Legumes Translated Deliverable Report

Deliverable 3.3

Legumes Translated Development Guide: Transition plans for Transition Networks

Due date: 4/2022

Project start date: 1 November 2018

Duration: 42 months

Work package: Synthesis of production-related knowledge (WP3)

Work package leader: Christine Watson, SRUC

Relevant task: Sector-level knowledge synthesis for transition (Task 3.4)

Relevant task leader: Casimir Schauman, HEL

Nature of deliverable: Report

Dissemination level: Public (PU)

Legumes Translated (Translating knowledge for legume-based farming for feed and food systems) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817634

Objectives of the tasks supporting the deliverable

Work Package 3 focuses on the technical/production challenges, especially those on farms. The overall objective is to compile quality-assured agronomic and other technical information in Actor Groups and to combine this with economic and environmental validation (from WP3 and 4). Original Actor Group knowledge will be brought together in Syntheses to support practice Abstracts and Development Guides, which will be further processed in WP 6. The objectives of WP 3 are to:

1. identify the business production goals and related expectations of the Actor Groups (and Operational Groups);
2. identify constraints and how they differ between regions, production systems, and AGs; 3. compile information from within and between Actor Groups about specific cropping systems;
3. facilitate transfer of relevant knowledge, practices, and technical support for innovation.

The work reported here is covered by one task: Task 3.4 (led by HEL, involving ZALF and SRUC).

The work was described in the description of action (DoA, work plan) as follows.

Development is often constrained by market barriers, lack of processing facilities, and coordination problems among actors. Along with Task 5.2 we will identify the value chain-related economic information needs and seek solutions from comparable settings. Synthesis of value chain and cross-sector knowledge within Transition Networks will compile information on factors such as actors' engagement in horizontal and vertical collaboration, communication of clear provenance and practices, and consistent product quality to consumers and whether different actors in the chain have similar rewards and risks in their transactions. Building up trust among food chain participants improves knowledge about the economic and technological characteristics of an innovation reducing the uncertainty. Based on this, a description of the development pathways from and for Transition Networks based on the input of Actor Groups will be provided. These provide the foundation for prioritising and targeting communication outputs (in WP6). A session in the kick-off meeting (Task 2.3) will be dedicated to the description of desired outcomes or transition pathways for legume crops in EU. Starting from the combination of their practical experiences (linked to Task 3.1), Actor Groups, supported by Transition Network coordinators, will identify shared constraints, goals and expectations. There will be two-way interaction in co-learning cycle 2 with WP3, 4 and 5 working on the compilation of knowledge. These discussions will be vital in identifying the route to gathering and synthesising knowledge and to Practice Abstracts and audio-visual outputs and so this task will interact closely with WP6.

This deliverable report will comprise the Legumes Translated Development Guide on knowledge on transition plans for increasing European legumes in value chains. This will provide insight into potential transition paths to increasing legumes in Europe.

Activities undertaken

Several activities were undertaken to provide useful insights from lessons learnt through the interviews with key actors in legume value chains. Interviews were conducted

between January 2021 – November 2021. All of the interviews were transcribed. In addition, a Legumes Translated workshop was organized in June 2021 in which concrete steps were presented to increase European legumes in value chains. In conjunction with the workshop, the preliminary results from the interviews were presented. SRUC presented during the workshop its investigation into the UK retail perspective of including legumes in value chains. The collected and transcribed interview materials were summarized and analysed by HEL (interviews) and the workshop results by ZALF. Information into the current situation of marketing legumes as feed was provided by SRUC. There were several discussions between consortium member organisations - HEL, ZALF, SRUC - to advance the deliverable report.

Results

The results of this study are reported in detail in the attached report. This provides the basis of a published report, which will be published through the European Legume Hub.

Three broad areas emerged as important for transitioning towards an increased production and consumption of legumes. These are

1. production and consumption (as food for humans);
2. harnessing the power of networks; and
3. using differentiation strategies in value chains to support consumption.

All of these can be applied together for inducing a transition that increases the production and consumption of European legumes.

