LEGUME PERSPECTIVES

'Home-grown' Legumes

Increasing their cultivation, use, and consumption

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'Emma', courtesy of Prof. Marta Vasconcelos,
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EDITORIAL

Welcome to this issue of Legume Perspectives, which aims to showcase some over-arching examples of legume science across the value chain. Modern value chain structures and their associated business models should help ensure that the existential challenges facing humanity are addressed. These challenges are climate change and biodiversity loss, the latter includes crop diversity and the facilitation of different approaches to crop breeding, including the use of underutilise legume types. Ultimately this would ensure that a greater range of fit-for-purpose legumes better adapted to a wide range of biotic and abiotic stresses and delivering enhanced traits for ex-farmgate processes. Consequently, the legume science-base must also be multifactorial in its application, delivering improvements to environmental functions and nutritional provisions. Also, to do so in a manner that ensures that legume crops and their resultant processed products are commercially viable, for all the stakeholder involved across the value chain, and especially those at the extreme ends of the chains. Income protection for producers, and for consumers that legume-based products meet 'Quadruple-A' ideals: available, accessible, attractive, and affordable. These are significant science challenges, since we must surpass the academic, and adopt new ways of working, including the adoption of inter- and trans-disciplinary approaches, and social science methodologies. These will help inform research and development, and so choice-options: whether for business-models, consumption, or policy. The challenges are complex, and there is no "silver bullet". Legume-based solutions will therefore also take a diversity of forms depending on bio-geographical, socio-economic, and cultural contents. Towards this end, this Issue of Legume Perspectives also introduces the Legume Innovation Network, or LIN. Currently, a virtual and informal social network which aims facilitate legume-focused science-business interactions and ultimately to help deliver more-sustainable and -resilient system functions.

Pietro Iannetta
Roger Vickers
Frédéric Muel
Managing Editors of
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In this issue we draw together only brief perspectives and examples of the science, business and social innovation which is applied across legume-based value chains. The content is intended to provide inspiration to those readers who wish to help ensure that their research and development efforts have impacts – in terms of our understanding of the roles, and even potential roles, of legumes in food- and feed-systems, and so how best to apply that knowledge to achieve greater levels of 'home-grown' legumes. The call for more home- (European) grown legumes, is usually applied to grain legumes since the EU is conceived to be 'forage self-sufficient'. However, in many regions across Europe pasture-fed animals are supplemented with grains. Consequently, were there greater uptake of grass-legume combinations, and were these managed optimally, there would be decreased demand upon arable areas for cereals to supplement animal feeding. Reducing such competition for arable space may therefore facilitating crop diversification, including more cultivation of grain legumes for higher premium markets, such as those offered by aquaculture, human food, and even as you will learn here, beverage alcohol production – among many other potential markets.

It is also important to mention that global trade of legumes will and should remain an important contribution to the provision of feed- and food-security. However, a reality persists which sees the legume-dependant food system of Europe as 'legume import dependent', and these imports are directed towards mainly feed uses. As such, the potential environmental and human health benefits of home-grown (grain) legumes persist as forfeitures, and a 'better-balance' of imported and home-grown legume crops remains to be realised. Reinvigorating a love for local legume-based food cultures, and so increasing awareness among consumers of the fundamental role well-managed home-grown legumes play in achieving true sustainability - where environmental and societal needs are also better-balanced via more ethical and sustainable models of business and governance.

In reading this Edition of Legume Perspectives, I hope you will appreciate the need to exercise caution against an over-emphasise upon 'productionist' approaches which places undue pressures of growers and the production environment for ever greater yields, and instead balance this perspective towards ex-farmgate actors who are equally well-placed to deliver improved system functions. This 'better balance' can only be achieved by a diverse and cohesive community of legume-focused facilitative capacity-builders from all aspects of society, commerce, research, and NGOs - from across the value chain. In this, the power of an informed consumer, and of any age, should not be under-valued.



Left to right: Pietro Iannetta, Roger Vickers and, Frédéric Muel

The concept of the Legume Innovation Network

Frédéric Muel[1], Pietro Iannetta[2], Roger Vickers[3]

Abstract: The concept of the Legume Innovation Network (LIN) was borne in the outline plan of the TRUE project funded by Horizon 2020, the EU Framework Programme for Research and Innovation. It recognised that a valuable opportunity arises to maintain and grow a 'legacy-network', a connected web, linking people with similar interests enabling challenges to be resolved more-easily, with potential partners finding resources for mutual benefit, helping one another in an industry that is currently at a low level. Working with partners in the LEGVALUE project and as both projects neared their conclusion, the LIN was launched in the spring of 2021.

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Introduction

The world of legume research, innovation and trade is small compared to many other crop types. Dwarfed by interests in cereals and oilseeds, the significantly smaller crop area occupied by legume reflects relatively low current commercial values and investments surrounding legume crops.

In 2017 two large EU funded projects, embarked on a 4-year quest to empower legume-supported food and feed production across Europe, including the provision of advice to policy makers on how they might positively influence the production of legumes within the EU.

The TRUE project was largely focussed on innovations with legumes beyond the farm gate. The LEGVALUE project was more focussed on studies at production level and values along the supply chain. Both projects used real case studies in industry, at both pilot- and commercial-scales, working together to maximise the impacts produced. Networks have resulted, linking researchers and research bodies, industry with industry, industry with researchers and everyone with policy makers, brokers, and consultants, throughout Europe and wider afield.

A valuable opportunity therefore arises to maintain and grow a 'legacy-network', a connected web, linking people with similar interests enabling challenges to be resolved more-easily, with potential partners finding resources for mutual benefit, helping one another in an industry that is currently at a low level. This has huge potential, as the importance and multifunctional benefits of legumes are being increasingly realised by the wider world. The LIN can be a stakeholders' forum to promote awareness of new insights, services, or requirements for more commercially competitive production and consumption of legume crops in Europe - and directly help realise more sustainable agri-food systems.

The concept of this network has been coined as the **"Legume Innovation Network" (LIN)** and was launched softly towards the end of the TRUE project in spring-2021.

The LIN will initially, be started by those who formed the concept, but with a view to being quickly adopted by others, thereafter continuing to evolve to meet the needs of those within the network. The LIN should retain an enduring focus on legume-science, research, and innovation to address those issues, spanning the legume supply networks. Additionally, the LIN should be guided, by a founding constitution that ensures a wide membership base that embraces all aspects of:

- input and production, commodity processing and food technologies;
- trading markets, retailing plus new and emerging markets;
- cultural aspect including 'sustainable consumption and environmental impacts; and,
- socioeconomics, governance, and policy-development.

What is the primary objective of the LIN?

To connect legume-focused businesses, NGOs and research and technology organisations to help facilitate and accelerate knowledge exchange and sustainable commercial development within Europe. It is envisaged that bi-annual events might develop remotely, take place in different EU countries, or in partnership with other existing legume-based networks - ensuring special focus on identifying and understanding the opportunities and barriers which are particular to legume-uptake within each host country.

How was the LIN launched?

Throughout April and early May in 2021 a series of 8 extended webinars were hosted by the LEGVALUE and TRUE projects, during which their progress and findings were shared. The first in the series introduce the concept of the LIN, with presentations from influencers and policy makers. The last, saw the value chain coming together with the International Legume Society, presenting the case for the establishment of a coherent and enduring network, "*Bringing the Legume Innovation Network Together*". The full series of presentations can be found on the Legume Innovation Network YouTube channel (link), and the full virtual conference and associated resources are hosted on an explorable time line on the LIN web site (link).

Who can join the LIN?

The LIN is not exclusive. Partners of all forms will be welcomed by their common interest – to help realise sustainable and resilient legume-supported agri-food systems. Those interested in participating in this Innovation Network can register on the Hub (link) and ensure that they use the specific terms "Legume" and "Legume-innovation-network" as the "Key Words" section of the registration process. Registration is free: here.

LIN content is contained in a dedicated website (rebranded from the LegValue project) legumeinnovationnetwork.eu/, where interested parties can register in the stakeholder directory. Individuals should also join the LIN community to exchange interesting news, views, and ideas in a closed LinkedIn group (link), by simply accessing the Network and asking to join.

Anyone keen on closer engagement, with a vision for how they might use their connectivity to bring strength to the sector and encourage greater legume utilisation, is also welcome. Those with an ambition to see the growth of a diverse, effective, extensive, and stable network of legume connectivity may even wish to take a leading role in the development of the LIN for the future, and they are encouraged to help take the LIN forward.

LIN Legume Innovation Network

Pushing the boundaries in legume breeding

Frédéric Muel[1], Josiah Meldrum[2], Donal O'Sullivan[3], Diego Rubiales[4], Leopold Rittler[5], Bernadette Julier[6], Stig Uggerhøj Andersen[7], Fred Stoddard[8], Martine Leflon[1], Roberto Papa[9]

Abstract: This webinar, "*Pushing the boundaries in legume breeding*" was held on 29th of April 2021, devoted to the goals and objectives in legume breeding, the gaps, gap-opportunities, and management of expectations. It showed some recent advances and effort in legume plant breeding, a key element for the development of legumes in Europe. Legume breeding has been supported by the European Commission (EC) during the last decade, and several networks are established across the European Union (EU) to facilitate improved connectivity between the scientific and applied-practice communities. All the presentations of this webinar are accessible via hyperlink by clicking on the blue underlined coloured text below.

[1] Terres Inovia, France
[2] Hodmedod's, UK
[3] Reading University, UK
[4] Institute for Sustainable Agriculture, CSIC, Spain
[5] Donau Soja, Austria
[6] INRAE-P3F, France
[7] Aarhus University, Denmark
[8] Helsinki University, Finland
[9] Universita Politecnica della Marche, Italy

Opportunities from a retailer's perspective

A top-down approach was adopted here, since historically and 'productionist' perspectives have dominated attempts to enhance legume uptake, and it was thought potentially useful to start with a stakeholder who is the last in the value chain to be consumer-facing. Towards this end, Josiah Meldrum offered a presentation entitled, **'Gaps in legume availability, access and awareness of suitability for regional production in Europe'**.

The historical context is significant here and Hodmedod's was founded in 2012 following a community project that asked whether a small regional city could feed itself in a manner that addressed climate change and resource constraints. Quickly realising that the critical missing link was vegetable protein and specifically pulses, Hodmedods set about creating higher value, short routes to market that would incentivise production and consumption. Co-founder Josiah Meldrum explained how that work came to involve varietal selection, agronomy, and development of post-harvest processing capacities at small and artisanal scale, as well as marketing. Hodmedod's also sees an opportunity of such businesses to develop a role in plant breeding, to better respond to the growing demand among consumers for pulse crops, and a greater diversity of these, for human-consumption.

What now follows is a summary by species regarding the current state-of-the-art in legume crop breeding.

Faba bean – Donal O'Sullivan presented preliminary results from a small, experimental faba bean breeding programme conceived to cater for peripheral agroclimatic zones where large plant protein demand remains unmatched by commercial breeding of protein crops. In essence, he showed that a very simple approach of intense recurrent selection on individual plant seed yield from a highly diverse, highly outcrossing population leads to rapid gains in yield potential. Furthermore, this basic scheme can be adapted to local needs across multiple neglected agroclimatic zones with the use of stochastic simulation to optimise scheme designs and enhanced by a common marker-

Figure 1. Phenotyping of the ProFaba panel germplasm collection studying their interaction with the ProFaba rhizobial library.

assisted breeding platform.

Pea - Diego Rubiales. After decades of decline in dry pea cultivation in Europe we are facing a speedy recovery thanks to public awareness of the environmental and health benefits they offer. This development has directed policy measures to help promote pea cultivation domestically, within Europe. Parallel to the decline of pea cultivation in Europe there was a remarkable increase in Canada, made possible by a significant investment in pea crop breeding (and supported by the opportunity of high demand globally, mainly for animal (and aquaculture) feed). The predicted increase in pea cultivation in Europe, reinforces the need for concerted public-private efforts in pea breeding, to deliver cultivars adapted to more diverse cultivation areas, satisfying the needs of both the producers and consumers. Modern crop breeding and research-reporting was initiated with pea experiments of Mendel. However, subsequent progress in pea genomics has lagged other species over decades. Despite such restrictions, pea breeding science has made significant progress in genomics and phenomics. This has allowed some success in selecting cultivars capable of meeting the diverse needs of pedoclimates, producers, processors, and consumers. Progress is facilitated characterisation of a diverse array of genetic resources (i.e., pea germplasm collections) via the adoption and adaptation of existing tools, such as marker assisted selection, association genetics and genomics, and perhaps most recently 'speed breeding'. Some of the excellent achievements made are illustrated in the presentation.

