CYCLE

FOOD - FEED - FERTILIZER - FUEL - FUTURE

2013–2017

PROJECT SUPPORT
BY RESEARCH
COUNCIL OF NORWAY

Total utilization of raw materials in the supply chain for food with a bio-economical perspective.

Composed by:
Aleksander Eilertsen
Marit Aursand
Ana Karina Carvajal

Designed by:
Aleksander Eilertsen
with Fagtrykk Trondheim AS

Project
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Total utilization of raw materials in the supply chain for food with a bio-economical perspective.

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Total utilization of raw materials in the supply chain for food with a bio-economical perspective

Main objective

Introduce a holistic approach to improve resource utilization in the Norwegian food chain by developing knowledge and sustainable solutions for eco-friendly bioprocesses and technology within a bio-economical perspective

Objective 1

a) Develop sensor systems for optimal quality differentiation of raw materials, co-streams and waste;
b) Develop automated concepts for an efficient and precise sorting of raw materials, co-streams and waste.

Objective 2

To increase the resource-efficiency of food industry by developing new food applications for edible co-streams based on bioprocesses

Objective 3

Convert waste not appropriate for utilization as human food to feed, feed ingredients or fertilizer, possibly in combination with energy production.

Objective 4

To study the challenges of managing and controlling the complex logistics processes in the food chain from manufacturing until end of life.

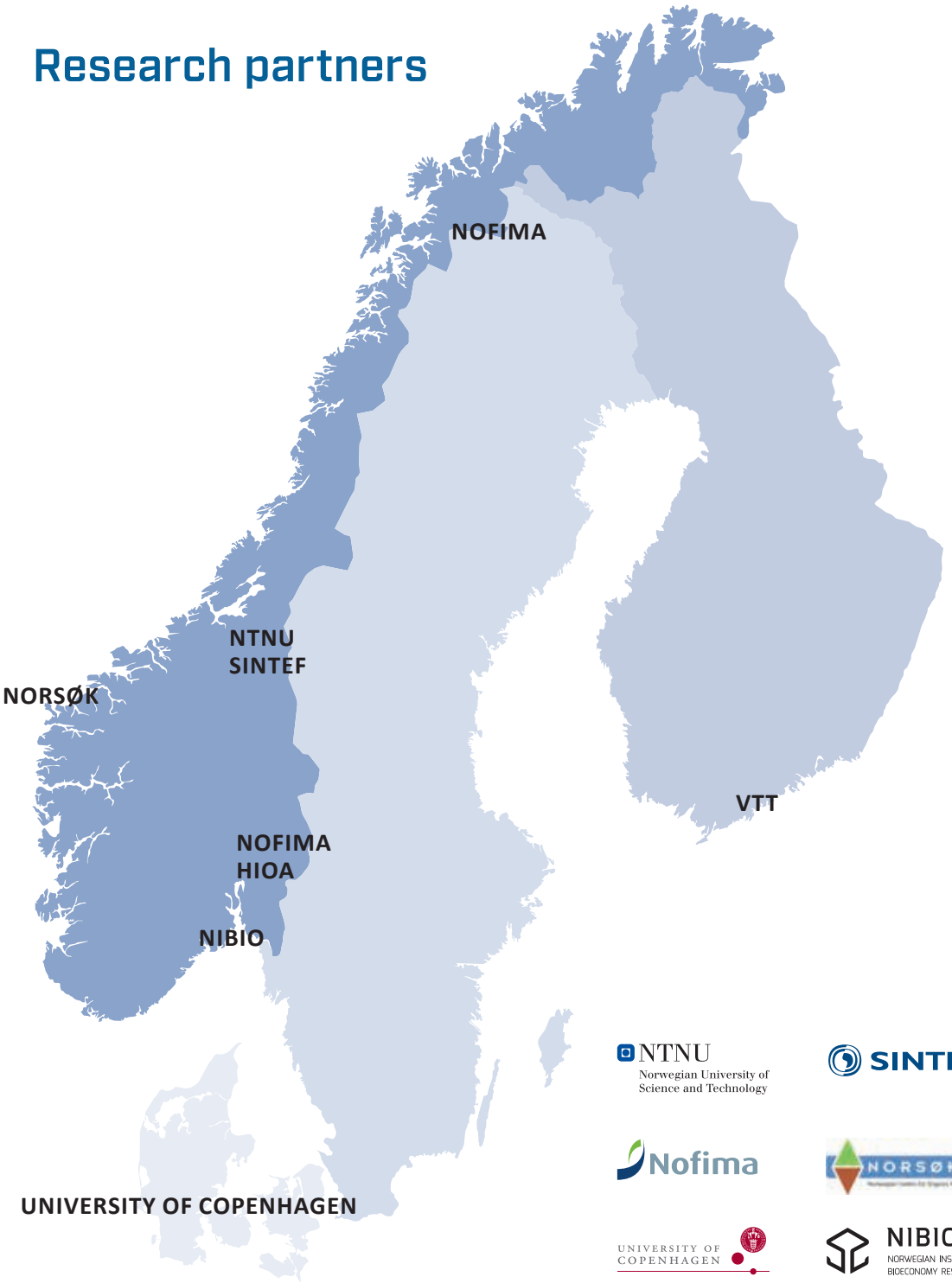
Objective 5

Study economic and institutional factors influencing production of co-streams and waste in value chains for chicken, fish, and vegetable. Investigate the role of consumers, in sustainable consumption and integrate natural and social sciences in demonstrating macroeconomic values and policy options with a view to sustainable solutions.

Objective 6

To disseminate and demonstrate the knowledge and results and to establish a close connection between R&D partners and participating industries for further innovations.

Research partners



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OSLO AND AKERSHUS UNIVERSITY COLLEGE OF APPLIED SCIENCES

VTT

Preface

Being the project leader of the Cycle project has been educational, exciting, challenging and last but not least, a great journey with top competent researchers and engaged industry partners. Our goal was to improve resource utilization in the food chain, both in agriculture and marine sector, with a bio-economical perspective. In parallel with the ongoing Cycle project, the circular economy both globally and nationally, has been on the agenda for a more sustainable utilization of both biological and technical resources.

The main project mantra has been; In bio-economy, the entire raw material has to be utilized and processed into a wide range of products where co-product (not waste) from a value chain becomes valuable raw material in another.

The following important questions are asked in the final stage; have the project goals been achieved and what are the value for the society? Have we managed to create new and useful knowledge for the food industry by working with researchers with expertise in sensor technology, machine vision and robotic automation, logistics, bioprocess technology, social economy etc. The answer is yes, we have generated new knowledge and novel concepts in all these disciplines that food industry and technology vendors can utilize. This undertaking has not been a simple exercise. As a project manager, I am impressed by how the interaction has been between professional disciplines and between industry and researchers, since on the one hand, we have generated novel knowledge of high scientific quality, and on the other, this research has been relevant and driven by the industry needs.

The dissemination of new knowledge is of crucial importance for further use and usefulness. Throughout the project, the Cycle project has focused on dissemination, by publishing the project results in peer reviewed international journals, arranging and attending national and international conferences, but not least visualizing results through interviews and films, so that the results become available to all interested parts.

In CYCLE, the ”cyclical thinking” has been leading all our research activities where we have focused on the value chains for fish, vegetables and chicken for total utilization of the raw material.

This report is a result of our focus on disseminating results beyond the project group in a hopefully easy-to-understand way. Those who wish to go deeper into research results can read the listed international publications generated from results in CYCLE project.

As a project manager, I am proud of what we have achieved together in the CYCLE project. During the project period, many new projects have been generated together with the industry where the industry plans to implement new technology and/or to build new process lines for products based on the results from CYCLE. CYCLE is a start of future research, development and innovation for total utilization of food resources. We hope, the results will contribute to even more sustainable food processing industry in Norway and beyond.

Marit Aursand
Project manager

Industry partners

Input from industry partners regarding the CYCLE project

– What practical benefits have you and your company obtained rom participation in the project?

Felleskjøpet (FK)

The practical benefits have been excellent both from a personal and a company perspective. Personally, I have learned more about rest raw materials from the foodstuffs industry, established new contacts, and obtained insights into another industrial sector and a variety of research centres. This is knowledge and skills development that will benefit Felleskjøpet. Moreover, spin-off projects have been launched that appear to offer FK real added value.

Nergård

It is important to the Nergård Group that the seafood industry, and Nergård in particular, operates sustainably. In this context, projects such as CYCLE are important to the industry. We also believe that we must identify solutions by means of collaborative efforts involving commercial companies, customers, suppliers, business organisations, R&D centres and other stakeholders. Increased profitability resulting from better utilisation of raw materials and new products go hand in hand with increased wealth generation and sustainability. The Nergård Group wants to play an active role in these developments.

BAMA

Bama's expectations of the project included obtaining input, ideas and knowledge as a basis for establishing a greater focus on the utilisation of rest raw materials at our company. We have succeeded in this aim and have a number of new projects currently underway. These include: utilisation of rest raw materials from the potato industry; using biofilms to combat weeds; close collaboration with customers aimed at reducing waste at retail outlets; sustainable biogas (as part of the BIONÆR programme); "KuttMatsvinn2020" (reduce food loss) in the major catering sector.

> *We are focusing on how rest raw materials can be converted into food and drinks products.*

Our most important work is preventive. We want the industry to produce as little loss and waste as possible. We are evaluating and carrying out continuous recording and follow-up of what really happens at all stages of the value chain for various rest raw materials.

Norilia

This project has enabled us to gain access to knowledge and expertise about new technologies and processes that have been useful in our work to boost the value of our raw materials. It has been of particular benefit to test the transferability value of some of the processes and technologies that have been developed and put to use in other industries such as the fish sector. At the end of 2016, Norilia/Nortura decided to invest in a new processing facility for the enzymatic hydrolysis of poultry bones. A knowledge of process requirements and product analyses has been particularly useful during the design of this facility.

The meat industry has the potential to utilise more of its rest raw materials in products for human consumption. It is one of our aims to move raw materials currently used to produce low-value feed or energy into higher-value applications, and in so doing boost our wealth generation. We have benefited greatly from our participation in the project linked to the development of the sensor technology that uses measurement, regulation and control processes as a means of facilitating the production of stable and tailored end products. The use of sensorics enables us to achieve a more optimal utilisation of raw materials. It also allows us to use the data in our targeted quality assurance work.

The work to automate chicken fillet removal has been useful and relevant and, if the current pilot project can be commercialised, will result in major savings in manpower costs and reduced loss

The CYCLE project has also examined methods for the processing and better application of feathers for feed purposes, and has contributed to useful skills development. Moreover, the concept of using lime from eggshells to improve soils has been tested with excellent results, and the necessary documentation is now available for its application.

> *The CYCLE project has enabled us to expand our network with Norwegian and global business partners and research institutes, and this has been of enormous value.*

Looking to the future, it is important to continue researching into the development of new technology and bioprocesses tailored to Norwegian conditions so that we can better optimise the utilisation of resources from the Norwegian fisheries and agriculture sectors. It is also important to focus on the transferability value between sectors as a means of developing

> *Bioprocesses and technology will be key if we are to achieve this aim. We must have the capability to deal with raw materials, which at times exhibit great variation, and process them to produce tailored and innovative food and feed ingredients efficiently and profitably.*

and applying the best solutions. At the same time, it is important to put in place measures to reduce the gap that exists in the industry between research and the implementation of new knowledge and solutions. Currently, there appears to be a lack of technology suppliers who are willing to bear the risks and costs associated with developing pilot projects and producing research results for commercial application.

Orkel

We had expected to participate in the joint identification of new systems, new applications of existing systems, or the documentation of the impact of our existing systems.

The provision of access to effective technical preservation systems and more efficient logistics. We at Orkel are working extensively with this and will be happy to contribute with our experience. Among other things, we have seen that by-products from, for example, cotton and sugar manufacture have become valuable materials as a result of better preservation and more efficient logistics. In these cases, the materials have been compressed to remove the air and then wrapped in plastic bales.

The practical benefits have primarily been in connection with network building.

Epcon

Our expectations of the CYCLE project included increasing our knowledge of developments in this exciting field, while at the same time consolidating our network with other industrial players in the sector. The project also provides us with an opportunity to disseminate information about evaporation technology, including the fact that energy consumption using state-of-the-art industrial applications may often be lower than the figures we are familiar with from published literature. We hope and believe that this will make a difference to the planning of innovative process lines for rest raw materials.

> *The increased utilisation of raw materials is very important, and our future focus should be on the development of effective projects that demonstrate practical benefits to both consumers and the industry.*

Content

Vegetable related research

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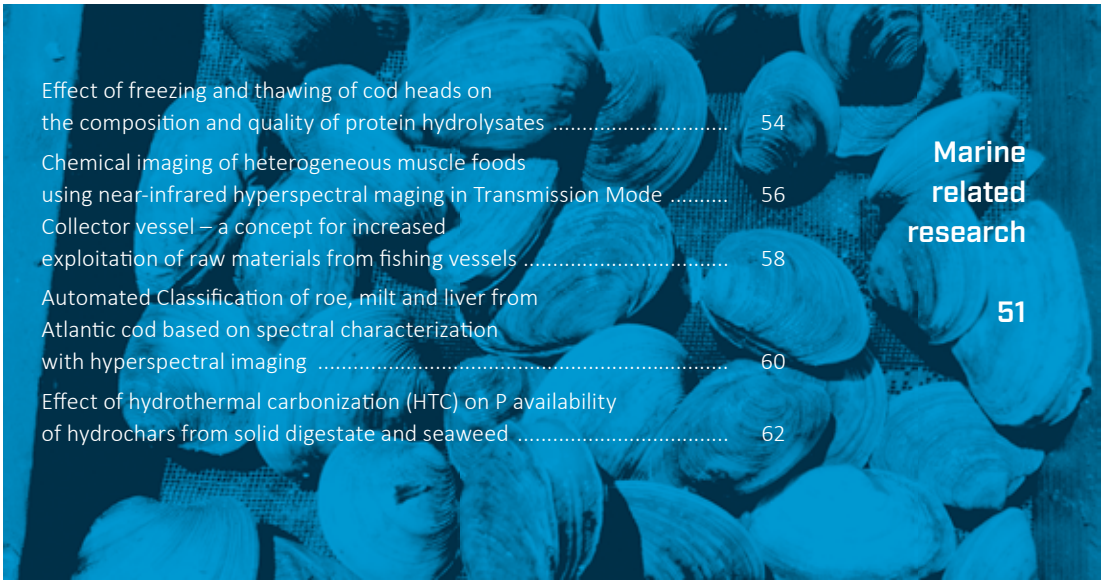

Marine related research

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Value chain
related research

ANITA ROMSDAL

How grocery stores are stealing shelf life from customers and contributing to food waste

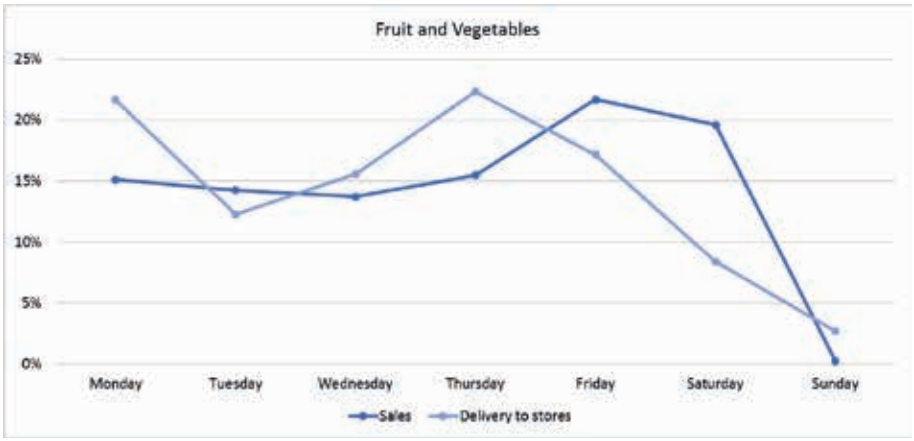
Consumers buy more food towards the weekend, while stores restock shelves early in the week. This reduces the days of shelf life available to consumers and increases the risk of waste

Sustainability is a growing concern for all actors involved in the food supply chain, particularly since 1/3 of food produced for human consumption is lost on the way from production to retail shelves and consumers' fridges. Previous studies have identified supply chain related causes of food waste, including lack of information sharing, forecasting difficulties and inappropriate ordering policies. There is however less evidence on how actors can change supply chain practices and policies to reduce food waste. This is particularly important for the fruit and vegetables category that represents the largest volumes of avoidable waste in food supply chains.