Production
Conventional livestock and aquaculture producers that want to use more European legumes are dependent on the availability of non-GMO commodity production and have to consider the price of grain legumes. Addressing the European protein deficit through EU-grown legumes will inevitably require vast amounts of regional legume production to substitute the currently imported soybean. Increasing production ultimately requires scaling up to achieve low prices and large volumes based on large-scale farming enterprises across Europe. However, it is unclear whether affordable food prices can be maintained in a setting increasingly defined by stricter standards e.g., carbon emission reductions and limited pesticides use. In line with Ricardo's laws of comparative advantage, farmers in Europe are concentrated on growing cereals largely because they grow well, in other words cereals capture the resources efficiently, generating high yields.[1] To make legumes profitable and competitive at farm level, improving their efficiency to capture resources remains central.

Simple production-related subsidies are not capable of inducing long-lasting changes, yet they remain important to incentivise production. Connected to improving farmers' profitability is the development of cultivars through focused breeding activities, institutional improvements such as suitable contracts for production, the empowerment through local knowledge provision on crop production and connecting practices to market requirements, the provision of agri-technological solutions for pest and weed issues in

[1] Murphy-Bokern. 2022. Developing legume-supported cropping systems in Europe: have we forgotten something? Annals of Applied Biology, in press.

legume cropping or the introduction of small-scale processing equipment. It should be acknowledged that the uptake of novel crops is slow and gradual, as it also involves demonstrating their benefits to farmers that have little or even no experience of growing legumes.

Consumption of grain legumes as food
The change of consumption patterns of is best addressed either through educational campaigns or a range of information provision tools that allow consumers to make knowledge-based choices. There is still room to diversify plant-based food products made from grain legumes as well as providing guidance on adopting a plant-based diet by improving people's culinary skill-set. This is partly connected to the dietary trend that is moving towards increasing plant-based consumption, placing emphasis on flexitarian diets and reducing meat consumption. However, it is important to recognise the heterogeneity of consumers' preferences (e.g. regarding meat consumption, flavours). Any recommendation or strategy that might follow needs to consider this.

Networks and key actors
Connecting supplier (e.g., producers) and buyer (e.g., processors) is also a matter of providing the grower with specific market requirements. This involves networking and establishing suitable platforms to facilitate business relations.

There are key actors that facilitate change. This includes sourcing managers but also retailers that can make important decisions to support European feed use, as seen in the Austrian case. Retailers are not only focused on price, but also on organisations' and consumers' interests, when deciding what to put on their shelves. As shown in the case of UK, retailers are important when deciding what production strategies (e.g., feeding strategy) their linked supply chain should follow (e.g., livestock producers).

Moreover, local working groups are needed to identify what is done in a region and what is needed to grow and sell more legumes, specifically focusing on the evaluation of available information and infrastructure and the development of marketing concepts for special products. Such efforts could foster locally tailored solutions, which is highly relevant for legumes since the suitability of different legume crops varies between regions.

Lastly, producers ensure the availability of grain legumes yet their bargaining power is often small. Ensuring their economic outcomes through fair production prices is essential. Producers could organise into larger cooperatives in order to achieve higher prices in the negotiation process with potential buyers.

Value creation through differentiation
As stated by one interviewee "All we know is [the] price of everything and value of nothing''. The value-chains addressed in this report gain their distinctiveness from having a strong preference for using European legumes. These value chains differentiate themselves based on their strong regional identity and/or sustainability. Focusing on the environmental and resource impacts of legumes is clearly seen as a chance to encourage a legume-supported agrifood system, particularly in light of current trends either in society or EU policy, encouraging carbon zero or biodiversity conservation and actions to stall deforestation. Legumes are valued for their health (as food for human consumption), their environmental credentials, and often the geographical origin i.e.

where they have been grown. In many of the value chains the role of producers is mentioned assuring the consumer that the welfare of all value chain participants is important. In the case of producers, this can take the form of ensuring a fixed production price or a guaranteed top-up on the market price, which can also improve farmers' profitability. Besides the price factors, consumers buy products mainly for their superior taste, but also their ethical, health and environmental credentials. Livestock and food producers are able to capitalise on these credentials and differentiate themselves from the competition.

Conclusions

To increase grain legume production and consumption in Europe, there is a need to focus on the transformative power of key actors in adopting change. Niches destabilise current structures creating new trajectories for development. The niches observed in this report are value chains that include legumes as feed or food. In these cases, legumes are favoured for their local, environmental, health (plant-based food) related credentials.

