Food and fermentation

Content and applications

Copenhagen (and Denmark) has one of the strongest European environments for food research. These strengths derive in part from the historical importance of agriculture and the big food companies in Denmark. In recent decades research has especially been driven by the development of high value foods, enzymes and food safety.

Fermentation is due to chemical processes driven by micro-organisms such as lactic acid bacteria or yeast. Research is divided into fermentation for refining food products and the use of fermentation processes for making biofuels, chemicals and materials. The area has a great future potential.

Key environments and star researchers

Research is spread across a range of departments with many interfaces for example to health research, biotech and plant science. The two core environments in the food sector are University of Copenhagen FOOD and DTU Food (the National Food Institute) at the Technical University of Denmark (DTU).

Food fermentation is based at University of Copenhagen FOOD, while DTU works on fermentation with a focus on biotech with its DKK billion "Biosustain" investment. The centre also involves researchers at DTU Chemical Engineering and DTU Bioengineering in researching the use of yeast cells as 'cell factories' for use in the sustainable production of materials, chemicals and fuels.

Potential for attracting investment

There is considerable potential for attracting investment by virtue of increasing global demand for high value food products. In conjunction with Denmark's advanced industrial production, research has for many years been focusing on combining food production with high quality standards, shelf life and environmental sustainability, which carries a great global potential. Denmark has also specialised in investigating the health and nutritional aspects of food, including the influence of food chemistry on the human body.

Characteristics of the research area

Food research in Greater Copenhagen is a broad category of research covering a whole range of world-leading specialities. The areas share a focus on developing and producing high-value, high-quality food products. Research has grown out of a close interaction with Denmark's strong food sector. This applies to the hightech agricultural sector, the processing industry, including Arla, Dupont and Carlsberg, and the research-intensive biotech sector, e.g. Chr. Hansen and Novozymes.

This breadth has also resulted in the food sector being split into many different, relatively specialised sub-areas, which in many instances have close interaction with adjacent research areas such as protein research, nutrition and metabolism research and plant science.

One important outcome from food research is Greater Copenhagen's strength in fermentation technology. On the one hand, research is done into food fermentation related to conservation and spoilage of food products, including biocontrol, microbial food safety and hygiene, intestinal microflora and probiotics as well as food quality assurance. On the other hand, in particular DTU investigates the use of fermentation processes for biotechnological purposes including the development of yeast-based cell 'factories' that can be used to produce biofuels and new materials (such as plastic) from agricultural residue.

The two main actors in food research are the University of Copenhagen's Department of Food Science (FOOD) and National Food Institute (DTU Food). Food and food product related research are also done at the Department of Veterinary Disease Biology, the Department of Food and Resource Economics, the Department of Sport and Nutrition, Department of Veterinary Clinical and Animal Sciences at the Department of Large Animal Sciences. DTU Biosustain, DTU Vet (the National Veterinary Institute), DTU Chemical Engineering and DTU Bioengineering do research into the biotechnological opportunities for fermentation.

International top quality niches

Copenhagen has numerous research niches which are among the absolute global elite, including:

- Research into safety and quality control, with the application of spectroscopic, data-driven quality assurance methodologies to study industrial food production faster, cheaper and more efficient than using traditional random sampling.
- Research into food product design and food chemistry focusing on the molecular composition of food with respect to health and nutrition issues and the effect of food products on the body.
- Research into human sensory perception, acceptance and behaviour in selecting and rejecting food products. It also includes research into molecular gastronomy that have had a major impact in the development of the new Nordic cuisine.
- Research into sustainable food production, i.e. how to optimise the use of resources in food production while minimising waste and environmental impacts.
- Food microbiology, including advanced fermentation technology used in the food industry for processing food products but which also plays a part in research aimed at manipulating residue from agriculture in the production of biofuels and new materials.

All these areas feature Danish researchers, who are positioned in the Top 5 internationally.

Bibliometric key figures

The strong niches in the field of food and fermentation are not especially well captured by bibliometric categories, as they are divided between various categories comprising e.g. applied microbiology. This reflects the fact that the research to a high degree is practical and application-oriented, leading to the development of new methods and technologies for implementation in the commercial sector.

The bibliometric indicators for research production and quality do however show that Greater Copenhagen occupies a clear leading position in Europe when it comes to research into applied microbiology and bioengineering. Researchers at University of Copenhagen and DTU published more than 2000 scientific articles between 2005-2015 in internationally recognized journals.

Food and fermentation research is especially strong with respect to joint publication with the commercial sector which reflects close links between industry and research, and a strong application-oriented dimension.

Further, Greater Copenhagen is highly specialised in the field which means that research into food and fermentation accounts for a significantly larger proportion of research production in Greater Copenhagen than in the relevant European regions of comparison.

Copenhagen is also leading in joint publications in terms of the number of co-publications with authors from the private commercial sector.