In CYCLE we wanted to provide empirical evidence on the mechanisms that contribute to food waste in grocery stores, in particular looking at sales patterns and ordering practices between stores and wholesalers.

We collected data from 230 grocery stores and one wholesaler with multiple warehouses over a period of 3 months. We collected daily data on shelf life, inventory levels and sales for 12 fruit and vegetable variants. We also collected data on orders and deliveries between the wholesaler and the stores for the products in the same period. Data was mainly collected from the companies' information systems, supplemented with interviews and site visits.

Fruits and vegetables are perishable products with very short shelf life. Every hour a product spends in inventory reduces product quality and time available for consumption, thus increasing the likelihood of



The graph shows a mismatch between supply and demand during the week. The unnecessary time products spend in inventory consumes shelf life that should be available to consumers

Fruits and vegetables have very short shelf life and contribute to large amounts of waste

the product ending up as waste. To ensure that supply matches actual demand, and products spend a minimum amount of time in inventory, stores and wholesalers must synchronise ordering, packing and delivery with actual sales in the grocery stores.

> *Every hour a product spends in inventory reduces product quality and time available for consumption*

The empirical data revealed a clear pattern of sales vs. orders and deliveries. Stores place their orders to wholesalers so that large volumes of fruit and vegetables are supplied to the stores early in the week. However, the majority of sales take place towards the end of the week. This suggests products spend unnecessary days in inventory in stores. In addition to contributing to food waste, we assume that the current ordering practices and policies are leading to value loss due to price reductions for excess inventory and loss of brand loyalty due to reduced product quality.

Our study confirms a mismatch between supply and demand in the retail and wholesale stages of the supply chain. The findings have provided insights that practitioners can use to test new ordering and delivery policies, which in turn can reduce the food waste in the retail and consumer stages of the supply chain.

In the future, retailers should share real-time sales data with wholesalers and food processors. These can in turn use the information to better plan their own purchasing and processing operations so that products spend a minimum amount of time in inventory in all stages of the supply chain.

NTNU
Norwegian University of Science and Technology

CONTACT:
Anita Romsdal
anita.romsdal@ntnu.no

ANITA ROMSDAL

Understanding waste in food supply chains

If we want to reduce waste, we need to understand waste. This study identifies why and where in the supply chain waste occurs for meat, fruits and vegetables, and fish and seafood

Food requires large amounts of resources for its production and distribution. It is estimated that 35 % of food produced for human consumption is currently lost in the supply chain, thus having a substantial environmental impact without adding value.

Despite a growing number of studies on the extent of food waste, supply chain actors still struggle to find ways to identify and reduce waste. The first step in reducing waste is therefore to generate a better understanding of why and where food waste occurs at the different stages of the supply chain.

> *... one supply chain actor's decisions can affect waste generation up and downstream in the supply chain*

A number of previous studies have focused on specific types of food waste, specific product types and individual supply chain stages. We know that the environmental burden at each supply chain stage varies substantially between product types. We therefore used existing literature to analyse food waste in a supply chain perspective.

We analysed waste for three product types: 1) meat, 2) fruits and vegetables, and 3) fish and seafood. We wanted to know how different product types contribute to waste, and to identify the main drivers of waste in each supply chain stage: primary production, processing, distribution, and consumption.

Before we can implement effective preventative measures for reduction of food waste, we need in-depth knowledge on the reasons for and scale of waste generation in each supply chain stage. By

Enormous amounts of food wasted. Around 35 % of food produced for human consumption is lost in the supply chain (Parfitt et al., 2010)

Three product types were investigated: 1) meat, 2) fruits and vegetables, and 3) fish and seafood

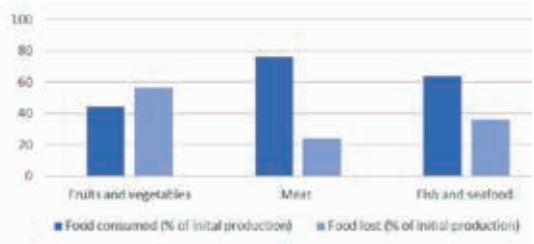
taking a supply chain perspective, we could identify how decisions in one supply chain stage affect waste generation in another. This will enable us to target efforts for waste reduction and increase the amount of food available for human consumption.

Our investigation found that fruits and vegetables are by far the biggest waste contributors, followed by fish and seafood, and meat. However, meat has the highest environmental footprint.

Most waste occurs in the consumption stage, followed by the primary production, distribution and processing stages. Waste that occurs towards the end of the supply chain has consumed more resources than waste that occurs early.

The key drivers of food waste include retailers' specifications of physical aspects for fruits and vegetables, inappropriate or defective packaging, poor temperature management, mismatch between supply and demand, and poor instore handling and stock management.

The insights from the study have been used in several new case studies. One study investigates how waste



Consumption vs. loss. The graph shows volume consumed vs. lost in percentage of initial production for different product types (adapted from Gustavsson et al., 2011)

of fruits and vegetables can be reduced when actors use information sharing to better match ordering and production patterns to retail sales.

Our study demonstrates that one supply chain actor's decisions can affect waste generation up and downstream in the supply chain. Supply chain collaboration and information transparency is needed to reduce the total amount of food waste in the supply chain and in turn increase the sustainability of the whole sector.

NTNU
Norwegian University of Science and Technology

CONTACT:
Anita Romsdal
anita.romsdal@ntnu.no

HENRIK EGENLYNG

Cascading and Upcycling for a Circular Bioeconomy

Crosscutting analysis of CYCLE results from a transdisciplinary and socio-economic perspective.

Crosscutting analysis of CYCLE results showed that while avoiding food losses and transforming co-streams to new products of higher value characterizes the poultry industry case and part of the 'blue' sector, challenges remained in the 'whitefish' area where a higher share of fish resources ends up as rest raw materials not fully utilised.

Cascading and Upcycling potential of selected CYCLE results were investigated, and the crosscutting analysis showed how CYCLE based innovations may enable cascading and valorisation of co-streams and why an upcycling potential exists as well. The main contribution of the crosscutting analysis is in demonstrating feasibility of transdisciplinary research and innovative options for bioeconomic transition towards sustainability.

> *Co-stream values now surpass primary products*

We demonstrated how co-stream values now surpass primary products and provided estimates for potential economic values of selected cascading options CYCLE research contributed to enable. Conclusions drawn indicates that research enabling cascading of food chain co-streams, in the sense that these are processed and utilized for a more profitable purpose than before – may also constitute a potential for industries to ´upcycle´ and move further towards a more circular and perhaps eco-efficient bioeconomy. We used cascading theory to conceptualize the basic challenge faced by individual companies aiming to further valorise co-streams. In contrast, we spoke about upcycling when both utility (market value) and resource-economic optimization of products increase: cascading of rest raw materials into higher value products with less total economic impact is upcycling.

Nordic countries share a common vision for a circular bio-economy in spite of different access to natural resources. However, an exploration of policy and strategy documents aiming to advance our bioeconomies indicates unclarity about what is really at stake. Is any new innovation made to exploit biological resources ´bioeconomic´ progress? Is the yardstick for such progress monetary profit? Is an aspect of eco-efficiency – at local, regional, national or global scope – a prerequisite to bio-economic progress? To what extent does adding the pre-fix ´circular´ make bioeconomic progress more eco-efficient? A transdisciplinary perspective was added to help raise these and other research questions able to help situate CYCLE in a larger context.

The value per kilo of by-products from meat production in general is increasing much faster than the value of meat in total, indicating co-streams are having an increasing significance also in the chicken industry. Similar developments were identified for fish and fish products. Assuming 226.000 tonnes of whitefish rest raw materials are currently unused – cascading or upcycling these to a level between USD 5 and 60 per 5 kg would add between 0.23 – 2.7 billion USD annually to Norwegian society. A valorisation potential from cascading 2nd class carrots into smoothie can

Implementing cascading options based inter alia on CYCLE results can reach hundreds of millions NOK annually

Is an aspect of eco-efficiency – at local, regional, national or global scope – a prerequisite to bioeconomic progress?

be estimated for the Norwegian carrot co-stream fraction to a level of about NOK 52 million. Finally, the Norwegian chicken co-stream sector may realize NOK 80 million/year through innovations relating to enzymatic hydrolysis. Upscaling this figure to a global level could add up to NOK 28 billion per anno.

The monetary value of the Norwegian food industry implementing a full array of cascading options based inter alia on CYCLE results can be estimated to reach hundreds of millions NOK annually. CYCLE has widened the knowledge base for social actors aiming to contribute towards the goal of a circular Norwegian and global bioeconomy through upcycling, creating higher values with less environmental impact.

In terms of future ´bio-economic´ research needs, we identified a need for research on institutional and environmental complexities involved in actually achieving upcycling outcomes. ´Upcycling´ remains a theoretical concept and objective at the moment, given also Nordic countries operates in a global market playing by rules of games orchestrated by financial institutions with concerns for monetary governance rather than governing eco-efficiencies.

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SINTEF

NIBIO NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

CONTACT:
Henrik Egenlyng
he@ifro.ku.dk

Chicken
related research

ANITA ROMSDAL

Upcycling chicken co-streams

A potential for upcycling co-streams in the chicken meat industry was identified in a global situation confirming socio-economic relevance of innovations allowing Norwegian poultry industry to pursue export of upcycling capacities.

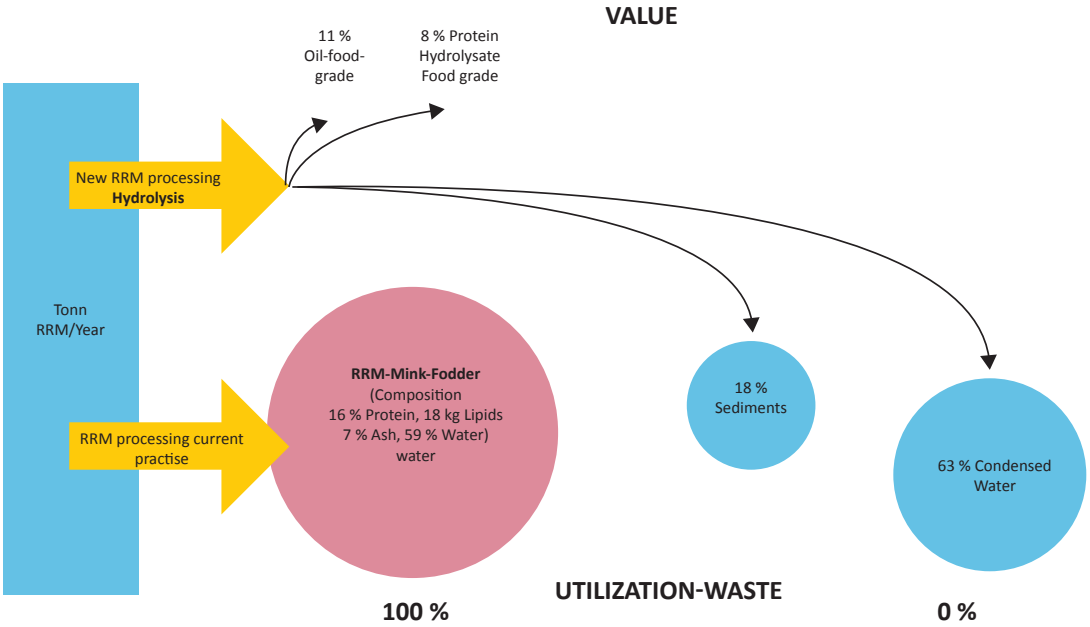
The global state of poultry co-stream processing involves situations where potential byproducts from slaughtering are lost and represents environmental hazards. The industrial nature of the global poultry sector is evident in [the National Geographics 2014] pictures from a poultry farm where eight million hens lay 5.4 million eggs a day. Major economies like Brazil and China increases the scale of poultry industry and imperative of efficient resource use. Global demand for protein adds a profitability perspective to cascading chicken co-streams, based on enabling innovations. Norway was investigated as a strategic case in which use of residues from slaughtering is already highly developed and where the challenge is upcycling of co-streams into high-value products. CYCLE innovations provide Norway with increased cascading capacity and know-how of global relevance.

Automatic or machine vision based fractioning of different raw material qualities are important areas of upcycling enabling innovation. Knowing material shares of fat, protein, and bone in residues can provide a basis for processing optimization with a view to maximize yield and minimize losses of co-streams and thus optimize cascading and upcycling. Automation of sorting blood stained versus not blood stained chicken breasts and enzymatic hydrolysis of chicken rest raw materials are advanced innovation goals. Comparative study aiming to optimize enzymatic hydrolysis of chicken and find processing conditions giving hydrolysis products of high quality CPH (chicken protein hydrolysate), indicated enzymatic hydrolysis of chicken co-streams is well suited for applications in human nutrition, on par with FPH from herring.

The concept of bioeconomy is already strong in the Norwegian research landscape with technical innovations aiming to help ´cycle´ raw material streams destined to end up as food loss. The emerging bioeconomic research landscape is however somehow challenged when it comes to develop a social science based understanding of the nature of socioeconomic and institutional challenges facing aspirations for a green economy. Therefore, drawing inspiration from cascading theory and industrial ecology, and as an initial step, we imported the term ´UpCycling´ from its design context (Mahoney 2005), and used it in our case to denote innovations expected to reduce environmental impact relative to economic value.

Edible byproducts from poultry have an increasing share of total export of, indicating more focus on upgrading and value adding of animal byproducts.