According to transition theory, niches usually have distinct objectives, either to 'fit-and-conform' or 'stretch and transform' the prevailing regimes.[2] The objective in *fitting and conforming* is to persuade society that the niche is able to become competitive on regime criteria. For large users of feed materials, two important criteria are identified: price and availability. Some of the interviews reported a general concern over Europe's ability to supply enough raw materials and at the same time remain competitive as a non-GMO production region in the world, without affecting consumer prices for animal and fish products. Europe gains its distinctiveness from other global markets with its strong non-GMO profile and "greening" policies. However, stricter standards add costs to production. To maintain a level of competitiveness legumes have to be profitable at the farm level. Breeding programmes are central in improving the resource capture of legumes (especially carbon through photosynthesis). This suggests that legume production is more likely to increase if it fits and conforms to the rules of competition.

The objective in stretching and transforming is to develop the consensus in society that the "rules of the game" need to undergo some changes. From a production point of view, it could be about re-defining the economic competitiveness of cropping systems, maybe by revising understanding of optimum yield across a cropping system. The non-market outputs of grain legumes related to their environmental credentials are not well recognized.[3] This transformative agenda involves some level of systems-thinking that looks at the contributions of crops and supply chain activities to the system as a whole, whether it is about improving biodiversity, the livelihoods of farmers or the climate impact of food products. All of this would mean a larger shift in consumers' behaviour, but given the current changes and uncertainties in world food markets, there is a huge potential for a more regionalized sustainable agricultural production.

[2] Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy. 41(6), 1025-1036.

[3] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

Legume Translated practice guide

Transition plans for Transition Networks

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Legumes Translated

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Contents

Introduction

Europe has the opportunity to increase its production of legumes for both the feed and food uses. There is currently a demand for GM-free value chains in Europe, however, the predominant socio-technical system is technologically locked-in to intensive use of synthetic fertilisers and imported feed.[4] Known barriers to consuming more plant-based food in Western cultures are both a structural lack of infrastructure[5] and individual food choices. Legume production is still marginal, yet their increased production in Europe could help close the protein deficit,[6] reduce the need for synthetic fertilisers,[7] and if eaten by humans, reduce the negative environmental impact by substituting meat to plant-based foods.[8] This report offers insight and lessons directly from actors active in the different value chains that are currently using or aspire to use more legumes in animal or plant-based production. It provides information on the actors' perceptions of existing challenges and barriers, as well as concrete steps to increase the use of European legumes in value chains.

The ambition of Legumes Translated is to find ways to increase the production and consumption of grain legumes in Europe. This report, therefore, gives insight into the challenges and opportunities for increasing the proportion of grain legumes in European value chains and aims to identify pathways that support a transition. The extensive network of Legumes Translated was used to conduct interviews with key actors in legume-supported value chains.

The main objective of the work reported here is to compile relevant challenges and opportunities for a transition to occur. This was done using a multi-level-perspective framework that investigates the challenges and opportunities from a market, consumer preference, science, technology, infrastructure, network and policy perspective.[9] In addition, concrete steps are suggested to increase the proportion of grain legumes in value chains. The multi-actor project Legumes Translated provides the ideal frame for this research concept, with a range of legume-experienced actors from all over Europe.

[4] Voisin A-S, Guéguen J, Huyghe C, Jeuffroy M-H, Magrini M-B, Meynard J-M, Mougel C, Pellerin S, Pelzer E, 2014. Legumes for feed, food, biomaterials and bioenergy in Europe: a review. Agron. Sustain. Dev., 34, 361–380

[5] Magrini, M.-B., Anton, M., Cholez, C., Corre-Hellou, G., Duc, G., Jeuffroy, M.-H., Meynard, J.-M., Pelzer, E., Voisin, A.-S., Walrand, S., 2016. Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecol. Econ. 126, 152-162.

[6] Zander, P., Amjath-Babu, T.S., Preissel, S. *et al.* Grain legume decline and potential recovery in European agriculture: a review. Agron. Sustain. Dev. 36, 26.