Key bibliometric indicators

	Specialisation	Output ranking (No. articles)	Highly cited article ranking (%).	Co-publication ranking (%)
Applied microbiology and biotechnology	1.92	1 (1045)	3 (18.6%)	1 (12%)
Bioengineering	1.5	4 (1854)	2 (24.9%)	1 (12.4%)
Endocrinology, diabetes and metabolism	1.69	1 (2436)	2 (21.9%)	1 (26.1%)
Plant science	1.58	1 (1735)	3 (21.7%)	1.3

Period: 2005-2015. Regions of comparison: Amsterdam, Berlin, Dublin, Geneva-Lausanne, Hamburg, Helsinki, Munich, Oslo and Stockholm/Uppsala.

Specialisation is an expression of the size of a field of research compared to all research production at University of Copenhagen, DTU and Copenhagen Business School (CBS) compared with its size in the regions of comparison. A specialisation level 1 indicates that Greater Copenhagen is on level with the regions of comparison. Specialisation of >1 indicates that Greater Copenhagen is more specialised in the field of research than the regions of comparison.

Output ranking measures Greater Copenhagen's position in the field concerned among the regions of comparison in terms of article production (with the absolute numbers of articles in brackets).

Highly cited article ranking indicates Greater Copenhagen's placing in the regions of comparison for the proportion of articles in the field of research in Copenhagen that are among the 10% most cited worldwide (percentage in brackets).

Finally, co-publication ranking indicates Greater Copenhagen's rank among the regions of comparison for the proportion of articles in the field published jointly with the business sector (percentage of overall article production in Greater Copenhagen in brackets).

Key arguments for the research area's potential to attract investment

Food safety and food supplies are facing increasing challenges globally. This is partly because of a growing demand for high value food products, reflecting the rise of the middle classes in the major growth markets. Food scandals abroad have emphasized the need for effective, precise quality assurance systems. Another issue is that food production implies major climatic and environmental impacts, especially by way of waste water and greenhouse gases. Finally, there is an ever increasing focus on the nutritional and health aspects of food production.

Greater Copenhagen's food research directly addresses these global challenges. A significant part of food research heavily reflects the application and commercially-oriented issues arising from close interaction with major research-intensive companies such as Chr. Hansen, Arla, Carlsberg, Dupont and Novo Nordisk, and the processing industry and primary producers.

But high-tech food research has also given rise to new biotech openings, especially the use of fermentation technology that can be used to refine food products and protect them from micro-organisms to ensure their shelf life, and 'cell factories' to catalyse the production of biofuels and new materials.

Copenhagen's food research is interesting for e.g. foreign companies working on the development of high value foods and for the biotech sector as such, which may benefit from the more wide-ranging opportunities and applications deriving from the research. Furthermore, the strong position in data-driven methods for quality control of food products is interesting for industrial food producers. Finally, there are very considerable perspectives in fermentation technologies for improved preservation and refining of food products and for reducing dependence on fossil fuels.

Star researchers and major scientific breakthroughs

At University of Copenhagen FOOD, Prof. Søren Balling Engelsen's team carries out research into high-tech food production solutions, including foodomics and nutritional metabolomics. They investigate bioactive substances and biomarkers that indicate how the human body reacts when ingesting specific foods.

The team employs Process Analytical Technology (PAT), which uses spectroscopic instruments (NMR and NIR) to do continuous real-time readings (e.g. in food production) to control and optimise process parameters.

The research team has also specialized in chemometrics, which use advanced multivariate data analysis to process the increasing dataflows from quality assurance systems and the new 'omics' technology platforms. These methods have enormous potential for ensuring food quality, safety and uniformity in large production systems. This field is especially led by Prof. Rasmus Bro.

From an international point of view, food chemistry is another very strong area at University of Copenhagen FOOD. This area is headed up by Prof. Leif Horsted Skibsted, who is among the most frequently cited Danish food r esearchers. In his research, he investigates the interaction between the chemical composition of foods and the human body. This covers such things as butter going rancid, browning reactions (which can also have an effect on the development of cancer), the effect of minerals such as calcium on the body and how food can be chemically designed to be more nutritious.

In the field of ingredients, Prof. Wender Bredie, University of Copenhagen FOOD works on human sensory perception of food, including characterising the taste of food products and changes in acceptance of food throughout the course of life.

Fermentation technology and biorefining are some of Copenhagen's absolute core strengths. At University of Copenhagen FOOD, Prof. Susanne

Knøchel works with starter cultures and fermentation-based preservation technologies. Prof. Lene Jespersen investigates the use of micro-organisms to increase the quality and healthiness of our food. Amongst other things, she has investigated the development of starter cultures for optimising fermented food products such as bread, beer, wine, cheese and other dairy products and cultures for inhibiting micro-organisms that are harmful to health.