Volumes of edible byproducts play an increasing role in EU export and in terms of values the export of animal byproducts has increased much faster than meat exports. A simple curve can illustrate value addition through cascading, product development and innovation, in the poultry industry: as we move up the curve, we move away from waste or products with negative value. Added value and higher price of the products



along the curve indicate that raw materials are improved and utility increase, as judged by the market. We would speak upcycling if both market value and resource-economic optimization combine into higher values and less environmental impact.

Enzymatically hydrolysated chicken protein (EHCP) is one of the CYCLE innovations with a strong cascading and perhaps upcycling potential for the Norwegian chicken industry. Our estimate of the cascading potential is that up to ten percent of current rest raw materials can be value-added by up to a factor 100 (one hundred), if moved up the value ladder from mink through pet feed to food grade & perhaps further to the health/sports drink market.

Used as mink feed chicken co-streams are at a valorization level for Norway at NOK 39 million. Used as ingredients for human consumption the same costream could take Norway at least up to a NOK 80 million mark. Norway accounts for 0.1 per cent of world total poultry production and 0.3 per cent of total poultry production in Western countries. Globally cascading the chicken co-stream in question could be worth NOK 28 billion.

NTNU
Norwegian University of
Science and Technology

CONTACT:
Anita Romsdal
anita.romsdal@ntnu.no

JENS PETTER WOLD

Process control of enzymatic hydrolysis of poultry byproducts

It is possible to control the enzymatic hydrolysis of poultry byproducts towards high yield and desired end quality by use of on-line spectroscopic determination of the byproduct composition.

Enzymatic hydrolysis of byproducts from food production is increasingly used to create value-added products such as oils and protein powders. A challenge in this kind of bioprocessing is that the quality of raw material varies significantly. It is crucial to handle such raw material variation, since it can affect the process and end products in an undesirable way. A strategy to solve this challenge is to continuously monitor the relevant variation by use of on-line and non-destructive spectroscopic methods. Then, parameters such as hydrolysis time and type of enzymes can be adjusted accordingly to obtain high yield and desired product quality.

In CYCLE we tested this strategy on the hydrolysis of poultry byproducts.

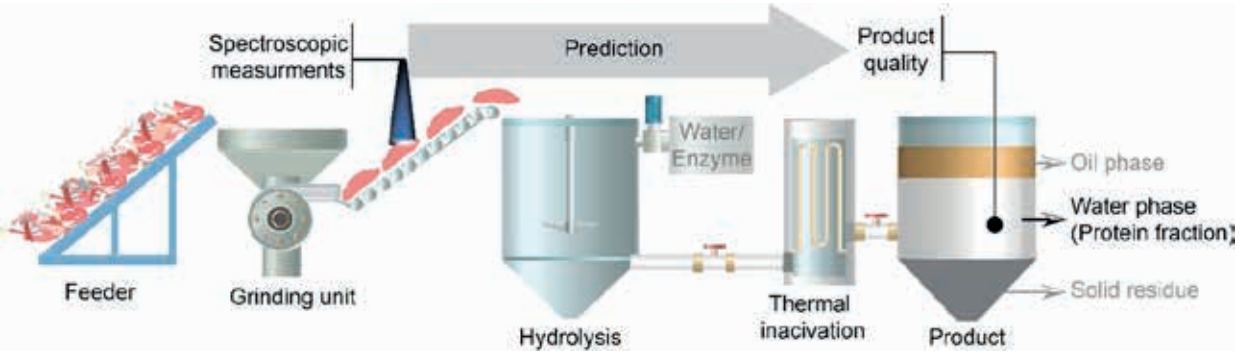
Byproducts from processing of poultry carcasses consists of skin, tendons, bone, cartilage and meat. Depending on the process as well as the incoming birds (chicken or turkey), the composition of this material can vary a lot.

We tested near-infrared, Raman and fluorescence spectroscopies for on-line detection of fat, water, protein and bone concentrations in typical samples from the poultry processing. These samples were also subjected to hydrolysis to investigate how the end product quality was affected by the raw material composition and process settings.

When the composition of the poultry rest raw material can be determined in real time prior to the hydrolysis process, it enables adjustment of the process settings to obtain the best possible end products. This is important, since requirements to end product quality can be strict. Quality deviations may reduce value and usability of the hydrolysates. Control of the process is therefore important to reduce waste and increase quality and profit.

We discovered that composition of poultry byproducts varies widely. Fat and bone concentrations were in the ranges 15- 46% and 0- 13%, respectively.

The spectroscopic techniques could in true time determine fat, protein and bone with high accuracy. It was also possible to model the end product characteristics of the hydrolysates based on process settings and spectroscopic measurements on the raw material.



Enzymatic hydrolysis of poultry byproducts. Spectroscopic measurements on the raw material are used to control process

The results demonstrate that it is possible to control a rather complex bioprocess where the input material varies notably in composition and quality.

Based on the positive results, we propose a novel process control concept for enzymatic hydrolysis of poultry byproducts. Such process control tool will secure profitable and sustainable use of valuable by-products. The concept can easily be adapted to hydrolysis of other food byproducts of marine and terrestrial origin.

This proposed control concept is presently being further developed together with industrial partners. We hope to see the first implementation in 2018. The methodology has a large potential to control complex

Nofima

SINTEF

CONTACT:
Jens Petter Wold
jens.petter.wold@nofima.no

ANNE-KRISTIN LØES

Eggshells for liming and nutrition

Eggshells are excellent for liming of soil, but may also be of interest for nutrition purpose.

CYCLE industry partner Norilia wants better utilization of 800 tons of eggshells collected annually at their egg product factory in Revetal. A separate industry is established to utilize eggshell membranes for medical purpose. Hence, the eggshells are collected in a very pure state. Literature studies revealed that eggshells have a good liming effect, and also contain valuable macro- and micronutrients. Norwegian eggshells contain about 33% calcium, 5% nitrogen, 2.8% magnesium, 0.8% phosphorus and 0.5% sulphur and potassium. We conducted a field experiment to get some practical experiences from eggshell application in large scale, and study the effects in soil.

A field experiment was conducted to compare grinded eggshells with traditional lime. The nutrient content of dolomite lime, which is made from magnesium carbonate rock, was 24% calcium, 11% magnesium and 0.1% phosphorus. After grinding, the eggshells were somewhat coarser than the dolomite powder. 52% of particles were between 2 and 0.7 mm, 41% between 0.7 and 0.25, and 7% below 0.25 mm. For dolomite, 45% were below 0.25 mm. About 0.5 tons were applied per ha for eggshells, and 0.4 tons for dolomite. Five soil samples for each treatment were taken in spring and autumn and analyzed separately.

> *Calcium in eggshells seems to be much more biologically active than rock-based calcium*

Eggshells are a valuable resource, and should be utilized much better than the current practice of deposition. This is a really unsustainable practice, even if it has no big negative environmental impacts.

Grinded eggshells are an excellent source of lime and plant nutrients.

Grinded eggshells were easily spread, with no problems of dust, odor or clumping. However, the uneven particle structure challenged an even distribution by spreading. This is a practical problem which can be solved by better grinding. Soil pH increased from about 6.0 to 6.3 for both lime types. The amount of plant-available calcium increased much more for eggshells than for dolomite. The value increased from 109 to 160 mg Ca per 100 g soil with eggshells, but only from 124 to 128 for dolomite. This likely reflects that the calcium in eggshells is much more biologically available than rock-based calcium.

Eggshells should definitely be used for liming rather than being treated as food waste, but it may be even better to use them as a food or feed ingredient. Recent feeding trials with minks conducted by Norilia revealed better uptake of calcium from eggshells than from normal lime.

Norwegian producers of eggshells, and of feed and soil products, are considering how eggshells can best be used as feed, feed ingredient or as an ingredient for garden soils.

NORSØK

CONTACT:
Anne-Kristin Løes
anne.kristin.loes@norsok.no

STEFFEN ADLER

Chicken feathers for protein feed? Amino acid composition in solubilized and residual fractions of hydrolyzed feathers

Poultry feathers are composed of resistant structure proteins, which can be broken down by hydrolysis. Na_2SO_3-treatment combined with pressure cooking gives high digestibility and low losses of valuable amino acids.

Feathers are composed of keratin, with disulphide bonds hampering degradation. Commercial production of feather meal is usually conducted by pressure cooking. Addition of alkali (NaOH), sodium sulphite (Na_2SO_3) and proteolytic enzymes can support dissolution of feathers. Former studies have usually concentrated on a mixture of solubilized (S) and residual (R) parts of hydrolyzed feathers. We studied effects of these treatments on in vitro pepsin digestibility and amino acid composition in S and R fractions separately.

We conducted two sets of experiments with chicken feathers. First, a mathematical model was developed for solubility and digestibility of S and R fractions, for the effects of different combinations of enzyme, NaOH, Na_2SO_3 and pressure cooking. Enzyme had no effect, but the other treatments had. Secondly, NaOH, Na_2SO_3 and pressure cooking were combined in different treatments based on a model with a predicted digestibility of 90%. Digestibility and amino acid composition of both fractions were analyzed.

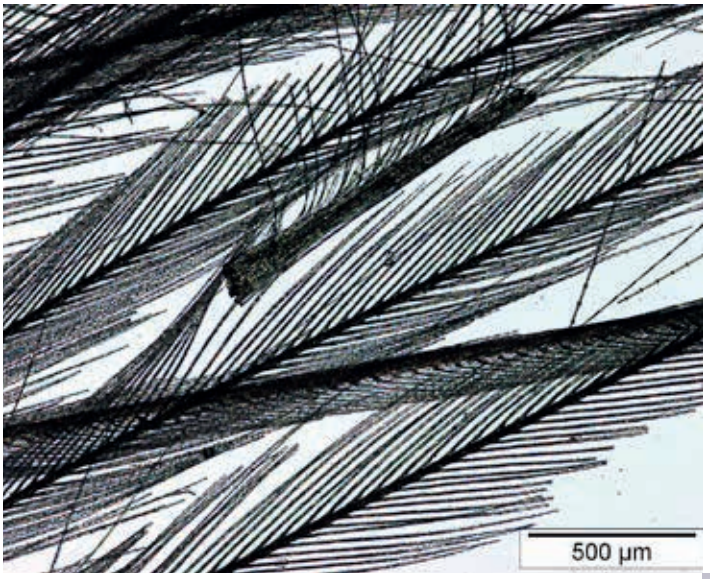
Poultry feathers are poorly utilized due to low digestibility of the protein. Feather meal is not yet produced commercially in Norway. We aimed to developed gentle hydrolysis methods to produce feather meal with high digestibility and low losses of valuable amino acids as a feed ingredient for monogastric animals including fish. Feather meal is used for fish elsewhere, but has not yet been considered relevant in Norway.

The tested enzymes had no effect on solubility or digestibility of feathers. NaOH and Na_2SO_3 combined with pressure cooking increased digestibility. NaOH gave higher solubility than Na_2SO_3 and higher digestibility in S than R fractions. For Na_2SO_3, no differences between the digestibility of the two fractions were found. Cysteine was the essential amino acid with the highest losses during hydrolysis. Losses were lower for Na_2SO_3 than NaOH treatments. Considering the amino acid profiles, treatment with Na_2SO_3 and pressure cooking resulted in the most valuable experimental feather meal for salmon.

> *Application of Na_2SO_3 increases the availability of valuable amino acids such as cysteine. The feather meal may be used to feed growing salmon.*

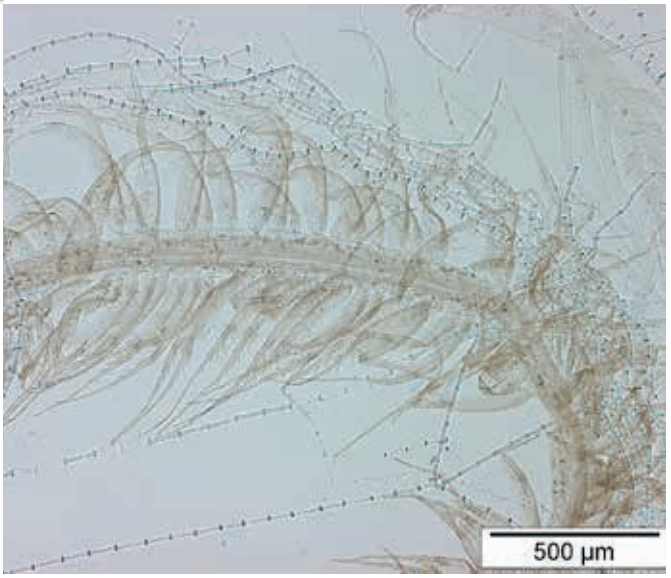
Application of salt increases the sodium concentration and ash content to levels above those wanted in feed compounds. The results were used to assess the economic value of feather hydrolysis products for Norwegian feed industry. Until now, a national industry will not be able to compete economically with imported feather meal.

Tested proteases did not improve feather digestibility in the CYCLE experiments. In future, sets of complementary enzymes may be developed for efficient degradation of disulphide bonds. This may improve the nutritional value of feather meals and reduce processing costs in commercial hydrolysis plants.



Untreated chicken feathers seen by microscope.

Treated (2.5 M NaOH, 50°C, 40 minutes) chicken feathers seen by microscope.



NORSØK

SINTEF

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

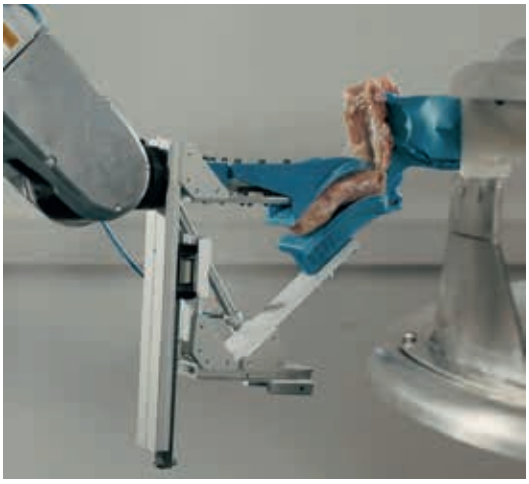
CONTACT:
Steffen Adler
steffen.adler@nibio.no

EKREM MISIMI

GRIBBOT – 3D Vision guided robotic harvesting of chicken fillets

GRIBBOT is a novel robotic 3D vision-guided concept for chicken fillet harvesting. GRIBBOT operates in a way that it both scraps the carcass and grasps the chicken fillets automatically to complete the harvesting operation.

In Norway, the final stage of front half chicken harvesting is still a manual operation due to a lack of automated systems that are suitably flexible with regard to production efficiency and raw material utilization. GRIBBOT functions using a compliant multifunctional gripper tool that grasps and holds the fillet, scrapes the carcass, and releases the fillet using a downward pulling motion. The gripper has two main components; a beak and a supporting plate. The beak scrapes the fillet down the rib cage of the carcass following a path determined by the anatomical boundary between the meat and the bone of the rib cage. GRIBBOT is an example of a concept with a potential for the flexible robotic automation of the chicken fillet harvesting operation. Its potential commercial application, with further development, can result in automated fillet harvesting.



