Social and political factors in sustainable food systems

Priorities for a sustainable agri-food system

Dr. Gavin Milligan, Director.
GreenKnight Sustainability Consulting Ltd.

The talk will discuss how 'sustainability' might be interpreted and the themes within it prioritised by a range of stakeholder groups in the context of a globalised agri-food system, the tensions which can exist between environmental and social ambitions, and the types of action required to deliver a 'just transition' to a sustainable future.

Local industrial strategy: links to the food and agricultural sectors

Will Morlidge, Chief Executive.
Local Enterprise Partnership for Derby, Derbyshire, Nottingham and Nottinghamshire (D2N2LEP).

Since the outbreak of the Covid 19 pandemic, Government policy on regional economic development has shifted significantly. Where we once had Local Industrial Strategies, we have moved quickly through recovery strategies to low carbon plans and levelling up strategies. Funding that was once routed from the EU back into the UK is now coming to an end and new funding approaches are taking shape. Some powers that once resided in Whitehall have been or are being devolved to locally elected leaders to move delivery, funding and accountability closer to local people. In my slides I will share a high-level view on the new economic delivery landscape as well as sharing some insights from the Derby, Derbyshire, Nottingham and Nottinghamshire area and from our partners elsewhere in England about the support that has been and is available to the food sector and to the rural economy.

Exploring meat eating consumers' willingness and motivations to reduce meat intake and accept protein alternatives between Australia, China and the UK.

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The increasing global demand for meat causes additional environmental, public health and food security issues. Adoption of a healthy and sustainable diet through the reduction of meat consumption can be considered as one of the approaches to tackle these problems. As meat consumption habits are embedded in cultural traditions, it is important to consider cross-cultural differences when understanding consumers' willingness to reduce meat and acceptance of different protein alternatives (meat substitutes, edible insects, cultured meat). This study used an online survey to collect responses from meat-eaters in Australia (n=457), China (n=616) and the UK (n= 489) to explore key motives in meat-reduction and acceptance towards protein alternatives. Results found around 70% of Chinese and 67% of British consumers were willing to reduce meat consumption in the next year for sustainability/environmental reasons, compared to 36% of Australian consumers. The environmental benefits were one of the key motivators across the three countries, but the strength of importance varied with China significantly more motivated by food safety. Overall willingness to try protein alternatives

differed across countries with consumers in China and the UK more willing to try meat substitute products followed by cultured meat and edible insects, with the reverse order found for Australian consumers. These findings highlight the importance of understanding cultural differences when designing sustainable eating strategies across countries. Further research is needed to drive cross-cultural insights regarding intentions to reduce meat intake considering other key variables such as meat attachment and the environmental perceptions of food.

Why IP is essential in delivering sustainability

Sara Holland, Alice Mortibou and Lucy Sharples
Potter Clarkson LLP

There is often a perception, amongst both academics and those working on “green” technologies that aim to solve global issues, that the best route to enabling that technology is to publish your research and let others take it forward. Making a profit from such technology can be seen as “wrong”.

This talk is largely aimed at academics, spin-outs and start-ups who typically have little exposure to IP education and will explore how intellectual property (IP) rights are critical in enabling innovations in sustainability get to market.
We will look at the importance of protecting your IP rights from the start, and how these rights can help to attract investment, recoup costs and encourage collaboration both within and between industries. Effective innovation is often cumulative and while IP rights can allow the owner to monopolise their own innovation, they can also be used to create a more open, sharing approach of ideas.

This talk will finally touch on the interplay between IP rights, policy and industrial regulation and standards. We will explore what are the drivers in moving towards more sustainable solutions and what is potentially hindering the move to a more sustainable planet.

Green chemicals from the circular economy

Dr. Neil Parry, R&D Programme Director.
Unilever.

In 24 years at Unilever, has successfully commercialised of a range of new ingredients with suppliers in our product portfolio. Awarded Unilever scientist of the year in 2016/17. Most recent innovation from idea through to commercial scale and landing in the market was the biosurfactant, Rhamnolipid, first launched into Latin America portfolio in 2019. Inventor on 45+ patents. Holds advisory posts on external boards in Industrial Biotechnology (European Union, Industrial Biotechnology Leadership Forum, Biotechnology and Biological Sciences Research Council etc). In 2018 became a non executive board director for the newly established National Biofilms Innovation Centre in the UK that links the community of researchers across academia, SME and corporate bodies.

