UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

FOOD INSTITUTE

LINKING THE FOOD CHAIN

A look at our researchers and their work.

Spring 2020

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

College of Science, Engineering and Food Science
Coláiste na hEolaíochta, na hInnealtóireachta agus na hEolaíochta Bia

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Contents

University College Cork has been delivering excellence in food and dairy research since 1928. Against the unique background of the COVID-19 pandemic, our researchers have created this short research compilation, highlighting the breadth of activity that our postgraduate students, postdoctoral researchers and principal investigators have been working on. We hope you enjoy learning about our research and its impacts across the Food Chain, from infant nutrition to dairy processing to developing new food products and improving how nutrition can aid us in illness recovery.

For further information on our research and degree opportunities in UCC, please view the UCC website (www.ucc.ie).

Stay safe and enjoy reading!

Prof Sarah Culloty,
Head of College of Science, Engineering & Food Science (SEFS)

Ina Bremenkamp

"Novel Eco-friendly Food Plastic Packaging"

Plastic packaging properties offers many possibilities to the food sector. The transparency of plastic allows the consumer to see the purchased product, while its light weight reduces transportation costs. Furthermore, variable packaging permeability provides an optimal atmosphere for different food products, prolonging shelf life while maintaining food quality. The implementation of plastic packaging was a major advance in the food industry.

But, as we all know, the consequences of using fossil based raw materials and the long degradation process of plastic materials are two factors which can have a detrimental effect on the environment. One way to tackle such challenges is the use of bio-based materials for the production of plastic packaging. Ideally, such bio-based materials would be derived from substances which are categorized as “by-products waste” and are not essential for other purposes, or alternatively, production side products whose value can be improved by transforming them into plastics. Other possible bio-based materials are fast growing raw materials which are not in direct competition with food production, such as algae.

What is the role of packaging?

The most important question which should be considered during package design is: Is there a reasonable function for using the chosen packaging? A package can be a box, a film, a wrapping or even an invisible edible layer applied to the product surface, ie. a coating. The primary function of packaging is to ensure food quality and safety. Apart from this main function, a package is also a communication platform, a means of marketing, and can also provide the consumer with a convenient way to transport or prepare the product. Moreover, the packaging can be designed for a specific target group. In addition to these

Figure 1.
Interreg Europe helps regional and local governments across Europe to develop and deliver better policies by creating an environment and opportunities for sharing solutions.

functions, it is crucial during packaging design to follow a circular approach. What is meant by this is that the main function of the packaging (the protection and promotion of the product) is not the sole consideration in packaging design, but also the steps before packaging production, such as the sourcing of raw materials, their harvesting, and the recycling process of the packaging. A circular design describes an approach based upon reusing materials as well as combining different material circles in order to minimise the amount of waste produced.

Marine innovation

In light of this, the EU Interreg Atlantic Area Seafood Age project tackles a common social and economic challenge in the Atlantic Area: an ageing population. The project will exploit the maritime dimension of the Atlantic Area regions and will adopt circular economy concepts to generate ready-to-eat seafood for healthy ageing, produce novel eco-packaging and develop a smart label for better quality, safety and minimum food waste.

The Seafood Age project is co-financed by the Interreg-AA program through the European Regional Development Fund. The challenge of developing novel eco-packaging is one aim of the UCC team within the EU Seafood Age project, by exploring marine biobased raw materials for the production of plastic packaging. As mentioned previously, packaging design is influenced by numerous factors, including the primary function of packaging in maintaining food quality, safety and shelf life, as well as facilitating handling for elderly consumers. This is a highly pertinent area, as it is only with innovative developments in food packaging that the diverse supply of food from around the world and the purchasing of highly perishable products is made possible.

Ina is a PhD student in the Department of Process & Chemical Engineering, School of Engineering and funded by EU Interreg-AA under the remits of the Seafood-Age project. She is supervised by Dr Maria de Sousa-Gallagher and co-supervised by Dr Jorge Oliveira.

Ina Bremenkamp & Dr Kashub Tumwesigye

"Smarter Dairy Products - Entrenching a Quality by Design (QbD) Tool in Dairy Industry"

The production of high quality and competitive milk-based products is a moment celebrated by any Dairy industry. Nonetheless, these celebrations have been compromised by low yields and poor-quality products. In most factories, the current way to determine the yields and quality is by testing the end product. The product can only be purchased as a high-quality product when its quality fulfils the internal quality-requirements, for example food quality (colour, size, texture) or food safety (microbial contamination) criteria. Therefore, it is important to prevent the industry shortcomings by analysing the whole production process and provide real time solutions.

Quality by Design for Dairy

The challenge of dairy industries is the length of the current process to determine the causes of low yield and poor quality of end products. In order to address such problems, the quality of the end product is predicted based on parameters measured at an early stage during production by use of research-based approach, known as Quality by Design (QbD).

The aim of the project “Quality by Design in the dairy industry” is to demonstrate the potential of a Quality by Design (QbD) concept for the Dairy sector. In the course of the project a cooperation with two dairy industry partners was conducted involving a case study on milk powder production process and a fermentation process.

One advantage of implementing a QbD concept is to reduce food waste during the food production process by avoiding produced products with low quality. In most factories the current way to determine the quality of the end product is by testing the finalized product. By implementing a QbD concept the quality of the end product is predicted based on parameters measured at an early stage during production. Due to the knowledge gained during production carried out in preceding years, linkages can be made, and the quality of the end product can be foreseen and or adjusted, so that the required quality is achieved.

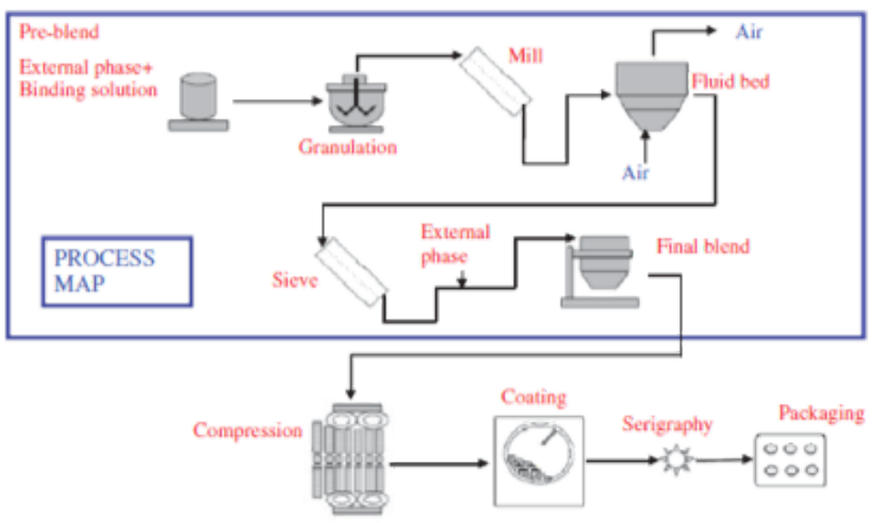


Figure 1.
A typical dairy process map

Importance of data

Quality by Design is a production improvement and product development strategy, commonly applied in the pharmaceutical industry. In light of that, it can be used to develop new products or to improve the production of current produced products. The digital development in the food industry in last years are the basement for the project Quality by Design. During food production many quality parameters are measured, e.g. raw material composition, process parameters, material attributes etc. Mostly, the collected information is used to get real time information about the process performance and are stored afterwards to provide a reliable traceability. The stored production data is called retrospective data. Only in few cases the additional value of the stored data is used to gain fundamental information about production process and to improve further productions. The retrospective data can give relations between process parameters, raw material and the produced product which don't show an obvious linkage. This is due to fact that food production, in general, is a highly complex system influenced by many factors.

The complexity of food production can be seen by having a look into the food production process. When producing food product mostly 2 up to 20 operations units are involved. At each production unit 2 to 20 process parameters or product quality parameters can be measured and additionally the used raw materials can have natural variations. All these factors should be considered to identify "critical process parameters" which can be seen as key factors to predict the performance of the end product.

Dairy Processing Technology Centre (DPTC)

QbD is a project of the Dairy Processing Technology Centre (DPTC). DPTC is an industry-academic collaborative research centre with a research agenda driven by the long-term growth opportunities for the dairy sector. The centre is funded by Enterprise Ireland and the Dairy Industry Partner. The aim of the Centre is to fuel growth in the Irish dairy sector by performing research focused on cost-efficient processing, facilitating a step-change in environmental sustainability and creating, validating and commercializing a pipeline of science and technology-based manufacturing platforms for dairy ingredients.

Ina is a PhD student in the Department of Process & Chemical Engineering, School of Engineering, supported by Dr Kashub Tumwesigye who is a postdoctoral researcher. They are supervised by Dr Maria de Sousa-Gallagher, senior lecturer in Process & Chemical Engineering.

Linda Corcoran

"Does an animal's diet influence our liking of beef?"