[7] Voisin A-S., Guéguen J., Huyghe C., Jeuffroy M-H., Magrini M-B., Meynard J-M., Mougel C., Pellerin S., Pelzer, E. 2014. Legumes for feed, food, biomaterials and bioenergy in Europe: a review. Agron. Sustain. Dev., 34, 361–380

[8] Xu, X., Sharma, P., Shu, S., Lin, T.-S., Ciais, P., Tubiello, F.N., Smith, P., Campbell, N., Jain, A.K., 2021. Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nat. Food. 2(9), 724-732.

[9] Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. Res. Policy. 31(8), 1257-1274.

Materials and methods

Data source

This report's main focus lies in identifying pathways to increase EU legumes in livestock and food sectors by looking at common challenges and opportunities as well as concrete steps that need to be taken. Judgmental and volunteer sampling was used to select the interviewees. The interview objects were initially recommended by actor group representatives and selected based on their sectorial knowledge. Actors with good oversight of sectoral or value chain activities in the respective sectors were interviewed. This included two actors involved in the poultry sector, two actors from the pig sector, three actors involved in dairy and beef production, one actor from the food sector, one actor from the aquaculture sector and one actor involved in seed production. All interviewees agreed to participate on the basis that they will remain anonymous.

Data collection and analysis

The data collection was conducted between 2020 and 2021. This involved the method of semi-structured interviews with 10 persons and an online workshop with members of the consortium. The guiding question examined is how to increase the proportion of regional legumes in European value chains? This is very much in line with the overall aim of Legumes Translated, namely, to increase the production and use of grain legume crops in Europe as part of an overall change in how protein is sourced and used in Europe.

The interview questions followed a semi-structured interview guide (see Annex 1). The interviews were conducted and recorded online (Zoom). The material was transcribed (a total of 63 pages), analysed and categorised in Excel.

In addition to the interviews, a half-day workshop with representatives from each of the seven networks was organized to jointly design transition pathways for increasing the share of European legumes in value chains. The workshop participants were divided into two groups (group 1 and group 2) of 7 people each. Moderators facilitated each group using a digital visual collaboration tool (Mural). The workshop results were also analysed and categorised in Excel. For an overview of the workshop structure and questions, see annex 3.

In the following section the results of the interviews and workshop are presented. Although the interviews and workshop form the basis of the presented results, additional research articles or documents have been used to elaborate some of the ideas brought forward by the interviewees and workshop participants. This is done to connect the results to the relevant literature on the subject matter.

Results

Value chains

The value chains involve several production stages. Legumes are directly present in the initial stages of primary production and feeding and indirectly present in the packaging directed towards consumers. The discussions were mostly focussed on the value chain, from the perspective of growers in connection to processors. Intermediaries are retailers and organisations issuing certification.

Value chains come in different sizes and can be divided into different lengths containing different amount of production stages. There is no exhaustive definition of a short value chain. By "short" it can be the number of intermediaries involved in the supply chain or the physical distance from primary production to consumer. Governance structures (e.g. production contracts) are also important to consider i.e. the collaboration between the actors in the chain. These short value chains are contrasted to global value chains that in general involve several intermediaries and extensive coordination.[10] The value chains involved in this report include:

- A dairy company in Serbia that defines itself as a short value chain. The company purchases soybean seeds and sows them on plots. After cultivation the soybeans are stored in silos. Subsequently, the soybeans are processed to soybean cake. The soybean cake is sold but also to feed the farm's cows.

- A plant-based food company in Finland that defines itself as a short value chain. The company identifies itself as being in the organic niche and buys from accredited sources. They produce legume-based food products from soybean, pea and faba bean. Soybeans are bought from Europe from an intermediary that cleans the soybeans and evaluates their quality, before packaging and delivering to the food company for further processing. Previously the company procured their soybean from Brazil but have shifted to European sources. Dehulled faba beans and pea are bought domestically directly from a domestic processor.

- A project that supports regional value chains for poultry feed in northern Germany. The project uses local grain legumes that are sent to a feed mill. The distance between the farmers and the mill is on average 100 km in the case of peas and faba beans. Soybean is sourced from domestic sources i.e. with greater distances. The project is currently one year into their goal of building a value chain based on local feed. This feed allows egg producers to market their product as regional and GMO-free. Another integral part of this project is the online trading platform that was created for selling and buying domestic legumes. The volumes are small but more importantly their work shows the importance of capturing small production streams.