Lignin recovery from cocoa bean shell using microwave-assisted extraction (MAE) and deep eutectic solvents (DES)

Yujie Mao and Eleanor Binner.
Low Carbon Energy and Resources Technologies (LCERT) research group, Faculty of Engineering, University of Nottingham

Lignin is the second most abundant natural polymer after cellulose that are mainly found in the cell wall of woody biomass. Lignin has attracted many attentions over the last decades because lignin derivatives can be incorporated in many emergency and promising applications, including controlled release, saccharification of lignocelluloses, bioplastics, composites, nanoparticles, adsorbents and dispersants etc. Lignin is often isolated using strong acid or toxic organic solvents at elevated temperature or using expensive enzymes at enlonged processing time, which is either not environmentally friendly or commercially practicable. Therefore, there is an increasing need to develop novel lignin extraction methods using better solvents or different heating techniques.

This work studied lignin extraction from cocoa bean shells while decoupling the use of Deep Eutectic Solvents (DES) and microwave technology. Deep eutectic solvents (DES) have recently emerged as sustainable alternatives to water and organic solvents because of their advantages such as low cost, low toxicity, and biodegradability. The results from recent studies have shown that DES have good lignin solubility and the lignin obtained from the DES extraction of woody biomass has unique structural properties such as the absence of ether linkage and low molecular weight distribution, which makes them ideal for some certain applications [1,2]. Other existing data has shown DES has relatively high dielectric property and can be heated much faster under microwave than other traditional solvents [3], which makes it theoretically promising for microwave-assisted extraction of lignin. Specifically, we will identify the use of P-Toluenesulfonic acid: choline chloride: glycerol (2:1:1 mole ratio) as the DES and investigate the effect of different processing conditions for lignin extraction performance in terms of the lignin yield and purity. Further results to be presented at the conference.

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Production of 2,3-butanediol by Bacillus subtilis

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2,3-Butanediol (2,3-BD) is a promising platform chemical that could be produced from microbial cell factories, in particular Bacillus subtilis. Alternative low-cost nitrogen sources, including corn steep liquor, soybean meal, ammonium sulphate and urea were investigated to replace more expensive nitrogen sources (peptone, yeast extract, meat extract) commonly used by the biomanufacturing industry, in a modified MRS medium containing 20 gL-1 of sucrose. Moreover, different carbon to nitrogen (C:N) molar ratios of 6, 11, 17, and 22 were explored to establish a suitable ratio for bacterial growth and 2,3-BD production. Optimal fermentation characteristics, including a maximum growth rate of 0.10 h-1, a high 2,3-BD concentration of 5.4 g/L, a production yield of 0.35 g/g and a productivity of 0.22 gL-1h-1 were obtained when corn steep liquor was applied as nitrogen source with a C:N molar ratio of 11 in batch flask fermentation. In addition, in order to evaluate the effect of dissolved oxygen (DO) on 2,3-BD production, different DO controlling regimes were assessed in a 2L bioreactor in which sucrose (20 gL-1) and corn steep liquor (20 gL-1) were employed as carbon and nitrogen sources, respectively (30oC, pH 6). These included: (i) controlling the DO at 5%, (ii) controlling the DO at 10%, in both cases through cascade agitation, (iii) uncontrolled DO (fixed stirrer speed of 180 rpm), and (iv) a two-stage DO control: controlling the DO at 5% with cascade agitation from 0-9h, followed by anaerobic conditions (no oxygen input into the bioreactor). The best fermentation characteristics were obtained with uncontrolled DO, i.e. a maximum 2,3-BD concentration of 7.0 g/L, a production yield of 0.42 g/g, and a productivity of 0.23 gL-1h-1. The metabolic pathway involved in 2,3-BD production most likely included a three-step reaction, i.e. from pyruvate via α-acetolactate and acetoin to 2,3-BD (catalysed by acetolactate synthase, acetolactate decarboxylase, and butanediol dehydrogenase, respectively). The higher 2,3-BD production in the case of the uncontrolled DO fermentation indicated that the limited presence of oxygen (DO decreased to zero within 5 h of growth) favoured 2,3-BD production.