Consumer liking of a product is strongly linked to its sensory quality. In today's consumer-driven marketplace, ensuring consistently tasty beef is essential for the continued success of the Irish beef industry, both nationally and internationally. In Irish beef farming, animals spend up to 8-months annually at pasture, providing a competitive advantage for marketing our beef products. However, the feed cattle receive in winter can vary depending on the farm, and the practises of the country of origin. To understand the sensory quality of different production (feeding) systems, the question needs to be answered; does the animal's diet affect the sensory quality of beef?

What's my project about?

My project researches the effects of the feeding systems on consumer liking of beef steaks, using an innovative sensory testing technique. The systems being investigated are:

1. 100% grass-fed : pasture-fed in summer and silage fed in winter.
2. Majority grass-fed : pasture-fed in summer and grass silage-fed with small amounts of grains (barley) in winter.
3. Majority grass-fed with grain finishing : as system 2 but grain (barley) is increased to diet majority for the last 4 months.

The effect of animal diet on the colour and nutritional value of beef is well researched, however, less is known on the impact on sensory quality. It is critical that a consumer's eating experience matches or exceeds their expectations. Therefore, the liking of a steak's characteristics such as tenderness, juiciness and flavour will strongly dictate if a consumer will re-purchase a particular brand. There has been an increase in demand for Irish grass-fed beef internationally and exports have increased to countries outside the EU, notably the US, UAE and China. Understanding the sensory profile better could assist national marketing strategies promoting Irish beef. This would be especially relevant for China, as Bord Bia has found that Chinese consumers are more interested in the eating quality or 'taste' of beef, especially beef of European origin, rather than the grass-fed image of nutritional quality.

Why these diets?

The first and second production systems I mentioned are popular in Ireland, the UK, Australia, Brazil, and New Zealand. The second system is also common in some of mainland Europe (France, Italy) and the third is the norm in major beef producing countries, but here grain type can differ. Grain finishing results in fast weight gain, which shortens time to slaughter and improves profitability. Total grass-fed uptake is slow from both farmers and the meat industry as cattle fed grass take longer to reach slaughter weight, and marketing grass-fed beef in the US is subject to strict regulations by retailers. However, this

makes the US an attractive market interest for Ireland as we already have our grass-fed infrastructure and grass-fed beef can be sold at a premium price in the US.

How do we measure liking?

Traditionally consumers are asked to indicate their liking for a product by providing a single score on a type of scale. However, during the eating process, a consumer's opinion can change many times, and giving a single overall response doesn't capture these changes. For this project, we are using a novel method called temporal liking. Temporal liking asks the consumer to indicate when their liking of a product (e.g. steak) or its characteristics (tenderness, juiciness, flavour) changes throughout the eating process.

- The first opinion is formed about the appearance of the steak. If it smells good, has good colour and the 'right' amount of fat (varies), expectations of the steak would be high.

- When the steak is cut and pierced with a fork, the effort it took to cut will form expectations on tenderness.

All before the eating process has even begun!

- The first stage of eating involves the teeth piercing the meat. The amount of force we use to bite, and the release of juice or lack thereof will also influence liking.

- During chewing, juiciness can increase enjoyment if the flow is stable or could decrease liking if it fades. Yet, if a steak dry, it will almost certainly be disliked. Liking of tenderness will be characterised by time, the longer chewing takes, the more liking decreases.

- The final stage is swallowing and aftertaste. A steak may have been juicy and tender, but if it has a strange aftertaste, that will be the most memorable characteristic.

All these stages can influence if consumers will re-purchase the brand in the future!

Linda is a PhD student in the School of Food & Nutritional Sciences and funded by the Teagasc Walsh Fellowship Programme. She is supervised by Dr Maurice O'Sullivan, with co-supervision by Dr Emily Crofton and Dr Eimear Gallagher (Teagasc)

Tom France

"Development of advanced milk protein ingredients using cold microfiltration technology for nutritional applications"

Membrane filtration technology is widely used in the dairy processing industry to concentrate, fractionate, isolate and purify different target macro-molecules, such as proteins, phospholipids and lactose. One of the more rapidly evolving types of membrane filtration being increasingly used by the dairy industry globally is microfiltration (MF). Based on the size difference between casein micelles (D = 200 nm) and whey proteins (1-5 nm), MF technology is capable of fractionating the major proteins in milk in a clean, chemical-free, environmentally-friendly and sustainable manner. It can also be used to remove undesirable spore-forming bacteria from valuable dairy ingredients intended for use in premium nutritional applications, such as infant formula.

More specifically, newer membrane filtration plants are configured to operate at lower temperatures (5-20°C) than would have been used traditionally (45-55°C), due to the associated microbiological and protein quality benefits. With the accelerated adoption of this technology by the dairy industry, a number of scientific questions relating to the partitioning and processing performance of the technology need to be answered.

My research questions

- to determine the effects of temperature and transmembrane pressure on protein, mineral and enzyme partitioning during the cold microfiltration (i.e., ⩽ 20°C) of skim milk;
- to determine the effect of fouling on the partitioning of proteins and plasmin during MF;
- to determine the energy costs associated with operating MF systems at such low temperatures.

The adoption of cold MF technology also presents opportunities to create new and innovative dairy protein ingredients, such as b-casein, which is the dominant casein fraction in human milk, and which is also used for encapsulation of hydrophobic (water-repelling) drug compounds.

The effect of temperature

To date, we have found that temperature has a significant effect on the composition of the permeate stream of MF processing of skim milk, with permeates generated at 4°C containing higher concentration of total calcium,

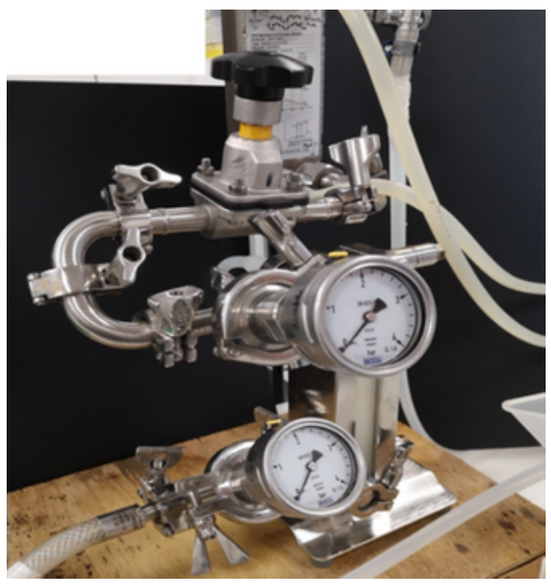


Figure 1.
Lab-scale, pressure driven, cross-flow filtration device used in this project

ionic calcium and b-casein, compared to those generated at higher processing temperatures (i.e., 12 and 16°C). We found that operating at high transmembrane pressure (TMP) resulted in higher permeate flux (the rate of extraction) values; however, fouling (unwanted deposits on internal surfaces on equipment) was more extensive, which reduced the permeation of proteins; in comparison, operating at low TMP resulted in significantly higher protein in permeates and a lower extent of fouling.

During the filtration of milk and other dairy streams many dairy companies operate at high TMP as it results in higher initial fluxes; however, our results have shown that in spite of the higher initial permeate fluxes, the use of high TMP results in more extensive membrane fouling which ultimately reduces protein partitioning and negatively impacts the life span of the membrane.

Temperature and protein concentration

Depending on the processing temperature, both the extent and form of fouling change, which affects the partitioning of b-casein and whey proteins during cold MF. The highest plasmin (main indigenous proteinase in milk and dairy streams) activity in the permeate was measured following MF at 4°C, which was also associated with the highest concentration of b-casein. This may potentially increase the hydrolysis of b-casein, reducing the technological functionality of ingredients generated from such permeate; subsequent research will provide further information on this.

My research is based in the Food Ingredients Research Group in UCC, where I am supervised by Dr Seamus O'Mahony. This work is funded by Enterprise Ireland through the Dairy Processing Technology Centre (DPTC), which provides me with excellent opportunities for building collaborations with industry partners (e.g., Kerry Group, Carbery and Glanbia) and other research performing organisations such as Teagasc Food Research Centre.

All of my exciting research findings to date have been presented to the industry partners, with the information provided greatly helping them in understanding and adopting such cutting-edge dairy processing technology for the production of innovative new ingredients

Tom is a PhD student in the School of Food & Nutritional Sciences and funded by Enterprise Ireland through the Dairy Processing Technology Centre (DPTC). Supervisory team led by Dr Seamus O'Mahony, including Dr Shane Crowley and Prof Alan Kelly.

Dr Cormac Gahan

"Understanding the influence of diet and the microbiota on foodborne disease"

Foodborne pathogens such as Listeria, Salmonella and Campylobacter remain a significant threat to the safety of our food supply. Food and water borne diseases cause 23 million illnesses in the European region with 5,000 deaths per annum, and represent an increasing challenge to the health of the global population. In addition to the direct health implications of foodborne illness, outbreaks of foodborne disease have the potential to negatively impact entire sectors of the food industry, resulting in large-scale food recalls and loss of consumer confidence.