- A producers' association of independent livestock farmers producing and processing pig meat. It focusses among other things on how regionally grown legumes can be adopted in their farmers' feed rations. This includes a chain starting from growing the

[10] Gereffi, G., Humphrey, J., Sturgeon, T., 2005. The governance of global value chains. Rev. Int. Polit. Econ. 12(1), 78-104.

feed input, logistics i.e. the transportation of the pigs to the slaughterhouse and meat processing. The meat is prepared to a certain degree by the farmers' association after which a subsidiary takes over to produce consumer products e.g. sausages and cured meats. The group also owns outlets to sell their products but external vendors such as independent butchers are mainly used for retail purposes. The value chain is rather short and regional in scope, especially considering that the meat is even marketed as a regional product. The chain is certified non-GMO and this helps to reduce costs compared to buying from external sources, which increases transaction costs.

- An aquaculture company in Greece that is experimenting on including more European legumes in their fish feed. The company has an integrated value chain from hatchery units, fish farms, packaging centres, processing centres and with distribution to many countries around the world. The feed raw materials are bought on the market with specifications related to quality (e.g. protein content, low moisture) and purity e.g. non-GMO or pesticide free. The raw materials mostly consist of traditional fish meals, and concentrated soybean protein and soybean meals. The company is exploring the use of alternatives to using fish oil and soybean meals. This includes using cool-season grain legumes together with feed materials high in protein such as animal by-products. The over-arching aim is to respond to the societal pressure to be more sustainable and to protect natural resources by reducing their dependence on imported soybean. The value chain has a vertically integrated chain, including their own feed production.

- A commercial seed enterprise in Ireland that provides seeds higher value crops e.g. low tannin faba beans. The company is the agent for breeders and protects property rights by collecting royalties on breeders' behalf. It serves farmers by ensuring that cultivars selected from breeders' programmes are suitable for Irish growers. The company takes new genetic material and tests the seeds on a private trial site and proposes official trials with the ministry of agriculture. After three years of successful trial the cultivar is recognized by the ministry as suitable for cultivation. The company engages in seed multiplication of legumes such as faba bean and cereals. The seeds are sold on the market. Seed growers are recruited on a contractual basis by a contract manager.

- An association based on promoting poultry products (eggs and poultry meat) in Austria. Their activities range representing the economic and veterinary interests of the poultry sector within the policy community, supporting poultry farmers with access to knowledge, working with universities in science and research, and engaging with media. The association has deep insight into the Austrian poultry sector.

Development of legumes as feed and food in Europe

The livestock and aquaculture sectors are the largest and most developed users of grain legumes in Europe. Import soybean dominates, yet there are clear signs for a willingness to shift to more home-grown alternatives. Aquaculture is increasingly demanding more vegetable feed sources. Moreover, non-GMO soybean production is also increasingly in demand. Legumes for human consumption is still low in many parts of Europe.

Legumes as feed – large volumes and the prominent role of soybean

The livestock sector is the main consumer of grain legumes in Europe which is why it has a strong impact on markets.[11] The amount of meat consumed in Europe has increased (Figure 1). According to the feed protein balance sheet by the European Commission, a total of 83 million tonnes of protein was fed to EU livestock in the year 2019-2020, with 64 million tonnes originated in the EU with a self-sufficiency rate at 78%, with especially poor self-sufficiency for high-protein feed sources (30-50% protein content). In one study, the total feed supply in EU-27 was estimated at 593 million tonnes.[12] The consideration of eight aggregated feed classes showed that grass, annual forage and cereals accounted for 86% with the 14% representing protein-rich, brans, animal & fish based feed, oil & sugar crops and other feed classes.[13] The total allocation of protein-rich feed for each animal category in the EU-27 in the year 2010 was estimated at 34% for pigs, 24% for chicken, 18% for dairy cows, 14% for other cattle, 7% other animals and 2% sheep & goat of the total dry mass consumed.[14]