On food legumes (pulses): such as lentils, chickpea, and dry common beans the breeding effort is even smaller than that targeted to pea and faba beans. However, there is today an increased interest for these crops due to the demand by the consumers for more healthy and sustainable food, and this has been recognised by food industry processors and retailers. Several commercial companies, and community interest companies and non-commercial charitable agencies, have initiated breeding programmes for these food legume species.

Soybean and, **The contribution of Donau Soja for developing soybean production and use in Europe'** - Leopold Rittler. During the last 10 years, soybean production in the EU and its neighbouring countries has experienced an enormous increase in production. Prolonging this trend, as well as embedding other grain legumes in a holistic and sustainable protein strategy for Europe, is a priority for Donau Soja. Donau Soja supports all its partners and members in progressing change to address social, environmental, and economic challenges in soya production and consumption. This will increase efficiency, fairness, and sustainability in European food and feed protein value chains.

EU projects on legume breeding: in addition to the species-focused efforts highlighted above, it was also noted that there is very strong interest from the European commission to support breeding focused research on legumes, especially during the last decade and via the Horizon 2020 framework programme, though now also the Horizon Europe programme too. Looking back at H2020, some are highlighted here.

EUCLEG: a foundation to boost legume breeding - Bernadette Julier. The full title of the EUCLEG (2017-2021) is "*Breeding forage and grain legumes to increase EU's and China's protein self-sufficiency*", and it developed improved breeding strategies for legume species that are commercially important: two commonly used forage species (alfalfa and red clover), and three grain species (pea, faba bean and soybean). Hundreds of accessions of each species were evaluated under multisite field trials and controlled conditions and genome-wide genotyped. Objectives and first results were presented illustrating the huge genetic diversity which is available for yield, quality, resistance to the major biotic and abiotic stress in all species. QTL have been detected through GWAS for most traits and genomic prediction has been shown to be very promising. This project highlighted that the genetic progress could be improved through molecular breeding. The breeders who participated to the project and benefited from classes are motivated to implement such a molecular breeding.

ProFaba: Developing improved *Vicia faba* breeding practices and varieties - Stig Uggerhøj Andersen. Europe currently has a substantial deficit in plant protein production, especially when it comes to grain crops with high protein content. With an average protein content of 29%, faba bean (*Vicia faba*) is a prime candidate for a widely adapted protein crop that could substantially contribute to reducing soy imports by increasing the local and sustainable production of plant protein in Europe. ProFaba has brought together faba bean researchers engaged in several national and international projects, including NORFAB, Papugeno, BEANS4N.AFRICA, PeaMUST, EUCLEG and Abo-Vici. The project carried out multi-site trials using two common germplasm collections. A broad, general panel, 'ProFaba200', and the 'Göttingen winter bean panel' which is dedicated to studying frost tolerance. The trials provide us with quantitative data on yield, disease and agronomic traits that are collected in a common 'Faba Base' repository (**https://faba.au.dk**), which we will use for analysis of 'Genotype x Environment' (GxE) interactions and phenological modelling. In addition, the project conducted in-depth phenotyping and detailed genetic investigation of specific traits of interest, including autofertility, disease resistance, bruchid-, acid- and frost-tolerance, rhizobium interactions, and protein quality."

DiVicia: a PRIMA project to revalorize faba bean and vetches in Mediterranean agriculture - Diego Rubiales. DiVicia (2020-2023, **divicia-project.org/project/**) is a project funded by PRIMA (Partnership for Research and Innovation in the Mediterranean Area), and Coordinated by Joëlle Fustec, Ecole Supérieure d'Agricultures of Angers, France. This project aimed to restore agrodiversity in Mediterranean cropping systems by revalorising faba bean and vetches. One major work package addressed characterisation of genetic diversity in *Vicia faba* and *V. sativa*, and ways to increase that diversity. For this, a collection of 300 Mediterranean accessions of each species has been gathered, multiplied, and distributed among partners for characterisation. They are currently being field phenotyped in multiple environments to support modelling of GxE interactions to predict genotype responses under climate-change scenarios. Dedicated screening for major diseases and drought responses are being performed for both species. The project collections will also be genotyped by high-throughput genotyping-by-sequencing. Phenotypic and genotypic data will be used in Genome Wide Association Studies (GWAS) to deliver molecular markers closely linked to the traits of interest, and so reduce the time taken to screening for breeding.

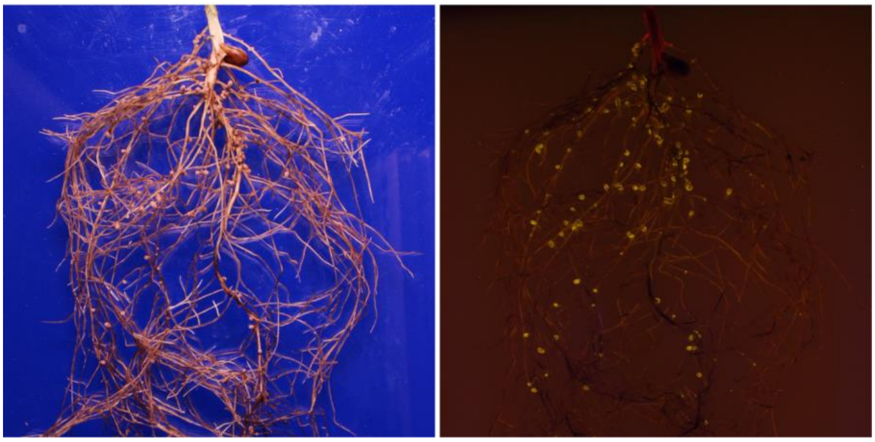

Figure 2. Left: Example of faba bean root systems after competition assays for nodule formation between tagged-rhizobial strains and indigenous rhizobial strains. Right: Roots exposed to a blue-light transilluminator to check nodules expressing GFP belonged to Tagged-strains.

The LegumeGap Project - Fred Stoddard. LegumeGap is an ERANET SusCrop project on yield-limiting factors for soybean and faba bean in Europe. It employs crop modelling, data mining, field experiments and geographical information systems to estimate potential yield across Europe – and, also, yield-impacts due to agronomic and value chain management, adaptation, and knowledge-sharing factors. Breeding-related results show if these legume species are to contribute to European crop and food systems, the high importance of resistance to abiotic and biotic stresses, along with regionally appropriate phenology, need to be more widely recognised and addressed.

Breeding networks: there is also important collaborative breeding and seed (genetic diversity) sharing ventures which take place among a diverse range of public and private stakeholders and through several networks which span Europe. Plant geneticists are well connected with plant breeders in this regard, and so the transfer from science to practice is operational in EU, though the extent of this is variable depending on the country (and/or regions) concerned. In addition, the extend and impact of participatory breeding among more-artisanal stakeholders and communities is less clear.

NORFAB and IMFABA: public-private partnerships in faba bean breeding - Stig Uggerhøj Andersen. NORFAB was established with the aim of developing a genomics-based breeding platform for faba bean through a collaborative effort by partners from Denmark, UK, Finland, and Canada. Through this program, genetic and genomic resources were established, including a high-quality reference gene set, a diversity panel and MAGIC populations. These new resources allowed the identification of the *vc1* mutation, which is the only known source of low content of the anti-nutritional, non-nutritional (or, 'antifeedant') factors, vicine and convicine. The Danish breeders, *Nordic Seed,* and *Sejet Plant Breeding* are central partners in the NORFAB project, and this public-private partnership is continued in IMFABA. IMFABA focuses on protein qualities, drought tolerance, yield stability, and the selection of inbred parental lines for generation of 'synthetic varieties' (*i.e.,* maintained by open pollination in isolation).

Groupement des sélectionneurs de protéagineux (GSP) - Martine Leflon. GSP is an economic interest group, which gathers the largest seed trading companies to facilitate and direct the research and breeding efforts of its members to improve of pea and faba bean (in France). Currently, GSP has 6 members (Agri-Obtentions, Florimond-Desprez, KWS-Momont, Limagrain, RAGT and Serasem), and receives direct support from Terres Inovia, the French technical centre for the oil and protein sector and Terres Univia, the French interbranch organisation for oil and protein crops, and products. Within the GSP, breeders jointly create and maintain pre-breeding populations to produce genetically improved donors. They also develop tools and methods and carry out field trials and tests under controlled conditions to characterise germplasm. The GSP activities are organised in three axes: 1, the resistance of pea to diseases, and more-particularly to *Aphanomyces*; 2, the genetic improvement of winter pea; and 3, the genetic improvement of faba bean.

Intelligent collections and participatory research for Food Legume breeding (INCREASE) - Roberto Papa (Bellucci *et al.*, 2021) (**https://www.pulsesincrease.eu**). INCREASE uses a cutting-edge approach to develop multi-omic strategies to facilitate the use of genetic resources for breeding of food legumes, and in particular of chickpeas, common bean, lentil, and lupin. At the same time, the project embraces a 'participatory breeding approach' with the stakeholder consortium, and a Citizen Science experiment.

To conclude, there is a large diversity of legume breeding programmes all over Europe, especially on pea, soybean, and faba bean, with a series of networks allowing good interaction between scientists and plant breeders. A targeted call on legume breeding is now closed for proposals, and those which are successful should gather potentially impactful legume breeding companies in the release of new legume varieties suitable for Europe, and so facilitate an increase in research, development, and open innovation for grain legumes worldwide. Presentations can be found on the website **LEGVALUE website.**

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Additional references can also be found on the website of **Legume Innovation Network**.

On-farm legume growing: barriers, opportunities, and success stories

Marie-Hélène Jeuffroy[1], Henrik Hauggaard-Nielsen[2]

Abstract: Despite the numerous agronomic and environmental benefits of leguminous species, their growing areas are still low across Europe. However, identifying successful farmer strategies provided experience-based knowledge to increasing legume cropping across Europe, and supporting agroecological transition, and protein sovereignty. Participatory research is a major determinant by which scientific knowledge gaps can be addressed. Furthermore, derived locally adapted knowledge, formulated through practical answers to frequent questions from farmers, advisors, and collectors, was organised in a specific decision-support tool. Yield assessment studies which modelled the potential impact and potential of current and future climates indicated that large areas of Europe are suitable for growing a wide range of legumes, and that available growing areas would also shift due to climate change.

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Even though legumes can deliver many agroecological benefits, they are not widely grown by farmers in Europe. Recent studies showed this is due to several barriers, one being that some farmers feel they lack knowledge regarding the agroecological impacts of legumes (1,2).

In addition, the attitudes, activities, and approaches of farmers to and for legume crop production are diverse. On one hand, many farmers are reluctant to grow legumes as they are usually less profitable than other major cash-crops (*i.e.,* wheat, barley, oilseed rape, maize, etc). Contrarily, farmer success stories exist about the environmental, social, and economic benefits of growing legumes. When surveyed, most of these farmers describe how they value the ecosystem functions and services which can be provided by legumes in their cropping systems, such as for example: decreasing input use for the subsequent crops; improving multi-year gross margins and profits thanks to their positive impacts on soil functions and so crop-nutrition and -health and overall performance. In an on-farm innovation tracking study, the approaches, reasons why, and assessment criteria used by legume growing farmers were studied, including legume-cereal intercrops (3). Around fifty technical leaflets were generated that formalised the knowledge derived from successful legume implementation, and these characterise the many ways farmers can optimise legume growing strategies. In some cases, legume growing was improved by intercropping with cereals.

