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NEW VALUE LANDSCAPES FOR PLANT PROTEIN PATHWAYS

D5.6 Practice Abstracts – batch II

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Executive Summary

This collection of Practice Abstracts provides an overview of seven innovative approaches developed within the VALPRO Path project to support knowledge transfer, value chain development, and the adoption of sustainable practices among stakeholders involved in plant protein production systems. The document follows the EIP-AGRI Practice Abstract format and aims to translate project results into accessible, practical knowledge for end users, including farmers, processors, researchers, industry representatives, and policymakers.

The Practice Abstracts presented in this deliverable highlight key innovations emerging from the project's Innovative Production Systems (IPSs), addressing challenges across the entire plant protein value chain, from crop production and varietal selection to processing, storage, valorisation of side streams, and supply chain optimisation. Through these summaries, the document provides practical recommendations, demonstrates potential environmental and economic benefits, and supports the wider uptake of sustainable plant protein solutions across Europe.

Summary of the 7 Practice Abstracts Featured:

Pulse Nutri-Track (Page 7) : The Pulse Nutri-Track system provides a dynamic modelling approach for tracking nutrient flows throughout plant protein value chains, from crop cultivation, post-harvest processing to final food product development. By integrating cultivation data, processing parameters, and product formulation scenarios, the tool enables stakeholders to assess mass balances, explore alternative production pathways, and support decision-making for the sustainable valorisation of protein crops.

Designing sustainable, resilient, and scalable supply chains for plant-based proteins (Page 9): This Practice Abstract presents modelling approaches developed to support the design of sustainable and resilient legume supply chains across Europe. By evaluating factors such as intercropping systems, processing infrastructure, climatic risks, and food/feed allocation strategies, the research provides insights into how supply chains can be optimised to improve economic viability, reduce losses, and strengthen European protein self-sufficiency.

Interdisciplinary Phenotyping as a Method of Varietal Selection for Lupin in the EU (Page 11):

This innovation introduces an interdisciplinary approach to legume phenotyping that combines physiological, biochemical, and nutritional analyses to identify climate-resilient varieties. By expanding traditional crop performance assessments to include grain nutritional composition under abiotic stress conditions, the approach supports the development and selection of future-proof lupin varieties adapted to changing European climates.

Valorisation of Crop Waste Using Peanut and Pea Crops as Examples (Page 14): This Practice Abstract explores the transformation of agricultural side streams, such as peanut shells and pea pods, into high-value bio-based materials. Through the development of lignocellulosic fillers for thermoplastic biocomposites and lightweight aerogels, the approach demonstrates how crop residues can be integrated into circular bioeconomy models, reducing waste while creating new opportunities for sustainable material production.

Varietal Selection Tool (Page 16):
The Varietal Selection Tool provides a decision-support system to assist farmers and stakeholders in selecting the most suitable protein crop varieties based on regional climate conditions, agronomic performance, and nutritional characteristics. By combining multi-country trial data with environmental and production considerations, the tool supports evidence-based decisions, improves crop resilience, and promotes more sustainable protein crop cultivation.

Hermetic Bagging System (Page 18)
The Hermetic Bagging System introduces a low-cost, portable storage solution designed to preserve the quality, safety, and traceability of legumes and pulse-based products. By using controlled atmospheres within sealed storage bags, the system reduces insect damage, fungal growth, moisture variation, and reliance on chemical fumigation, supporting sustainable and decentralised plant protein supply chains.

Collectively, these abstracts provide novel insights into the challenges addressed, solutions developed, practical recommendations, and potential environmental impacts associated with each innovation. Each abstract has been prepared according to the EIP-AGRI format to ensure accessibility, facilitate knowledge exchange, and encourage the adoption of VALPRO Path results among relevant stakeholders. Through their publication and dissemination via valpropath.euand associated communication channels, these abstracts will increase awareness and underpin future initiatives to support the wider uptake of sustainable plant protein innovations across Europe.

1. Introduction

The Practice Abstracts compiled in this document represent a key knowledge transfer and dissemination output of the VALPRO Path project, supporting the uptake and exploitation of innovative solutions developed within the project's Innovation Production Systems (IPSs). Their primary objective is to translate complex scientific research into concise, practical, and accessible information that can be readily applied by stakeholders across European plant protein value chains.

Practice Abstracts are an important dissemination instrument within Horizon Europe Innovation Actions, bridging the gap between research and practice by presenting project results in a format tailored to farmers, advisors, industry representatives, policymakers, and other end users. By summarising the challenges addressed, the solutions developed, practical recommendations, and their expected impacts, these abstracts facilitate knowledge exchange and encourage the wider adoption of sustainable and innovative practices beyond the project consortium.

VALPRO Path aims to strengthen European plant protein value chains by developing innovative solutions that improve production efficiency, resilience, sustainability, and market opportunities for protein crops. The Practice Abstracts presented in this deliverable reflect the multidisciplinary nature of the project, covering a broad range of topics from primary production and crop improvement to processing technologies, post-harvest management, supply chain development, and circular bioeconomy approaches.