Food production and farming practices

Alternative protein sources for food and feed

Professor Andy Salter.
Future Food Beacon and Division of Food, Nutrition & Dietetics, School of Biosciences, University of Nottingham.

Currently, sufficient protein is produced to meet global requirements, but there are major inequalities in how this is used and distributed. Over half of protein produced is currently used for animal and fish feed, but only about a third re-enters the food chain. In high -income countries many individuals consume more protein than required, with majority being derived from animal products. However, while for many in such countries, animal-derived foods represent an affordable source of high -quality protein, their production results in significant greenhouse gas emissions, and account for large amounts of water and land use. As such, there is a growing consensus that, in the face of further population growth and climate uncertainties, current protein production systems are unsustainable, with increasing emphasis on diversifying sources of dietary protein both for human consumption and as constituents of animal feed. This includes not only plant-derived sources but also single cell organisms and insects.

Protein quality represents a combination of an appropriate indispensable amino acid composition and digestibility, with animal -derived protein representing the highest quality. The amino acid composition of other sources is much more variable, and digestibility may be retarded by both the physical nature of foods and presence of antinutritional factors. This may potentially be overcome by consuming protein from a range of different sources, and by processing methods that improve digestibility. However, determining the impact of such treatments on digestibility has been hampered by the lack of availability of reliable and affordable techniques for measuring it. Working with colleagues around the world we have developed an in vitro system for determining amino acid availability. This enables relatively high throughput screening of different sources and processing techniques, which should enhance our ability to safely introduce novel protein sources into the human diet and develop more sustainable animal feeds.

Atypical phase behaviour of quinoa protein isolate-maltodextrin mixtures

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Quinoa protein is of high nutritional quality and its properties have been increasingly studied in the last few years, aiming at the development of new plant-based food and healthcare products. For some applications, such as the processing of shear-induced anisotropic structures, it is necessary to mix a protein with a polysaccharide to adjust the final product properties, such as microstructure, sensory attributes, and mechanical strength. Here, the phase behaviour of mixtures of quinoa protein isolate (QPI) and maltodextrin (MD) of two different dextrose equivalents (DE) were studied. QPI was extracted from quinoa flour at pH 9, precipitated at pH 4.5 and freeze dried. It was then resuspended at pH 7 and centrifuged to separate the soluble fraction, which was used to create mixtures of different initial compositions with MD in 0.1 M NaCl at pH 7 and 22°C. The mixtures were centrifuged, and phase diagrams were constructed based on analytically obtained protein and polysaccharide concentrations in each phase. For both DE, the two phases region of the phase diagram showed a different shape from the one observed for biopolymer mixtures that form water-in-water emulsions; the type of microstructure required for the creation of shear-induced anisotropic structures. We applied molecular weight (Mw) distribution and microstructure analysis to define whether the atypical shape of the phase diagrams was due to Mw fractionation of both MD between the two phases. We further investigated if the modulation of molecular interactions in the mixture would result in a less atypical phase diagram, i.e., by decreasing the ionic strength in the system or by pre-treating QPI to promote protein unfolding.

Microwave inactivation of enzymes in pulses

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Food waste and loss is a large and increasingly urgent problem. In the case of high value crops, they require processing soon after harvesting for preservation before joining the global food supply chain. Enzymes are directly or indirectly associated with foodstuff losses in quality and nutritional properties regardless of food temperature treatment i.e., freezing or blanching by steam or hot water. At the same time, carbohydrates such as starch, are one of the essential nutrients fundamental for humans and their structure must be preserved as to ensure the nutritional value of foods.

The aim of this research was to investigate whether whole yellow peas can be blanched using microwave energy whilst minimising starch gelatinisation. As one of the more thermally stable enzymes in vegetables, peroxidase (POD) was chosen to serve as a general indicator of enzymatic deactivation while lipoxygenase (LOX) inactivation was monitored in relation to LOX's relation to undesirable changes in colour, flavour, texture, and nutritional value of food products. Heating trials at 2450 MHz assessed that POD is the more temperature resistant enzyme, and below 80 ^{o}C its activity is not nearly halved. Nevertheless, beyond this point its thermal stability sharply weakens, reaching a deactivation > 90 % for 5 min at 90 ^{o}C and 100 ^{o}C. LOX is always less stable than POD, reaching a total deactivation at 100 ^{o}C. Regarding the starch gelatinisation, the enzyme kill vs. starch kill ratio appeared particularly favourable at two points. The first is 60 ^{o}C for 2 min, which provides a 17 % POD and 29 % LOX elimination for only a 3 % starch gelatinisation. The other is at 90 ^{o}C for 1 min, where 22 % and 7 % residual POD and LOX activities gelatinise 15 % of the starch. The studied microwave assisted treatment has the potential to be scaled up in a dedicated equipment, which can be built in a mobile, containerised equipment, electrically powered by renewable energy and without the need of any additional chemicals to process produce close to or at source, as such dramatically reducing food spoilage.