Picture from live demonstration of the concept of Gribbot. Machine vision for analyses of where to grasp and functioning tool for harvesting of chicken fillet.

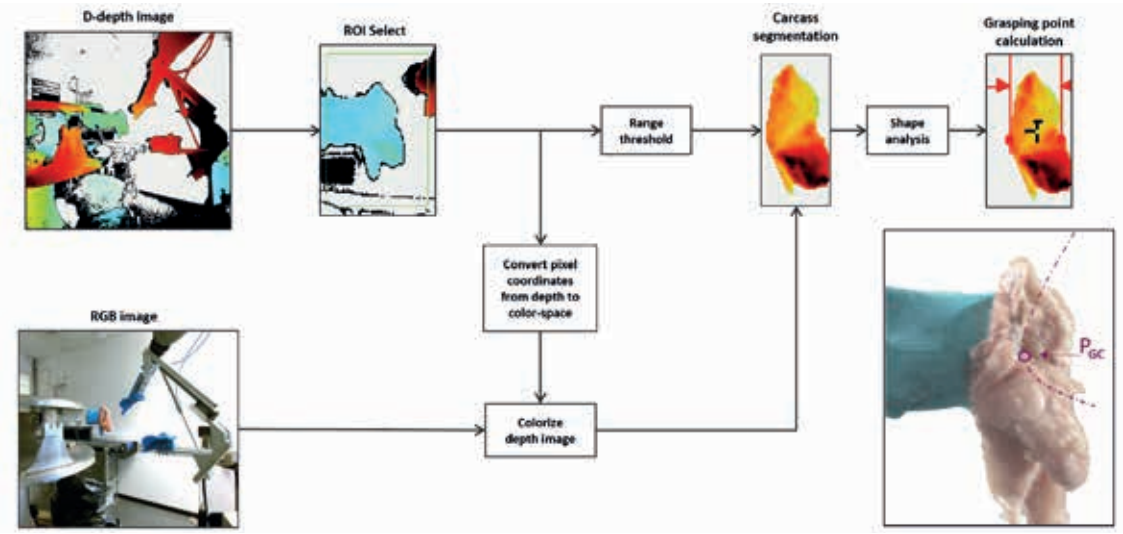
Traditionally, the harvesting of chicken fillets is based primarily on two methods: (a) Manual harvesting of fillets from the carcass preceded by a cutting operation using a knife or similar cutting tool. (b) A fixed machine-based operation using a knife or similar cutting tool combined with a mechanical system designed to release the fillets from the carcass.

The main challenge facing the development of an efficient automated harvesting technology for chicken fillets is to design and build in adaptability to the variations in the size, shape and orientation of the fillets attached to the carcass. These variations require precise identification of the grasping point and adaptive harvesting by means of an effective grasp, scrape and release procedure.

Around the world, poultry processing is a massive industry with a global annual production estimated to be 92.7 million tons, generating revenues of USD 132 billion. Chicken fillets represent the highest-earning product from the entire bird and there is a pressing need from the processing industry to introduce an automated front half fillet harvesting technology that can adapt to anatomical variation, while at the same time optimizing raw material utilization.

Gribbot represent a concept contributing towards automation of the harvesting operation in industry with a potential to increase the raw material utilization.

The GRIBBOT succeeded in correctly calculating the 3D coordinates and location of the fillet's grasping point. The motion paths controlling the robot arm enabled the GRIBBOT to scrape the fillet following the path



Computer vision algorithm steps for segmentation of the carcass and calculation of the grasping point-as a fist contact point of the gripper tool with the chicken.

> *To automatically be able to handle and process compliant raw materials there is a need to develop better 3D vision algorithms for localization of raw material and machine learning algorithms for recognition and classification from the visual data. It is also important with robot learning based on learning from demonstration or deep reinforcement learning, and novel robot tools for dexterous manipulation that are able to imitate the delicate handling with human hands and to maximize the raw material use. GRIBBOT is a milestone in this roadmap towards achieving this goal.*

determined by the anatomical boundary between the meat and the carcass' rib cage bone. The result was the successful harvesting of front half fillets, including the tenderloin, from the carcass. The entire robot-based harvesting procedure for a single fillet was carried out in less than 4.75 s. GRIBBOT is an example of research and technology development with potential for flexible and adaptive robot-based automation in food processing. This is due to adaptivity both with respect to the localisation of the grasping point enabled by a 3D vision algorithm, and in relation to the potential for optimization of raw material utilization.

We believe that the GRIBBOT has significant commercial potential both in the poultry industry and other food industry applications where flexible robotic automation can contribute to higher levels of production sustainability and bio-resource efficiency.

Additional developmental steps required to bring the GRIBBOT closer to full commercial use include the issues already described in this Section, combined with close collaboration with a capable technology vendor that can move current development status to a higher Technology Readiness Level.

SINTEF

CONTACT:
Ekrem Misimi
ekrem.misimi@sintef.no

MINNA VIKMAN

Hydrothermal carbonization of poultry by-products

By-products from mechanical deboning of chicken contain phosphorus, which is one of the critical raw materials in EU. Hydrothermal carbonization enables processing of industrial by-products into fertilizer/soil amendment products.

The rapid growth of global poultry industry has led to the generation of food-processing by-products like viscera, bones and feathers that often are discarded or used as animal feed. One of these by-products is residues that are formed in mechanically deboning of chicken meat (MDM).

Enzymatic hydrolysis of chicken MDM residues can be used to produce broad spectrum of protein hydrolysates and food ingredients. In addition to hydrolysates, a wet solid material containing phosphorus-rich bones is formed. Efficient processing methods are needed to treat this residue in a way that all the valuable components can be turned into products.

> *By-products from animal production and meat processing industires are potential sources of phosphorus.*

In hydrothermal carbonization (HTC), wet organic raw material is heated at moderate temperatures in self-generated pressures using water as the carbonization medium. This results in dehydration and partial degradation of the raw material and the formation solid hydrochar, liquid fraction and a minor gas phase. The HTC can be used, for example, to treat sewage sludge, manure or industrial by-products.

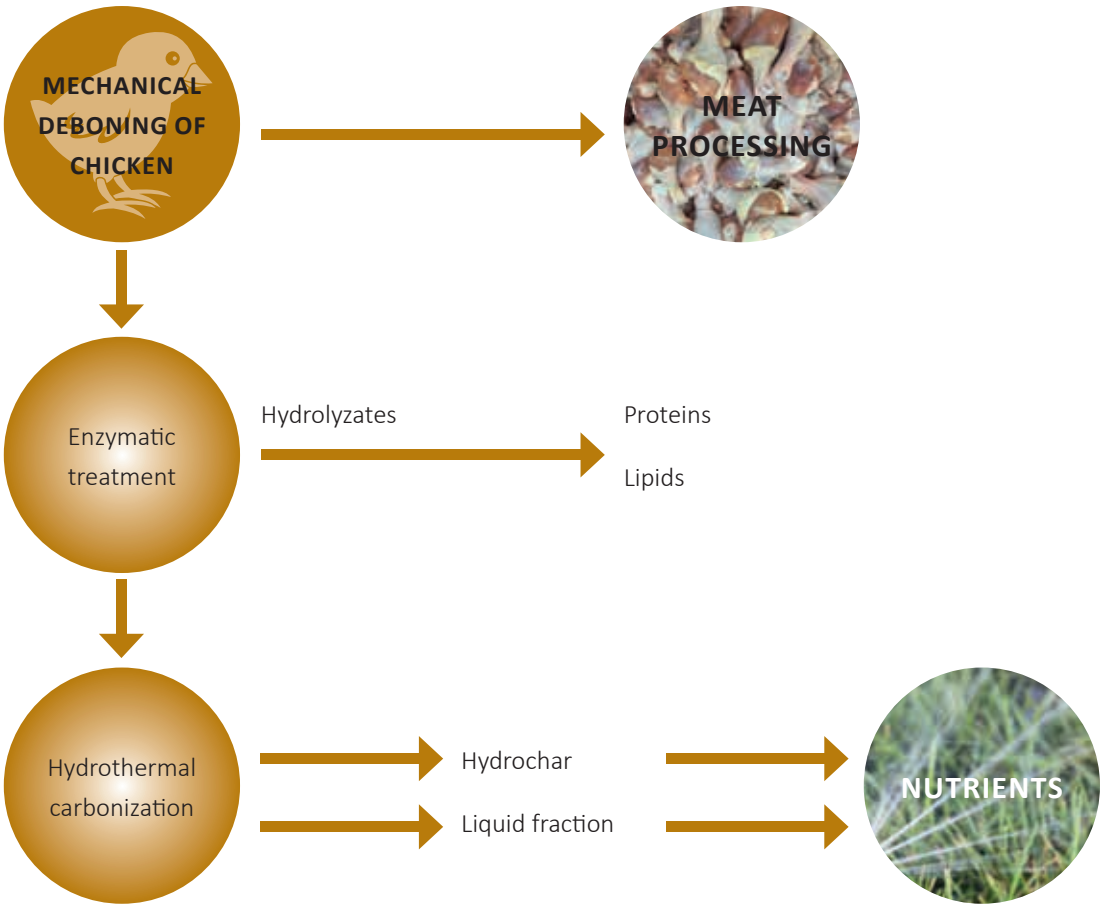
In addition to the characteristics of the raw material, processing conditions influence on the properties of the produced hydrochar and liquid fraction. Optimized process conditions can be used to control the migration of nutrients originally present in the raw material between the different fractions.

Essential nutrients for crop growth in agriculture are phosphorus, nitrogen and potassium. Phosphorus is listed as one of the critical raw materials in EU and there is no substitute for P in agriculture. The recovery of recycled P from industrial by-products is becoming an attractive alternative for non-renewable and limited mined phosphate resources.

Our results demonstrate that HTC can be used to process by-products from poultry industry. The distribution of phosphorus between the liquid and solid fractions can be controlled by adjusting the process conditions. With higher pH the majority of P was distributed to the solid hydrochar while N was concentrated in the liquid fraction. With lower pH the majority of both N and P were in the liquid fraction.

Hydrochar can be used as a nutrient-rich fertilizer/soil amendment, solid fuel or it can possibly be upgraded to high value products. If desired, phosphorus can be recovered from the solid hydrochar as a separate product using acid extraction. Alternatively, nutrients can be recovered from the liquid phase.

Technologies for the productization of recovered nutrients have big potential as nutrient scarcity becomes more imminent. Further HTC process optimization is needed to control the carbon migration during the process to increase the energetic value of the hydrochars. In addition, the recovery of the nutrient and their plant-availability should be evaluated.



Value chain for by-products from poultry industry.

CONTACT:
Minna Vikman
minna.vikman@vtt.fi

RASA SLIZYTE

Co-streams from poultry industry as a raw material for high quality ingredients for human consumption

Right choice of processing technology for fresh poultry co-streams gives high quality chicken oil and proteins for both human consumption and feed production.

The global increase in production and consumption of chicken has led to the generation of large amounts of rest raw material that often are discarded or used as animal feed. Rest raw material of animal origin, such as chicken, contain valuable biomolecules like proteins and lipids that can be recovered and processed for various applications in the food, pharmacy and cosmetic industry. Therefore, with a growing global demand for food, optimal uses of unexploited or under-utilized resources are increasingly important.

Chicken rest raw material after mechanically deboning of chicken meat was used as rawmaterial in the tests. The rest raw material consisted of 15.8 ± 0.6% protein, 17.5 ± 2.0% lipids, 5.8 ± 1.9% ash and 37.7 ± 2.2% water Thermal extraction as well an enzymatic hydrolysis (including endogenous and commercial enzymes) were used for screening tests in order to find the most optimal processing technologies leading to maximum yields and quality of valuable fractions such aslipids and protein/hydrolysates.

Rest raw materials form chicken processing gives large amount of fresh high quality material rich in proteins and lipids. The aim of this works was to develop knowledge, screen for technology and processes which leads for better utilization of co-streams in the poultry industry with focus of human consumption.

The produced chicken oil have a low oxidation status (low peroxide value and anisidine value) and high stability compared to industrial used oils. Thermal treatment resulted in an oil with lower oxidation status compared to enzymatic hydrolysis.

Hydrolysis with Protamex gave the highest protein hydrolysate yield and it was shown that hydrolysis time of 60 min is sufficient as prolonged hydrolysis gave no significant increase in hydrolysate yield.

The protein hydrolysates had good sensory properties, desirable amino acid composition, good nutritional value and exhibited antioxidant activitiy for Hb-mediated lipid oxidation.

From rest raw material to ingredients: technological tests. Dried chicken protein hydrolysate – valuable protein rich ingredient.

The sediments contained relative high amounts of PL (16.7 – 25.2%), high protein (nitrogen) recovery values, a desirable amino acid composition and high nutritional value. Both the protein hydrolysates and sediment fractions from chicken rest raw materials were found to have high contents of the predominant amino acids of collagen.

All fractions obtained after processing poultry co-streams should be introduced in different food and feed matrixes in order to ensure profitable recovery of the high quality ingredients. Different food and feed formulation should be tested to find the most optimal utilization of functional, bioactive and nutritional properties of the ingredients and to ensure stable products during whole supply chain.

Processing of poultry co-streams gives three fraction which, based on their composition and quality, can be use in different formulations:

Hydrolysates:
ingredient in food products as meat cakes, sausages, or as protein supplement.

Oil:
lipid source for pet-food and feed, but also possible ingredient in food products.

Sediments:
pet-food, feed.

SINTEF

CONTACT:
Rasa Slizyte
rasa.slizyte@sintef.no

Vegetable
related research

HENRIK EGENLYNG

Harvesting Soil with Potatoes

Norwegian authorities demand soil leaving potato packing plants to be deposited as waste. Depositing soil from potato processing plants is associated with significant cost for Norwegian producers. Therefor CYCLE investigated potato soil harvesting from an innovation and socio-economic perspective.

In all industrialized countries soil adhering to carrots, onions, potatoes and other vegetables is ´harvested´ along with crops and transported into processing plants, where the soil is washed of and left to a fate that ´depends´ on a combination of economic, institutional and technological factors. This soil loss is defined as soil loss due to crop harvesting (SLCH). Norway may in the next 40 years loose four million tonnes of agricultural soil. Political, social and economic drivers of soil loss and erosion have been neglected in social sciences, however, there is a growing political awareness of the value of soil, and the challenge to create socio-economic conditions and policies to support soil conservation. Therefore the Norwegian case of harvesting soil with potatoes was explored as reported below.