The seven Practice Abstracts presented in this deliverable include:

1. **Pulse Nutri-Track** - a systems modelling tool for tracking nutrient flows and supporting decision-making in plant protein value chains.
2. **Designing sustainable, resilient, and scalable supply chains for plant-based proteins** - modelling approaches for improving the sustainability, scalability, and resilience of European legume supply chains.
3. **Interdisciplinary Phenotyping for Abiotic Stress Tolerance as a Method of Varietal Selection for Legumes in the EU** - an advanced phenotyping approach supporting the identification of climate-resilient legume varieties.
4. **Valorisation of Crop Waste Using Peanut and Pea Crops as Examples** - a circular bioeconomy approach for converting agricultural residues into sustainable bio-based materials.
5. **Climate Resilience in Blue Lupine** - research supporting the development of climate-adapted lupine varieties with improved production stability and nutritional quality.
6. **Varietal Selection Tool** - a decision-support tool enabling farmers to select protein crop varieties according to regional conditions and market requirements.
7. **Hermetic Bagging System** - an innovative storage solution supporting quality preservation, traceability, and sustainability in legume value chains.

Together, these Practice Abstracts demonstrate the diverse innovations generated within VALPRO Path and highlight their potential contribution to strengthening sustainable plant protein production systems across Europe. They provide stakeholders with practical knowledge and recommendations that can support informed decision-making, encourage collaboration across the value chain, and facilitate the transition towards more resilient and sustainable food systems.

2. Pulse Nutri-Track

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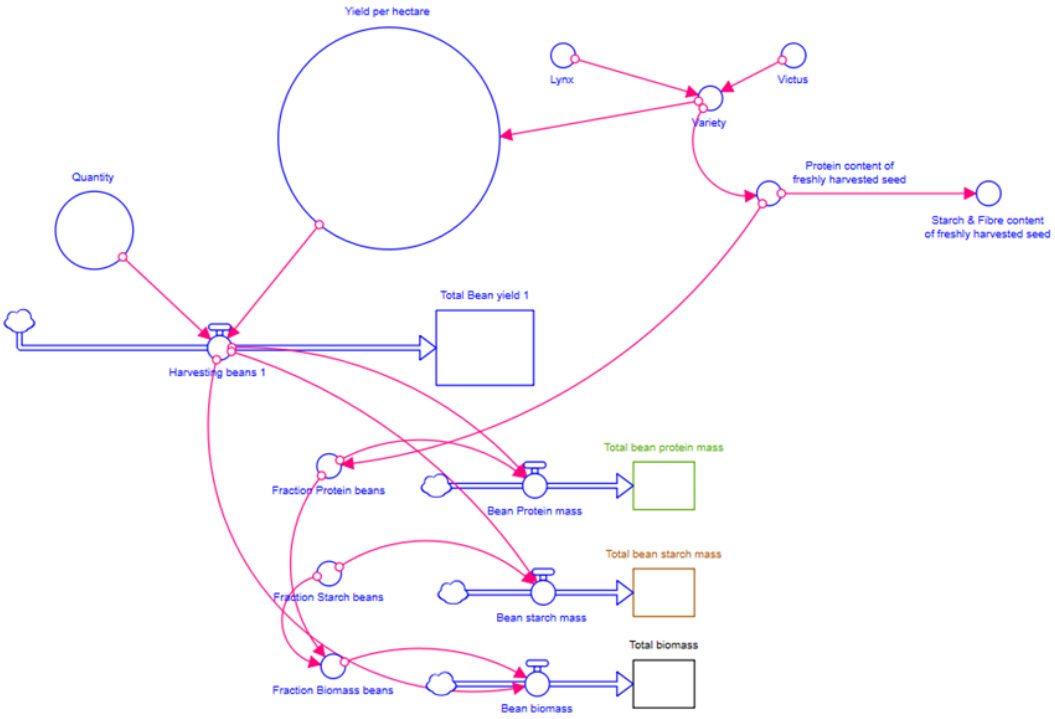
Email: richard.lynch@teagasc.ie

2.1.1. Problem Statement

Understanding the availability of macro-nutrients such as protein, starch and fiber, through the lens of a food system, from farm to fork, is difficult due to the many complex interactions that occur within a biological system. However, to maximize the valorization of a particular system of production, it is important to understand the quantities of core products available at each stage of the process and the impact of alternative management on the mass balances of macro-nutrients within each of these products. The use of protein crops to deliver high-value food and feed ingredients is one such complex system that requires close monitoring and tracking of nutrient flows to ensure its economic sustainability.

2.1.2. Solution

To complete supply chain nutrient tracking and environmental assessments in protein crop production systems, a systems modelling approach was applied, using data derived from the processes of crop cultivation, ingredient development and product formulation. Using the dynamic systems modelling tool Stella Architect, a software programme developed by ISEE systems (see 2.1.6), a simulation of system boundaries to produce a range of plant-based products was developed. The schematic below illustrates the various components and configuration used in the nutrient tracking model. The model components can be adjusted to investigate different scenarios in relation to agronomy (varietal effect, composition, yield etc.), processing parameters and external factors along the processing and supply chain.



