further information on DCA activities as well as contact information at [dca.au.dk/en](http://dca.au.dk/en).

### Composition of Perspective

In the following pages you find examples of research, policy support and industrial collaboration within the 13 thematic areas:

#### A development and growth-oriented food industry

- Sustainable livestock production
- Sustainable crop production
- Sustainable technology development and technology assessment
- Bioeconomy, bioenergy and rural development
- Resource efficiency

#### The responsible management of natural resources

- Food production and the cultivated soil
- Food production and bioresources
- Food production, landscape, nature and biodiversity
- Food production, adjuvants and the environment
- Food production, climate and greenhouse gases

#### Food safety, consumer choice and healthy dietary habits

- Food quality
- Consumer behavior and food preferences
- Importance for health of dietary and eating habits



## THEMATIC AREA: SUSTAINABLE LIVESTOCK PRODUCTION

# POSITIVE COOPERATION TO THE BENEFIT OF ANIMAL WELFARE

The Department of Animal Science at Aarhus University and the Department of Large Animal Sciences at University of Copenhagen collaborate closely with the authorities within the framework of the Danish Centre for Animal Welfare (DCAW).

In 2009 a political decision allocated specific funding for animal welfare in the National Budget fulfilling a wish to improve animal welfare in Denmark. In 2010 this funding helped establish the Danish Centre for Animal Welfare (DCAW).

The centre is a part of the Danish Veterinary and Food Administration and its primary aim is to contribute to the improvement of animal welfare in Denmark. When the centre was established it was decided that its future efforts should be carried out in close collaboration with the universities, including the Department of Animal Science at Aarhus University, as one of the major centre purposes is to carry out research in and communicate knowledge on animal welfare.

Professor Jan Tind Sørensen from the Department of Animal Science is a member of the DCAW project group (cf. fact box) and he points out that the universities' joint efforts within animal welfare are rewarding in many ways.

- When we cooperate with the industry research should be very application-oriented. DCAW research is application-oriented but does not necessarily have to result in profits for the industry. On the contrary, it may be about welfare just for the sake of welfare itself, says Jan Tind Sørensen and as examples he mentions research in the use of sick pens as well as research in relation to whether pigs with hernias are fit for transportation.

### More future possibilities

As mentioned above it is a DCAW purpose to communicate knowledge on animal welfare. An annual publication on the status of animal welfare in Denmark serves this purpose as well as an annual meeting attracting up to 250 participants from both the industry, NGO's, authorities and universities. Sharing the knowledge achieved is also in the interest of the university, Jan Tind Sørensen explains:

- As I see it, the possibilities for relevant research in animal welfare are far from exhausted. In DCAW we started out with cattle, poultry and pigs and along the way mink and horses have been included.

In addition, our research has been extended to include communication on animal welfare and also to comprise animal welfare for family animals, says Jan Tind Sørensen. He further explains that together with his colleagues he has collaborated closely with the University of Copen-

hagen (KU) over the years and benefitted from the interdisciplinary projects, for instance via Cepros – Centre for Production and Health Control.

- When the centre closed in 2005 it left a kind of vacuum. The establishment of DCAW meant a revival of the fruitful cooperation with KU, now focusing on welfare and welfare assessments. This, as well as the cooperation with the Danish Veterinary and Food Administration employees, many of whom are scientists, is different and refreshing.

### Research to the benefit of horses

Associate Professor Janne Winther Christensen from the Department of Animal Science is in charge of a DCAW project. Among other things Janne Winther Christensen carries out research in horse welfare, and DCAW funded a study examining the value of shelters for Icelandic horses during the winter.

### Facts on the Danish Centre for Animal Welfare

Danish Centre for Animal Welfare (DCAW). DCAW is located at the Danish Veterinary and Food Administration. The centre received National Budget funding in 2009 – and as a result of what is known as the Veterinary Settlement 2013-2016 it continues for a new four-year period. The centre steering group consists of five members:

- Per Henriksen, Chief Veterinary Officer, Danish Veterinary and Food Administration (DVFA)
- Charlotte Vilstrup, Head of Division, DVFA
- Paolo Drostby, Head of Division, Ministry of Environment and Food of Denmark
- Hans Henrik Dietz, Head of the Department of Large Animal Sciences, University of Copenhagen
- Klaus Lønne Ingvartsen, Head of the Department of Animal Science, Aarhus University

The DCAW secretariat handles day-to-day administrative tasks and is located at the DVFA. The DCAW Project Group prepares project proposals for the steering group to decide on. The project group consists of DCAW secretariat employees, heads of research departments from Aarhus University and the University of Copenhagen as well as an administrative officer from the Ministry of Environment and Food of Denmark.

Through the years she has received funding from the Danish Council for Independent Research in relation to projects focusing on fear reactions in horses, the superior aim of which was to reduce the risk of accidents.

- DCAW funding emphasizes the welfare aspect of research and, to a higher degree, considers the animals. It can be difficult to apply for this kind of funding via the industry, as industry funding may tend to place less emphasis on e.g. challenges for horse welfare in relation to training, explains Janne Winther Christensen.

She currently received DCAW funding for a book communicating her knowledge on how horses learn and how to train horses without straining them.

#### **Benefits for all parties**

The head of the Department of Animal Science Klaus Lønne Ingvarsen shares the view that collaboration with DCAW is beneficial for all parties.

- Improved knowledge and background for regulations and future legislation will also benefit the industry. Research in animal welfare, initiated by DCAW, has a social value even though it does not appear so from the budget. Even marginal efforts have a value for animal welfare, says Klaus Lønne Ingvarsen and continues:

- Our collaboration is very constructive in the way that we look at and discuss different problems in relation to animal welfare together – and actually knowledge from the centre formed the basis of other major tasks, e.g. research in whether animals are fit for transport, an area in which we have continued our cooperation with the University of Copenhagen.

#### **Do you want to know more about the Danish Centre for Animal Welfare?**

Read more about the Danish Centre for Animal Welfare at the website of the Danish Veterinary and Food Administration. Here you will find annual reports on animal welfare in Denmark as well as a survey of research projects funded by DCAW since the centre was established in 2010. Research projects funded by DCAW almost always result in scientific and popular science publications.



Private photo

The Danish Centre for Animal Welfare is a joint venture between authorities and universities and its superior aim is to strengthen the efforts within animal welfare.



## THEMATIC AREA: SUSTAINABLE LIVESTOCK PRODUCTION

# BREEDING FOR ORGANIC DAIRY PRODUCTION

Scientists have asked farmers which characteristics they consider to be important in an organic dairy cow. This knowledge will be part of future efforts to develop breeding goals better suited for organic milk production.

We are used to hearing about the differences between conventional and organic dairy productions. Cows on organic farms receive special feed, must be kept on grass for most of the year and generally have different living conditions than cows on conventional farms. But there is no genetic difference between the animals in the two types of production. Organic farmers choose breeding material from the same group of bulls as their conventional counterparts.

In the SOBcows project (funded by the Green Development and Demonstration Programme) scientists from Aarhus University will be examining whether it is possible to develop special breeds adapted to organic milk production and to develop new dairy products from cows with specific genetic traits.

- There are strong indications that specifically organic breeding material would be optimal for the organic dairy farmers, since cows in this production category ought to have different traits from cows in the conventional production. With genomic selection we are now able to develop lines with these special qualities, says project manager and Senior Consultant at the Department of Molecular Biology and Genetics, Morten Kargo.

He explains that cows on an organic farm would need to be more robust since organic farms wish to rely less on antibiotics.

- It is also conceivable that the strength of the cow's limbs is important because the cows spend more time outdoors. There is also evidence that fertility is less important than in conventional production, says Morten Kargo.

Since the ultimate beneficiaries of the new breeding lines are the organic farmers, the project intends to involve the farmers to a great extent. Thus, for the first time ever, Danish cattle farmers were given the opportunity to contribute to the discussion of how to weight certain characteristics in future breeding goals. The scientists sent questionnaires to the cattle farmers and received 600 answers.

The results are currently being processed and will be included in the future efforts to develop a breeding goal in line with the end users' wishes and in a way that ensures maximum financial breeding progress.

Researchers from Aarhus University will develop dairy cattle breeds that are specially suited to organic production.

Photo: Henning Thomsen

### Project facts

The SOBcows project is part of the Organic RDD 2 programme coordinated by ICROFS (International Centre for Research in Organic Food Systems). The project is funded by the Green Development and Demonstration Programme under the Ministry of Environment and Food of Denmark. Project partners include the Department of Molecular Biology and Genetics and Department of Food Science (both Aarhus University), SEGES (Dairy and Beef research centre and Organic Farming department), Foundation for Registration and Milk Recording (RYK), VikingGenetics, Nord-Gen and the organic dairy Naturmælk.

**THEMATIC AREA: SUSTAINABLE LIVESTOCK PRODUCTION**

# BROILERS GIVEN A BETTER LAST RIDE

Scientists and private enterprises join forces to improve the transportation of broilers to the slaughterhouse. This will boost animal welfare, the environment and food quality – and will save the poultry industry 40m DKK.

The conditions of the last ride in the life of a broiler to the slaughterhouse can vary greatly depending on the weather. The production company Linco Food Systems and Aarhus University will try to improve this and, with support from the Ministry of Environment and Food of Denmark, they have teamed up to develop a new climate-controlled transport system that will improve chicken welfare, reduce stress levels and make the transport more efficient.

The project partners expect the new system to provide added value and cost savings of about 0.40 DKK per broiler, corresponding to a saving of 40m DKK for the Danish poultry industry as a whole.

As things are now, chickens are transported in crates stacked in racks on a truck. The boxes usually have perforated sides and bottoms to ensure some ventilation. The load is ventilated purely by natural ventilation and thus depends on wind conditions and vehicle speed.

A new climate-controlled transport system will make it possible to control the temperatures and humidity levels which the chickens are exposed to during transport.

In addition to the climate-controlled transport system, a new design of the transport crates will mean that the space in the truck can be used optimally since the animal density is then independent of the outdoor temperature. The number of transports can thus be reduced by 36 percent, equivalent to 1.0 to 1.5 million km by truck and a reduction in emissions of 1000-1500 t CO<sub>2</sub> per year.

The project participants expect chicken mortality during transport to fall by 30 percent – from 0.3 percent to 0.2 percent. When chickens are exposed to stress it may affect the meat quality leading to pale, soft and exudative (PSE) meat. The project partners expect that the incidence of PSE meat will be halved from the current 30 percent to 15 percent.

The scientists from Aarhus University will examine and validate the physiological effects on the chickens and the meat quality.

**Project facts**

The project "Sustainable, efficient transport of broilers using a new climate controlled transport system" is led by the production company Linco Food Systems. Other project participants include Aarhus University, the food enterprise HKScan Denmark and SEGES Organic farming.

The three-year project has received a 7m DKK grant from the Green Development and Demonstration Programme under the Ministry of Environment and Food of Denmark.

Researchers from Aarhus University are collaborating with the poultry industry to develop a gentler and more environmentally friendly method of broiler transportation.  
Photo: Colourbox



THEMATIC AREA: SUSTAINABLE CROP PRODUCTION

# NEW CEREAL VARIETIES NEED LESS PESTICIDE

Scientists from Aarhus University, in collaboration with industry, are developing new wheat varieties that are both high-yielding and resistant to a number of fungal diseases.

Wheat is one of the world's most important crops feeding millions of people. However, infection by a number of fungal diseases can impair both its quality and yield. The cheapest and most effective method to prevent plant disease is the cultivation of resistant wheat varieties.

This is why scientists from Aarhus University and plant breeders from Nordic Seed A/S will develop new high-yielding varieties of wheat that are resistant to the most serious fungal diseases. The activities are part of a five-year project that has a total budget of 22m DKK, of which Innovation Fund Denmark has contributed 17m DKK.

The scientists already have some new genetic material with promising resistance to several diseases, which they intend to develop further.

Photo: Jesper Rois





Photo: Colourbox

Using varieties that are resistant to several fungal diseases helps reduce the need for pesticides in agriculture for the benefit of the environment and the farmer's economy. It will also facilitate agriculture to comply with the EU directive on implementing integrated pest management (IPM) practices, which contain a number of different approaches to protect the plants. Moreover, the new varieties may be used by organic growers who are not allowed to use fungicides to fight fungal diseases.

- Breeding of high-yielding and disease-resistant cereal crops is essential to reduce crop dependence on pesticides. The major challenge is for the variety to be resistant to all the major fungal diseases in wheat while ensuring that the resistances preserve their effectiveness over the years, says the leader of the new project Professor Mogens Støvring Hovmøller from the Department of Agroecology at Aarhus University.

#### **Wheat and fungi under the microscope**

The goal is to develop two to three new high-performance and multi-resistant wheat varieties; i.e. varieties that are resistant to several fungal diseases. An important part of the project is to develop new phenotyping techniques for the assessment of disease resistance in plants.

The scientists will be using new technologies and sources of resistance, including marker technology and mapping of genes in wheat. New insights into the infection biology and pathogen diversity are also central to the project, where different types of disease resistance will be examined both macroscopically and microscopically in order to develop new, improved methods for selection for resistance.

The scientists and breeders are not starting from scratch. They not only have promising breeding lines of wheat but also a large variety of fungal samples from around the world that they will use in the project.

- We already have some new genetic material with promising resistance to several diseases, which we intend to develop further. We also have access to a large number of fungal isolates from around the world, which we can use in our quarantine laboratories. They are essential for examining the persistence of the new resistance, explains Mogens Støvring Hovmøller.

#### **Project facts**

The project "Disease resistance in wheat" will be carried out in collaboration between Aarhus University, Nordic Seed A/S and a number of foreign partners. The five-year project has a total budget of 22m DKK, of which Innovation Fund Denmark has granted 17m DKK.

## THEMATIC AREA: SUSTAINABLE CROP PRODUCTION

# GRASS BECOMES MORE ROBUST AGAINST ROOT-FEEDING INSECTS

The development of the first commercial grass plants carrying natural root protection against pest infestation will lead to a reduction in the use of pesticides and strengthen Danish commercial seed production.

Golf courses, football turfs, lawns, and pastures the world over are sown with seeds from Denmark, but just a few centimetres below the surface the dangers are lurking: grubs of crane flies and chafers. These and similar pests love eating the roots of grasses and this kills the grass plants.

This is a problem that scientists from Aarhus University are now trying to do something about. In a new project along with the Danish seed company DLF they aim to develop the first ever turf and forage grass varieties that are robust against root-feeding pests such as the grubs of crane flies and chafers.

The method to be applied will be naturally occurring endophytic fungi. These fungi live in the wild in symbiosis with grass inside the plants where they produce a variety of substances without harming the host plant. Some of the substances produced by the endophytic fungi are directly beneficial to the plant and protect it from drought, insect attacks, and foragers such as sheep, cattle and horses.

The project partners are particularly interested in lolines. These are some of the compounds produced by endophytic fungi in the meadow fescue species. Lolines make grass plants more robust by deterring insects. Lolines are harmless to mammals and can also make the grasses more drought-resistant.

### Tests in Danish golf courses

The first step in the project is to collect a variety of meadow fescue plants with endophytes and screen the endophytes for their production of loline. Subsequently, they will be tested under different conditions in greenhouses and climate chambers.

### Project facts

The three-year project will be carried out in collaboration between Aarhus University, the seed company DLF and Dansk Golf Union (DGU). The Green Development and Demonstration Programme under The Danish AgriFish Agency has granted 3.7m DKK to the project.

In the next phases of the project, the grass will be tested for their resistance to root-feeding insects. Testing will take place in the laboratory as well as on selected golf courses which actually have problems with chafer grubs and other beetles. These tests will be carried out in collaboration with Dansk Golf Union (Danish Golf Association), which also participates in the project.

The project builds on the materials and skills developed in previous joint projects between DLF and Aarhus University.

- If we succeed in developing these more robust grass varieties it will significantly strengthen the competitiveness of Danish grass varieties and increase the earnings of Danish seed growers and DLF. It will also reduce pesticide consumption, says project leader Senior Scientist Birte Boelt from the Department of Agroecology at Aarhus University.

