



The National Food Institute

50

60<sup>th</sup> anniversary publication:

**At the forefront  
of healthy, safe,  
and sustainable food**

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1<sup>st</sup> EDITION, September 2019  
**60<sup>th</sup> anniversary publication:** At the forefront of healthy, safe, and sustainable food. The National Food Institute, 2019.  
**COPIES:** 1.000  
**ISBN:** 978-87-93565-52-4  
**FRONT PAGE:** Salmon  
**PHOTOS:** Colourbox  
**EDITING:** Heidi Kornholt and Fokus Kommunikation  
**CONTENT:** Fokus Kommunikation and the National Food Institute with contributions from the Institute's staff  
**TRANSLATION:** Miriam Meister and Kirsten Becker Hansen  
**GRAPHIC DESIGN:** Rentegner.dk  
**ILLUSTRATIONS AND GRAPHICS:** Rentegner.dk and Susanne Carlsson  
**PRINT:** STEP  
**COPYRIGHT:** National Food Institute, Kemitorvet, Building 202, 2800 Kgs Lyngby, tel. +45 35 88 70 00  
[www.food.dtu.dk](http://www.food.dtu.dk)

# The National Food Institute celebrates its 60th anniversary and continues having high ambitions

The National Food Institute wants to make a difference, nationally and globally, as it continuously conducts ambitious research of high international quality in favour of society.

The Institute provides benefit and brings its knowledge into play by offering teaching, value-creating innovative solutions, and providing advice to national and international public authorities for the benefit of society. This motivates everybody at the Institute and gives staff a sense of purpose in their work.

The vision of the National Food Institute is to prevent disease and promote health, to create sustainable technological solutions, and to develop new and better food products for a growing world population. These visionary goals are consistent with the UN's 17 Sustainable Development Goals. Thus, the Institute wants to solve some of the biggest challenges the world is facing.

Most of the Institute was founded back in 1959 when the law on establishing a united national food institute was adopted. Based on research and monitoring, the Institute was to advise Danish public authorities and other national stakeholders on food safety and nutrition. Since then, the Institute has achieved many results and expanded its working area significantly.

I am immensely proud of being at the head of the dedicated staff at the National Food Institute these years. It gives me great pleasure to celebrate the Institute, its staff, and many opportunities on the occasion of the Institute's 60th anniversary.



We hope that this anniversary publication will inspire you, whether you are a student, a cooperating partner from public authorities or the industry, or a research colleague from other universities. Moreover, we would like to invite you to a deeper conversation at the National Food Institute so that we can discuss how we can make a difference together and solve some of the world's global challenges.

Happy reading.

Christine Nellemann  
Director of Institute



# At the forefront of healthy, safe, and sustainable food - for the benefit of society

In its capacity as an adviser, the National Food Institute helps public authorities and businesses provide consumers with good health and safe food. Innovation paves the way for new, value-creating solutions for businesses. Education disseminates experience worldwide. And world-class research forms the basis of new solutions to global problems.

"For the benefit of society! Those were the words uttered by the Danish physicist H.C. Ørsted back in 1829 when DTU was founded. Today, 190 years later, those words still characterize the National Food Institute on the occasion of our 60<sup>th</sup> anniversary," Director of Institute Christine Nellemann says.

The chronology of the Institute formally started when the law on a food institute etc. was adopted on 5 June 1959. In a report six years earlier, the Danish Health Authority had proposed to establish a central national institute that would perform several tasks.

By means of chemical analyses, the Institute was to observe the occurrence of nutrients and unwanted substances in foods. Several incidences from that time had created an awareness of the increasing use of chemical substances, such as giving antimicrobials to fish, hormonal castration of chickens, using pesticides to exterminate rodents, and adding new preservatives and sweeteners to foods.

According to the report from the Danish Health Authority, the Institute was tasked with assessing how chemical substances affected the health of food. A documentation service was tasked with collecting and communicating knowledge to consumers. Finally, dietary surveys and advice on the composition of the diet was part of the original bill proposal.

Through the years, the Institute has had many names, and its tasks have been characterized by the changing needs of society. Since it was established, genetically modified organisms, dietary habits, and lifestyle diseases have also come under the spotlight. In addition, new focus areas have been added at the Institute: endocrine disruptors, food microbiology, epidemiology, and food technology.



The National Vitamin Laboratory, whose history goes back to 1931, was in 1969 merged with the National Food Institute of the time, which is one of the precursors of the present National Food Institute.

📷 Laboratory at the National Vitamin Laboratory cirka 1940. National Food Institute



The National Food Institute has at its disposal approximately 6,700 m<sup>2</sup> chemical laboratories, food technological laboratories, microbiological laboratories, laboratories for effect studies, and animal testing facilities.

📷 Laboratory for research in the area of microbial biotechnology and biorefinery in Building 202. Mikal Schlosser

## Affiliations of the past - parts of the Institute are more than 60 years old

The National Food Institute has adapted to changing ministries, governments, and framework conditions many times. Today, the Institute is part of DTU (Technical University of Denmark) and falls under the Ministry of Higher Education and Science. Previously, the Institute has fallen under the Ministry of the Interior, the Ministry of Environment, the Ministry of Health, the Ministry of Food, and the Ministry of Families.

In the course of time, the Institute has had its professional origin in several organizations, both smaller and larger than the Institute's current size: E.g. the National Vitamin Laboratory, the National Pesticide Laboratory, the National Food Institute (Statens Levnedsmiddelinstitut), the National Food Agency, the Danish Veterinary and Food Administration, the Food Directorate, and the Danish Institute for Food and Veterinary Research.

Over the years, mergers have led to the addition of new research areas. When the Danish Institute for Food and Veterinary Research was established in 2004, the Food Directorate's Institute for Food Safety merged with the National Veterinary Institute. A large part of the professional activities at the National Food Institute within zoonoses and epidemiology originates from the National Veterinary Institute, which was founded in 1908 and is thus more than 110 years old today.

Thanks to the merger with DTU, food technology became a new research area in 2007, when a unit from DTU Bioengineering became part of the Institute. The past history of this part also dates back more than 110 years to 1906.



For more than 50 years, Mørkhøj Bygade in Søborg was home to the majority of the National Food Institute's activities.

📍 Building C in Mørkhøj, National Food Institute



In 2017, the National Food Institute gathered all of its activities at DTU's Lyngby campus. Most staff members are located in a new building complex in Buildings 201-205B, which features state-of-the-art facilities.

📍 Building 202, Adam Mørk

### Risk assessment and risk management are clearly separated

Through the 1990s, the importance of separating statutory responsibilities from advice-giving and research activities was at the centre of debate. Among other things, the debate was based on a case related to bovine spongiform encephalopathy, BSE. This case showed the need for a clear separation between those who scientifically assess a risk and those who are going to make political decisions on how to manage the risk.

In order to separate risk assessment from risk management, the Institute for Food Safety and Nutrition merged with the

National Veterinary Institute in 2004 - and the Danish Institute for Food and Veterinary Research was born.

When the Danish Institute for Food and Veterinary Research merged into DTU, risk assessment was embedded in the Ministry of Science of the time. Thus, Denmark achieved the greatest separation between the two activities seen on a global basis, until now. Therefore, the National Food Institute is also a global pioneer within this area.

### The tasks of the National Food Institute

#### Continuously enriched by new areas

In 2010, the Institute was again expanded with a brand new area that has a history dating back to 1931 where the Technological Laboratory of the Ministry of Fisheries was established at the Polytechnic Association, now DTU. A large group of researchers from DTU Aqua moved in and shared their knowledge of all aspects - microbiological, technological, and nutritional - of fish as food. This supplemented the Institute's work with healthy and sustainable foods, and put a spotlight on everything that moves beneath the water.

In 2014, the Institute was further enriched with a new research group. The group had a focus on biotechnology and biorefining and thus increased the Institute's technological skills in the area of creating healthy and better foods and food components in a sustainable way.

"With a strong research focus, we do not only save people's lives, we also promote health and prevent disease. Furthermore, our work benefits the environment. All things being equal, food production has an adverse impact on the environment. The new groups create balance because they are working on a more sustainable food production that can feed the growing world population in the future," Christine Nellemann says.

Delivers state-of-the-art scientific advice to national and international public authorities and businesses

Translates the Institute's research results into innovation, value-creating solutions for businesses and public authorities

Solves, through research, some of the biggest societal challenges the world is facing

#### Ready for solutions to today's problems

The world is facing severe global problems. The welfare of the future depends on the development of sustainable and value-adding solutions within foods and health. The Institute is prepared to help find solutions to these problems.

"Today our Institute is based on research, and from this, we also offer scientific advice, innovation, and teaching. The Institute's way of benefiting society has expanded over the years. The Institute still advises national and international public authorities, and - to a greater extent - it also helps the industry to develop better and healthier products. Furthermore, we train people nationally and internationally in areas that are vital to the global food market: food technology, food safety, and nutrition," Christine Nellemann says.

Teaches at all levels students for business, public authorities and research in the area of food technology, food safety and nutrition

#### Part of the university environment

The merger with DTU in 2007 was a turning point in the Institute's history. Being an active player in the university environment offers new ways of using the Institute's qualifications and skills. With an engineering degree from DTU in the area of foods, you can conduct research, work in a food company on the development of healthy, sustainable products, or you can work for a public authority. The degree programmes cover the entire spectrum, from large general practices to small practical things, such as how to clean production machines in an easier way with an excellent level of hygiene.



### Degree programmes at DTU within the area of food

- Bachelor of Engineering in Food Safety and Quality
- Bachelor of Science in Food and Nutrition in collaboration with the University of Copenhagen with the possibility of doing an internship
- Master of Science in Food Technology
- The study programme Aquatic Food Production - Safety & Quality
- Master's Degree in Food Quality and Safety
- PhD studies at the National Food Institute.

The National Food Institute also continuously offers various continuing education courses, including free Coursera e-learning courses.

### DTU Foodlab - a playground for innovation of foods

In 2018, DTU established a 300 square metre innovation playground for foods. Here students, researchers, and businesses can test their ideas within the area of foods. The facilities offer a fermentation plant and a test kitchen.

The Foodlab is part of DTU Skylab, an innovation hub focusing on promoting student innovation for all students at DTU.

DTU Foodlab is the setting for part of the National Food Institute's teaching activities, and together with Foodlab, the Institute plans several innovation competitions with foods as a focal point.

### From waste to side streams - innovation on the plate

Besides education and training, innovation has become a much bigger activity as the Institute has grown over the years and merged with industrial research environments from other departments at DTU.

At the centre is the development of sustainable technological solutions within the areas of health and foods. What was previously known as waste in the production of food, the Institute would now rather consider as innovative side streams. How can you use residual products to create new high-quality products such as proteins and fish oils?

The Institute also helps the industry avoid harmful substances and bacteria in the production process. Innovation increases the health and safety of the consumers through optimized products, which at the same time strengthen the businesses' position in the market.

### Student innovation helps SMEs

Combining education and innovation adds up to student innovation. Through internships and theses, students help small and medium-sized enterprises, SMEs, with innovation. This benefits both parties. The students get to test their theories in practice, and small enterprises gain access to research much faster than by being co-applicants in big research projects which - on the other hand - may lead to more thorough, complicated, and long-term studies. Companies who participate in research collaborations grow more than companies that do not, and thanks to student innovation, more companies can achieve this benefit.

### Data at the centre of scientific advice

Data and knowledge form the basis of the Institute's scientific advice services. In respect of research, the strength of the Institute is data on the state of Denmark and the world when it comes to nutrition as well as the chemical and the microbiological areas.

For example, sewage samples offer the researchers an overview of the levels of antimicrobial resistance worldwide.

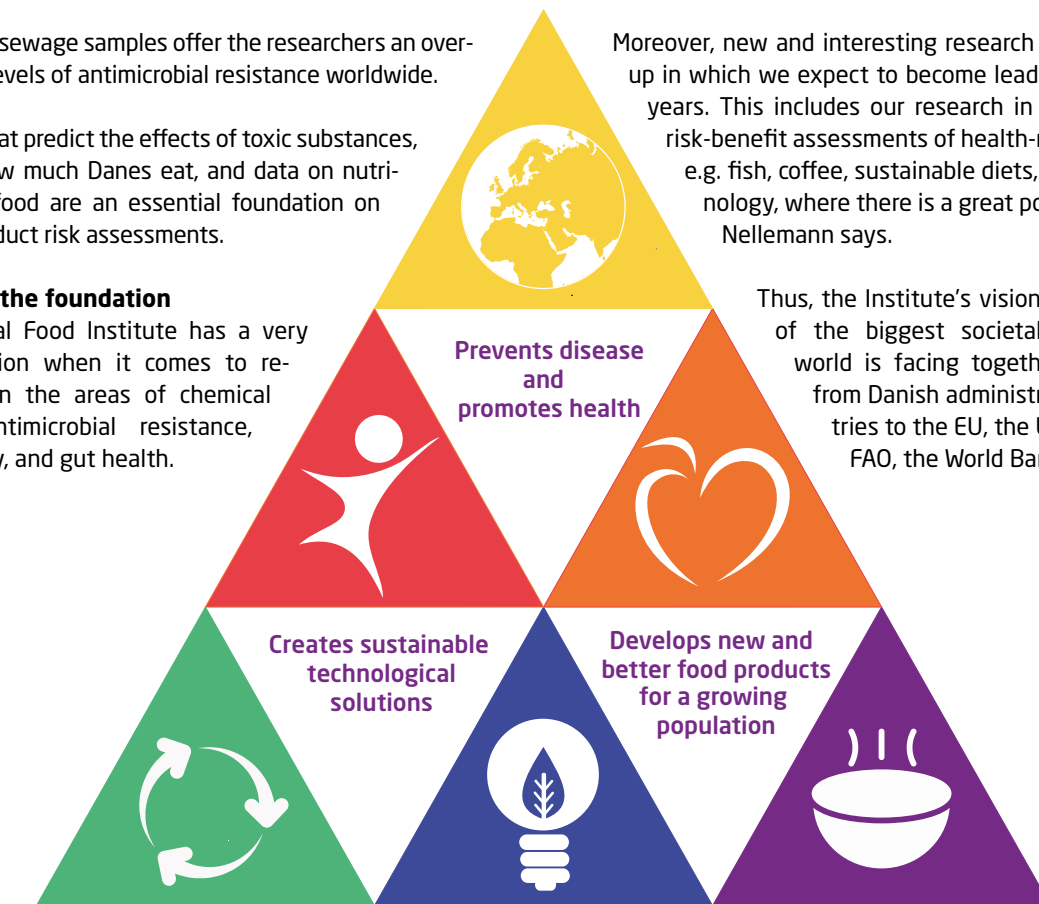
Databases that predict the effects of toxic substances, what and how much Danes eat, and data on nutrients in our food are an essential foundation on which to conduct risk assessments.

### Research is the foundation

"The National Food Institute has a very strong position when it comes to research within the areas of chemical cocktails, antimicrobial resistance, sustainability, and gut health.

Moreover, new and interesting research areas are coming up in which we expect to become leading over the next years. This includes our research in food allergies, in risk-benefit assessments of health-related aspects of e.g. fish, coffee, sustainable diets, and in food technology, where there is a great potential," Christine Nellemann says.

Thus, the Institute's vision is to solve some of the biggest societal challenges the world is facing together with partners from Danish administrations and ministries to the EU, the UN system, OECD, FAO, the World Bank, and WHO.



The vision of the National Food Institute

### Mission and vision

The National Food Institute conducts research into and disseminates - through advice, innovation, and teaching - sustainable and value-creating solutions in the area of food and health for the benefit of society. The Institute delivers its outcomes through an interdisciplinary cooperation between the disciplines of nutrition, chemistry, toxicology, microbiology, epidemiology, and technology.

The Institute's vision is to make a difference by generating future prosperity through research into food and health. The National Food Institute:

- prevents disease and promotes health
- develops new and better food products for a growing population
- creates sustainable technological solutions.

**The vision and mission correspond with the UN's Sustainable Development Goals**

The vision of the National Food Institute supports the UN's Sustainable Development Goals and contributes particularly to these goals:



"The vision and mission of the National Food Institute are oriented towards the global challenges. We are an ambitious Institute and want to help save the world, both in respect of the health of each individual and the big environmental challenges related to the production of food," Christine Nellemann says.

**International cooperation**

In the beginning, the National Food Institute primarily served as a national institute. Today it is an international centre for research and knowledge where most of the research is conducted in international networks and consortia.

"I will say that the Institute is among the world leaders within our areas of expertise. Foreign countries often

contact us and ask us to visit them or whether they can come visit us. In lectures, we talk about our cooperation with public authorities, the industry, and universities. Countries outside the EU are also interested in European food regulations. Countries that are going to establish a food safety system are inspired by our work. It is an advantage for the industry that the rules are organized as in the EU," Christine Nellemann says.

EFSA is the European Food Safety Authority, an independent agency of experts providing scientific advice to the EU on food safety, nutrition, and animal and plant health. In 2008, EFSA established collaborating centres (focal points). In all the years, the National Food Institute has represented EFSA's work in Denmark.

The National Food Institute has several important global cooperating partners, including the French agency ANSES, the German institute BfR, the Japanese Food Safety Commission, and the Chinese CFSA. Other important cooperating partners are Lund University, Hong Kong Polytechnic University, and University of Bologna, which together with the National Food Institute make up the Joint Centre of Excellence in Food Safety - DISH.

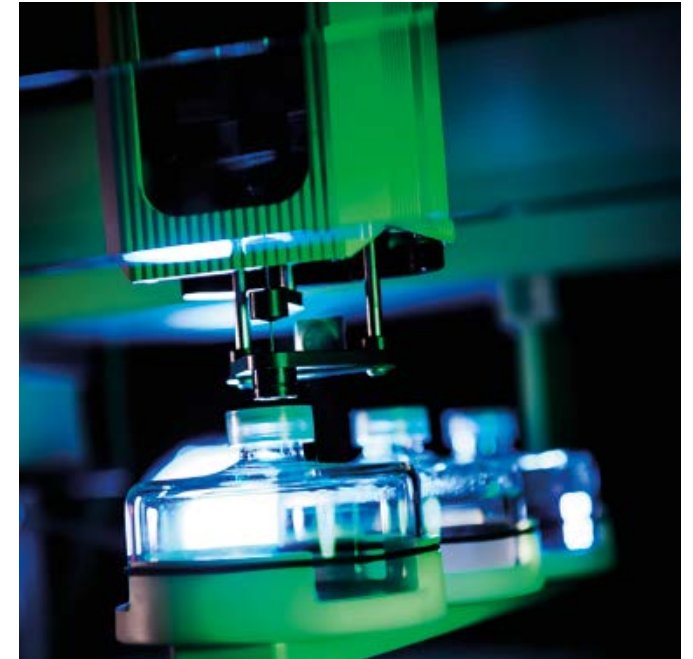
**Acknowledged for its high professional expertise**

Since 2006, the Institute has served as an EU reference laboratory (EURL) for antimicrobial resistance (EURL-AR) and for pesticides in cereals and feeding stuff (EURL-CF). In 2018, the Institute was also awarded the honour of being responsible for processing contaminants in food (EURL-PC) and for metals and nitrogenous compounds in feed and food (EURL-MN). This appointment shows that the National Food Institute offers high professional competencies and quality.

Since 2001, the National Food Institute has been WHO Collaborating Centre for Antimicrobial Resistance. In 2016, the Institute was appointed as WHO's first collaborating centre for genomics. This is recognition of the Institute's pioneering research in the area of whole genome sequencing - a technology that allows a microorganism's entire DNA profile to be mapped simultaneously. The technology can be used to monitor and combat foodborne disease outbreaks.

The Institute's researchers and advisers have joined several expert groups, panels, committees, and working groups, indicating the international level of the Institute's activities within the framework of:

- The European Food Safety Authority (EFSA)
- The European Committee for Standardization (CEN)
- The European Union (EU)
- The Food and Agriculture Organization of the United Nations (FAO)
- The Nordic Council of Ministers and the Nordic Council
- The Organisation for Economic Co-operation and Development (OECD)
- The World Health Organization (WHO).



As European reference laboratory, the National Food Institute sets international standards for how laboratories worldwide test for antimicrobial resistance, pesticides, metals, and processing contaminants in foods.

☞ Liquid chromatography mass spectrometer. Joachim Rode

**Good advice from the Advisory Board at the National Food Institute**

The National Food Institute receives good advice from the Director of Institute's Advisory Board on the Institute's activities in respect of research, education, advice giving, business cooperation, and innovation:

- Deputy Director General Annelise Fenger, Danish Veterinary and Food Administration
- Vice President - External Collaboration Esben Laulund, Chr. Hansen A/S
- Research Director Morten Andersen Linnet, Danish Agriculture & Food Council
- Industry Director Leif Nielsen, DI Foods (The Confederation of Danish Industry)
- Senior Food Adviser Camilla Udsen, Danish Consumer Council.

# The National Food Institute from 1959-2019

**1959**

On 5 June, the Danish parliament adopts law No. 182 on a food institute etc. Thus, the seeds of most of the Institute were sown.

**1960**

The National Pesticide Laboratory is established in consequence of the law on a food institute etc.