2.1.3. Benefits

Starting at the cultivation stage, inputs such as variety chosen and time of sowing can be used to determine the yield per hectare of a given crop (in the initial case study, data for faba bean was used). This biomass can then segment into its constituent parts of protein, starch and fiber through a series of processing stages that include dehulling, milling and fractionation, with mass balances recorded for each. Through data generated in the VALPRO Path project, a range of novel processing technologies can be simulated within the model, such as the isolation of protein fractions through both dry and wet fractionation techniques. Further iterations of the model will include alterations to the milling process using data generated from trials on a wet-milling and roasting processes.

Finally, the plant fractions produced in the protein extraction stage can be included in a simulation of the production of a range of plant-based ingredients and products such as a plant-based beverage or energy bar.

2.1.4. Practical recommendations

This simulation model is a purpose-built scenario analysis tool that enables users to cohesively track nutrient flows through the production lifecycle of a plant-based product. Outputs can be subsequently

communicated through a purpose-built systems simulation 'Pulse – Nutritrack', which will act as an important decision support tool for all stakeholders involved in valorising plant-based value chains.

2.1.5. Environmental Impact

Work is underway to include environmental (carbon capture and GHG emissions) outputs from the model which will ultimately allow the user to run multiple scenarios and sensitivity analysis for multifactorial decisions taken on a range of protein crops and their respective food applications.

2.1.6. Weblinks

https://www.iseesystems.com/store/products/stella-architect.aspx

3. Designing sustainable, resilient, and scalable supply chains for plant-based proteins

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3.1.1. Problem Statement

Europe's shift towards plant-based proteins necessitates expanding domestic production. However, to achieve this, it is important to first scale up crop supply chains, which currently remain underdeveloped, due to several key barriers across the EU. These include limited processing infrastructure and specialised facilities for legume post-harvest and processing (see 3.1.6), uncertainty in end-use allocation between food and feed, which complicates balancing volatile feed markets with rising high-value food protein demands, and increased climatic vulnerability leading to higher crop loss risks. Since legume supply chains are not yet established, determining the required infrastructure is challenging (see 3.1.6). It remains uncertain whether a decentralised supply chain design of local hubs or a centralised industrial cluster is more viable. This lack of a clear strategic framework limits the growth of new protein products and deters the long-term investments necessary for EU self-sufficiency in plant proteins. These issues decrease economic viability, elevate spoilage risks, and limit legumes' role in achieving EU protein self-sufficiency.

3.1.2. Solution

Our work combines insights from two complementary modelling studies (Figure 1):

1) **Intercropping and lodging risk:** A two-stage stochastic optimisation model evaluates how intercropping peas and faba beans, under wind-related lodging uncertainty, affects downstream supply chain design. The model identifies efficient configurations for (de)centralised sorting, processing, and allocation of beans for food-grade or feed uses. The model can be applied to different mixed-crop systems, climatic regions, and countries across Europe. We applied the model to a case study in Italy.

2) **Infrastructure resilience and scalability:** A multicriteria decision analysis framework evaluates legume supply chains, specifically focusing on the trade-offs between centralised vs. decentralised network designs. The developed model is applied to the case study of faba beans in Ireland, as a representative of scaling up underutilised crop legumes. The study explores the

transition from increased land use and identifies the infrastructure requirements for drying and storage to reduce spoilage risks, along with food and feed processing techniques.

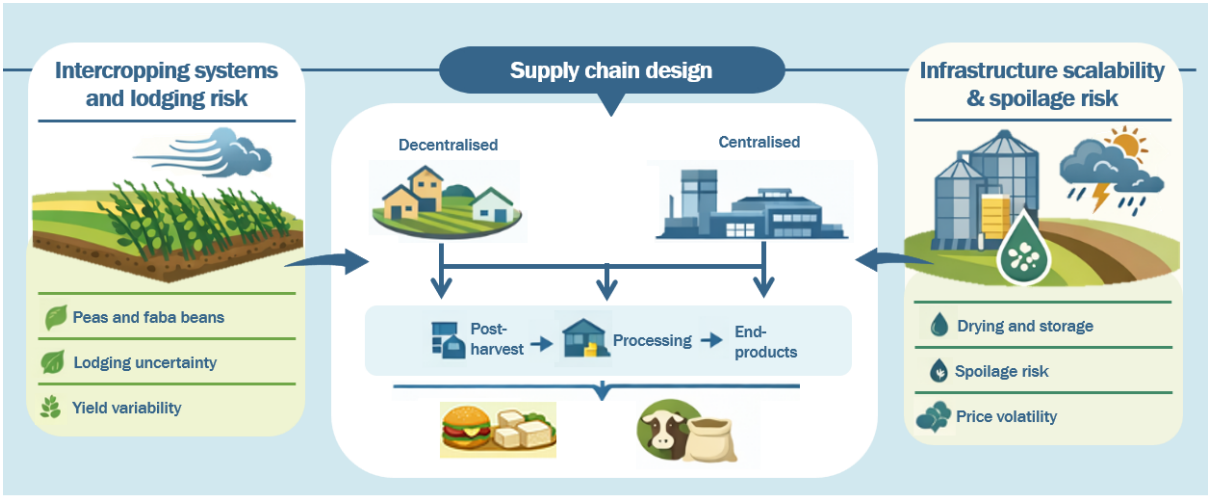


Figure 1: Framework for legume supply chain resilience. The conducted studies link agro-climatic risks and infrastructure scalability (right) to optimise supply chain design and end-product allocation.