With the aid of certain fungi, grass can stave off pests that eat their roots.



Photo: Jesper Raas

**THEMATIC AREA: SUSTAINABLE CROP PRODUCTION**

# IMPROVED GRASSES

## ENSURE BETTER MILK AND MEAT

Genomic selection may be an important step towards grass improvement. Improved grasses will ensure better meat and milk and will also benefit the Danish grass seed export industry.

The genomic selection technology that revolutionized livestock breeding is now being applied to plant breeding. This has been demonstrated by results from the ForageSelect project, in which scientists from the Department of Molecular Biology and Genetics collaborated with the world's leading grass seed breeding company, DLF.

The aim of the project was to apply genomic selection to improve ryegrass, which is used as animal feed. Applying genomic selection was very successful and DLF now uses this method commercially – a fact that gives the company a strong competitive advantage in the global market.

- Traditional breeding programmes are time-consuming and expensive. It takes at least 10-11 years to establish whether a potential line is suitable and can be upgraded to a marketable product. In addition, progress in breeding for certain traits is relatively slow, explains Senior Researcher Luc Janss from the Department of Molecular Biology and Genetics.

Genomic selection will make breeding programmes faster and more effective. This technique will make it possible to predict whether a specific plant has the desired traits or if it should be culled at an early stage of the breeding process. This will reduce the duration of the process to 7-8 years. Furthermore, the project demonstrated that genomic selection can ensure greater progress in improving yields, seed production and resistance to the fungal disease crown rust.

Aarhus University and DLF are continuing their collaboration in a new research project with a specific aim towards using genomic selection to improve the nitrogen utilization of grasses. This will significantly reduce nitrogen leaching and provide more nutrient-rich grass to the benefit of the cows and the production of meat and milk. Funding for this new project includes a 13.5m DKK grant from the Green Development and Demonstration Programme.

**Facts on ForageSelect**

ForageSelect was a four-year project which ended in August 2015. The project was headed by the Danish clover and grass seed supplier DLF and was carried out in collaboration with Aarhus University.

The goal of ForageSelect was to implement genomic selection in breeding programmes for grasses in order to improve the breeding programmes.

ForageSelect had a total budget of 18.6m DKK which included a 10.2m DKK grant from the Green Development and Demonstration Programme.

Read more about ForageSelect at [www.forageselect.com](http://www.forageselect.com)

THEMATIC AREA: SUSTAINABLE TECHNOLOGICAL DEVELOPMENT AND TECHNOLOGY ASSESSMENT

# WHEN MACHINES BECOME INTELLIGENT

With the aid of big data we can develop machines with artificial intelligence that can make their own field treatment decisions. The challenge now is to collect data and make these available for innovation.

For most people it is fairly simple to learn to recognize ordinary weeds and distinguish them from culture plants. Once you know what goose-foot and knotweed look like you will immediately spot them. Robots are quite different. They can recognize weeds if they look exactly like the previous weed plant.

There are enormous gains to be had if data could be gathered in usable formats that could freely be used for developing machines with artificial intelligence.

However, weeds never do; different light and shade, wind, humidity, turgidity or plant cover can vary, making it difficult or impossible for the robot to recognize the weed.

This is a shame, because if it was possible robots could micro-spray in the fields. This could reduce herbicide use by more than 90 percent depending on the amount of weeds. While spraying the robot could map any nutrient deficiencies and crop diseases if the robot was able to recognize them.



Photo: Colourbox



Photo: Rasmus Nyholm Jørgensen

### Machines and artificial intelligence

Machines can learn to recognize complex structures such as plants that look different in different situations if they are provided with a kind of artificial intelligence, also known as machine learning.

Artificial intelligence means that the machine learns to recognize structures in something very complex, i.e. something that is very different from traditional, usual software. This is also known as deep learning. The more complex a structure is, the more data are required. A significantly large amount of data and complexity is known as big data.

Recognition of weeds is just one example of an area in which artificial intelligence will hugely influence today's farming.

- Big data gives us the possibility to develop machines that can notice problems in the field and provide the solutions themselves. We will have machines that remember how a certain field was cultivated in previous growth seasons and use this experience to optimize future treatment, explains Senior Researcher Rasmus Nyholm Jørgensen from the Department of Engineering at Aarhus University.

Big data can be used not only in the field, but in agriculture in general. For example, it can be used when a cow starts arching its back on its way to becoming lame. By means of big data a surveillance system can be developed that informs the farmer when he needs to contact a hoof trimmer or a veterinarian.

### Infinite opportunities

The possibilities of applying intelligent machines seem almost infinite: efficient and targeted plant protection, improved nutrient utilization and reduced leaching, improved surveillance of animal health and welfare.

The possibilities for collecting data are also very promising. These data can come from the combine harvester, tractor, fertilizer spreader, sprayer or sowing machine or can be gathered from satellites, air photos or drones.

There are significant perspectives with regard to the application of collected data in relation to certification and documentation of e.g. environmental regulation.

### Data from many sources

Big data come from thousands of machines performing the same procedures repeatedly. An example is the Tesla car's autopilot. This function allows the car to automatically steer down the highway, change lanes, and adjust speed in response to traffic, in addition to taking care of parallel parking.

In agriculture the problem is that data often do not get any further than the tractor. A lot of data are collected but not many joint platforms exist for data collection, just as machine producers use different data standards. Developments have been so rapid that standards have not been able to follow suit.

- This area entails numerous possibilities for small innovative companies if they were given access to big data, but inaccessibility constitutes a barrier to development. There are enormous gains to be had if data from agriculture could be gathered in usable formats that could freely be used in the development of machines with artificial intelligence, says Rasmus Nyholm Jørgensen

In Future Cropping, a project described on the next page, the desire is to establish an open data platform in which large amounts of data from agricultural and environmental technologies can be integrated with e.g. land and weather data.

These data would be the basis for development of intelligent, efficient and sustainable technologies, solutions and cultivation methods for location-specific and high-yielding crop production with a low environmental impact.

## THEMATIC AREA: SUSTAINABLE TECHNOLOGICAL DEVELOPMENT AND TECHNOLOGY ASSESSMENT

# FUTURE FARMING COMBINES SUSTAINABILITY WITH PRODUCTIVITY AND EFFICIENCY

Scientists from Aarhus University are involved in a project with a total budget of nearly 100m DKK that will prepare farming for a future where sustainability and intensive, efficient and productive crop production go hand in hand.

Danish environmental regulations for the supply of nutrients to plants mean that the emission of nutrients from agriculture to the aquatic environment has been reduced. This has, however, come at a cost. The suboptimal fertilization in relation to crop needs has led to stagnating yields and quality in the past 20 years.

The agricultural initiative recently launched by the Danish government, which to a great extent is based on research results from Aarhus University, aims to remedy at least part of this imbalance. The innovation project Future Cropping supports this development by making it possible to get the best of both worlds: protecting the environment while maintaining a high-yielding and efficient crop production.

This is to be achieved by integrating a range of data, decision support systems and various technological solutions that enable the farmer to tailor his management according to the local and actual conditions in the field. The project partners expect that project results may lead to an increased annual turnover in crop production and the agricultural technology sector of around 0.6b DKK, and that it will create new jobs in the agricultural sector by 2030 while also reducing the environmental impact.

### Differentiated treatment of fields

Not all fields are created equal and it would do the environment, agriculture and the economy a favour if they were not treated equally in the future. The comprehensive innovation project will provide research-based knowledge developed and tested in practice in cooperation with the industry and give agriculture the opportunity to treat the fields on the basis of their individual characteristics and conditions.

The government's Commission on Nature and Agriculture has recommended that regulations for general fertilizer standards and constraints on production change to a more differentiated and targeted regulation. The new agricultural initiative makes this possible.

The Future Cropping project therefore aims to develop and commercialize more efficient and sustainable solutions for crop production which will increase the yield per hectare by about two percent per year. The increased efficiency coupled with the sustainability principle will benefit Denmark's environment, agriculture, employment and export market.

### Integration of data as a basis for further development

What is new and special about the project is that it will develop a platform for information and communication technology (ICT) to enable the collation and integration of large amounts of data from diverse information sources. These data will form the basis for the development of intelligent, efficient and sustainable technologies, solutions and cultivation techniques for site-specific and high-yielding crop production with a low environmental impact.

Besides developing an advanced ICT platform, the project will develop, test and demonstrate techniques and technologies for, among others, intelligent tillage and crop establishment, intelligent and sustainable fertilization, intelligent harvesting, and differentiated nitrogen regulation and drainage.

### Project facts

The project has a total budget of 100m DKK, of which Innovation Fund Denmark has granted 50m DKK. Project partners: Aarhus University, University of Copenhagen, Kongskilde Industries A/S, SEGES, Orbicon A/S, Ejlskov A/S, Yara Danmark Gødning A/S, Novozymes A/S, Agro Business Park and AgroTech A/S. The project coordinator is SEGES.

THEMATIC AREA: SUSTAINABLE TECHNOLOGICAL DEVELOPMENT AND TECHNOLOGY ASSESSMENT

# SCIENTISTS AND INDUSTRY DEVELOP AUTONOMOUS FEEDING ROBOTS

Aarhus University has a long tradition for cooperating with the industry – particularly within the food and agricultural sectors. An example of this is the development of the mink feeding robot FIX-Robo.

On behalf of the private company Minkpapir A/S the company Compleks Innovation approached Aarhus University and the University of Southern Denmark in order to receive the necessary help and knowledge to develop the world's first autonomous robot to be fixed directly onto the present feeding machines. The robot navigates around the mink farm and places the mink feed on top of the individual cages, thus taking over a major part of the monotonous task of feeding that is usually carried out by mink farmers or their employees.

Compleks Innovation primarily works with the development of mobile robots. Several PhD students and Postdocs from the Department of Engineering have been affiliated to the company.

The researchers have helped develop the navigation, steering and localization parts. Mink farms are not identical, and this means that the robot must be adjusted to local conditions. In addition, it has been a major challenge to make the robot compensate for all the movements of existing feeding machines.

- When steering a feeding machine the driver is able to compensate for e.g. backlash – but in case of a fully automatic robot this requires a lot of adjustment. From an engineer's point of view this has been an

interesting experience, says Research Assistant Morten Stigaard Laursen, Department of Engineering, Aarhus University.

Managing director at Compleks Innovation, Tom Simonsen, is very satisfied with the collaboration with the scientists:

- When establishing our company five years ago we recognized that if we wanted to be a serious actor in the market, we would have to be close to the scientists and a university environment. The researchers have the most recent knowledge, and we are very strong within development. When we collaborate we can convert research to actual products to the benefit of the industry, says Tom Simonsen.

Compleks Innovation and Minkpapir A/S hope to be able to put the mink feeding robot into production in the very near future.

Mink are nocturnal animals and the new robot allows the mink farmer to start feeding during the night.



Photo: Minkpapir

THEMATIC AREA: BIOECONOMY, BIOENERGY AND RURAL DEVELOPMENT

## NEW PLANT IMITATES NATURE'S OWN OIL PROCESS

In May 2015 Aarhus University inaugurated an HTL pilot plant at AU Foulum. The new plant converts organic materials such as grass or organic waste into bio-crude oil, which can replace fossil oil for producing fuels and chemicals. The plant is based on newly developed, ground-breaking technologies.



Photo: Jesper Raas

Aarhus University carries out research in the extraction of proteins from grass and using it as feed for poultry and pigs.

More than 85 percent of the world's total energy consumption is based on oil and other fossil fuels. Correspondingly, the majority of products used in everyday life is also based on fossil fuels. However, global climate challenges have increased the need to find sustainable alternatives.

Recent years have witnessed an increasing interest in the biobased economy concept. The fundamental idea is that fuels, chemicals and materials are produced by renewable and plant-based biomasses instead of oil and natural gases as we do today.

As a part of its policy support Aarhus University provides advisory services and research in scientific issues in relation to bioeconomy. The university has very strong competences within this particular area. Since the turn of the millennium scientists at Aarhus University have worked hard to establish technology platforms to form the research basis for biobased production of energy, feed and other high-value products.

### Imitates nature in 20 minutes

The year 2015 turned out to be a historic one. A so-called HTL pilot plant was officially inaugurated at AU Foulum. HTL (hydrothermal liquefaction technology) is a process in which organic material such as straw is mixed with water and exposed to high pressure and temperature. The result is viscous oil that can be refined to diesel oil and a considerable number of other products.

- The plant simply imitates nature's own oil-producing process. However, nature requires millions of years to produce oil and we are able to do it in 20 minutes. This technology may be a genuine quantum leap in the struggle to reduce dependency on fossil fuels, says Associate Professor Ib Johannsen from the Department of Engineering at Aarhus University. He further explains that although the method has been known since the 1930's, it has never really taken off on a large scale, particularly because the process is connected with significant technological challenges.

- In the design process we have focused on making the plant energy-efficient and easy to upscale. Actually, we are currently designing a significantly bigger plant based on these principles, says Ib Johannsen.

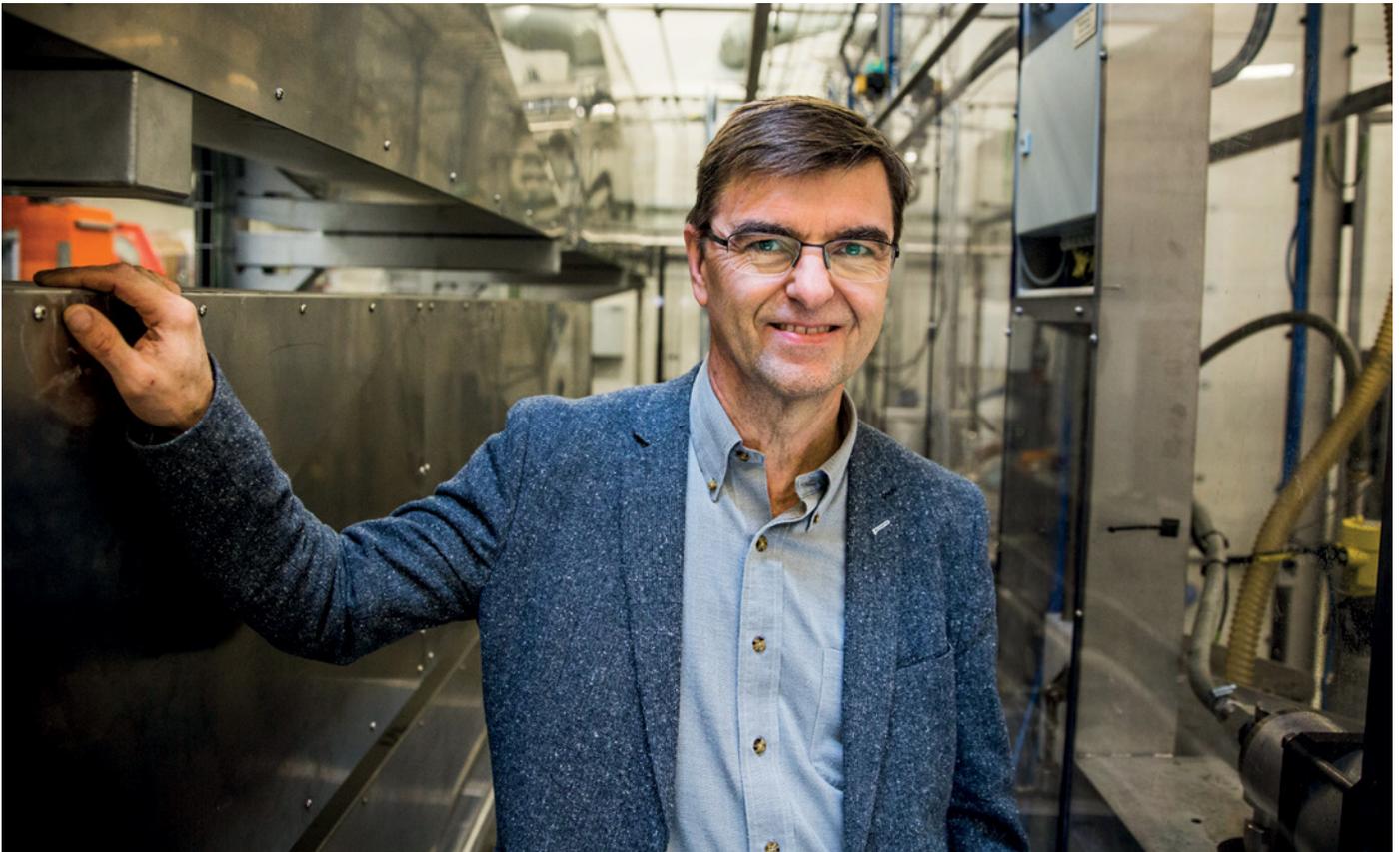


Photo: Jesper Raas

### Grass feed for pigs

The new plant will form part of ground-breaking new facilities. Utilization of all parts of the biomass is an essential prerequisite for establishing a sustainable biobased economy, and therefore the new plant is combined with another plant. This plant first extracts green biomass from e.g. grass or clover before the residual product, the pulp, is used for oil production.