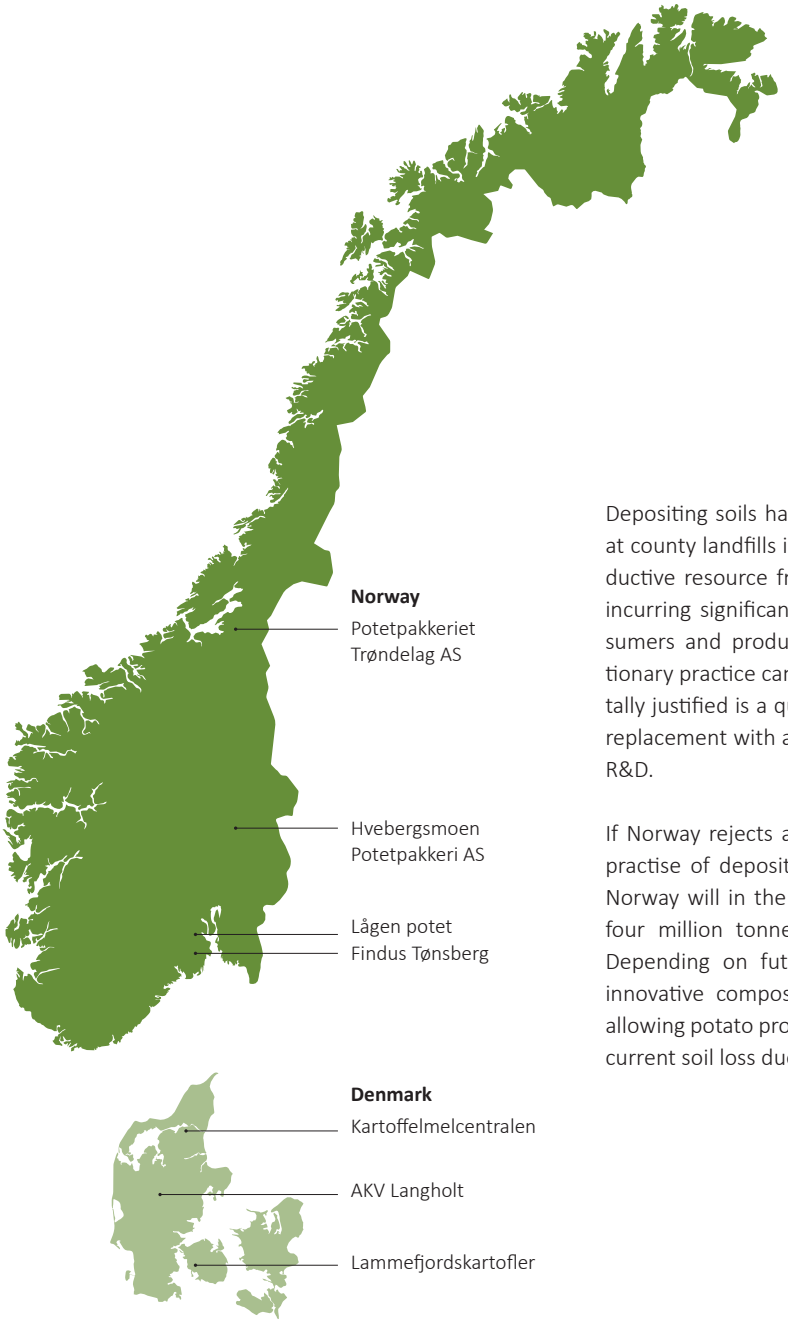
In Norway, wet soil sludge mixed with crop residues is commonly deposited as landfill in long-term storage facilities, to avoid that possible pest organisms, e.g. potato cyst nematodes, may be spread and infect farmers' fields. The economic rationale at stake is that for individual farmers and potato processing companies, monetary costs associated with SLHC directly affects financial bottom lines of each company. Processors perceives current regulation impacting SLHC management as a hindrance to competitive performance and see a need for innovative solutions to the SLHC problem. Referring to SLCH as ´food soil´, the farmers and processing industries are aware that the SLHC is a productive resource for the food economy and they wish for society to make best possible solution to the challenge of what to do with this resource, other than treating it as [dangerous] waste.

Depositing fertile soil represents a loss of productive natural capital. SLCH has received increased attention in recent years, and a detailed overview of biophysical factors affecting the amount of soil co-extracted with carrots, leek, potatoes, sugar beets and some other crops across several countries has been obtained. In Belgium economic loss related to SLCH in sugar beets was estimated at 60 million Euro/year (Verstraeten et al 2006), however no similar figures for Norway were available.

> *About 100 000 tons of valuable soil are lost annually by the deposition of soil from potato packaging*

Main soil loss due to potato harvesting is attributable to 3-4 large packers some of which has their own landfills on private land, and several smaller processing plants depositing the soil to municipal landfills, where the soil is perhaps mixed with other types of waste.

Risk from plant pathogens or pest species potentially present in soil waste from potato processing plants include potato cyst nematodes, bacterial ring rot of potato and potato bacterial wilt. Due to imported products being treated in the processing plants, there is also risk of introducing new pest species. Composting metholodogies developed by CYCLE research and industry partners can potentially minimize the risk of soil borne contaminations to a level low enough to accept re-cycling of soils currently lost due to the mandatory requirements from public authorities for producers to deposit soils harvested along with potatoes.



Depositing soils harvested with potatoes for 30 years at county landfills is a costly solution, removing a productive resource from the production landscape and incurring significant transaction cost on society, consumers and producers. Whether this highly precautionary practice can be economically and environmentally justified is a question for future research just like replacement with alternative practices will depend on R&D.

If Norway rejects alternative solutions to the current practise of depositing soils harvested with potatoes, Norway will in the course of the next 40 years loose four million tonnes of agricultural soil to landfills. Depending on future research investment policies, innovative composting solutions may be developed allowing potato processing plants to compost away the current soil loss due to potato harvest problem.

UNIVERSITY OF COPENHAGEN

NORSØK

SINTEF

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

CONTACT:
Henrik Egenlyng
he@ifro.ku.dk

JENS PETTER WOLD

On-line determination of dry matter content in whole unpeeled potatoes

NIR spectroscopy can be used for on-line determination of dry matter in whole potatoes. This will greatly reduce fault production and improve utilization through sorting and optimal processing.

Prediction of dry matter content in whole potatoes is a desired capability in the processing industry. Accurate prediction of dry matter content may greatly reduce waste quantities and improve utilization of the raw material through sorting, hence also reducing the processing cost.

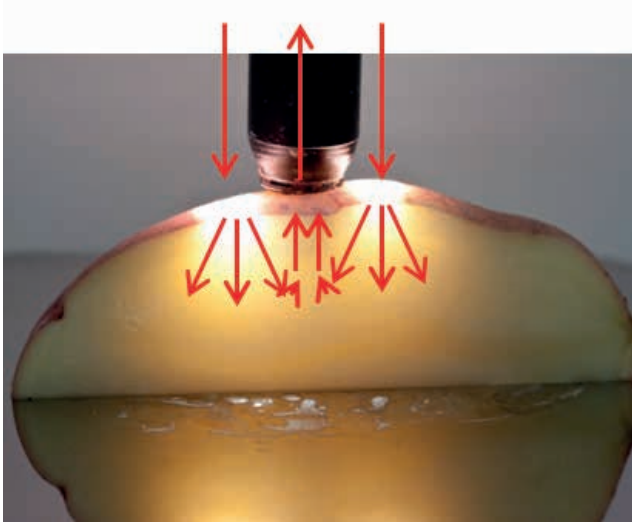
The following study demonstrates the use of a low resolution, high speed NIR interactance instrument combined with partial least square regression for prediction of dry matter content in whole unpeeled potatoes.

A total of 240 potatoes from seven different potato cultivars were measured with two different NIR measurement methods: 1) Off-line measurements with contact between the potato and the NIR instrument; 2) On-line non-contact measurements of the potatoes moving on a conveyor belt.

NIR spectra were captured in the 760-1040 nm region, 70 spectra per sec. Dry matter percentages for each potato were calculated based on the weight before and after drying.

Multivariate regression was used to calibrate the NIR instrument and to validate the performance.

The potato processing industries, and especially the frying and starch industries, are heavily dependent



Light is transmitted into a potato. Detected light at the surface contains information about dry matter concentration.

on reliable measurements of dry matter content. This is an important quality parameter frequently used to determine both the cost of the raw material and, most importantly, the subsequent choice of processing parameters.

Accurate on-line estimation of the dry matter content enables sorting into more uniform streams of raw material and optimal processing.

The offline contact measurements gave a prediction performance of R2=0.89 and a prediction error of ±1.19%. Significantly better performance was obtained with the on-line measuring configuration (R2=0.92), which yilelded a prediction error of ±1.06. This illustrates the possibilities of using this kind of instrument for on-line measurements. In addition it was shown that the dry matter distribution across the individual tuber could be predicted by the NIR calibration obtained. This can be useful for a more detailed characterization of each potato.

The current study shows that the use of a high speed NIR interactance instrument with a low resolution spectrophotometer measuring 15 wavelengths is a feasible approach for on-line prediction of dry matter content in potatoes.

The development of a user friendly instrument with the necessary hardware adapted to suit industrial environments is the natural next step in this development. This follow-up project with industry has already started and is being funded partly by industry and partly The Norwegian Research Council.

Nofima

CONTACT:
Jens Petter Wold
jens.petter.wold@nofima.no

STEFFEN ADLER

Ensiling out-sorted potatoes for improved utilization

Significant amounts of potatoes are sorted out due to odd size or damage during packaging. Ensiling prolongs shelf-life and may increase income.

CYCLE industry partner Produsentpakkeriet AS at Frosta wants better utilization of about 4000 tons of out-sorted potatoes annually, which are currently used for industrial purpose or fresh feed and poorly paid. Discussing this issue with another industry partner, Orkel AS who constructs agricultural machinery, we decided to test ensiling potatoes in large-volume. Ensiling increases shelf-life, and may add additional value to the feed. This may possibly increase the economic surplus from out-sorted potatoes. CYCLE-partners came together in April 2015 at Orkel in Fannrem equipped with 4 tons of potatoes to conduct this test.

For cutting, a traditional beet chopper was inefficient due to limited size. Crunching potatoes by a heavy tractor was also tested. Potato pieces were mixed with beet pulp to suck up effluents, and grass silage to support ensilaging. The mix was compacted and wrapped

Potatoes were ensilaged in a round bale, using an Orkel compactor MP2000.

by an Orkel compactor MP2000, designed for packing anything from maize silage to household waste into a round-bale of about 1400 kg. Two bales were made and stored. Bale 1 contained 77% cut potatoes, 10% silage, 13% pulp and had 29% dry matter (DM). Bale 2 contained 96% crunched potatoes, 3% grass silage, 1% beet pulp and had 24% DM.

It is disappointing to see food quality plant products being poorly utilized. The products are excellent animal feed, but hard to utilize due to short shelf-life. Could ensiling in compact round bales be used as a simple method for improved utilization of out-sorted potatoes?

The bales were analyzed after 6 and 12 weeks. Bale 1 had no effluents and stable content of DM after storage. From bale 2, there were effluents increasing the DM to 31% after 12 weeks. Both silages had a fresh, acidic odor at both samplings and the pH values were 4.4 for bale 1 and 4.9 for bale 2. Cutting the potatoes to ensure proper ensilaging and avoid risks of suffocating animals posed a challenge in this pilot test, but can be solved with appropriate equipment. Make potatoes stick together long enough to wrap the bale completely also posed a technical challenge.

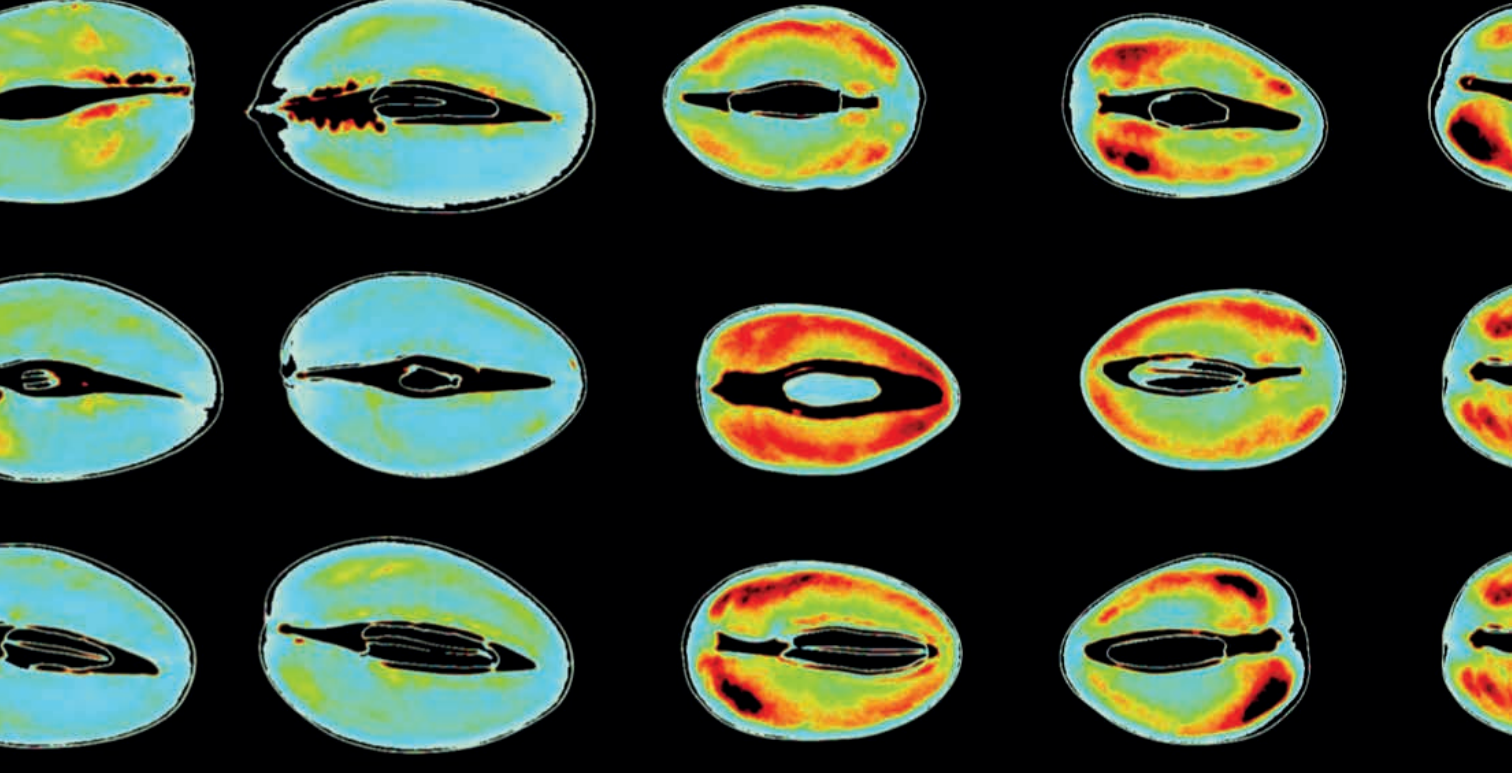
Feeding studies indicate a value of 460 NOK per bale. The compactor costs 1.2 million NOK. Wrapping costs per bale is 40 NOK. Is the possible income enough to buy a compactor and crushing equipment, and pay the required work? Costs and income should be compared with 140 NOK for selling the potatoes for industry.