Successful model approaches for key species can be drawn upon from the narratives (case studies) which have been presented from across Europe. For example, in a small area of Italy (Le Murge, Provincia di Potenza, Basilicate), a community group decided to reintroduce lentils cultivation after 40 years of absence. With its unique soil quality, Le Murge was found to produce lentils with very attractive nutritional qualities, and this provision is perceived to be the historic reason who drove ancient farmers to focus on the cultivation of this specific legume species. The initiative was supported by strong collaboration of dedicated actors from across the value chain

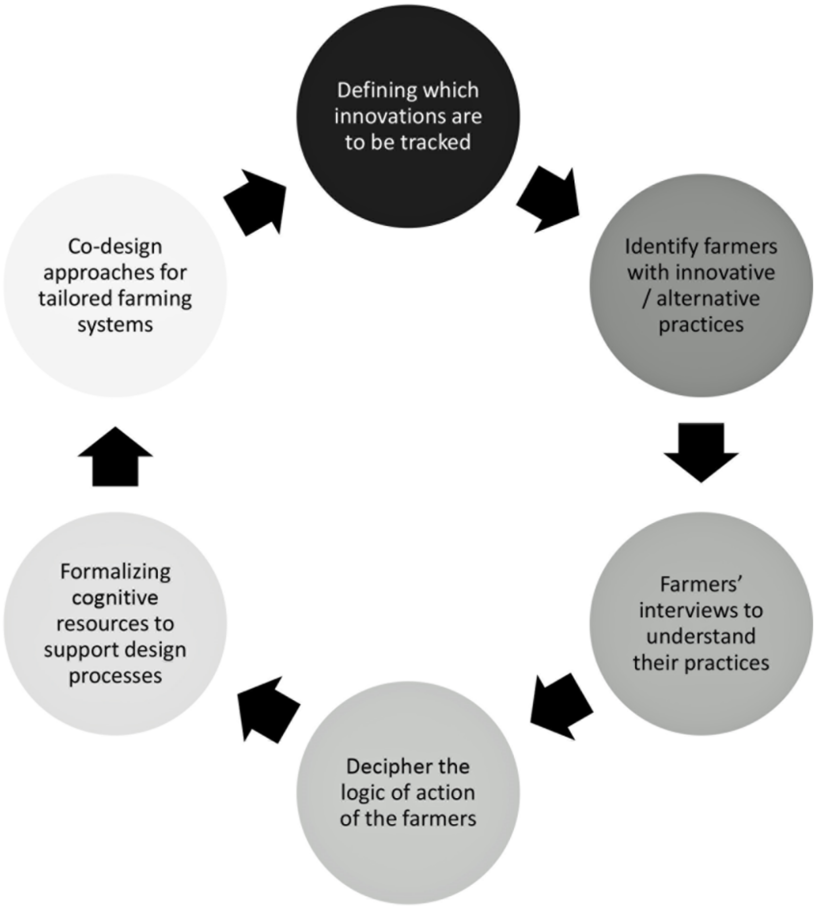

Figure 1. A schematic diagram highlighting how the impact of specific innovation may be better tracked via a specific sequence of researcher-stakeholder interactions. The feedback loop accommodates continuous interaction, and iteration of management decisions to achieve the specific ecosystem functions desired.

which included 196 farms cooperating on production, and the market value of these regional types attained 2.5 times more than that of the national average. In the UK, vining peas are grown on 40-50,000 ha, producing up to 200,000 tonnes of peas for the fresh-frozen market. Production is carried out by co-operative groups in areas suitable for pea production, from Eastern Scotland to the South-East of England, with two key partners – the Green Pea Company which contracting growers, and Birds Eye UK as processors. The issues associated with intensive production were highlighted, including the limited geographic area of the UK facilities good proximity to processing factories. The best farming locations offering particularly qualities for good high-quality yields and maturity prediction, based on specific pedo-climatic factors, to meet very strict factory schedules.

Nevertheless, a systematic literature review, based on 163 papers reporting on ecosystem services delivered from cropping systems with or without legumes, showed that published legume research, performed in the EU in the last 30 years, has mainly concentrated on a narrow range of services and legume species. Also, these were restricted to plot-level data, and within-season scales, and neglecting to account numerous other agroecosystem functions in which that farmers and ex-farm value-chain gate actors show strong interest, including a broad range of functions of importance to society more broadly (4). Therefore, if research aims to support farmers in overcoming knowledge gaps which are shown to be a barrier to increase legume growth in Europe, a number of additional objectives should be addressed. For example: i) more knowledge regarding the full range of legume species; ii) inclusion of ecosystem functions and services in system analysis, and for improved systems management, and; iii) local adaptation, including from farm scale and multi-year studies, in order to provide the agroecological knowledge base farmers need to increase the value of their legume growing.

Consequently, a decision-support tool-box prototype was developed to deliver knowledge and answers to the questions frequently posed by farmers regarding legume cultivation. The 'LEB-BOX' adopts local knowledge to support farmers and advisors through a full crop rotation economic calculator, describing the potential benefits of new legume crop production and with respect to main existing market outlets. For producers who use grain legumes, the tool provides recommendations on the best crop species for their pedoclimate, and system design to ensure optimised ecosystem functions, such as: improved soil fertility, lower inputs (nitrogen, pesticides, etc.), reduced greenhouse gas emissions, or better yield qualities.

In 2020, the European legume crops area represented less than 5% of the total agricultural land. This is despite the interest of legumes as key species for the political agroecological transition goals based upon the numerous agronomic, environmental and nutritional services they provide. Identifying suitable areas for legumes production under current and future climates appears essential. With this aim, a unique European Grain Legume Dataset was developed (5), gathering data from field experiments including legumes across Europe (~5000 yield observations in 21 countries). Moreover, simulation of achievable grain yield for five major grain legumes (soybean, field pea, faba bean, chickpea, and lentils) in current and future European climate scenarios was performed using a data-driven approach that combines observed crop yields in field experiments with machine learning techniques (6). Yield projections suggest high suitability for most crops under current climate, and important shifts in suitable areas for future climate. 'Blind spots', which are regions that provide no experimental data, were identified for several legume species in Europe, highlighting that there are likely to be important knowledge-gaps for crops that will be of interest for specific farmer communities and ex-farm gate value chains going forward.

An analysis of cropping systems across Europe showed a decreased nitrogen-fertiliser and pesticide use with similar working time and gross margins when legumes are included in the crop sequence (7). Using this data, scenarios increasing the share of legume-based cropping systems have been designed in workshops involving local stakeholders in six EU countries (France, Germany, Latvia, Lithuania, Netherlands, and Switzerland). These scenarios explore four contrasted socio-economic contexts depending on the relative importance given to either the environmental benefits, or open-global trading. The assessment modelled 3, 5, 15, or 19% of arable land dedicated to legumes in 2040, in comparison to 4% currently. While stable protein production may be achieved whatever the scenario, those scenarios which increase the legume cultivation in Europe lead to significantly lower use of mineral nitrogen (and energy), and produce nearly the same amount of proteins, leading to a much better efficiency of nitrogen, energy use, and so potential environmental benefits.

In conclusion, and though they are still not yet widely cultivated despite their benefits, it is demonstrated that greater cultivation of legume crops, provided: i) farmers added value via improved ecosystem functions (services), and great resource use efficiency for other crops in their crop sequence; ii) evidence and tools for farmers and farm-advisers to assess their (potential) economic benefits on a multi-year scale; and iii) the development of ex-farm gate capacities to ensure increased commercial value of legume grains, especially where improved nutritional and local-food cultural characteristics are offered.

More detailed information regarding the content presented here can be found on the Legume Innovation Network website **here**.

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Legume based value chains, farm gate and the market beyond

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Abstract: The development of legumes is strongly dependent on the ways markets and value chains are organized. The organizational arrangements in value chains impact the ways the added value is shared. They also affect the capacity of the stakeholders to collectively overcome various lock-ins which prevail among legumes as compared to major crops. In addition, institutional arrangements increase access to relevant information required for the business of the stakeholders. The aim of this study is to focus on two main insights: first, how the organizational arrangements that link economic stakeholders on markets favour a learning curve for legume production; second, how to increase the market transparency by sharing data on outlets, prices, price indicators and market forecasting, in order to help stakeholders to engage in legume production and marketing. Those insights were discussed by several researchers and illustrated by success stories of stakeholders from the case studies analysed.

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Introduction

Considering how value chains are organized and actors interact in markets, we know that a diverse range of networks exist, with many different mechanisms by which farmers may be linked to markets. This session focused on the fact that these networks can be strengthened through specific organizational arrangements such as crop 'production contracts'. A production contract is an agreement on a crop price, and on the production conditions and crop-specific qualities that are expected by the buyer. Those contracts are established before sowing and usually refer to 'certified seed' to be used. In most cases, it is observed that there is a 'chain of contracts' – for example, in the same way that a 'production contract' exist between an intermediary (e.g., seed trader or aggregator) and a farmer, contracts are also established between intermediaries and downstream actors such as 'processor', and so to retailers and markets. Usually, these contracts between the processor and intermediary generate those established with the farmers. In a few cases, it was observed that some processor-based contracts were directly drawn up with farmers. Moreover, those production contracts exist both for food and/or feed outlets. In all cases studied, production contracts committed all the value chain stakeholders to experiencing a learning curve regarding the best ways to develop legumes (1), highlighting a general and cross-value-chain lack of capacity in this regard.

Consequently, and given the relative underuse of home-grown legumes, developing legume-based value chains requires the establishment or renewal of the stakeholders' knowledge-base to overcome the lock-in situation. However, there is no consensus on the best mechanisms by which this knowledge capacity may be generated right across the value chain. Since such a capacity demands effective knowledge transfer through research-, extension-, and technical-advice services. The scale and organisation of such services varies greatly across the diverse range of socioeconomic models spanning EU countries and regions, which often means that such provisions are only weakly developed. The experience and knowledge of stakeholders is therefore increasingly recognised as complementary to the scientific and advisory knowledge services, and studies have shown that inter-organisational (i.e., non-governmental)

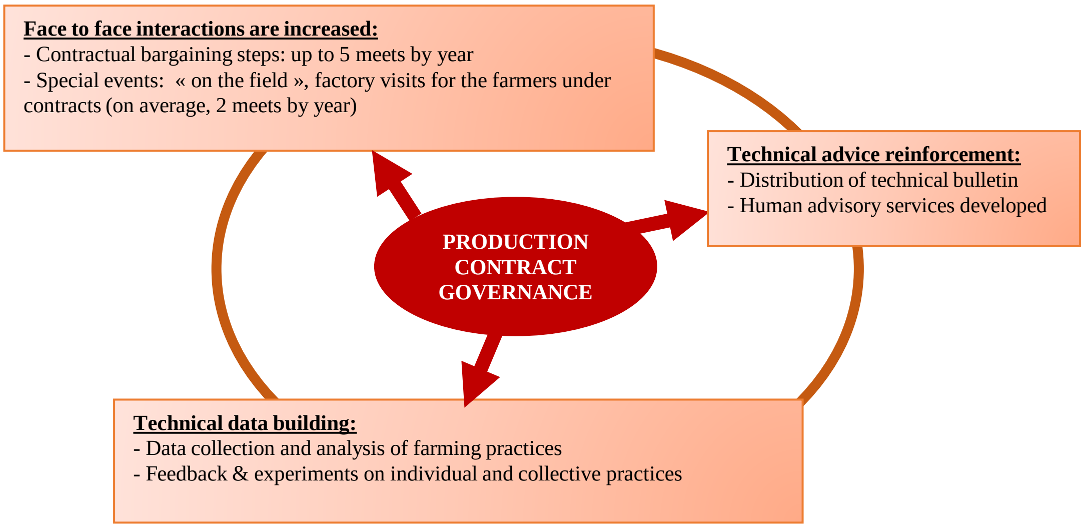

Figure 1. The socio-technical interactions generated by the production contract governance.

arrangements (*e.g.,* value chain governance structure) and cooperation allow more-direct social interactions, and so more-efficient coordination of knowledge exchange. Yet, the connection between those organisational arrangements and knowledge dynamics is poorly understood. The contracting of "propertisable knowledge" has been studied intensively and most notably via research and development contracts. However, there is a lack of evidence regarding how the contracting of goods may also favour knowledge creation and transfer. This session therefore provided an opportunity to highlight the differences between traditional crop-marketing contracts, where only the supply, quantity and price conditions are set, and crop production contracts (2). Production contracts generate interactions between actors in value chains determining the conditions for crop-production (Figure 1). In this process, these socio-technical interactions lead to an exchange of knowledge. These positive effects, in addition to the greater security in investments and incentive prices for farmers, take the form of the added values that production contracts initially target. First, those socio-technical interactions are face-to-face interactions when negotiating contracts. Also, special events such as meetings, workshops, demonstrations, which bring the farmers and ex-farmgate value chain stakeholders together, also contribute greatly towards more and improved knowledge sharing. Second, this knowledge sharing is also reinforced through additional technical advice that the contract-linked stakeholders decide. Third, for most case studies, the stakeholders invested in organising the collection of technical data for analysis, in order to develop adapted and improved advice for farmers.

