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EMERGING RESEARCH

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# An innovative food system approach to diversifying protein intake: Protein-I: Shared Island sustainable healthy nutrition

Lorraine Brennan[1] | Aoife O'Gorman[1] | Susanne Barth[2] | Trevor Cadden[3] | Moira Dean[4] | Fiona Doohan[5] | Maeve Henchion[6] | Ronan McIvor[3] | Breige McNulty[1] | Cathal O'Donoghue[7] | Seamus O'Reilly[8] | Joseph Rafferty[3] | Helen M. Roche[1,4,9] | Fiona Thorne[6] | Martina Wallace[1] | David Wright[10] | Anne P. Nugent[1,4]

[1]Institute of Food and Health, School of Agriculture and Food Science, University College Dublin, Dublin, Ireland

[2]Teagasc, Carlow, Ireland

[3]Ulster University Business School, Belfast, UK

[4]Institute for Global Food Security, Queen's University Belfast, Belfast, UK

[5]School of Biology and Environmental Science, University College Dublin, Dublin, Ireland

[6]Teagasc, Dublin, Ireland

[7]National University of Ireland, Galway, Ireland

[8]Cork University Business School, University College Cork, Cork, Ireland

[9]Conway Institute, University College Dublin, Dublin, Ireland

[10]School of Medicine, Dentistry and Biomedical Sciences, Queen's University of Belfast, Belfast, UK

**Correspondence**
Anne P. Nugent, Institute for Global Food Security, Queen's University Belfast, Belfast, Institute of Food and Health, School of Agriculture and Food Science, University College Dublin, Dublin, Ireland.
Email: a.nugent@qub.ac.uk and anne.nugent@ucd.ie

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## Abstract

There is a need to transform our current food system if we are to feed the rapidly expanding global population while maintaining planetary health. Within the island of Ireland, there is an urgent need to diversify the foods that currently contribute to our populations' protein intake. A Shared Island Innovative Food System approach is required to achieve this in a manner that is sustainable and provides benefits to producers, consumers and other supply chain participants. The *Protein-I* project employs such an approach, with the paradigm focusing on production of plant food through to human health, while paying particular attention to the development of the rural bioeconomy. Using an interdisciplinary approach, the team will develop strategies to maximise sustainable plant protein production in a traceable/transparent fashion and assess the impact of changes to existing value chains and the development of new value chains for the rural economy. A smart supply chain technology solution tailored to the needs of the agri-food industry will be developed and tested. Additionally, we will co-design consumer-led approaches to diversify plant protein intake, model the impact of changes at the population level and perform human interventions to demonstrate efficacy in terms of achieving adequate nutrition and improved health. Comprehensive engagement with stakeholders is embedded throughout the whole project to embrace the multi-actor approach. Overall, the project will be a key step towards future-proofing our food system on the island of Ireland and moving towards protecting planetary and population health, within the context of a just transition.

**KEYWORDS**
bioeconomy, dietary change, food systems, plant based, protein, supply chain

## INTRODUCTION

The need to transform food systems so they become sustainable, healthy, safe and inclusive is well documented (Bhunnoo & Poppy, 2020; DAERA, 2021; EU, 2020). Such a system approach is essential where one cannot implement changes in one sector without consideration of the co-benefits/trade-offs for other sectors. Hence, integrative and participatory research and innovative approaches are deemed crucial (Den Boer et al., 2021).

The present project, *Protein-I*, adopts such a food system approach to both the production and consumption of protein for food purposes. The core driver of *Protein-I* is the need to diversify plant-based foods on the island of Ireland, with a final objective to diversify the foods contributing to dietary protein intake and enable a shift towards sustainable dietary patterns.