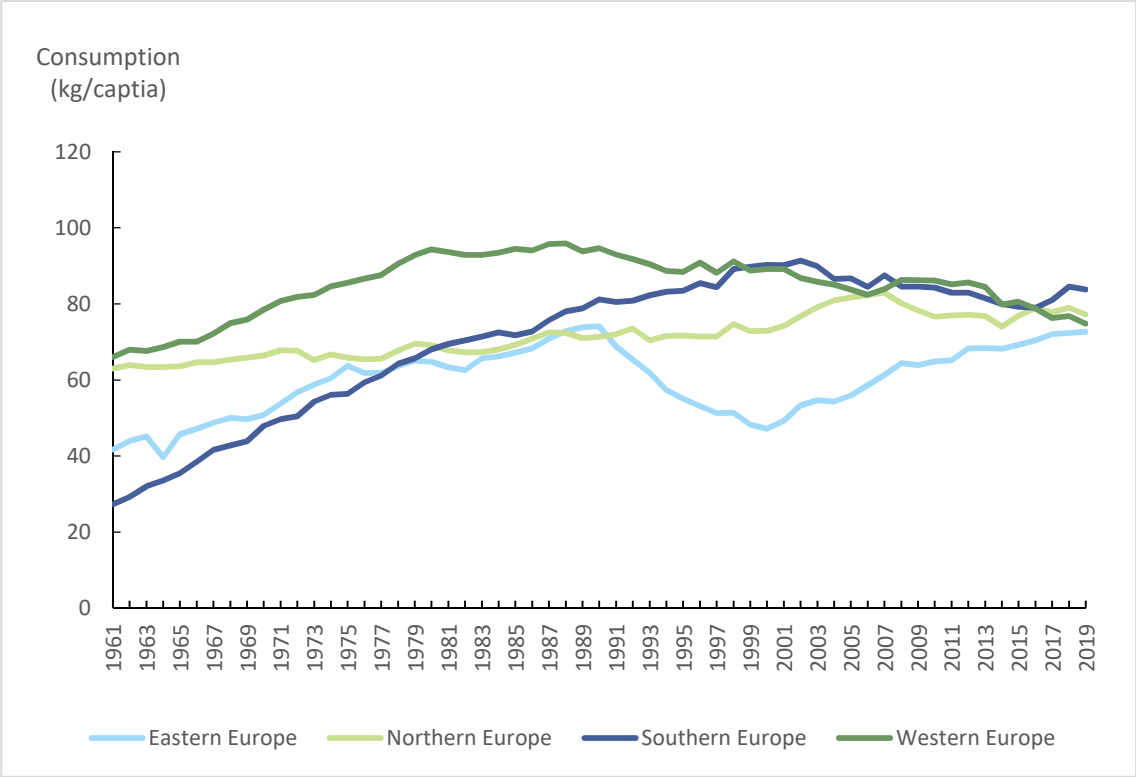

Figure 1. Changes of per capita carcass meat[15] consumption in Europe. (Source: FAOstat)

Soybean and soybean products have become a key protein feed for European farmers since changes in trade policy enabled broad access to these high-protein inputs that serve well in intensified production systems in which livestock is decoupled from land

[11] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

[12] Hou, Y., Bai, Z., Lesschen, J.P., Staritsky, I.G., Sikirica, N., Ma, L., Velthof, G.L., Oenema, O., 2016. Feed use and nitrogen excretion of livestock in EU-27. Agric. Ecosyst. Environ., 218, 232-244.

[13] Ibid.

[14] Ibid.

[15] This includes bovine meat, mutton & goat meat, pig meat, poultry meat, horse meat, camel meat, rabbit meat, and game meat

resources. Soybean meal is the main high-protein oilseed meal used in compound livestock rations, accounting for 84% of all use worldwide.[16] Estimates have shown that the largest share of soybean meal is used for production of monogastrics.[17] However, other sectors are also relevant consumers: Aquaculture has so far relied heavily on fish meal based feed (based on fish products), but due to ethical and sustainability concerns, fish meal has partly been replaced with soybean feed, even though the use of some fish meal is still important when considering the nutritional requirements of carnivorous fish. The price of soybean has been historically low, only during the most recent years (2019-2021) prices have increased rapidly. Therefore, livestock producers are starting to favour the use of alternative protein sources in feed, with cool-season grain legumes growing in their importance. However, our interviews indicate that soybean continues to be important in the livestock and aquaculture sector due to its high protein content, suitable amino acid profile and easy availability of consistent and large amounts.