Our gut bacteria

The resident bacteria that live in our gastrointestinal (GI) tract (the gut microbiota) provide an effective barrier to gastrointestinal infection, through a process known as Colonization Resistance. Studies in animal models clearly demonstrate a role for the microbiota in resistance to foodborne pathogens and there is evidence in humans that commensal gut bacteria are important in resistance to infection. However the mechanisms by which gut bacteria protect against foodborne disease are unclear. Current evidence supports a role for the microbiota in influencing immune responses and barrier function and competing with pathogens for local nutrients.

However the precise molecular mechanisms and the particular commensal bacteria that promote colonization resistance remain to be identified. An understanding of colonization resistance could lead to the development of methods to reduce the incidence or severity of foodborne infection through dietary supplements and/or rationally-selected next-generation probiotics.

Listeria monocytogences

Our research focuses upon understanding the molecular mechanisms by which the gut microbiota protects against the important foodborne pathogen, *Listeria monocytogenes*. This pathogen causes a potentially life-threatening infection (listeriosis), predominantly in elderly or immune-compromised individuals. *Listeria* also causes serious infection in pregnant women, resulting in infection of the foetus and miscarriage. The disease can occur in common-source outbreaks linked to mass consumption of contaminated ready-to-eat foods. A large outbreak of listeriosis occurred recently in South Africa linked to a contaminated ready-to-eat meat product, in which the pathogen caused over 1,000 cases of illness with 216 deaths.

The effect of diet

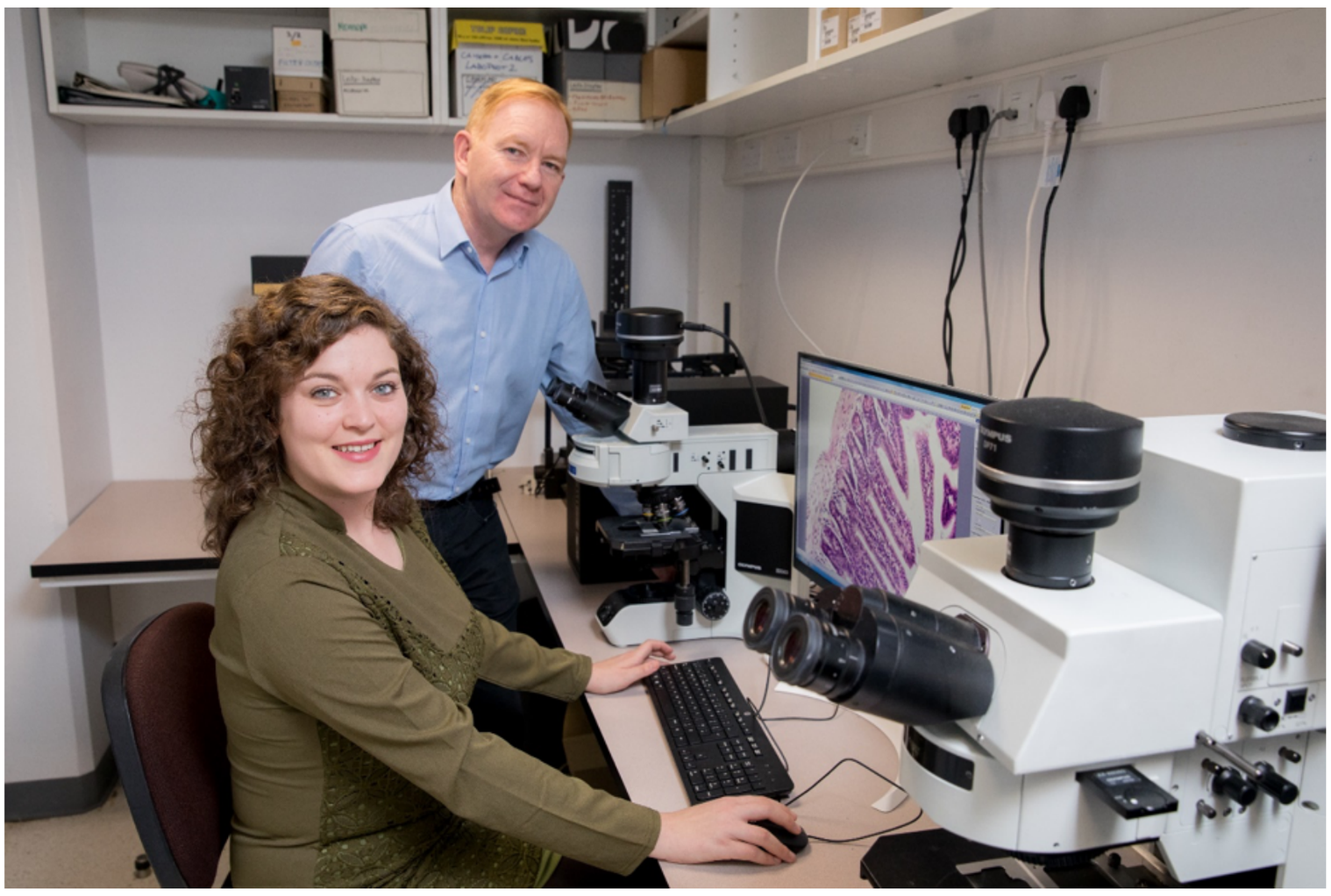
We have recently shown that diet significantly influences the gut microbiota with resultant effects upon resistance to *Listeria* infection in mice. We found that feeding mice with a "westernized" diet, which is high in fat and low in fermentable fibre, affected both the immune system and the gut microbiota. Short-term consumption of the high fat diet, over a period of just two weeks, was found to change the intestinal landscape, promoting an increase in the number of a

particular type of cell (goblet cell) in the gut which is the target for infection by *Listeria*, as well as causing profound changes to the microbiota composition and immune response to the pathogen. More recent work in our lab has shown that the negative effects of the high fat diet can be reduced by administering a particular commensal strain of bacteria along with the westernized diet. This suggests that rational selection of novel probiotic bacteria (selected based upon evidence from our studies), may have the potential to protect against this pathogen.

Partnering good diet with good bacteria

While it may seem self-evident that a healthy diet promotes a healthy immune system and protects against infection there are actually relatively few studies which investigate the precise components of diet that influence the immune system or determine the mechanisms by which this occurs. We are now in a position to further understand the nature of colonization resistance at the molecular level. Previous work in our lab has shown that disruption of the microbiota, through antibiotics or diet, changes the molecular signalling pathways by which gut commensal bacteria communicate with the host.

Our current work is examining the role of particular bacteria-derived signalling molecules upon colonization resistance with an overall goal of understanding how dietary influences upon the gut microbiota may influence susceptibility to infection, and exploiting this understanding to improve resistance to food and water borne disease.



Dr Cormac Gahan (pictured with Dr Vanessa Las Heras) is a lecturer in the School of Microbiology and School of Pharmacy in UCC, and a Principal Investigator in APC Microbiome Ireland.

Nadia Grasso

"Formulation and processing of sustainable and nutritious plant-based dairy alternative food products"

I am a first year PhD student, working under the supervision of Dr Seamus O'Mahony in the Food Ingredients Research Group at the School of Food and Nutritional Sciences in UCC. I came to Ireland first in 2018 on an Erasmus funded internship and was subsequently awarded a Lauritzson Food Research Scholarship to study plant-based protein ingredients and their applications in the development of sustainable, high quality and healthy alternatives to dairy products, in particular cheese.

Alternative protein sources

The need to study dairy alternatives arises from the challenge to find sustainable food sources to meet the increasing demand for dietary protein. In fact, the increase of global food demand is predicated to lead to a substantial increase in overall food production by 2050 due to the estimated growth of the global population by more than one billion people over the next 30 years, reaching 9.8 billion by 2050. The type of food demanded by consumers has changed, is still changing, and will continue to change in the coming years due to the higher standards of living in developing countries and urbanisation, eventually leading to an increase in animal food production if existing trends continue uninterrupted.

On the other hand, increased consumer awareness about the impacts of food production and consumption on the environment and health is contributing to an increase in the demand for plant-derived food products in developed countries.

Looking at the current market

From an initial screening of the cheese-type products available commercially, it emerged that there is no plant-based dairy-type product on the market that actually meets with the desirability criteria of a cheese product. The products currently available have low protein and high saturated fat levels, and several contain allergenic ingredients such as nuts and/or soy. Moreover, these products often have taste and flavour profiles that are not well appreciated by consumers.

As a starting point, we analysed a selection of commercial plant-based Cheddar-type cheese substitutes, comparing them to Cheddar and processed cheese. This first phase of analysis allowed us to describe in greater detail the complex inter-relationships between composition, structure and function of these commercial plant-based cheese substitutes and to identify the relevant key quality attributes. The commercial plant-based products analysed were found to have generally poor melting properties and very low protein content, all being heavily dependent on coconut oil and starch ingredients.