### Protein-I conceptual approach

There has been increased emphasis to shift towards more plant-based protein for environmental and dietary reasons (BDA, 2021; FSAI, 2019; Willett et al., 2019). Current plant production systems in Ireland are optimised for a narrow range of plants, with scope to expand to meet the growing demand for plant proteins in a sustainable manner. However, the system is facing a number of challenges, which at present restricts its development. Such challenges were highlighted in a recent report and include for example the need to develop resilient crop varieties to cope with water and temperature stresses in context of a change in use of plant protection products due to EU policy (Crops 2030, 2020). Further, the majority of crops grown (cereal, oilseed rape and protein crops; e.g. peas and legumes) are used as feed for the livestock, pig and poultry sectors (Crops 2030, 2020). Between 2014 and 2018, Ireland's self-sufficiency decreased from 41% to 21% due to the animal sectors' increasing dependence on imported feed. Therefore, there is significant potential for growth and enhancement of the local economy by utilising locally grown crops to support both animal feed and food production as part of any transition to a more plant-based diet (Crops 2030, 2020). To overcome these and other challenges, new actions are needed.

However, any such shift towards increased plant production will not be sustainable if it is not economically viable or equitable unless there are alternative income or livelihood options available to the actors involved. To support the agri-food industry with such changes, a tailored, smart supply chain technology solution is required. From a diet and health perspective, the impacts of such shifts on nutritional adequacy or on benchmarks of population environmental footprint are unknown. Due consideration is needed about how such a change may influence metabolism and health outcomes, including specific population groups where optimising protein intake is recommended (e.g. older adults). At present, it is suggested that only 16% of Irish adults adhere to a flexitarian diet with much lower proportions adopting vegetarian (8%) or vegan diets (2%; Bord Bia, 2021). This is supported by national dietary survey data which suggests that, similar to other Western countries, Ireland has broadly adequate mean intakes of protein (~18% energy/day [IUNA, 2009; PHE, 2020]) which are mainly animal-based (63% of protein) rather than plant-based proteins (37% protein; Hone et al., 2020). Essentially, given that diversification of protein intake and any dietary shifts will depend on consumer acceptance, there is also a need to evaluate and co-create with consumers any solutions designed to facilitate uptake of healthy, sustainable diets. *Protein-I* will address these considerations. Funded by the Department of Agriculture, Food and the Marine (Ireland) and the Department of Agriculture, Environment and Rural Affairs (Northern Ireland), the project aims to future-proof the island of Irelands' food system through engaging in an interdisciplinary project ranging from crop production to human health, while paying particular attention to the development of a rural (bio)-economy. Starting in April 2022, this 5-year project, led by Prof Lorraine Brennan at University College Dublin, brings together an interdisciplinary team from six universities and research institutes across the island of Ireland (National University of Ireland, Galway; Queen's University Belfast; Teagasc; University College Cork; Ulster University). Contributing scientists bring expertise in crop science and plant health, human nutrition, consumer psychology, operations and supply chain management, social and public policy and the rural bioeconomy. Through a series of 10 inter-dependent work packages, the overall concept of *Protein-I* is to provide the evidence base to enable a diversification of protein production and consumption on the island of Ireland (see Figure 1). Underpinning this programme will be continued engagement with stakeholders and industry to ensure there is a long-term pathway to impact. For example, we will engage with local regional organisations such as Cill Ulta (a centre promoting food sustainability and sovereignty in North West Ireland; https://cillulta.ie/).

### Work packages

The project is composed of 10 interlinked work packages (see Figure 2). Work packages 1 and 10 relate to knowledge transfer and project management respectively with the remaining eight work packages focusing on the scientific work programme, stakeholder engagement and the dissemination of results arising from the research. A brief description of the work programme is given below.