From Beer to Biorefinery: Extracting protein from Brewer's Spent Grain

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Awarded a student bursary sponsored by Inglehurst Foods.

Brewer's Spent Grain (BSG) is a waste biomass produced by beer breweries with a potential for providing renewable chemicals, materials, and protein as a value-added product. Currently it is underutilised as animal feed, where its nutritional value lies solely in its protein content. Ionic liquids (ILs), which are liquid salts at ambient temperatures, have been proven to effectively pre-treat a variety of lignocellulosic biomass types. Lignocellulosic biomass can be successfully broken down using ILs by selectively extracting the hemicellulose and lignin, to produce a pulp that is rich in cellulose. However, this process has not been optimised for protein-rich lignocellulosic biomass such as spent grain.

The aim of this study is to design a process for the extraction, recovery, and purification of BSG proteins, while maximising the quality of the other biopolymer fractions present: cellulose, hemicellulose, and lignin. Once established, the BSG fractions can be valorised to create a variety of bio-derived chemicals and materials, such as biofuels, carbon fibres, hydrogels, and plastics, as well as protein-enriched products.So far, we have successfully implemented a protein pre-extraction step which will be applied prior to IL treatment, to maximise protein recovery. Selected ILs have been used to fractionate the protein depleted residue. This presentation presents the optimisation of BSG protein isolate extraction and recovery, as well as the characterisation of the protein.

Making sustainability decisions

Development of novel value chains from cocoa pod husks in Indonesia

Prof. Dimitris Charalampopoulos.
Department of Food and Nutritional Sciences, University of Reading.

Cocoa pod husk (CPH) is the main by-product (ca. 70-75% weight of whole fruit) of the cocoa harvest, an important and economic crop in Low- and Middle-Income Countries (LMIC), such as Indonesia. An existing practise is the return of CPH to soil with potential benefits (or disadvantages) for cocoa productivity and soil sustainability that have not been fully characterised. As part of a multidisciplinary project, an integrative approach was taken to identify and address the technological, environmental and economic challenges of developing a novel value chain for CPH. The project provides insights on: (i) the use of alternative processes for the viable fractionation of CPH to key biomacromolecules and their subsequent utilisation or bioconversion to biofuels; (ii) a choice modelling method to assess the economic viability of CPH valorisation; and (iii) a soil health and nutrient evaluation from diverting CPH from its role as a natural fertilizer. The results of the technology study proposed two potentially viable process designs to produce a range of co-products including soluble and non-soluble fibre, pectin and bioethanol. The results of the economic viability assessment suggested that farmers require higher levels of compensation than might be expected for a waste material. However, improvements in infrastructure and integration of processes directed to CPH innovative uses in existing agri-businesses could lower initial costs. The assessment of soil health concluded that, because of the large internal carbon (C) and nutrient cycle in cocoa, CPH plays a minor role in the maintenance of soil nutrients except for potassium (K). In the longer term, CPH removal from the field could cause K deficiency. Hence, any decision to deviate CPH from its conventional use should consider the long-term effects on soil health, especially since it might create increased reliance on chemical fertilizers.

Greenhouse gas removals via biochar derived from food waste digestate

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[3]Coal Products Ltd

Biochar can potentially make a major contribution to the UK target for Greenhouse Gas Removal (GGR) of 35M tonnes of carbon/year by 2050, but risks being constrained by the availability of conventional feedstocks such as wood. Biomass wastes, particularly anaerobic digestate, can extend the scale of biochar deployment. Hydrothermal carbonisation, with subsequent high temperature torrefaction, is capable of directly producing stable biochars from wet wastes such as digestates. Here we evaluate the potential scale of biochar production from anaerobic digestates in the UK to 2030, and assess the techno-economic and life cycle environmental viability of this approach.