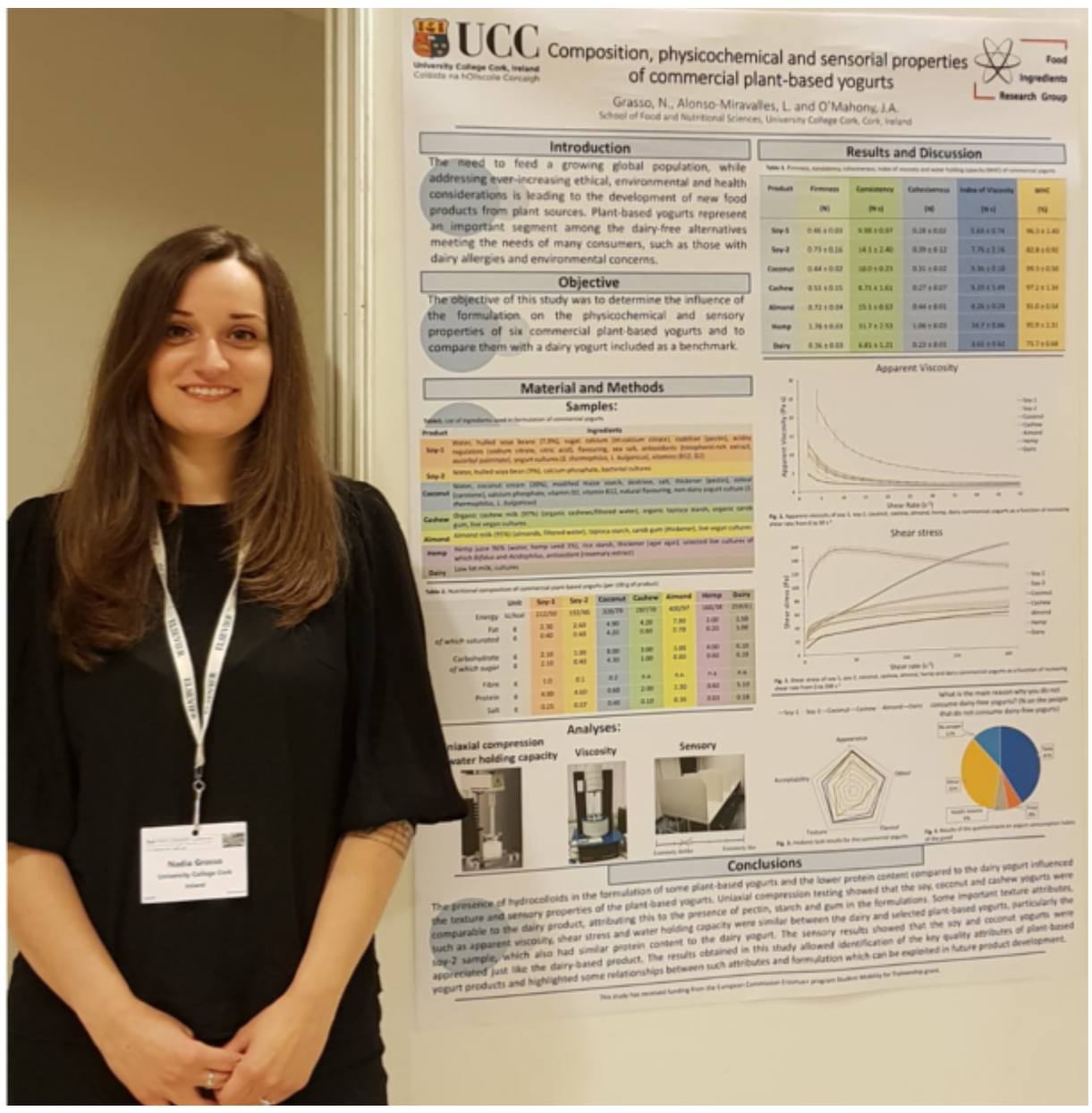
Indeed, the physicochemical characteristics of these samples, which is how ingredients interact together, as well as their internal structure, are strongly influenced by the ingredients employed in the formulation (e.g., hydrocolloids, which are gel-like thickeners). The study conducted so far will be relevant to the next stages of the project, where different approaches to develop a new plant based cheese substitute prototype, starting with novel plant-protein ingredients, will be explored.

Also, from collaborative work with another UCC PhD student on plant-based yogurts, conducted during my internship in the Food Ingredients Research Group, I have gained more knowledge and a strong background in methods related to the characterisation of dairy substitutes. Indeed, this work has been recently published in a special issue on “Milk Alternatives and Non-Dairy Fermented Products”, of the journal Foods.

The knowledge of the collective

My PhD project is supervised by Dr Seamus O’Mahony, Prof Elke Arendt and Dr Shane Crowley, all academic staff in the School of Food and Nutritional Sciences, and it allows me to harness in a multi-disciplinary manner, their collective expertise in dairy chemistry and technology, cereal science and technology, food formulation and food processing. Additional collaboration with specialists within UCC, such as Prof Yrjo Roos, and outside UCC will also be developed in responding to challenges and opportunities we will face in executing this exciting and timely project.

The outcomes of this highly novel and timely research will be of relevance to academic and industrial food scientists and their translation into industry will underpin the development and commercialisation of nutritious, good tasting and sustainable plant-based alternatives to traditional dairy-based cheese products.



Nadia is a PhD student in the School of Food & Nutritional Sciences and funded by the Lauritzson Food Research Scholarship. She is supervised by Dr Seamus O'Mahony, with co-supervision by Prof Elke Arendt and Dr Shane Crowley.

Darren Heenan-Daly

"The Use of Plant Growth-Promoting Rhizobacteria for Sustainable Agriculture"

The focus of our research lies in examining the relationship between plants and the bacteria which live around and/or in the plant itself, particularly the root structure. The term 'rhizobacteria' is suggestive of where these bacteria can be found, '*rhizo*' stems from the Greek word for 'root'. Our research examines the activity of these bacteria, particularly the plant growth-promoting rhizobacteria (PGPR) in protecting the plant from pathogens which can damage or kill it, resulting in yield losses of food crops. To obtain these beneficial bacteria we decided to look towards the historically infamous crop associated with Ireland, the potato.

Agriculture is having to rapidly adapt to the ever-increasing threat of climate change and also to stricter rules regarding the use of biocides and fertilisers, especially in the European Union. Just as humans and livestock can be given probiotics and antibiotics to promote health and fight infection, plants can be treated in much the same way with PGPR. We can enhance and modulate the plant microbiome using PGPR to combat particular diseases, increase the availability and uptake of particular nutrients such as phosphates, iron and zinc. They can also 'prime' the plant to get ready to fight infection in a similar fashion to a vaccine.

Given the sometimes differing opinions on whether organic or conventional agriculture is best practice, we decided to investigate both systems for the presence of PGPR by taking soil samples from potato roots grown under both systems. Interestingly, we found bacterial isolates which were common to both systems as well as bacteria which were unique to both systems. This finding indicates that potato and crop plants in general probably recruit a 'core' membership to their respective root microbiomes.

Volatile organic compounds

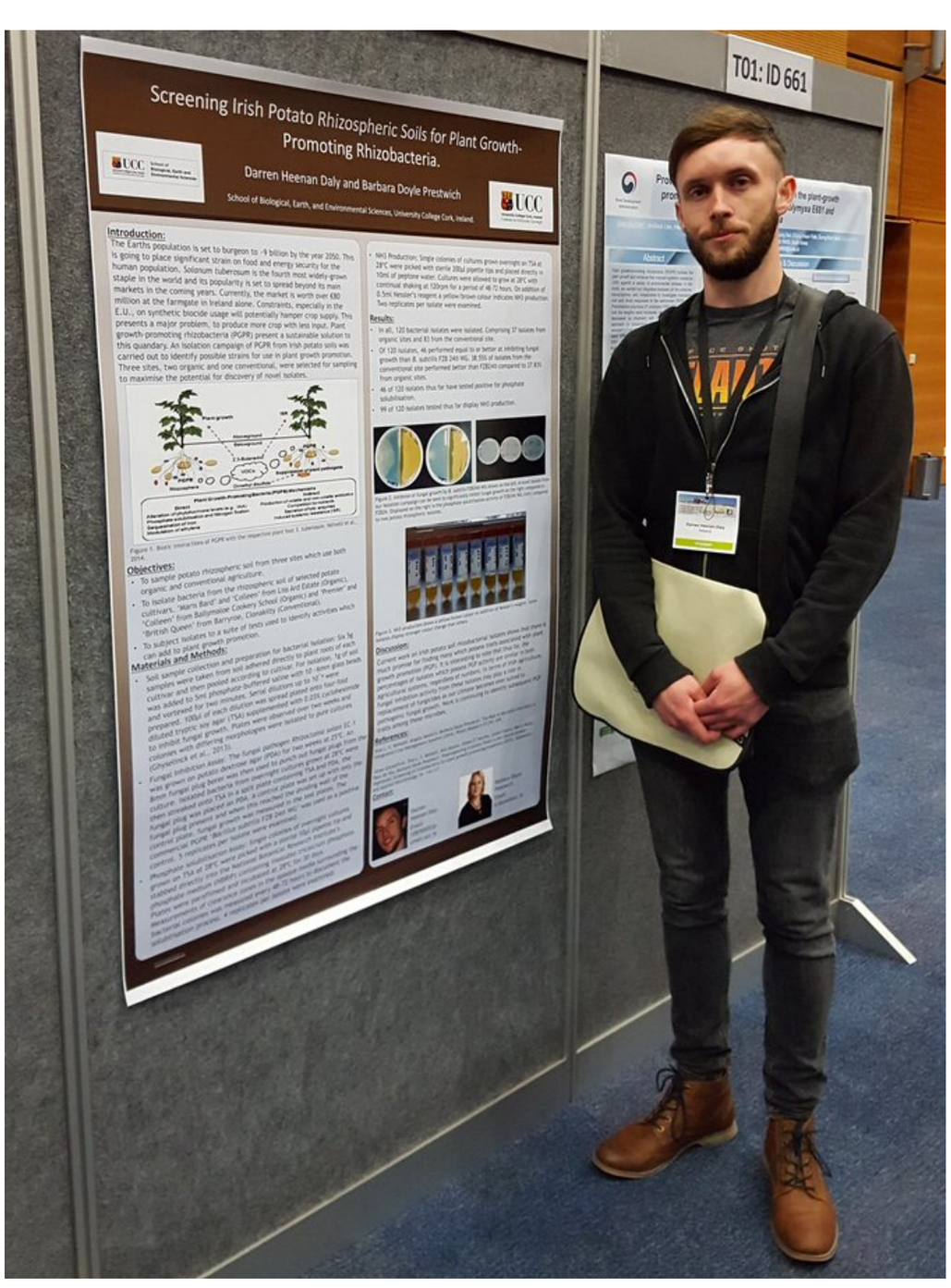
The main biochemical activity of PGPR associated with my PhD research is how they can use gaseous chemicals called volatile organic compounds (VOCs) to combat the growth of pathogenic fungi and bacteria. Plants are also capable of "smelling" these gases which in turn can increase the activity of genes involved in growth and defence responses. Understanding the effect that these VOCs can have on the growth of pathogens and the health status of the plant is important as it can lead to the identification of novel VOCs. Following this, application of the PGPR themselves or of pure preparations of their respective VOCs can be applied in the field as alternatives to synthetic biocides.