The protein extracted from grass may be used for poultry and pig feed. Grass and clover is an optimum protein source for monogastrics that are not able to fully utilize grass due to the high contents of cellulose and lignin. It would entail significant environmental advantages if we were to replace the soya used in pig and poultry feed today. Soya comes primarily from South America, and to meet the requirements of the Danish pig production alone, an area of about 7,000 km<sup>2</sup> is needed, corresponding to a sixth of Denmark's area.

The new facilities will play alongside established activities at AU Foulum in fields such as biogas and harvest technology, as well as extensive experiments with improved resource efficiency in biomass production. In addition, the scientists will try to convert various side streams into higher-value products by means of new pilot plants for chemical and microbial conversion.

– AU Foulum is Denmark's most well-equipped development centre for biorefinery. This position will be strengthened once the new HTL plant is established. We hope that research and technology development will contribute to the establishment of new companies and lines of business within the biobased economy, says Ib Johannsen.

Together with his colleagues Ib Johannsen has worked to make the plant energy-efficient and ready for upscaling.

### HTL facts

HTL (hydrothermal liquefaction technology) is a process in which organic material is mixed with water and exposed to high pressure and temperature. The process takes place in a 120-metre-long pipe, where the watery biomass is heated to 450 degrees and subjected to a pressure of up to 350 bar. The result is viscous oil.

The actual process in the HTL plant builds on research carried out by the Department of Chemistry at Aarhus University, and the design is based on an already existing experimental plant in this department. The pilot plant is designed in order to accommodate a subsequent upscaling to demonstration and full-scale levels.



**THEMATIC AREA: BIOECONOMY, BIOENERGY AND RURAL DEVELOPMENT**

# REVISED FIGURES FOR THE CARBON FOOTPRINT OF WHEAT AND OILSEED RAPE GROWN FOR BIOFUEL

Scientists at Aarhus University have updated the figures for the impact on the climate of growing wheat and oilseed rape for biofuels.

Ethanol and biodiesel produced from agricultural crops are considered as sustainable biofuels with an increasing potential to replace fossil fuels. An important driver for this development is the desire to limit the total climate impact from the transport sector.

However, the production of biofuels, based on crops such as winter wheat and winter oilseed rape, requires an input of labour, energy and agrochemicals that should be included in the total climate impact of biofuels.

Against this backdrop, the EU introduced the Renewable Energy Directive that sets a maximum value for the carbon footprint of the value chain if biofuels are to be included in the EU target of 10 percent renewable energy in the transport sector by 2020.

According to current regulations, the carbon footprint of biofuels must be 35 percent lower than that of fossil fuels. This value will be increased to 50 percent in 2017.

In 2009 the Danish Energy Agency asked the Ministry of Environment and Food of Denmark to prepare a report on greenhouse gas emissions from the growing of crops for biofuel in Denmark. Using a Swedish report as a starting point, the work was delegated to DCA – Danish Centre for Food and Agriculture, that – with input from scientists at the Department of Agroecology, Aarhus University – met this part of Denmark's obligations within the Renewable Energy Directive of the European Commission.

In 2014 The Danish AgriFish Agency asked DCA to examine whether there were grounds for a revision of the Danish calculations. The scientists behind the report collected any new results that had emerged since 2010, and an updated report was accepted by the European Commission in July 2015.

The new report shows that estimates of greenhouse gas emissions from winter wheat for the five Danish regions in 2015 ranged from 18.9 to 23.4 g CO<sub>2</sub> equivalents per megajoule of ethanol. In 2010, the corresponding figures ranged from 20.1 to 24.4 g CO<sub>2</sub> equivalents.

For winter oilseed rape the range for 2015 was from 21.4 to 24.4 g CO<sub>2</sub> equivalents per megajoule biodiesel, while in 2010 they ranged from 23.7 to 28.2 CO<sub>2</sub> equivalents.

- This means that the Danish figures almost always are below the standard values listed in the Renewable Energy Directive of 23 and 29 g CO<sub>2</sub> equivalents for wheat and oilseed rape, respectively, says Associate Professor Lars Elsgaard from the Department of Agroecology, Aarhus University adding:

- As we stated already in the 2010 report, it is natural that these assumptions are assessed on a regular basis to reflect new knowledge and technological development. This especially applies to our knowledge on emission factors regarding nitrous oxide (N<sub>2</sub>O) which primarily comes from supplied nitrogen and which contributes significantly to the total climate impact. However, the interpretation of the Renewable Energy Directive also causes differences between various EU countries and we need to be aware of these. Thus, the prerequisites for using crops for energy purposes develop continuously.

According to current regulations, the carbon footprint of biofuels must be 35 percent lower than that of fossil fuels.

Photo: Jesper Rais

THEMATIC AREA: BIOECONOMY, BIOENERGY AND RURAL DEVELOPMENT

# BIOGAS PRODUCTION REDUCES NITROGEN LEACHING FROM MANURE



Photo: Lise Balisy

Nitrogen from anaerobically digested slurry is more readily available to crops than nitrogen from untreated slurry even when considering long-term developments in the field. This is the main conclusion from a research project in which scientists from Aarhus University have developed a new model that can calculate nitrogen leaching from degassed slurry compared to untreated slurry.

When slurry is digested in a biogas plant, the organic matter in the slurry degrades. This means that some of the organically bound nitrogen becomes mineralized. This is good news for the crops as the slurry will then have a reduced content of organic nitrogen, which is not readily available to the plants, but a higher content of inorganic nitrogen, which is readily available to the plants. The increased availability of nitrogen will – all things being equal – result in higher yields in the field.

It is also good news for the environment because the more nitrogen that the crops can absorb and utilize, the less nitrogen is leached to the aquatic environment.

This project was initiated and financed by the Biogas Task Force of The Danish Energy Agency in cooperation with The Danish Environmental Protection Agency and the Danish AgriFish Agency.

The AU biogas plant includes an extruder – a mixer that shreds bales of hay and straw and mix it with deep litter or ensilage. In addition, the extruder opens the biomass in order to utilize the gas potential within the given retention time.

## Research in biogas

The world's largest biogas plant for research purposes is located at AU Foulum. The plant is used by both national and international scientists and companies for projects within biogas production as well as slurry separation. Animal manure, feed remains, meadow grass, straw and maize ensilage from the university's huge livestock buildings and fields are used as raw materials in the plant.

The biogas produced is used to produce electricity and heat; the electricity is sold to the electricity network whereas the heat is used for heating the university buildings.

The biogas plant has a 1200 m<sup>3</sup> reactor and a daily biogas production of approx. 4800 m<sup>3</sup>. On average, the biomass has a retention time of 15 days in the reactor before it is pumped to the post digester tanks.

Photo: Jesper Rais



## THEMATIC AREA: RESOURCE EFFICIENCY

# ONIONS SNITCH ABOUT THEIR AILS

Aarhus University carries out research on promoting resource efficiency in all parts of the food chain. This includes a large project in which researchers and the industry are collaborating to prevent discarding several tons of onions annually. The aim is to make onions tell about their diseases before it is too late.

Evaluating onion quality can be difficult, even for Danish onion growers. Today, the quality at harvest is assessed according to whether producers expect their onions to be stored for a long period or if the onions are to be shipped to consumers shortly after harvest in order not to be wasted.

Unfortunately, not all quality issues are visible to the naked eye at harvest and several tons of onions may be discarded each year because they deteriorate during storage.

At Aarhus University scientists carry out research in resource efficiency at many levels and test various methods to prevent food losses and waste during storage. An example of this is a major project aiming at reducing waste of onions.

- High storage wastes mean that production costs are divided on less salable produce and that primary producers will miss out on income as they have already paid growing, harvesting and storage costs. Onions are inexpensive products and it is therefore important to sell as much as possible of the production. A little less waste can tip the balance towards a sustainable business, says Associate Professor Merete Edelenbos from the Department of Food Science at Aarhus University.

### All onions count

The project is an innovation consortium focusing on the entire value chain from the field until the product reaches retail. The long list of project participants ranges from primary producers, technology companies and suppliers to interest groups, sales organizations and knowledge institutions.

Merete Edelenbos is in charge of the project's research. Together with her colleagues she is developing methods that will make it possible to evaluate product quality during storage. As their specific starting point the scientists use the onions' release of volatile organic compounds. The scientists gather the volatile compounds from onion storage rooms and bring back the samples for laboratory analysis. They also bring back onions to examine the quality.

- Onions are stored in two-ton boxes. It is therefore important that producers stock onions that are fit for storage. However, it is very difficult to evaluate storage shelf life at harvest time. We therefore aim to find 'snitches' that can help us measure quality changes before they become visible to the naked eye. If we can get onions to tell us about

their shelf life ability during storage, we might be able to avoid situations in which the producer has to discard a significant part of the production, says Merete Edelenbos and further explains that a major goal is to use research results to develop actual tools.

### For the benefit of producers

The private company Axel Månsson A/S, located in Brande, is one of Denmark's major vegetable producers and one of the industrial project partners. The company is very pleased with the scientist focus on this particular subject.

- The food waste problem is as topical as ever before. For raw material producers like ourselves it is particularly important to focus on the production stage before the products reach retail. It is important to achieve the highest possible product utilization to achieve optimum competitiveness, says CEO Axel Månsson, who hopes that the project results will cause a ripple effect:

- We hope that our contribution may affect the consortium in such a way that the results benefit the producers.

### Project facts

The project "Strategies and technologies to reduce food waste in potatoes and vegetables" is managed by the Danish Technological Institute - AgroTech and has a total budget of 37.3m DKK, of which 14.6m DKK is funded by the Danish Agency for Science, Technology and Innovation under the Ministry of Higher Education and Science. The participating companies and research institutions provide the remaining funding.

At Aarhus University scientists develop methods that can make it possible to evaluate onion quality during storage.

Photo: Colourbox



**THEMATIC AREA: RESOURCE EFFICIENCY**

# MORE NITROGEN FOR ORGANIC FARMING

In the NCHAIN project scientists will examine the possibility of ensuring an increased supply of nitrogen in organic farming by increasing the use and efficiency of nitrogen-fixing plants.

- The nitrogen chain in milk and meat production begins with the fixation of atmospheric nitrogen by soil bacteria in white clover root nodules. From here it is transported to the clover plant itself and on via the surrounding soil and grass to end up in grazing cows, explains Assistant Professor Stig Uggerhøj Andersen from Department of Molecular Biology and Genetics, Aarhus University.

- We will optimize this chain by systematically studying the correlation between clover yields and the three organisms in the nitrogen chain – soil bacteria, clover and grass. We will focus specifically on the genetic composition of these organisms, says Stig Uggerhøj.

Other project partners include: York University, DLF, Legume Technology and SEGES. The project has a total budget of 22.5m DKK, of which the Innovation Fund Denmark has granted 17m DKK.

Researchers will study the correlation between clover yields and the three components of the nitrogen chain – soil bacteria, clover and grass.



## THEMATIC AREA: RESOURCE EFFICIENCY

# MEASURING AGRICULTURAL EFFICIENCY IN DENMARK

Scientists from the Department of Agroecology at Aarhus University have drawn up a robust model that can put actual figures on the efficiency of our agricultural production and use of resources. The model uses readily-accessible data.

Danish agriculture is constantly getting better at utilizing resources efficiently to produce meat, milk and cereals. This is demonstrated by new figures that are based on a new method to quantify the development of production and resource efficiency using publicly available data. There are figures available for the use of resources in agriculture as a whole but not for the individual types of production.

This makes it difficult to decide where to prioritize new initiatives in connection with, for example, the recommendations by the Commission on Nature and Agriculture and the government's policy for trade and growth in the food sector.

The AgriFish Agency therefore asked DCA – Danish Centre for Food and Agriculture to evaluate the possibilities of using generally available data to describe resource efficiency and its evolution for selected central parts of agricultural production, i.e. the production of milk, pigs and cereals. The method used to describe the development and efficiency of these selected areas has been detailed in a report published by DCA.

### Resources are used more efficiently

The results show that agriculture's utilization of resources is moving in the right direction. As for grain production, however, the efficiency has been stagnant with a fairly constant yield measured in DM and net energy per hectare, while there has been a tendency for the production of protein per hectare to decline. The annual production of meat from slaughter pigs per sow has increased by 35 percent from 1990 to 2012. At the same time feed consumption in pig production has decreased by six percent and consumption of protein has fallen by 22 percent. A combination of improved feed utilization and increased yield per unit area used for protein crops means that the area used to produce one kilo of pork has fallen from 6.8 m<sup>2</sup> in 1990 to 5.6 m<sup>2</sup> in 2012.

Milk production shows the same tendency. Milk production per cow-year has risen 40 percent from 1990 to 2012. If you factor in meat production, which has not changed, to the concept of animal product, production has increased from 8525 kg per cow-year in 1990 to 10,694 kg in 2012. The area used to produce one kg of animal product from dairy farming was 1.23 m<sup>2</sup> in 1990; by 2012 this had been reduced to only 1.08 m<sup>2</sup>.



Photo: Jesper Raas

Danish agricultural production has increased its resource utilization efficiency. An example is that the area used to produce one kilo of pork has been reduced by 1.2 m<sup>2</sup> since 1990.

## THEMATIC AREA: FOOD PRODUCTION AND THE CULTIVATED SOIL

# NEW TOOL CAN HELP INCREASE SOIL CARBON CONTENT AND THEREBY IMPROVE SOIL FERTILITY

Agricultural soil is the basis for our crop production and should be carefully managed to maintain its fertility. Results from an EU project will make it easier for farmers and consultants to identify the best cultivation practices for this purpose.

Agricultural soils provide the basis for more than 90 percent of the global food production, but throughout the world there are serious threats to soil quality. Soil degradation reduces soil fertility and threatens food supply in the long term.

The reasons for soil quality deterioration are to be found in simplified crop rotations where much of the straw is often removed resulting in little return of organic matter to the soil. However, it is possible to change agricultural practices and thus maintain or increase soil fertility – which will also benefit crop productivity and long-term farm profitability.

The European research project SmartSOIL, which was coordinated by Professor Jørgen E. Olesen from the Department of Agroecology, Aarhus University, has developed a decision support tool to ease decision-making.

The tool is part of a toolbox located within a website that helps advisers, farmers and policy-makers to identify cost-effective methods in order to optimize yield and soil carbon stocks for different types of soil, climate and cropping systems. The tool and its many functions can be found on the project website at [www.smartsoil.eu](http://www.smartsoil.eu).

In order to develop the tool, the scientists examined how changes in soil carbon content interact with soil fertility and how this affects yields and the input needed, especially of nitrogen fertilizer.

The project also identified five methods likely to increase soil carbon content. The methods improve soil fertility, increase productivity and reduce the need for nitrogen fertilizer, and will in many cases improve the farmer's economy.

### Carbon is crucial to soil functionality

It is crucial to ensure that soil has adequate carbon content. But what has carbon got to do with soil fertility?