**1961**

The land of Mørkhøjgård in Gladsaxe Municipality is acquired for the purpose of construction and to gather geographically spread units, which were later going to constitute the National Food Institute (Statens Levnedsmiddelinstitut).

**1968**

The National Food Institute (Statens Levnedsmiddelinstitut) is formally established as an institute under the Danish Ministry of the Interior.

**1994**

The Danish parliament adopts the law on zoonoses and includes livestock in the work with food safety. The National Food Agency starts advising on disease-causing microorganisms and putrefaction bacteria in food.

**1995**

The DANMAP programme is initiated with the purpose of monitoring the consumption of antimicrobials and the occurrence of antimicrobial-resistant bacteria in animals, foods, and humans.

**1997**

The National Food Agency merges with the Danish Veterinary Service and becomes the Danish Veterinary and Food Directorate under the newly established Ministry of Food.

**2000**

The Danish Veterinary and Food Directorate changes its name to the Danish Veterinary and Food Administration.

The work with research and monitoring in the area of antimicrobial resistance leads to the appointment as a WHO collaborating centre in this area.

**1969**

The National Vitamin Laboratory, the National Pesticide Laboratory, and the food and nutrition-hygiene service of information and literature under the Danish Health Authority are amalgamated and move to Mørkhøj. The opportunity to conduct toxicological studies is added.

**1971**

The National Food Institute (Statens Levnedsmiddelinstitut) is transferred to the newly established Ministry of Pollution Control (later called the Ministry of Environment).

**1973**

The Danish parliament adopts a law on foods, including on the National Food Institute (Statens Levnedsmiddelinstitut).

The Institute's researchers prepare the first Danish positive list of allowed food additives.

**1979**

The Danish parliament adopts a law on chemical substances and products. Thus, the new rules on classification and labeling provide the Institute with new advisory tasks.

A new unit of nutrition under the National Food Institute (Statens Levnedsmiddelinstitut) is going to work with nutrients, food composition tables, dietary surveys, etc.

**2002**

The Danish Veterinary and Food Administration concentrates its research and risk-assessment activities in the Institute for Food Safety and Nutrition.

The Food Databank is launched, and the official food composition tables are publicly available online.

**2003**

The work with research and monitoring within antimicrobial resistance also leads to the appointment as an EU reference laboratory.

**2004**

The Danish Veterinary and Food Administration's Institute for Food Safety and Nutrition and the Danish Veterinary Institute merge and become the Danish Institute for Food and Veterinary Research. The Institute is transferred to the new Ministry of Family and Consumer Affairs. This merge significantly increases the activities in the areas of food microbiology and epidemiology.

**2007**

The Danish Institute for Food and Veterinary Research merges with several other sector research institutes and the Technical University of Denmark (DTU), leading to the establishment of the present National Food Institute.

**1981**

The first official nutrition recommendations are published in Denmark. They are based on the Institute's cooperation in the Nordic countries on common Nordic nutritional recommendations.

**1983**

The Institute publishes the first official Danish food composition tables in book form, containing the nutritional content in Danish foods. Moreover, it starts conducting systematic analyses of nutrients in typical foods.

**1985**

The National Food Institute (Statens Levnedsmiddelinstitut) changes its name to the National Food Agency and conducts the first national dietary survey.

**1986**

The world's first law on genetic technology is adopted by the Danish parliament, based on the preliminary work and recommendations from, amongst others, the National Food Agency.

**2008**

The European Food Safety Authority, EFSA, appoints the National Food Institute as collaborating centre in Denmark.

The National Food Institute takes over the area of food production engineering from DTU and adds food technology as a new professional field.

**2010**

The industry-oriented research conducted by DTU Aqua in fish and shellfish moves to the National Food Institute with 70 employees.

**2011**

The first students enter the bachelor of engineering programme in food analysis (now BEng in Food Safety and Quality).

**2013**

The DTU Centre for Hygienic Design opens at the National Food Institute.

**1987**

The National Food Agency is transferred to the newly established Ministry of Health.

**1989**

For the first time, the National Food Agency publishes the so-called Drogeliste containing risk assessments of plants, fungi and parts thereof that are used in dietary supplements and herbal tea.

**1991**

The Ministry of Health and the Ministry of Industry, Business and Financial Affairs share the national information obligations on nutrition. The National Food Agency is responsible for information on the connection between diets and health/disease. The Danish Consumer Agency focuses on the consumer-related aspects.

**1992**

The EEC directive concerning zoonoses is adopted, leading to systematic monitoring and annual analyses of antimicrobial resistance and zoonoses in Denmark.

**2014**

A research group from DTU Bioengineering moves in at the Institute, increasing the focus on developing new sustainable foods and food components.

**2017**

The Institute is located at Lyngby campus, amongst others in the largest new building at DTU.

**2018**

The EU appoints the Institute as an EU reference laboratory for process contaminants in foods and metals, and for nitrogenous compounds in feed and foods.

**2019**

The National Food Institute celebrates its 60th anniversary.

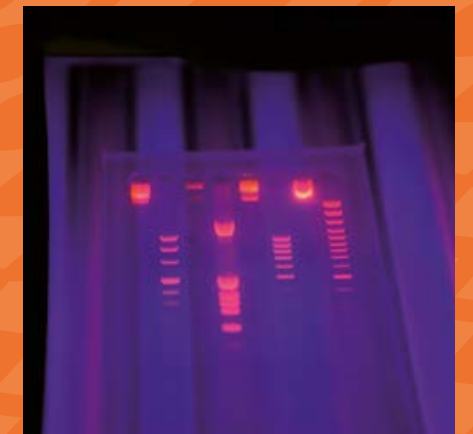
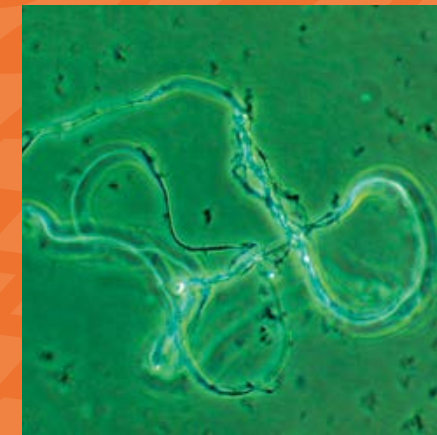
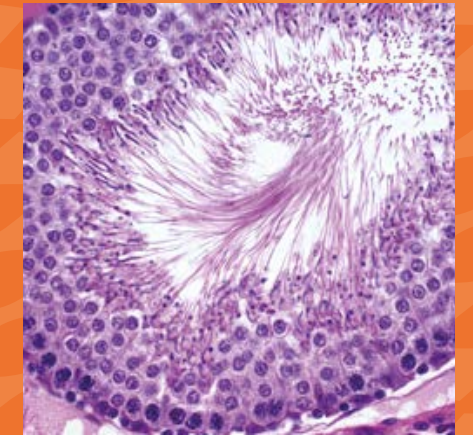
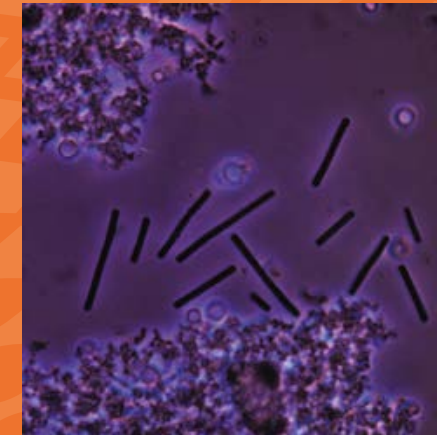
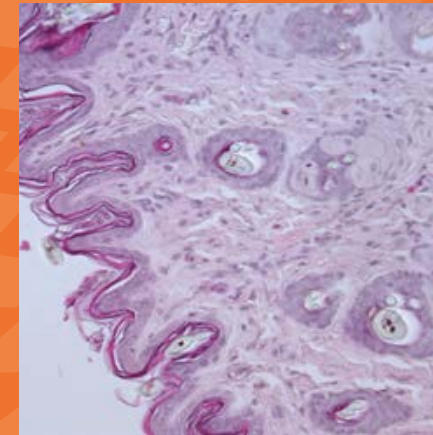


# The National Food Institute prevents disease and promotes health

Consumers are increasingly interested in their health, and you can hardly read a magazine or watch the news without finding articles or advice on healthy eating, exercising more, and healthy living in general. The demand for healthy and safe foods continues to increase. However, at the same time, more and more people are affected by infectious diseases, lifestyle diseases - such as diabetes, overweight, and cardiovascular diseases - and exposure to chemicals, which can lead to cancer and inhibit our ability to reproduce. Thus, research that promotes health and prevents disease is very important.

The majority of the research projects, scientific advice to authorities, cooperation

with businesses, and teaching activities at the National Food Institute have the fundamental vision to make a difference by preventing disease and promoting health. This applies within the areas of antimicrobial resistance, unwanted effects of chemical substances, nutrition, food allergy, microbiological food safety, hygienic design in the production of food, risk-benefit assessment of health effects, chemical food analysis, nanomaterials in foods, risk assessment, gut health, as well as the development of healthy food and ingredients - some of the most essential research areas at the National Food Institute.





# When antimicrobials don't work - one of the biggest threats to health

According to figures from the EU, antimicrobial resistance kills 25,000 Europeans annually. The WHO considers antimicrobial resistance to be one of the biggest threats to human health, and the National Food Institute has made Denmark a global pioneer in the battle against resistant bacteria.

Repeated use of penicillin and other types of antimicrobials can cause these substances to lose their effect because the bacteria develop resistance to the substances. This can make it more difficult - and impossible at worst - to treat bacterial infections in humans and animals. When bacteria become resistant, even a trivial infection can be fatal.

"In the 1990s, cows and pigs were brimming with antimicrobials. They were added to the feed in order to promote growth. Large amounts of antimicrobials made the bacteria resistant and this spread to humans via the food chain," Professor and Head of Research Group Frank Møller Aarestrup says.

The problem was not identified until 1994. Ever since, the National Food Institute has researched antimicrobial resistance and participated in the global monitoring of the ways in which resistance spreads. Bacteria can quickly spread to the entire world, e.g. when we travel or eat imported meat.

The research is crucial in order to advise national and international authorities and other stakeholders on how to minimize

antimicrobial resistance nationally and globally. The monitoring efforts - e.g. via the national VetStat - ensures that the amount of medicine given to Danish animals is controlled.

In 2000, Denmark was the first country in the world to ban the use of growth promoters in animal feed, and in 2006, the ban was implemented across the EU.

Other countries pay great attention to the research conducted in Denmark, and the National Food Institute has been appointed both as an EU reference laboratory for antimicrobial resistance and as a WHO and FAO collaborative centre for antimicrobial resistance.

In order to monitor the occurrence of antimicrobial resistance in Denmark, a national monitoring programme was established: DANMAP, which monitors the consumption of antimicrobials and the presence of antimicrobial resistance among bacteria in animals, people, and foods in Denmark. The programme, which has existed for more than 20 years, was the first of its kind in the world and is often highlighted overseas as a good example.

Whole genome sequencing and vast amounts of data are used at the National Food Institute to develop systems for the global surveillance of pathogenic microorganisms and antimicrobial resistance.

Human DNA. Philippe Plailly, Science Photo Library, Scanpix





The National Food Institute develops detection methods that can be used to determine the cause of foodborne disease outbreaks both in Denmark and abroad.

📷 Lollo Bionda salad. Colourbox

### Data ensure better surveillance

Since the National Food Institute took steps back in the 2000s to create a global overview of antimicrobial resistance in Salmonella bacteria, the way in which research is conducted has developed significantly. Previously, information arrived from all over the world in the form of Excel sheets, faxes, photocopies, and even handwritten pages in languages almost as diverse as the abundance of Salmonella bacteria.

“Today we use the large quantities of available data in our research in an intelligent way in order to create an overview, and we look at many other threats than just Salmonella. We use a brand new technique - whole genome sequencing - which can identify disease-causing microorganisms’ entire DNA profile in one go,” Frank Møller Aarestrup says.

This new approach offers the researchers a head start when trying to discover outbreaks of diseases among animals and

people, and the huge amounts of data are collected and analysed in collaboration with DTU Computerome.

Whole genome sequencing and the use of data make it possible to increase monitoring and reduce the consequences and costs when recurring epidemics and food outbreaks threaten the health of humans and animals.

Besides putting pressure on the healthcare system and the barns with domestic animals, the epidemics also put pressure on consumers’ trust in foods.

“The sooner we are able to detect an outbreak of for example Salmonella, Ebola, or the flu, the sooner we can make an effort to stop it, make the authorities intervene, and return to normal conditions,” Frank Møller Aarestrup says.

The National Food Institute is running a large EU project, COMPARE, which is working to develop a global platform that makes it possible to quickly and efficiently identify and analyse disease-causing microorganisms that may cause outbreaks of diseases worldwide.

### Sewage reveals resistance

Researchers at the Institute have also examined the sources that create a basis for outbreaks of diseases and cause bacteria to develop resistance. In an international study headed by the National Food Institute, sewage from 74 cities and 60 countries has been analysed in order to create an overview of the amount and type of resistant bacteria that healthy people carry. The results have shown that it is not only an excessive use of antimicrobials that creates resistance.

“Sewage analyses can very accurately show the types of bacteria that are prevalent in an area. Sewage also serves as a great source for the analyses since consent from each individual is not needed because sewage cannot be linked to individuals. Another interesting aspect is that it is not very costly to analyse sewage,

so it is definitely possible to create a surveillance programme - also in developing countries,” Frank Møller Aarestrup says.

### Denmark has the sixth lowest occurrence of resistance

All the DNA material in the sewage samples has been mapped out, and the results show that North America, Western Europe, Australia, and New Zealand have the lowest levels of resistance, while Asia, Africa, and South America have the highest levels.

Using data from the World Bank, the researchers have predicted the levels of resistance in 259 countries/territories and drawn a map of the occurrence of resistance in healthy populations. Denmark reports the sixth lowest occurrence of resistance. The Netherlands, New Zealand, and Sweden have the lowest levels of resistance, whereas the highest levels were found in Tanzania, Vietnam, and Nigeria.

“The results of the sewage analysis show that sanitary conditions are crucial in the development of resistant bacteria along with the population’s general state of health,” Frank Møller Aarestrup says and adds: “So a good place to start the fight against resistant bacteria is to make an effort to improve the sanitary conditions and to reduce the spread of rubbish. In some places, this would actually be more efficient than to limit the use of antimicrobials.”

### A step closer to global surveillance

When new resistance genes are identified in the future, the researchers will be able to reuse publicly available raw data from whole genome sequencing in order to quickly identify how these resistance genes have emerged and spread.

The researchers want to use the experiences from the projects to meet the overall ambition to develop a global surveillance system that can continuously survey the occurrence and spread of disease-causing microorganisms and antimicrobial resistance.

### Whole genome sequencing detects disease outbreaks faster

Until a few years ago, it could take several weeks for doctors and veterinarians to identify which disease-causing microorganism is causing a disease, and how the disease has spread.

Today, techniques for whole genome sequencing can quickly and relatively cheaply map the entire DNA profile of disease-causing microorganisms in one go. By mapping the genetic material of bacteria, it is also possible to determine their kinship and other factors such as virulence and antimicrobial resistance. This provides an understanding of how bacteria are related and have developed over time.

Whole genome sequencing has revolutionized the work of investigating disease outbreaks because technology makes it possible to more quickly and precisely identify the source of the outbreak. The consequences of and the costs related to the outbreak are thus reduced. Whole genome sequencing can also provide knowledge about antimicrobial-resistant genes in bacteria by monitoring resistant clones in people and the environment.

The National Food Institute conducts research in whole genome sequencing techniques. The Institute’s research sets the international standard for the identification, monitoring, and study of the global spread of disease-promoting microorganisms and antimicrobial-resistant bacteria. The Institute also makes an effort to promote the use of the technology internationally.

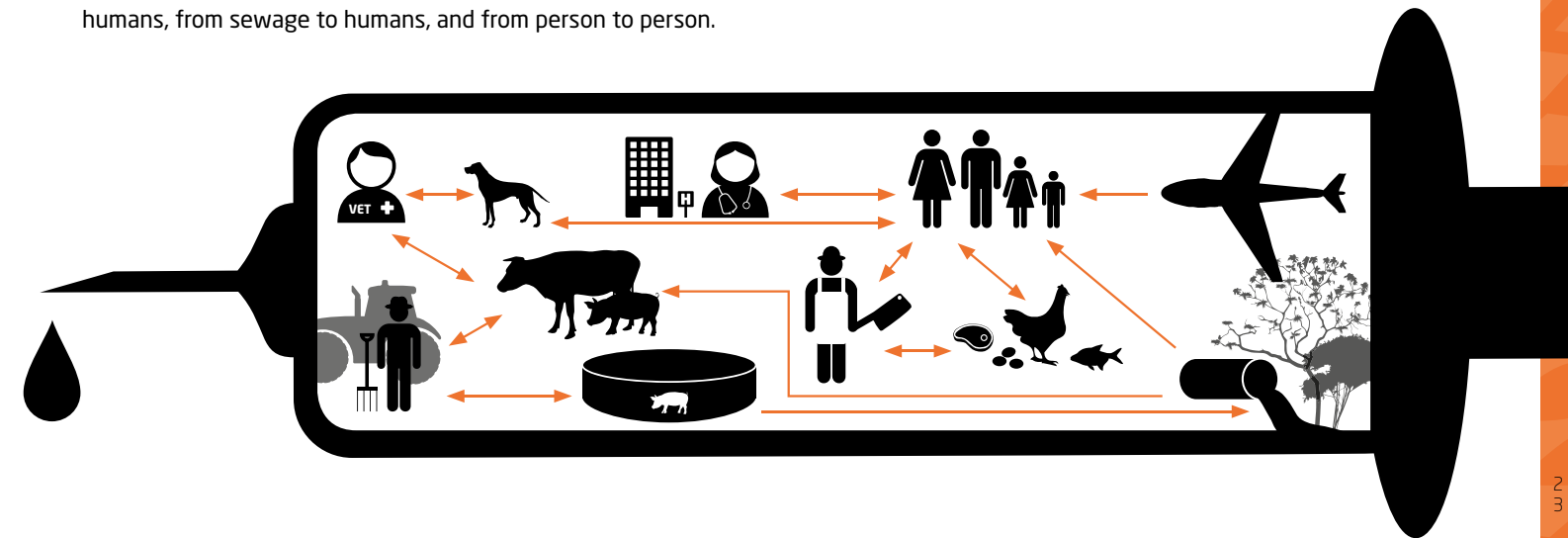


“The ambition is to develop a surveillance system that makes it possible to exchange and interpret data on disease-causing microorganisms in ‘real time’. In that way, it would be possible to use the global surveillance data, for example to tackle diseases when they are at risk of spreading beyond a country’s borders and turn into pandemics such as Ebola, measles, polio or cholera.”

**Frank Møller Aarestrup**  
Professor and Head of Research Group

#### Many ways to spread resistant bacteria

The use of antimicrobials for animals and humans causes the bacteria to develop resistance, which can be spread via many routes - from animal to animal, from animals to humans, from food to humans, from sewage to humans, and from person to person.



#### DANMAP - the Danish monitoring system

Researchers, authorities, and industry in Denmark have long been aware that decision-makers need to be equipped with solid data in order to make knowledge-based decisions on how to handle problems related to antimicrobial resistance.

In 1995, this realization led to the establishment of the DANMAP programme, which is operated by the National Food Institute and Statens Serum Institut (the Danish national institute for surveillance and preparedness of human infectious diseases). In this programme, the researchers monitor the use of antimicrobials in humans and animals in Denmark and the occurrence of antimicrobial resistance in bacteria in animals, humans, and foods.

Since 1995, DANMAP data have, among other things, led to a ban on the use of antimicrobial growth promoters in the last part of the 1990s. DANMAP's continuous focus on the use of antimicrobials in domestic animals was also instrumental in the implementation of the 'yellow card' initiative, which was developed by the Danish Veterinary and Food Administration for livestock with a high consumption of antimicrobials.

The farming sector has also actively used data from DANMAP. The farming sector has voluntarily minimized the use of cephalosporins in domestic animals - antimicrobials that are critically important in the treatment of humans.

The National Food Institute conducts research into and gives scientific advice on the One Health approach and teaches how it can be applied to find solutions to the challenges that arise in the complex interaction between animals, people, food, and the environment.

© Bkage. Colourbox

### PROVIDES IMPORTANT CONTRIBUTIONS TO THE DEVELOPMENT OF THE FOOD INDUSTRY

"The National Food Institute makes important contributions to the development of the food industry. In relation to the science-based contingency planning, we appreciate a good and open dialogue and an active approach to improving the quality of the advice giving to and communication with stakeholders and the public.