It is particularly interesting to observe how the social interactions generated by the production contract and governance support develop new specific value chains through knowledge sharing. Historically, the impact of such interaction on knowledge, did not receive much consideration academically, for example in the development of theories on organisational economics. Therefore, beyond the case of legumes, the session provokes new considerations on the role and nature of contracts on value chain development. Results suggest that highly coordinated value chains, from agrifood firms to farmers can speed-up the agrifood transition we are aiming towards. The production contracts we studied clearly create more group commitments with specific investments in breeding, advice for farmers, though also informal opportunities for interaction and knowledge sharing. Hence, highly coordinated value chains present more learning effects, and facilitate the cultivation of new, or under-used crops and for the benefit of all stakeholders. Mainstreaming understanding through learning takes organisational effort, and a considerable period of time, and this long-term investment will be necessary to initiate uptake and learning-innovation frameworks for legumes.

From the perspective of grain aggregation, and even before considering any organisational arrangements linking the stakeholders of value chains, it is fundamental to consider that legume markets are currently still fragmented and non-transparent in many European countries (3). This is also a bottleneck for new market entrants. Increasing market transparency should make it easier for new stakeholders to enter markets for cultivation and use of legumes. In this session, an overview of international trade in field pea, field bean, chickpea and lentils was presented with a special focus on Europe. The main stakeholders with their specific outlets and the current trends were illustrated (4).

Three price indicators to support stakeholders' decisions were presented (Figure 2). The first is based on regression analyses with other crops used for feed, such as wheat and soybean. This reflects the lowest value and quality of grain legumes. The second price indicator is based on the determination of feed value of legumes in animal production. The third is determined by global trade data, and is known as a 'unit value', and can indicate added value of grain legumes routed to human food production. The simultaneous use of the three price indicators would help to identify a more-appropriate level of remuneration for home-grown legume grains, and which is in-line with their value-adding potential (5). The calculated price indicators would thus constitute practical upper- and lower-price thresholds, as an 'acceptable price band' within which cost negotiations between market players would take place based on quality, location, and time.

Finally, with respect to policies, we can uphold that the contractual markets generate a stronger "leverage effect" on crop

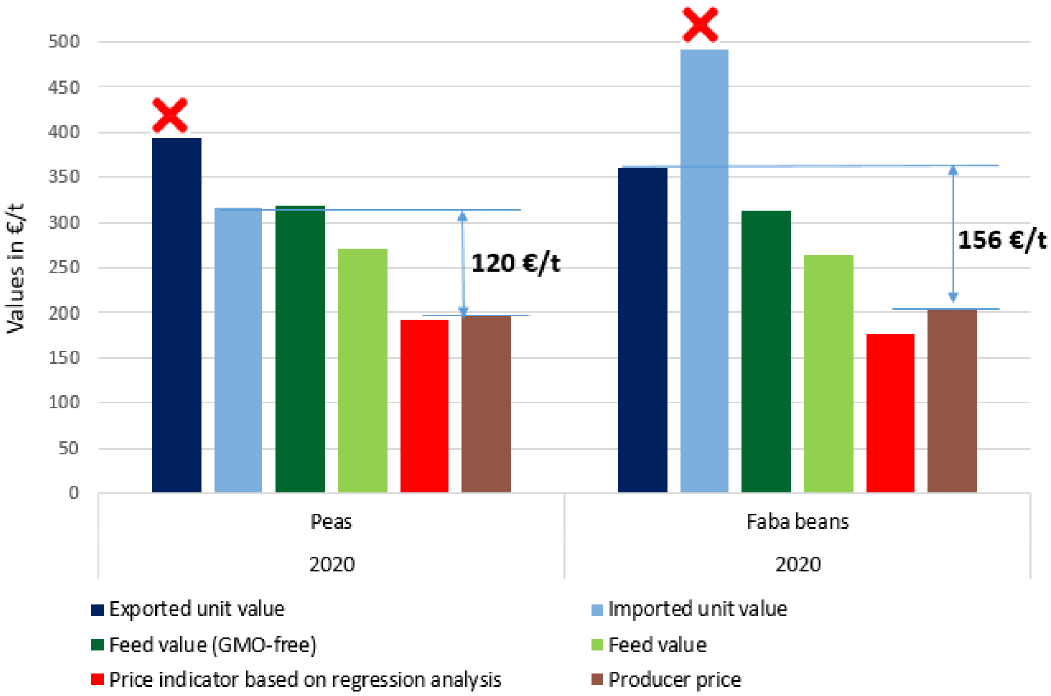

Figure 1. Price indicators for legumes.

subsidies, because commodities markets (or what we call 'spot markets') have not generated long-term investment in legume cultivation across Europe. This is an important point to consider for future legume policies. Furthermore, paying more attention to the market analysis and more-effective dissemination of market information on legumes is helpful for the value chain stakeholder's – especially for market segments catering for human food. Identifying, developing, and using various price indicators to help all stakeholders, especially farmers, to sell their legumes more profitably could provide an incentive for growing and marketing more legumes.

More detailed information regarding the content described only briefly here – please see the Legume Innovation Network webpages [here](#).

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The diversity of end-uses for legumes

Carla S. Santos[1], Marta W. Vasconcelos[1]

Abstract: Legumes have been reinvented in a multitude of innovative products (drinks, cereal bars, bread, meat replacers, snacks, flours, and several others) often combining ancient traditions of legume consumption 'with a spin', incorporating new legume technological knowledge in food (and feed) product innovation. Results suggest that consuming even only 80-100 g per day may be enough to maintain overall health, improve gut microbiota, and even help prevent cardiovascular diseases, diabetes, obesity, and/or cancer. However, the transition to legume consumption and utilisation has been slow and hampered by many cultural, societal, political, and economic impediments. Here we summarise the results from a selected number of initiatives presented at the Legume Innovation Network webinar entitled, "The diversity of end-uses for legumes". These aimed to enable the comeback of legumes and their placement in a diversity of end uses, becoming more prominent in human diets and animal feeds. The diversity of topics ranged from innovation for consumers and citizens, exploring the European food and feed system, to demonstrating developments in academic and industrial R&D, with a focus on health and nutrition.

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Food production needs to be improved to help realise more sustainable systems which are less dependent on mineral nitrogen and phosphorus inputs, use water more efficiently, and offer significantly lowered levels of greenhouse-gas emission, and increased carbon sequestration (1). In this context, more sustainable eating patterns have been suggested, based on the increased intake of plant-based protein in place of animal-based protein (2). Incorporating low-cost legume grains, that are rich in nutrients and demand low N synthetic nitrogen fertiliser requirements, into daily food items, can improve the nutritional and sustainability profile of national diets (3). Increased awareness of the need to move to sustainable-food systems via -consumption is revitalising legume production and food purchasing patterns across Europe. This has led to a compilation of innovations and initiatives that aim to re-establish legumes as a foundation for the food-system transformation. Many factors may have led to the exclusion of legumes from consumers diet in the past, including: 1) a low environmental or agroecological awareness; 2) the marginalisation of knowledge regarding legume´s health/nutritional benefits; 3) the long cooking and/or preparation time required for legume grains; and 4) their potential secondary effects via non-nutritional components. Strategically, the global food industry has been increasingly orienting its activity to tackle these consumer obstacles and this is reflected in contemporary food-fashion or dietary trends (e.g., flexitarian, vegetarian, gluten-free, etc.) in their innovation portfolios, increasing the incorporation of legumes and legume-based ingredients. This has led to the development of healthier and more sustainable food products at an unprecedented scale.

This webinar therefore summarised initiatives that aim to enable the return of legumes and their more-equal placement via improved understanding regarding versatility, and so diversity of end uses. Such capacity realisation will facilitate an increase in their prominence in human diets and animal feeds. The session focused on innovation for consumers and explored the European food- and feed-systems, showcasing both developments in academic and industrial R&D sectors.

A first contextualisation of legumes uses and trends in foods was given by Marie-Benoit Magrini and Tristan Salord. It was evidenced that the majority of the new food products being currently developed are soybean-based (4). However, increasingly, new food products also include pulses such as chickpeas, lentils, and peas. Main drivers for legume inclusion in legume innovations are their sustainability in the environmental dimension and their associated health attributes. On the other hand, one of the main factors locking-in legumes exploitation is that the full diversity of legume types or species is yet to be utilised in practice.

To enable the use of legumes in different contexts and for product development, it is important to improve the existing technological methods for processing. Kathleen Zocher explained that legumes can be used as fresh, frozen, or canned, and highlighted that the grains can also be further treated in by shelling, roasting, squeezing, milling, freezing, flaking, pelletising, polishing, or extruding (for example). All of these must account for the presence of potential non-nutritional factors that can hinder legumes digestibility, and that might have a more worrying impact in the feed sector.

As the trend for using legume isolates is increasing, starch processing or oil, protein and fibre extraction methods were also noted. On this subject, Benjamin Voiry presented the current investments in pea and faba bean protein isolate extraction in Europe. The easy adaptation of these protein isolates to different end-uses makes them convenient to add nutrition whilst responding to the demand for dairy and meat alternatives enriched with protein. This demand is generally associated with consumers who have an interest in healthy lifestyles, and who are generally concerned with diet-related issues. This constitutes a major market opportunity for investment. It was also highlighted that all legumes' components must be valorised, not only the protein fraction, but also the hull, starch, and fibre fractions. In that, yellow peas are currently the main crop being used for fractionation, and the full range of available legume diversity should be explored further.

Clearly, legumes' health benefits are one of the major drivers to enable their inclusion in current diets (5). Helena Ferreira presented scientific evidence on these health benefits (Figure 1), and on the effects of shifting from an omnivorous diet to a plant-based diet. The author presented a dietary intervention study and showed that there are specific human biomarkers which can be associated with a plant-based diet, and specifically to pulse consumption, since major metabolic changes were observed.

Another dietary intervention study was presented, specifically the 'BEAN MAN', which involved the participation of 102 men. Essi Päivärinta explained that a reduction from a 760 g/week of red meat intake (25% of protein intake) to 200 g/week (5% of protein intake) complemented with legume-based products providing 20% of protein intake (pea and faba bean) led to improved blood lipoprotein profile and decreased the formation of possible carcinogenic compounds in the gut.