- All organic material contains carbon. This also applies to organic matter in the soil, which supports all the essential functions that the soil carries out for crop growth and production. Crop growth relies on sufficient supplies of water and nutrients (especially nitrogen) as well as good crop health, not least a good crop establishment, and all these functions are affected by soil organic matter, explains Jørgen E. Olesen.



Photo: Jesper Raas

Carbon is an essential part of soil organic matter and contributes to a healthy soil, increasing earnings for the farmer because the soil is more fertile.

Changes in soil carbon content also contribute to climate change. If the soil can store more carbon, the increase in atmospheric carbon dioxide (CO<sub>2</sub>) will be smaller. This would thus mitigate the greenhouse gas effect. The effect is not permanent, however, since the soil carbon content will find a new equilibrium following changes in management.

#### SmartSOIL website provides a reference point

It can be difficult to comprehend the full range of available options for improving soil carbon content and fertility, and there will be many local factors to be taken into account. To provide inspiration and a reference point, SmartSOIL has developed a range of information material (fact sheets, videos, case studies, etc.) that are available in a practical form on the website. SmartSOIL has identified five general management practices that individually or in combination can help to optimize the balance between crop productivity, soil functionality and soil carbon balance. The methods primarily work by increasing the supply of plant residues or organic matter from manure or compost.

The five management practices are:

- Crop rotation
- Residue handling
- Adding manure or compost
- Cover crops/catch crops
- Conservation agriculture, which includes reduced soil tillage, returning plant residues to the soil, permanent soil cover with – particularly – cover crops – and changes to the crop rotation

The management practices are described in more detail in five easy-to-read fact sheets that also contain information on the advantages, disadvantages, financial implications, etc., of the methods.

#### A healthy soil brings financial rewards

Identification and analysis of the five methods and the knowledge underpinning the tool box are based on research conducted in different countries by means of controlled field experiments and supplemented with experience from commercial farms.

For Denmark this includes results from long-term experiments (up to 20 years) performed at Aarhus University's experimental station in Askov and the experience of farmer Bjarne Hansen from Zealand.

The farmer found that his costs were reduced by 36 percent and his margin increased by approx. €360 (2688 DKK) by introducing reduced tillage, increasing the use of cover crops and incorporating plant residues in the crop rotation.

- I spend €180 (1354 DKK) less per hectare than other farmers in my area. The savings in fuel consumption were very obvious because we spent less time using the farm machinery. We also needed less nitrogen fertilizer because of improved nitrogen utilization in the field, says Bjarne Hansen.

You can read about all the farmers who participated in the project and their experiences at the SmartSOIL website.

- It is essential that the improvement of soil fertility through improved soil carbon management practices is supported by the right incentives for the farmer. SmartSOIL has therefore developed a number of recommendations to promote this, including better advisory systems, targeted subsidies through reform of the agricultural subsidy schemes and better interaction with environmental regulation, says Professor Jørgen E. Olesen.

#### Project facts

Project partners included 12 research institutions from 10 European countries. The project ran for four years and was supported by the EU's Seventh Framework Programme with 22m DKK. Project coordinator was Professor Jørgen E. Olesen, Department of Agroecology, Aarhus University.

Read more about the project at [www.smartsoil.eu](http://www.smartsoil.eu).

## THEMATIC AREA: FOOD PRODUCTION AND THE CULTIVATED SOIL

# ORGANIC VEGETABLES BENEFIT FROM INTERCROPPING CATCH CROPS BETWEEN CROP ROWS

Scientists from Aarhus University have examined how to reduce the risk of nitrate leaching by growing catch crops together with organic leek and cauliflower.

Some organic crops are more difficult to grow than others. One of these is cauliflower. It is easily attacked by plant diseases and insects. In addition, a limited nutrient supply reduces harvest quality. Another tricky vegetable is leek. Leek has a superficial root system as well as a significant need for and low utilization of nitrogen.

At Aarhus University scientists are trying to optimize the production of organic vegetables to the benefit of organic vegetable producers. In the recently completed CORE ORGANIC project INTERVEG the scientists, in collaboration with colleagues from other countries, examined if intercropping of catch crops with organic cauliflower or leek can improve growth and reduce the risk of nitrate leaching.

A total of seven two-year field trials were carried out in Italy, Slovenia, Germany and Denmark, during which factors such as different varieties, time for catch crop establishment, field design and fertilizer levels were examined. In Denmark a greenhouse experiment was carried out in addition to the field trials in order to examine the use of white clover as fertilizer in two different soil types.

The results are promising. The scientists discovered that nitrate leaching from organic vegetable production can be reduced by growing catch crops together with the main crops. Moreover, the use of legumes as catch crops can increase the supply of atmospheric nitrogen. This reduces the need to apply additional nitrogen from other sources.

However, the success of intercropping depends on a successful control of catch crop competition; neither too little, nor too much. When selecting catch crops and cultivation methods it is important that the main crops are able to develop and that the catch crop is able to develop its root system and absorb surplus nitrogen.

- Research has provided new knowledge on nitrogen dynamics and control of competition between species when intercropping organic vegetables and catch crops. Intercropping is not commonly used in commercial vegetable production, but obviously there are certain perspectives to be considered and applied in organic production, says project manager and Science Team Leader Hanne Lakkenborg Kristensen from the Department of Food Science at Aarhus University.



Photo: Yue Xie

### INTERVEG facts

The three-year INTERVEG project was carried out in collaboration between Aarhus University and research institutions in Italy, Slovenia and Germany. INTERVEG is a part of the CORE ORGANIC II programme coordinated by ICROFS and partly funded by the Danish AgriFish Agency.

**THEMATIC AREA: FOOD PRODUCTION AND THE CULTIVATED SOIL**

# RESEARCH FROM AARHUS UNIVERSITY ENSURES IMPROVED OPPORTUNITIES FOR ENVIRONMENTAL MANAGEMENT

The Danish peatland area has been reduced by approximately 50,000 ha since 1975, according to studies from Aarhus University. These results are the basis on which new Danish legislation regarding wetlands and permanent removal of peatlands from agricultural production builds and is an example of how applied research ensures improved opportunities for environmental management.

Since 1975 the peatland area in Denmark has been reduced by 50,000 ha. This can be seen in surveys and mapping carried out by scientists from the Department of Agroecology at Aarhus University. These results can be applied directly in the central Danish environmental management.

- We have prepared a map of the distribution of peatlands in Denmark. The map has been used to designate areas that can be included in the new wetland scheme in which peatlands are permanently removed from agricultural production. The landowner is fully compensated for the removal, explains Senior Scientist Mogens H. Greve from the Department of Agroecology.

The government has decided to establish a subsidy scheme for nature projects on carbon-rich wetland soils with the aim of implementing compensatory climate action. This initiative is a follow up to the previous government's Climate Plan and the Nature and Agricultural Commission's recommendations.

**Nature, water and the climate will benefit**

Removal of peatlands means a permanent stop to tillage and fertilization as well as raising the water table to ground level. This will be done by filling ditches and disconnecting drains. The wetland scheme has a range of positive effects on nature, the aquatic environment and the climate as it:

- Reduces agriculture's emission of greenhouse gases from carbon-rich wetlands
- Promotes the quality, interconnectedness and resilience of nature
- Promotes biodiversity
- Contributes to a better aquatic environment

The effects of the wetland scheme on the climate are incorporated in Denmark's report to the UN's climate panel IPCC regarding reduction of greenhouse gases. Reduction of agriculture's emissions from the carbon-rich wetlands is expected to be 33,000 tons of CO<sub>2</sub>-eq/year, corresponding to 13 tons of CO<sub>2</sub>-eq./ha/year.

In the period from 2014 to 2017 a removal of approximately 2,500 ha is expected. The total economy of the scheme is 165.2m DKK and is co-funded by the EU.

## THEMATIC AREA: FOOD PRODUCTION AND BIORESOURCES

# GROWING INTEREST IN VINTAGE VARIETIES

There is a growing interest in old varieties of fruit, vegetables and cereals. This is the experience at both the Nordic Gene Bank (NordGen) and Aarhus University's horticultural research site in Aarslev who administer the national collection of vegetatively-propagated vegetables. The people showing a rising interest are primarily private gardeners and hobby breeders, but there is also budding commercial interest for the vintage varieties.

Aarhus University's research station in Aarslev is responsible for maintaining the national collection of a number of vintage varieties of vegetables that are not propagated by seed. This means that they must be preserved as growing plants in the soil.

These old varieties represent a large diversity, and often have characteristics that differ from newer cultivars. They may be more resistant to diseases, tolerant to drought and high temperatures or have properties beneficial for human health. It is therefore important that they are preserved, both for the sake of diversity, but also so that they can be included in future breeding programmes.

The collection at Aarslev numbers 51 different horseradish clones, 78 variants of rhubarb, 18 clones of Jerusalem artichoke and 28 varieties of shallots. The collection additionally boasts 41 varieties of hops. It is constant work preserving and maintaining the collection – it has to be regularly renewed and planted out and the different varieties of, for example, Jerusalem artichoke have to be kept separate in order that they do not get mixed up.

You can acquire plants of the vintage varieties supplied both as a commercial enterprise and as a hobby breeder; some of the varieties of hops originating from Funen are, for instance, used in beer brewing at some of the local breweries. Lars Henrik Jacobsen, research assistant at the Department of Food Science and who manages the collection, says that there is great interest in the old varieties:

- People can normally get only one or two varieties in the supermarket and are often astonished when they see that Jerusalem artichokes, for example, are available in a number of completely different sizes and colours. The collection is not just for the decoration and pride of future generations, says Lars Henrik Jacobsen:

- We are constantly trying to get the collections included in cultivation experiments so that we can get the material out to work.

### Run on seeds – new strategy in the pipeline

The seed-propagated species are kept at NordGen who will also supply small samples of the stored seeds to researchers, breeders and hobby breeders. NordGen has seen a large increase in interest in recent years, which is resource-demanding both in terms of propagation of the seed material and handling of the many enquiries.



Photo: Jesper Raas

Lars Henrik Jacobsen manages the national collection of vegetatively propagated vegetables. He has experienced a growing interest in the vintage species.

In the past 15 years, Denmark has prepared strategies, action plans and awarded project funds to stimulate activities in the area, but the actual storage and maintenance of preservation-worthy seeds takes place at NordGen. The advisory committee for plant genetic resources at the Danish AgriFish Agency is currently working on a new Danish strategy for the area. The chairman of the committee is Birte Boelt, senior researcher at the Department of Agroecology at Aarhus University. She clarifies:

- In the committee we are working on a model where we divide the crops according to how widely used they are. One group consists of the main agricultural crops that undergo commercial breeding in Denmark. This group is well described and regulated and the varieties sold commercially. Then there are the smaller species that are not commercially bred in Denmark. For some of these, there is a growing commercial interest – for example, in relation to the New Nordic Food concept – and, finally, there are seeds for private individuals. In future we would like to ensure the continued development within all three areas.

#### **Vintage varieties to the fore**

Seeds for commercial use are covered by EU legislation on seeds, while private individuals can swap seeds for non-commercial use. And the private realm is not unimportant in the work on describing vintage varieties since there is a great deal of interest in them among private individuals. This is felt, for example, in the association Frøsamlerne (“seed collectors”) which organizes seed-swapping days throughout the country.

MOVE (Marketing of Organic Vintage plant material) is a new project that focuses on making old vegetable varieties available to organic growers. The project works with cabbage, beetroot and spinach. Project manager Lise Christina Deleuran, Senior Adviser at the Department of Agroecology, explains:

- Many of the old varieties can have properties that have been bred out in the modern varieties, such as bitter compounds in cabbage. But bitter compounds have been shown to have health benefits. It is important to note, however, that older varieties are not necessarily better than the newer varieties. If the old varieties are to be used commercially, there is a need for larger seed quantities that meet the requirements for purity and quality.

The project is therefore a joint venture with the seed company Vikima Seed that has extensive experience with the propagation of vegetable seeds. MOVE has organic growers as the target group, since many of the old varieties are adapted to less intensive cultivation and therefore might be of interest to organic growers.

The project is financed by the Green Development and Demonstration Programme (GUDP).

#### **Why preserve?**

Which crops will we be relying on in 20, 50 and 100 years' time? This is hard to predict, but the genetic material we protect now can contribute valuable properties to the development of future plants. It is therefore important to save the species, even those we do not use today, since they may have properties that may be beneficial sometime in the future – under a different climate, say. In Denmark varieties of vegetatively-propagated vegetable species are kept in the national collection at Aarslev, while the Pometet collection at the University of Copenhagen consists of varieties of fruit trees and bushes. The seed-propagated species are primarily kept at NordGen, and funds are regularly distributed to projects on the conservation or use of the old plant genetic material. A new Danish strategy is now under way that has a stronger focus on how we can make greater use of plant genetic resources.

#### **NordGen:**

NordGen is an institute under the Nordic Council of Ministers that is responsible for the preservation and sustainable use of Nordic plants, animals and forests. Their main storage depot for the Nordic plant seeds is in Sweden while their basic seed collection is in Denmark at Aarhus University's Aarslev site. On Svalbard you will find the global seed vault, where copies of plant seeds from seed banks all over the world are kept as a safety backup. These include variants of the most important agricultural crops in the world. The vaults at Svalbard store seeds from 4000 different species.

## THEMATIC AREA: FOOD PRODUCTION AND BIORESOURCES

# TO THE RESCUE OF THE EUROPEAN DARK BEE

Honey bees play a crucial role as pollinators of both agricultural crops and wild plants. The European dark bee – which is the original North European race – has, however, come under pressure. While apiculture is generally undergoing a positive development, this brown insect is in many ways in need of a helping hand.

Senior Researcher Per Kryger from Aarhus University is involved in NordGen, the collective effort of the Nordic Council of Ministers to preserve heritage species. They are currently looking at the populations of dark bees in Denmark, Norway, Sweden and Finland with a view to creating a Nordic alliance for the exchange of genetic material to give the bees a new lease of life.

Particularly the Finnish and Danish populations of the dark bee are so small that they are unlikely to be sustainable in the long term, and the Danish population is showing signs of inbreeding. This is why NordGen is now setting up apiaries in the four countries, where dark bee queens from the other respective countries will be installed to ascertain whether they are sufficiently robust in the new surroundings so that they can start a more systematic exchange of genetic material.

In Denmark the European dark bee lives in a protected area on the island of Læsø, where the easternmost part of the island has been a bee reserve since 2008. A site for breeding pure strains has furthermore been established on the island of Endelave where breeders of the dark bee can mate their queens with purebred drones. The dark bee is not

particularly effective on early-flowering agricultural crops such as oilseed rape, but is, on the other hand, very productive in areas with, say, heather and therefore produces a lot of honey at the tail-end of the season. The dark bee has also preserved a number of natural traits because it has not been intensely crossbred. It is, for example, robust in the cold winters of Northern Europe, where it is resistant to diseases and can survive the winter on less feed than the currently preferred honey bee strains.

### Many new breeders

Besides giving the bees a new lease of life, there is also a shortage of new beekeepers who wish to keep dark bees. The existing breeders tend to be older, so there is also here a need for new blood.

- There is a need for more people who would like to work with these bees. Although there has been increasing focus on beekeeping and honey production in recent years, we have neglected to draw attention to the plight of the dark bee. This is why we are using the Nordic network to write a web-handbook on how to keep dark bees, says Per Kryger.

Because the bees are not suited to large and open agricultural areas, and because the breed is protected and therefore cannot be crossed with other kinds of bees, segregated areas and areas with a varied landscape are needed to keep dark bees.

### EU project to protect original bee strains

Per Kryger also participates in the EU project Smartbees, where the aim is partly to develop a bee that is resistant to the parasites that in many places has caused sudden bee death and partly to preserve the original European bee strains, including the dark bee. A major genetic study of the European bee populations has therefore been initiated. Most European bee strains have now been collected, but it will be a few years yet before the results are ready.