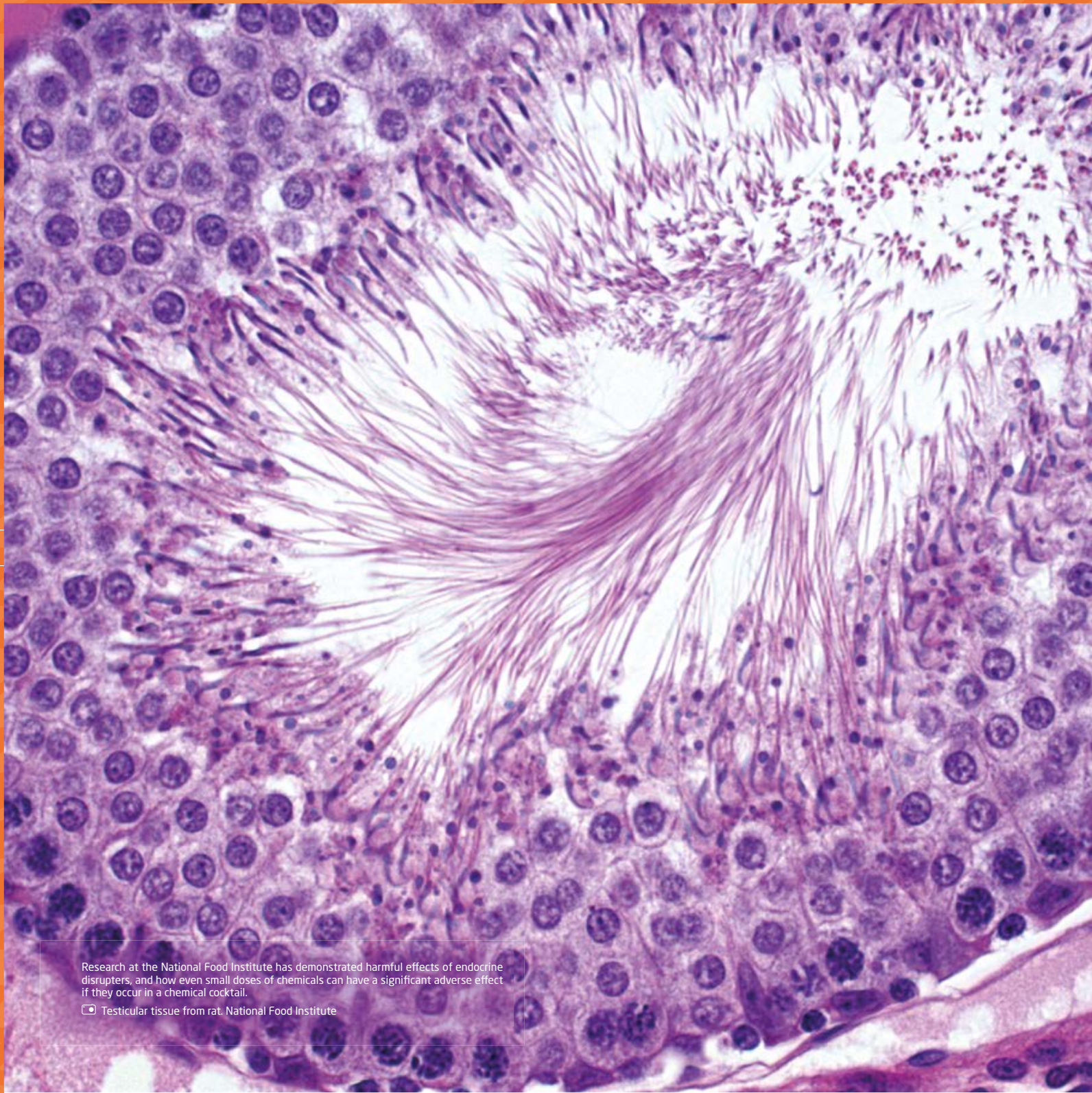
The Institute constantly works to create the positive synergy between regulatory functions, business cooperation, and teaching, which provided the background for the merging of the Government Research Institutes with the universities. Among other things, it is of great importance that the Institute works actively to make it attractive for the employees to work with advice giving tasks and industry cooperation," says Morten Andersen Linnet from the Danish Agriculture & Food Council, who is also a member of the Advisory Board at DTU National Food Institute.



© Danish Agriculture & Food Council

Morten Andersen Linnet  
Danish Agriculture & Food Council





Research at the National Food Institute has demonstrated harmful effects of endocrine disruptors, and how even small doses of chemicals can have a significant adverse effect if they occur in a chemical cocktail.

📷 Testicular tissue from rat. National Food Institute

## The unborn child must be better protected from chemical cocktails

Even small doses of a chemical substance can be harmful when it occurs in combination with other substances. Knowledge about the cocktail effect is pivotal when legislators set the allowable limits for substances that are allowed in industrial products. At its core, the National Food Institute's research and advice is a matter of protecting the unborn child.

"The most important aim of our research is to protect the unborn fetus against the harmful effects of endocrine disruptors," Senior Researcher and Head of Research Group Terje Svengen says.

The Institute's research focuses on how chemicals disrupt the body's hormones in relation to reproduction. Many chemicals have turned out to be able to imitate or disrupt sex hormones. If there are chemicals present in a pregnant woman's body from food, cosmetics, etc., such chemicals can disrupt the hormonal development of the fetus. Phthalates block, for example, the synthesis of testosterone.

Because of the chemical impact on the pregnant woman, an increasing number of boys are born with deformed genitals. An example of deformation could be that the urethra does not open from its usual location on the head of the penis, also called hypospadias. This condition is associated with an increased risk of having or developing other issues related to the reproductive system.

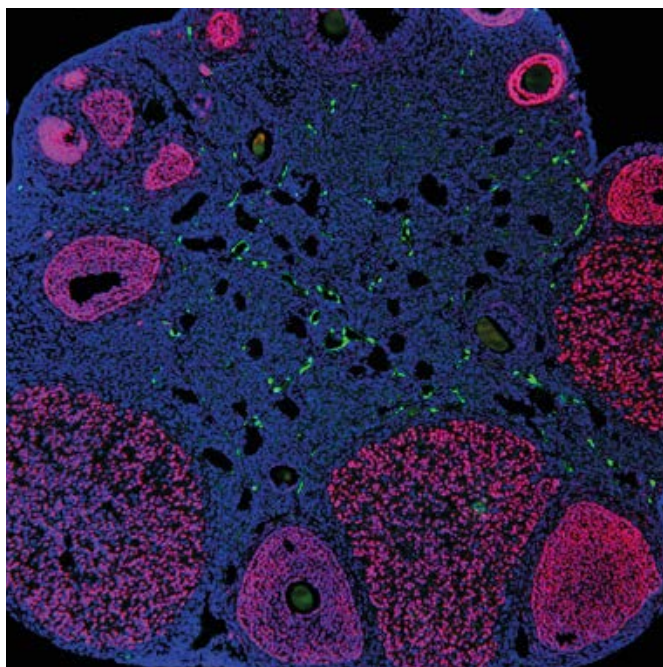
### Girls are underdiagnosed

"The number of girls with congenital genital malformations is probably underdiagnosed. For example, the location of the urethral opening is more difficult to detect in girls than in boys. However, some researchers assume that this is also a problem for an increasing number of girls. If such malformations are associated with other reproductive problems - such as lower fertility - this is a problem we should look into," Terje Svengen says.

Another example of endocrine disruptors' impact on girls is that they can enter puberty earlier, and correspondingly hit menopause earlier as grown women. Furthermore, PCOS (polycystic ovary syndrome) and ovarian cancer may be associated with endocrine disruptors.

The National Food Institute's extensive knowledge about the harmful effects of endocrine disruptors is brought into play in two projects supported by the EU's special programme for research and innovation, Horizon 2020. The purpose of both





Research from the National Food Institute has provided knowledge of how endocrine disruptors affect the female reproductive system.

Adult rat ovarie. National Food Institute

projects is to develop new and better methods to test the harmful effects of different chemical substances.

### Better protection of women's fertility

One project, FREIA, is named after the goddess of fertility in Norse mythology. The purpose is precisely to explore how chemicals can disrupt women's ability to have children, and how better testing of chemicals can protect women's reproductive health.

By collecting new data on how the chemicals affect ovaries and puberty in animals, the project will provide more knowledge of the harmful effects chemicals have on women's fertility. Moreover, the researchers are going to develop so-called QSAR computer models that can predict the chemicals' possible harmful effects.

Researchers from 11 partners from seven EU countries participate in this project.

### Thyroid hormones and brain development

The other project, ATHENA, shares its name with the Greek goddess of, amongst other things, wisdom and is focused on the hormonal impact on the brain. The project aims to develop better methods to screen for chemical substances that affect the thyroid's production of hormones, which in turn regulate the body's metabolism. These hormones play a crucial role in a fetus' brain development, and it is very important that mother and child have normal hormone levels during pregnancy. If pregnant women are exposed to certain chemicals, the child may be at risk of mental development disruptions, which affect both the ability to learn and intelligence.

### We are not protected well enough

A significant part of the problem with the harmful effect of these substances on human reproductive health is the so-called cocktail effect. When chemicals occur together - in a chemical cocktail - even small doses of each substance can cause harm. Therefore, the Institute has in recent years worked to calculate their cocktail effect and to limit the number of substances we are exposed to. In projects commissioned by the national authorities, the researchers have examined how chemicals typically work together. The experiments and mapping clearly indicate that if many chemicals are present even in small quantities, it may have a considerable harmful effect. In other words, 'little strokes fell great oaks.'

Knowledge from the research projects shows that the current method for assessing risk does not sufficiently protect people because the harmful effect of a chemical is only considered in isolation, not in combination. What's more, the substances typically occur in combination when we come across them in foods, cosmetics, and other products in our daily lives.

### New tools for risk assessment

Therefore, in two national research projects, the researchers at the National Food Institute have developed a toolkit that takes cocktail effects into account when assessing the risk of being exposed to chemical substances.

A so-called Hazard Index can predict the overall risk of chemicals when they occur in a specific mixture. The calculations can be made at several levels depending on the amount of data that is available for each chemical in the mixture. At the lowest level, all chemicals are put into one group regardless of the effect, and most data will be rough estimates as there is only very little data on the chemicals. At the highest level, the calculation of the Hazard Index is based on actual, measured values, and the chemicals are grouped according to their effects. Here the calculation will result in a more precise estimate of the risk of cocktail effects. The more available data, the more accurate the calculations.

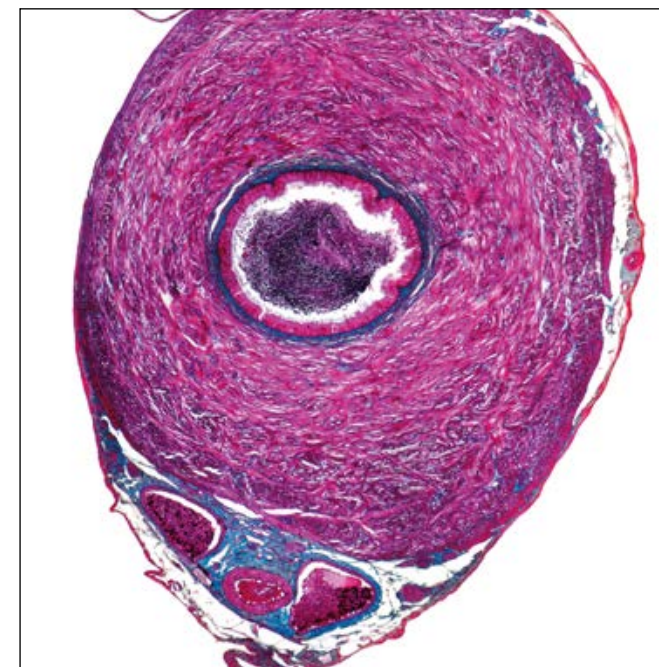
The Institute's software - Cocktail Effect Calculator - can provide information on each chemical in a given mixture. The software can also calculate predicted harmful effects.

"We are in the middle of a paradigm shift. We know we need to get away from looking at only one substance at a time. Now the big question which we are focused on at the moment is what tools are most useful when we assess the risks. In order to improve and expand the toolbox, we need more basic knowledge of how chemicals interact with molecules and cells in the human fetus, and how they harm the fetus," Terje Svingen says.

### Research helps companies and authorities

Knowledge of cocktail effects helps authorities to determine allowable limits for the chemical content in the products that companies manufacture. This means that we as consumers can look forward to safer products as the researchers map the cocktail effect and make it possible to measure it even more precisely.

"In Denmark, the National Food Institute works closely with the Danish Veterinary and Food Administration and the Danish Environmental Protection Agency. This has made Denmark a frontrunner in the area of chemicals for many years. Denmark is a country that encourages other countries within this area," Terje Svingen says.



The National Food Institute uses a number of methods to understand how chemicals affect living organisms, including QSAR models, cell experiments and animal studies.

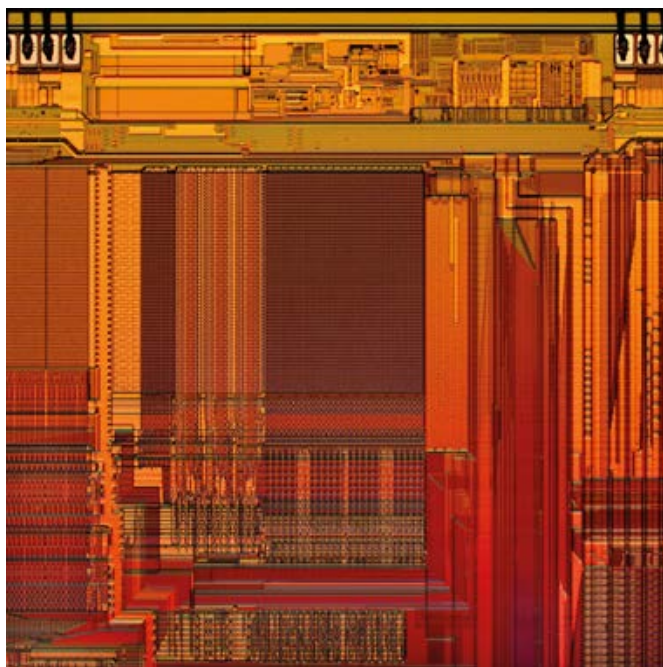
Cross section of a ductus deferens from a rat. Colourbox

### Less animal testing

3R stands for the concepts of reduction, refinement, and replacement. The Institute wants to reduce the number of animal experiments, reduce the discomfort related to necessary animal experiments as much as possible (refinement) - and, in some cases, completely replace animal experiences with other approaches.

An understanding of the mechanisms behind the effects of possible toxic chemicals based on cell experiments and computer models may help replace or reduce the number of animal experiments.

In 2016, researchers from the Institute received the 3R Centre's award for their work on predicting harmful effects of chemicals by developing and using computer models, so-called QSAR models, as a contribution to avoiding animal experiments.



DTU develops so-called QSAR models to predict the harmful effects of chemical substances.  
Microprocessor component. Antonio Romero/Science Photo Library/Scanpix

### Computer models predict harmful effects

The National Food Institute has developed advanced QSAR computer models that are able to predict the harmful effects on health of chemical substances. QSAR stands for Quantitative Structure-Activity Relationship.

The models can predict the harmful effects of the substances, based on whether the chemical structure of the substances resembles other substances that have already been tested.

The Institute's researchers have built a QSAR database, which contains predictions from more than 200 QSAR models and for more than 650,000 organic substances.

The database is publicly available and is continuously developed.

In 2018, the EU decided to recognize four phthalates as having an endocrine disrupting effect on humans and to acknowledge the cocktail effect. The National Food Institute has contributed a significant amount of the documentation for this proposal. The decision is the first step towards stricter regulation relating to the use of these substances in consumer products.

### Important test of OECD's requirements to the industry

The OECD's Test Guideline Programme develops globally recognized standard test methods that are used to assess the safety of chemicals. The National Food Institute has the important job of filling one of Denmark's two national coordinator positions in relation to the OECD test guidelines. Thus, the Institute is able to influence the statutory tests, which the industry must carry out before they can bring e.g. endocrine disrupting chemicals on the market.

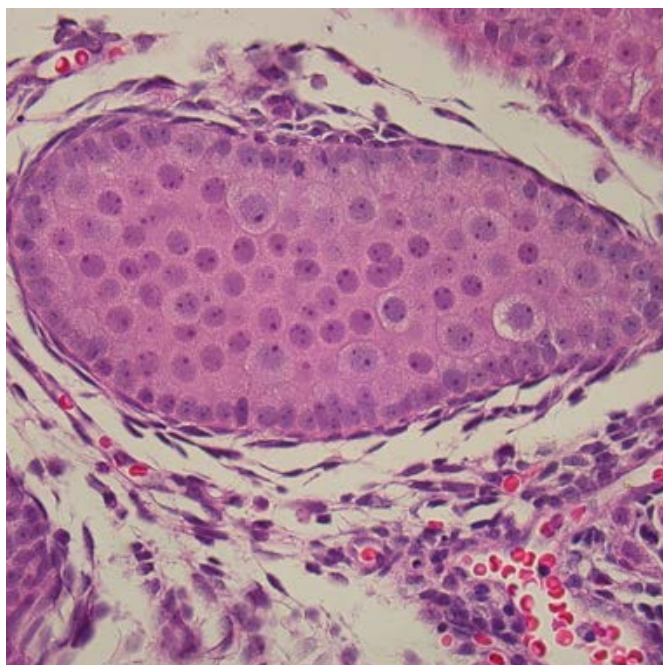
"In 2016 and 2018 we have been able to ensure that the industry has to measure the AGD - the anogenital distance - in order to have a substance approved. When the industry conducts experiments in which rats are exposed to relevant substances, the experiments must include a measurement of the distance between the anus and the genitals. This distance is a biomarker and can be applied to determine the sex of e.g. kittens. In male rats, the distance is normally twice as long compared with females. The distance will be relatively shorter if the level or the effect of testosterone is lower than normal. This reveals whether the substances cause an endocrine disrupting effect in the form of a lower level or function of testosterone, which is often associated with poor sperm quality, testicular cancer, and other disorders. We are proud to have had the AGD test included on the list, as it is an important marker for endocrine disrupting effects," Terje Svingen says.

“The ambition is to build enough knowledge and develop good tools that can be used to quickly and efficiently analyze the potential harmful effects of all new chemical substances on a child's development. The dream scenario is to develop an advanced computer programme which can tell that this specific substance has an effect at given levels of exposure if three other given substances are also included in the cocktail.”

Terje Svingen

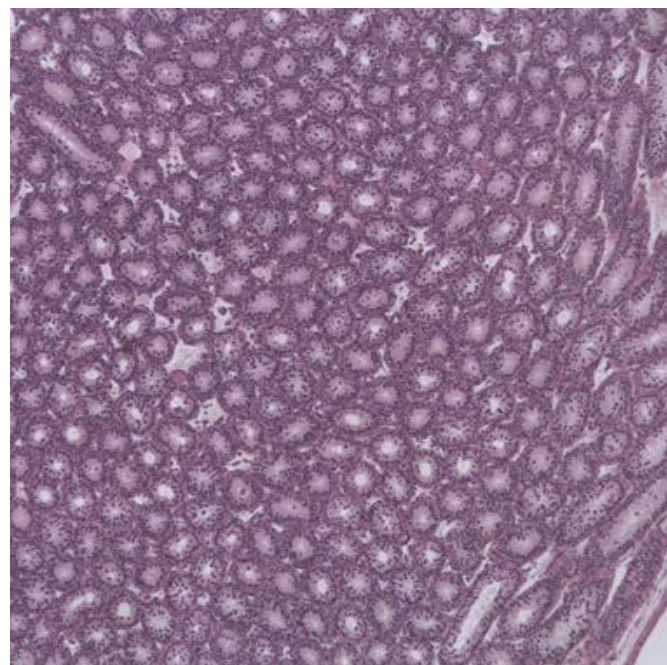
Senior Researcher and Head of Research Group





Studies from the National Food Institute show that if rats are exposed to phthalates during early development, it can lead to altered testicular development and lower sperm count.

☐ Fetal rat testis. The National Food Institute



The National Food Institute studies the degree of human exposure to chemical substances through food and consumer goods, and the harmful effects of these substances on laboratory animals' reproductive systems.

☐ Young rat testis. The National Food Institute

### Animal testing facilities help produce important knowledge

When computer calculations and cell-based test methods on their own do not provide the knowledge needed, the National Food Institute has animal testing facilities at its disposal. Here, the researchers collect information on harmful or beneficial effects of dietary factors, chemical substances, and microorganisms, including genetically modified microorganisms.

The studies support the Institute's work within the area of food safety and the health-related effects of chemical substances which we are exposed to in our daily lives.

The animal testing facilities include a number of ordinary animal rooms with the opportunity to house smaller test animals

such as rats and mice. In insulators, the researchers can handle germ-free mice (mice born without any gut bacteria) or work with dangerous substances. Moreover, the Institute has room for behavioural testing, dissection rooms, and various auxiliary rooms for feed manufacturing, cage washing, etc.

The animal testing facilities also conduct animal experiments for other departments at DTU, other research institutions, and companies.

On 1 September 2019, the animal testing facilities at DTU will be gathered in DTU's new joint centre, Bio Facility, which will be anchored under the National Food Institute.

### THE NATIONAL FOOD INSTITUTE IS IMPORTANT FOR DANISH CONSUMERS

"The National Food Institute is very important for Danish consumers. The Institute's research in respect of e.g. food safety, antimicrobial resistance, pesticides, and endocrine disruptors helps make Danish foods and their packaging safer. Moreover, research in nutrition and eating habits forms the basis of dietary advice and other initiatives which make it easier for consumers to make healthy choices.