Adding vegetables and probiotic bacteria to the potatoes may increase the palatability and the value of the ensilaged feed product by addressing issues in animal productions where intestine health is a problem, such as for piglets and calves who are easily infected by diarrhea.

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

NORSØK
Norwegian Centre for Organic Agriculture

CONTACT:
Steffen Adler
steffen.adler@nibio.no



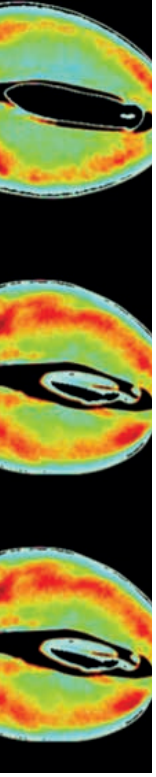
Color scaling of the X-ray absorption of unripe (left) and ripe (right) mangoes. The difference is significant and simple image features can be used as an input to the SVM classifier to build a model that is able to classify unripe from ripe mangoes.

EKREM MISIMI

Characterization of avocado and mango ripeness based on X-ray images

A potential for upcycling co-streams in the chicken meat industry was identified in a global situation confirming socio-economic relevance of innovations allowing Norwegian poultry industry to pursue export of upcycling capacities.

Internal defects in fruits and vegetables are one of the common reasons for discarding these products at the consumer stage. Very often, when we buy avocado they have a very nice appearance on the outside. When we want to consume them, they have internal defects, which if they would have been detected on time, would have saved a great deal of effort in all stages of the value chain. Early detection of such defects helps in sorting the products according to the right raw material to the right product and market. Such a detection maximizes the use of the raw material and reduces food loss and waste in all stages of the value chain. For example, our defected avocado could have been used to other products such as making a pure of guacamole instead of selling it as a whole product.



> *Machine learning and artificial intelligence models based on deep learning have recently enabled development of prediction models with much higher accuracy. Internal structure characterization requires a smart combination of a sensor technology such as X-ray and machine learning algorithms for interpretation of these images.*

Ripeness is one quality parameter that very often is difficult to quantify. We often squeeze the avocadoes or mangoes in order to find the "right" product to buy. Although an intuitive this is highly a subjective technique. Bama Industries came up with the suggestion to develop a technique that has potential to quantify the ripeness and potentially other internal defects. Although some research is carried regarding application on Near Infra Red Spectroscopy, the limitation is that this technique does not enable penetration for the internal investigation of the whole product. Therefore, the hypothesis for this case was that X-ray imaging and especially CT imaging would enable us to quantify ripeness and also inspect the internal 3D structure of the avocado and mango. In Figure 1 is shown the color scale of the X-ray absorption of the unripe and ripe mangoes. It is seen that the absorption is higher in unripe bananas and beased on these images and some extracted features we designed a classifier based on Support Vector Machines (SVM) algorithm. The resulting classification accuracy in discrimination of unripe from ripe mangoes was 100%. Research results from this case study are relevant and promising regarding use of commercial planar X-ray imaging devices for sorting according to ripeness and detection of other internal defects.

SINTEF

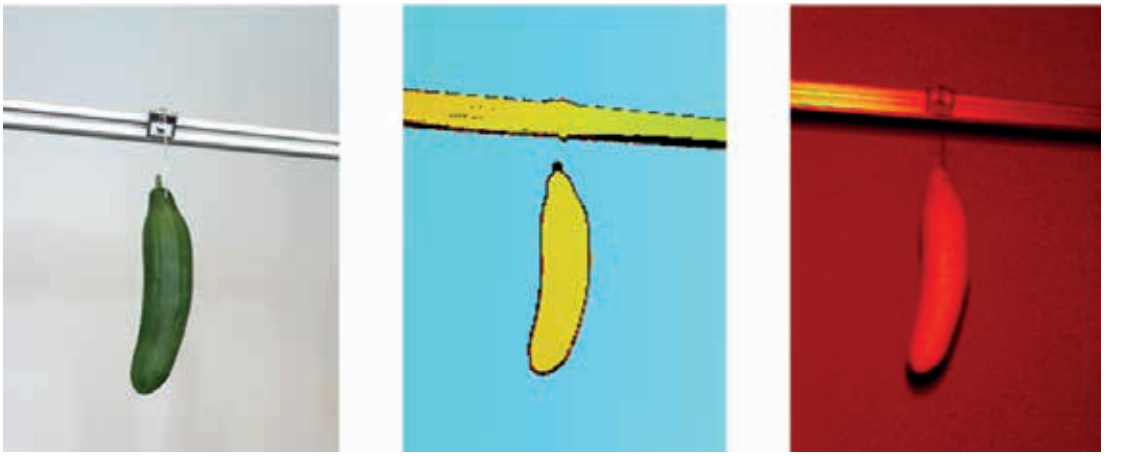
CONTACT:
Ekrem Misimi
ekrem.misimi@sintef.no

EKREM MISIMI

Weight estimation of cucumber based on RGB-D images

A potential for upcycling co-streams in the chicken meat industry was identified in a global situation confirming socio-economic relevance of innovations allowing Norwegian poultry industry to pursue export of upcycling capacities.

Current harvesting of cucumbers in Norwegian green houses is still manual and to enable this the Norwegian producers recruit season workers to harvest cucumbers. This process is laborius, inaccurate, and expensive. High production cost linked to these aspects is making producers less competitive and they operate with very small margins. In addition to being laborius and expensive, manual harvesting is very inaccurate since it is based on the subjective weight estimation. Namely, the season workers hold the cucumbers before harvesting in order to get a feeling of how much it weighs. The magic weight is 350 gr. Cucumbers should be sorted in classes below 350 and over 350. Now imagine how difficult it is to "guess" this without using any measurement tool. Development of an objective weight estimation system would increase the compet-



Real image raw from Kinect 2.0, showing from left RGB, Depth and IR imaging.

> *Robotic harvesting requires an increased focus in the field of 3D vision, machine learning/deep learning for both image recognition and robot learning, as well as novel design of dexterous multifunctional gripper tools. Such systems are aimed to harvesting the fruits and vegetables without downgrading the quality and enabling harvesting of the right product at the right time to the right market.*

Cucumbers in a green house.

itiveness of the producers and would definitely decrease the food loss due to the less cucumbers ending up in a wrong weight class.

The producers are very interested for a robotic based harvesting system that can measure non-destructively the hanging cucumbers, estimate their weight and gently harvest them with a compliant gripper attached to a robotic manipulator mounted onto a mobile platform that can go between the rails in the green house and harvest cucumbers. As a first step, in the CYCLE project we have worked with a method for an image based weight estimation of cucumbers. A Kinect v2 camera was used for acquisition of the RGB-D images of the cucumbers (Figure 2). An image based algorithm was developed for extracting relevant morphological 2D and 3D features from the RGB images and these were used to build a weight estimation model. The research results are very promising as they demonstrate the potential for an image based non-destructive weight estimation of the cucumbers and further development towards a robotic based harvesting will be pursued in some new project initiatives with the respective industry partners.

SINTEF

CONTACT:
Ekrem Misimi
ekrem.misimi@sintef.no

Sensory evaluation of smoothie products.

RANDI SELJÅSEN

Edible co-streams from vegetable industry as carriers for probiotic bacteria

Lactic acid bacteria fermentation can be used to create new, sustainable products while rerouting side streams back into edible food with additional health benefits.

Consumer demand for natural, healthy foods has resulted in renewed interest and growing market for probiotic foods. In addition, prevalent veganism and milk-related allergies raise the need for non-dairy probiotic products.

Food industry produces large amounts of edible raw material residuals which could be rerouted back into food applications.

Aim of the study was to examine the suitability of different types of fruit and vegetable side streams as carrier materials for lactic acid bacteria and formulate vegetable based probiotic ingredients and food applications.

Fruit and vegetable side streams from food industry were used as production media for probiotic lactic acid bacteria (Lactobacillus rhamnosus and Bifidobacterium animalis subsp. lactis) via fermentation and their technological properties were evaluated. The stability of fermented products was studied during cold storage. Sensory properties and storage stability of probiotic smoothies was evaluated.

Dairy bases used for fermentation with probiotic bacteria may restrict the potential customer range as they are unsuitable for people with restrictions such as lactose intolerance or special dietary preferences like vegans. Various vegetable and fruit bases have been shown to work as carriers for probiotic bacteria

despite their challenges. Combining the edible food streams created by the food industries with fermentation by lactic acid bacteria could be used to create new, sustainable products while rerouting side streams back into edible food with additional health benefits.

Multiple vegetable co-streams were shown to support fermentation with both L. rhamnosus E800 and B. animalis E2010. L. rhamnosus E800 retained viability in all co-streams well and no significant differences in cell viability were detected after 16 d storage. Highest viability after storage was in Swedish turnip followed by cabbage.

> *Vegetable co-stream can feasibly be valorised into probiotic food applications.*

Probiotic smoothie products formulated with cabbage or carrot fermented with L. rhamnosus E800 (16 h at 37 °C) were shown to have acceptable sensory properties and good storage stability.

Vegetable co-stream can feasibly be valorised into probiotic food applications. By fermentation large part of the edible raw material residuals could be rerouted back into food applications.

Consumers are looking for healthy alternatives e.g .for snacks. Probiotic smoothies provide an added-value and healthy choice for the consumer. Several fruit and vegetable side streams are promising carrier materials probiotic lactic acid bacteria.

VTT

NIBIO
NORWEGIAN INSTITUTE OF BIOECONOMY RESEARCH

CONTACT:
Randi Seljåsen
randi.seljaasen@nibio.no

RANDI SELJÅSEN

Smoothies and purees from vegetable co-streams

Low value fractions of vegetables were tested as ingredient for smoothies and purees at Nibio. Physical quality properties and taste were evaluated. Suitability for fermentation was measured by testing sugar content and acidity.

The low value fraction of Norwegian processing industry consist mainly of vegetables with cracks, wrong size, malformed shape or other minor visual defects like small spots. Today these fractions are mainly used as feed, but they are nutritious and major parts are suitable as human food.

One relevant way of utilizing these fractions is in smoothies and purees. Those can be used as raw material in drinks and in ready to use meals or as tasty, healthy ingredient in minced products of fish and meat.

Making purees of the raw materials is an easy way of processing the co streams to existing products as well as raw materials to be used in new products, e.g. in mixed products with meat or fish. For use as ingredient in tasty smoothies, the vegetable extracts can be combined with other ingredients like fruit. The requirement for raw materials to be suitable for fermentation is a sugar content above 5 % and acidity above of pH 5.

The value of upcycling vegetable co-streams can be significant as the sector in Norway employs five thousand people full time and adds 2.8 billion NKK to the Norwegian Economy. There is a potential for increasing health and improving food security by making new ready to use products where vegetables are included in different kind of products.

Our test panel disliked a 100% carrot smoothie due to cloying taste, but liked carrots in combination with acidic ingredients like apple juice or fruit. Juice of Swedish turnip improved fresh and strong taste. Carrots in combination with mango were the most popular smoothie, followed by iceberg lettuce in combination with melon. By combining fruits and vegetables it was possible to make combination of raw materials suitable for fermentation as vegetables balances the high acidity of fruits.

Purée of carrots, Swedish turnip and head cabbage leaves were suitable for fermentation. The cabbage leave variant had mild taste and texture and colour similar to traditional pea puree.

If applied to industrial scale, utilisation of vegetable rest fractions to purees and smoothies may contribute to a significant reduction in food loss at the processing stage. It also has a potential to increase the consumption of vegetables and thereby contribute to health aspects for the population.

A wide variety of vegetable and fruit combinations can be investigated to develop smoothies. Making pureè from carrots, Sweedish turnip and head cabbage leaves is relevant in the market as pureè products or new mixed products with fish or meat, like ‘fish cakes with invisible vegetables’, which already are emerging at the Norwegian market by Findus.

Shape and size doesn't matter anymore in the vegetable world – whether you are slim or fat, bent or cracked – you could become a perfect tasty super-food.

Raw materials for utilization of smoothies and purees. Research Scientist Randi Seljåsen, Nibio. Photo Erling Fløystad, Nibio

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

CONTACT:
Randi Seljåsen
randi.seljaasen@nibio.no

Marine
related research

ANA KARINA CARVAJAL

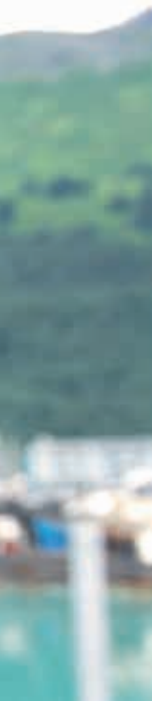
Effect of freezing and thawing of cod heads on the composition and quality of protein hydrolysates

Freezing of cod heads in order to increase the shelf life of the raw material prior to further processing does not have a negative effect on the final product and is a potential strategy for increase resource utilization.

The Norwegian fisheries produces around 300 000 tons of whitefish co-products (heads, backbones and guts) each year. In 2015, approximately 166 000 tons of the co-products were discarded and not utilized, resulting in a significant loss in potential value creation.

The sea-going fleet accounts for 83 % of the unutilized raw material, and in order to improve their resource utilization and increase the value creation and new commercial opportunities, several issues need to be addressed. One of the issue is to improve on-board handling and preservation in order to increase the quality and shelf life of the raw material.

Enzymatic hydrolysis was used as technological solutions for production of protein hydrolysates from Atlantic cod heads. The heads were processed fresh or after freezing and thawing. The parameters that were



Freezing of cod heads on-board the fleet can be a strategy for increased resource utilization

investigated included storage conditions; frozen storage of minced heads versus whole heads for 3 weeks, thawing methods: air thawing (4 °C for 20 hours) versus water immersion (6 – 10 °C for 3 hours), in addition the effect of hydrolysis time (30 minutes versus 60 minutes) when using the commercial available protease ProtamexTM.

Biochemical characteristic and changes in the raw material and final products (protein hydrolysates) were determined.

There is a great potential for increased utilization and profitability from cod heads. However, there is a need for improved methods for on-board handling and preservation of the raw material. The aim of the work was to study if freezing can be used as a strategy for increased shelf life of the raw material without lowering the quality of the ingredients products from cod heads.

Freezing and thawing of the cod heads lead to small changes in the composition of the raw material and the resulting fish protein hydrolysates. Slightly higher protein content was found in the hydrolysates produced from fresh heads compared to heads after mincing, freezing and thawing.

The degree of hydrolysis (a reflection of the number of broken peptide bonds in the product) ranged from 14 to 21 %, and was higher in the protein hydrolysates produced from thawed heads compared to fresh heads.

Sensory evaluation of the protein hydrolysates showed no difference between the different hydrolysates, meaning that freezing/thawing and mincing did not have a negative effect on the hydrolysates.

Mincing and freezing of the cod heads in order to reduce storage volume and increase the shelf life of the raw material can be used as a strategy for increasing the possibility for utilization of the raw material. No significant difference in composition and quality were shown in the protein hydrolysates produced from fresh and frozen raw material. However, the thawing of the head should be carried out under controlled conditions in order to minimize quality degradation.