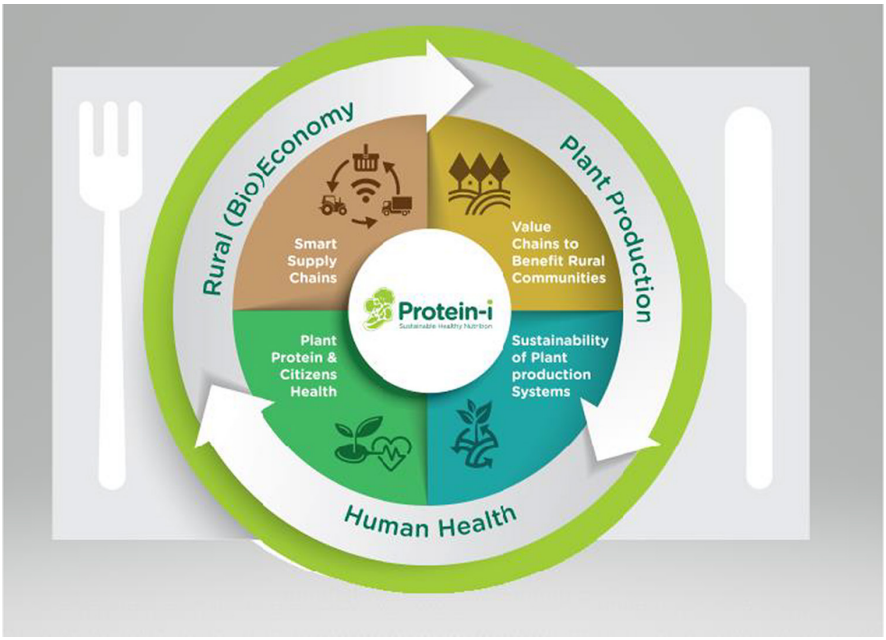


**FIGURE 1** Schematic overview of Protein-I conceptual approach. The figure highlights the system approach taken by the project in terms of its multi-disciplinary work packages. The project incorporates plant production (value chains and sustainability) (WPs 2, 5); human health (WPs 4 & 6) and rural (bio) economy (WPs 3 & 7) in a system approach. WPs are independent but interlinking with other WPs.