As the effects of global warming become more prevalent, PGPR can also be employed to help plants cope with the environmental stresses which will continue to sweep across the planet, the scope of which is wide-ranging as PGPR can help plants survive through flooding stress, drought stress, increased soil salinity and cold stress to name but a few.

Impact on modern agriculture

The impact that PGPR can have on the way we grow food is significant, we can lower the amount of inputs such as synthetic biocides and fertilisers while at the same time potentially saving costs and the environment. In many countries, particularly those in Asia, PGPR are routinely used in agriculture as biofertilisers and biocontrol agents. In the European Union a number of PGPR are registered for use and intense research focus has been placed on their application for future food production.

Indeed a large proportion of the H2020 budget under "Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy" is heavily focussed on the use of microbes in sustainable agriculture. This commitment from the European Commission shows the importance placed on the intensification of the use of PGPR and other beneficial microbes. To solve most problems you have to work "from the ground up", and that is exactly what we are doing.



Darren is a PhD student in the School of Biological, Earth & Environmental Sciences and the Environmental Research Institute (ERI). He is supervised by Dr Barbara Doyle-Prestwich.

Shauna Heffernan

"Marine Hydrolysates for Health"

In an age of obesity, heart disease, and diabetes epidemics, it is of growing interest to researchers to investigate safe and natural compounds to combat these diseases. Consumers today want natural foods which can potentially improve health, and reduce the risk of, or delay the onset of, disease. My research involves assessing the potential health benefits of blue whiting fish protein hydrolysates using cell culture model systems.

This is a collaborative project with academia (University of Limerick, University College Cork, University Ulster and Galway-Mayo Institute of Technology) and industry (Bio-marine Ingredients Ireland Ltd.). Following analysis of the bioactivities in the hydrolysates using cells grown in culture, their bioactive potential will be tested in mice studies and eventually incorporated into a food product for human consumption.

Why marine-derived protein hydrolysates?

As an island nation, fishing has always been economically and socially important to Ireland. It is responsible for the generation of income whilst providing local employment. Bord Iascaigh Mhara (BIM) reported that in 2018, the GDP of the Irish Seafood industry was valued at €1.245 billion with over 14,000 people employed, many of whom live and work in rural coastal communities throughout Ireland. Unsustainable fishing practices in recent years have presented major problems, affecting both fish stocks and the fishing communities.

A large number of fish processing co-products were produced by the fishing industry, with discards being the most significant co-product. The European Common Fisheries policy has made a huge effort to reduce discards by introducing a 'landing obligation'. Many fish species including blue whiting which were commonly discarded due to minimum landing size requirements and market considerations are now seen as a potential resource for new, value-added product generation which can potentially be used by the food and pharmaceutical industries. There is an abundance of research demonstrating the ability of marine protein hydrolysates to exert a beneficial effect on human health by exhibiting anti-obesity, antioxidant, anti-inflammatory, anti-cancer, anti-hypertensive, anti-diabetic and cardio-protective bioactivities.

Health benefits of blue whiting protein hydrolysates

Cell culture involves removing cells from a plant or animal and growing these cells in a controlled environment. Testing with cell culture systems is often used for preliminary research prior to testing in small animals and ultimately in humans, as it is inexpensive and can produce rapid and consistent data. Various cell lines were used in this study for testing the potential bioactivities of blue whiting protein hydrolysates.

Anti-obesity activity

Body weight is normally controlled by food intake vs. energy expenditure. An imbalance of this system favouring food intake can cause obesity. With the incidence of obesity increasing worldwide, the condition has become a serious health concern as it facilitates the development of chronic diseases such as coronary heart disease, hypertension, stroke, type two diabetes mellitus and some forms of cancer. The demand for new anti-obesity intervention strategies is increasing.

The control of food intake via appetite regulation is one approach which can be taken to reduce occurrences of obesity. An increase in appetite controlling hormones (such as glucagon-like peptide-1 (GLP-1) and cholecystokinin (CCK)) makes the consumer feel fuller and eat less. In this study, blue whiting protein hydrolysates were found to increase the secretion, or production of appetite-modulating hormones from STC-1 cells; a useful model for human endocrine (hormone) cells of the gut.

Obesity is associated with an increase in triglyceride fat content and an increase in the size and number of fat cells known as adipocytes. The ability of blue whiting protein hydrolysates to prevent obesity via reducing triglyceride content and preventing adipocyte formation will be assessed in this study. There is a gap in the market for a naturally derived anti-obesity products as increasing numbers of people are refusing to take chemically synthesised drugs due to the fear of potential side effects.

Protective effects in obesity related diseases

Obesity is also known to increase chronic low grade inflammation and oxidative stress which are directly involved in the development of cardiovascular disease, insulin resistance and impaired lipid metabolism. Possible ways blue whiting protein hydrolysates can reduce obesity related diseases therefore include i) preventing the production of pro-inflammatory signalling molecules known as cytokines in adipocyte cells and ii) protecting cellular antioxidant enzymes and preventing oxidant-induced DNA damage.

Bioactive blue whiting protein hydrolysates should be further broken down in future studies to isolate and identify the peptide responsible for the biological function. In the future, bioactive peptides may be more common in food and medicine applications- but more research is needed to get there.

Shauna (pictured with Dr Yvonne O'Callaghan) is a PhD student in the School of Food & Nutritional Sciences and funded by the Department of Agriculture, Fisheries & Marine (DAFM). She is supervised by Prof Nora O'Brien with co-supervision by Dr Linda Giblin (Teagasc)

Dr Eoin Lettice

"Novel methods in crop production: getting to the root of sustainability"

There is now irrefutable evidence that human society is going through a 'food security crisis' at the same time as the planet is undergoing a climate crisis. These two are inextricably linked and solving one will necessitate solving the other. Various international reports such as the 2019 UN Intergovernmental Panel on Climate Change (August, 2019) and the EAT-Lancet report on Healthy Diets from Sustainable Food Systems (2019) have pointed to the importance of plants in improving food security as well as reducing and mitigating the effects of climate change. This is in light of the sobering statistics that humans currently use between one quarter and one third of the planet's available land for agriculture and 70% of global fresh water resources for food production.

Integrated pest management

As a plant pathologist, I am particularly interested in tackling plant pests and diseases through an integrated pest management (IPM) approach. That entails, using all the available tools (chemical, physical and biological) to manage plant pests and pathogens so that their impacts on global crop resources are minimised. For example, I have investigated the biological control of plant pathogenic nematodes of the potato crop. As the third most important food crop in the world after rich and wheat, potato (*Solanum tuberosum*) is extensively consumed globally due to its potential for high yields and useful nutritional characteristics. In Ireland, the potato holds a very important place in our food culture and shopping basket. One report estimates that potatoes are bought every 2 seconds in Irish retailers.