- In a lot of places in Europe the original bees are being replaced with strains that have been bred for production potential but under completely different conditions. It is of course not up to us to decide which bees the growers should choose, but both for the sake of genetic diversity and keeping in mind the major changes to climate and environment, I think we would miss the dark bee and other indigenous bee species if they completely disappear, says Per Kryger.

In Denmark the European dark bee lives in a protected area on the island of Læsø where the easternmost part of the island is a bee preservation area.



Photo: Per Kryger

THEMATIC AREA: FOOD PRODUCTION AND BIORESOURCES

# STRATEGIC CHANGES IN FUNGICIDES PREVENT RESISTANCE

In Denmark only a limited number of fungicides are available for use against the fungal disease Septoria. Septoria is a leaf spot disease that causes significant yield losses in winter wheat each year.

The limited number of fungicides with different modes of action may result in development of resistance in the fungus, which might lead to insufficient control.

Recent experiments carried out in the Department of Agroecology at Aarhus University show that the individual farmer can actually do something to help prevent resistance towards fungicides. The risk of developing resistance can be reduced by using fewer sprayings, carefully considering changes between different types of fungicides and choosing an integrated crop protection strategy that includes the most resistant crop varieties.

Regarding the approval of pesticides, Denmark is located in EU's so-called North Zone. Due to specific environmental requirements in relation to pesticides, fewer active substances are available for use in Denmark than in the neighbouring countries. This increases the vulnerability for developing resistance as there are fewer pesticides to choose from.

Research shows that the individual farmer can do something to help prevent resistance towards fungicides.



Photo: Janne Hansen

## THEMATIC AREA: FOOD PRODUCTION, LANDSCAPE, NATURE AND BIODIVERSITY

# THE ENVIRONMENTAL IMPACT OF BEEF

Beef production affects the climate, environment and biodiversity, but the effects depend on how the meat is produced.

It is no secret that the production of beef has a large impact on the climate. What is less known is how the different beef production systems, on which the steak on our plate is based, affect the climate and the environment and which part of the production chain you should focus on to reduce the impact on climate and the environment.

Scientists from the Department of Agroecology, Aarhus University, have calculated how different beef production systems affect the climate and environment. This was carried out as part of the project "Evaluation of the environmental impact of veal and beef production" by the Danish Agriculture & Food Council with financial support from the Danish Cattle Levy Fund.

The results show that veal and beef from dairy cattle have smaller carbon footprints per kg meat than from beef cattle. The production of dairy-based beef also results in lower eutrophication per kg meat produced. Meat from beef breeds, on the other hand, has a positive effect on biodiversity. Regardless of production system, the largest contribution to the environmental impact by far is from the primary production with a much smaller impact from the slaughter process.

### Differences in environmental load

The scientists carried out life cycle analyses of 13 different beef production systems from one dairy cattle breed (Danish Holstein) and two beef cattle breeds (Scottish Highland and Limousin). For the three different breeds there was a further division into production systems (organic and conventional) and into meat from veal calves (8-12 months), young cattle (12-24 months) and beef cattle (>24 months).

The scientists examined the effect of the different production systems on a number of environmental impact categories per kg edible product (i.e. meat and edible by-products) leaving the slaughterhouse. They calculated the carbon footprint in kg CO<sub>2</sub>-eq. emission, fossil energy consumption, eutrophication (nutrient enrichment) measured in kg NO<sub>3</sub>-eq. and loss of biodiversity.

- There are large variations in the environmental impact of meat from different production systems. The different types of meat also have different rankings depending on the environmental impact category, says Associate Professor Lisbeth Mogensen from the Department of Agroecology.

The analysis showed that the carbon footprint and nutrient enrichment from meat derived from calves and young cattle of the dairy breed were only a third of that from the beef breeds. For all types of meat from the dairy breed, there were only small differences in carbon footprint and nutrient enrichment per kg meat, with the exception of meat from steers which had a higher carbon footprint than the other types of meat from dairy breeds.

The type of feed grown has an impact on biodiversity. Generally, a positive effect on biodiversity is achieved with permanent pasture – particularly if it is grazed – than with an annual crop such as a cereal. When looking at the impact on biodiversity of beef production, there is only a very small impact for most types of beef.

There is a small loss of biodiversity when producing beef from a dairy breed and a small increase in biodiversity when producing beef in an intensive cow-calf production system with Limousin. In an extensive production system with Scottish Highland Cattle there is a large positive impact on biodiversity because of the considerable size of the area grazed.

### Scope for improvement

There is scope for reducing the impact of beef production on climate and the environment. Since the largest impact from veal and beef production is at the primary production stage, any innovative measures must take place here. The slaughtering process is already very energy and resource efficient.

- However, when an animal is slaughtered, only about half of its live weight ends as edible products. If you are able to increase the proportion of the live weight that is utilized, this will have a significant impact on the climate and environmental load per kg edible product of beef production, says Lisbeth Mogensen.

### Project facts

The project was carried out by Aarhus University and the Danish Agriculture & Food Council with financial support from the Danish Cattle Levy Fund.

The climate footprint left by beef production differs according to the type of production system. Scottish Highland cattle have a positive effect on biodiversity.

Photo: Colourbox





THEMATIC AREA: FOOD PRODUCTION, LANDSCAPE, NATURE AND BIODIVERSITY

# INCREASED BIODIVERSITY IN PERENNIAL FALLOW FIELDS COMPARED TO ANNUAL FIELDS

Is it necessary to sow specific plant species in order to achieve optimum biodiversity in fallow fields? The Danish AgriFish Agency asked scientists at Aarhus University to examine this.

In 2016 new regulations regarding fallow fields were introduced allowing the farmer to plough the area in spring if he subsequently – and no later than 30 April – sows a mixture of seed and nectar-producing plants. If this demand is met the farmer does not have to mow the fallow field later as is otherwise required in fallow fields.

In preparation for regulating fallow fields, the Danish AgriFish Agency wanted to know if farmers should sow specific types of annual plants in order to achieve an optimum biological diversity in areas that will lie fallow for one or more years.

The short answer is that you achieve the highest biodiversity by creating variation – whatever the fallow period. However, it is difficult to point at specific plant species to sow as several factors are at play. Actually, it may be an advantage not to sow anything at all – and just let nature take over.

- In many areas you will achieve increased variation in annual fallow fields by not sowing anything at all and simply letting wild weeds grow. On sandy soils in particular nature will benefit from allowing the seeds in the soil to germinate, grow and bloom, say Senior Researcher Rasmus Ejrnæs and Senior Consultant Morten T. Strandberg from the Department of Bioscience, Aarhus University, in their reply to the Danish AgriFish Agency.

In their reply Rasmus Ejrnæs and Morten T. Strandberg present several important points. One is that it is not advisable to sow plant types that attract perennial hosts such as butterflies in fields that are to be mowed or used in rotation. Nor should plant species that are invasive or potentially invasive, or that will outcompete the wild flora be sown.

- Ploughing fallow land every year is a problem of the fallow land scheme because many of the insects that can benefit from wild Danish plant species overwinter in the vegetation as larvae. Ploughing can also destroy the nests of soil-dwelling bees, they explain.

One solution to the problem might be to refrain from ploughing 10 percent of the fallow area each year so that overwintering species can survive to the next generation.

Narrow-bordered five-spot burnet (*Zygaena lonicerae*) is one of the insect species attracted by perennial plant species.

Photo: Janne Hansen

## THEMATIC AREA: FOOD PRODUCTION, LANDSCAPE, NATURE AND BIODIVERSITY

# BIOTOPES ARE IMPORTANT LANDSCAPE ELEMENTS

Protection of areas around water holes and archaeological and heritage sites is important for the promotion of biodiversity and other environmental advantages in the intensively farmed Danish landscape.

The Danish landscape is dominated by agriculture with approximately 62 per cent of its surface area under agricultural production. Most of this area is used for growing annual crops, which makes Denmark one of the most intensively farmed countries in the world.

There also has to be room in the landscape for nature conservation, which the Danish legislation helps to ensure. One of the initiatives is the requirement that farmland is kept in "good agricultural and environmental condition" (GAEC). Compliance with these requirements includes the protection of small lakes and ponds with buffer vegetation up to 2000 m<sup>2</sup> and the protection of ancient monuments up to 2000 m<sup>2</sup> – the so-called GAEC-protected landscape features.

In 2015 the Danish AgriFish Agency asked DCA to describe the effect of increasing the maximum limit for the area classified as GAEC-protected landscape features from 2000 m<sup>2</sup> to 5000 m<sup>2</sup>. The conclusion was clear: Biotopes contribute positively to biodiversity and nature conservation in agricultural landscapes.

- Raising the maximum limit of GAEC-protected landscape features from 2000 m<sup>2</sup> to 5000 m<sup>2</sup> provides agriculture with an opportunity to make a greater contribution to the protection of the Danish natural and cultural landscape, also when the derived consequences are taken into account, wrote Professor Tommy Dalgaard and Research Assistant Inge T. Kristensen from the Department of Agroecology in their response to the Danish AgriFish Agency.

The researchers estimate that the number of biotopes in this way can be increased from roughly 30,000 to 35,000. This corresponds to increasing the area with the special landscape features from approximately 1,800 hectares to 3,300 hectares, with a corresponding effect on the protection of the land's intrinsic value for the associated biotopes.

The best effect is achieved in two ways: One is to prioritise the protection of existing biotopes against cultivation; the other is to add and protect new biotopes in conjunction with existing biotopes.

Besides their natural value, the conservation of the areas around historical sites and lakes is also of value to the environment. The areas help to sequester carbon in the soil, which is a positive step in the battle against climate change, and they collect excess nutrients from the surrounding farmland, which benefits the aquatic environment.

Buffer strips along water courses and the use of cover crops will, however, have a more focused environmental impact, and growing woody crops for bioenergy can potentially have a higher production value than GAEC landscape elements, even though GAEC areas can be grazed and thus contribute to the production on farms with grazing animals.

Besides their natural value, the conservation of the areas around historical sites and lakes is also of value to the environment.

Photo: Colourbox



## THEMATIC AREA: FOOD PRODUCTION, ADJUVANTS AND THE ENVIRONMENT

# ENVIRONMENTAL REGULATION OF AGRICULTURE CHANGES TRACK

In December of 2015 the Danish government introduced a proposal for a new food and agricultural package which presents a significant shift in the environmental regulation of agriculture which will be more targeted and differentiated in the future. Major parts of the agricultural package build on knowledge and research provided by Aarhus University.

The Danish government's new agricultural package includes several initiatives that build on knowledge provided by Aarhus University. The package implies that the nitrogen norm reduction will be phased out which in the short term will mean an increased impact on the environment.

In the long term, however, the environmental regulation of agriculture will be more spatially targeted and based on an evaluation of local needs for measures. By the end of 2021 the targeted environmental regulation will contribute to an annual reduction of nitrogen emission by 3,800 tons.

Regulations comprise four principles:

1. Leaching access will be differentiated geographically in accordance with the goals for the nitrogen conditions in individual coastal aquatic environments. When calculating leaching access consideration will be taken to the removal of nitrogen lost from a particular place of land (retention).
2. The individual farm will be allotted an access for nitrate leaching to the aquatic environment, calculated as maximum kg nitrogen permitted to be leached per ha.
3. The individual farm must be given flexibility with regard to how to comply with the leaching access.
4. A compensation scheme will be established which compensates farms for expenses related to the reduced rights to leach in accordance with the targeted regulation.

### Measurement of nitrogen from land to water

Nitrogen can find its way to the aquatic environment via many routes. The amount of nitrogen that is actually transported to the aquatic environment varies significantly from location to location depending on the ability of the land to remove or retain the nitrogen. A priority in the new agricultural package is therefore to create new knowledge about the impact and routes of nitrogen on its way from the land to the aquatic environment.

This will take place by, among other things, expanding the measurements significantly. One of the measures will be to supplement the new measurements with 100 additional measuring stations and 1,200 extra measurements. Another important measure will be to take measurements upstream in the river system in order to get a better idea of where the source of the nitrogen pollution actually is.

In addition, funds will be earmarked in Aarhus University's policy support contract with the Ministry of Food and the Environment of Denmark to gain more knowledge about drain measurements, more efficient placement of measures, and nitrogen turnover on land types for which we currently have poor knowledge, such as wetlands.

According to Senior Researcher Charlotte Kjærgaard from the Department of Agroecology at Aarhus University, calculations demonstrate that targeted implementation of wetlands – including the implementation of small constructed wetlands and targeted drain measures – may compensate for an increased leaching from areas in relation to which drainage is a primary transport route.

### The agricultural package and the climate

Agriculture impacts not only the aquatic environment but also the climate. An implementation of targeted regulation together with increased total fertilization will result in a neutral net effect of fertilization or a minor increase in emissions.

- Increasing the allowed amount of nitrogen fertilizer to an economically optimum level will result in increased nitrous oxide emissions corresponding to 0.4 million ton CO<sub>2</sub> equivalents. To this should be added increased nitrous oxide emissions as a result of increased nitrogen leaching, which will however be reduced with time as a consequence of other targeted initiatives to reduce leaching. The effects of nitrous oxide emissions will – to a minor extent – be counteracted by increased soil carbon storage as a consequence of increased yields and thus increased supply of carbon to the soil.

Naturally, this effect depends on the size of the yield increases achieved by means of increased fertilization, but it will be within the range of 0.2 to 0.4 million ton CO<sub>2</sub>, explains Professor Jørgen E. Olesen from the Department of Agroecology at Aarhus University, adding:



Photo: Janne Hansen

- There is a range of potential measures to help reduce the agricultural emission of greenhouse gases but they are far from sufficient to achieve the goals in relation to extensive requirements for emission reductions. In connection with nitrogen efforts there is a specific need to look at instruments that can reduce agricultural nitrogen impact and climate impact at the same time. Extraction of peatland areas in river valleys may be efficient if combined with the establishment of wetlands that may further ensure nitrogen reductions.

#### **Long-term solutions to be evaluated**

Scientists from Aarhus University will contribute to the evaluation of instruments to be included in the long term in order to achieve good ecological status of the aquatic environments. Scientists from Aarhus University have and will continue to contribute knowledge on the efficiency of measures for reducing nitrate loading to the aquatic environment as part of the policy support to the Ministry of Environment and Food of Denmark as to which instruments may be applied in 2017/2018.

- We believe that targeted regulation is possible in a cost-efficient way – if implemented appropriately. This means that compensating instruments are efficient and applied where they are most useful, says one of the scientists in the investigation, Professor Jørgen Eriksen from the Department of Agroecology at Aarhus University.

Scientists from Aarhus University will contribute to the evaluation of instruments to be included in the long term in order to compensate for short-term leaching.

#### **Research-based policy support in relation to the Danish food and agricultural package**

In connection with the food and agricultural package negotiations, the Danish AgriFish Agency asked Aarhus University to calculate the leaching consequences in relation to a withdrawal of the compulsory restriction of plant-available nitrogen to below the economically optimal level, compulsory catch crops and ban against soil tillage in autumn. In addition, scientists were asked to make calculations as to the application of Environmental Focus Area elements such as catch crops, marginal areas, fallows and low forest cover. The calculations can be found in several answers and memorandums available at the DCA website (in Danish).

THEMATIC AREA: FOOD PRODUCTION, ADJUVANTS AND THE ENVIRONMENT

## GLYPHOSATE IS A RARE GUEST IN DANISH GROUNDWATER

Aarhus University, the Geological Survey of Denmark and Greenland (GEUS) and the Danish Environmental Protection Agency share the task of examining whether approved pesticides and their metabolites are leached to groundwater when used in normal farming practices at approved dosages.

Recent results from the Danish Pesticide Leaching Assessment Programme (PLAP) for the period 2011 to 2013 show that the most commonly used pesticide in Denmark – glyphosate – is rarely found in the groundwater, although it may be found in drainage water. Glyphosate and its metabolite AMPA are frequently found in drainage water that flows from the fields to nearby watercourses. Detection in drainage water may explain why the two substances are found in almost all analyzed water samples from watercourses in drained and clay-rich catchment areas. Regulation on the use of glyphosate is not necessary to protect the groundwater.