It is very important to have research that does not have a one-sided commercial goal, but which can strengthen our knowledge of risks and consumer protection, and which can form a scientific basis for the legislation in Denmark and in the rest of the EU," says Senior Food Adviser Camilla Udsen from the Danish Consumer Council, who is also a member of the Advisory Board at the National Food Institute.



☐ The Danish Consumer Council

Camilla Udsen  
The Danish Consumer Council



# Foods we can trust

Foods may contain substances that can have a harmful effect on our health. The National Food Institute assesses risks that can be found in the entire 'from farm to fork' chain to ensure the safety of food so that neither Danish nor international consumers will get sick from the food they eat.

Foods contain important nutrients, which are necessary for our health. However, foods can also contain harmful chemicals, such as pesticide residues, process contaminants, natural toxins, heavy metals, and disease-causing microorganisms such as *Campylobacter* and *Salmonella*. Therefore, it is very important that we as consumers can safely eat the foods we buy from the shops.

When the authorities, for example, recall smoked salmon from the supermarkets because *Listeria* has been detected in the product, researchers at the National Food Institute have analysed the bacteria and forwarded the result to the authorities.

## **Danish results reverberate throughout Europe**

Denmark has a proud tradition for close collaboration between authorities, researchers, industry, and stakeholders to improve food safety. This not only promotes a feeling of security among Danish consumers, it also reverberates throughout the world, where Danish foods and Danish expertise are in great demand. Based on their great expertise, four employees at the National Food Institute have been appointed to participate in the expert panels of the European Food Safety Authority (EFSA).

"The spirit of collaboration in the area of food safety, which is unique in the Nordic countries, works very well in Denmark, where this collaboration also contributes to a high level of credibility," Head of Division Flemming Bager says. He emphasizes that the Institute's advisers are often involved in complicated assessments, which in some cases may have a significant financial impact on the industry.

"Thus, a high degree of professionalism and professional self-confidence is required when conducting risk assessments, and basing the recommendations on scientific evidence generates credibility - both in Denmark and in Europe," Flemming Bager adds.

## **Access to data is crucial**

For many years, Denmark has had a science-based approach to food safety and was a first mover by publishing a positive list of approved food additives. This became a model for the much later positive list which the EU published in the 1990s. It was the forerunner of the Institute, the National Food Institute (Statens Levnedsmiddelinstitut), which prepared the Danish positive list back in 1973, based e.g. on an assessment of the harmful effects of different substances. Thus, the proud traditions go way back.

The National Food Institute conducts risk assessments of chemical substances and microorganisms - and develops new tools for assessment of the risks to which humans are exposed.  
Gelelectrophoresis. Mikkel Adsbøl

### Analytical infrastructure brings all food molecules into focus

The National Food Institute has an analytical infrastructure available for chemical food analysis, which is part of the national and European contingency plan for chemicals in food.

Generally speaking, the analytical infrastructure can quantify all small molecules and other biological matrices, including vitamins, fatty acids, trace elements, and nanoparticles. Particularly, the focus is on detection of substances which have an impact on people's health.

The infrastructure is based on the fact that the Institute has more than 20 modern mass spectrometers at its disposal. Along with chromatography - a technique that separates substances in a sample - and procedures for sample purification, the mass spectrometers serve as the backbone to provide detailed, reliable, and accurate data on the chemical composition of food. Moreover, the Institute analyses degradation products caused by lipid oxidation in oils and foods. Lipid oxidation can destroy

taste and smell due to oxidative rancidity and have negative health effects.

In addition, the Institute's analytical infrastructure can determine the authenticity of foods by means of isotope ratio mass spectrometry, determine nanoparticles by means of e.g. ICPMS, and study biochemical effects in cells and organisms via metabolomics.

The National Food Institute is accredited by DANAK (the national accreditation body in Denmark) in accordance with the standard ISO 17025 for a wide range of food chemical analyses and is accredited for the provision of proficiency testing in accordance with the standard ISO 17043. This is crucial to the Institute's function as a national reference laboratory for most unwanted substances in foods and as the EU reference laboratory for pesticides in grain and feeding stuff, for processing contaminants in foods, and for metals and nitrogenous compounds in feed and food.

As they did back then, the researchers at the National Food Institute are still dependent on solid up-to-date data on population groups' food intake, the nutrients in foods, and exposure to chemicals and disease-causing microorganisms in food. In 1995, DANMAP was initiated. The programme, which collects data from all parts of the 'from farm to fork' chain, monitors the use of antimicrobials and the occurrence of antimicrobial resistance among bacteria in animals, humans, and foods in Denmark.

The National Food Institute is also responsible for the QSAR database, which was developed in cooperation with the Danish Environmental Protection Agency. The QSAR database contains information about the properties and harmful health effects of chemical substances.

### Denmark separates assessment and management

Risk analyses are a recognized global tool, which the authorities use to protect public health. A risk analysis consists of three elements: risk assessment, risk management, and risk communication.

In Denmark, we have a long tradition of separating risk assessment and risk management. This separation became even more pronounced in 2007 when the Danish university reform merged the Danish Institute for Food and Veterinary Research with DTU. Thanks to this clear separation, Danish risk assessments have a high degree of credibility - also abroad.

The National Food Institute conducts risk assessments within the area of food while the Ministry of Environment and Food of

## RISK ANALYSIS



Denmark, The Danish Environmental Protection Agency, and the Danish Veterinary and Food Administration are responsible for managing the risk. The National Food Institute and the authorities jointly communicate about the risk - e.g. if there are problems with *Campylobacter* or *Salmonella* bacteria in chickens.

In addition to risk assessments of foods, the Institute also carries out tasks for the Danish Environmental Protection Agency in relation to risk assessments of substances in drinking water, soil, and air, as well as writing comprehensive toxicological reports. These contribute to the Danish Environmental Protection Agency's work within the EU in relation to the approval of chemicals.

### Constant focus on foods

A risk assessment is often based on the fact that a specific food is suspected of containing harmful substances or bacteria. Consumers have experienced such cases e.g. in relation to listeria in 'rullepølse' - a Danish cold cut made from pork - or salmon, which were quickly recalled from the supermarkets.

Another model for risk assessment is to explore how chemical substances affect the human body. An example is inorganic arsenic, which is found e.g. in rice. In 2009, EFSA decided that inorganic arsenic is toxic at lower doses than previously thought.

### National food databases are rich in knowledge on food and health

The National Food Institute's databases are the Institute's most significant research capital and a cornerstone of the consulting services it provides to authorities and the risk assessments it prepares. The databases consist of a number of unique datasets that contain long time series with great methodological consistency. The central databases focus on:

- Danes' intake of food and nutrients
- Nutrient content of foods
- Chemical contaminants in foods
- QSAR predictions for health effects of chemical substances
- Assessment of plants, fungi, or parts thereof in food supplements and herbal tea
- Zoonosis, bacteria, and antimicrobial resistance.



This finding caused the researchers at the National Food Institute to take another look at rice and rice products as they are a significant source of inorganic arsenic, and many Danes eat rice from a very early age.

The intake of rice in Denmark is estimated to be so high that it may cause a small increase in the risk of developing cancer in the lungs, urinary bladder, and the skin. In the end, Danes were advised that the risk of cancer exists, but it is small. As such, you do not have to avoid eating boiled rice as long as it is part of a varied diet. Danes can lower the risk further by washing the rice and/or boiling it in surplus water.

#### **Risk assessment lets Denmark enjoy special status**

Sliced cold cuts of processed meat is a mainstay of a Danish

lunch. Due to our love of sliced meat, Denmark has had a set of rules since 1973 which state that the level of nitrite used to preserve the shelf life of sliced meats must be as low as possible. Nitrite impairs the growth of disease-causing bacteria such as *Clostridium botulinum*, which can cause botulism (also known as 'sausage poisoning' - caused by a neurotoxin that can paralyze the muscles). Thus, nitrite serves an important function in the products. However, the challenge is that nitrite can form small quantities of nitrosamines, which can be carcinogenic.

Despite the fact that the regulation regarding the use of nitrite in processed meat has been harmonized in the EU, Denmark has been allowed to keep its national regulation - both with respect to products manufactured within the country's borders and the products we import.



By collecting and analyzing large amounts of data on dietary intake, nutrients, pesticides, and other chemical substances, the National Food Institute can assess both the nutritional value and possible risks from eating different foods.

Apple. Colourbox



By monitoring the presence of disease-causing microorganisms and antimicrobial resistance in the food chain, the National Food Institute can carry out risk assessments and advise the authorities on ways to manage these risks.

Campylobacter. Mikkel Adsbøl

“The ambition is that the Danish consumers, with a few clicks, can collect useful information about the advantages and disadvantages of eating foods from the supermarket shelves. Therefore, the National Food Institute would like to explore how we can make such data easily accessible and useful for the Danish consumers in the future.”

Flemming Bager  
Head of Division

In the same way, many years of cooperation between researchers, authorities, and the industry in relation to eradicating Salmonella in the poultry production has given Denmark recognition by the EU that our production of table eggs and broilers is effectively Salmonella free.

#### **Danes must be able to find information on their own**

The National Food Institute wants an even greater transparency so that the average Danish consumer can have access to all the Institute's food data.

"The average consumer has access to the database Food Data (Fødevaredata), which contains data about the nutritional content of 1,200-1,300 different foods found on Danish supermarket shelves. The National Food Institute wants to be able to guide the consumers to a 360 degree view of the foods by also offering them a better overview of unwanted substances," Flemming Bager says.

This would make it possible for the consumer to get a full picture of what it means to our health when we eat an apple that has been sprayed with pesticides, or the advantages or disadvantages that relate to eating one particular type of nut over another.

This openness would help to increase the high degree of confidence which consumers already have in Danish assessments of foods.

"The National Food Institute wants to be better at meeting the consumers at eye level, and giving them improved access to our data on food composition (Fødevaredata) together with our other data can help ensure that," Flemming Bager says.

#### **Food Data (Fødevaredata): Database of nutrients in food**

The National Food Institute carries on a very long tradition of publishing tables of the nutrient content of foods on the Danish market. This information is one of the central tools within the area of nutrition science.

Today, the National Food Institute publishes food data online in a mobile-friendly database: Food Data (Fødevaredata), [frida.fooddata.dk](http://frida.fooddata.dk). Here you will find information about energy and nutrients (vitamins, minerals, fat, protein, and carbohydrates) in more than 1,000 foods. The database is intended to reflect the food supply in Denmark.

Users can search information on their own in Food Data (Fødevaredata). They can also download data onto their own computer so they can continue working with the data from there. The database is particularly interesting for people who work with nutrition professionally.

The experiences from the analytical work suggest that the nutritional content in foods is generally stable. For example, the nutritional content in eggs has hardly changed over the past 50 years. This shows that just because data are old, they are not necessarily obsolete.

#### **AN IMPORTANT PROVIDER OF RESEARCH-BASED CONSULTANCY**

"The National Food Institute is an important supplier of research-based consultancy to the Danish Veterinary and Food Administration in the area of chemical and microbiological food safety. Along with the food industry associations and authorities, the Institute contributes its expertise to the unique cooperation on action plans for different pathogens.

In the chemical area, we receive risk assessments that are of a high professional standard with respect to incidents and rule-setting, just as research is conducted which supports the quality of risk assessments, exposure to chemical risks, and risk-benefit assessments of foods.

Furthermore, the National Food Institute is an important collaborator when tracing the source of foodborne disease outbreaks. In our experience, the research-based consultancy we receive is of international standard. On top of that, we have an open and constructive dialogue about our need for advice," says Deputy Director General Annelise Fenger from the Danish Veterinary and Food Administration, who is a member of the National Food Institute's Advisory Board.



Annelise Fenger  
Danish Veterinary and  
Food Administration



# The key to good health lies in your gut

Bacteria in the gut affect the risk of developing lifestyle diseases such as type 2 diabetes and cardiovascular diseases. The National Food Institute conducts research in order to understand how bacteria in the gut affect our sensitivity to substances which we get through our food.

Most people know how important a healthy gut is to our well-being. The gut is a highly specialized organ that hosts more than 10,000 billion bacteria. As such, we have more bacteria in our gut than we have cells in our body.

It has been said that if we unfold our intestine, its surface area will be the size of a tennis court. Even though recent research shows that the intestine may be a little smaller than this, it is still larger than our skin and is thus the largest surface in our body. This is important to understand as a significant part of the communication between the bacteria in the gut, the substances in the gut, and our body takes place via the surface of the gut.

"Over the past years, we have witnessed an explosion in our knowledge of how the interaction between our diet, the bacteria in our gut, and our immune system affects the risk of developing lifestyle diseases. This huge leap is especially due to the fact that DNA analyses have become faster and cheaper. Moreover, new options within information technology have given us the opportunity to handle the large quantities of data which the bacteria's DNA offer," explains Professor and Head of Research Group Tine Rask Licht from the National Food Institute.

## **Whole grains reduce inflammation in the body**

Since 2013, choosing whole grains instead of refined grain products has been one of the official food-based dietary guidelines, and research results from the strategic research centre Gut, Grain and Greens (3G) backs up this guideline. With Tine Rask Licht at the helm, the 3G Centre has conducted one of the most comprehensive dietary intervention studies of its kind. The research project has examined how whole grains in our food affect the bacteria in the gut as well as a number of health-related biomarkers.

"The study shows that there is a good scientific basis for the authorities' dietary advice, and it makes good sense to replace refined grain products such as white bread and white pasta with various types of whole grain products," Tine Rask Licht says. She adds: "We can show that an intake of whole grain products reduces inflammation in the body, which particularly constitutes a risk for overweight people who are susceptible to developing cardiovascular diseases and type 2 diabetes."

## **Gluten can stay on the menu**

Rye in particular seems to have a positive effect on reducing inflammation. In addition, whole grains are more satiating, which can help people to lose weight.

The National Food Institute conducts research to understand how the food we eat affects our immune system and metabolism - and how our gut bacteria influence the development of e.g. food allergies.

📷 Lactic acid bacteria. John Walsh/Science Photo Library/Scanpix



The study also shows that the much-discussed gluten protein is not unhealthy - except for the small part of the population that suffers from either celiac disease or is allergic to wheat protein. Gluten is found in e.g. wheat, rye, and barley, and replacing such foods with alternatives that are low in gluten, including oat, rice, maize, and quinoa, does not reduce inflammation in the body. However, a diet low in gluten causes the beneficial bifidobacteria - which live on the special types of fibre and polysaccharides in grain - to disappear from the gut. As such, there is no reason to remove gluten from your diet if you are generally in good health.

#### **On the way towards personalized dietary advice**

The 3G Centre has been very important in promoting the interdisciplinary cooperation between a number of Danish research environments with different expertise within the areas of bacteria in the gut, diet, and lifestyle diseases. Researchers at the National Food Institute and at the University of Copenhagen are still analysing the huge amount of data from the project, and Tine Rask Licht has a hypothesis:

"We believe that the bacteria in the gut play a big part in why people react differently to the same diet. In the future, this knowledge may lead to personalized dietary advice and medication based partly on faeces samples, which can be brought to the doctor's office."

#### **Faeces can save lives**

The recent knowledge of gut bacteria does not only back up the authorities' dietary advice. It can also save lives and change the treatment options within the healthcare system.

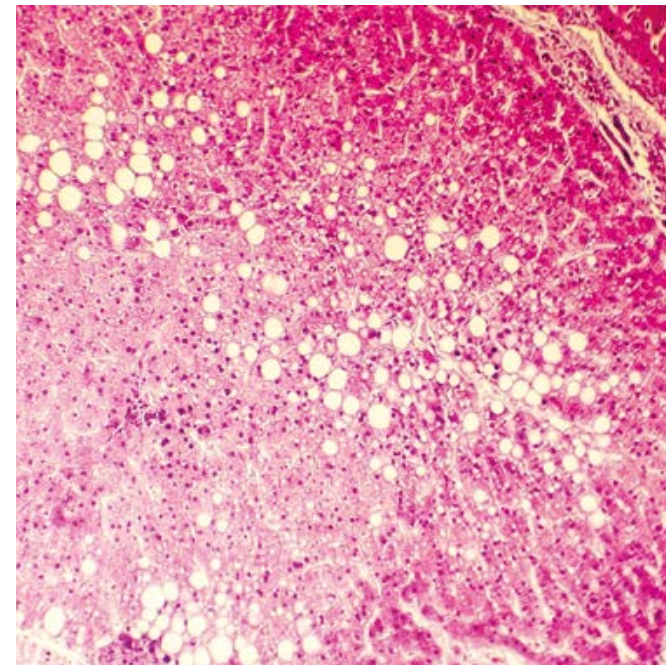
The National Food Institute conducts research with Aarhus University Hospital, among others, in how faeces from healthy people can cure the life-threatening gut disease *Clostridium difficile*, which is currently being treated with antimicrobials.

"Staff at Aarhus University Hospital have experienced that nine out of ten patients get well in as little as a few days after a faecal transplant. This is important because some of those patients cannot be cured by antibiotic treatment," Tine Rask Licht says.

Today many of the patients are treated with two or three types of antibiotics. However, treatment with faeces may be an excellent alternative in the future. The high percentage of very sick patients who get well because of a faecal transplant is challenging the general assumption that some patients are too sick to get a transplant.

#### **The future lies in the gut**

Until now, the researchers have only solved a small part of the complex mysteries of the gut, and in the future, the National Food Institute will have an increased focus on understanding how the different bacteria in our gut affect our sensitivity to e.g. the chemicals and hormones, which enter our body via foods and packaging.



Research from the National Food Institute has showed that the intestinal microbiota may influence processes in the liver.

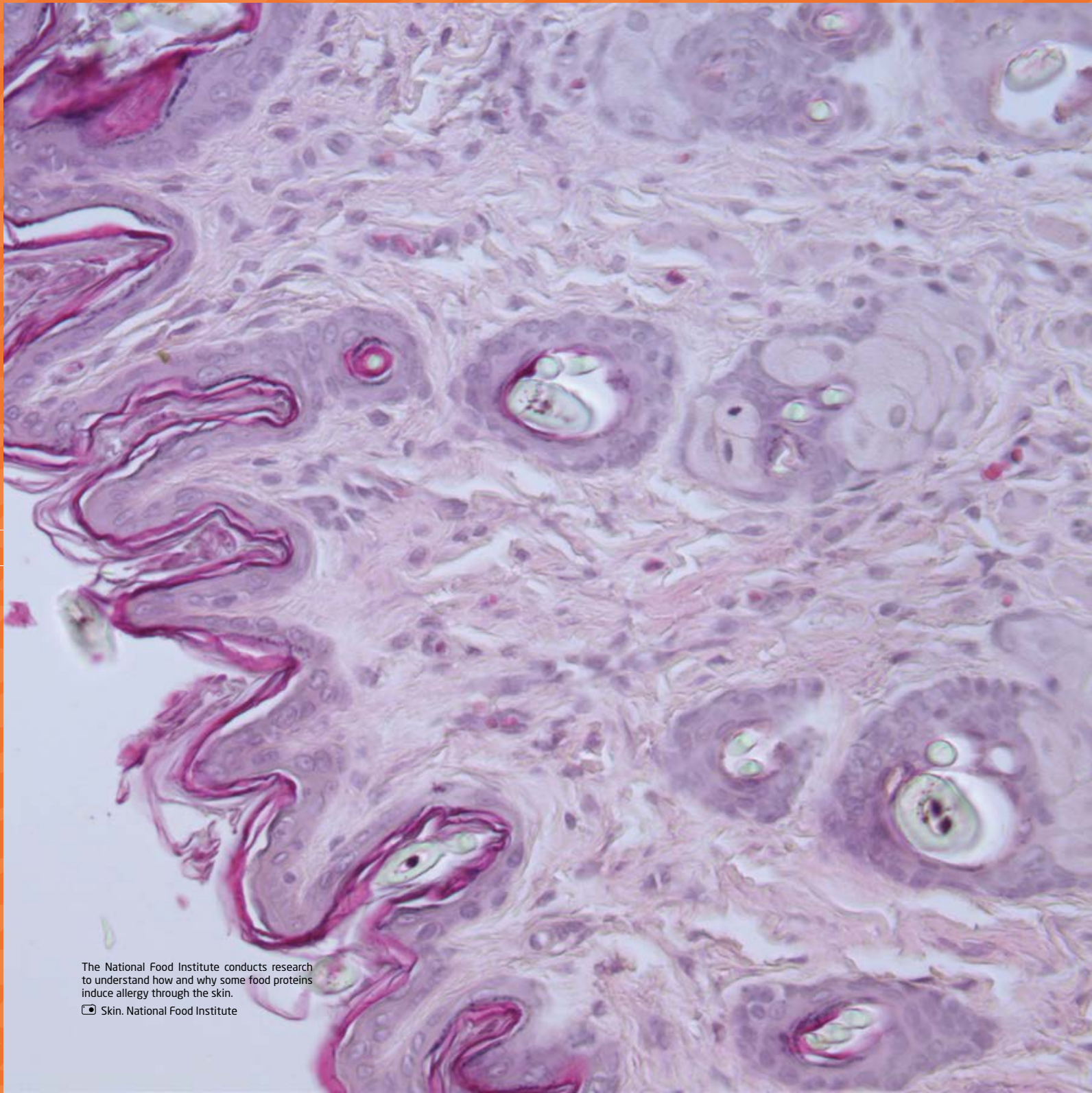
© Histological section of the liver. Shutterstock

“The ambition is at to gain an even greater understanding of the complex bacterial composition in the gut and its influence on health. This can lead to personalized dietary advice and medication. At the National Food Institute, we will explore how genetically modified bacteria may be used as an alternative to medication, and how advanced methods for encapsulation of bacteria can promote the colonisation of desirable bacteria in the gut.”