Potatoes and the rhizosphere

My work on potatoes focusses on the Potato Cyst Nematodes (PCN; *Globodera pallida* and *G. rostochiensis*), two of the most heavily regulated nematodes in agriculture. The species are competing differently with one another in the field due to the contrasting control measures used to control each. These control measures often include synthetic chemical fungicides which are known to have some detrimental effects on the environment and their production contributes to the carbon footprint of agriculture. I have developed novel biological control measures for PCN using bacterial isolates from the rhizosphere (the root-soil interface). These bacterial isolates have the capability of triggering nematode hatch in the absence of their required food source (i.e. the potato crop), thus starving the nematode of food.

The rhizosphere, defined as the zone of interaction between the plant root system and the surrounding soil will play a central role in the sustainable intensification of global agriculture in the coming decades – the so-called 'brown revolution'.

By opening up and elucidating this ‘black box’ we will be able to understand the processes and interactions that take place there and exploit these to increase yields and mitigate the effects of climate change.

In addition, I am also interested in the use of novel genetic methods to improve crop production and agricultural sustainability. In collaboration with another research team within the School of BEES, we have developed tools to alter the genome of the potato to knock out genes associated with the production of glycoalkaloids. These compounds have natural defensive properties for the plant but their accumulation in tubers has food-safety impacts on human consumption of the crop. Here, the research team is exploiting the novel CRISPR Cas9 system for the genetic improvement of the potato plants.

Celebrating Cork's tree heritage

I also have an ongoing research and teaching interest in sustainable and organic crop production. I previously held the position of Director of the Centre for Organic Horticulture Research (COHR) at University College Cork and was the joint coordinator of the MSc in Organic Horticulture. My other research interests including the impact of trees and green spaces on urban environments and I coordinate the UCC Open Arboretum Project – designed to encourage the appreciation of the UCC historic tree collection for the greater understanding of the roles played by plants in all our lives.

Dr Eoin Lettice is a Plant Scientist at the School of Biological, Earth and Environmental Sciences at University College Cork and is a Primary Investigator in the Environmental Research Institute (ERI). His main area of research is sustainable crop production through novel plant pest and pathogen control.

Dr Ritika Puri

"Development of super-premium membrane filtered milk protein ingredients for nutritional applications"

My project, PREMPRO, aims to focus on the development of sustainable processes for the manufacture of novel dairy protein ingredients for premium applications like medical, clinical and infant nutrition products.

The ingredients of milk

The research project will develop greater understanding of fractionation of milk constituents during membrane filtration, impact of processing and storage on quality and functionality of the ingredients and applicability of ingredients in premium food applications. Dairy ingredients such as milk protein concentrates and isolates are rich sources of casein and whey protein, and are manufactured by removal of lactose and minerals naturally from milk using clean filtration technology. Membrane filtration process is a physical separation technology characterized by its ability to separate constituents of different sizes and characteristics. Its driving force comes from pressure difference between the two sides of a porous membrane.

Challenges of filtration

Membrane filtration technology can enable industry to develop milk protein ingredients with improved quality and at lower overall production cost. However, the high protein content of these ingredients can result in manufacturing challenges during their large scale production, such as high viscosity of concentrate before drying as well as functionality issues during storage of the liquid products (e.g., UHT treated clinical nutrition drinks) containing these ingredients causing sediment, gelation and thickening. Additionally, there can be changes during storage, leading to losses in organoleptic properties of the products such as protein hydrolysis due to the action of milk enzymes giving rise to bitter tasting drinks. These enzymes are heat stable and survive the processing temperature and may exist in protein ingredients making their way into final product.

Innovation and impact

This project aims to create innovative processing strategies for the manufacture of premium dairy protein ingredients that will result in superior tasting, highly nutritious, protein rich products with greater physical stability. To implement the defined objectives, the ongoing project is investigating the impact of membrane filtration process, particularly processing temperature on partitioning behaviour of major and minor constituents of milk. The two streams generated during membrane filtration of milk, retentate and permeate, are being studied for various parameters including total content of

protein, ash, lactose and solids, physicochemical properties such as viscosity, milk protein size and pH, distribution of different milk proteins like casein and whey and activity of protein dissociating enzyme.

The impact of processing temperature can be substantial on quality and functionality of protein ingredients which could influence applicability of ingredients in premium food applications. The project is endeavouring to benefit industry–academic collaborative organisations by creating pipeline of new knowledge, know-how, methods and insights for developing efficient and cost effective processes for manufacturing milk protein ingredients. It will also support dairy industries to fuel their economic growth and give them competitive edge by means of exploring new market opportunities. Sharing new knowledge and transferring developed technologies to Irish dairy industries can positively impact their position in global dairy export market. Overall, this project showcases potential to positively impact the Irish economy and society.

Career FIT

Career-FIT is a trans-national scheme launched in 2018 and co-funded by Enterprise Ireland and the European Union that offers an opportunity for experienced researchers worldwide to develop their careers in market-focused applied research in Ireland's Technology Centres. Through this scheme, I am hosted in the Food Ingredients Research Group led by Dr Seamus O'Mahony, who is a principal investigator in the Dairy Processing Technology Centre (DPTC).

Dr Ritika Puri is a postdoctoral researcher and a Marie Skłodowska-Curie Career-FIT Fellow. She is hosted in the School of Food & Nutritional Science under the supervision of Dr Seamus O'Mahony. Funding is provided under the European Union's Horizon 2020 Research Programme.

Dr Lana Repar

"New Sustainable Solutions for the Food Industry and Future Consumers"

Consumers are at the centre of the food industry. In the midst of a global health and economic crisis unravelling in front of us daily, it is important to understand and effectively answer the needs of the consumers. We have to be able to enter the consumers' mindsets and bring out their preferences, worries, attitudes and expectations of food.

Consumer Behaviour

In our Consumer Behaviour research, we are studying one population that has been experiencing significant challenges in the last few years: Gen Z. Population born roughly between 1995 and 2012 has been at the forefront of the digital media and technology usage, often caught in the middle of sustainability battle while at the same time being labelled as easily distracted, and is now becoming an important part of the global consumer market. Our mixed methods study is exploring eating habits of Irish and French college students aged between 18 and 24. We are interested in their perceptions, attitudes and behaviours related to daily foods and drinks choices. This study will help us better understand Gen Z population and their food behaviour in order to create innovative concepts and guidelines for marketing, policy and organisational approaches that sustainably support feeding this generation's appetites.

Food entrepreneurship

The food industry represents an immense source of inspiration for new flavours and experiences that can be delivered to consumers in a relatively short period of time. Innovation is one of the fundamental pillars of the food industry and food entrepreneurs are often leading the way. In our Food Entrepreneurship study, we are exploring how artisan food entrepreneurs perceive their business environment. Through numerous interviews and questionnaires, we look at their respective businesses, paths to market, developed networks and satisfaction with professional life. We are also asking an important question: how do they define growth and what does it mean for them. Artisan food entrepreneurs can often be misunderstood or considered as less profitable compared to small, medium or large companies. This research will help to re-define the growth for artisan entrepreneurs and assist in developing new policies targeted at supporting these entrepreneurs in their mission to preserve small, local, adventurous and sustainable food production.

New product development

The observed trends show that consumers will demand more and more sustainable, transparent and healthy foods in future. Many companies witness that satisfying such requirements is becoming their main focus.

The New Product Development (NPD) sections of our research are spread in three directions.

- First, we are looking at what strategies companies have in place when it comes to their NPD. It might come as a surprise, but often only a small percentage of food companies have a robust market-oriented NPD process. We want to find out how to optimise a company's NPD strategy to involve consumers in the early stages of the process and co-create products in synergy with consumers.

- Second, we are exploring new functional marine ingredients that could be used in new foods and beverages. We learned that consumers are concerned about their health and are trying to incorporate functional foods and beverages into their diet – but they want them to be appetising and innovative. This research will yield new ideas for functional foods enriched with marine ingredients and it will generate useful concepts that can be further develop into sustainable functional foods. In addition, this research is done in partnership with Bord Iascaigh Mhara (BIM) and it will support innovation in the Irish seafood industry.

- Third, we are studying consumers' responses to offering new fish species. Our study explored consumers' interest in new fish species and then identified what formats consumers prefer the most. The key benefit of our Conjoint Analysis study is identifying which combination of attributes is the most attractive to consumers, when they are given hypothetical products with different levels of product characteristics. This research assists in launching more successful new products and eliminating failures, which is critical in the fast-paced food industry.

Plant-based foods

Spurred by social media and a significant amount of information available 24/7, consumers are questioning their choices and changing their perceptions of food supply chains, packaging and recycling. We are studying Plant-based foods and looking at what motivates consumers to opt for plant-based foods, what are their attitudes about this types of foods and what purchase barriers they face. We are also interested in finding out what types of plant-based products consumers mostly consume.

This information will feed into designing new concepts for plant-based foods: yes, we want to create new plant-based food and beverage products together with consumers. The results will help in terms of: (i) more market-oriented value-addition in plant-based foods; (ii) innovation in plant-based food categories; (iii) policy and regulation development; and (iv) marketing strategies for key stakeholders.