Together, these works provide a system-level assessment of how agronomic practices, infrastructure, and end-use choices shape the sustainability and resilience of EU legume supply chains.

3.1.3. Benefits

Across both studies, the modelling results show that:

- **Enhanced economic value:** Shifting from low-value bulk feed to higher-value feed-grade and food-grade uses (e.g., protein isolates) increases the "economic density" of domestic land use, making legume cultivation more competitive with imported crops such as soy.
- **Waste reduction:** Lower spoilage and higher economic returns are achieved when drying and storage capacity are adequate and strategically built to buffer against high-moisture "wet" harvest years.
- **Climate resilience:** Diversified processing networks allow for diverting weather-damaged crops to feed while preserving high-quality batches for human consumption.
- **Scalability roadmap:** The research identifies the production thresholds where processing technologies such as dry fractionation, wet extraction, and heat treatments become viable.

3.1.4. Practical recommendations

Based on the combined evidence:

- **Support dual-purpose infrastructure:** Invest in flexible drying and processing facilities capable of handling both pure and intercropped legume streams.

- **Promote intercropping systems** where agronomically suitable, as they introduce a broader harvest window for farmers with the potential to stabilise yields and reduce losses due to inclement weather in the ~4 weeks before harvest, when the crop is vulnerable.
- **Develop market incentives** for human-consumption legume products to shift beans from low-value feed uses.
- **Incentivise food-grade processing:** Establish food-grade processing facilities to increase the value of domestically grown legumes and reduce reliance on imported protein sources, while balancing the monetary gains with environmental impacts associated with transport and production.

3.1.5. Environmental Impact

The modelling results show that:

- Local processing helps cut transport emissions and prevents spoilage waste by handling high-moisture crops close to the farm.
- Our approach highlights the trade-offs between conflicting goals, such as environmental impact and economic benefits.
- Processing food-grade crops at high values boosts the "protein yield per hectare" for human consumption, decreasing the total land needed to support European nutritional requirements.
- Supporting the economic sustainability of (inter)crop legumes, the models promote the growth of nitrogen-fixing crops, which reduces dependence on synthetic fertilisers.

Together, these effects foster more sustainable, circular, and resilient plant-protein supply chains.

3.1.6. Weblinks

https://edepot.wur.nl/692165

https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.692137/full#B17

4. Interdisciplinary Phenotyping as a Method of Varietal Selection for Lupin in the EU

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4.1.1. Problem

There is growing pressure for self-sufficiency of plant proteins within the EU, and indeed an emphasis on legume crop diversity. Planting underutilised crops such as chickpeas, faba beans, broad beans, and **lupins** will contribute to maximising protein production across the variety of pedoclimatic zones across the EU.

The lupin cropping area in the EU fell sharply during the late 20th century, in spite of its ability to grow in different climate and soil conditions, including sandy soils. Up to 42 % of farmers reported drought-tolerant cultivars as an absolute necessity for an increase in lupin cultivation, illuminating the importance of climate stress-tolerance phenotyping and further breeding efforts. It has been shown that there is a large pool of unexplored genetic diversity in *L. angustifolius* accessions, and thus a potential for further improvement in climate resilience and yield.

4.1.2. Opportunity

• Climate change represents a strong incentive for transformation of the European cropping systems towards more sustainable plant-based protein production for human consumption.

• With the EU currently importing approximately 75% of its plant protein, the focus on plant-based protein production in the EU would strongly contribute not only to lowering its CO2 footprint, but also to its protein production self-sufficiency as per the recently published EU Protein Plan (see 4.1.7)

• Typical projects focused on evaluating climate stress tolerance on crop performance focus mostly in terms of biomass production, yield components, and plant physiology. However, with legume grains expected to have high protein content as well as capped contents of anti-nutritionals, the target performance becomes more complex.

4.1.3. Solution

In light of the **complex target performance** of ideal future-proof legume varieties, traditional climate tolerance phenotyping studies must expand their scope. These studies will include the additional dimension of grain nutritional composition, along with physiological and biochemical analyses in response to various abiotic stressors. The **interdisciplinary** nature of such phenotyping allows for a more nuanced and relevant selection of legume varieties, through a scientific approach more robust and unique to the current phenotyping landscape but which is equally focused on the needs of the food processing industry. The efforts of plant phenotyping have until now primarily focused on plant performance from the perspective of biomass production and physiological functioning. However, a heat stress trial at the Department of Food Science of Aarhus University clearly showed the pronounced varietal effect of supra-optimal temperatures **Figure 2C**, where the varieties Primabella and Primadonna were more sensitive to heat stress relative to the rest of the tested varieties. Primabella and Primadonna also perform poorly in terms of yield (**Figure 2D**). A significant reduction in the carbohydrate content in grains of heat-stressed plants relative to controls was also seen (**Figure 2E**). Notably, Mirabor was the only variety capable of maintaining its grain carbohydrate concentration after heat stress treatment. On the other hand, the grain protein concentration increased substantially as a response to heat stress (**Figure 2F**). However, only in varieties with sensitive photosynthetic apparatus, Primabella and Primadonna. The rate of CO_2 assimilation showed a strong correlation with the grain carbohydrate and protein concentration at maturity, indicating the viability of physiological and biochemical measurements as predictors of grain nutritional composition (**Figure 2G, H**).