**Tine Rask Licht**

Professor and Head of Research Group





The National Food Institute conducts research to understand how and why some food proteins induce allergy through the skin.

📷 Skin. National Food Institute

# Food allergy may develop through the skin

Food allergy not only develops after ingestion of food. What we put on our skin and in our hair can also cause allergies. The more knowledge we have about how allergies develop, the better the options for preventing and treating them will be. The National Food Institute works to prevent and treat allergies and to promote tolerance.

Millions of people around the world suffer from food allergies, and, in the worst cases, the condition can be fatal. Therefore, the National Food Institute conducts research on how to prevent, treat, and manage food allergy.

When people become allergic, it is mostly - with a few exceptions - the proteins, which people develop allergies towards. The body can create a type of antibodies whose original purpose was to fight parasites. When such antibodies start reacting to foods that are normally harmless, a faulty response has occurred in the body, which then causes the allergy.

Why do people primarily become allergic to certain foods and not to others? The basis of the research is to understand why some food proteins are allergenic and others not. Therefore, the researchers study both the allergenic and tolerogenic properties of proteins - i.e. the properties that contribute to allergy and tolerance development, respectively.

It is important to explore both aspects because this provides the researchers with the knowledge they need to develop new strategies that can prevent and treat allergies. One purpose of the research is to change the structure of a protein, so that the protein may still give us tolerance but not cause allergy.

## Scratches and inflammation increase the risk

The Institute's research is conducted through rat experiments. This provides the researchers with the opportunity to examine what happens when the animals are exposed to the given protein for the first time. Almost all research related to the sensitization phase of allergies (where the allergy occurs) is conducted on animals as it is impossible to retrospectively go back in a person's life to see how this person developed the allergy. However, by studying sensitization in the animals, the researchers can obtain knowledge that will help them to prevent and treat allergies.

A number of the Institute's research projects relating to exposure suggest that we are likely to develop allergies through the skin, i.e. when allergenic substances come into contact with your skin from the environment or from the cosmetics we use, including shampoos, conditioners, etc. The researchers are, therefore, working on projects relating to skin sensitization, which focus on examining how and why some food proteins can cause allergy through the skin.

"We know that the nature of the skin affects whether you will develop allergies. If the barrier of your skin is broken, you may be at greater risk. Furthermore, if you have an inflammation

such as in the skin disease atopic dermatitis, you are also more exposed,” Senior Researcher and Head of Research Group Katrine Lindholm Bøgh says.

“It would be amazing to have the resources to develop tools and techniques to retrospectively diagnose how the patient has developed his or her allergy: Did the person develop the allergy after food ingestion or through the skin? Such knowledge would be of great significance in respect of both the treatment and prevention strategies, which would make life easier for patients who are predisposed to developing an allergy - or who are already allergic,” Katrine Lindholm Bøgh says.

#### **If we haven't eaten it, we shouldn't put it on our skin**

How easy or hard it is to become allergic to a substance that we put on our skin is among other things dependant on the properties of the proteins.

Proteins that have been used in a bottle of shampoo may have been modified. The manufacturer of the shampoo may have used processed food proteins which have been made more emulsifying and foaming through hydrolysis. Because the proteins have been modified people may be at greater risk of developing an allergy to it. This is because we have not previously eaten the exact same protein. The immune system sees it as a brand new protein to which the body has not yet developed any tolerance.

Modified food proteins in cosmetic products thus constitute a greater risk than non-modified proteins.

“It is very important that you have eaten a food protein before you put it on your skin. Otherwise, it could cause the immune system to see it as a new substance with various consequences. You can become allergic to a substance when you are exposed to it for the first time, but you are also at risk of losing tolerance to something which you were previously able to tolerate,” Katrine Lindholm Bøgh explains.

“From Japan we know examples of people who have used a soap with modified wheat protein and subsequently became allergic to the modified wheat protein, while others also became allergic to non-modified wheat which they tolerated before using the soap,” Katrine Lindholm Bøgh says.

Whether a protein can cause an allergy also depends on the context in which the protein occurs. It probably matters whether the protein occurs in a soap, lotion, or oil. Therefore, the researchers are studying what influence the context - or matrix - has on developing an allergy.

#### **Interaction between industry and authorities benefits consumers**

The researchers closely collaborate with the industry in respect of testing products and helping to develop innovative solutions.

One example is birch sap, which many people with a birch pollen allergy have started to drink to reduce their allergic symptoms. There is no scientific evidence of the positive effect of birch sap yet, and, therefore, the researchers are testing birch sap by using animal studies to find science-based evidence of the effect of the sap.

Another example is the Innovation Fund Denmark project ALLEVIATE, that aims to develop new products which can prevent cow's milk allergy and treat peanut allergy. The new products would be able to promote people's tolerance to the proteins in food that can cause allergies. The aim of the project is to develop partly ingredients for an infant formula that prevents babies and toddlers from becoming allergic to cow's milk, partly a drug candidate for the treatment of peanut allergy.

The recommendations and risk assessments which the Institute delivers to the Danish Veterinary and Food Administration and the Danish Environmental Protection Agency also help the authorities to decide what ingredients should be allowed in the products on our supermarket shelves.

“**The ambition is** to contribute to fewer people becoming allergic in the long run, that more people can get treatment, and that people with allergies can manage their allergies in an easier way. It would increase the quality of life if allergy sufferers could go to the supermarket knowing which products are safe to buy and use, and which products they must avoid. Moreover, it is our ambition to get a better understanding of the connection between stress and allergy. We know that the risk of developing allergic reactions is greater when we are exposed to the allergen while we are physically or mentally stressed. As both stress and allergy are on the rise, it is obvious and essential to look at the connection between the two phenomena, which both have a negative effect on our quality of life.”

**Katrine Lindholm Bøgh**

Senior Researcher and Head of Research Group



# A 360° view of the effects of foods

By exploring both the beneficial and the harmful health-related properties in foods, consumers and authorities become better equipped to predict the health effects of individual foods, nutrients, and diets. The National Food Institute is leading in the area of risk-benefit assessments.

Fish is an important source of beneficial fatty acids and vitamin D, but fish can also contain harmful heavy metals such as methylmercury. Nuts contain healthy fats, but they can also contain carcinogenic moulds (aflatoxins). And red meat is one of the main contributors when it comes to unhealthy intake of saturated fat, but at the same time it contains important dietary iron.

“Risk-benefit assessments allow us to quantify, compare, and measure the health effect of specific foods or food groups,” says Senior Researcher and Head of Research Group Morten Poulsen, whose group heads up the International Network on Risk-Benefit Assessment of Foods.

## What is a healthy diet?

The National Food Institute, which has a long tradition of research in the field of food safety, is leading within the area of risk-benefit assessments.

Among other things, risk-benefit assessments are used to quantify the health impact of eating in accordance with the official food-based dietary guidelines or following a specific diet compared to what an average Dane eats. Furthermore, the calculations make it possible to explore segmented population groups such as women of childbearing age or men over 50 years, and examine what happens to your health if one type of food is replaced by another.

## Replacing steak with fish results in better health

A risk-benefit assessment conducted by the National Food Institute showed that the health of the average Dane - and in particular men over 50 and women of childbearing age - would benefit if people replaced some of their meat intake with fish and thus reach the recommended weekly intake of 350 grams of fish.

“The Institute’s calculations show that the Danish population can gain up to 7,000 healthy years of life annually if all Danes eat fish instead of red meat. However, the health benefit depends on the type of fish the consumer chooses. The greatest health benefit comes from eating fatty fish (such as herring and mackerel) or a combination of fatty and lean fish (such as plaice and pollock). The benefit is smaller if the consumer eats only lean fish”, Morten Poulsen says.

If consumers decide to eat only tuna, the overall assessment shows a significant health loss. Tuna is low in beneficial fatty acids and can have high concentrations of methylmercury. The health loss is assessed to be particularly high among women of childbearing age as a large intake of mercury can damage unborn children’s brain development.

## Interdisciplinary cooperation is the key

Risk-benefit assessment is a relatively new discipline that draws on a number of disciplines such as nutrition, toxicology, microbiology, and epidemiology.

Risk-benefit assessments from the National Food Institute are used, e.g., to assess the effect of fortification, production methods, and dietary recommendations.

Red lettuce. Colourbox





The National Food Institute develops models to be used in risk-benefit assessments, which evaluate foods' harmful and beneficial effects.

📷 Salmon. Colourbox



The National Food Institute calculates the burden of disease of various foodborne diseases and can compare risks associated with different foods.

📷 Raspberry. Colourbox

In the assessments, the researchers often calculate the beneficial and harmful health effects by using the health metric disability-adjusted life years (DALY). DALY is a measure of how many years people will have to live with a reduced quality of life due to illness, and/or how many years are lost because a person dies earlier than expected.

#### **Intervene to ensure as few people as possible become ill**

Besides risk-benefit assessments, health metrics can be applied to explore the burden of disease in the population caused by different chemicals and disease-causing microorganisms, contaminants in food, and dietary risk factors such as a high intake of sugar or a low intake of fruit and vegetables.

Studies show that Campylobacter is the foodborne bacterium that makes the biggest contribution to the burden of disease in Denmark. Even in countries like Denmark, which have excellent monitoring systems, it is difficult to determine how many

people are affected by a foodborne disease every year. Many of these illness cases often stay under the authorities' radar because not all patients seek medical care, not all doctors seek a sample, and not all samples are analysed.

Researchers at the National Food Institute have estimated the burden of disease of the three foodborne pathogens Salmonella, Campylobacter, and verotoxin producing Escherichia coli (VTEC). These show that Campylobacter ranks highest followed by Salmonella.

The results help the authorities and food producers to assess where to intervene so that as few people as possible get sick from the food they eat.

"Risk-benefit assessments have given us an effective tool to examine the health effects in the population, promote healthy eating habits, rank food-related risks, and in the production of foods," Morten Poulsen says.

“The ambition is to use and streamline even more data so that the risk-benefit assessments can reach the public sooner. This would, for example, make it possible to conduct a risk-benefit assessment of different diet trends as soon as they reach the consumer. Today it takes too long, and the trends are usually over by the time the results are ready. We also hope to build a bridge between the industry, consumers, and authorities through even more interdisciplinary cooperation when it comes to assessing both the harmful and the beneficial.”

**Morten Poulsen**

Senior Researcher and Head of Research Group



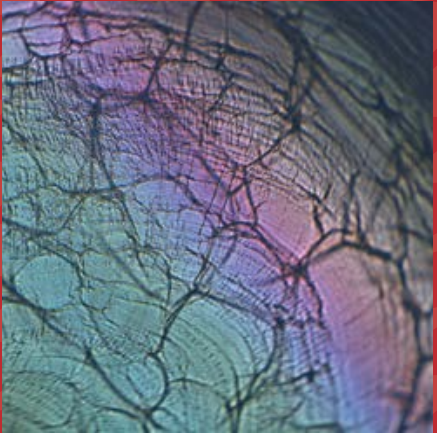
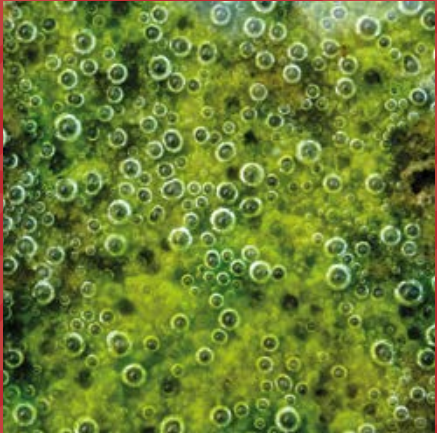
# The National Food Institute develops new and better food products for a growing population

According to forecasts from the UN, the world population will grow by more than two billion people over the next decades so that the total world population will reach 9.7 billion people by 2050. Moreover, the middle class is also growing, and more people are moving from the countryside to the cities. As such, there will be more mouths to feed, and the demand for healthy and convenient foods is also increasing.

The UN estimates that in 2050 we must produce 70 % more food than we do today in order to feed the world population. However, the current way of producing food will most likely not be able to meet this demand. There is a need for research and innovation to find new

sources of healthy, safe, and better foods and food components.

The National Food Institute's vision is to make a difference by developing new and better food products for a growing population. The Institute is striving to achieve this by finding new sources of raw materials and ingredients, assessing their nutritional content and the safety in using them - and by finding technologies that can be used to produce them. For example, proteins from grass and seaweed can be developed to become high-quality products, and mealworms and other insects may also be on the menu of the future. Food must be healthy, safe, and preferably also tasty.





# Cell factories produce milk protein without the use of a cow

Take a residual product from the food industry and instead of discarding it, look at it as a side stream and use it to develop a new food. The National Food Institute can e.g. make milk protein without the use of a single cow. Rather, a cell factory does all the work.

At the National Food Institute, the researchers can make a bacterium produce milk proteins in a so-called cell factory. This is a smart idea - because if you can make bacteria convert side streams into milk proteins efficiently and profitably, you can produce foods that are high in protein without having access to animal products.

As the world population keeps growing, there is an increased demand for healthy and tasty foods that are rich in proteins. Finding efficient and environmentally friendly methods to produce and grow foods that are able to feed billions of people is proving to be quite a challenge.

"At the National Food Institute we can produce milk proteins without the use of a cow. For example, we modify the bacterium *Bacillus subtilis* slightly so that it starts producing large quantities of milk proteins with good functional and nutritional properties. For this process, it is possible to use residual products from the industry as feedstock for the bacteria - that is the food the bacterium gets so it can grow," Professor Peter Ruhdal Jensen says.

A cell factory is not a building or an instrument. The factory consists of the bacterium itself as well as the processes that take place inside this bacterium.

## **Previously the pigs could have it - at best**

An important part of working with cell factories is to utilize the side streams - residual products - which are created during the production of foods and thus produce another product from the side stream. Whey from milk processing contains large quantities of sugar, which may have previously been thrown out or used as pig feed, at best. Instead, dairies will in the future be able to convert the sugar into a substance which will be very valuable to the food industry in the future. This will offer a more efficient resource utilization and thus a more sustainable food production.

"Some of the food ingredients which can be developed by cell factories may be of interest worldwide as a means to feeding the constantly growing population. If we look 30 years ahead, we will be almost 10 billion people on Earth. We might be able to provide food for all these people if we utilized all land areas, cut down the rainforest and so forth. However, we would rather do this in a sustainable way to ensure that the impact on the environment is as small as possible. A sustainable solution is that we learn to use our resources in a suitable and efficient way. In the future, we do not want any unutilized side streams. Everything must be used - and preferably to produce food for humans," Peter Ruhdal Jensen says.

The National Food Institute develops bacterial cell factories that can produce food ingredients from sustainable resources such as residual products from the food industry.

📷 Fermentor. Mikal Schlosser



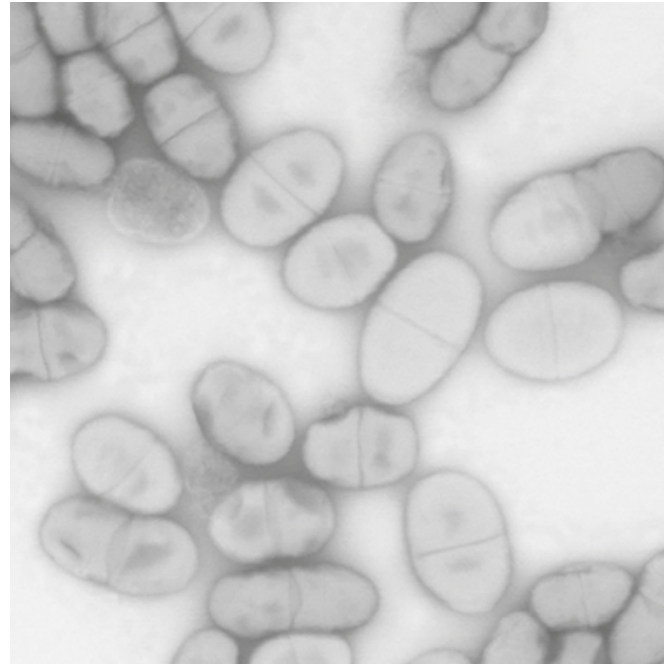
### A cell factory turns one substance into something else

The cell factory can turn a side stream such as lactose into butter aroma by feeding a bacterium with the milk sugar which then spits out butter aroma - a food ingredient that food companies can use as flavouring in different products, from cookies to sauces. To produce the butter aroma, the researchers have slightly modified certain processes, which naturally take place inside the bacterium. The bacterium has been genetically modified: Some genes have been removed whereby routes in the metabolism have been redirected and the enzymatic reactions have been changed.


The Institute can make cell factories in two different ways: One is the natural way, another is by means of genetic modification. In the natural way, the researchers screen for suitable bacterium. They are looking for a needle in a haystack so to speak, and they may find a lactic acid bacterium suitable for producing butter aroma. The good thing about this method is that the researchers can produce an ingredient, which does not require a GMO - genetically modified organism. Therefore, the industry is free to use it to produce food and without labelling. However, the disadvantage of this process is that it is very time-consuming to identify which bacteria have the desired properties.

The genetic modification method, on the other hand, is much faster, but the disadvantage is that the food ingredient must undergo an authorization process and will subsequently be subject to labelling requirements because it is a GMO. According to the Professor, this is a paradox:

"In the butter aroma example, genes from other organisms have not been added, and the genetically modified version has fewer and more accurate genetic changes. Based on a rational assessment, the genetically modified version should thus be preferred to the 'naturally' produced one. Therefore, it would be nice to have a more nuanced debate as we really need to be able to use these techniques in the future race to secure a sustainable food production," Peter Ruhdal Jensen says.



By using cell factories, the National Food Institute is able to get slightly modified lactic acid bacteria to produce milk protein by feeding the bacteria with residual products from the production of food.

 Lactococcus lactis, lactic acid bacteria. National Food Institute

“The ambition is to learn how to make the most of all side streams. This will have a positive impact on our emission of greenhouse gases, and when all comes to all: The greater utilization of the foods we produce, the smaller impact on our agricultural land. Thus, we can avoid using all of nature and preserve e.g. the rainforest. We should not just do this because nature is beautiful, but also because it is important to maintain biodiversity. Moreover, the forests also keep the CO<sub>2</sub> level low.

In the future scenario, we will not only use the side streams from dairies, breweries, and other food production. We will also utilize all resources from the agricultural sector. Today, we burn straw from wheat production in straw-fired boilers and make heat from it. In the future, we have hopefully found even more alternative ways to produce heat, making it possible to use straw as a feed for the microbiological production of foods, chemicals, and jet fuels.”

Peter Ruhdal Jensen  
Professor

### Alcowhey turns lactose into alcohol

Alcowhey is the name of a spinout company from the National Food Institute, which is based on patented technology in the form of a cell factory developed at the Institute. By means of lactic acid bacteria, the cell factory turns residual lactose from dairies into ethanol - the alcohol contained in spirits.

In the production of cheese, nine-tenths of the milk ends up as whey. As previously mentioned, whey contains sugar and protein. Large dairies such as Arla have the technology and know-how to further process these side streams themselves. However, small dairies do not necessarily have the resources to process the whey. In addition, it is a low-value product and is usually either sold as animal feed or it ends up as waste. Alcowhey offers the dairies a solution which enables them to use the whey in a more profitable way.

Alcowhey can help small dairies to convert whey to ethanol. Subsequently, the dairy can sell the ethanol to distilleries, who in turn use it in the production of alcohol. Alcohol is usually made from e.g. maize, cane sugar, or wheat - that is foods which could feed people. Therefore, it is also an advantage from a sustainability perspective that a residual product can be used to produce the alcohol.

In brief, the cell factory creates value in many ways: It turns a residual product into a new high-value product instead of drawing on foods that we could eat instead. In addition, it helps the dairies to develop a new business area.

### Something is brewing - new ways to more foods

The National Food Institute has invested in new fermenters. They can convert side streams to new food ingredients by using these as growth media for growing bacteria. This is a sustainable utilization of resources and part of the solution to the problem with feeding the growing population.

Fermentation converts a side stream - such as lactose from whey - to butter aroma by feeding the bacteria with lactose.

The bacteria used may be genetically modified so that they produce a substance which they would not produce naturally. In order to make the bacterium convert e.g. lactose to butter aroma, the researchers have removed some genes from the bacterium.

In other cases, the researchers can compare different bacteria which had their different genes 'turned up' or 'turned down'.

This allows the researchers to examine which bacterium would be the right candidate for the ingredient someone is wanting to produce.