Sustainability

While food is essential for human survival, so is our environment. In the last few decades, the emphasis has been on introducing sustainable practices in food production. Our studies in Sustainability look at both ends: production and consumers. We are studying sustainable beef production in Europe. We selected five leading beef producing countries in Europe and systematically reviewed what has been reported on sustainability levels across triple bottom line in the period between 2015 and 2020. We are now evaluating how sustainability is measured across Europe. This research will determine how sustainable European beef production really is. In addition, our consumer research focuses on different generations and their perceptions, attitudes and sustainable habits when it comes to healthy eating. The study will also look at the potential of digital media in encouraging different generations to switch to more healthy eating, through more targeted messages using various digital tools (e.g. apps).

Digital media

The latest developments at a global level have caused significant disruptions in our daily lives. While some industries are slowing down, the food industry is at the centre of the fight against COVID-19. Food producers, distributors and retailers adapted their operations overnight to serve consumers with minimal delays. One domain that has not been impacted is the one residing online: digital media marketing. Despite the chaos, the virtual domain is showing its strength and ability to transmit the message loud and clear to worried consumers. Our Digital Media study looks at how food retailers, SMEs and food-related companies are responding to the COVID-19 crisis through their social media platforms. It explores the types of content communicated, as well as the interactions and responses from the consumers.

Dr Lana Repar, and her colleagues are members of the Department of Food Business & Development, Cork University Business School (CUBS). Additional article contributors include Professor Joe Bogue, Professor Thia Hennessy, Ronan O'Farrell, Dr Emma Beacom, Dr Elizabeth McKenzie, Richael Connolly, Isin Yazicioglu, Simon Patterson, Solenn Breton.

Megan Ross

"3D Printing of Dairy Ingredients and Formulations - a multidisciplinary project"

3D food printers are a relatively young and novel technology, having been in existence since the early 2000s, when a group of students from Cornell University developed the first open-source 3D food printer called the 'Fab@home'. Since 2005, multiple foods and their suitability to 3D printing have been tested and studied. Liquid chocolate has been the most prominent food material to be 3D printed, however, fruit and vegetables, meat, bread and cookie dough, cheese and even insect-based cereal snacks have also been investigated.

Local leadership

Our research stemmed from an industrial query of whether commercially manufactured processed cheese could be 3D printed. Camille Le Tohic successfully proved this concept at UCC in 2018, using a modified desktop plastic 3D printer to 3D print processed cheese and subsequently published the findings in the Journal of Food Engineering which gained plenty of media attention. However, more research needed to be completed on the topic and this is where I joined the research team. My PhD research topic deals with building a knowledge base surrounding the 3D printing of dairy ingredients and formulations.

My research questions

- How does formulation affect the printing characteristics of a sample?
- How can 3D printing parameters, such as infill density (i.e., percentage thickness/density of the printed structure), print speed and printing temperature affect the printing of the sample?
- How can we use the heating and cooling characteristics of the 3D printer to create novel structures and textures from dairy ingredient formulations?

In addition, we also wanted to incorporate other research angles, such as engineering design of the 3D printer and measure how consumers perceive the technology using focus groups and surveys, into the project to create a multifaceted approach to this novel topic.

A multidisciplinary team

Working with Dr Alan Morrison and Michael O'Shea from the Department of Engineering in UCC, a syringe system design was designed to fit to a traditional desktop plastic Cartesian (i.e., prints in two fixed perpendicular oriented lines, X and Y) 3D printer. Professor Mary McCarthy, of the Cork University Business School in UCC, helped and advised in creating focus group sessions, where 24 consumers were invited to communicate and share their attitudes and initial opinions on 3D printed food and hypothetical applications where 3D food printers could potentially be utilised.

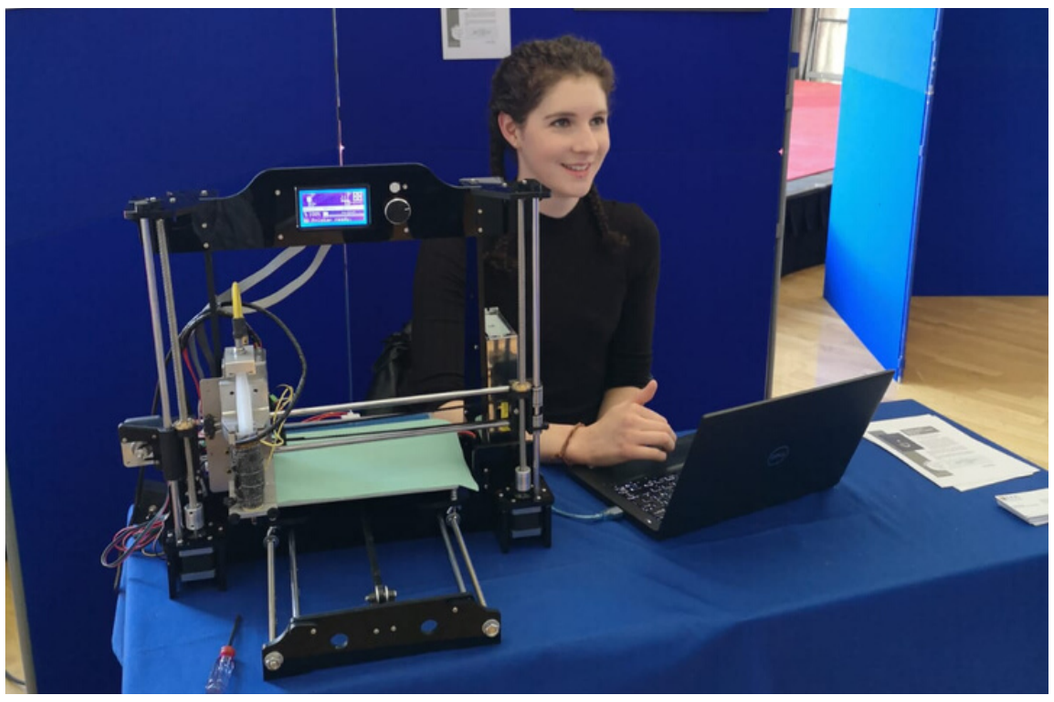
This project was done in conjunction with VTT, a research centre based in Finland, who carried out focus groups both in Finland and Belgium with the view of comparing the attitudes of consumers from differing countries on 3D food printing. After identifying themes generated from the focus group sessions, a survey (1,000 respondents) was designed based on these themes to develop various hypothesis in order to evaluate which are the main determinants of consumers' willingness to try 3D printed foods. With this information, 3D food printers can be designed more appropriately with consumers in mind, but also employ 3D food printers in areas most suited to consumer needs.

Future impact

The main reason I've chosen this research topic is due to the exciting multidisciplinary element of this project. Though my background is food science, I am also invited into the worlds of social science and engineering, which I may not have received the opportunity to do so in other projects solely involving topics in food science. It is of course very appealing to be a part of the research of a novel technology where 3D food printing has the potential to benefit multiple groups of individuals globally.

For example, functional 3D food printing first gained traction at NASA in 2013 when the agency funded a small Texan company to develop foods suitable for 3D printing in space, where astronauts would have access to nourishing foods specifically customised to the individual astronaut's health needs, but also could be rehydrated and produced on demand. Another example is the PERFOMANCE project funded by the European Commission 2015; 3D food printers were deployed to create tasty, nourishing and personalised meals for individuals with a difficulty with swallowing, a condition called dysphagia. Meals were designed for each patient according to their taste and flavour preferences, weight and specific health needs, before being 3D printed into interesting designs or even to mimic the original form of that specific food (e.g., 3D print carrot purée into a realistic carrot shape).

All in all, 3D food printing is a new and exciting space to be working in, and I'm so glad to be a part of it. I'm really looking forward to seeing what more the technology has to offer, both in my own research and potentially helping individuals all over the world.



Megan is a PhD student in the School of Food & Nutritional Sciences and funded by the Lauritzson Food Research Scholarship. She is supervised by Prof Alan Kelly, with co-supervision from Prof Mary McCarthy and Prof Alan Morrison.

Dr Aoife Ryan

"Nutrition in Oncology"

My research focus is in clinical nutrition and dietetics. I established and manage an active research programme on nutrition in oncology at UCC. My main areas of research interest are as follows:

- Cancer-associated wasting (particularly muscle loss (sarcopenia) which is very common in cancer patients. I am very interested in how muscle wasting impacts on quality of life, tolerance to chemotherapy and overall survival. We use gold standard CT scans to examine body composition which are readily available in oncology.

- Novel nutritional supplements and tube feeds that can be used before and after major cancer surgery as a means to improve nutritional status and quality of life. I have led a number of large randomised trials in this area.

- Modulating appetite, particularly in those with a poor appetite (again common in cancer). Oral intake of energy and protein is significantly suppressed in the majority of patients with cancer. I am interested in novel bio-actives that can stimulate appetite and also in the development of novel low volume protein supplements to augment intake to slow down muscle loss.