Freezing and thawing of cod heads prior to enzymatic hydrolysis need to be tested under pilot conditions on-board the fleet and at the processing site in order to identify challenges related to industrial implementation. The process conditions need to be optimized and further tested so the method can be successfully implemented.

SINTEF

CONTACT:
Ana Karina Carvajal
ana.k.carvajal@sintef.no

JENS PETTER WOLD

Chemical imaging of heterogeneous muscle foods using near-infrared hyperspectral imaging in Transmission Mode

It is possible to use transmission imaging for rapid, nondestructive, and representative spectroscopic sampling of very heterogeneous foods such as fish and meat.

Foods and biomaterials are, in general, heterogeneous and it is often a challenge to obtain spectral data which is representative for the chemical composition and distribution. Near-infrared (NIR) hyperspectral imaging is becoming increasingly established as a feasible method for detailed non-destructive chemical studies of complex foods. A limitation with these systems is that they measure mainly the surface and do not probe deep enough to capture the total sample heterogeneity.

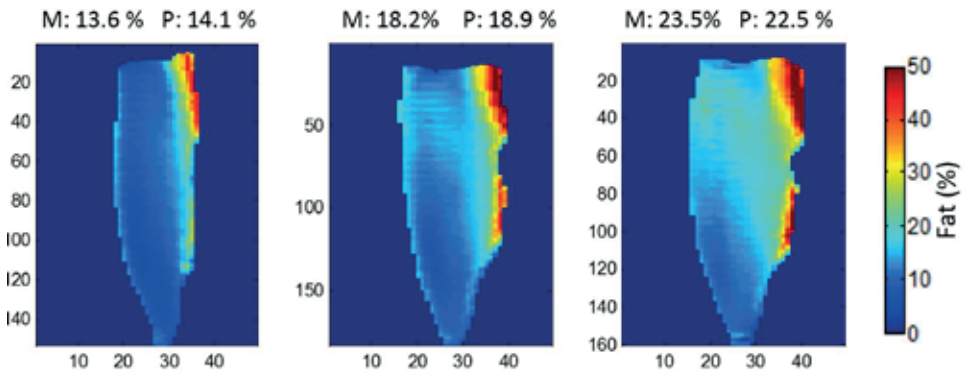
This study presents a setup for near-infrared (NIR) transmission imaging where the samples are completely trans-illuminated, probing the entire sample.

We constructed and tested a setup for NIR transmission imaging for large food samples such as fish fillets and whole pork rib flanks. The setup was based on falling samples, meaning rapid movement of samples and relevant for industrial use.

Model samples composed of ground pork meat were used to illustrate quantitative imaging of fat distribution also when the fat was embedded inside the samples. We also tested if the system could be used to determine average fat and fat distribution in salmon fillets with skin and whole pork bellies up to 5 cm thick.

In the food industry it is often required to quantify the chemical composition and distribution in every product on the line. The ability to quantify and map fat in fish fillets is, for instance, useful for subsequent classification and sorting. The same is the case for quality grading of certain meat cuts. Correct classification ensures optimal utilization of the raw material and a reduced amount of more low-value byproducts.

Regression models for fat were developed for ground pork and salmon fillets with high correlations (R=0.98 and R=0.95, respectively). The regression models were



Images of predicted fat distribution in salmon fillets with skin. M: Actual fat content, P: NIR estimated fat.

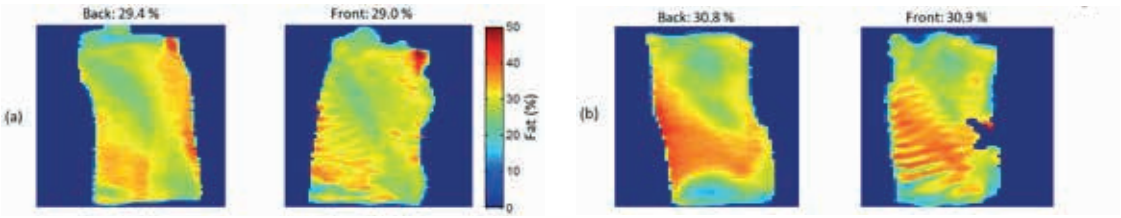
A pork rib flank is a good example of heterogeneous foods

applied at pixel level in the hyperspectral transmission images and resulted in images of fat distribution where also deeply embedded fat clearly contributed to the result.

Quantitative imaging of internal chemical composition is feasible, even when samples vary in thickness or are covered with skin or rind, as with the salmon fillets and pork bellies, respectively.

The results suggest that it is possible to use transmission imaging for rapid, nondestructive, and representative sampling of very heterogeneous foods. The proposed concept is suitable for industrial use. Transmission measurements for larger samples can be implemented on conveyor belts separated with narrow slits.

Development of commercial on-line quality assessment systems progresses fast and is pushed by needs and requirements in the food industry. We have now shown that industrial transmission imaging is feasible, and then the way to implementation can be short.



Images of fat distribution in two pork bellies (a, b) measured with the front and back sides facing the NIR scanner.

CONTACT:
Jens Petter Wold
jens.petter.wold@nofima.no

ANITA ROMSDAL

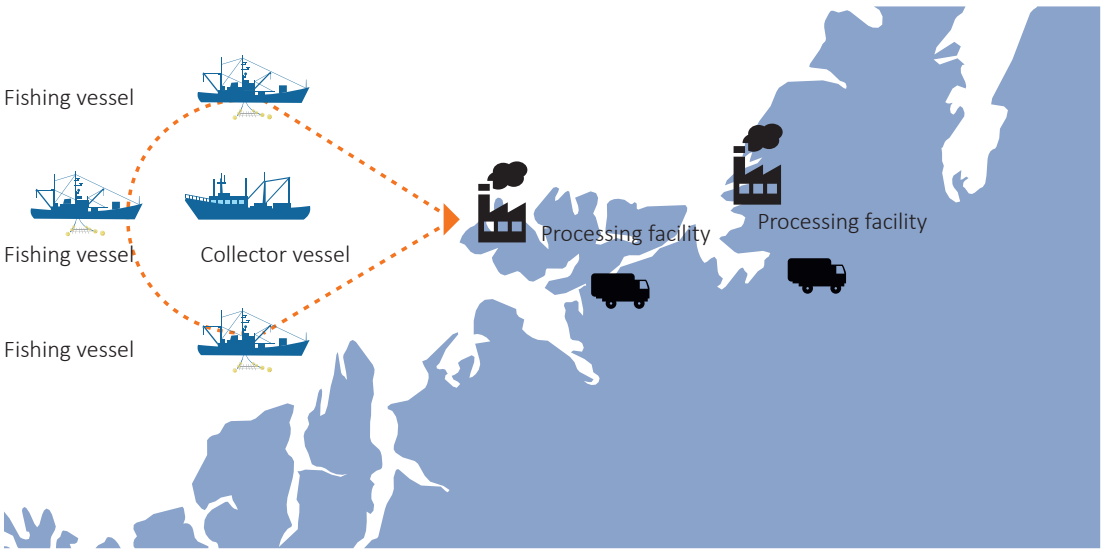
Colector vessel – a concept for increased exploitation of raw materials from fishing vessels

A vessel dedicated to the collection of rest raw materials from fishing vessels can enable onshore processing and value extraction from raw materials currently thrown away at sea.

In a world where 1/3 of food produced for human consumption is wasted, resource utilisation must be maximised. Seagoing fishing vessels mostly process their catch on-board, storing the most valuable parts of the fish to be sold on land. Rest raw materials such as heads, viscera and bones constitute 50-70 % of the volume of captured wild fish and are usually thrown away at sea. In this study, we investigated how the concept of a 'collector vessel' could increase the exploitation of rest raw materials from trawlers.

Increased exploitation of rest raw materials has been a focus in the industry for years, but the fishing fleet still lacks technical and logistics solutions, as well as economic incentives to bring rest raw materials ashore for higher-value upgrading. We therefore investigated how a collector vessel could collect available rest raw materials from trawlers and transport them onshore for further processing. We focused on the Norwegian seagoing whitefish fishing fleet, mapping the types of rest raw materials generated at sea and their potential uses. We then analysed the logistics issues and technical solutions needed to realise the concept.

The Norwegian whitefish processing industry is struggling with low profitability, with businesses closing and employment decreasing. Limited space and preservation possibilities onboard trawlers limit the amount of



The concept. A vessel collects rest raw material from trawlers and transports it onshore for processing into value-added products

Potential value of cod. If rest raw materials are fully utilised, the value of a cod can be quadrupled (adapted from Sigfusson, 2014)

materials that can be stored and transported onshore. Studying the feasibility of extracting value from rest raw materials is therefore important since it could create new business opportunities in both collection and processing, as well as increase the sustainability of the fishing sector.

> *If rest raw materials are fully utilised, the value of a cod can be quadrupled*

We found that full utilisation of marine rest raw materials could quadruple the value of the catch. Potential applications range from fertilisers and fish feed to high value pharmaceuticals and cosmetics ingredients.

The collector vessel concept requires establishment of a parallel supply chain. Associated value propositions, business models and profit formulas must be developed for fishing vessels, collector vessels, onshore processors, and end customers.

Cost efficient logistics solutions must be developed to capture and collect the rest raw materials from fishing vessels, and to store and transport the materials onshore. Traceability and appropriate environmental conditions are required to ensure high product quality.

The collector vessel is still at the concept stage. The goal of our study was to investigate the potential value of raw materials currently thrown away at sea. Realisation of the concept would involve great financial risks, as both supply and demand is highly uncertain.

A large number of challenges must be addressed before the concept can be realised. Examples include establishment of entire new supply chains, identification of new markets and customers, development of new products, and finding practical logistics solutions both on vessels and onshore.

NTNU
Norwegian University of Science and Technology

CONTACT:
Anita Romsdal
anita.romsdal@ntnu.no

EKREM MISIMI

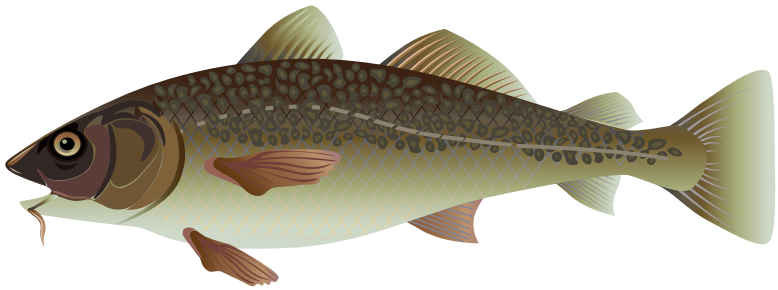
Automated Classification of roe, milt and liver from Atlantic cod based on spectral characterization with hyperspectral imaging

In Norway, the whitefish industry operates with small profit margins. Annually, 0.34 million metric tons (44% of the total catch) of rest raw material (by-products) are generated. Rest raw material is the raw material that is generated after the fish are gutted and processed, and for the whitefish industry, the most frequent rest raw materials are heads, tongues, roe, liver, and milt. Only 30% (113 800 tons) of these rest raw materials are utilized, while the remaining 226 000 tons are not utilized at all. Therefore, the potential for an increased utilization of rest raw material is large and it would lead to a more sustainable and profitable whitefish industry.

The primary reason for the absence of the higher utilization of rest raw material from white fish is the lack of technological solutions that can enable automated classification and sorting on-board the vessels. Typically, the abovementioned rest raw materials from white fish are piled randomly in fractions after gutting and there is a need to physically separate them before they can be utilized or stored. Automated classification and sorting could make possible for a general increase in utilization of these rest raw materials and contribute in a higher bio-resource efficiency of the whitefish catch and reduction of waste.

Automated classification of roe, milt, and liver, due to the similarities in the appearance manifested in colour and texture, is a very challenging research task. To enable automated classification we performed a complete characterization of roe, liver and milt [1] in VIS/NIR (420 – 990 nm) and SWIR (960 – 2500 nm) range. Each sample was placed on a separate petri dish and labeled with a corresponding group letter and sample number. The samples were used to extract spectral characteristics, establish and verify the classification models. Hyperspectral images were acquired using two push-broom line scanning hyperspectral cameras HySpex VNIR-1600 and HySpex SWIR-320m-e (Norsk Elektro Optikk AS, Skedsmokorset, Norway). The working spectral range for the VNIR-1600 system was 400-1000nm with a spectral resolution of 3.7 nm, thus producing the total of 160 spectral bands, while the SWIR-320m-e system acquired hyperspectral images in the wavelength range of 960-2500 nm, producing the total of 256 spectral bands. The aim with spectral characterization was to select the optimal wavelengths that maximize the class separability between roe, milt, and liver, because it is known that reflectance spectra can reveal information about the differences in colour of raw material with high colour similarities.

The average reflectance profiles of the roe, liver and milt in the whole spectral range of 400-2500 nm were calculated from the extracted spectra. In Fig. 1 are shown the reflectance spectra for the VIS/NIR range, while in Fig. 2 are shown the reflectance spectra for the SWIR range. While characterization in SWIR range is interesting, for practical applications we considered only the optimal wavelength selection on the VIS/NIR range. The reason is that for this range there are



much more affordable cameras and light/illumination sources, as our intention was to develop an approach that has a high practical feasibility for industrial applications. Spectral similarity measure (Spectral Angle Mapper – SAM) algorithm was used to calculate intra- and inter-similarity of the roe, liver and milt in 400-1000 nm range. We employed Leave-One-Out cross validation for optimal spectral band selection for Model I and Model II. Five wavelengths were selected as optimal for Model I (classification with single band) and twenty band combinations for Model II (classification as a combination of two optimal bands). For more details the reader can refer to work in [1].

> *To enable robotic sorting onboard the vessels, there is a need for robotic 3D active vision to localize the raw material prior to handling and manipulation as well as robot learning in order to give the robots the autonomy in performing the sorting operations. The developed classification algorithm in CYCLE can be downscaled into a practical machine vision system that can operate onboard.*

Classification performed with wavelength 444 nm (Model I) reached 74%, 71% and 65% for material roe, liver and milt, respectively. Classification corresponding to Model II were superior to Model I. for example, the accuracy with Model II reached 96%, 97%, and 100% for combination of 415 and 990 nm wavelengths. In Fig. 3 is shown the classification map for roe, liver and milt achieved with Model II. Miss-classified pixels have their origin in high spectral similarity between raw materials, and the overall performance of image classification can be improved by optimizing the classification algorithm, e.g. by taking spatial content into account.

For practical industrial applications, the combination of two different wavelengths from Model II can be solved by triggering two lasers (with respective wavelengths from Model II) alternately every second frame of the camera in order to generate almost simultaneously two images that can be used for analysis and image classification. For example, for the abovementioned 415 and 992 nm wavelengths one can use commercially available lasers at 405 and 980 nm respectively.

Generated classifications models show high accuracy for classification between roe, liver and milt and it shows that discrimination of cod liver, roe and milt is possible using combination of two optimal bands and that hyperspectral system, which is costly for industrial use, can be easily downscaled to a practical image acquisition system with a camera having a solid spectral response and by triggering two lasers (at two optimal wavelengths) alternately every other camera frame. This is the first step towards automated sorting of roe, liver and milt on-board fishing vessels and a potential toolkit for a viable and bio economically efficient whitefish fisheries in Norway but also worldwide.