To compare different bacterial strains, the Institute has invested in several BIostat® A-fermenters: Ten of them have a volume of one litre and two of them have a volume of five litres. Here the researchers can control the conditions in the fermenters such as oxygen, temperature, and pH.

The purpose of the work is to compare the bacterial growth and metabolism, under controlled circumstances, and thus to gain valid knowledge of the process and the result so that the new substances can be used in innovative industrial collaborations over time.

### WIDE SPAN IN RELEVANT RESEARCH AREAS FOR THE INDUSTRY

"As representatives from the industry, we really appreciate the cooperation with the National Food Institute. The Institute has a wide span in relevant business areas for the industry, and it is thus easy to access qualified knowledge and know-how.

We in the industry are favourably disposed to the fact that the Institute wants to be among the leading national food institutes in Europe, and that this is done through research cooperation with recognized universities.

It is a great strength that the National Food Institute works very closely with the industry and serves the authorities at the same time. It offers more substance to the cases on which we in the industry collaborate with the Institute.

Finally, the focus on life-long learning really makes sense. The industry demands opportunities to keep their employees up-to-date with the recent research-related development," says Vice President Esben Laulund from Chr. Hansen A/S, who is also a member of the Advisory Board at the National Food Institute.



Esben Laulund  
Chr. Hansen A/S

Chr. Hansen





The National Food Institute develops methods which can be used to create value from waste products from dairies and breweries and from underutilized resources such as seaweed and microalgae.  
Bladderwrack seaweed. Colourbox

## The hunt for nature's own additives

In general, aromas, emulsifiers, and preservatives do not make up a large part of our foods. However, they make a big difference for their taste, texture, and shelf life. The researchers at the National Food Institute are searching through the building blocks of foods in order to develop new, natural, and sustainable additives.

For several centuries, additives have been used to extend the shelf life of foods and to provide them with a better texture and taste. However, today's consumers often demand natural additives that do not require an E number.

In order to help the industry give the consumers what they want, researchers at the National Food Institute have developed methods to identify naturally occurring additives e.g. in food proteins, which can help slow down the process of fatty acids in foods going rancid, among other things.

Along with bioinformaticians from DTU Health Tech and colleagues from Aalborg University, the Institute's researchers have developed tools that are able to extract those parts of the proteins that can be used in the production of additives.

### Better resource utilization

The researchers have found the active peptides - which are the building blocks of proteins - in e.g. residual products from the production of potato starch and the processing of seaweeds. This ensures a much better and sustainable resource utilization of raw materials.

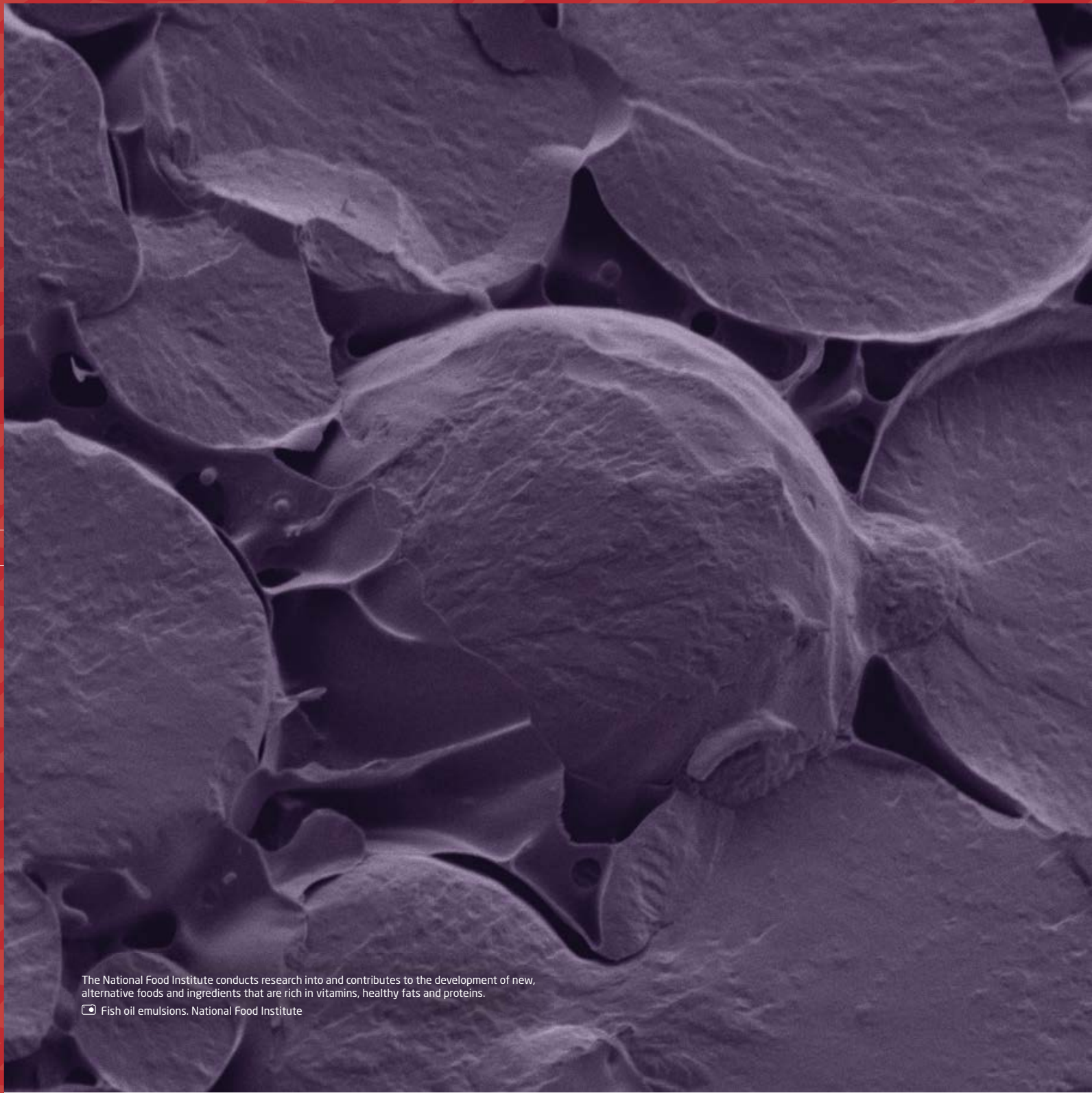
"As the additives also extend the shelf life of foods, our research contributes to combatting the waste of resources in several ways," Professor Egon Bech Hansen says.

### Huge increase in value


The large quantities of residual products generated by the food industry are typically sold at a kilo price of between one and 15 Danish kroner to other companies, who convert them to biogas or use them as animal feed.

However, depending on what it is used for, the food companies can sell the extracted protein mass at a kilo price that is ten to a thousand times higher than the price at which they currently sell the residual products.





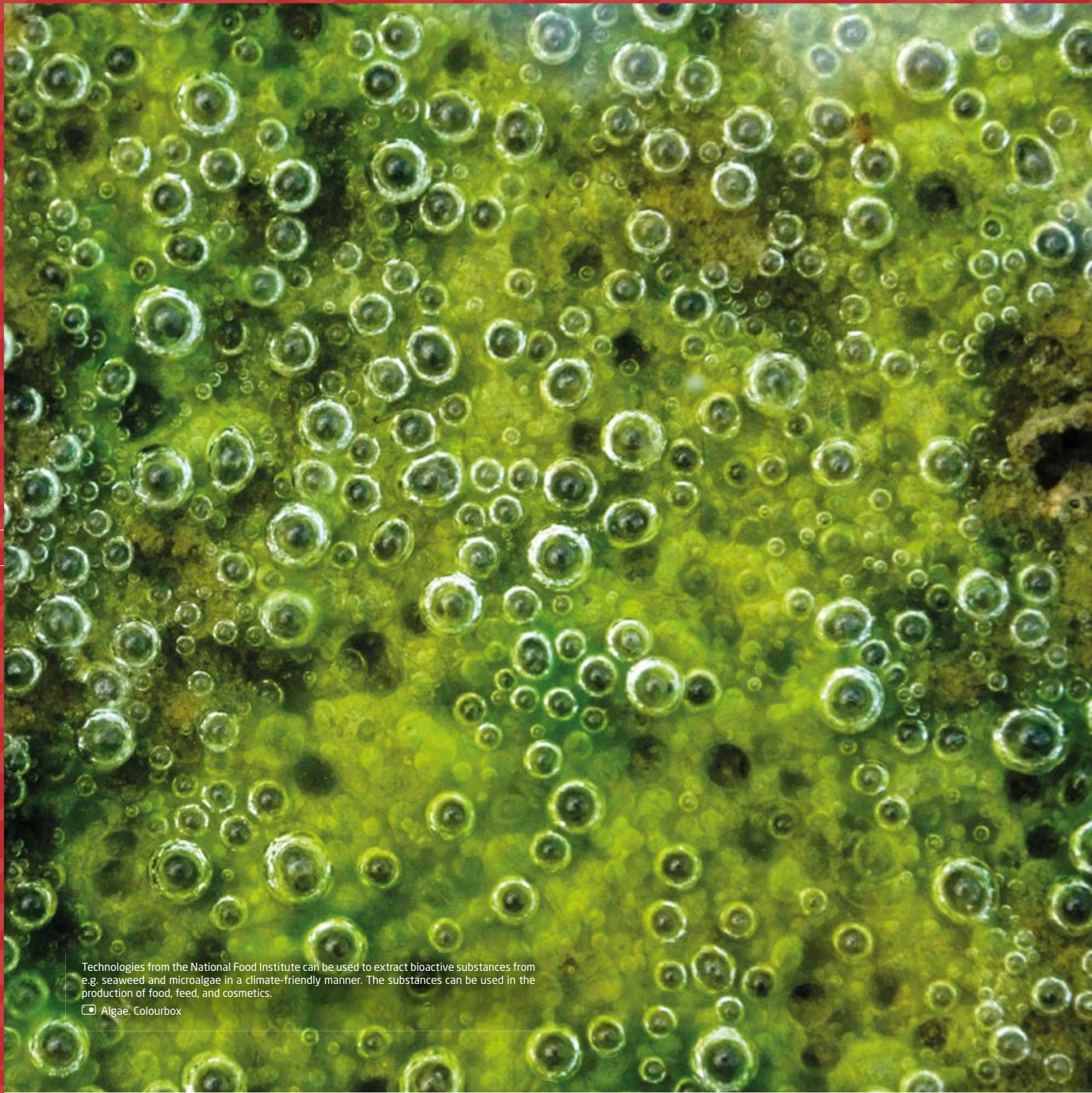
The National Food Institute conducts research into and contributes to the development of new, alternative foods and ingredients that are rich in vitamins, healthy fats and proteins.

 Fish oil emulsions. National Food Institute

“**The ambition is** to transfer the methods we use to find new ingredients in a number of other vegetable or animal residual products. With the very large quantities of residual products generated by the food industry, the Institute’s methods have a great potential to create added value for the companies while they can also ensure a better utilization of Earth’s limited resources.”

**Egon Bech Hansen**  
Professor





Technologies from the National Food Institute can be used to extract bioactive substances from e.g. seaweed and microalgae in a climate-friendly manner. The substances can be used in the production of food, feed, and cosmetics.

Algae. Colourbox

## Seaweed and micro algae on the menu

In order to be able to produce enough food for the growing world population in the future, the National Food Institute is exploring the great potential in utilizing aquatic resources such as seaweed and microalgae for foods.

We need new ideas for food sources as the world population is growing. Naked farmland is becoming sparse, and therefore, the National Food Institute is looking under the surface of the ocean to explore the potential for growing nutritional resources such as seaweed and microalgae on a large scale.

The plants in the sea are a rich source from which omega-3 fatty acids, antioxidants, and bioactive peptides can be extracted and included in the food production and as ingredients for food and feed.

Think seaweed in new ways

For many Danes, seaweed is either a foul-smelling acquaintance on the beach or a nuisance that tickles between your toes when you get out in the waves. However, seaweed is looking increasingly like a nutrition-rich raw material in the production of food, and bladderwrack seaweed in particular can turn out to be a useful, healthy, and sustainable ingredient in foods.

"Bladderwrack contains antioxidants, and the National Food Institute has conducted research on how the antioxidants can prevent fatty acids in some foods from becoming rancid. As such, the antioxidants can give the foods a better taste," Professor and Head of Research Group Charlotte Jacobsen says. She adds:

"It is essential that the foods of the future also taste good if they are to gain the consumers' acceptance and become profitable for the food industry." At the National Food Institute, a professional sensory panel working in accordance with the ISO standards assesses the taste experience.

The results show potential within the production of foods but also for inclusion in cosmetics and in the pharmaceutical industry where the natural antioxidants from bladderwrack can replace the synthetic antioxidants used by the industry today. However, more research on the antioxidants is needed before the industry can transform the Institute's results into products.

The research has also opened up opportunities for using environmentally friendly methods to extract antioxidants. Among other things, the National Food Institute has with great success used hot water under high pressure to extract antioxidants from seaweed.



### Seaweed changes all year round

The researchers at the National Food Institute are carefully following the different natural phases that seaweed undergoes throughout the year in order to find the best harvest time for seaweed.

“Seaweed contains a number of positive and beneficial substances, but at some times of the year certain types of seaweed contain too much iodine to become feed or foods. At the Institute, we work with different types of seaweed and on mapping the ideal seaweed harvest time. Moreover, we are looking for methods to reduce the iodine content in seaweed,” Charlotte Jacobsen says.

### The small, green features of the sea

Seaweed is not the only resource that has captured the researchers' attention in the hunt for the foods of the future. There is also potential in extracting ingredients from algae which can be used in the production of foods. Therefore, the National Food Institute is exploring the possibilities of growing algae in large scale.

In a project financed by the Danish Innovation Fund, the aim is to grow seaweed in the form of brown algae in Danish and Faroese waters. Brown algae contain antioxidants, protein, polysaccharides, and minerals, and they could be interesting for the industry in relation to the production of functional ingredients in foods, feed, and skin lotions. For example, the sugar molecule



DTU develops technologies that enable better utilization of marine resources. These technologies include harvest, extraction, concentration, and fractionation of bioactive substances from e.g. seaweed.

Seaweed. Colourbox

laminarin has turned out to have an anti-tumour, anti-inflammatory, and anti-coagulant effect.

### Microalgae are growing at the National Food Institute

The National Food Institute grows different types of microalgae species, which promotes a strong analytical platform. Within the Institute's microalgae facility, ten different microalgae strains are growing under the best growth conditions. Here the researchers can work with the entire production chain, right from the growing phase to the final granulate.

Thanks to the facility, it is possible to test what it takes for the different types of algae to achieve the optimum content of

the wanted nutrients so that they can produce new ingredients such as omega-3 fatty acids, pigments, and proteins. The aim is that the ingredients can make a positive contribution to the new foods, cosmetics, and nutraceuticals of the future.

The facilities make it possible to work with the microalgae in a very small scale, from small test tubes to large 50 litre tanks. The plant can be upscaled to 4,000 litres, and the National Food Institute has developed a drying facility that can produce microalgae meal, which the researchers can then study.

“The ambition is that the National Food Institute can contribute knowledge which would enable the industry to create healthy, nutritionally balanced, and sustainable foods from the ocean's resources. Globally, we must be better at utilizing the resources so that we are able to feed the growing population in the future as well.”

Charlotte Jacobsen  
Professor and Head of Research Group



# Eating grass is not for ruminants only

The juice of grass contains protein, which - in its concentrated form - is a new ingredient with the potential to become an important alternative to the proteins that are derived from meat in particular. This is one of the ways the National Food Institute works to feed the growing world population where more and more people will need protein on their plates.

How is it possible to develop sustainable foods to feed the growing world population? Part of the answer may be grass. Together with the research centre AU Foulum at Aarhus University, researchers from the National Food Institute have developed a method to extract protein from grass. The new ingredient has a good amino acid composition comparable to the one of soya, eggs, and whey. However, production of grass protein has a significantly lower impact on the environment and climate.

The composition of the world population places new demands on the production of food. The world population is growing fast, and many people are getting richer and richer and want to have a different type of diet. This means that there is a growing demand for proteins and thus, basically, for animal products.

Alternative and better methods to produce proteins, which do not have an adverse impact on the environment, are therefore needed. This is where grass enters the picture, because grass is an environmentally friendly crop. It is very hardy, it does not need much fertilizer, and people can actually eat it. However, it takes special methods to convert grass to food.

## **Grass juice becomes protein powder**

People cannot eat grass, because unlike cows we do not have four stomachs. Grass is very rich in fibres and cannot be metabolized in our stomach.

However, the researchers at the National Food Institute have, together with AU Foulum, found a method to convert grass to an edible ingredient. First, grass is passed through a dewatering press, which works just like a huge juicer. It separates the raw material into two parts: One part consists of dry matter high in fibres, which can be used for cattle feed, and the other part consists of high-protein fluid. When the proteins are separated from the fluid, the result is a powder that consists of protein. The kilo price of protein powder is approximately ten times higher than the price as feed. The dry matter part can still be sold as cattle feed, which makes the concept relatively profitable and even more sustainable.

## **Grass can taste like liquorice and peanut butter**

Besides grass being so high in fibres that people cannot eat it, it isn't very tasty. The taste is bitter and in large quantities, it

The National Food Institute is searching for solutions that can help feed the world's growing population in an economically viable and sustainable way, e.g. through the biorefining of a wide range of raw materials.

Grass. Colourbox

will be very uncomfortable for us. This may be nature's way of telling us that we should not eat grass in its pure form.

However, the National Food Institute has succeeded in making products such as protein bars with a grass protein content of up to 10 per cent, without people disliking the taste. The taste of grass is camouflaged by adding aromatic ingredients such as peanut butter, honey, ginger, and liquorice. As soon as the researchers manage to reduce the taste and colour of grass even more in the protein powder, the industry can use the properties of the protein in a wide range of foods.

#### **Ryegrass is rich in the right amino acids**

The most important quality parameter for proteins is the amino acid composition. Therefore, not all protein sources are good substitutes for protein sources from animal such as meat, eggs, and milk. Grass has turned out to be a good protein source as the amino acid composition in the protein concentrate from ryegrass etc. is very beneficial. In several cases, it is even better than products made from soy protein already on the market. This makes ryegrass an excellent protein source.

Eating grass does not solve all of the world's food problems. However, it is an important piece of the puzzle along with other alternatives such as insects and seaweed.

#### **New on the plate**

##### **- and on the way to being approved by EFSA**

It is one thing to enable the production of grass protein. It is another to ensure that it is safe to eat. Grass protein is a so-called novel food and as such it must undergo a process of approval by EFSA, the European Food Safety Authority. This approval means that EFSA assesses that the ingredient is safe to eat, meaning that it is not toxic and does not cause allergies e.g. in people who are allergic to grass pollen.

In the so-called InnoGrass project, the National Food Institute is at the head of studying the nutritional content of the grass protein and any unwanted substances such as toxins and allergens. The goal is to have the grass protein approved as food so that businesses can start using it in their own productions.

InnoGrass is financed by GUDP (Green Development and Demonstration Programme).

Some food businesses are already interested in using the grass protein in their products. However, applying for a novel food approval would be a large financial burden for most small and medium-sized companies. Therefore, the National Food Institute plays an essential role in the approvals process by contributing the necessary research-based documentation.

"For the National Food Institute, we see it as an important job to facilitate the approval of grass protein as a food ingredient. In that way, the Institute contributes to us moving closer to a radical change in our eating habits - away from animal proteins that have an adverse impact on the environment and towards more sustainable alternatives," Peter Ruhdal Jensen says.

“**The ambition is** that research from the National Food Institute can make the utilization of grass profitable. It must be able to compete with cheap products such as soya. It should be cheap to buy, offer good functionality in the foods, and it must be tasty. The idea is that we will eat many products based on grass. In particular, the market seems to be big among young consumers who, fortunately, pay great attention to the environment and sustainability.”

Peter Ruhdal Jensen  
Professor





The National Food Institute is researching whether it is safe to use a wider range of waste products from the production of food and private kitchens as insect feed.  
© Mealworms. Colourbox

## Insects' safe journey to the dinner table

The production of insects emits 100 times less CO<sub>2</sub> than the production of cattle. Thus, insects are an excellent protein source for sustainable and healthy foods and for animal feed as well. The National Food Institute works closely with authorities and producers to pave the way for a production where feed and food safety are paramount.

Denmark aims to be a pioneer in the production of insects for food and feed, which is in its infancy. Insects do not need much space, and from ten kilos of feed, you can obtain 4.5 kilos of mealworms but only 2.5 kilos of pork or a mere 1.1 kilo of beef. In order to mass produce insects, manufacturers need access to cheap and sustainable sources of growth substrates as feed for the insects, and this means that feed and food safety will need to meet certain requirements.

"In a legal context, insects are defined as farmed animals, just like for example cattle. Therefore, the insects are subject to the strict feed and food legislation in the EU to ensure the health of people, animals, and the environment, and to avoid the spread of serious domestic animal diseases and the like," Head of Division Dorte Lau Baggesen says. She believes that we are close to a breakthrough where insects are allowed as feed for animals with only one stomach, such as pigs and poultry.