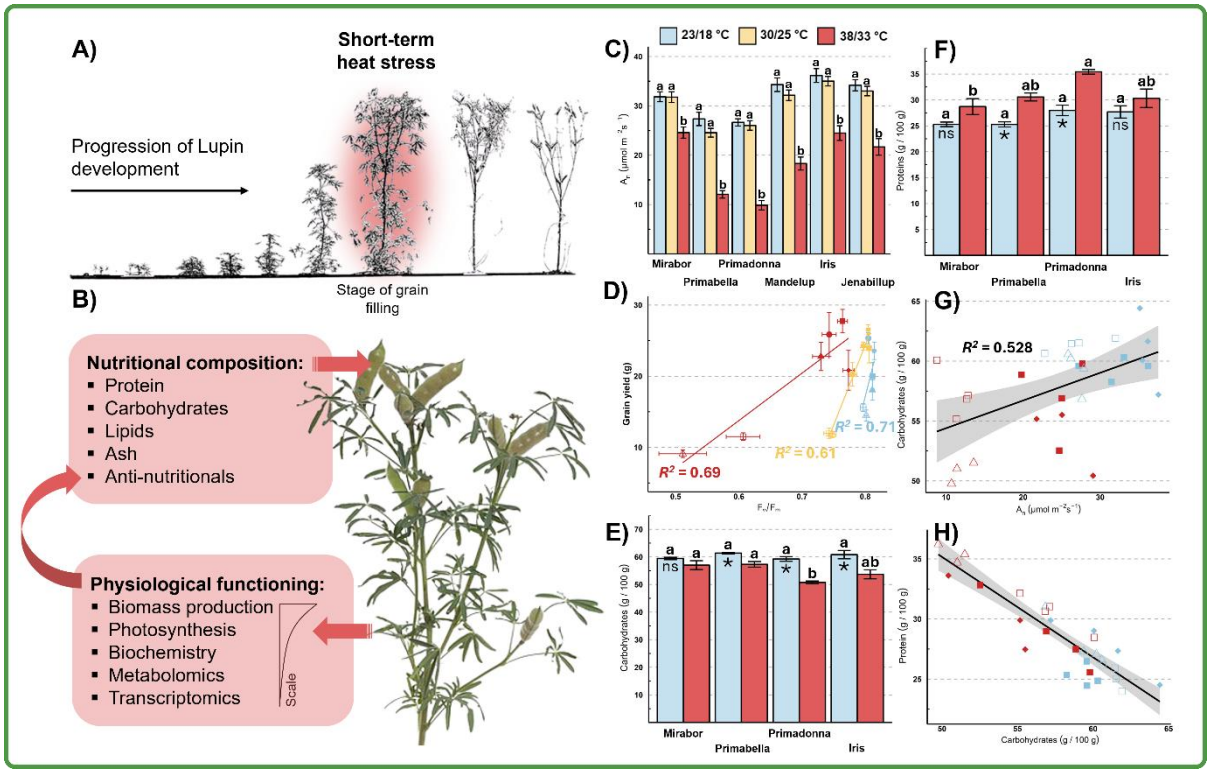


Figure 2. Effect of short-term heat stress on the physiological functioning of Lupinus angustifolius and its connection to grain nutritional composition at maturity. **A)** Progression of L. angustifolius developmental phases and timing of the heat stress in a controlled environment. **B)** Connection between the physiological functioning during stress and the associated downstream effects on yield as well as nutritional composition of grains at maturity. **C)** A_n of the six tested varieties in response to three temperature treatments; the compact letter display (CLD) indicates statistical differences between the temperature treatments within the varieties. **D)** Relationship between the F_v/F_m and the grain yield, for each of the three temperature treatments and the associated Pearson correlation coefficients (R^2). **E)** Carbohydrate concentration in grains of control and heat-stressed plants of selected varieties. **F)** Protein concentration in grains of control and heat-stressed plants of selected varieties. In figures E) and F) the CLD indicates statistical differences between the tested varieties within the treatment, while stars indicate significant differences between treatments within varieties. **G)** Relationship between the A_n and carbohydrate concentration in grains of control and heat-stressed plants and R^2. H) Relationship between the carbohydrate and protein concentration in grains of control and heat-stressed plants and R^2. In scatter-plots, the varieties are represented by the following symbols: ■ (Mirabor), □ (Primabella), △ (Primadonna), ▲ (Mandelup), ◆ (Iris), ● (Jenabillup).

4.1.4. Benefits

- Varietal selection based on a deep understanding of crop performance under various abiotic stress scenarios, combined with knowledge of the spatial distribution of dominant climate stresses across the EU, can enhance production efficiency and improve yield quality under future climate. This approach can lead to increased agricultural output, providing greater value from the land for EU farmers.