While the multiple contributions of legumes at the agricultural level are well documented (6), the environmental footprint

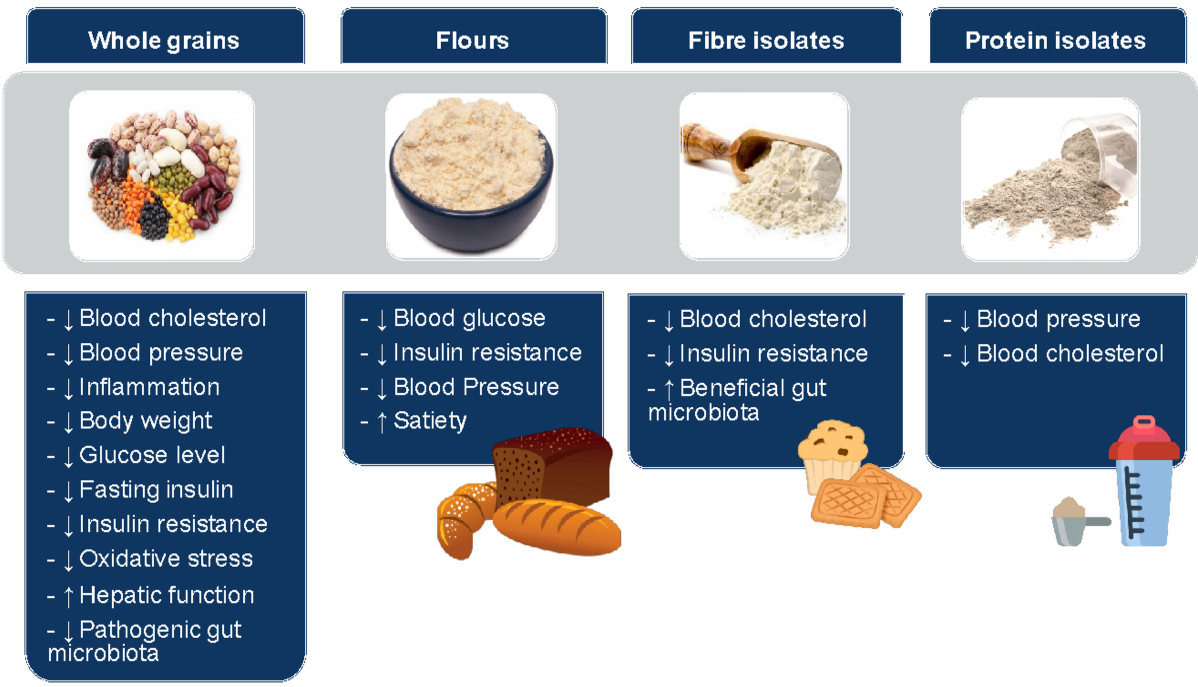

Figure 1. Health benefits of legumes as whole grains, flour and fibre or protein isolates (image prepared and kindly provided by H. Ferreira).

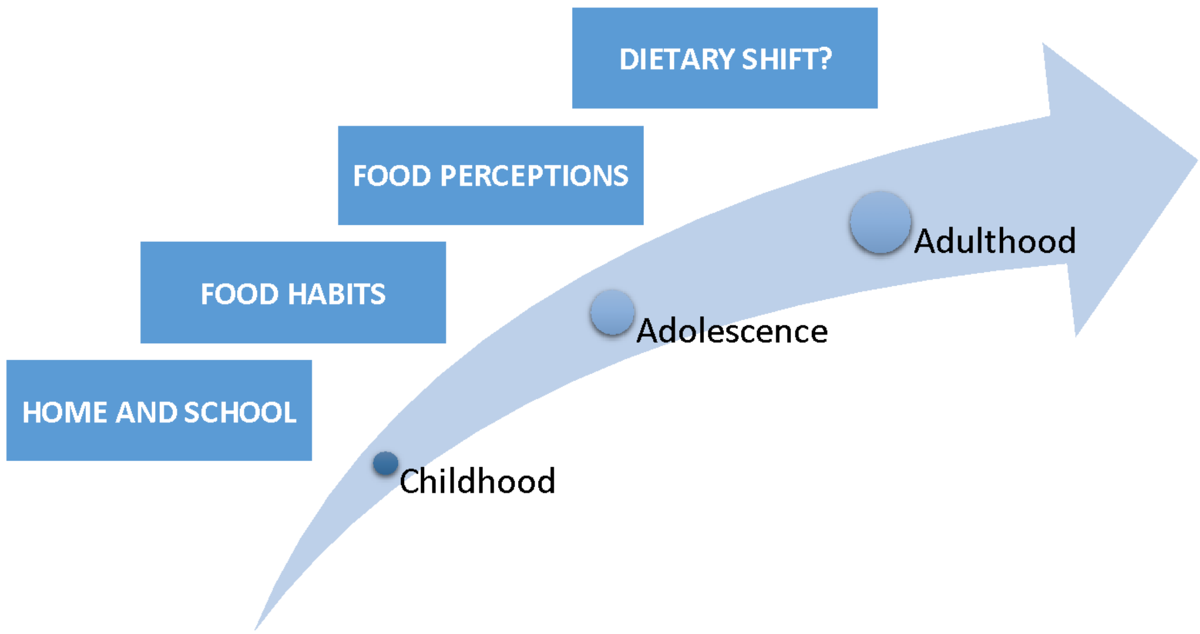

Figure 2. Modulating food habits and introducing legumes in general diets may be dependent on targeting children to develop a sustained and long-lasting dietary shift.

of legume-based alternatives to their traditional counterparts needs to be further analysed to support environmental sustainability claims. Using Life Cycle Assessment (LCA) methodology, Mike Williams showed that legume replacement of traditional food items, namely, in the case of wheat pasta (7), beef meatballs (8) and beef burger patties (9), perform significantly better over parameters associated with eutrophication and global warming burdens.

It is important to raise awareness amongst the consumers about these health and environment benefits. The "Choose Beans" initiative, presented by Elisete Varandas, helped to increase legume consumption frequency in EUREST restaurants chain by increasing legume-based options in their menus and developing more attractive recipes. Also, different consumer segments can be more susceptible to diet changes than others. Carla Santos argued that, by targeting children and developing products adapted to their preferences with legumes, a long-lasting dietary shift can be achieved by implementing healthy and sustainable food habits from a young age (Figure 2).

As shown in Figure 2, the early stage of human development and early-schooling, also play an important part in modulating and determining food habits. In 2019, an online survey was implemented in France to understand the role of legumes in institutional food services, such as school canteens. As presented by Hugo Fernandez-Inigo, the institutional food services that include legumes (only 16% of the respondents) have a strong sustainability profile. However, further actions are required to increase the inclusion of legumes even in their menus. Possible solutions may be the development of new recipes, training working professionals and increasing the awareness of legumes' health and environmental benefits.

Martha Walter presented legume-based food innovations in pasta, bakery products and extrudates for meat-like products. These showed high potential, and the baking and extrusion methodologies were successful and can be adapted to different materials. Alexandre Santos explained how the snack market poses an opportunity for improvement and for the promotion of healthy habits, and 'Bean Go' was presented as a successful case study for the development of a snack which is convenient, with few ingredients, that taste well besides being healthy. Kirsty Black presented the climate positive beer and spirits developed in scope of the TRUE project. Using faba beans as starch source, Barney's Beer has as an additional advantage the generation of high protein co-products with potential in animal nutrition (10). Using green peas, the Nàdar gin was developed, and its production was analysed for the environmental impact using LCA methodology when compared to the usage of wheat (11). This study showed that the allocated environmental footprints for pea-gin were smaller than for wheat-gin across 12 of 14 environmental impact categories considered. Such valorisation of product claims is allied to novel grain legume-specific marketing and knowledge sharing campaigns via media specialists – to help emphasise the critical importance business-research partnerships in acceleration uptake, and product appeal and resilience in the marketplace (e.g., [YouTube link]).

Finally, when looking at the impact of home-grown legume inclusion in feed options, Mathieu Guillevic showed how the use of legume grains in animal feed allows environmental valorisation of these crops, and increased uptake. It was demonstrated that it is important to find the best species and varieties to use as feed, as well as the better combination of treatment to improve digestibility. Testing was performed in trout, broiler (chicken) and pig diets, after appropriate processing treatments were defined. Aila Vanhatalo demonstrated the value of using faba bean and lupin as protein alternatives to rapeseed meal in dairy cow diets. This substitution achieved similar performance in terms of milk yield. However, milk protein yields were not as effective. Regarding the use of legume grains such as lupin, faba bean, pea or sustainably produced soybean as possible replacement in fishmeal, Matthew Slater highlighted the success in producing feeds for fish and shrimp. Specifically, feed formulations for the aquaculture of salmon, shrimp and sea bass containing legumes were achieved with positive outcomes in terms of the improvement of aquacultural sustainability.

These findings and the resultant discussions showed the importance of a system wide and integrated perspective of legumes use, and how legumes can lead to strong and common ties, based on whole food system sustainability ideals, between farmers through markets to the consumer. The insights also highlight the importance of exploring legume diversity for a wider range of end-uses than is currently accommodated, and that legume breeding efforts should be mindful of providing adapted forms to local pedoclimates and added values beyond yield. For example, increasing levels of specific health promoting nutrients and compounds, and lowering levels of non-nutrients. Since, breeding for such processing and consumer focused markets may increase even further the ´home-grown legume-appeal´ to, and so market pull from, consumers across Europe.

More detailed information regarding the content presented here can be found on the Legume Innovation Network website **here**.

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Development, processing, and acceptance of a faba bean (*Vicia faba*) based porridge

Jazmín Osorio Perez[1], Carla S. Santos[1], Marta W. Vasconcelos[1]

Abstract: The development of legume-based food products allows the promotion of healthy and nutritious plant-based alternatives, which are also environmentally sustainable. Porridges are often healthy, simple to prepare and suitable for various segments of the population, constituting a good option for food innovation. In this study a faba bean-based porridge was developed, using freeze-dried faba bean flour. A randomised sensorial analysis was performed. In terms of colour, 43% of panellists indicated that they "like it to some extent", while the texture was the most appreciated characteristic which was evaluated. Results showed that overall appreciation of the porridge was 40%.

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Introduction

The necessary dietary shift to achieve the SDGs by 2050 can be leveraged by increased plant-derived sources of protein intake, such as that of legumes (1). The market for meat and dairy alternatives is particularly promising, with a growth of 49% in the last two years (2). Legumes contain a very rich fibre, micronutrient, and amino acid profile that complements that profile offered by cereals and other small (non-legume) grains (3). Legumes can positively impact human health (4) and have environmental benefits since they can help fix atmospheric nitrogen and reduce the need for chemical fertilisation (5).

The development of plant-based products with traditional and innovative uses of food legumes, represents a high interest for the food market sector, which aims to develop food products that meet the consumer's requests for healthful and more environmentally sustainable diets. Literature shows that novel food products which promote more sustainable production locally and European food traditions are determining factors for consumer preference (6). Faba bean (*Vicia faba* L.) holds the capacity to grow in the winter and spring seasons indistinctly and can be used for both human and animal consumption (7). Nutritionally, they have a high content in minerals and vitamins, being rich sources of phosphorus, iron, potassium, and some vitamins from the B complex (8). Faba bean cultivation in Europe is slowly beginning to expand and in 2017 this crop was given the third largest area for legumes in Europe, and it was the seventh most produced legume in the continent that year (9). Countries with the highest yield are France, followed by Italy, Spain, and Belgium (FAOSTAT, 2018, accessed on 29 July 2018).

Processing legume grains enhances their digestibility and overall sensorial qualities by creating new aromas, textures, and visual appeals. Amongst these methods, freeze-drying is a processing technique employed for water removal in food products. It combines freezing and vacuum mechanisms that can preserve heat-sensitive nutrients such as vitamins and minerals (10). This research aimed to exploit the potential of freeze-dried faba bean flours for the development of a new food product that could increase consumer interest in consumption of locally grown legumes.

Table 1. Results for colour, flavour, and texture of the sensorial analysis of the faba bean-based porridge.

Colour		Flavour		Texture	
Dislike at different levels % (95% CI)	Like at different levels % (95% CI)	Dislike at different levels % (95% CI)	Like at different levels % (95% CI)	Dislike at different levels % (95% CI)	Like at different levels % (95% CI)
56,7 (43,2; 69,4)	43,3 (30,5; 56,7)	46,6 (33,6; 60,0)	53,3 (40,0; 66,3)	38,3 (26,0; 51,7)	61,6 (48,2;73,9)

CI – Confidence Interval

Methods

Five hundred grams of green de-hulled faba beans were freeze-dried in a lyophiliser (SP VirTis BenchTop Pro with Omnitronics®) at -85 °C for 72 h. Afterwards, beans were milled into flour using a kitchen robot (Kenwood Robot kCook Multi CCL401WH®) at the highest speed for 5 minutes. The porridge was prepared by bringing 500 mL of water, two cinnamon sticks and 10 g of sugar to a boil. The faba bean flour was added to the boiling mixture and cooked to the desired texture (Figure 1). A sensorial analysis evaluation took place with 60 participants, ranging from 18 to 52 years of age. A total of 35 participants were women while 25 were men. Participants assessed the colour, texture, flavour, and odour of 30 mL of the faba bean porridge at 20 °C, using a nine point-hedonic scale where 1 corresponded to 'dislike extremely' and 9 to 'like extremely'.