The monitoring programme examines whether approved pesticides and their degradation products leach to the groundwater following normal agricultural practices and regulations in Denmark. The results from PLAP form part of the Danish Environmental Protection Agency's overall assessment of the leaching risk of pesticides to groundwater. PLAP consists of five fields that are sprayed with approved pesticides in maximum dosages. Analyses are then carried out to assess whether the pesticides leach to groundwater and drainage water.

Since 1999 the monitoring programme has investigated the leaching risk to groundwater of 101 pesticides and/or their degradation products. Many of the pesticides tested have not given rise to any changes in their approval, but based on the results from PLAP, among others, the Danish Environmental Protection Agency has banned the substances metribuzin, terbuthylazine, rimsulfuron, metalaxyl-M and bifenox.

### Fungicide affects the quality of the Danish groundwater

PLAP results show that the fungicide metalaxyl-M and two of its metabolites continue to leach from sandy fields to groundwater following its use in potatoes in 2010. As a result of these findings, the sale and use of metalaxyl-M was banned in 2013. After screening a series of groundwater samples metalaxyl-M and the two breakdown products are now included in the list of chemicals that water works screen for in potato-growing areas in their control of drinking water.

The results from PLAP for the period 1999-2012 are described in a series of reports prepared by the Geological Survey of Denmark and Greenland (GEUS), the Department of Agroecology at Aarhus University and the Department of Bioscience, Aarhus University.

Glyphosate is rarely found in the Danish groundwater.



THEMATIC AREA: FOOD PRODUCTION, ADJUVANTS AND THE ENVIRONMENT

## DO PIGLETS HAVE ESPECIALLY HIGH ZINC REQUIREMENTS AT WEANING?

Research results indicate that the zinc requirements of piglets during the physiologically critical period just after weaning are higher than the recommended level of 100 mg zinc per kg feed. Actually, a zinc supplementation of 2500 mg/kg feed increases piglet growth significantly and prevents diarrhea with up to 50 per cent. Why is this so?

A group of scientists at Aarhus University will try to answer this question. An on-going project examines the intestinal ability to absorb and transport zinc in weaned pigs. Zinc absorption is facilitated by various zinc transporters in the intestinal cells. The project focuses on how these transporters are affected by the piglet's zinc intake and age.

More knowledge about zinc absorption in piglets is crucial to determine their zinc requirement. This knowledge is necessary for the development of zinc feeding strategies that precisely fulfill the newly weaned pigs' requirement of zinc. Therefore, the project will contribute knowledge to ensure the balance between not feeding newly weaned pigs

1. a too small amount of zinc in relation to their requirement, as this will increase the incidence of diarrhea and thereby the use of antibiotics or
2. an excess amount of zinc in relation to their requirement, as this will increase the excretion of unabsorbed zinc to the environment.

The project is funded by the Danish Council for Independent Research, Technology and Production Sciences and Aarhus University.

Piglets should be given neither too much nor too little zinc. Aarhus University scientists are trying to ensure this balance.



Photo: Colourbox

## THEMATIC AREA: FOOD PRODUCTION, CLIMATE AND GREENHOUSE GASES

# DANISH AGRICULTURE MUST ADAPT TO CLIMATE CHANGE

It is no longer sufficient to simply discuss what can be done to reduce agriculture's impact on the climate. It is imperative that Danish agriculture adapts to the inevitable climate changes.

In recent years Denmark has experienced the growing consequences of global climate change. The climate is getting hotter and wetter, and this has an impact on a wide range of factors in our cities, coasts, aquatic environment, nature and the agricultural landscape. Climate change is also important to agriculture and we need to adapt to the fact that climate change will offer new opportunities as well as problems and challenges.

As part of Aarhus University's policy support, a number of scientists focus on this particular problem. One of them is Professor Jørgen E. Olesen from the Department of Agroecology. He has contributed knowledge and material to the Danish Nature Agency.

- Climate change is already taking place and we have reached the stage where it is no longer sufficient to simply discuss what can be done to reduce emissions of the greenhouse gases responsible for human-induced global warming. We must now get on with finding solutions so we can adapt to climate change

### Flood the fields

From an agricultural point of view climate adaptation is about adjusting production conditions to the actual or expected climate conditions and their subsequent implications. Danish agriculture will not be as strongly affected as the countries in Southern Europe. However, this does not mean that there is no need for adaptation. According to Jørgen E. Olesen the major challenge is linked to increased and more intense precipitation.

- Increased precipitation is already a significant problem as it increases the groundwater levels, and this is one of the reasons why farmers have flooded fields that are difficult to till. This problem will only get worse in the future, says Jørgen E. Olesen and continues:

- In order to prevent flooding in the fields we need to investigate how to improve our drainage systems. But this seems an impossible task in some areas, and we may not be able to design water courses to remove the water fast enough. We need to think in new terms.

Therefore, the scientists are working with several scenarios. One scenario is to utilize farmers' drainage experience. Farmers may actually contribute to protecting cities against flooding by regularly flooding areas not suited for farming. This will create a new line of agricultural business, and Jørgen E. Olesen suggests that we consider this an opportunity to help improve nature and to utilize the flooded fields as wetlands that can reduce nitrogen leaching.

### Improvement is part of the solution

Water is not the only challenge. A longer and hotter growing season will mean that the yields of many crops will change. Some crops will have higher yields while others will have lower yields. If Danish agriculture is to contribute to global food production it is essential that we grow crops that benefit from a longer and hotter growing season.

- We simply have to consider if it is possible to improve well-suited and more robust crop varieties and cultivate other crops such as grass, beets and maize. We will also be able to cultivate completely new crops, such as sunflowers and grapes. In addition, cultivation systems should be adapted in order to improve the utilization of water, says Jørgen E. Olesen, and he adds that a warmer climate will result in more evaporation, thus increasing the risk of drought in the summer. This will mean a greater need for watering the fields, especially for crops with a long growing period.



Photo: Janne Hansen

Danish agriculture must prepare for a hotter and wetter climate in the future.

- We must also think about how to make use of the new climate conditions to maximise biomass production. We have to move away from cereals and towards beets, grass and miscanthus (elephant grass), which can be used for biorefinery in protein and energy production, says Jørgen E. Olesen.

#### **Time to adapt**

It is impossible to forecast with any certainty just how the emission of greenhouse gases will develop in the future and how societal development will appear over a longer period. There is also an element of uncertainty connected with predictions of floods, health risks, water shortages, extreme events, loss of biodiversity and other secondary effects of climate change.

One thing is sure – the weather will vary significantly, and this entails a new reality for Danish agriculture. The effects of climate change will cost a considerable amount of money if we do not prepare for them and take the necessary precautions to reduce the negative effects.

- Even if we stopped emitting greenhouse gases today, it would not slow down their impact immediately. Therefore, it is imperative that we consider climate change impact on agriculture and adapt production accordingly, says Jørgen E. Olesen.

THEMATIC AREA: FOOD PRODUCTION, CLIMATE AND GREENHOUSE GASES

# PREPARING CROPPING SYSTEMS FOR CLIMATE CHANGE

Climate models can be improved with more knowledge on how crops respond to climate-related stress and the atmospheric concentration of CO<sub>2</sub>.

Climate change is upon us. Until we seriously reduce the emission of greenhouse gases and their secondary effects, climate change will affect our crops. The big question is how plants will react to the new climate. Farmers and plant breeders need answers to this question so they can be prepared to improve and grow suitable robust crops.

The three-year EU project Modcarbostress, which has the participation of scientists from Aarhus University, will try to produce answers to this question. The scientists will create new and more detailed knowledge about how crops respond to the combination of increasing CO<sub>2</sub> concentration, drought, heat other stresses. The new knowledge can be used to improve the climate prediction models when several stress factors are at play in combination with increasing CO<sub>2</sub> levels.

- Global climate change creates a need for a more precise description of the impact on our crops. The aim is to improve our knowledge of plant physiological responses when crops are exposed to stress and high levels of atmospheric CO<sub>2</sub>. This is one of the areas in which the current models do not quite get it right, says Professor Carl-Otto Ottosen from the Department of Food Science at Aarhus University – one of the partners in the EU project which received a grant of 8m DKK from the ERA-net FACCE JPI Agriculture, Food Security and Climate Change.

## Top-notch test facilities at Aarhus University

With a changing climate there is a need for a more intelligent, efficient and stable agricultural system. The new climate is expected to be volatile and unpredictable, which increases the need for the ability of computational models to predict which combinations of varieties, crop rotations, sowing times and other crop management factors are the best under the given circumstances. Such models would be of great benefit to farmers and plant breeders throughout the world.

The current models lack accurate data on the combination of stress factors, especially CO<sub>2</sub>, and this is the problem that Modcarbostress will help to solve. It is especially here that the Department of Food Science at Aarhus University will be contributing to the project via its excellent experimental facilities and experience in photosynthesis.

- With our advanced greenhouses, climate chambers and photosynthesis facilities, we have extensive experience in the control and measurement of responses to CO<sub>2</sub>, explains Carl-Otto Ottosen, who together with colleagues from the University of Copenhagen and research institutions in the Netherlands, Wales, Germany and France will generate essential physiological data, develop models and control the models using data from field trials from other projects.

### Facts on the project

The project Modcarbostress is an EU project funded by the ERA-net: FACCE JPI Agriculture, Food Security and Climate Change via each country's own FACCE JPI resources.

The three-year project has a budget of 8m DKK. It is led by the research institute INRA in France with partners from Denmark, the Netherlands, Germany, France and Britain, including Aarhus University and University of Copenhagen.

THEMATIC AREA: FOOD PRODUCTION, CLIMATE AND GREENHOUSE GASES

# LEGUMES USED AS CATCH CROPS DO NOT INCREASE NITROUS OXIDE EMISSIONS

By means of biological nitrogen fixation legumes are able to absorb nitrogen from the soil as well as from the atmosphere. Therefore, these crops are the obvious choice to use as catch crops in organic farming as they contribute to increasing harvest yields by improving soil fertility. However, legumes can have a negative climate impact as they may increase the emission of nitrous oxide.

Aarhus University is involved in two research projects from which the results indicate that legumes used as catch crops do not necessarily increase nitrous oxide emissions. In a one-year field study the scientists compared the impacts of different catch crops on nitrous oxide emissions as well as yield in the subsequent crop.

It turned out that catch crops based on legumes gathered significantly more nitrogen than catch crops without legumes, and more than half of the nitrogen came from biological nitrogen fixation. In addition, the yields increased significantly because of an improved nitrogen supply. Laboratory studies demonstrated a potential risk of increased nitrous oxide emissions when using plant residues from legumes, but no increase was observed in practice when emissions were measured on an annual basis.

Catch crops based on legumes gather significantly more nitrogen than catch crops without legumes.



## THEMATIC AREA: FOOD QUALITY

# BROAD COLLABORATION PROJECT TO IMPROVE MILK QUALITY

A too high level of free fatty acids in milk may cause a rancid taste. Scientists are therefore trying to find new ways to limit free fatty acids as well as new methods to measure the levels of these within the framework of the major innovation consortium FUTUREMILQ. The consortium aims to examine how dairy herds can supply consistent, high-quality milk.

Deviations in raw milk quality are a challenge to farms with automatic milking systems. The problems are caused by bacteria that are resistant to heat treatment – the so-called thermo-resistant bacteria – or a too high level of free fatty acids which give the milk a rancid taste. Within the framework of the FUTUREMILQ consortium, Associate Professor Lars Wiking and Postdoc Mette Marie Løkke from the Department of Food Science at Aarhus University are measuring the levels of free fatty acids.

- The problems with free fatty acids increased 10-15 years ago when automatic milking systems were introduced. It is a complex problem caused by many factors ranging from feed, milking frequency, pumping to the storing temperature of the milk. Lars Wiking describes the aftertaste as “somewhat like billy goat”, while Mette Marie Løkke uses words like “the smell of parmesan cheese”.

- One problem related to the rancidity caused by free fatty acids is that it is very volatile and changes over time, which makes it very difficult to measure. Therefore, several measurement methods have been applied, and the aim is to develop a rapid and mobile measurement method to be used on-farm, explains Mette Marie Løkke.

- We want to be able to bring our tool to a farm with problems and carry out measurements, push some buttons, measure again and see if the problem is solved. During this project we have demonstrated different methods that may be applicable if they are developed further. Today, the level of free fatty acids is included in the settlement criteria for some dairies, and this means that farmers are paid less for their milk if the level is too high.

### A question of method

Lars Wiking and Mette Marie Løkke have spent quite some time developing methods and comparing different measurement methods to the reference methods. The so-called BDI-method is the primary reference method, but it is expensive and cannot be performed quickly or directly at the farms and is therefore not used as a standard method.

- However, other methods have the potential of becoming on-farm solutions: a small measuring device using infrared light seems promising – this is also the principle used in laboratories to measure fat and protein contents of milk. We still need a lot of testing to ensure that the method is not too imprecise, Mette Marie Løkke emphasizes.

### When can you taste whether the milk is rancid?

Another method, examined as a part of the AU project efforts, is sensory experiments in which a test panel tastes milk samples with varying levels of free fatty acids in order to identify when you actually register the rancid taste. The experiment demonstrated that test panel experiences varied significantly and that it is very difficult to identify and evaluate the rancid taste. The sensory experiments were compared to a series of other measuring methods to determine which method most accurately describes the aftertaste and thus is eligible as quality control. The aim is to find a quick type of quality control measuring according to the taste deviance.

Lars Wiking’s and Mette Marie Løkke’s results are now incorporated into the remaining project work. A so-called “measuring ambulance” (mobile monitoring system) to bring to the farm will be developed; it contains equipment able to measure milk quality in new ways.

### Joint efforts on many fronts to improve milk quality

Anette Gravgard from the Danish Technological Institute, AgroTech, is FUTUREMILQ project manager and she explains that – in addition to measurement methods – the project also includes efforts in relation to hygienic design and development of monitoring and early warning systems that make it easier to identify problems with heat-resistant bacteria and free fatty acids.

- Data from the 30 participating farms are now available and the individual farmer can follow and log his own quality parameters. We aim to develop methods that allow the farmer to currently correct the milking parameters that may cause problems and that also allow milking robot producers to utilize the knowledge achieved on hygienic design – and maybe also incorporate some of the measuring methods that we develop, says Anette Gravgard.

At present a manual on hygienic design is being prepared – describing hot spots in the milk flow from robot to milk tank where problems may arise.

### Strength lies in joint efforts

Quality manager of global milk production in Arla Foods dairy company, Helle Skjold, is a member of the FUTUREMILQ steering committee, and she states the following reasons for joining the project:

- The dairies are the end users of farm products and if we want to produce high-value products to ensure higher prices it is of the utmost importance that the milk quality is excellent. Therefore, our efforts to reduce the prevalence of free fatty acids and bacteria – including heat-resistant bacteria – are very important to us as well as to our farmers who are paid for their milk quality. For instance, cheese ripening takes several months and it is essential that the raw materials are as good and fresh as possible. Also, Arla sells a lot of liquid milk and the taste of this fresh milk is very important, she says.

Helle Skjold considers the consortium design an advantage, representing both research and the entire value chain:

- Automatic milking systems constitute a challenge. Therefore, it seems natural to team up with milking robot producers as technological development is essential in order to solve the problems. To us it is important that research is applied – and that is exactly what this consortium can do because all partners have helped define what they consider necessary.

Arla has participated in several of the project's work packages and has made data from Arla's analyses available, including annual screenings for heat-resistant bacteria.

#### Project facts

FUTUREMILQ is a four-year project running from April 2013 to October 2017. The budget is 23.2m DKK, of which 10.6m DKK is funded by the Danish Council for Technology and Innovation. The project is managed by AgroTech and project participants include a number of partners such as the Department of Food Science, iNANO, both Aarhus University, and SEGES.

#### What happens when milk turns rancid from lipolysis?

Milk fat consists of fat globules encased by an outer membrane. This membrane may become unstable or damaged if milk is not treated correctly during milking. If the membrane is damaged the milk enzymes will come in contact with the core fat, releasing free fatty acids and giving the milk a rancid taste.