- Data presented here clearly demonstrate the connection between physiological performance and nutritional composition under both optimal and abiotic stress conditions. Allowing for the development of a robust, interdisciplinary, high-throughput phenotyping protocol.

4.1.5. Practical recommendations

- **Yield Optimisation:** Selection of stress-resilient cultivars, based on data from controlled climate trials, will secure a more robust production under future climate.
- **Reliable production of plant protein:** Selection of cultivars best suited for regions with different prevailing climate stresses.
- **Improved understanding** of the interaction between climate stress, yield and quality is needed to improve the commercial use of lupine.

4.1.6. Environmental Impact

More robust crops secure a more stable production under fluctuating climate conditions so the losses will be lower.

4.1.7. Weblinks

https://valpropath.eu/
https://agriculture.ec.europa.eu/farming/crops/cereals/reducing-plant-protein-deficit-eu_en
https://www.sciencedirect.com/science/article/pii/S2667064X26000199
https://pubmed.ncbi.nlm.nih.gov/40848642/

5. Dry Valorisation of Crop Waste using peanut and pea crops as example

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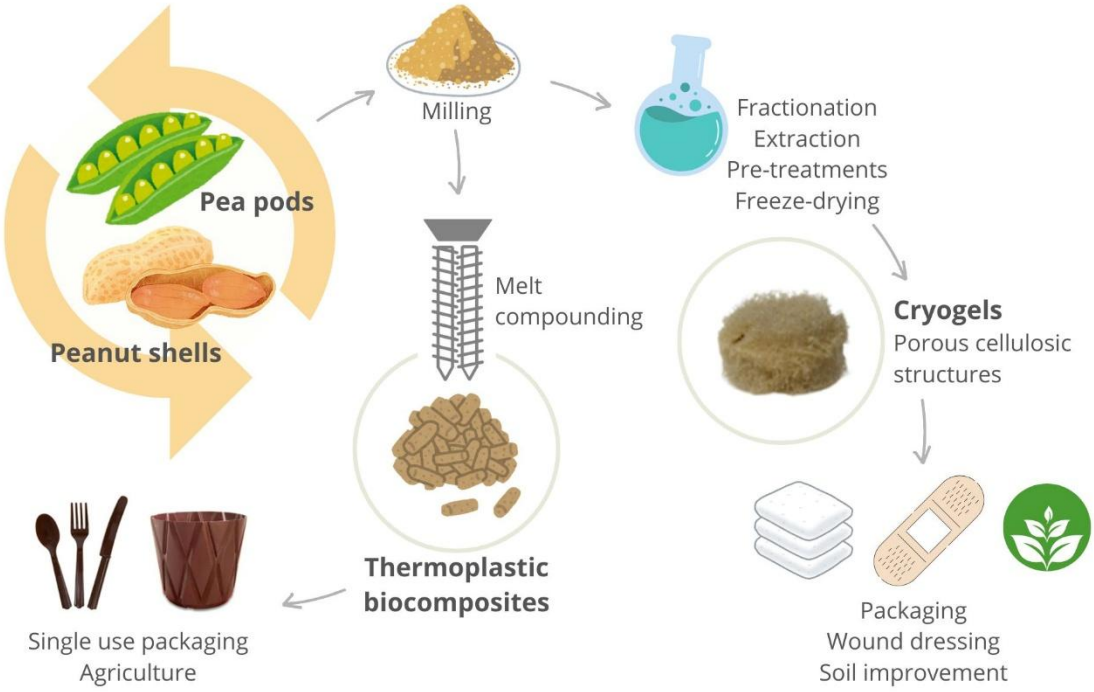
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5.1.1. Problem Statement

The production and processing of peanut and pea crops generate significant amounts of agricultural side streams, particularly peanut shells and pea pods, which are often underutilised or disposed of into low value markets. This linear management approach not only represents a loss of potentially valuable bio-based resources, but also contributes to environmental burdens associated with waste handling and inefficient biomass use. At the same time, there is a growing demand for sustainable materials to replace fossil-based plastics and high-impact products. However, integrating lignocellulosic residues from these crops into high-performance applications remains challenging due to variability in composition, limited knowledge of their functional properties, and the need for compatible processing strategies. Addressing these challenges is essential to unlock the full potential of crop residues within circular bioeconomy models.

5.1.2. Solution

To address the underutilisation of crop residue, example residues of peanut shells and pea pods were utlised, with an integrated valorisation strategy developed focusing on their application as functional bio-based materials. The side streams were characterised in terms of composition and physicochemical properties and subsequently processed as lignocellulosic fillers for thermoplastic biocomposites and as raw materials for the development of lightweight aerogels. Optimised compounding and processing routes were established to ensure compatibility with polymer matrices and to enhance mechanical and thermal performance, while tailored fibre suspension and drying approaches were applied to obtain structured aerogel materials. This dual approach demonstrates how agricultural residues can be transformed into high-value products for sustainable material applications, contributing to resource efficiency, waste reduction, and the advancement of circular bioeconomy models in peanut and pea crop value chains.