### Science can pave the way for a law change

Today, legislation requires that feedstuff for breeding insects must be of vegetable origin and of feed-grade quality approved

also for other food production animals. Together with its project partners, the National Food Institute is exploring how more residuals from the production of food can be used as a growth substrate for insects. In particular, the legislation places strict restrictions on the use of residuals and waste products containing fish and meat.

"More scientific documentation is needed in order for the law to change so that more types of substrates can be used as feed for insects. The National Food Institute is working on showing that the production of insects can be done without spreading any biological and chemical hazards that might be present in the substrates," Dorte Lau Baggesen says. The National Food Institute is also exploring how heat treatment and processing in the production chain affects the insects. These results may provide the authorities with the necessary scientific basis for making a decision on an amendment of the legislation.



“The ambition is to ensure a profitable mass production of insects in the industry in the short term so that they can be used in food and feed. Hopefully, insect-based feed can alleviate the lack of proteins for domestic animals, and if the Scandinavian cuisine and the gourmet restaurants are open to using insects, this may make insects palatable to the general population. In the long term, it is our hope that it becomes legal and safe for organic household waste, which today ends up as biogas or in the incineration plant, to be used as a growth substrate for insects.

Even though it will be a while before mass-produced insects reach our dinner tables, we probably have to get used to the idea. Many of us have probably forgotten how sushi was initially received, so in time consumers will probably also accept the idea of eating insects.”

**Dorte Lau Baggesen**  
Head of Division



The National Food Institute considers mealworms and crickets to be among the foods of the future.

📷 House cricket (*Acheta domesticus*). Shutterstock



Other insects such as black soldier flies have potential as animal feed and will in future be included in the National Food Institute's research.

📷 Black soldier fly (*Hermetia illucens*). Texas A&M AgriLife Center at El Paso

#### Tingling and crawling in the insect facilities

The interest in producing edible insects for both animals and people is increasing. Therefore, the researchers at the National Food Institute are carefully following how insects can become safe to eat and meet the high food safety standards that we know from other foods.

The National Food Institute has special facilities for growing insects. Here it is possible to control the temperature and humidity in the room so that the insects achieve the optimal growth conditions.

Growing the insects makes it possible to conduct different studies which shed light on the risk that disease-causing bacteria are spread, as well as how to control this in order to ensure a high level of food safety in the future production of insects.

Until now, mealworms and crickets are the best bet in terms of insects for foods. The EU has approved seven types of insects for fish feed: black soldier fly, common housefly, yellow mealworm, lesser mealworm, house cricket, banded cricket, and field cricket.



# Nano-designed ingredients with improved properties

The National Food Institute uses carbohydrates, proteins, and lipids to develop natural so-called nano-microstructured ingredients, which the food industry can use to produce functional, healthier, tastier, and safer foods.

All foods - both natural and processed - contain nanostructures. For example, milk contains casein, a kind of milk protein with a diameter of between 100 and 200 nm, and meat consists of protein filaments that are far less than 100 nm thin.

By using carbohydrates, proteins, and lipid nano- and microstructures, the researchers at the National Food Institute can develop new natural ingredients with a better functionality. Due to the size and improved properties of the designed ingredients, the food industry can make products with the same pleasant taste, but with a lower sugar, fat, and salt content. This is due to the fact that the industry does not have to use the same quantities of the new ingredients.

## Enhanced delivery of bioactive substances

In addition, nano- and microstructured ingredients have a larger surface area per unit compared to similar ingredients with a larger structure. This makes these ingredients more biologically active, thus making it easier for the body to absorb them. The researchers at the Institute utilize this property to develop optimized delivery systems of bioactive substances - such as antioxidants, vitamins, and polyphenols - to the body so that the substances end up where they are most needed.

## Healthy probiotic bacteria with a protective layer

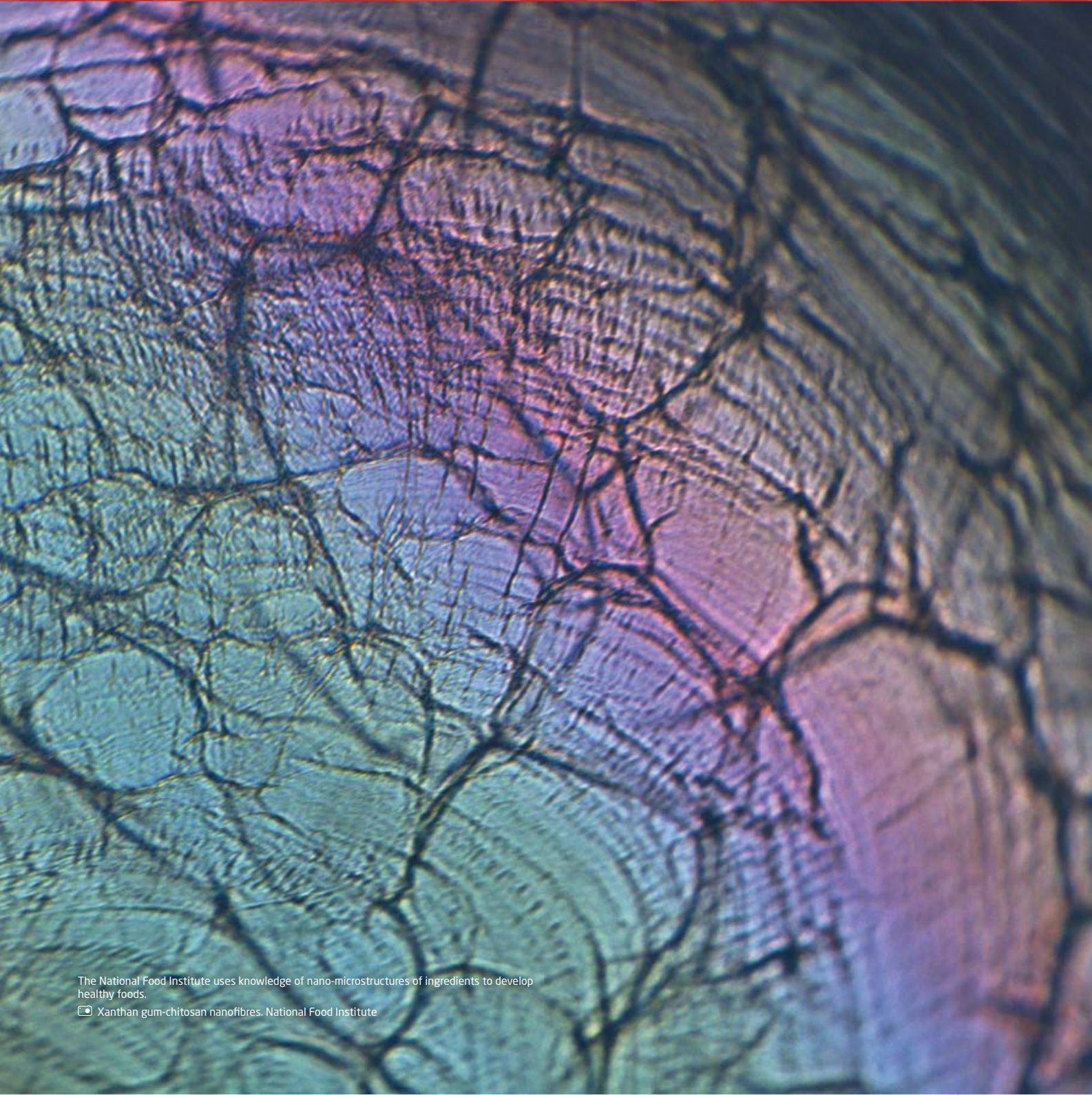
The researchers at the Institute work with the ingredient company Chr. Hansen to encapsulate probiotic bacteria, which for example can create balance in the bacterial composition of the gut after someone has received a harsh dose of antibiotics or following a period of illness. In order for the bacteria to work as intended, a significant number of them must be alive when they reach the gut.

In this project, the researchers use their expertise to coat the bacteria with a protecting membrane of nano-microstructures of sugar molecules. The membrane improves the stability of the bacteria so that they become less sensitive to changes in temperature and they stay intact if they are e.g. mixed into moisture and low pH rich foods such as juice and yoghurt.

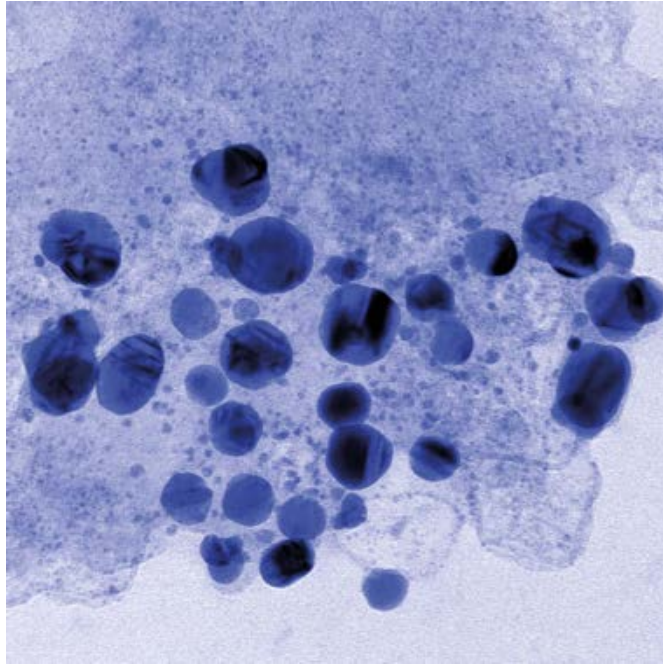
The knowledge from the project will make it possible to produce a wider range of food and beverages that contain probiotic cultures and have a longer shelf life than today.

"The project provides us with a greater knowledge of how the body absorbs different nano- and microstructures. Thus, the Institute can develop techniques that can control where and

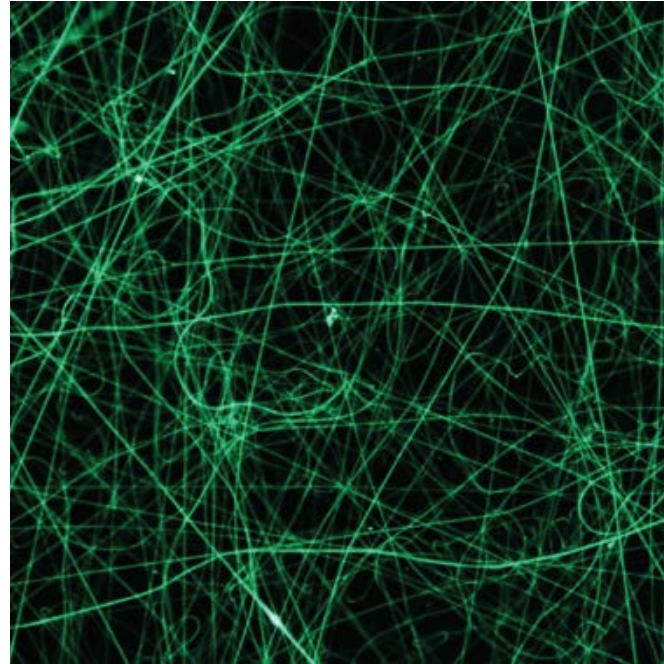
The National Food Institute uses knowledge of nano-microstructures of ingredients to develop healthy foods.

 Xanthan gum-chitosan nanofibres. National Food Institute





The National Food Institute conducts research into foods' nanostructures to find ways of developing healthier, tastier, and safer food ingredients and foods.  
© Silver nanoparticles. National Food Institute



The National Food Institute conducts research to study the body's uptake of different bioactive substances and ingredients in nano- or microsize.  
© Nanofibres. National Food Institute

when encapsulated bioactive substances are released in the body to achieve the desired effect," Professor Ioannis S. Chronakis from the National Food Institute says.

#### **Cracking the code for the production of vegan sausages**

In addition, the researchers use their knowledge of nano- and microstructures to develop edible 'film' made from plant-based ingredients, which can be used by manufacturers of vegetarian and vegan foods.

Their innovation may be used e.g. to provide vegan sausages with the right 'snap' - something that used to cause manufacturers headaches. Moreover, it will be cheaper to produce the improved film with the methods from the National Food Institute. This will be a great help to small manufacturers in particular.

The researchers can design the film so that it contains substances that are also able to protect against disease-causing microorganisms. Moreover, the researchers' innovations can easily be adapted so that a number of different industries can use them.

“**The ambition is** that the research at the National Food Institute can help to meet the demand for ingredients with added value which have specific health-beneficial effects and are manufactured sustainably with less resources. Moreover, the goal is to improve people's health and quality of life by continuously developing profitable nano- and microtechnologies which the food industry can apply to create functional, healthier, tastier, and safer foods. The Institute will also work on adapting these methods so they become useful for manufacturers of pharmaceuticals, textiles, cosmetics, packaging, and feed.”

**Ioannis S. Chronakis**  
Professor



# The National Food Institute creates sustainable technological solutions

Studies suggest that the food consumption accounts for approximately 25 % of the total climate impact per person. Reducing the climate and environmental impact of our diet requires new and gentler production methods that emit less CO<sub>2</sub>. In addition, the consumers must change the composition of their diet.

The vision of the National Food Institute is to make a difference by creating sustainable technological solutions - e.g. to ensure that raw materials are better utilized in order to avoid production waste and to utilize the production processes

more efficiently, and to make it easier for consumers to choose sustainable, high-quality foods.

For example, the work of the Institute focuses on how food companies can recycle water safely, optimize food production and save on energy and CO<sub>2</sub>, and better utilize residual products from the production of food and feed in order to develop high-value products. Furthermore, mathematical calculations of the climate impact of foods is a new focus area within the Institute's nutritional research.



# Sustainable foods with less power consumption, less raw material use, and less waste

To make it possible to feed the growing world population, rethinking the food industry's production processes is imperative. The National Food Institute helps the industry make the processes more efficient and sustainable.

"By applying mathematical models, new production technologies, and 'out-of-the-box thinking', the National Food Institute finds new ways to produce healthy, safe, and sustainable foods of the highest quality with a minimal power consumption, less raw material use, and less waste," Associate Professor and Head of Research Group Amin Mohammadifar says.

For example, the National Food Institute is changing the way sour milk products are produced. This will make it possible for the industry to meet the consumers' demand for easy-to-eat, firm yoghurts made without thickeners.

In the new production process, the researchers use ohmic heating, which quickly and homogeneously heats a product by running electrical power through it.

With a lower power consumption, the method provides the sour milk products with a better texture than products made in a traditional way. In addition, they are made in a shorter time, and less amounts of added dry matter are required to reach the desired consistency.

## **Maths is an essential ingredient**

One of the researchers' essential tools is mathematical modelling, which they apply to understand the influence that production parameters such as temperature, humidity, and equipment have on the taste and safety of foods. With the models, they are able to predict e.g. how changes in temperature and cooking time can ensure a juicier piece of meat which does not contain any disease-causing microorganisms.

The researchers at the Institute also develop prediction models, which can e.g. replace the time-consuming manual inspection that fish manufacturers use to decide for which purposes fish is best suited.

The models apply different biochemical data and computer-generated pictures to calculate the structure and quality of the fish and to assess whether the fish should be sold as cut, fresh fillets, or as smoked products. The process should help to ensure that as much fish as possible is utilized in products of the highest quality.

The National Food Institute develops technologies and models that are used to optimize the sustainable production of healthy, safe, cost-effective, and high-quality foods with minimal production of waste.

Hygienic design test rig, National Food Institute



“**The ambition is** for the National Food Institute to design foods with specific functional and nutritional properties that take the consumers’ different needs into account, based on age, sex, health, activity level, and food preferences. We will do that by intensifying the interaction between the Institute’s food technological knowledge and other relevant fields.”

**Amin Mohammadifar**

Associate Professor and Head of Research Group

The researchers’ prediction models can also be applied to predict the shelf life of fish and thus help to reduce food waste.

#### **From worthless to valuable**

Recycling the industry’s residual products is essential in a sustainable food production. Therefore, several projects at the National Food Institute focus on how low-value side streams can become a source of income.

For example, the researchers have developed a process line where mussels that are too small to be sold as food for human consumption instead become chicken feed without having to undergo an expensive and energy-intensive boiling process.

In an innovation project, the Institute also contributes research, which will enable the production of biodegradable food packaging made with residual products from the food production. In another innovation project, the Institute’s expertise is applied in order to turn chickpea brine into a vegan product that can replace egg whites.

#### **DTU Centre for Hygienic Design identifies the causes of bad cleaning**

At the DTU Centre for Hygienic Design, manufacturers can have their equipment tested and assessed based on international guidelines for a cleaning-friendly design. Subsequently, the Centre can certify equipment so that the manufacturer can prove that the equipment can be cleaned safely.

The Centre combines research, teaching, and advice giving for the biotech and food industry in respect of hygienic design. The Centre is the only test centre in Denmark for EHEDG (The European Hygienic Engineering & Design Group) with a DANAK accreditation to issue hygienic certificates for production equipment in Denmark.

The Centre uses methods that visualize bad design solutions which can make it difficult to clean equipment properly and thus generate a risk of microbial contamination of the equipment.

#### **Pilot Plant - a food technological test facility**

The Pilot Plant at the National Food Institute is built as a test facility where the researchers can work with production processes on the type of machines used by the industry - only on a smaller scale.

Testing ideas in the Pilot Plant can provide the answer to whether a process which works in the laboratory can also work in large scale within an industrial production line.

Companies can collaborate with the Pilot Plant on process and product development of foods, equipment, and technologies.

Pilot Plant is also used for teaching purposes, and the students use the test facility for different projects.

Pilot Plant has various permanent machines at its disposal such as an autoclave and a test oven that simulates the conditions in a tunnel oven. Moreover, the Pilot Plant has heat exchangers and pumps at its disposal, which can be combined in different ways to study a range of production processes.

DTU Centre for Hygienic Design and DTU Brewery are both integrated in Pilot Plant.



The National Food Institute develops technologies and techniques that promote food safety and quality, including hygienic design of production equipment and methods to rapidly identify disease-causing microorganisms.

Lab-on-a-chip. Anders Wolff

### **PROVIDES THE FOOD INDUSTRY WITH SOLUTIONS IN RESPECT OF CLIMATE, SUSTAINABILITY, AND HEALTH**

“At the Confederation of Danish Industry, we really appreciate our long-running and strategically close cooperation with the National Food Institute.

The food industry is a central part of the national economy and the solution to the societal challenges in respect of climate, sustainability, and health. However, the industry is far from having all the answers to how we can meet the ambitious global goals. There are many dilemmas and nuances in our work with sustainability and health, so we invite everybody around us to contribute good ideas and suggestions for solutions, which the industry can test in partnerships with strong Danish research institutes, such as the National Food Institute.

Our sincerest congratulations on your 60th anniversary. We look forward to continuing our close cooperation with the Institute,” says Industry Director Leif Nielsen from the Confederation of Danish Industry (DI), who is also a member of the Advisory Board at the National Food Institute.



Confederation of Danish Industry

Leif Nielsen  
Confederation of Danish Industry



# Less water from sea or field to plate

A food product's journey from sea or field to plate requires water. Industrial food production can utilize water in a more sustainable way by using less potable water and discharging less waste water. The National Food Institute can help the industry achieve this.

"Our research can help to reduce both the water consumption and the environmental impact associated with a food business' production of e.g. a pizza, right from the dough to the cheese," Professor and Head of Research Group Lisbeth Truelstrup says.

When a dairy makes cheese, the raw material is milk, and milk consists of 90 % water. The dairies can recycle the surplus water. You can extract all whey proteins and lactose from the residual products so only water is left. The dairy can use this water for cleaning. This streamlining has inspired other industries to get involved in research projects in which the National Food Institute takes part, with the purpose of increasing the recycling of water in the production.

## **Clean chicken feet with 50 % less water**

Chicken feet are a delicacy for Asian consumers. The companies can wash the chicken feet more efficiently without compromising on food safety. The Institute has documented this along with the Danish Technological Institute and a company. When the wash water was filtered, the company could reuse it in the first wash of the next batch of chicken feet.

In another project, the Institute has examined whether it is possible to lead used drinking water through an advanced wa-

ter treatment plant and then treat it with ultraviolet light. The analysis has shown that reusing water is possible. However, to comply with the current regulations, the recycled water has to be piped through separate pipes.

## **Safe recycling**

As a rule, and according to legislation, food businesses must use drinking water in their production of foods, including for cleaning in connection with the production. However, they can use other types of water as long as the water does not compromise on food safety. And this is where the National Food Institute can provide help. If an industry wants to recycle water from their production, the Institute can inform whether and how it is possible to do so in accordance with legislation.