Associate Professor Lars Wiking and Postdoc Mette Marie Løkke from the Department of Food Science are working on finding methods to measure the level of free fatty acids in milk.

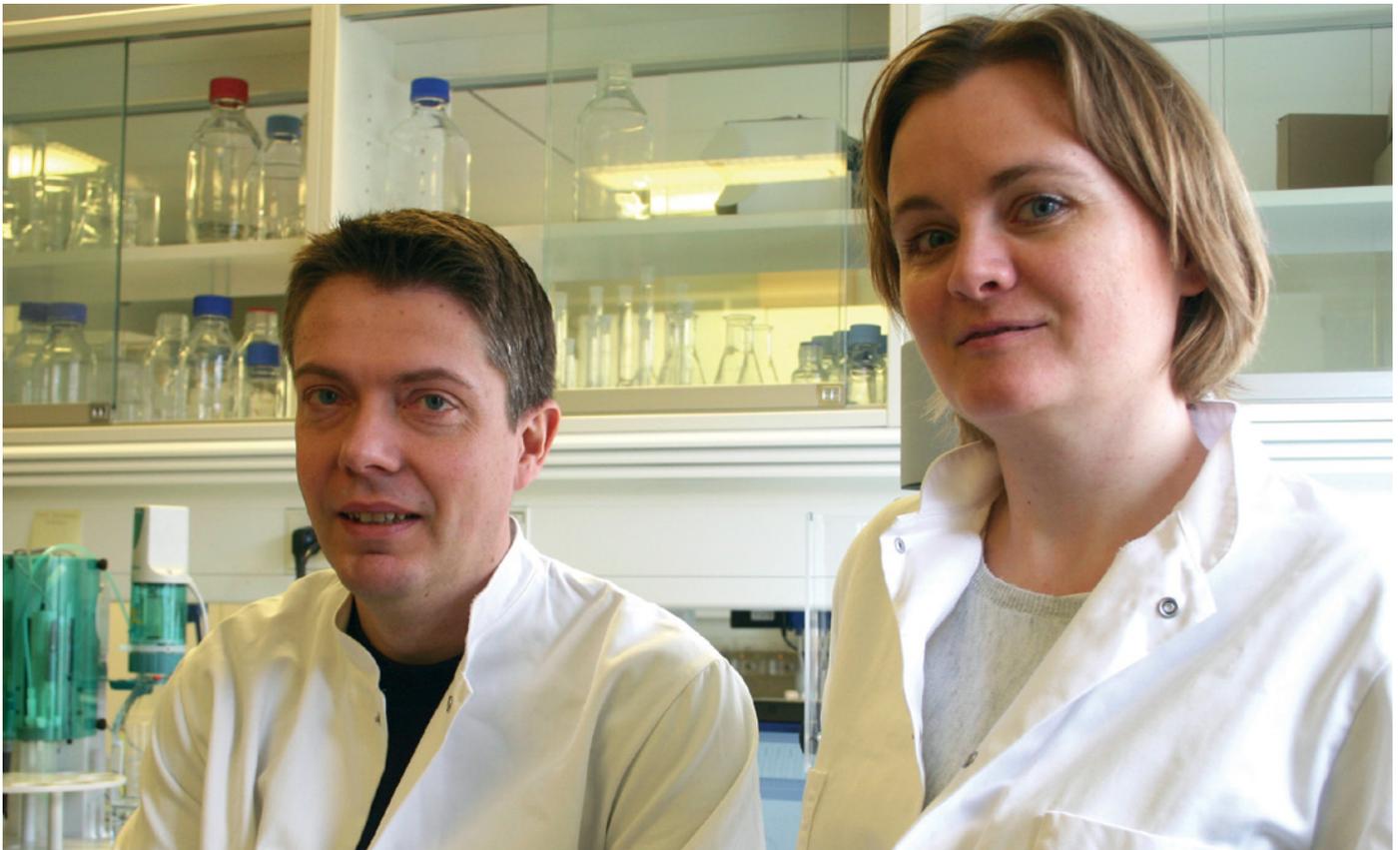


Photo: Janne Hansen

## THEMATIC AREA: FOOD QUALITY

# VOLATILE ORGANIC COMPOUNDS CAN REVEAL WILD ROCKET SALAD QUALITY

When consumers buy fresh fruit and vegetables freshness is essential. Most of us have brought home packaged wild rocket salad or other leafy green vegetables from the supermarket – only to discover upon opening the package that the leaves are rotten and unfit for human consumption.

Scientists from Aarhus University have demonstrated that a relation exists between changes in wild rocket quality and the build-up of the so-called volatile organic compounds (VOCs).

The results were achieved by means of a new analytical method developed by Research Assistant Alexandru Luca from the Department of Food Science at Aarhus University in his PhD project.

- The overall project aim was to develop a method to examine – by means of VOCs – how and why the quality of leafy green vegetables changes after harvest, says Research Assistant Alexandru Luca, and explains further:

- The project demonstrates that the release of VOCs from wild rocket may be related to the quality of the raw material at the time of packing, the O<sub>2</sub> permeability of the packaging material and the storage conditions after harvest.

In the long term perspective the project participants hope that the method will be used by companies that produce and manage packaged fresh fruit and vegetables, thus providing consumers with higher quality packaged fresh produce.

Scientists have demonstrated that there is a relation between the quality of packaged wild rocket after harvest and the release of volatile organic compounds.



## THEMATIC AREA: FOOD QUALITY

# TOWARDS ZERO PESTICIDE RESIDUES IN DANISH APPLES

Research shows that it is possible to reduce or eliminate pesticide residues in apples. The research results are now being tested in practice.

Because apples are exposed to many pests and diseases it is often necessary to spray the fruit with pesticides. Although we consumers put great store on the cosmetic appearance of fruit, we really would rather not eat pesticide residues.

Research results from Aarhus University offer several suggestions for how to solve this dilemma in conventional fruit production. Scientists in collaboration with the horticultural advisory service will test research results in practice in a four-year project allocated 4.8m DKK from the Green Development and Demonstration Programme.

- Requirements for its cosmetic appearance and a large number of pests make apples one of the most heavily sprayed crops. Therefore, pesticide residues are often found on the fruit. The quantities left on the fruit do not constitute a health risk, but the fact that they are there often gives negative publicity and politically there is pressure to reduce pesticide use, explains the leader of the project, Senior Researcher Marianne G. Bertelsen from the Department of Food Science at Aarhus University.

### Zero residues

Scientists at the Department of Food Science have previously demonstrated that with optimal spraying of fruit in the period before fruiting, it is possible to avoid treatments in the period when the fruits develop without this leading to large losses and to pesticide residues in the fruit.

In DAFRUS, these research results are subjected to a reality check in three commercial fruit plantations. Here the strategy will involve different disease pressures, cultivar combinations, microclimates and spraying agents. This will result in a better basis for evaluating the extent and the costs of the implementation of the pesticide-free strategy in the industry. In addition, the scientists will develop tools that can give advance notice of how serious the rot/fungus attacks are expected to be. The tools are to be used both in orchards and apple storage facilities.

- With this project we can get a better understanding of whether and, if so, how much of the Danish apple production could be produced without pesticide residues. And by reducing the incidence of rot through the use of optimized pre-treatment technologies we can reduce wastage from stored fruit, says Marianne G. Bertelsen.



Photo: Lise Balsby

### Project facts

The project "Danish fruit without pesticide residues" is a four-year project allocated 4.8m DKK from the Green Development and Demonstration Programme under the Ministry of Environment and Food of Denmark. It is carried out by Aarhus University in collaboration with GartneriRådgivningen - HortiAdvice Scandinavia (the horticultural advisory service).

## THEMATIC AREA: CONSUMER BEHAVIOUR AND FOOD PREFERENCES

# DIVIDED OPINIONS ON VITAMIN D ENRICHMENT

A new study from Aarhus University shows that Danes generally accept food products enriched with vitamin D, but when in the supermarket Danes prefer food products which are not enriched with vitamin D.

Vitamin D is important for the absorption and metabolism of calcium, as well as for maintaining healthy bones and muscles. Danes generally have too low a level, and this is mainly because the sun – the main source – is absent for much of the year. Getting an intake of vitamin D through the diet will therefore be relevant for many, but are consumers actually interested in buying foods with added vitamin D?

This is the question that researchers at the MAPP Centre at Aarhus University have asked 1,263 Danes in an online survey. The survey is part of the agreement on policy support to the authorities according to which the university, among other things, examines consumers' attitudes to and understanding of nutrition and health labelling such as the Keyhole and Whole Grain Labels.

The results show that to a large extent the population is divided in their attitudes to enriched foods. The majority is positive towards the possibility of adding vitamin D, but that does not mean that they would buy those products themselves. Although the concept is widely accepted, Danes prefer products that do not contain added vitamin D.

- It is easy to say that you accept a product, but quite another thing to actually buy it. Danes are generally skeptical of enriched foods, and this is primarily because a food product that is enriched is less natural. When it also alleges to affect your health, this arouses skepticism, explains George Tsalis, Research Assistant at the Department of Management and one of the authors of the study.

He states that this is problematic since vitamin D deficiency is associated with a variety of ailments such as depression, bone and muscle pain and even cancer. It is particularly critical to a number of population groups – particularly the elderly, people with dark skin and persons with limited sun exposure.

- It is detrimental to the health of the individual and costly in many ways for society to undo the damage of prolonged vitamin D deficiency. If we could change the approach to fortified products and make them an everyday part of the Danish diet, it would have a major beneficial effect in the long term, says George Tsalis.

### Milk is ideal

In the new study, the researchers asked about general consumer knowledge of vitamin D and perception of vitamin D enrichment – on a general level as well as specifically in relation to selected products such as milk and bread. In addition, the researchers investigated whether consumer perception of the fortified products depends, for example, on whether the packaging clearly states this and if vitamin D is added at the recommendation of the Danish Veterinary and Food Administration.

The results show that the Danish population's acceptance of food products with added vitamin D is primarily influenced by three factors: Consumer attitudes towards vitamin D, the perception of the health benefits of vitamin D and who is in control of the enrichment.

Although it appeared that respondents were generally not overly willing to buy the enriched products, the researchers found that milk was the product that the consumers thought was most suitable for vitamin D enrichment. This may be because vitamin D fortified milk has already been introduced to the Danish market, albeit without much success.

- In general, the study shows that Danes want freedom of choice. They want the authorities to control vitamin D enrichment, and they prefer that food producers do not add the vitamin at will, says George Tsalis. He further elaborates that two out of three respondents also pointed out that it was insufficient to mention in the list of ingredients that the product contains added Vitamin D. It should be clearly stated on the packaging.

- This is in accordance with the previous results which demonstrated that respondents emphasize the importance of being able to deselect vitamin D fortified products.

### Communication is the only solution

The question is whether the Danish attitude to fortified products can be changed. According to George Tsalis it is important to communicate the benefits of vitamin D in order to create a basis for further acceptance of the concept. At the same time it should be clarified that the authorities have the overall responsibility for regulating the enrichment of food products with vitamin D.

- When it comes to public policy, communication is the only solution. Only by highlighting the usefulness of vitamin D and the consequences of its deficiency can we change attitudes and behaviour, says George Tsalis.



## THEMATIC AREA: CONSUMER BEHAVIOUR AND FOOD PREFERENCES

# YELLOW CHEESE WITH REDUCED SALT CONTENT

It is possible to produce cheese with a reduced salt content without a negative effect on product quality.

The salt intake in Western societies is about twice as high as the recommended level. WHO and the EU aim to reduce salt intake by reducing the salt content in a range of food products, including cheese. In order to meet the keyhole label requirements, the salt content has to be reduced in the yellow Danish cheeses such as Danbo and Samsø.

In a current research project, scientists from Aarhus University and the University of Copenhagen – together with industrial partners – have examined the possibility to reduce the salt content of Danish yellow semi-hard cheese and still maintain the quality of taste and texture.

So far, the project has demonstrated that it is technically possible to produce cheese with a reduced salt content, and to counteract the potential negative effect that may appear on some quality characteristics of the product. A shorter brining time reduces salt content but makes the cheese softer and more elastic and the taste less salty and more bitter.

A consumer survey including tasting will demonstrate just how much salt content can be reduced. To a certain degree, the use of various starter cultures and rennet types seems to be able to counterbalance the effect of reduced salt content on cheese texture and taste.

The project partners expect that the knowledge achieved can be used directly in the development of Danish yellow cheeses with a lower salt content and high quality in relation to sensory and texture properties.

The total project budget is 10.7m DKK, and is funded by the Danish Dairy Research Foundation, Arla Foods and the Future Food Innovation consortium of the Central Denmark Region.



## THEMATIC AREA: CONSUMER BEHAVIOUR AND FOOD PREFERENCES

# WHAT DO THE ELDERLY THINK OF THEIR FOOD AND MEALS?

There is a lot of knowledge about nutrition for the elderly, but how do you actually define a good meal? Researchers at Aarhus University have been examining this via a pilot project using a 'meals on wheels' service for senior citizens in their own home. The project is the precursor for a larger investigation in 2016.

The pilot project in 2015 was commissioned by the Danish Ministry of Environment and Food who sought better knowledge about the importance of food and meals for the quality of life, including food enjoyment and ability to eat, of elderly people in their own home. The project is a precursor for a national survey with a similar focus taking place this year.

The investigation involved qualitative interviews with senior citizens in three local authorities (Holstebro, Odder and Odense) who had their meals delivered. Interviews were also carried out with the relevant staff in the local authorities, in the community care system and with the caterers supplying the meals. A total of 21 persons participated in the investigation.

Helle Huus Bjerger, research assistant at the Department of Food Science at Aarhus University was the anchor person on the project, which was a joint effort with the MAPP Centre at Aarhus University. She says:

- The most surprising element was that all other stakeholders bar the elderly themselves thought that the social aspect of a meal would be extremely important; for the elderly this was not such a big issue. What they actually prefer to do is to eat with someone they know, but not necessarily to have company at meal times at all costs. Some were, for example, sceptical of concepts such as mealtime companions and meal cafés.

### Nutrition and rehabilitation go hand in hand

Among the elderly who participated in the study there was general satisfaction with the meals supplied, and there was a continuous focus on quality development and evaluation at the interviewed caterers. However, there was a plea for flexibility from both the caregivers and the elderly, both regarding the timing of the meals and, in a broader sense, regarding meal solutions. The collaboration with, for example, physiotherapy on rehabilitation could be better integrated with the work on meals than is the case today.

- There is still a certain degree of disconnected fiscal planning in the municipalities, says Helle Huus Bjerger, and continues:

- The two areas of nutrition and rehabilitation are closely interlinked and interdependent so that better teamwork would be an obvious way forward.

### New project on the way

The project that will be started this year is likely to be a national survey of nutritional status, quality of life and food preferences of senior citizens in their homes. Design and planning of this project is still in the preparatory stages in association with the Danish Veterinary and Food Administration. The survey will use questionnaires for citizens above the age of 65, and the entire project is expected to finish in September 2016.

The elderly like to have the company of someone they know during their meal, but do not want company at any price.



Photo: Colorbox

THEMATIC AREA: IMPORTANCE FOR HEALTH OF DIETARY AND EATING HABITS

# START YOUR HEALTHY EATING HABITS AT SCHOOL

Healthy and bright children with better learning abilities is the reward when good eating habits are introduced in a structured way at school. A Danish study shows that about half of the country's schools have introduced measures to promote healthy eating habits.

If your stomach is rumbling with hunger it may be difficult to concentrate on learning at school, and if you fill yourself with sweets, chips and fast food, it can, among other things, lead to malnutrition and obesity. Neither of these situations promotes health in body and mind.

Several of Denmark's schools are doing something about this problem because they believe it is important to stimulate and help children to eat healthily. How prevalent the use of various schemes and initiatives in the country's schools and municipalities is, and whether we can learn from

each other's experiences was the focus of a nationwide study conducted by researchers from the MAPP Centre at Aarhus University.