DTU Food hosts several star professors, featuring several interesting research breakthroughs. Prof. Tine Rask Licht heads up a research team, researching diet, applied micro-organisms and intestinal microbiology. The team investigates the effect of diet on the composition, activity and exchange of genes in the intestinal flora, and studies the effect of intestinal bacteria on health and resistance.

DTU Food also works on biorefining industrial food residue and waste, with a view to boosting sustainability and adding value in the food sector. Furthermore they work on bacterial 'cell factories' for producing chemicals, biofuels and food ingredients, including microbial production of high quality proteins that have many different applications. The team is headed up by Prof. Peter Ruhdal Jensen.

Prof. Krist Gernaey, DTU Chemical Engineering, also focuses on modelling and optimising industrial fermentation, biocatalysis and production processes in the food and pharma industries. His research employs PAT technology and process control /monitoring.

Finally, Prof. Jens Nielsen, DTU Biosustain, works on fermentation by manipulating the metabolism of micro-organisms to get them to produce chemicals so cost-effectively that the method can be used in industry as an alternative to the oil-based chemical industry.

Large talent pool

Greater Copenhagen has a large pool of talent engaged in the food industry. About 130 PhDs have been admitted within food research at the University of Copenhagen. DTU has a similar number of PhDs doing research on food at DTU Food, the National Veterinary Institute (DTU Vet) and the Department of Aquatic Resources (DTU Aqua). PhDs, which are in strong demand in the food and biotech industry. University of Copenhagen also runs two Masters courses in Food Science and Technology and in Food Innovation and Health, with a total of 60 students completing the two courses in 2015.

In conjunction with the University of Copenhagen and DTU, CBS runs a Master's course in Business Administration and Bioentrepreneurship, with 13 graduating in 2015. 15 students graduated from the Masters course in food technology run by DTU in 2016. Various other Masters courses are relevant to the food industry, including Biochemistry, Public Health Science, Aquatic Food Production, Human Nutrition and Sustainable Agricultural Development.

DTU's Brewery is an incubator for innovation and innovative thinking focused on brewing beer, where students, researchers and companies can get together. The brewery is a collaboration between Novozymes, Nørrebro Brewery, Ingeniøren (The Engineer journal) and DTU, enabling food companies to get close to DTU's talented students, also by way of specific student projects. Similarly, DTU Skylab provides access to a broader group of entrepreneurial university students, and to innovative new student-run start-ups.

Unique research facilities

The Life Science & Bioengineering building is under construction at DTU. It will house around 800 personnel from three departments: DTU Aqua, DTU Food and the DTU Vet. Research will range widely from sustainable exploitation of the oceans, via nutrition, food safety and antibiotic resistance, to surveillance and combating disease in livestock, including vaccine development. The construction budget is DKK 13bn with completion scheduled for 2017.

DTU Biosustain investigates yeast-based cell factories, i.e. how to genetically modify yeast cells to produce materials, fuel, etc., and thereby reduce our dependence on fossil raw materials. DTU Biosustain is interdisciplinary and attracts a wide range of research niches such as synthesis biology, gene technology, biorefining and protein research. Its strength comes from the Danish expertise in fermentation deriving from close interaction with Carlsberg, Chr. Hansen and Novozymes, the University of Copenhagen and KTH, Stockholm (the Royal Institute of Technology in Sweden). The centre has approximately 300 employees and operates on the basis of a DKK 1.1bn grant from the Novo Nordisk Foundation.

Strong collaboration with leading international research environments

Food research in Copenhagen has strong international relations. DTU and University of Copenhagen collaborate with the highest ranking agricultural university in the world, Wageningen in the Netherlands, and elite universities such as TUM in Munich. DTU Biosustain has operations at the University of California, San Diego (UCSD), KTH and Chalmers University in Sweden. All these universities are generally among the 30 best in the world in the fields concerned, such as applied microbiology where the University of California and Chalmers are in the global Top 10.

Extensive corporate collaborations

Food and fermentation research has traditionally given greater priority to commercial applications than research excellence. This means in practice that researchers generally get more external funding from innovation-oriented bodies such as the former Strategic Research Council, Innovation Fund Denmark and Horizon2020 than for example the National Research Foundation or the European Research Council.

Commercialisation of food research in Copenhagen has especially been done by way of licensing. Food research at University of Copenhagen led to eight licences and two spin-outs between 2013-2015. The spinout company Biosyntia originated in this field of research. In addition research collaboration with companies such as Novozymes, Carlsberg and Chr. Hansen is extensive.

Biosyntia is a company spun out from DTU's fermentation research. The company employs biocatalysts to make complex chemical substances at high speed and efficiency. The method significantly reduces the costs of production and environmental impacts compared to other processes such as chemical synthesis. The company works with fine chemicals producers (flavours, fragrances, pigments, additives, etc.) with the focus on developing sustainable production processes. Biosyntia is located at Symbion in Copenhagen.