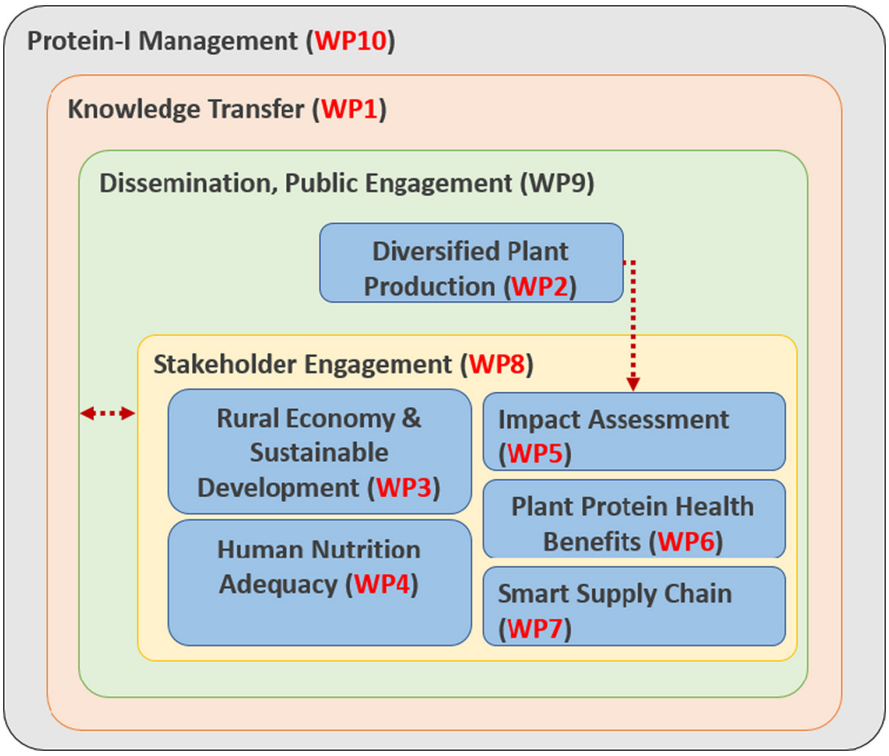


**FIGURE 2** Protein-I work package structure

## Smart, sustainable and diversified plant production (work package 2)

The rapid increase in the consumption of plants (vegans, vegetarians, flexitarians) coincides with the roll-out of the EU Farm to Fork strategy (EU, 2020), which is based on the development of sustainable food systems, including reductions in pesticide and fertiliser inputs. Thus, there is potential to reimagine crop production systems such that farmers are offered the potential to produce a diversified portfolio of crops under sustainable management regimes, serving regional needs of food processors and distributors to produce products targeting both national and international markets. This work package will focus on enhancing the sustainability of such production systems, through the assessment of alternative and reduced input regimes, the potential of diversified crops and the conversion of crop waste material into value-added protein. Crops to be examined include but are not limited to oats, wheat, peas and quinoa. Organic manures and recycled bio-based fertilisers will be trialled as the nutrient source

to lessen reliance on imported conventional mineral fertilisers. Many of these fertilisers also contain carbon and thus may help to retain or build soil carbon levels in tillage soils with sustained usage compared to a purely mineral fertiliser approach. Biological seed treatments will be trialled to determine their potential to replace and/or augment chemical treatments in order to improve crop establishment and enhance resistance/disease resistance. They have shown potential for enhancing the performance of crops at field level, including disease control and enhanced performance under low input systems (Lamichhane et al., 2022). While diseases pose a threat to crop production, many of the causal fungi may also have the potential to convert crop residues to high value-added protein and thereby embrace a circular economy. This will also be investigated.

## Rural economy and sustainable development (work package 3)

While a shift in diets is required to enhance nutrition and health and to reduce the negative environmental impact of food production (Clark et al., 2019), such a shift will not be sustainable if it is not economically viable for all actors concerned. Furthermore, it will not be just unless options, for example, in terms of new income streams and livelihoods, are generated for the actors affected by such shifts. The utility of assessing value chains and co-designing pathways to support the realisation of the proposed value chains is increasingly recognised. 'Promoting value chain development is increasingly being recognised as a promising approach to address not only economic development, job creation and inclusive growth, but a wider range of social and environmental development issues' (Stamm & von Drachenfels, 2011).

This work package adopts such a value chain approach. It will engage with primary producers, social enterprises, rural communities and other supply chain and food system actors to assess the impact of the dietary shifts proposed within *Protein-I*, in line with the need for such changes to occur within more bio-based, sustainable, circular systems. It will work with such actors to co-design pathways to sustainable business models that will enable the realisation of associated value chains. It is recognised that realising the opportunities identified and progressed in this project will require primary producers to enter new value chains (e.g. quinoa, not previously grown in Ireland), upgrade existing value chains (e.g. shifting from producing crops for animal feed to human food) or establish new value chains. Such value chains may be local, regional, national and/or international. Through a series of value chain mapping, quantitative surveys, co-design workshops and economic, spatial, social and environmental impact assessments (Boulanger et al., 2022; O'Donoghue et al., 2012, 2019; Ramilan et al., 2011; Sckokai & Moro, 2009), this work package will address key areas such as:

> integration of primary producers into existing value chains; how can producers work with others to establish such chains; factors impacting their willingness to do so; impact on economic viability of these alternative value chains at the farm level and the subsequent impact on the local/regional/national economy, greenhouse gases (GHGs) and nutrition.

The work package will be approached at a local, regional and national level so that appropriate governance systems can be developed and policy recommendations can be made at different scales. Central to this work package will be continued engagement with associated partners (such as Cill-Ultra), members of the project stakeholder advisory group and other relevant actors locally and nationally. A critical initial output from this engagement will be the definition of what is meant by local, regional and national scale in the context of *Protein-I* value chains.