Results and Discussion

Given that faba beans in Europe are often consumed in their fresh (not dried) state, the green colour on the beans and on the porridge is relatable to the consumer. In the present study, 43% of the participants reported to like the colour of the product (Table 1). This is a valuable result given that earlier research has shown that 85% of consumers' food purchasing decisions are influenced strongly by product colour (11). Also, a recent study also links consumers' perception of product colour-saturation with that of flavour perception, or expectation (12). Here too both traits were correlated, and higher scores given for flavour were matched by those given for colour.

The texture was found to have the highest average scores on the porridge's attribute evaluation, which presented a consistency that remained constant through the temperature variations of the product (Table 1). This trait relates to the homogeneity of the flour obtained through freeze-drying, producing a very high-quality ingredient (13). The results seem to indicate that this is an effective method for processing the faba bean flour, adding the advantage of preserving the structure of the ingredient and nutrient content alike, while eliminating water content (14).

Lastly, 40% of the panellists indicated to like the porridge at different levels of the overall 'global appreciation' categories (Figure 2), which align to scores given to porridge traits which were scored. Similar results were obtained during another sensorial evaluation of porridge prepared with faba bean flour (15). A very important attribute of the porridge developed here is also mentioned in other studies and concerns the ability to 'mask' or 'eliminate' the characteristic 'beany' flavour which is often associated with food products formulated with legume grain-based flours. Historically, these aspects have negatively affected the sensorial analysis scores of such products (16,17).

Legume-based beverages represent an important market sector to explore, since there is a wide range of processing methods that can further improve the nutritional quality of the final product (18). A novel food product prepared with fermented faba bean flour resulted in greater scores than the ones given to this porridge, a result that the authors attributed to the fermentation of the faba beans before turning them into flour (data not shown). This method seemed to improve the final taste in the product while increasing the protein and fibre content (19).

Pre-treatments, or contrasting processing methods other than the ones employed for this formulation, are an interesting path to explore during further porridge-focused experimentation. Supplementary analysis on the nutritional composition of this porridge could be of interest as well once the sensorial

Figure 1. Processing thread of faba beans into porridge: A) fresh de-hulled faba beans; B) lyophilised faba beans; C) faba bean flour, prepared with lyophilised faba beans; D) faba bean porridge.

parameters are optimised to provide more positive results. Research shows that acceptability of drinks, specifically, can be influenced by the amount of information that is given to the subject prior to the tasting, and that by removing the ingredient information from the evaluation, higher scores are usually obtained (20). This suggests that different results could have been attributed to the porridge if the main ingredient had not been disclosed.

A replicate of this sensorial evaluation, with the participation of a specific segment of the population (*e.g.,* vegetarians, flexitarians), could also lead to different scores, since subjects with specific dietary patterns tend to be already familiar with the palatability of legumes, as well as be more sensitive of the health and environmental benefits associated to legume consumption (21).

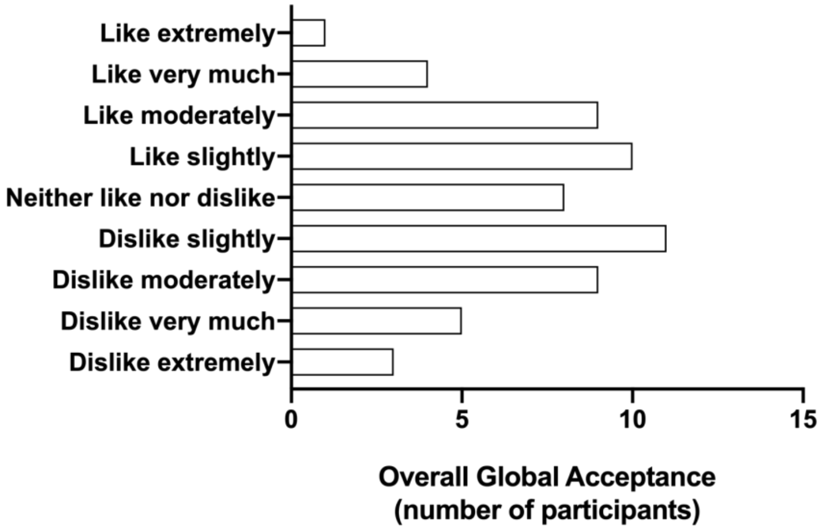

Figure 2. Sensorial analysis results for the overall global acceptance of the faba bean-based porridge.

Conclusion

The idea of an eco-friendly diet that is high in plant-protein utilising faba bean products is attractive. But not every segment of the population is equally motivated to consume such products. Adding flavourings, or more effective marketing of this porridge as light textured and an easy-to-drink beverage could potentially attract more consumers, contributing to the increased interest of European consumers for faba beans, and legumes in general.

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Pea protein isolate as key ingredient facilitates innovation in meat and milk substitutes with profound value chain implications

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Abstract: Traditionally, peas were a food in Europe with high nutritional value for humans. Despite this, they have appeared in markets mainly as an animal feed and were gradually replaced by soya due to its higher protein content and continuous availability. Nevertheless, the increased demand and the use of regional (food) products has led to a rise in home-grown pea production recently. Although peas are still predominantly used for feed, the current development towards a less animal-protein based nutrition enhances the revival of peas in human nutrition. Peas are processed to provide protein isolate used in convenience foods. Peas have become a quality-determining ingredient and sometimes they are used in considerable quantities. This trend could be an important lever for the increased cultivation of legumes. The aim of this study was to give an overview of perspectives on the use of legume grains - especially of peas - in food products for human consumption, and to demonstrate how product development helps drive increased cultivation of grain legumes.

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Introduction

Over the last 20-30 years, home- or European-grown peas were nearly replaced entirely by soybeans, often as genetically modified organism (GMO), as a feedstuff due to its higher and consistent protein content, protein qualities, and continuous availability (1). The new trend demanding GMO-free foods and feeds, and regional trends have promoted growth of pea cultivation and pulse-based industries across Europe, and globally. Thus, while the use of peas as a raw material in animal nutrition has risen, this is less lucrative for farmers than their use as food ingredients i.e., for human food consumption (2). Examples of markets for processed peas include meat alternatives (Figure 1) as well as milk alternatives (3).

The production of meat and milk alternatives are prominent examples of how added market value may be achieved from home-grown peas and other grain legumes. This work investigated several commercial innovative pea-based products, which have been introduced in the German market. Product websites were first surveyed, and this was followed-up by phone calls and e-mail exchanges to discuss open-questions

Figure 1. Burger patty based on pea protein isolate.

regarding how the product was brought to the market (market-entry point), and the origin of the raw materials. The results of the data collection were compared with information from the literature and were discussed as follows.

An increasing number of companies are bringing pulse-based meat and milk alternatives into the market. In the meantime, this is almost valid for all grain legumes such as soya, pea, lupin, field bean, lentil, and chickpea. Due to improved technical processes, it is possible to achieve higher protein yields and better protein enrichment to be used in a food, especially for peas (4). Separating the components enables the full utilisation of pea grains, because fibres and starch can also be used in diverse food applications (5). Protein isolates from peas also offer improved organoleptic properties compared to other legume-protein isolates. The following table shows an exemplary overview of companies and products made from pea protein isolates. The number of companies and products is constantly increasing.

Table 1. Companies that create products from pea protein isolates. Overview of some companies producing products from pea protein isolates. The protein content of the products per 100 g as well as the percentage of the pea protein isolate is indicated.

Companies	Product Name	Protein Content (g/100g)	Pea protein isolate (%)
Meat Alternatives			
Rügenwalder Mühle	Sliced sausage	3.9 – 4.4	2.0 – 5.0
Rügenwalder Mühle	Spreadable sausage	2.6 - 2.7	2.4 - 2.9
Endori	Burger	23	
Endori	Bratwurst	16	
Endori	Vegan balls	13	
Endori	Vegan Meatballs	16	
Vossko	Vegan Burger	15.5	81 (rehydrated)
Veggie Meat	Vegini Burger	16	
Veggie Meat	Vegini Bratwurst	14	
Beyond Meat	Vegan Burger	18	18
Like Meat	Vegan Curry Chicken	18	24
Milk Alternatives			
Vly Foods	pea-drink	2.5 | 3.5 | 5.2	2.1 | 4.1 | 6.2
Princess of the Pea	pea-drink	3.2	3.9

The content of pea protein isolates used as an ingredient in these products varies from 2 to 24 %. For sausage products listed in Table 1, the average protein content is lower than for traditional animal-meat based sausages. For the remaining plant-based meat and milk alternatives in Table 1, the protein content is in a similar range as compared to conventional animal-based products. Consequently, even a meatless and milkless diet can provide protein uptake sufficiently, including a balanced amino acid composition. Legume-based products made from processed peas are favourable alternatives to soy-based foods because they have lower levels of potential allergens. Thus, they are acceptable to a wider range of consumers, and it is not necessary to use specific dietary warning labels. Another advantage of pea protein isolate is the short cropping cycle of pea, from the sowing to the harvest compared to the other grain legumes. This aspect is very attractive to farmers and processors. For the latter, they can start sooner with the processing to gain protein isolate. As pea variety selection processing purposes might become more important in the future, decision cycles are shorter for peas. Furthermore, beside the expansion of crop rotation due to their introduction, grain legumes store better than oleaginous. These advantages (regionality, complete utilisation of the pea components, very low/no-allergenic potential, short cycle, expansion of crop rotation and better storage) are probably the main reasons for German food manufactures to use pea protein isolates as basis for their meat and milk alternatives. The generally higher environmental sustainability credentials of pea and tied marketing potential of an innovative product are the most important marketing levers for all legume-based products (6).

The market-entry of pea-based products is often limited due to their relatively high purchase price, as customers prefer the less expensive meat alternatives made from soya or wheat. A decreasing price over time can be expected because of increased competition among suppliers, and the increasing product range of plant-based meat alternatives (7). Due to efficiency processing improvements, cost of processing will become better and will reduce too. Model calculations show that decreasing prices of plant-based meat alternatives lead to decreasing animal meat demand and a reduction in greenhouse gas emissions (8). This is confirmed by comprehensive life-cycle assessments that included land use for feeding beef cattle and the respective carbon opportunity costs (9). For Europe, Pilorgé *et al.* (10) illustrated that if pea protein isolates and rapeseed oil, as the main ingredients of plant-based meat alternatives increase, land currently used for animal feed production would become partly available. Imported proteins from deforested regions could also be decreased: a substitution of 25% of meat consumption would allow supply of equivalent food protein without extending the cultivated areas in Europe, while avoiding soya and maize imports for feed.

Information about the supply chain of peas and pea protein isolates in the food sector is often characterised by a lack of transparency. Thus, information about the origin of the processed peas is usually not provided by the producing company. According to our investigation, it can be assumed that the raw material for the pea protein isolates used, is mostly grown in Europe. Various companies purchase their protein isolates mainly from France or Eastern Europe. Other countries of origin are Germany, Belgium, Scandinavia, and India. However, the pea proteins used are also partly sourced from peas grown in Canada and China (6).

The biggest companies processing peas in Europe are the Roquette Group (with production sites in France and the Netherlands), Cosucra (Belgium and Denmark) and Emslandstärke (Germany). Contract farming is the common means to source domestically (i.e. European grown) peas (11), though often no detailed information is given on products of raw material provenance. The companies keep their supply chain relationships confidential and have confidentiality agreements in their contracts with the farmers. This lack of value chain transparency among product suppliers highlights a high degree of information asymmetries between the players in the legume-based niche.

Currently, small quantities of peas processed for food can easily be produced domestically. When the demand for pea-based meat and milk alternatives continues to increase, new cultivation and marketing opportunities for peas could continue to rise. This could have a positive impact on the farmers as they could sell their peas to the processing companies in the food sector (3). Marketing to the food sector enables farmers to potentially achieve a higher profit than selling only in the animal feed sector. However, this will depend on the specific business developments in those supply chains. Equity and power asymmetries have still to be addressed for the financial potential to materialise at the farm level. Farmers can also benefit agronomically though: as expanding, their crop rotation with peas serves a renewable source of nitrogen, and other complex soil function enhancing provisions, as a positive side effect for the farmers.