SINTEF

CONTACT:
Ekrem Misimi
ekrem.misimi@sintef.no

ANNE-KRISTIN LØES

Effect of hydrothermal carbonization (HTC) on P availability of hydrochars from solid digestate and seaweed

HTC reduced P solubility in hydrochars. More solids dissolved from fresh material. Most phosphorus (P) is maintained in the hydrochars. Arsenic and strontium are present in high concentrations in seaweed.

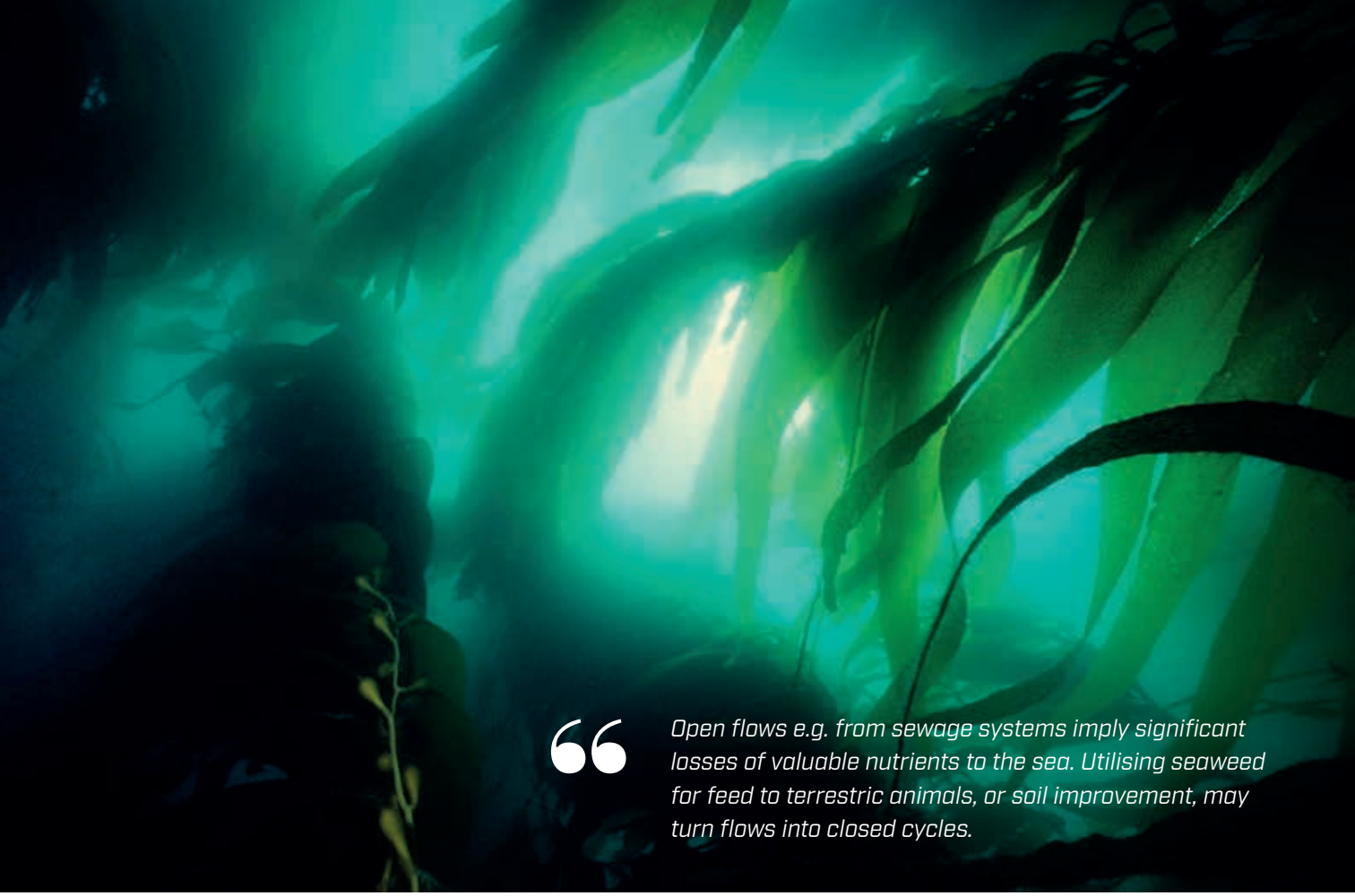
By hydrothermal carbonization (HTC), moist organic materials are treated by medium high temperatures (150-300°C) under high pressure. The process, invented in Germany in 1913, mimics the formation of charcoal. Solids, liquids and gases may be the demanded output. Solids are called hydrochars to distinguish them from biochars produced by higher temperatures. Hydrochars may be applied to soil for carbon storage. In seaweed and solid digestate, we studied the effect of HTC on morphology, elemental composition and P solubility. We expected the major part of P to be recovered in the hydrochars, and increased temperature to reduce the P solubility.

HTC was done with seaweed and solid digestate at 150 and 200°C. We conducted scanning electron microscopy, elemental analysis and sequential extraction of P on raw material and hydrochars. By sequential extraction, the sample is subject to gradually stronger extractants. We assessed the recovery of elements in hydrochars, and the concentrations were compared with limits of potentially toxic elements (PTEs) for soil amendments such as composts.

Studied substrates were digestate from Ecopro AS, and wild seaweed. Anaerobic digestion is used for food residues, including slaughter waste. Hence, digestate is a part of the CYCLE food streams. Both substrates are part of the nutrient flow, where especially phosphorus, a finite resource, is important to recover. Knowledge was required on P-availability of hydrochars from seaweed and mixed municipal waste, and the effect on P-solubility of moderately high temperatures.

Parr reactor (250 ml) for hydrothermal carbonization. Photo by Judit Sandquist, SINTEF Energy Research.

Increasing with temperature, 20% of initial dry matter dissolved for digestate, and 55% for seaweed. Except from arsenic and strontium in seaweed, concentra-



Open flows e.g. from sewage systems imply significant losses of valuable nutrients to the sea. Utilising seaweed for feed to terrestric animals, or soil improvement, may turn flows into closed cycles.

tions of potentially toxic elements were acceptable. About 85% of P was recovered in digestate chars. For seaweed, 97% was recovered at 150°C and 84% at 200°C. P-solubility decreased by HTC, and more with higher temperature.

Low temperature HTC may be used to extract P from seaweed and concentrate it in a solid material. Reduced plant P-availability in hydrochars is negative for fertilization, but may be beneficial for soil storage of C, to reduce risks of eutrophication of water bodies.

New methods for utilizing organic materials, e.g. for fuel, create new organic co-streams which also should be utilized efficiently. Application to soil for C sequestration is relevant, but care must be taken to avoid potentially toxic elements.

NORSØK

SINTEF

CONTACT:
Anne-Kristin Løes
anne.kristin.loes@norsok.no

Summary

The CYCLE project aims to achieve total utilization of raw material from fish, chicken and vegetables. This will be carried out by means of the development of new bioprocesses and technological solutions, combined with assessments of socio-economic challenges focusing on sustainability.

The project includes industrial participation involving partners from the agricultural and marine food sectors alongside feed industry, energy and logistics companies, as well as equipment manufacturers. These food resources account for some of the largest volumes of loss and waste produced by the Norwegian food processing industry, retailers and consumers. The holistic and sustainable approach adopted by the CYCLE project has provided the platform necessary to apply current technological developments and innovation in the food sector in the prevention of loss and the generation of added value, as well as increases in raw materials circulation and the utilization of rest raw materials.

Expertise and knowledge obtained from different value chains has been used to address new bio-economic challenges in which rest raw material resources from one chain represent the raw materials in another.

Chicken value chain

The world's first robotics system for the removal of chicken breasts is demonstrated. On-line methods for characterising the quality of chicken fillet are studied, and biological processes are developed for the conversion of raw meat materials using enzymes to prepare protein powders and oils. Protein concentrate from chicken products displays anti-oxidative properties and is evaluated in terms of its suitability as an ingredient in various foodstuffs.

Various on-line measuring techniques such as NIR and FTIR are investigated for process optimisation in situations where such techniques utilize measurement, regulation and control procedures to facilitate the production of stable and tailored end-products. Poultry feathers are currently poorly utilized. The CYCLE project uses hydrolysis, in combination with pressure cooking and Na_2SO_3 treatment, to produce a high-quality feather meal for salmon feed. A study using ground eggshells as a soil additive demonstrates that eggshell calcium exhibits greater biological availability than rock-derived calcium.

Vegetable value chain

As part of the sorting process, new methods have been developed for the automated detection of ripeness in mangos and avocados. A method to estimate cucumber weight using machine vision prior to harvesting is also under development. Rest raw materials derived from potato and carrot production have been used to develop a biodegradable film, as well as growth medium for probiotic bacteria that in turn can be used as an ingredient in various foodstuffs. Rest raw material from potatoes have also been used in the development of ensiled products in compact round bales for use as feed. The addition of vegetables and probiotic bacteria to potatoes may increase the value of the ensilaged feed product.

> *Total utilization of and reduction in rest raw materials has been key focus in this research project.*

The HTC (hydrothermal carbonization) technique is investigated to see if certain rest raw materials can be considered for the production of fertilizers. Deposits of potato soil, which is a rest raw material derived from the packaging process, have been investigated from an innovation and socio-economic perspective.

Fish value chain

The automated classification of cod roe, milt and liver is developed using spectral characterisation aided by hyperspectral imaging in VIS/NIR and SWIR. Cost-efficient logistics systems used to capture and collect rest raw materials from fishing vessels have been studied, in combination with an evaluation of the vessel's collection system. There exists a great potential for increasing the utilization of, and profitability from, cod heads. There is a need to improve methods for the on-board handling and preservation of the raw materials.

The effect of freezing and thawing of cod heads on the composition and quality of protein hydrolysates was studied, and it was found that the use of frozen raw materials does not affect the quality of the protein product. A general understanding of loss in the food supply chain has been established, and the stages in the meat, fish and fruit and vegetable supply chains where losses occur have been identified, together with the causes of loss.

A study has been carried out into how grocery retailers "steal" product shelf-life from customers, and how they contribute to food loss and waste. The study confirms the mismatch that exists between supply and demand in the retail and wholesale stages of the supply chain. A recent study has also been launched to investigate the potential for a multidisciplinary approach that combines social science with design theory with the aim of addressing challenges linked to the reduction of food waste in Norwegian households.

A Ph.D. thesis will be submitted at the end of 2018 in which the reduction in household food waste is the main topic.

PhD & Postdoc

PhD student Marie Hebrok

In the EU households stand for about 53% of the food wasted within the value chain. This calls for increased attention towards finding new ways of intervening into food waste practices within households. Scholars from a wide range of disciplines, applying quantitative and qualitative methods, have addressed food waste as a topic of research. Recent research has extensively mapped amounts, composition and demographic variables, as well as social and cultural antecedents of food waste- although the latter may still be somewhat underexplored.

This need for qualitative research on food waste drivers, and interventions, constitutes the point from which my PhD project departs. Working title: Reducing household food waste through design intervention. It is divided into two phases of research. 1) insight, 2) design intervention. In the first phase the main objective has been to gain an in depth understanding of the drivers of household food waste. The first step in this phase was to conduct an extensive literature review, in order to identify different promising intervention points for design, based on studies on how and why food waste is generated on such a scale in households. This literature review was published in the Journal of Cleaner Production. The next step was to visit households in order to gain deeper insights into the mechanisms that lead to food waste. This fieldwork included home visits and interviews, shop-alongs, and refrigerator studies in 26 Norwegian households.Households were recruited from the age group that waste the most food, people between 25-45 years.

This first phase of research has showed me that food waste on the consumer level is generated through socially and culturally shared ways of doing—through practices of everyday life. This perspective implies a broader focus on consumption than individual market choices. Hence, it is important to provide a different understanding of the causes of food waste than given by surveys and sales statistics. An important insight in this regard, is that in order to be implemented in everyday practices, solutions and interventions must be contextualised. Meaning, that they need to be active in the actual context of food related practices, because it is imperative that interventions become part of how people carry out everyday life. There are two promising areas for contextualized interventions: material structures and socio-cultural structures. Material structures include packaging, stores, and refrigerators. Socio-cultural structures include popular dissemination, reorganising meals and education. Concrete suggestions for interventions within these structures will be published later in the project. This is a work in progress. The next phase of my project will be focused on a practice oriented approach to suggest solutions and design based interventions for food waste reduction in households. The thesis will be submitted by the end of 2018.

Postdoc Eirin Bar

The duration of the Post Doc position was less than one-year full time spread over the period from 2015-2016. However, Dr. Eirin Bar has been involved in the CYCLE project as both a research scientist and contributing to the administration and facilitation of the project throughout the project from its start in April 2013, and have been working with research related to the topic of the PostDoc throughout the project period. In addition, she has been the administrative leader of an international conference on bio-economy initiated by the CYCLE project, the NoRest Conference, held in Copenhagen October 2016 as a joint venture between the three largest research projects funded by the bionær program directed by the Norwegian Research Council. Her research work has resulted in the following publications and conference contributions.

Postdoc Steffen Adler

The Post Doc position in CYCLE gave me an opportunity to study up-cycling of co-streams to animal feed components. After mapping co-streams from the Norwegian food industry, including vegetables, fish and poultry, we chose to have a main focus on chicken feathers. This protein-rich co-stream is currently not efficiently utilised due to low digestibility. We built our work on expertise in chemical hydrolysis (SINTEF Ocean), enzymatic hydrolysis (SINTEF Ocean, VTT), monogastric animal nutrition (Felleskjøpet Fôrutvikling), and animal feeds and feeding in general (NIBIO), in tight cooperation with the CYCLE industry partner Norilia. My personal learning in the Post Doc position included experience with hydrolysis experiments, action of enzymes, in vitro digestibility assessments, evaluation of amino acid profiles and animal requirements, and mathematical modelling. The learning process was supervised by the leader of WP3, Anne-Kristin Løes (NORSØK) and supported by partners in the CYCLE project. The work has resulted in a manuscript for a scientific publication. Feather hydrolysates have a potential as feed for fish if combined with complementary feed compounds rich in lysine and histidine. However, until now the fish farming industry has been reluctant due to possible challenges in consumer perception. Proteolytic enzymes did not increase feather digestibility in the experiments; further research is necessary and should focus on applying a combination of different enzymes. Furthermore, the mapping of other co-streams resulted in a pilot study on ensiling out-sorted potatoes and carrots as probiotic feed for animal productions where improved gut health is an important goal (Adler et al., 2017).

CYCLE Dissemination

Scientific publications

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11. Romsdal, A. (2014) *Reducing food waste through differentiated production planning and control.* 1st SLOW symposium on sustainable logistics, Trondheim, 4-5 June
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Project manager:
Marit Aursand
SINTEF Ocean
marit.aursand@sintef.no

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