Anaerobic digestion (AD) plants treated 12.5 million tonnes of feedstock in 2019; future growth in the sector will be driven by food waste management, where AD is viewed as an environmentally favourable treatment method for unavoidable food waste. Treating 80% of unavoidable food waste by AD in 2030 would require a 50% increase in AD capacity in the next 10 years. Our analysis indicates that there is sufficient AD fibre nationally to support biochar production delivering over 500,000 tonnes CO_2eq p.a. by 2030. Biochar production from food waste digestate achieves substantial greenhouse gas removals of approximately 1.6 kgCO_2eq/kgbiochar. Transport distance and soil effects are uncertain but are estimated to have a small impact on GHG emissions, highlighting that the majority of emissions reductions are from the physical storage of carbon in biochar. Commercial biochar production from food waste digestate is able to provide cost-effective greenhouse gas removals of less than £100/t CO_2 avoided. Other wet wastes, such as green waste, will command a lower gate fee and therefore would see higher costs of avoiding CO_2. The present study considers a highly promising opportunity to solve a waste disposal burden and remove atmospheric GHGs. Multiple sources of biochar will be needed to make significant contributions to the UK's GGR target, which is the subject of ongoing work.

Life Cycle Analysis of Sugarcane Bagasse for Power Generation: Environmental Benefits and Economic Viability.

Johnson Ho Lau, Edward Lester, Jon McKechnie, John Robinson, Orla Williams.
Faculty of Engineering, University of Nottingham, UK.

Large-scale biomass power generation has been used in the UK and many countries worldwide to reduce carbon emissions. Wood-derived fuels remain the predominant biomass source used in power applications. With the goals of improving environmental sustainability and economic viability, there is increasing interest from the industry in alternative biomass sources. The processing of sugarcane produces vast amounts of waste in the form of bagasse (process residues after the sugarcane juice is extracted). Bagasse is already widely used to power sugar mills, but large-scale usage remains limited.

This study uses CCalC and SimaPro to carry out Life Cycle Analysis to evaluate the potential of using bagasse from the sugarcane industry for large-scale power generation. The overall process consists of the collection of bagasse from sugar mills, processing and pelleting of the raw material, transport to the power station, and combustion. The base case scenario considered is the utilisation of bagasse from the United States in a power plant located in the UK. Specific scenarios with different raw materials, processing techniques, transport distance and other factors were considered and compared. The economic viability of the overall process and the potential benefits of novel processing technologies such as torrefaction were also studied, with a detailed comparison of the overall system performance when using different torrefaction conditions. The carbon footprint was calculated using the model for each scenario studied. It is shown that the use of sugarcane bagasse can be a viable replacement for traditional woody fuels for power generation and can provide significant environmental benefits.

Finding the right scale: evaluating the sustainability of local food production in the U.S. and UK

Nicole J Kennard.
Grantham Centre for Sustainable Futures, School of Biosciences, University of Sheffield.

Now more than ever, the sustainability and resiliency of global food supply chains have been brought into question. Our increasingly urbanised population has created a need for convoluted and often inefficient food supply chains, most of which operate under a linear, extractive system. This has created vulnerability to global shocks and stresses, as seen during the COVID-19 pandemic, with stresses only increasing with climate change. In light of these challenges, local and small-scale agriculture have been espoused as potential solutions for sustaining local food security, by being able to quickly adapt and respond to changing community needs; indeed, while supermarket shelves were empty during the COVID-19 lockdown, vegetable box subscriptions to local farms skyrocketed as this became a new main food source for many.

However, the sustainability of different scales of local agriculture, such as urban versus regional production, is unclear. This study compares environmental impacts from vegetable production on conventionally and organically managed urban, peri-urban, and rural farms in the U.S. and UK. The study examines the lifecycles of two high value crops – tomatoes and kale – across 25 farms. The material inputs, natural resources, and energy used to grow, process, package, and transport the crops to the consumer have been quantified. Preliminary results show that resource and material use across different farm types are influenced by economies of scale; intensity of production; yields; and farmer experience (especially on smaller farms). Lifecycle assessments (LCAs) are being conducted to compare the environmental impacts associated with this material and resource use across different farms, including impacts on global warming, resource extraction (land, water, and fossil fuel use), and pollution (e.g., acidification and eutrophication). Thus, this study will show how a farm's scale, distance to consumer, and management practices influence its overall sustainability, providing insight to the ideal scale of local agriculture.