Nutrition to support cancer recovery

Our papers over the past nine years have shown that 40-70% of Irish patients with cancer develop sarcopenia (severe muscle wasting) because of their disease. Muscle loss is driven by systemic inflammation and inadequate intake of protein. We have shown that sarcopenia is associated with more toxic side effects to many chemotherapy drugs as these drugs are distributed and metabolised in the lean component of the body. We have also shown that sarcopenia and weight loss is associated with a significant reduction in quality of life and overall survival in many cancers. We have pioneered the use of CT scans to measure lean and fat mass and shown that changes in body composition during treatment are associated with significant reductions in survival.

I have had the pleasure of supervising a number of very talented PhD students and post docs over the past 9 years I have been in UCC. In conjunction with these postgrads we have published a number of papers on wasting in cancer and translated this scientific evidence into free cookbooks for patients with cancer to help those with poor appetite, swallowing difficulties and those who are in remission from cancer. My postgrads have won many research prizes at conferences and I have been awarded both the Julie Wallace Medal and the Cuthbertson medal from the Nutrition Society in the last 4 years.

Engaging with patients

At the moment I am leading an Irish Cancer Society grant which aims to describe

the attitudes of patients with cancer to alternative and complementary therapies. I am also working with a clinical nutrition company to develop a novel protein enriched supplement for patients with cancer which we hope to test in an randomised clinical trial.

Cookbooks to support nutrition

I am working with the HSE to publish a cookbook for sick children called 'Making the most of Every Small Bite' and am currently in the final stages of publishing the second edition of 'Eating Well with Swallowing Difficulties in Cancer' which is a cookbook for patients with cancer of the head, neck and throat who cannot swallow normally. This is sponsored by Breakthrough Cancer Research and the National Cancer Control Programme (NCCP).

I am also working with a publisher for a cancer prevention cookbook entitled 'Stacking the Odds Against Cancer' which will be available in bookshops in the Autumn. This is an evidence-based cookbook based on cancer prevention recommendations from the World Cancer Research Fund. I am also working with Food for Health Ireland (FHI) on a bioactive which has appetite stimulating properties (through Ghrelin receptor) which we successfully investigated in FHI-2 along with colleagues in the Dept of Neuroscience and Neuroanatomy in UCC and in University of Limerick and University College Dublin. It is planned to investigate this bioactive further in FHI-3 and run a randomised trial in the elderly. This bioactive may also be suitable for oncology populations.

Human Nutrition & Dietetics

Outside of research I am excited to welcome our first cohort of students into the new MSc Human Nutrition & Dietetics programme at UCC in September 2020. This degree is two years in the making and I am delighted to act as interim programme director and acknowledge the great work of my colleague Dr Samantha Cushen in getting this programme off the ground. It is hoped that this course will be a flagship course within SEFS and that UCC will become a hub of continuous professional development for dietitians based in the south of Ireland.

For further information on this new MSc program, please see the UCC website **https://www.ucc.ie/en/fns/current/human-nutrition-dietetics/**

Dr Aoife Ryan is a senior lecturer and principal investigator in the Nutrition & Oncology research group in UCC, and interim program director for the MSc in Human Nutrition & Dietetics

Prof Astrid Wingler

"Improving the climate resilience of grass production systems with plant physiology"

Plants form the basis of food production systems, but plant growth and yield are threatened by climate change, especially by the increasing frequency of extreme climatic events. For example, altered rainfall patterns have increased the frequency of flooding, while crop production systems in large parts of the world are becoming more severely drought stressed. Although the overall rising temperature can be beneficial for plant growth at high latitudes, heat stress is threatening yields in already hot climates. In countries such as Ireland, cold snaps may become more frequent despite an overall warming climate and e.g. inhibit the growth of grass in spring. In addition to frequent flooding during autumn and winter, recent events that have affected grass production in Ireland include the unseasonal snow in March 2018, followed by a summer drought, which resulted in reduced grass growth and fodder shortages.

Understanding how plants respond to climate-related stress, and how we can select and breed for more climate-resilient crops is vital for future food security. By contributing understanding of how plants function and how they manage to survive and thrive in stressful conditions, plant physiology plays a key role in sustainable food production.

My research focuses on how plants adjust their metabolism and development to survive in stressful environments and what limits their productivity under climate-related stress. This research includes research on non-crop model plants to identify the fundamental mechanisms and genes that are involved in stress responses, followed by translation of this research into grass crops.

Fundamental research of plant stress responses

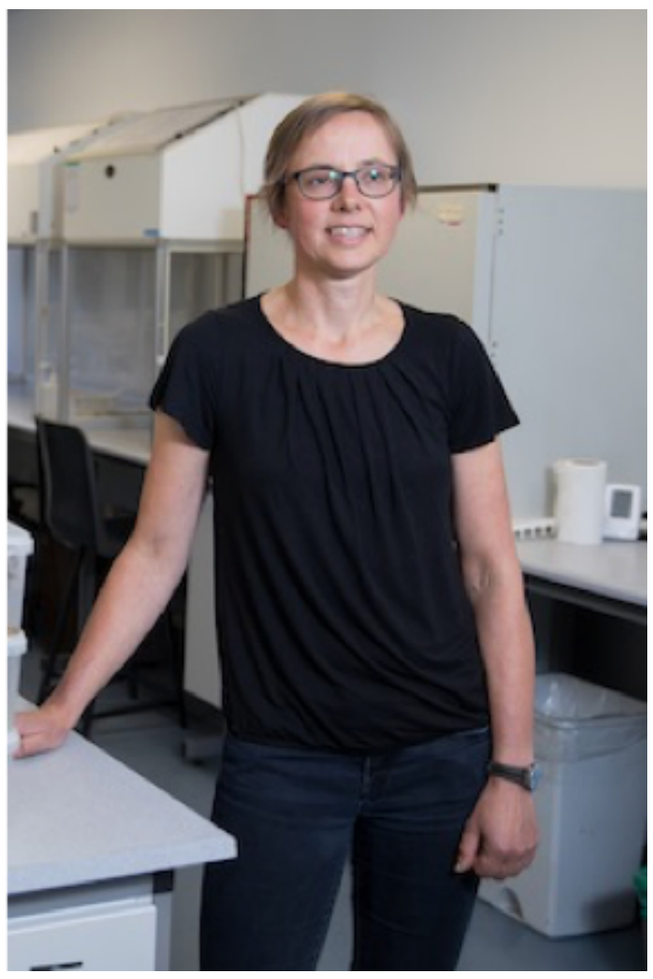
Laboratory experiments with easy to grow plant model species have contributed enormously to our understanding of the genes and mechanisms that enable plants to respond to stressful conditions, such as cold stress. Our own research on the most-widely used annual model, thale cress (*Arabidopsis thaliana)*, and its perennial relative, Alpine rockcress (*Arabis alpina*), has shown that cold tolerance is related to the ability of the plants to accumulate sugars and regulated by the plant hormone system. These adjustments allow cold-tolerant plants to survive without cold damage, but developmental processes and growth are delayed. Our findings are in line with other observations showing that plants, by nature, are conservative, and prioritise survival over growth during stress. How this growth limitation can be overcome in crops remains a challenge, especially as plants that grow better under mild stress may be more susceptible to damage under severe stress, such as sudden cold snaps.

How we transfer knowledge on stress resilience into grass crops

Grasses are the most important plant family for food production. The economically most important food crops, wheat, rice and maize, are all grasses. In addition, forage grasses provide the basis of dairy and meat production systems, for example in Ireland where grass contributes on average over 80% to the diet of a cow. To optimise grass growth, e.g. under different temperatures, we compare the impact of different growth conditions on the growth of different perennial ryegrass (*Lolium perenne*) cultivars. However, identifying and testing the function of genes in perennial ryegrass is a challenge. We therefore use another perennial grass, false-broom (*Brachypodium sylvaticum*), as a model for perennial grasses. Important advantages of *Brachypodium sylvaticum* include that it has a small genome and is easy to genetically manipulate, which enables us to create transgenic plants to test the function of e.g. stress-response genes. Once this genetic knowledge is available, it can be used for the breeding of other grass species, such as perennial ryegrass and grain crops.

Perennial grasses for climate resilience and carbon sequestration

Grain crops (such as wheat, rice and maize) are typically annual, i.e. they only grow during one season before they put all of their resources into the grain and die. While producing a high grain yield, annual crops do not have large root systems and are therefore not very good at exploiting soil nutrients and water. Perennial grasses that grow over several years, in contrast, have extensive root systems that make them less reliant on fertiliser input and irrigation, and more climate resilient. In addition, perennial grasses transfer more carbon underground which is important for counteracting carbon released as CO2 through burning fossil fuels. There is considerably more carbon in the world's soils than in the atmosphere, and if we can increase soil carbon by just 0.4% every year, this would compensate for the CO2 produced by human activities and thereby prevent climate change. However, how this can be achieved, is not well understood. How grasslands can be managed to improve soil carbon storage is therefore an important focus of our research.



Professor Astrid Wingler is Professor of Plant Biology and Head of Plant Science at the School of Biological, Earth and Environmental Sciences and Environmental Research Institute at University College Cork

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