Protein or starch content and qualities should also be a new differential quality features for plant breeders which processing companies could turn into purchasing criteria. In total, the use of peas for food is more valuable than use in animal feed, though the latter current offers larger market volumes. For this purpose, pea breeders should collaborate more closely with the food industry in order to integrate food quality specifications and techno functional requirements of the food industry with breeding goals – more comprehensive and integrated breeding programs forming part of future sustainable value chains. This will lead to new value chain collaborations, and business models among breeders, food processors and technologists, and consumers.

Elaborating the potential and opportunity offered by peas can be transferred to other grain legumes. So far, lupins, soybeans and especially field beans are already being used in the food sector to increase the protein quality (12). It should be noted that the different grain legumes offer a diverse range of functionally distinct forms, whether processed completely or in fractionate forms. Therefore, each ingredient type demands a specific knowledge, a certain quality specification, and industrial capacities for application of best-processing methods.

The interest in legume-based food is increasing as the recent activities of existing food processing companies, large ones, small and medium-sized enterprises (SMEs), as well as start-ups show. This is leading to a transformation of the food systems, affecting the farming sector, though the extent to which the potential benefits are realised locally and increasing demand for regional legumes, and development of local food cultures and farm-profitability, remains to be seen. Thus, farmers and breeding companies should be sufficiently prepared to embrace new expertise, cropping grain legumes, including a wider range of varieties, to take full advantage of the environmental benefits, and align these with consumer expectations.

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The role of policy in the transition to legume production and consumption in Europe

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Abstract: The increasing demand for food and feed protein presents unprecedented opportunities to transform EU policies to promote legume-based food cultures. The challenges are numerous and present analysts with the "legume paradox", the entire lock-out of grain legume production and consumption across Europe. Lessons from the TRUE-project (www.true-project.eu) policy-relevant studies enabled us to identify policy interventions leveraging barriers that hinder the production and consumption of legumes in the EU. We point to sobering and inspiring lessons in dynamic legume-based value chains, and transformation of our food system to be one which is 'home-grown grain legume-based'. While various policy scenarios aim to increase legume production and consumption across Europe, only a small number promote agroecological models for home-grown legumes.

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Introduction

Despite their multiple agri-environmental benefits, grain legume production and consumption in Europe is still low. Yet, demand for use of imported grains in animal and aquaculture feed is high, and the potential benefits of home-grown legumes are forfeited. This insight, also called the "legume paradox", was shared by many stakeholders, almost 600, from the TRUE-project (www.true-project.eu) partnership and beyond (1). During the four years of TRUE Policy Studies, we recorded a resonance among diverse value chain actors regarding the need for more home-, or European-grown grain legume-based food- and feed-systems. In TRUE, specific and structured policy assessment approaches enabled the involvement of a wide range of stakeholders and experts from across the value chain. Our analysis identified several policies to realise the benefits which only home-grown legumes can provide (1).

Policy integration not silver bullets: seeking solutions for the legume paradox

There are main barriers in the current governance system that hinder the coordination and integration of policies regarding the production and consumption of EU-grown grain legumes.

Firstly, the **Common Agricultural Policy and trade policies** focus on production without concentrating on enhancing the function and role of legumes. There is insufficient support, or awareness, along the value chain on the ethical importance and significance of 'internalising externalities', which is accepting full corporate and governance responsibilities for environmental damage and biodiversity loss, which is either manifest as 'offshored' by importing grain legumes, or 'forfeited' from avoid cultivation at-home. Consequently, the agroecological services provided by legumes are not recognised and so undervalued by producers and society.

Second, **N fertiliser policies** have not stopped the overuse and inefficient practices regarding synthetic nitrogen fertiliser use. The considerable impact of inorganic nitrogen loss by leaching or as greenhouse (i.e. global warming) gases persist.

Third, **research, development, and innovation policies**, especially in breeding and processing technology, are insufficient for state-financed and private institutions. Innovation programmes are few, and investment opportunities are too low to boost profitability for all actors in legume-based value chains.

Fourth, **policy coordination for knowledge transfer** is weak among extension services, processing facilities, and trading companies. This creates difficulties in supply and demand. It can be resolved if policies focus on decoupling imports by the feed sector, creating labels for homegrown-legumes and legume-derived products, redeveloping regional food cultures and creating short, regionalised feed- and food chains. Farmers question the profitability of legume production due to the high production costs, variable yields, competitively priced imports (e.g. soybean - despite the high environmental cost of their production). This commercial risk cannot be offset by the more comprehensive ecological (or societal) benefits.

Finally, **consumer-oriented food (and not feed) policies,** *i.e.,* including legumes in public food procurement and dietary guidelines, does not create an effective awareness among citizens of the functional, or ecological, significance of legume grains or legume-based products as food.

Policy case studies conducted in Croatia, Denmark, Germany, Hungary, Italy, Portugal, and Scotland focused on different upstream and downstream components of the legume value chains to explore policy prospects that support legume production and consumption. In fact, many ‘enablers’ are apparent for stakeholders, including the proximity to processing facilities, existence of legume-grain trading companies, access to independent extension services (i.e., unbiased agronomic advice to optimise legume production), regional support and innovation networks, training programs - see Figure 1.

Furthermore, in the framework of the TRUE-project many geographically dispersed experts were invited to reach a common understanding of the

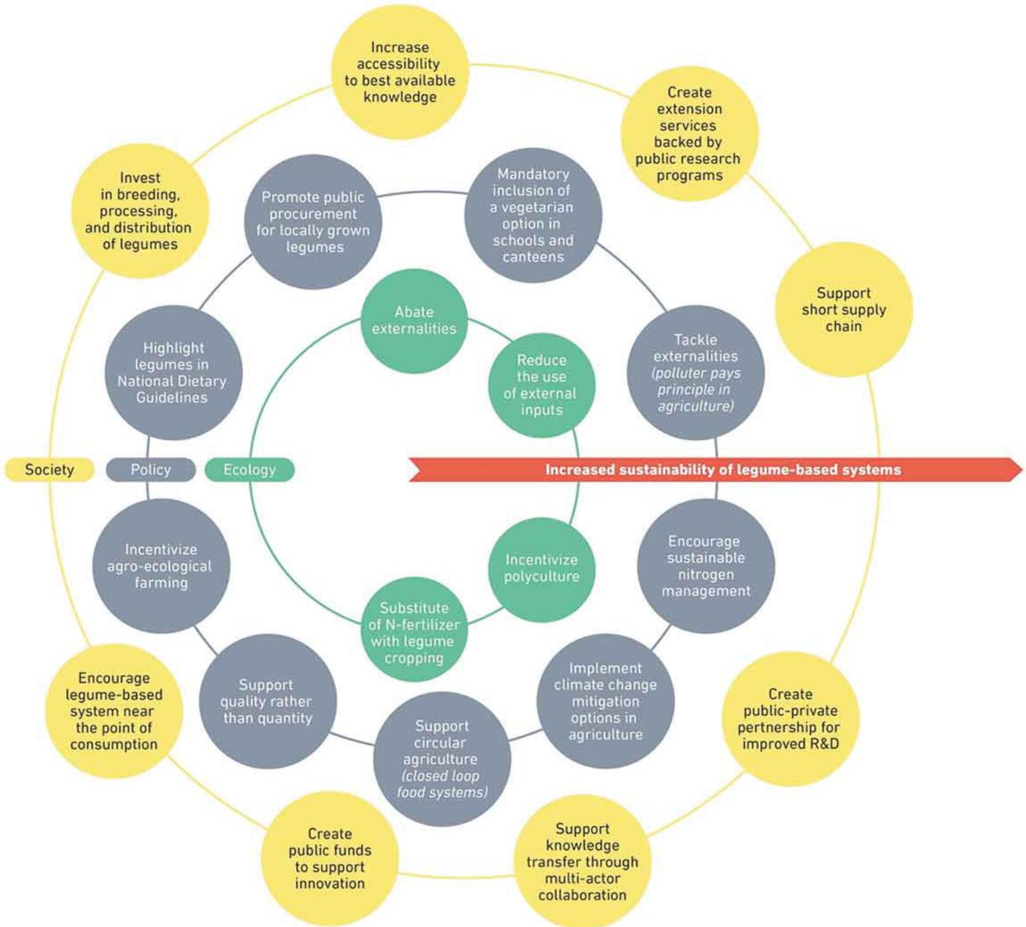

Figure 1. Transformation paths to more-sustainable legume-based food and feed value-chains in Europe (1).

inconsistencies across sectors to identify factors which may be used to leverage common barriers to legume production and consumption. To achieve this, TRUE applied a policy-Delphi (methodology) whereby stakeholder consultations listed factors contributing to the relatively low production and consumption of legumes in Europe. Then several promissory scenarios were developed which offered various pathways to different stakeholders for support legume production and consumption.

The findings identified three policy action areas as having the high potential to trigger change across sectors from the legume paradox. Number one is the investment in agri-food and -feed research and knowledge transfer to increase the competitiveness of protein crops and legume-based food products. Number two is a ban on the use of inorganic nitrogen fertiliser, which can create incentives for more legume production. Number three is diet, health and nutrition policies and public campaigns that could promote the inclusion of legumes in the human diet and could make legumes much more visible. Still, the question remains: *how do we combine different policies, including legal regulations, market-based incentives, and/or product labelling, to achieve optimal policy mixes?*

Furthermore, the impact of seven different policy scenarios, including different measures and instruments that support legumes' production and consumption, has been assessed (see details in Balázs *et al.* (2)).

For legume focused innovation, the primary hindrance is the inconsistencies among existing policies, making them difficult to implement effectively by stakeholders, and so their main aims remain unachievable. The inconsistency among policy measures affecting legumes, such as agricultural, environmental, research and innovation, consumption, bioenergy, feed, and trade policies, creates a clear multi-lock-in situation. TRUE addressed several routes to leverage these barriers for home-grown legume production and consumption, and these recommendations are highlighted in four TRUE Policy Briefs:

1. Promoting sustainable food and feed system;

2. Transition to legume-supported food systems via the Common Agriculture Policy;

3. Environmental policies; and,

4. Pulses on the menu: the role of nutrition

More detailed information regarding the content presented here can be found on the Legume Innovation Network website **here**.

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Science, innovation, and the empowerment of legumes

Paolo Annicchiarico[1], Pietro Iannetta[2], Susana Gaona Saez[3], Euan James[2], Christophe Salon[3,4], Barbara Smith[6], Moritz Reckling[7], Bob Rees[8], David Styles[9,10], Trine Kastrup Dalsgaard[11,12,13], Marta Vasconcelos[12]

Introduction

Susana Gaona Saez (Research Programme Officer for the European Commission) highlighted that research and innovation (R&I) are key drivers for improving the competitiveness of EU-grown protein plants. Under the EC R&I Horizon-2020 and HE frameworks, the Commission continues to fund transnational research projects benefitting legume crops at different scales. In addition, via the Rural Development Programmes (RDP), the EC also supports innovation activities through the 'European Innovation Partnership' for 'Agricultural Productivity and Sustainability' (EIP-AGRI). Also, under the EIP-AGRI, several Operational Groups (OGs) covering protein crops, have addressed more local challenges. Through all the activities, multi-actor and systems approaches will remain to be supported, to increase the competitiveness of EU-grown protein crops, while ensuring their role in delivering multiple other ecosystem services in cross-cutting approaches related to crop diversification, sustainable soil management, and nutrient cycles - in line with the objectives of the '*Report on the Development of Plant Proteins in the EU*', European Green Deal priorities, Farm-to-Fork- and 'Biodiversity-Strategies, plus EU Zero Pollution ambition.