Moving dairy manufacturing and distribution towards net zero carbon by 2050: An energy consumption modelling tool

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Dairy manufacturing and distribution are responsible for extensive energy-derived carbon emissions. Reaching the net-zero carbon target by 2050 is a global priority. To that end, the dairy industry must develop a robust emission reduction plan. Energy consumption modelling tools can facilitate any decision-making towards that target. This study presents a model that evaluates the energy consumption of skimmed milk and cream manufacture and distribution. To model the energy consumption for each individual component sequence-by-sequence throughout milk and cream manufacturing and distribution, chemical engineering process design, and empirical modelling approaches where used. This generic modelling approach allows simulation flexibility in processing conditions, the type of fuel burn in the production plant, the type of refrigeration vehicles, the distribution distance and more. The model was simulated under four different manufacturing and distribution scenarios, to assess the per product energy use of centralised and decentralised supply systems, and oil or natural gas use for steam production in the manufacturing plan. These scenarios were simulated up to the year 2050, by accounting for UK emission targets for electricity and transportation. The results shown that decentralised manufacturing with natural gas use as a fuel for heating needs on site was not only the least carbon emitting scenario of all, but also lead to the greatest emission reductions, of about 40% by 2050 among the scenarios tested. None of the scenarios was able to reach the net-zero carbon target, by 2050, which implies that governmental targets are not sufficient to allow the dairy manufacturing and distribution become net-zero without actions taken from the industry. Overall, the proposed model has the potential to support the dairy industry in the development of a robust emission reduction plan towards net-zero, by analysing the effectiveness of various net-zero carbon practices as they become available.

Emerging technologies for waste valorisation

Current status of microwave assisted extraction of pectin

Dr. Eleanor Binner.
Department of Chemical and Environmental Engineering, University of Nottingham.

There is increasing interest in developing new products from hairy pectins extracted from food wastes. Unlike conventional pectin extracted for example as a gelling and stabilisation agent in food products, hairy pectins can't be extracted using the existing industrial extraction process. This is because the "hairy" neutral sugar side chains that are thought to impart bioactive properties such as prebiotic or immune effects are destroyed in the process. Furthermore, industrial extraction uses fossil fuels and large amounts of acidic solvents. Microwave extraction has been proposed as a promising method to enable the extraction hairy pectins using mild processing conditions and renewable electricity sources. This presentation will review recent progress in pectin extraction using microwave technology.

Pomace and grape seeds oil from *Vitis vinifera* L. cv. Montepulciano d'Abruzzo: from waste to a potential functional food

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Grape pomace is commonly considered a waste product of monovarietal red wine production. Methods: HPLC-DAD analysis was performed to determine the polyphenol and flavonoid contents of all the extracts obtained from Montepulciano d'Abruzzo red wine and grape skins whereas, GC-MS was applied to the determination of fatty acid composition in grape seeds oil. Biological characterization involves antioxidant and antimicrobial assays for all the extracts and seeds oil; Their ability to inhibit α-glucosidase, α-amylase, α-tyrosinase, and ChE enzymes was also detected, together with anti-inflammatory activity on wine, grape skin extracts, and seeds oil by lipoxygenase (5-LOX) and LPS-stimulated macrophage release assays. Data indicate significative polyphenols content (199.31 ± 7.21 mgGAE/g), antioxidant (CUPRAC assay (1036.98 mgTE/g)), enzymatic inhibition (α-tyrosinase: 151.30 ± 1.20 mgKAE/g) and anti-inflammatory activities for wine-organic extract 2, while the antimicrobial activity of grape skin decoction is higher than those reported by wine extracts on three bacterial strains. Interestingly only dealcoholized wine and wine-aqueous extract exerts inhibitory effects on α-glucosidase (20.62 ± 0.23 mmolACAE/g and 19.81 ± 0.03 mmolACAE/g, respectively), while seeds oil is rich in oleic and linoleic acids. These results confirm the strong antioxidant properties of Montepulciano d'Abruzzo grape pomace, suggesting the potential use of this waste.

Enhanced Extraction in Biomass-Solvent Systems Under Microwave Heating May Not Be Caused by Cell Rupture.

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Awarded a student bursary sponsored by Inglehurst Foods.