The production and value of aquaculture is steadily growing in Europe, with Norway being the main producer.[18] The use of vegetable materials is increasing partly because of shortage of conventional feeds (fish meal and fish oil).[19] There is a clear opportunity to increase the use of legumes in fish feed, entirely or partly.[20] This shift is already unfolding to some extent. In 1990, three Norwegian aquaculture companies reported that their feed for salmon consisted mainly of marine protein sources (65.4% of a typical feed), where as in 2016 the share of marine protein source accounted for only 14.5% and plant protein sources 40.3% of salmon feed.[21] Fish producing companies seeking to make their production more sustainable in the future, are also able to utilize faba bean and sweet lupin, both considered good alternatives to soybean and fish meal.[22] [23]

Legume production – far from sufficient, making huge imports necessary

Considering legume production in Europe in light of the use of legumes for feed makes the deficit very clear. This is even though there has been support for legume related production in Europe over the years. This support started with the introduction of price support to soybean producers in 1963. More recent CAP reform in 2013 introduced a 'greening component' to direct payments including diversification requirements and ecological focus areas. Reform of rural development programme and voluntary support

[16] Watson, C.A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C.F.E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., Stoddard, F.L., 2017. Grain Legume Production and Use in European Agricultural Systems, in: Elsevier, pp. 235-303.
[17] Ibid.
[18] Eurostat, 2021. Aquaculture production and value, EU-27 and Norway, 2008-2018.
[19] Ernst & Young, 2017. The Norwegian aquaculture analysis (accessed 31.1.2022) https://mb.cision.com/Public/12397/2457990/818c800a18b3c888.pdf
[20] Watson, C.A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C.F.E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., Stoddard, F.L., 2017. Grain Legume Production and Use in European Agricultural Systems, in: Elsevier, pp. 235-303.
[21] Aas, T.S., Ytrestøyl, T., Åsgård, T., 2019. Utilization of feed resources in the production of Atlantic salmon (Salmo salar) in Norway: An update for 2016. Aquaculture Reports. 15, 100216.
[22] De Santis, C., Crampton, V.O., Bicskei, B., Tocher, D.R., 2015. Replacement of dietary soy- with air classified faba bean protein concentrate alters the hepatic transcriptome in Atlantic salmon (Salmo salar) parr. Comp Biochem Physiol Part D Genomics Proteomics 16, 48-58.
[23] Weiss, M., Zeytin, S., Fuchs, V., Hoerterer, C., Slater, M., 2021. Increasing competitiveness of sweet lupine and faba bean in feed value chains in Europe, Aquaculture Europe 2021, Funchal, Madeira, Portugal, October 04-07.

schemes added to this.[24] However, legume production is in many areas still marginal, with less than 3% of arable land devoted to grain legumes (Figure 2).