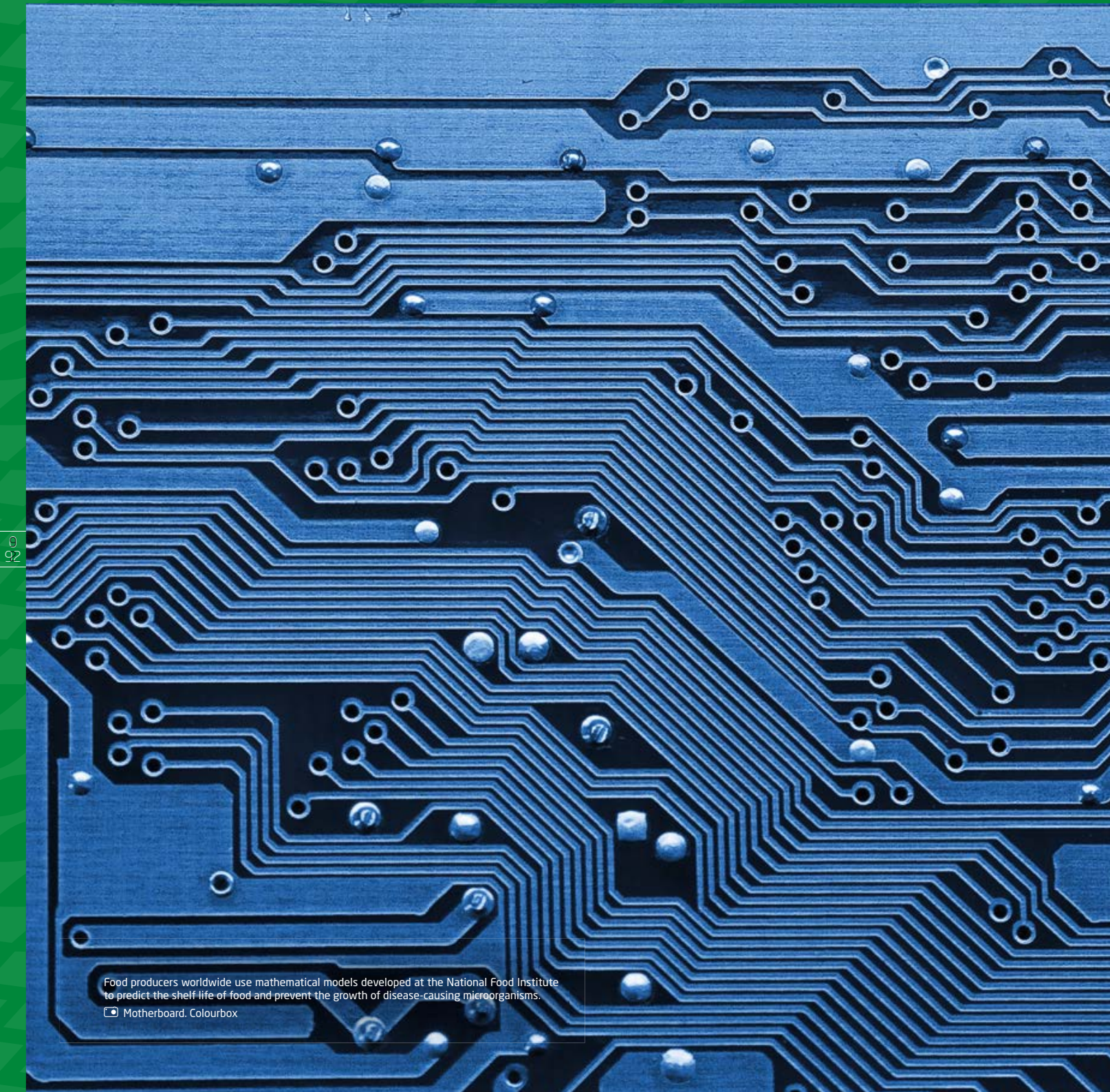
## **Of appropriate quality - what does that mean?**

Recycled water does not have to be of drinking water quality. It just has to be of an appropriate quality - but how does a company measure and document that the quality is appropriate? And how can the company perform own-checks and provide the documentation needed so that the Danish Veterinary and Food Administration can allow the recycling of water? In such case, the industry can help conduct a risk assessment and own-control plan.

One of the goals of the National Food Institute's research is to show how water used in the production of food can be cleaned, making it safe to reuse elsewhere in the production process.

Water. Colourbox





Food producers worldwide use mathematical models developed at the National Food Institute to predict the shelf life of food and prevent the growth of disease-causing microorganisms.

📷 Motherboard. Colourbox

“ **The ambition is** that we will be able to use purified seawater in the production of food in the future. Unlike Denmark, Greenland does not have enough freshwater in several local communities. Many fish factories up there use more than 75 % of the daily production of drinking water. This limits both the industries’ production and the growth of tourism, which would otherwise be able to bolster Greenland’s economy. The problem can be solved when it is safe and legal to use seawater for production. ”

**Lisbeth Truelstrup Hansen**  
Professor and Head of Research Group





The National Food Institute researches how residual products from the seafood industry can be used to produce new ingredients for feed and food.

Fish, Colourbox

# The waste from seafood to become the sustainable foods of the future

In order to achieve the UN's Sustainable Development Goals, we should utilize the ocean's resources and create nutritional foods from the seafood industry's side-streams, e.g. cod livers or off-cuts from fish fillets. The National Food Institute is looking beneath the ocean surface and is creating the foundation of the foods of the future.

The seafood industry's side streams contain a great potential as a source for developing nutritional and sustainable foods or feed for animals. The side streams are those parts of the catch or the fish that are not utilized today, but are simply thrown overboard and end up as waste or are used in low-value products such as mink feed. The National Food Institute works closely with the fishing industry on finding solutions as to how the sustainable and nutritional foods of the future can be produced on a large scale and reach the consumers.

"Cod livers can provide healthy omega-3 fatty acids, and shrimp shells contain both taste and colour which the industry can use to produce new types of foods," Professor and Head of Research Group Charlotte Jacobsen says. She stresses that until now only far too little research has been conducted on how the resources of the sea can contribute to new, healthy, and sustainable foods.

The researchers at the National Food Institute collaborate with the seafood industry on changing the logistics in the production so that e.g. cod livers are not discarded but instead used for food. The Institute is also exploring ways of utilizing skin from fish and extracting bioactive substances from carcasses, and how process water (waste water) from other types of pro-

duction can contribute to a more sustainable feed source in the production of algae.

"In the old times, dairies considered whey to be a residual and waste product, but today, it is one of the most valuable products in the production. Now is the time to explore how we can utilize the side streams of the seafood industry to produce new, more sustainable products, which are rich in beneficial bioactive substances such as fish oil and protein," Charlotte Jacobsen says.

## Valuable fish oil from fish waste

Filleting of fish results in tonnes of residual products which are full of healthy omega-3 fish oils. Instead of discarding the residual products, it would be more sustainable and add extra value for the seafood industry to extract the oils and use them as ingredients in health-promoting foods.

"Along with companies in the seafood industry, the National Food Institute conducts research in the design of omega-3 ingredients and the use of them in foods. Such ingredients will make it possible for food producers to enrich existing foods or develop new foods with a favourable health profile," Charlotte Jacobsen says.



### **The sea offers healthy fats**

In general, the National Food Institute works on how omega-3 fatty acids can become a more attractive alternative to less healthy fats in our food that also have a greater climate impact, such as animal fat.

"It is paradoxical how little omega-3 is actually in a shrimp salad so why not replace the unhealthy fat with the nutrient-rich oil?" Charlotte Jacobsen asks.

Other suggestions for foods where omega-3 could play a greater role are mayonnaise, dressings, tuna salad, fish pâtés, and protein bars – just to mention a few.

### **Starfish become animal feed**

The ocean and the seafood industry have a large and unfulfilled potential, not only when it comes to candidates for sustainable and nutrient-rich foods and food ingredients for people, but also as feed for animals.

The world's first starfish meal factory has opened its doors by the Limfjord where the plague of the seabed, starfish, is being turned into animal feed. For a long time, the large stocks of starfish – up to 50 per square metre – have been a problem for mussel fishermen in the Limfjord, because the starfish eat large quantities of mussels and oysters.

"Starfish meal contains 70 % protein, and in 2017 the product was, on Denmark's request, approved in the EU as feed for domestic animals, including chickens and pigs," Charlotte Jacobsen says.

Starfish also contain fats. The National Food Institute is exploring the composition of the starfish oil, and how it can be extracted from starfish with a view to a potential production of starfish oil rich in omega-3.

### **Algae and mussels can also become feed**

The small organisms of the sea, the microalgae, are also of interest when it comes to creating sustainable feed for domestic animals.

Therefore, the researchers at the National Food Institute are exploring ways of growing microalgae, which can replace fish-meal and fish oil in fish feed.

In the hunt for a sustainable future, the researchers have also developed a way to process mussels that are too small to be sold as foods into a financially viable, sustainable and organic ingredient in chicken and pig feed.

After experimenting with meat grinders, juicers, and various equipment from the Institute's test facility, the researchers have found a promising and sustainable method to process small mussels. The method leaves out the expensive cooking process and the time-consuming sorting process in which other species such as starfish and crustaceans are removed. Instead, the new method involves putting the mussels, including shells and any nutrient-rich by-catch, through a meat grinder and then through a press that separates the mass into a fluid and a dry matter. The fluid is then dried into meal, which can be mixed with the feed.

“**The ambition is** that the National Food Institute makes a contribution that – over the next ten years – will enable the industry to start, in earnest, to utilize the overlooked resources of the sea such as seaweed, microalgae, and residual products from fish so that we, in Denmark, can start producing new sustainable and nutrient-rich foods and live up to the UN's Sustainable Development Goals. Today, way too much nutrition is wasted, ends up in the sea, or at an incineration plant even though the potential is much greater.”

**Charlotte Jacobsen**  
Professor and Head of Research Group



# The golden opportunity of beer for increased sustainability

DTU Brewery brews beer in new ways for the benefit of the environment, and - among other things - has examined how you can skip the malting process by adding enzymes and thus save on CO<sub>2</sub>. The nutritional products contained within the side streams are also used in new and profitable ways. And you can even drink a beer made from leftover rice when sushi is made in the city of Lyngby.

DTU Brewery has examined how to skip the malting process and brew beer solely from barley - because it requires a lot of energy to convert barley to malt. First, the clean barley is soaked in water. Then, it must sprout under 100 % humidity. Finally, it must dry at a high temperature.

When you skip the malting process, the necessary enzymes in the barley are not activated for later use in the brewing process. To compensate for the lack of active enzymes that would usually be present in the malt, DTU Brewery instead adds industrially manufactured enzymes from Novozymes, Ondea Pro.

When you skip the malting process, the CO<sub>2</sub> emission is reduced by 8 % in the total brewing process, corresponding to 8.4 grams of CO<sub>2</sub> per bottle.

## **Better utilization of the side streams from beer**

The production of beer leads to a number of side streams, which is really another word for a residual product that we today focus on using instead of discarding. Brewers' spent grains - crushed malt extracted in water - are an example of a side stream. In the efforts to make the DTU Brewery more sustainable, the brewers

have developed a compact filter that makes it possible to utilize nutrients in the spent grains in a financially viable way.

The spent grains contain lots of fibre and approximately 6 % of the protein that is found in the raw materials. With extraction, the protein can be used in the production of enriched foods etc.

The idea of using spent grains in the production of food is not a new idea. However, until now it has not been financially viable to dry the mash. The newly developed technology makes it possible to separate the mash gently and cheaply into two parts through filtration and simultaneous pressing: one part liquid, and one part dry matter. The dry matter then undergoes a final drying or acidification process. Now the fibre-rich substance can be used e.g. in bread to make it more fibre-rich. The liquid is acidified or pasteurized and can be used to produce light beer or foods. Even the residues in the liquid, which contain proteins, sugar, and antioxidants, can be used to enrich milk products and protein drinks etc.

The technology is based on innovations developed and patented at DTU Brewery, which are being commercialised.

DTU Brewery in the National Food Institute conducts research into brewing techniques and brews beer by e.g. skipping the malting process and using up to 100 % barley with the addition of enzymes during the brewing process. This reduces CO<sub>2</sub> emissions.

Beer. Colourbox

### Sustainable beer from DTU Brewery

DTU Brewery is an incubator for innovation and new thinking at the National Food Institute. The Brewery is working to develop a sustainable brewery based on the latest technologies and interdisciplinary research. Students, employees, and the industry are working across disciplines to try out new ideas in practice and to conduct projects that involve all links in the production chain – from raw material to end product.

DTU Brewery is a non-profit brewery, which can brew beer from laboratory scale to test plant level up to 250 litres.

The size of the Brewery makes it possible to create results that are relevant to the industry. Being situated at a university allows for the basic principles of brewing to be explored, and makes it possible to initiate projects that can be commercially risky or not yet financially viable for commercial breweries. Here, the focus is on minimizing the consumption of resources in the brewing process and on developing new sustainable processes and products. The Brewery can do so by combining and optimizing technologies without compromising on the quality and shelf life of the products.

DTU Brewery collaborates with small and large breweries and with the associated industry such as enzyme manufacturers.

#### Put rice in the beer, not in the rubbish bin

Sushi and beer rarely make for a bad combination. And it is even possible to order sustainable draught beer made from the rice which Sticks'n'Sushi in Lyngby has left over after making sushi. Researchers from the National Food Institute have made that possible.

Sticks'n'Sushi cooks up large quantities of rice for its sushi production. Rice that isn't eaten ends up being drunk instead. The restaurant chain had help from the Institute to reuse the rice in a beer, which is specially developed for the chain's guests. The beer is called Gohan Biiru – which simply means rice beer – and it is brewed by the spinout company, Science Brew.



The National Food Institute is working to utilize residual products from the production of food such as surplus sushi rice to quench the world's thirst for sustainable beer.

© Rice. Colourbox

In Denmark, we mostly brew beer from barley. However, there is already a number of beers – especially Asian beer – made from rice on the international market. Brewing the Danish rice beer has not been easy. Rice is rich in starch and in large quantities tends to block the filters in the beer production in a way that grain-based mash does not.

However, Science Brew solved the challenge allowing the beer to flow. First, they succeeded in brewing beer in a scale of 10 litres, which consists almost entirely of surplus rice and water and a little malt. Science Brew has converted this recipe so that it can be used to brew beer on a much larger scale. At the moment, Gohan Biiru contains approximately 20 % of the malt substituted with boiled excess rice, but Science Brew expects to increase the rice content even further.

The beer is served as draught beer at Sticks'n'Sushi in Lyngby as it is less sustainable if bottled. In the long term, the restaurant hopes to put Gohan Biiru on its menu in all its restaurants.

“The ambition is to apply side streams, which has broad perspectives. The clever thing is that the side stream – e.g. spent grain from beer production – is already a food. This means that the side stream can be used directly without undergoing comprehensive authorization procedures, as would be the case with a novel food. When we can easily use side streams in this way, we can utilize the resources in a much better way and thus save CO<sub>2</sub> and the amount of land used for agriculture. At DTU Brewery, we hope that breweries worldwide in the long term will implement the techniques developed at the National Food Institute. Seen in isolation, we do not believe that we are able to save the whole world with sustainable beer. However, beer is just a small piece of the puzzle that can save the world – together with thousands of other small pieces.”

Tim Hobley  
Associate Professor



# A sustainable diet is healthy for us as well as the climate

If we follow the national food-based dietary guidelines, reduce food waste, and cut down on red meat, alcohol, and sweets, we can significantly reduce our impact on the environment. The National Food Institute creates the science-based foundation for integrating sustainability into food-based dietary guidelines that are nutrient adequate - both nationally and internationally.

In the Western world, the diet accounts for a quarter of a person's environmental impact. Therefore, an altered diet is a step towards the UN's 17 Sustainable Development Goals.

Using data from the Danish National Survey of Diet and Physical Activity, also called DANSDA, researchers at the National Food Institute have calculated an average adult Dane's CO<sub>2</sub> emissions from food. The results show that 57 % come from animal products of which red meat such as beef, lamb, and pork accounts for half. 15 % come from plant products such as vegetables, fruit, cereals, and bread products.

## **Alcohol and sweets leave their mark on the climate**

Many people follow the debate on how red meat is one of the worst climate sinners on our plate. However, surveys from the National Food Institute show that 24 % of the environmental impact is caused by sweets, sugary drinks, coffee, and alcohol. If Danes actually followed the food-based dietary guidelines, the diet would not only become more sustainable, but also healthier.

Even though the environmental impact of individual foods in different food groups varies, the environmental impact of animal products is typically 10-40 times higher per kilogram of food than the production of fruit, vegetables, grain products, and potatoes.

## **100 grams of red meat per week**

An interdisciplinary research team with representatives from 16 countries has made recommendations for a sustainable and healthy diet. They suggest that we only eat 100 grams of red meat a week and increase our intake of nuts and legumes to more than what the Danish food-based dietary guidelines suggest. The interdisciplinary research team, which collaborates with the EAT-Lancet Commission on Food, Planet, Health, also recommends that sugar constitutes no more than 5 % of the daily energy intake.

"The challenge is to let health and sustainability go hand in hand, and adapt this to national conditions. For example, it is important to explore what the consumer would eat instead of meat, milk, and cheese, while ensuring that the diet is optimized in respect of sustainability and the intake of vitamins and minerals," Senior Researcher and Head of Group Anja Biltoft-Jensen says.

Moreover, the researchers at the Institute are also exploring and assessing the international literature within this area so that the guidelines can reflect the scientific documentation while making the guidelines actionable and targeted to different groups with different needs and preferences.

In order to make the average Dane's diet more sustainable, there need to be fewer animal products such as red meat and cheese and more plant products such as legumes on the plate, according to calculations from the National Food Institute.

Legumes. Colourbox

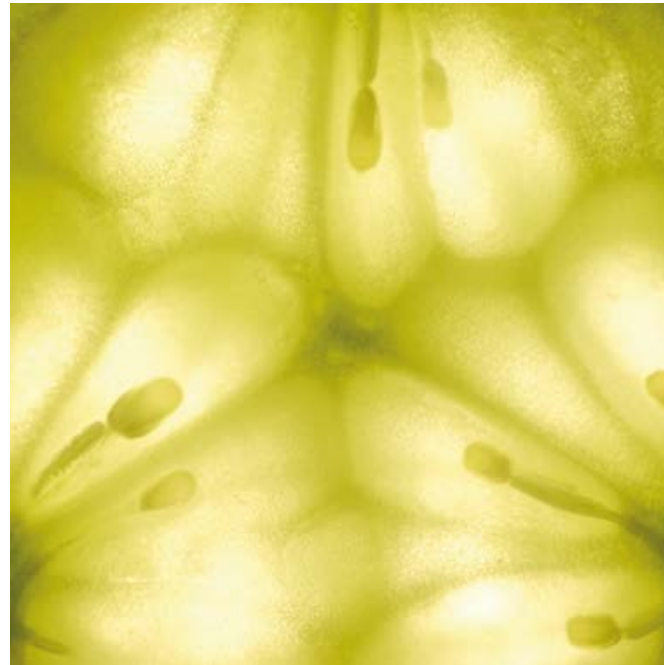


### Sustainable food-based dietary guidelines of the future

According to calculations from the National Food Institute, the diet's environmental impact varies depending on what the consumer eats instead of meat and fish. The environmental impact is reduced by 20 % if the consumers replace meat and fish with plant products such as legumes and vegetable oils. But sustainability also depends on what type of foods you put in your shopping basket. Danish vegetables, grain, and fruit have a smaller environmental impact than rice, plant-based meat, nuts, and certain imported vegetables.

The CO<sub>2</sub> emission is not the only relevant issue. Other factors, including land utilization, water consumption, and biodiversity have a significant impact as well. Therefore, the researchers at the National Food Institute collaborate with Aarhus University in an international research project (SUSFANS, Sustainable Food and Nutrition Security) around data and models that can calculate the sustainability of foods.

Until more results are available, it is a good idea to follow the official food-based dietary guidelines. This is the first step towards doing something good for the climate and ourselves.



The National Food Institute regularly conducts the Danish National Survey of Diet and Physical Activity, which show what we eat and our level of physical activity.

 Cucumber. Colourbox

### Mapping the dietary habits of Danes

To gain an insight into the dietary habits of Danes, the National Food Institute has conducted the Danish National Survey of Diet and Physical Activity, DANSDA, among children and adults since 1985. Since 2000, the Institute has also collected data on Danes' physical activity and weight.

Until now, data from 18,000 Danish children and adults are included in the surveys.

DANSDA is a national, representative, cross-sectional survey based on a simple, random sample of children and adults collected from the Danish Civil Registration System.

In addition to registering their dietary habits and physical activity, the participants are also asked about their social background, eating habits, physical activity, and consumption of dietary supplements in two personal background interviews.

The survey period covers the whole calendar year. For each participant, data on eating habits and physical activity are collected every day for a week. As the total collection of data covers a long period of time, it is possible to analyse trends over time.

DANSDA is used in a wide range of tasks, including advisory tasks and research, both nationally and internationally, and in teaching.

Do the Danes comply with the official food-based dietary guidelines and nutritional recommendations? What is the effect of health-promoting initiatives? And to what extent are Danes exposed to a particular risk through their diet, e.g. from unwanted substances such as pesticides or acrylamide? These are some of the questions, which DANSDA helps to answer.

“The ambition is that the National Food Institute's research and scientific advice to authorities will contribute to the food-based dietary guidelines ensuring that a sustainable diet is also healthy for all population groups, and that more Danes will eat according to the food-based dietary guidelines and thus eat more sustainably.”

**Anja Biloft-Jensen**  
Senior Researcher and Head of Group



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