Plant-based biomasses incorporate various bioactive extractables with considerable added-value, whose utilisation would support the efforts towards achieving a circular economy. Microwaves have been widely reported to enhance biomass-solvent extraction compared with conventional heating techniques, potentially enabling prevalence over many of the current process challenges related to cost, safety, controllability, and environmental considerations. However, efficient utilisation of this novel technology requires understanding the fundamental mechanisms with which microwaves enhance extraction in biomass-solvent systems. This is key towards developing the ability to predict process outcomes in various settings, but also to upscale the process to the envisaged industrial scales.

Microwaves are widely thought to loosen the microstructure of biomass materials by causing cell rupture, thereby improving diffusion/extraction in biomass-solvent systems. Two hypotheses have been proposed to link microwaves with cell rupture, namely Steam-Rupturing which entails intracellular steam generation due to rapid microwave heating; and Temperature-Induced Diffusion under which the temperature non-uniformity drives surplus water influx to cells, eventually causing rupture. Recently, a model was developed to quantify cell pressure under microwave heating at the cellular scale, which demonstrated that Temperature-Induced Diffusion is a more suitable alternative to underpin enhanced cell rupture under microwave heating (Taqi, 2020).

Despite the differences in the hypotheses discussed, both accept cell rupture as the rate-limiting step for achieving enhanced microwave extraction. This presupposition is arguably questionable as it is not fully supported by some recent experimental findings (Mao et al., 2021), as quantitative evidence in this regard is still lacking. Hence, this work employs mathematical modelling to demonstrate that enhanced microwave extraction is not necessarily caused by cell rupture, in contrast to the currently prevailing literature trends. It is intended to further expand this work to the scale of a full journal article.

Synergistic benefits for the food industry from the emergence of the biorefinery sector

Prof. Grant Campbell.
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Fears over antagonism between the food supply chain and biorefineries, simplistically presented as “food vs fuels”, have obscured the opportunities for synergistic benefits between the food industry and the emerging biorefinery industry. As well as environmental benefits that could be achieved through integration of co-located food and bioprocessing facilities, there are components of biomass of particular interest as food ingredients, but not currently economical to produce, that might be feasible in the integrated context of a biorefinery. Arabinoxylans serve as an interesting example, promising as food ingredients but not currently commercially available, and potentially able to be co-produced economically through integration with bioethanol production, enhancing the economic viability of the biorefinery and its opportunity to deliver its environmental benefits. In order to deliver these synergistic benefits, the biorefinery engineer needs to be knowledgeable about biomass fractionation, extraction and conversion technologies, and skilled in the tools of process integration, to design and operate technically feasible processes that maximise both environmental benefits and business profitability. The biorefinery engineer must also appreciate the complex and variable nature of biological raw materials, the strict hygiene and consistency requirements of ingredients for the food industry, and the complexity of food systems and ingredient interactions. These considerations introduce a new scope of awareness that has been absent as long as food and biorefineries were kept at arm’s length; the thesis of this presentation is that bringing these two sectors together offers synergistic benefits that will require a new scope of skills and knowledge for the biorefinery engineer seeking to include the food industry in the scope of the biorefinery sector’s beneficiaries.

Navigating the reduction of single-use plastics in the supply chain

Reducing Single Use Plastics with Alternative Retail Packaging for Mushrooms

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Coming legislation will remove single-use plastics from packaging. The Single-Use Plastics (SUP) Directive, requires all 27 EU member states to enforce the new guidelines. Norway, despite not being a member of the EU, is also implementing the SUP directive as a member of the European Economic Area. Next generation alternative materials must match or better the performance of existing technologies in both price and functionality. It is possible to do this by exploiting the particular properties of agricultural waste materials (better described as co-products). To ensure the commercial success of this project, manufacture methods were chosen that are based on current practice. The commercial uncertainty of introducing novelty in materials and manufacture will clearly militate against commercial take up. Further, the development work on materials has focused on augmenting those currently in commercial use: principally Kraft pulp which has been used in packaging since the 1860s. The original scope of work was based on mushrooms due to the potential for novel properties identified in previous work. The scope was extended to include carrots after examination of the quantities of raw materials available from various foodstuffs. Coffee grounds were also examined

The primary aim of this work described is to identify and quantify the range of physical and mechanical properties available to allow commercial end-users to select appropriate formulations to suit the end-users choice of application, whilst ensuring that the final products can be practically manufactured. In addition, assessments were made of the risks of microbial, pesticide and heavy metal residue contamination, food storage shelf life, the presence of allergens, the presence of acrylamides, and compostability (EN13432).