The study was initiated at the request of the Danish Veterinary and Food Administration (DVFA) who wished partly to gain an overview of the number of Danish local authorities and schools that focus on healthy food and food enjoyment, and partly to have an overview of the initiatives that can be used to develop and instill a healthy food culture in Danish schoolchildren.

Healthy food habits at school support learning and concentration in children



The study, which is described in a report published by DCA found that a major part of the country's schools have introduced initiatives and activities that make healthy food, and enjoyment thereof, part of everyday life at school. Just over half (53.3 percent) of the schools are working explicitly towards incorporating policies and concrete actions related to the promotion of healthy food and meals, while the same is true for just under a third (32 percent) of the country's local authorities.

- Children spend much time in school and day care, and up to half of the calories they eat are consumed during this time. It is therefore important that children are offered conditions that support healthy eating habits, says Research Assistant Trine Mørk from the MAPP Centre.

#### **Healthy eating habits improve learning**

Healthy foods in appropriate amounts promote children's health, well-being and learning. It is therefore also in the school's own interest that children eat the right foods. A healthy food culture at an early stage is also important in order to build skills in making healthy choices later in life.

Putting healthy food and food enjoyment on the school agenda allows children to learn about nutrition and strengthen their social and personal skills when they, for instance, lend a helping hand in the canteen and thus learn how to cook and collaborate with others. A positive secondary effect of eating healthy food in a social environment is that children and teachers find that social relations improve. With the aim of measuring the commitment of Danish schools and local authorities to making healthy food and food enjoyment part of everyday life at school, as well as how and why they do so, researchers sent questionnaires to all of the country's 1,675 schools and 98 local authorities. About half of the schools (810) and authorities (50) responded partially or fully to the questionnaire.

The most common measures used in schools are meal schemes. This usually takes the form of a lunch offer to replace a packed lunch, but also breakfast, fruit schemes, or a combination of these. In most of the instances where meal schemes are used, the school will set nutritional standards for the meals that are based on DVFA recommendations for healthy school meals.

Based on the answers to the questionnaires, the researchers completed in-depth qualitative interviews and observations at ten selected schools and two authorities to examine the schools' and the local authorities' policies in the area, as well as their experience and background for implementing the chosen initiatives.

- In general, it appears that the schools that are actively working on this have an ambition to provide the right conditions for healthy eating and food enjoyment and that they mainly do it to promote better eating habits and well-being in the pupils, says Trine Mørk.

#### **Half of all schools actively support healthy eating habits**

The most prominent reason among schools for initiating measures is that they wish to optimize student learning.

- Schools believe that healthy and hearty food has a positive impact on both student well-being and ability to concentrate, which can give teachers a better platform for effective teaching, explains Trine Mørk.

The 10.6 percent of schools where no actions have been initiated attributed that lack mainly to either having other priorities or a lack of resources. The authorities that are not active in setting an agenda for healthy eating in the schools indicate that this is primarily because such initiatives have been devolved to the schools. A common characteristic of the active authorities is that there is a high degree of dialogue and participation between the relevant stakeholders, including the children.

#### **Room for improvement**

In the vast majority of cases the motivation and drive in establishing and carrying out the initiatives lies with certain key people at the schools. Furthermore, support from management, teachers, parents and pupils alike is essential.

- Many good experiences have been recorded in schools and if these could be shared with others that would be a great plus says Trine Mørk. She also has a few other bits of advice to both schools and local authorities:

- It may be advantageous to give the focal actors – the children – more influence on the conception and creation of healthy meals. Children have lots of ideas and opinions. Political support and stronger anchoring at the school are also good starting points for further development.

THEMATIC AREA: IMPORTANCE FOR HEALTH OF DIETARY AND EATING HABITS

## CHEESE IS SURPRISINGLY HEALTHY

Scientists may have solved the conundrum of why the French can drink wine and eat lots of cheese – and still remain slim and healthy. It appears that cheese has several health benefits. When you eat cheese, the cheese affects the composition of the bacterial flora in the gut.

Cheese also helps to increase your body's energy consumption.

These interesting results are from a research project that scientists from the Department of Food Science at Aarhus University participated in together with the University of Copenhagen.

The test persons, who were given a diet containing cheese or milk, had a higher level of the anti-inflammatory fatty acid butyrate. Not only does butyrate help reduce cardiovascular disease, the fatty acid also acts as a catalyst for the metabolic rate, keeps the blood fat percentage low and helps prevent obesity. The changes were most pronounced in cheese eaters.

The study was supported by funds from Innovation Fund Denmark, Arla Foods and the Danish Dairy Research Foundation, and is part of the project "FIAF – Milk in regulating lipid metabolism and overweight. Uncovering milk's ability to increase expression and activity of fasting-induced adipose factor".

Postdoc Morten Rahr Clausen and his colleagues have found that cheese has several health benefits. When you eat cheese, the cheese affects the composition of the bacterial flora in the gut.



Photo: Nino Hermansen

## THEMATIC AREA: IMPORTANCE FOR HEALTH OF DIETARY AND EATING HABITS

# A SUMMER BOUQUET AGAINST DIABETES

Thyme, carrots and elderflower can do more than just smell fragrant and taste good. They also contain ingredients that have a positive impact on type 2 diabetes. Scientists from the Department of Food Science at Aarhus University demonstrated this in a number of studies, where selected plants were screened for compounds that can increase glucose uptake and therefore potentially prevent type 2 diabetes. Type 2 diabetes is a serious ailment that is becoming increasingly prevalent globally.

The researchers screened carrots, cabbage, broccoli, thyme, summer savoury, elderflower, roseroot and purple coneflower for potentially beneficial compounds. The researchers chose the eight plants based on either their medical background, such as traditional anti-diabetic agents, or their importance within food and nutrition.

- Our results show that the exploitation of bioactive substances from plants for producing new types of remedies against type 2 diabetes has potential, says Senior Researcher Niels Oksbjerg from the Department of Food Science.

The project was financially supported by Innovation Fund Denmark and was a collaborative project between the University of Copenhagen (project leaders), University of Southern Denmark, University Hospital of Southern Denmark and Aarhus University.



Photo: Colourbox

Carrots, elderflowers and thyme contain compounds that can be beneficial against type 2 diabetes.

## THEMATIC AREA: IMPORTANCE FOR HEALTH OF DIETARY AND EATING HABITS

# PIGS USED AS MODELS TO HELP PREVENT OBESITY PROBLEMS

Modern man is poorly adapted to energy dense diets low in fibre and high in fat and sugars. The consequence of such an unhealthy lifestyle is an increased risk of obesity, cardiovascular disease and type 2 diabetes. Professor Knud Erik Bach Knudsen from the Department of Animal Science at Aarhus University is in charge of a new research project that will explore how diets rich in protein and fibre alone or in combination can be used to mitigate obesity-related diseases and help improve public health.

Controlled intervention studies will be performed on human subjects with metabolic syndrome and in obese miniature pigs. A further aspect of the project is to develop a pig model that has metabolic abnormalities corresponding to those in people with metabolic syndrome.

A better understanding of how the body responds to fibre and protein can pave the way for the development by the commercial project partners of dairy or cereal-based products with beneficial effects on metabolic syndrome, or a protein snack that can be eaten before a meal with a beneficial effect on appetite and blood lipid levels following the meal.

The four-year project has a total budget of 23m DKK, including a grant from Innovation Fund Denmark of 17.5m DKK. The project will be carried out in collaboration between Aarhus University Hospital, Rigshospitalet, University of California – Davis, Norwegian University of Life Science, Arla Food Ingredients, Lantmännen and DuPont.

## MORE THAN RESEARCH

# IMMERSE YOURSELF IN FOOD AND AGRICULTURAL SCIENCE

Animal production, organic farming or food technology: At Aarhus University you can immerse yourself in all aspects of agricultural and food production.

If you want to get a degree in the area of agriculture, nature and food production, then Aarhus University may have the right degree programme for you. You can for example earn a bachelor degree in agrobiolgy. This programme focuses on how to develop sustainable and efficient agriculture while interacting with nature and the environment. Applications for this programme have almost doubled since 2012 and have increased every year since it was first introduced in 2008.

In this programme you will work with agroecology systems and how to find solutions to complex problems within agriculture and food production. Your rubber boots will sometimes be muddy and you will also sometimes be wearing a lab coat; you will study academic text books and process data. During your studies you will go on field trips, and there are excellent opportunities for internships where you will be introduced to agrobiolgy in practice.

If you already have a bachelor degree you may want to follow a master programme focusing on agricultural and food science. The M.Sc. in Agrobiolgy focuses on sustainable food production. The courses are taught in English and take place in an international research environment where you will gain significant biological knowledge about sustainable animal and crop production focusing on health, welfare, product quality, ecology and environmental impact. During your studies you will have the opportunity to specialise in animal production, plant nutrition or organic farming.

If you are specifically interested in the interplay between food and health, the master degree programme Molecular Nutrition and Food Technology may be ideal for you. With this M.Sc. in hand you are prepared to work with research and development in food and other companies focusing on the prevention of lifestyle diseases and raw material quality.

### Postgraduate programme in animal welfare

If you work with animal welfare in a professional capacity and need new inspiration and a more scientific approach to the subject you now have the opportunity for postgraduate education at Aarhus University. The Department of Animal Science offers a master programme targeted at veterinarians, advisors, agricultural college teachers and other professionals working with animal science.

The education programme is at the master level and focuses on biological, production-related, administrative and political aspects of animal welfare. The programme is scheduled so you can still have your day job. You must have a relevant bachelor degree and at least two years of relevant professional experience to be admitted.

### AU offers the following degree programmes in food and agriculture:

#### BSc programmes in food and agriculture

Agrobiolgy – Choose between three tracks:

- Animal biology and production
- Food quality
- Plant and environmental science

#### MSc programmes in food and agriculture:

- Agrobiolgy
- Organic Agriculture and Food Systems (EUR-Organic) (Double Degree)
- Agro-Environmental Management
- Molecular Nutrition and Food Technology
- Sustainable Animal Nutrition and Feeding

#### MSc programmes in food and agriculture:

- Master programme in evaluation of animal welfare in primary production

Read more about the programmes at [dca.au.dk/en/masters-degree-programmes/](https://dca.au.dk/en/masters-degree-programmes/)

## MORE THAN RESEARCH

# VISIT THE RESEARCH CENTRE

Everybody has the opportunity to get closer to the food and agricultural research taking place at Aarhus University departments in Foulum, Flakkebjerg and Aarslev.

### Want to know more?

Guided tours are arranged for technical and agricultural college students, high school classes and other groups such as associations or clubs for a minimum of 10 and maximum of 30 participants.

A guided tour usually lasts 1-2.5 hours.  
The guided tours are free.

Book a guided tour and read more about these and other activities at AU Foulum, AU Flakkebjerg and AU Aarslev at [dca.au.dk/en/about-dca](http://dca.au.dk/en/about-dca).

A very popular activity at AU Foulum is the free guided tours where groups can visit research environments, animals in experimental facilities and laboratories, and learn how a biogas plant works.

The guided tours are targeted at the individual group's interests and level of expertise, usually in a dialogue with the group. Different types of guided tours are offered: a general guided tour where the most exciting facilities and actual research projects are selected in advance. This tour is eventful, inspirational and an excellent choice for science classes. The thematic tour focusing on a single subject is another tour type.

For technical and agricultural college students it is possible to participate in practical assignments and tasks in connection with a guided tour. Finally, guided tours may also be arranged on special occasions, for instance if a visitor is in Foulum for a meeting and wants to see the facilities.

Every year several hundred Danish students visit Aarhus University in Foulum in order to get close to research.



Photo: Metta Randimo



Photo: Jørgen Weber

### AARHUS UNIVERSITY WELCOMES APPLE AS NEXT DOOR NEIGHBOUR TO AU FOULUM

Aarhus University in Foulum close to Viborg will soon have a new neighbour. The new neighbour will be located in the fields that have previously been used for growing crops.

The computer giant Apple has decided to locate a huge data centre adjacent to AU Foulum. In the long term the university hopes that new research collaboration emerges with the global company. Apple is very interested in sustainable energy. The technology giant has met with scientists at AU Foulum on several occasions to learn about the possibilities of using renewable energy.



Photo: Anders Trærup

### AARHUS UNIVERSITY'S AGRICULTURAL SCIENCE IN WORLD ELITE

With an impressive ninth place Aarhus University is ranked among the world's top ten universities with regard to agricultural sciences, according to the U.S. News Best Global Universities rankings. These rankings lean on Thomson Reuters bibliometric analyses. Aarhus University is the highest ranking Danish university and third best in Europe after Wageningen University and Ghent University.



Photo: Lars Kruse

### EUROPEAN PHD STUDENTS MET IN DENMARK

Thanks to a huge European research network the Department of Animal Science at Aarhus University succeeded in attracting PhD students from 14 European countries when the department hosted a two-week summer course in pig gastrointestinal health in August. The course programme included scientific presentations as well as a series of practical laboratory assignments. After the course, the organizers received top marks from the participants who declared that they had truly enjoyed the mix of theory and practice.

#### Subscribe to the DCA Newsletter

The monthly newsletter from DCA includes news on food and agriculture and upcoming events.

Subscribe to the DCA Newsletter at [dca.au.dk/en](http://dca.au.dk/en).



Photo: Lise Balsby

### HUGE THIRST FOR KNOWLEDGE AT ANNUAL FOOD FESTIVAL

Thousands of guests visited the Department of Food Science tent at this year's Food Festival in Aarhus. Visitors had the opportunity to get up close to science by evaluating the taste of various fruit drinks and discovering the difference between organic and conventional parsley. The Department of Food Science expects to participate in the popular Food Festival next year with even more activities.



Photo: Lars Kruse

### AGRICULTURAL COMPUTER GAME WINS EU AWARD

Scientists from Aarhus University helped develop the computer game "Future of Farming" that won the EU Commission award for being the best way to disseminate agricultural-political subjects. The aim of the game is to provide insight into agricultural development and the ways in which different development opportunities influence the environment, economy and a range of other factors. The target group is students in high schools and agricultural schools.



Photo: Lars Kruse

### VIVI HUNNICKE NIELSEN BECOMES VICE-PRESIDENT IN ANIMAL TASK FORCE

International Coordinator Vivi Hunnicke Nielsen, DCA – Danish Center for Food and Agriculture, has been elected vice-president in Animal Task Force.

At a General Assembly in November, Associate Professor Vivi Hunnicke Nielsen, DCA – Danish Center for Food and Agriculture, was elected new vice-president for the 17 European knowledge institutions in Animal Task Force (ATF), an organisation that also includes members from various agricultural sectors.

ATF is a European Public-Private Partnership (PPP) representing scientists, farmers and the agricultural industry and aims at encouraging a sustainable and competitive livestock sector in Europe through knowledge exchange and innovation.



Illustration: Colourbox

#### DCA AND SOCIAL MEDIA

DCA is on Facebook and LinkedIn, where you can find the most recent knowledge from food and agricultural research at Aarhus University.

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# 375

Number of scientists (incl. PhD students) at Aarhus University working in food and agriculture science

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# 19

Number of reports published by DCA in 2015  
See the full list at [dca.au.dk/en](http://dca.au.dk/en)

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# 277

Amount of money (million DKK) received by DCA in 2015 for research-based policy support from the Ministry of Environment and Food of Denmark

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# 9829

Number of times DCA reports were downloaded from [dca.au.dk](http://dca.au.dk) in 2015

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# 717,5

Total amount (million DKK) used by DCA on food and agricultural research via gearing of the funds from the Ministry of Environment and Food of Denmark

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# 46

Number of meetings and other events in 2015 which were open to the public

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# 150

Approximate number of commissions carried out by DCA as part of the agreement with the Ministry of Environment and Food of Denmark

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# 50

Number of PhD dissertations approved in 2015

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# 13

The number of areas of scientific expertise covered by the contract with the Ministry of Environment and Food of Denmark.

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# 615

Number of scientific publications

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