Towards these goals, Paolo Annicchiarico *et al.*, highlighted that legume crop breeding will remain as a strategic priority, since the EUs requirement for legume-based proteins, is driven by feed protein needs, and increasing demand for plant-based protein foods. This demand is currently satisfied mainly by imported legumes, mostly soybean and often GM (genetically modified). Such import dependency is mainly due to the large profitability gap of EU-produced legumes relative to competing crops such as cereals. Reducing this profitability gap is challenging, as there are many different grain- and forage-legume crop species which occupy modest (*i.e.,* low) crop areas. This discourages substantial commercial investments by private breeders, and so public research institutions are crucial for crop improvement research, pre-breeding, and the selection of the improved varieties which are to be licenced by seed companies for sale. With unprecedented demand on publicly funded institutions in mind, Paolo showcased examples of the public breeding programs for grain or forage legumes in different countries. There is a focus in these examples to select types with greater resilience against abiotic (climatic) and biotic stresses, and improved crop qualities such as disease resistance. The importance of molecular marker- or genome-enabled improvements was also stressed, and examples of R&I on key crops were discussed. There is a clear concentration of effort in the important grain legume crop, and genetic model pea, with genotypes being assessed for broomrape-, powdery mildew- and seed-borne mosaic virus resistance, and in fusarium wilt resistance in common bean. Also, the development of pea types which demonstrate low levels of phytate (a plant compound characterised as a non-nutritional or 'anti-nutrient'), and greater iron bioavailability, and reduced environmental pollution due to phosphorus loss were also showcased, and alongside drought-tolerance pea types too - the latter attribute was also

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discussed with respect to new plant lines of lupin. There was also mention of trait improvements of the important and high-biomass potential of forages, specifically alfalfa types with enhanced yield and yield qualities.

Breeding very often neglects to characterise specific traits, and this may be argued especially for root traits. Since breeding programs are commonly based-on plant selection under high input conditions. Yet, legume roots need to be acknowledged as a key breeding target to help them cope with low input systems (or poor soil fertility), whilst also coping with climate change-associated constraints. Also, because of the dependency of legumes on soil-microbial communities and symbionts (rhizobia and arbuscular mycorrhizal fungi, AMF) – optimising such associations via breeding is also poorly understood and generally not considered by breeders of most legume crops. This neglect is especially surprising, since the success of soybean has been underpinned by combining the best plant genotype and (brady)rhizobia combinations. Therefore, in 'going back to roots', Christophe Salon *et al.*, discussed how a multidisciplinary approach allowed improved phenotypic characterisation of roots by combining eco- and molecular-physiology approaches, and with special focus on root system architecture, including root-number, -angle, plus -elongation, and branching-rates. Also, root functions towards hydromineral resources uptake. The data is used to equip mathematical models to allow the accurate and rapid physio-genetic assessment, and the identification of key genes playing major roles in plant adaptation to drought, and other stresses. The new approaches, methods and tools also offer new and unprecedented opportunities to assess legume-crop interactions with the soil microbiome, plus critically important rhizobia, and AMF symbionts too - to increase biological nitrogen fixation and phosphorous resource use efficiency.

Keeping to these below-ground and symbiotic perspectives, Euan James *et al*, presented new insights into soil rhizobia (*Rhizobium leguminosarum* sv. viciae (*Rlv*)) population densities and diversity with respect to nodulation and biological nitrogen fixation for two of Europe's most cultivated grain legume crops – field (faba) beans, pea, and related genera (*Lens* and *Lathyrus*). Studies were focused on field sites from across the UK, and over time within a long-term experimental legume-based cropping system – which had had no history of legume cropping for more than 50 years. This showed that UK faba bean obtained most of their nitrogen (N) through biological nitrogen fixation, (ever 80%) regardless of plant genotype or year. Also, the use of an adapted qPCR approach clear out that soil rhizobial populations were also high and grouped into two large clades, one of *Rlv* and one consisting mainly of *V. faba* strains plus other strains isolated from *Pisum sativum*, *Lens culinaris*, *Lathyrus* spp., and other forage *Vicia*'s. Work is ongoing to assess the possibility that there is rhizobial selectivity among these highly genetically syntenous genera. A full account of this work presented is now published in the open access paper by Maluk *et al.*(1).

Looking towards other biotic dependencies Barbara Smith *et al.*, explored the significance of legume pollinators and beneficial insects, highlighting that the benefits of legumes to invertebrates are largely overlooked – and so there are significant knowledge gaps to be filled, such as: *which pollinators and beneficial insects visit key legume crops? Is there variation in insect identity and abundance visiting different legume crops and varieties? Does including legumes in the cropping system have an impact on pollination and natural pest control to neighbouring crops and habitats? Which cropping design is most likely to deliver services efficiently? What are the remaining key research gaps to enable the design of best practices?*

Of course, the potential of legumes to help address the climate emergency could not be overlooked, and Moritz Reckling and Inka Notz, showcased an integrated assessment highlighting that legume-based arable and pasture systems reduced nitrous oxide emissions by 21% and 26%, respectively. Also, synthetic nitrogen fertiliser use decay by 26 % and 45 %, respectively. In comparison, protein output was 13% and 5% higher. While gross margins were more variable due to site-specific factors, the commercial potential may be easily enhanced depending on target feed value chains, levels of subsidies, CO_2 tax scenarios, and the (rising) costs of feed imports. This value of such legume-based potential should not be downplayed, and the introductory comments by Bob Rees laid bare the reality of the situation before us - over 120 Tg of synthetic fertiliser nitrogen is currently used globally to drive agricultural production, a quantity which is expected to increase due to population growth. Yet agricultural systems are already suffering extreme environmental damage via lost qualities of water, soil, and biodiversity, while greenhouse gas emissions increase. So: *how can United Nations Environment Programme recommendation of reducing agricultural nitrogen loss by 50% be achieved whilst?* The opportunities and barriers explored here, and some are also highlighted in Iannetta *et al.* (2).

It is therefore critical that the environmental impact, and ecosystems services affected by legumes and legume-based systems, are fully accounted, and David Styles explained why Life Cycle Assessment (LCA) has become a default methodology to quantify the environmental efficiency of food systems, and "environmental footprints" of food products. However, while LCA originally emerged as a tool to evaluate the efficiency of industrial systems, adapting the approach for food systems to account system-functions as well as -impacts, has proven challenging. Not least since LCA has shown that high-input/-output systems can have smaller carbon footprints than low-input/-output systems. Therefore, advanced LCA methodologies should account for important ecosystem attributes such as nutrient cycling, soil health, and biodiversity In this context, David described what constitutes best LCA practice if the environmental sustainability of legume value chains is to be accounted more accurately.

The application of LCA tools for leafy legume biorefining is especially attractive, since these legume types such as lucerne, and clovers protein may be isolated for direct food use, that is bypassing the need for consumption by animals, and the protein losses incurred in that transformation process. Here, Trine Kastrup, explained that while this potential is real, processing challenges persist specifically 'enzymatic browning' for the extracts and consequent protein indigestibility. Procedures are being developed to overcome this challenge, and if successful will be highly commercially sensitive.

Despite the potential of any innovation in food- or feed-technologies, the final challenge of encouraging consumer change towards more sustainable norms is perhaps the biggest hurdle. Nevertheless, human nutrition specialist Marta Vasconcelos explored the often neglected role of citizens, as consumers, in promoting legumes as food "dietary vehicles" to improve health.

However, basic information remains to be gathered for example the specific nutritional characterisation of crop species and genotypes, including post-processing. Such insights will also help tailor and target legume-based products, and knowledge more generally to specific demographics. More directly, to empower legumes, Marta explained that the public must first be empowered by improved "food literacy" with respect to legumes – including the co-development of nutritional and culinary knowledge, in parallel with their environmental credentials.

In this context, Citizen Scientist approaches have not been widely exploited to help create cooperative legume communities whereby consumers are fully included as central actors in the scientific process. The example of the EU-H2020 **www.pulsesincrease.eu** was highlighted as one such example, and many other legume-specific networks are also emerging such as the Global Bean Project (**www.2000m2.eu**).

There are also already established networks which also include legumes, such as **www.cropdiversification.eu**, and newly emerged projects such as **www.RADIANTproject.eu** which also include several underutilised legumes crops, and these will also embody a future 'Underutilised Crop Network'. As with all such networks, the challenge is maintaining the community in a systematic fashion after a specific initial funding period ended. In addition, perhaps effort should also be made (by more persistent legume-based groups), to periodically draw such diverse multi-actor groups together - for nothing other than the benefits of mutual appreciation and learning.

More detailed information regarding the content presented here can be found on the Legume Innovation Network website **here**.

References

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ILS webinars are here!

Dear colleagues and friends of the ILS,

We are very pleased to inform you that ILS is going to host a set of open webinars on topics related to legume cultivation, improvement, and crop use.

Join us in the opening seminar by Dr. Christian Huyghe of INRAE on September 6 at 4 PM CET entitled "*Perspectives, opportunities, challenges and burning research issues for legume crops in Europe*", hosted by Nelson Nazzicari.

The webinars will be monthly, and all information, calendar and access links are available at LegumeSociety.org.

Share now with your contacts, the webinars do not require an ILS membership and will be made available to everyone on the ILS website!

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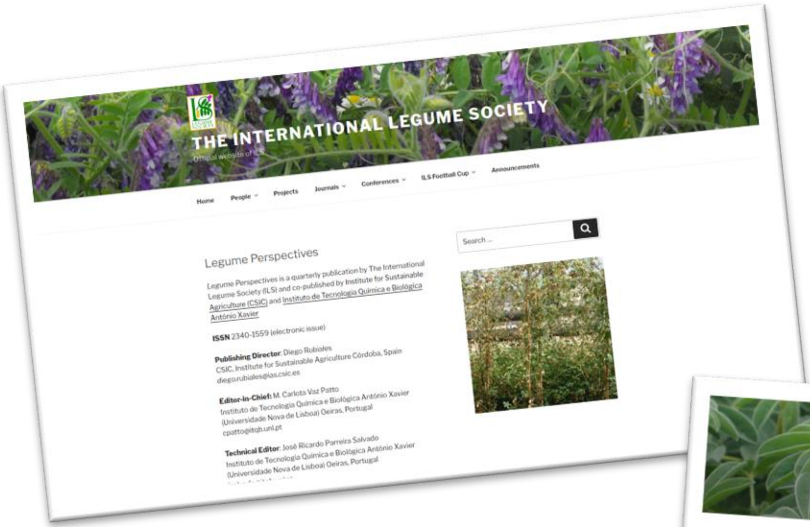

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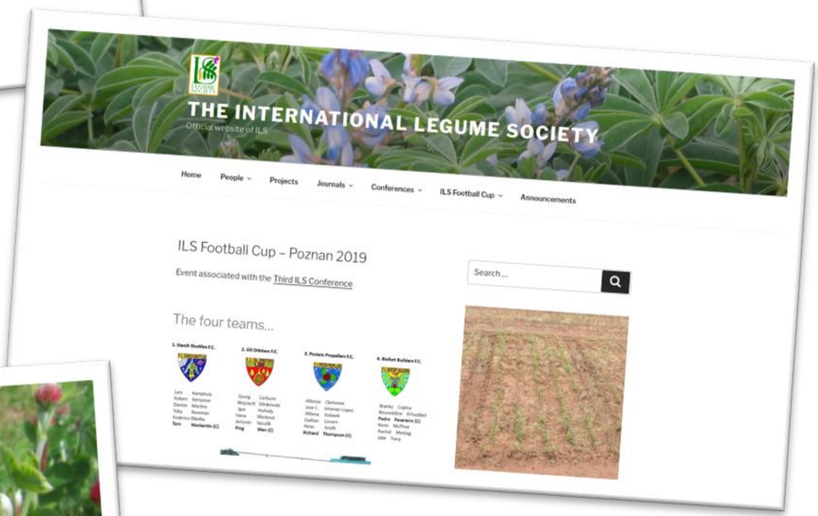

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Legume Perspectives is an international peer-reviewed journal aiming to interest and inform a worldwide multidisciplinary readership on the most diverse aspects of various research topics and use of all kinds of legume plants and crops.

The scope of *Legume Perspectives* comprises a vast number of disciplines, including biodiversity, plant evolution, crop history, genetics, genomics, breeding, human nutrition, animal feeding, non-food uses, health, agroecology, beneficial legume-microorganism interactions, agronomy, abiotic and biotic stresses, agroeconomy, sociology, scientometrics and networking.

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