5.1.3. Benefits

The proposed valorisation approach delivers multiple environmental, economic, and technological benefits across the peanut and pea value chains. By converting peanut shells and pea pods into functional fillers for thermoplastic biocomposites and into structured aerogels, the potential exists to redirect significant volumes of low-value agricultural residues from disposal towards high-performance material applications. This contributes to waste reduction, improved resource efficiency, and lower reliance on fossil-based raw materials. The incorporation of these lignocellulosic side streams can reduce the overall carbon footprint of polymer-based products while enhancing material properties such as stiffness and lightweight performance. In addition, the development of scalable processing routes creates new market opportunities for farmers, processors, and bio-based industries,

strengthening rural economies and supporting the transition towards a circular and sustainable bioeconomy.

5.1.4. Practical recommendations

Based on this study to maximise the uptake of peanut shells and pea pods in bio-based material applications, stakeholders should implement systematic characterisation and quality control protocols to ensure consistent composition and performance of the side streams. Standardised pre-treatment, drying, and milling procedures are recommended to improve compatibility with thermoplastic matrices and to optimise aerogel processing. Close collaboration between farmers, processors, and material manufacturers is essential to secure stable supply chains and traceability of residues. In addition, pilot-scale validation and techno-economic assessment should be carried out to support industrial scalability and market adoption. Integrating these practices into existing peanut and pea processing chains will facilitate the efficient transformation of agricultural waste into high-value, sustainable materials within a circular bioeconomy framework.

5.1.5. Environmental Impact

The valorisation of peanut shells and pea pods into biocomposites and aerogels has the potential to reduce the environmental footprint of material manufacturing systems. By diverting these lignocellulosic side streams from low-value uses or disposal, greenhouse gas emissions associated with waste management are avoided and the embedded biogenic carbon is retained in long-life materials. Replacing a proportion of fossil-based polymers and non-renewable raw materials with bio-based fillers and structures further contributes to reduced carbon emissions and resource depletion. Ongoing work includes the assessment of carbon footprint, energy demand, and life cycle impacts of the developed materials, enabling scenario analysis to optimise processing conditions and maximise environmental benefits across the peanut and pea value chains.

5.1.6. Weblinks

https://valpropath.eu/

5.1.7. Environmental Impact

1. Global Warming Potential (GWP): Increased local production of legumes secures less use of imported soy.

2. Eutrophication Potential (EP): Increased production of legumes reduce the use of chemical Nitrogen fertilisers

5.1.8. Weblinks

https://valpropath.eu/

6. A Data-Driven Decision Support Platform for Protein Crops Variety Selection

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6.1.1. Problem Statement

The growing demand for plant-based proteins across Europe presents a critical challenge in selecting protein crop varieties suited to diverse climates, farming systems, and market requirements. While crop production systems are evolving, the integration of agronomic performance with nutritional quality remains underexplored, leading to the risk of suboptimal crop and variety selection in rotations. The lack of decision support platforms to guide farmers in making evidence-based decisions hinders the potential for improving protein crop production efficiency, climate-resilient crop rotations, and regional plant-based protein self-sufficiency.

6.1.2. Solution

This varietal selection platform aims to assist farmers' awareness of the diversity in both agronomic performance and nutritional profiling of protein crop varieties based on their climate and specific regional requirements. This platform combines agronomic performance data with nutritional composition, allowing for a more adaptive selection of crops for varying end-use needs. By integrating multi-country trial data on yield, protein content, and climatic conditions, the platform lists the performance of crop varieties for different regions and hence potential markets.

6.1.3. Benefits

- **Smarter crop choices**: The platform helps make evidence-based decisions, allowing farmers to select crops based on multiple criteria rather than yield alone, thereby providing a more holistic perspective on what can be achieved to meet market needs.
- **Better regional performance**: The platform's adaptability ensures that the most suitable varieties for each region studied are selected.
- **Science meets sustainability**: The platform combines scientific research with practical farming decisions, such as selecting varieties better adapted to local environments, supporting resilient crop rotations, and improving regional plant-based protein production.
- **Support for climate-adapted production:** For crop species with relevant multi-environment data, the platform may assist in identifying varieties better adapted to specific climatic conditions.

6.1.4. Practical recommendations

- **Tailored varietal selection**: Farmers should review the information to support their decision on variety selection based on their region's specific climate conditions and production goals.
- **Diversify crop production**: The platform may support farmers in comparing varieties across different regional conditions based on available agronomic and nutritional datasets.
- By selecting varieties well-suited to local conditions, farmers can diversify their protein crop production and mitigate risks posed by climate variability.

6.1.5. Environmental Impact

The varietal selection platform supports evidence-based variety selection by integrating agronomic and nutritional datasets across multiple environments. The database enables comparison of crop performance under different regional conditions and supports more informed decision-making for protein crop production systems.

6.1.6. Weblinks

https://valpropath.eu/

7. Hermetic bagging system

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7.1.1. Problem Statement

Food-grade pulses and pulse flours must retain their identity, quality and safety from the field to the processor. Conventional bulk storage in silos is often unsuitable for small or differentiated lots because it requires substantial fixed investment and may lead to commingling, loss of traceability and dependence on ventilation or chemical fumigation. Smaller 25 kg bags are flexible but create high handling requirements, generate more packaging waste and do not allow operators to verify hermeticity. During storage and shipment, exposure to oxygen, moisture fluctuations, insects and fungi can reduce product quality, shorten shelf-life and increase the risk of contamination or mycotoxin development. These constraints are particularly relevant for organic producers, niche processors and plant-protein value chains that require residue-free pest control and reliable farm-to-processor traceability.