## Human intervention study to demonstrate plant protein diversification on dietary nutritional adequacy (work package 4)

Any attempts to reduce intake of animal proteins and increase consumption of plant proteins need to pay particular attention to the nutrient profiles of the diets. Indeed, the nutrient profile of different protein foods can vary considerably and there is no clear consensus on how we can alter the animal/plant protein ratio and maintain adequate nutrient profiles. Currently, there is limited information from randomised controlled trials (Itkonen et al., 2021; Pellinen et al., 2022). Concomitant with this is the need to develop novel approaches to enable individuals to shift their dietary patterns. Supported by recent literature (de Gavelle et al., 2019), *Protein-I* acknowledges the current protein dietary pattern as the starting base diet and seeks to introduce changes to enhance diversification of protein intake that take into consideration personal habits across food systems rather than focusing singly on specific animal or fish systems. For example, in Ireland, patterns of dietary intake can be established relating to predominately red meat, white meat, a mixed pattern or a flexitarian pattern. Food groups within each of these patterns will be identified and utilised to diversify protein intakes within this intervention. This novel approach to a dietary intervention has the potential to identify a mechanism to introduce protein diversification that will be achievable for the Irish population while ensuring

nutritional adequacy. Specifically, it will perform a dietary intervention to demonstrate the impact of diversification of protein intake on dietary nutritional adequacy, biomarkers of nutritional status and health while also capturing the acceptability of the dietary approach. The overarching aim of this work package is to supply evidence to support future implementation of diversification of dietary patterns in the island of Ireland.

## A holistic assessment of the impact of diversifying protein food sources in the Irish diet – dietary modelling, consumer studies and prototype considerations (work package 5)

As previously mentioned, national food surveys for the island of Ireland describe broadly adequate mean intakes of protein (~18% energy/day [IUNA, 2009; PHE, 2020]). Animal-based proteins are consumed to a higher degree, with intakes highest in 18- to 35-year-olds, typically consumed at dinner and lunch (Hone et al., 2020). In contrast, dietary recommendations advocate a shift towards inclusion of more plant protein (e.g. legumes, nuts) and setting upper guidance values for red meat as part of sustainable diets (FSAI, 2019; NHS, 2018), with a recognition that plant protein sources may be unequal: some associated with healthier diets than others (Baden et al., 2019; Salome et al., 2020). Previous research has also shown that when 'new' foods are introduced onto the market the level of acceptance depends on different factors: such as the country, the base product (staple, or hedonistic) and the processes involved (e.g. fortification, fermentation), as well the perceived level of need of the individual (Verbeke, 2005). Sensory, physiological and social factors are involved (Meiselman, 2008; Shepherd, 1989). Consumer research has also shown that food consumption is habitual and routine and changing food choice behaviours is notoriously difficult (van't Riet et al., 2011). Therefore, the introduction of diversified and diversified protein food sources requires that consumer needs and perceptions need to be identified from the beginning (Urban & Hauser, 1993).

Collectively, there is a need to understand the impact of including diversified and novel protein food sources on Irish dietary quality, diversity and adequacy, accounting for consumer needs and perceptions and likely adoption. This work package will holistically examine this need involving a series of dietary modelling studies accounting for a variety of dietary shifts using UK and Irish national food consumption data (IUNA, 2009; PHE, 2020) and quantitative and qualitative research with consumers with a view to co-creating solutions to facilitate uptake of alternative protein food products, processes and diets.

## Smart technology to support personalised nutrition interventions & health benefits of sustainable plant protein and fibre solutions (work package 6)

This work package recognises the requirement for innovative, value-added products for industry and that fundamental to this is the production of the scientific evidence base in terms of health benefits. Wearable sensors are a future technology that will assist health monitoring, in response to specific health-promoting food solutions. In this regard, *Protein-I* will address the combined benefits from concomitant consumption of both plant protein and fibre, using novel, non-invasive real-time health sensors. Adequate dietary protein and fibre intake prevents many age-related, diet-mediated chronic diseases (de Marco Castro et al., 2021; Murphy et al., 2021) and counteracts the adverse effects of high-saturated fat diets on metabolism and inflammation (Roche, 2021). Thus, targeting plant protein and fibre solutions may be particularly beneficial in vulnerable groups. Currently, intake of both nutrients by older adults in Ireland is sub-optimal (FSAI, 2021; Kehoe et al., 2021). Collectively, plant protein and fibres have great potential efficacy with respect to modulating several metabolic health parameters in this age group. Allied to this, real-time, health monitoring is developing very rapidly such that people will soon be able to 'measure' their 'health response' to food intake at home. This is both a challenge and opportunity for the food industry as it will allow consumers to measure their personalised health responses to eating a given food or meal.

