

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 CO₂. 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 CO₂, 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

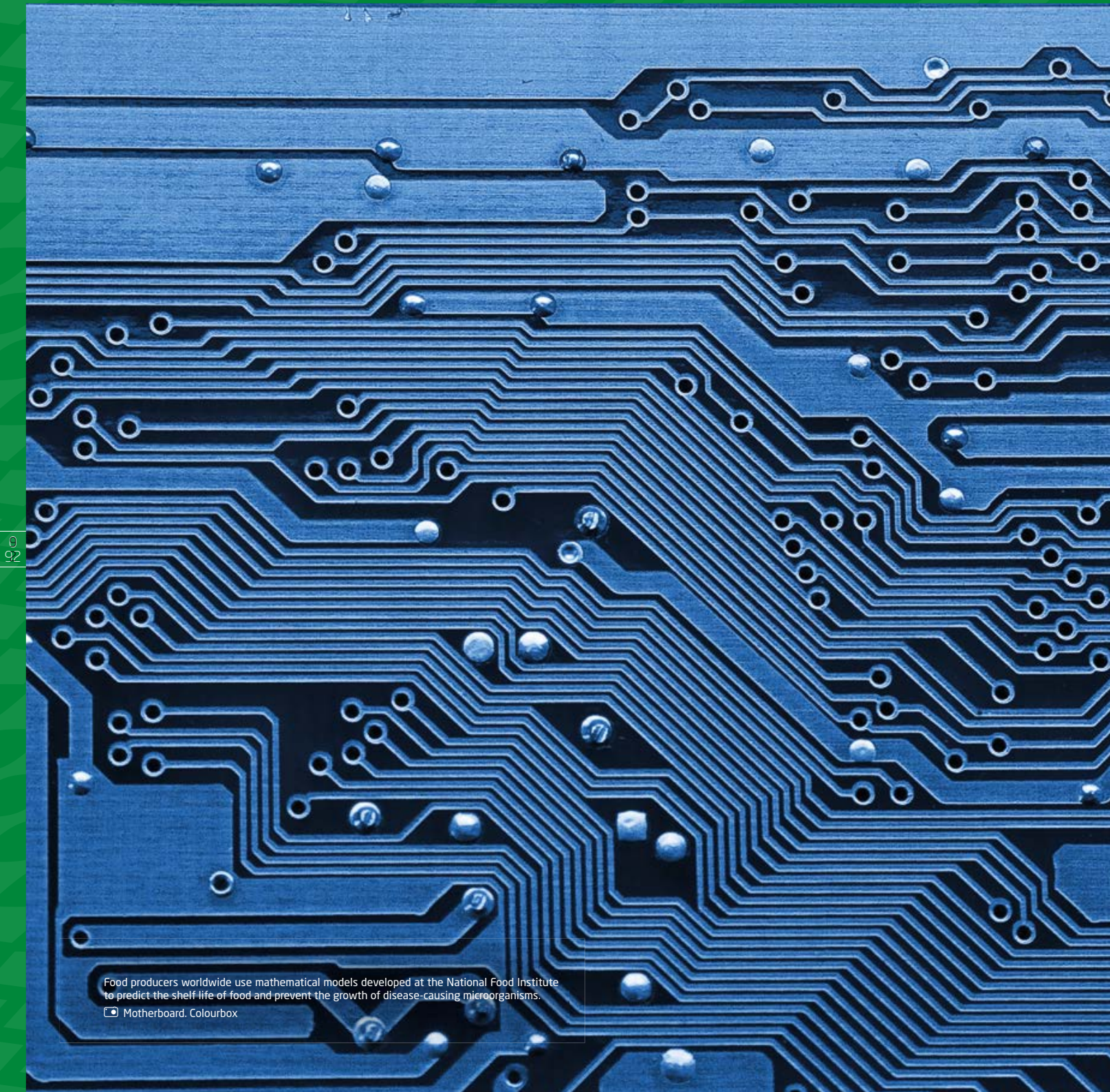
As a rule, and according to legislation, food businesses must use drinking water in their production of foods, including for cleaning in connection with the production. However, they can use other types of water as long as the water does not compromise on food safety. And this is where the National Food 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 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 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 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 CO₂. 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 CO₂ emission is reduced by 8 % in the total brewing process, corresponding to 8.4 grams of CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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.

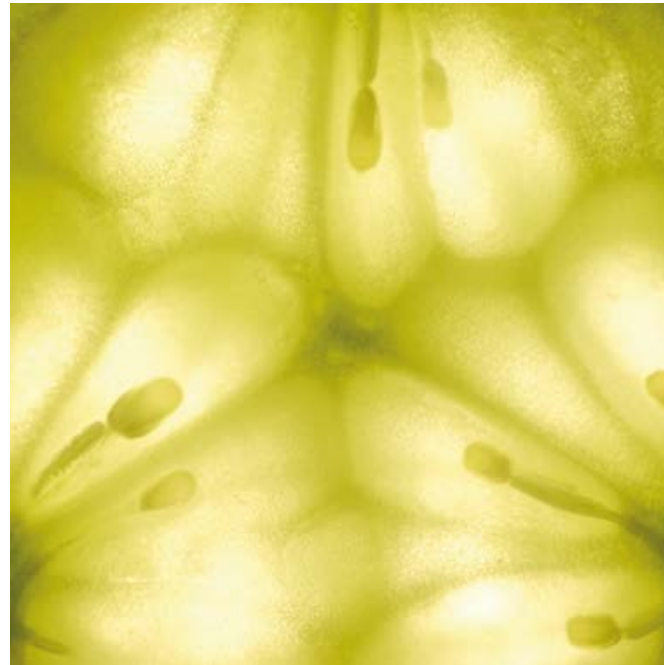
Legumes. Colourbox

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 CO₂ 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