7.1.2. Solution

The proposed system, studied within the VALPRO path project, combines a standard polypropylene raffia big bag (approximately 1 m^3 and 500-750 kg capacity) with a low-cost internal polyethylene liner that can be sealed hermetically. After filling, the liner is checked for leaks with an automatic pressure decay test and a controlled atmosphere is created by injecting carbon dioxide (CO_2) or nitrogen (N_2). The low-oxygen, high-CO_2 environment suppresses insects and microorganisms, stabilises moisture and limits oxidative deterioration. Each bag remains a separate, identifiable logistics unit, allowing information on field origin, crop variety, production practices and environmental indicators to travel with the product. The system is portable, can be transported on a pallet, is modular and suitable for on-farm storage, temporary storage and direct shipment to millers or food processors without the need for a dedicated silo.

7.1.3. Benefits

Trials demonstrated complete mortality of insects under the tested controlled-atmosphere conditions, while insects multiplied in untreated controls. Moisture remained stable and no fungal growth was detected after four months of storage. The approach can therefore preserve food-grade pulses and flours without routine chemical insecticides, while reducing contamination risk and maintaining batch identity. For farmers and processors, the main benefits are flexible storage capacity, direct farm-to-processor shipment, easier segregation of gluten-free or organic products, reduced manual handling compared with 25 kg bags, and the possibility of serving higher-value markets with verified traceability. Controlled atmosphere may also slow fat oxidation and rancidity in products such as chickpeas, supporting longer shelf-life and improved nutrient stability.

7.1.4. Practical recommendations

- **Use appropriate products:** Apply the system to clean, food-grade pulses or flours with moisture content suitable for safe storage. Do not use hermetic packaging to correct already mouldy, excessively wet or heavily contaminated material.
- **Protect and position the liner:** Insert the polyethylene liner carefully inside the raffia big bag, inflate it so that it adheres to the walls, and avoid punctures during filling, lifting and pallet handling.
- **Seal and test hermeticity:** Close the liner using a validated sealing procedure and check for leaks with a pressure decay test before gas injection. Hermeticity is essential because poor seals or mechanical damage can reduce the concentration-time exposure required for pest control.
- **Create and monitor the atmosphere:** Inject CO_2 or N_2 using suitable fittings and safety procedures. Record initial concentration and monitor its evolution, especially during the first days when CO_2 sorption by the grain can cause a rapid decrease. Maintain the atmosphere for the validated treatment period.
- **Maintain traceability:** Assign a unique bag identifier linked to field, variety, harvest date, moisture, treatment, gas concentration, storage conditions and destination. Use the bag as the traceable unit throughout storage and shipment.
- **Plan reuse and end-of-life:** Inspect the outer bag and liner after unloading. Reuse components only when food-safety and mechanical integrity are guaranteed, and select recyclable materials and local collection routes wherever possible.
- **Train operators:** Provide short training on liner installation, filling, sealing, gas handling, leak testing, monitoring and safe opening. Carbon dioxide can displace oxygen, so treatment and opening must be carried out in ventilated areas with appropriate risk controls.

7.1.5. Environmental Impact

The hermetic bagging system can reduce environmental impacts in several parts of the pulse value chain. Controlled-atmosphere pest management avoids or reduces phosphine and other chemical fumigants, lowering pesticide residues, operator exposure and emissions associated with repeated treatments. Stable moisture and suppression of insects and fungi reduce post-harvest losses, meaning that fewer land, water, fertiliser and energy inputs are wasted per tonne of edible product delivered. By maintaining quality during longer storage and shipment, the system may also reduce rejected lots and food waste.

Compared with many small bags, one large traceable unit requires less handling and can reduce the number and mass of packaging items used per tonne. Modular on-farm storage and direct shipment to processors can avoid construction and operation of dedicated silos, support shorter supply chains and reduce intermediate loading and unloading. The environmental balance nevertheless depends on liner production, gas supply, transport distance, reuse rate and recycling. For this reason, users should minimise plastic thickness while maintaining performance, favour recyclable mono-material solutions, optimise gas consumption, prevent liner damage and establish recovery routes. Environmental assessment should consider the complete system, including avoided product loss and chemical fumigation, rather than packaging material alone.

7.1.6. Weblinks

https://valpropath.eu/practice-abstracts/

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https://eu-cap-network.ec.europa.eu/projects/practice-abstracts/search_en

8. About these Practice Abstracts and VALPRO Path

These practice abstracts were elaborated in the VALPRO Path project based on the EIP AGRI abstract format. VALPRO Path, a Horizon Europe project spanning 4 years, from September 2022 until August 2026. With the participation of 22 partners from 9 countries, VALPRO Path is developing fresh possibilities, validating and showcasing ways to enhance plant protein production for food and feed in the EU.

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Project website: **https://valpropath.eu/**