In collaboration with the University of Texas (Prof Shalini Prasad), this work package will utilise a previously developed, wearable technology (smart watch) that measures a range of metabolic and inflammatory markers in sweat (Ganguly et al., 2021; Jagannath et al., 2020; Upasham et al., 2020). Using a series of intervention trials and with mix of plant proteins and fibres, the work package will examine the utility of the watch to characterise the metabolic and inflammatory responses to plant protein and fibre intake to support Personalised Nutrition solutions.

## Secure, tangible, supply chains supporting agri-food provenance and efficiency (work package 7)

The overarching aim of this work package is to establish a smart supply chain technology solution tailored to the needs of the agri-food industry which supports transparency. Specifically, it will develop a user-friendly, accessible and innovative, supply chain technology solution capable of providing security, traceability, visibility and sustainability throughout the supply chain.

Early studies of digitisation on supply chains have reported many benefits, including cost and reduction, enhanced environmental outcomes and innovation in organisations (Cadden et al., 2022; Dubey et al., 2019). However, weaknesses remain in current systems, particularly regarding security and confidentiality. This work package will utilise the team's prior learnings in Digital Technology research projects, such as 'Telco Management Forum – Smart supply chains for Industry 4.0' – which was an international award-winning multi-million-pound research project with over 30 blue chip industrial partners: https://dbm4.net/secure-supply-chain/. These learnings will assist in developing a Digital Technology solution that augments and expands what is currently available in research and commercial offerings in developed technology sectors and addresses the needs of the Agri-food industry, which is still in its infancy in the adoption of Digital Technology. Using the design concept known as 'dual hosted Distributed Ledger Technology', a method to securely track and verify the lineage of agri-food produce will be developed accounting for standard blockchain solutions and more 'lightweight' solutions where more flexibility may be applied regarding computational overheads and rigid functionality.

### Stakeholder engagement and dissemination (work package 8 and 9)

These work packages aim to create an efficient and open channel of communication between *Protein-I* and a diverse group of stakeholders from across the Food System and to ensure a wide-ranging yet targeted dissemination and public engagement strategy. This will ensure that the *Protein-I* work programme reflects end-user needs. Engagement with such stakeholders will be key in understanding the appropriate way strategies for maximising sustainable protein intake should be designed and implemented in the island of Ireland. In the context of maintaining planetary health and the increasing world population, this work package will advocate for sustainability and the need to diversify the foods that contribute to the protein intake of the population. This will be achieved through a series of workshops and one-to-one meetings on the needs of stakeholders regarding human health, economic value and further rural bioeconomy development. Dissemination and public engagement will centre on papers, people, place and policy engagement.

## CONCLUSIONS

*Protein-I* is an innovative, Shared Island, food system approach focusing on diversification of protein production and consumption on the island of Ireland. Our paradigm focuses on the production of plant food through to human health and consumer acceptance, while paying particular attention to the development of the rural economy and supply chain solutions. Although this article is written as discrete work packages, there are many inter-work package synergies, which are specifically designed so that learnings from one work package inform other relevant tasks as reflected in Figures 1 and 2. One such example relates to WP2 and WP4 where synergies between crop and human nutrition scientists will be exploited to select crops for optimal nutritional profiles/benefits and ensure that the human intervention trial uses food products relevant for Irish crops. Comprehensive stakeholder engagement is embedded throughout the project to maximise multi-actor engagement and ensure due diligence and to maximise co-benefits across the food system. Collectively, this Shared Island project will be a key step towards future-proofing the food system on the island of Ireland.

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## CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

## DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated, or the article describes entirely theoretical research.

## ORCID

*Anne P. Nugent* https://orcid.org/0000-0002-0206-1320

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