Control of Listeria monocytogenes in RTE foods using novel antimicrobial and biodegradable interleave film.

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Nowadays, common plastic packaging is giving rise to active food packages that also interact with the food product directly to increase both its shelf-life and microbial safety. Additionally, plastics pose a serious environmental hazard globally and should be substituted by eco-friendlier solutions. Hence, the development of biodegradable packaging has risen as a viable choice to plastics. In our study, we describe the formulation of carboxymethyl cellulose CMC films incorporated with the surfactant ethyl lauroyl arginate (LAE) that has been complexed with the polyoxometalate [SiW11O39]8-, to reduce the water solubility of LAE, forming LAE7[SiW11O39]- (POM-LAE).

Regarding the antimicrobial activity, POM-LAE has shown effectiveness against Listeria monocytogenes and Escherichia coli with minimal inhibitory concentrations (MIC) of 32 and 64 µg/mL, respectively, with the important finding that LAE inhibitory concentrations were 50% less in the POM complex than in LAE alone. In addition, POM-LAE is an effective inhibitor of biofilm formation and is also able to destroy pre-formed biofilms of L. monocytogenes and E. coli at MIC concentrations. POM-LAE was incorporated to CMC films cross-linked with citric acid to improve their water resistance, and casted in 96-well plates and 12x12cm square plates. For the in vitro assays, CMC films with 5-10% POM-LAE were able to reduce 7-8 logCFU of L. monocytogenes, respectively. Meanwhile, for the in vivo assay with cured ham, film pieces were placed as an interleaved film between two cured ham slices inoculated with L. monocytogenes. POM-LAE CMC films were able to avoid initial bacterial exponential growth, thus maintaining significant less bacterial counts during the storage period. Overall, this work provides new alternatives for the development of antimicrobial biodegradable films for RTE foods prone to be contaminated with pathogenic bacteria, especially Listeria monocytogenes and helps to circumvent the issues related with LAE incorporation and release from packaging films.

Innovative, eco-friendly, biodegradable and non-toxic: an active packaging based on cyclodextrin nanosponges for ethylene removal.

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Over the last decades, consumers are deflecting towards biodegradable or bio-based packaging over traditional ones, to overcome the rising environmental concerns caused by plastic materials and food waste. Unlike traditional ethylene scavengers such as potassium permanganate, cyclodextrin nanosponges (CD-NS) are biosourced and virtually nontoxic. The aim of this work is to use the potential of CD-NS to encapsulate small gas molecules such as ethylene and develop a new green active packaging by incorporating them into a compostable packaging material. In this work, a solvent-free, green synthesis of α-CD-NS was successfully achieved from a-cyclodextrin and carbonyldiimidazole at a 1:4 (CD:CDI) molar ratio on a PM 100 planetary ball mill. After a washing step with water, the presence of contaminants (unreactive CDI and imidazole) was assessed by validating a liquid chromatography coupled to a diode array detector (HPLC-DAD) method targeting imidazole, allowing to achieve high yield (>98%) food-grade CD-NS. The in-house synthetized CD-NS, and commercial zeolite and bentonite powders were exposed to an ethylene gas standard (10ppm) for three days. Then ethylene was measured using gas chromatography (GC) coupled to a flame ionization detector (FID). With a 39% scavenging efficacy, CD-NS demonstrated three times more ethylene removal capacity when compared to zeolites and bentonites. A series of different biopolymer films provided by NUREL S.A (Zaragoza, Spain) were assessed according to EU regulation 10/2011. Migration of non-volatile polyester oligomers exceeding in some cases the migration limit by 100 times, classified these films as potentially unsafe as food contact materials.

Due to their biological origin, scalability, and non-toxicity CD-NS can be considered an ideal ethylene removal candidate for novel bio-packaging approaches, as they have demonstrated a high scavenging potential. Manufacture of the biopolymer films studied should be further modified in order to increase their food safety. Overall, the in vitro results showed that CD-NS can effectively open the doors for an innovative, ecofriendly, ethylene removal active packaging.