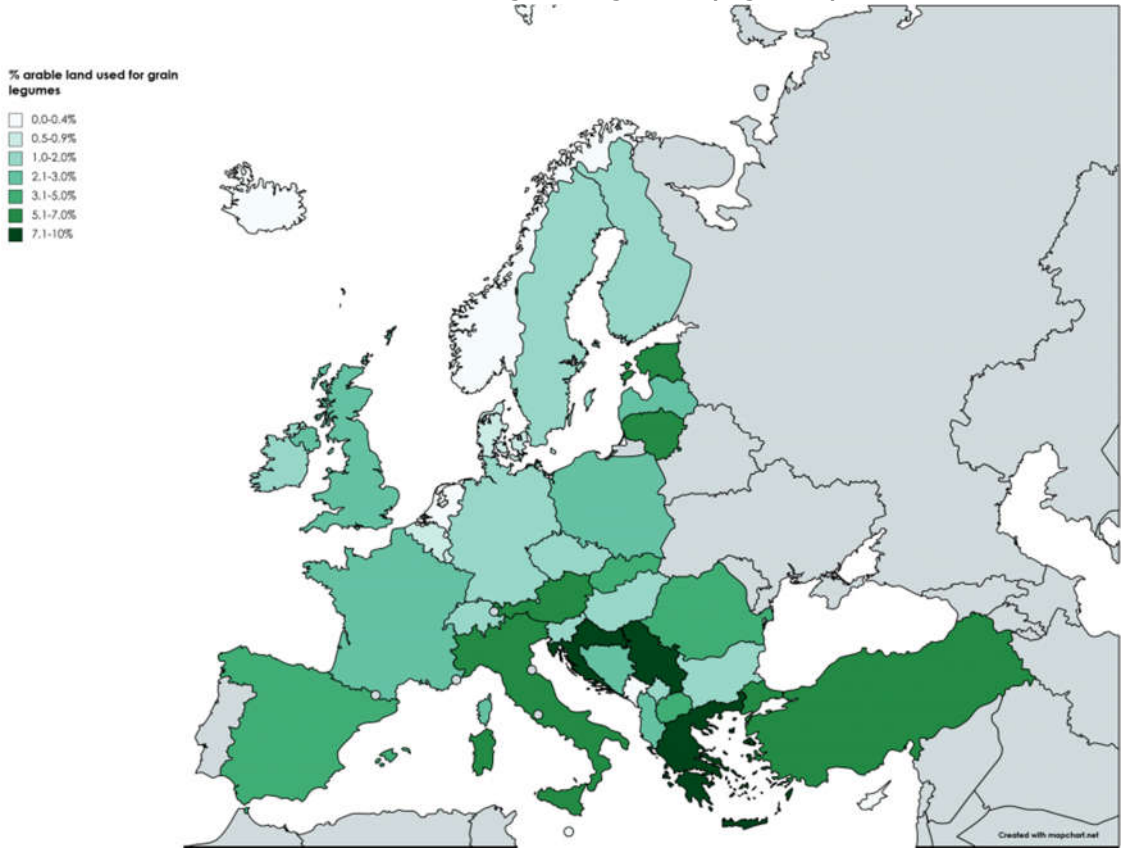

Figure 2. Arable land share for grain legumes used in Europe in 2019 (Source: Eurostat, 2020. European Commission, Brussels, Belgium.)

When focusing on the most used grain legume, soybean, the cultivation is mostly located in areas with preferable agronomic conditions with Italy, Romania and France being the largest producers.[25] However, soybean production in the EU is far from sufficient to cover the enormous demand, which makes large amounts of imports necessary. Significant quantities of soybean, therefore, are imported into the EU, especially from countries such as USA and Brazil.[26]

Legumes as food – low consumption, but new opportunities

Comparing the volumes of legumes used for food to those for feed, shows that the amount for food is only a small fraction of the amount for feed. In 2017, the EU's appetite for grain legumes used for food amounted to 2.3 million.[27] The main (dry) grain legumes used for human consumption in Europe include dry pea, faba bean, soybean,

[24] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A., 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

[25] Fediol, 2019. Where does the soy used in the EU originate from? Infographic by the EU Grain Chain (accessed December 2021) https://www.fediol.eu/data/Where%20does%20soy%20come%20from.pdf

[26] Ibid.

[27] Hamann, K., Vasconcelos, M., Löhrich, N., Odee, D., Vickers, R., Blazon, N., Trstenjak, M., Toma, L., Maaß, H., Kolmans, A., Tran, F., Bienkowski, D., Iannetta, P., 2019. A map of value chains for legumes used as food. Deliverable 4.1 for the EU-H2020 funded project 'TRansition paths to sUstainable legume-based systems in Europe' (TRUE).

lentil, chickpea and common bean. Changes of average grain legume consumption per capita demonstrate that intakes of Southern and Eastern European consumers decreased since 1961, while Northern and Western European citizens consumed slightly more legumes in 2019 than they did in 1961 (Figure 3). The consumption amounts are all on a low level, particularly when compared to meat consumption patterns (Figure 1). However, there is an increasing consumer interest in legumes as plant-based protein sources that is based on health, environmental and animal welfare concerns. This development allowed an increasing turnover on the meat and dairy alternative market of approximately 1.400 million euros in 2013 to 2.600 million euros in 2018.[28] Legumes are processed into ingredients (e.g. protein, fibre, and starch) that are used in the expanding plant-based food sector. Plant-based protein manufacturing companies prefer high-quality ingredients, including legume crops such as soybean, pea and faba bean and to some extent lupin. Although whole-bean consumption in Europe has decreased over the past decades, the development is expected to change in light of consumer trends. Moreover, there are approximately 40 pulses[29] with unique characteristics that are protected through EU schemes recognising their particular geographical origin (e.g. Puy lentils) which have - based on the certification - a special market position and re-connect to traditional legume consumption.

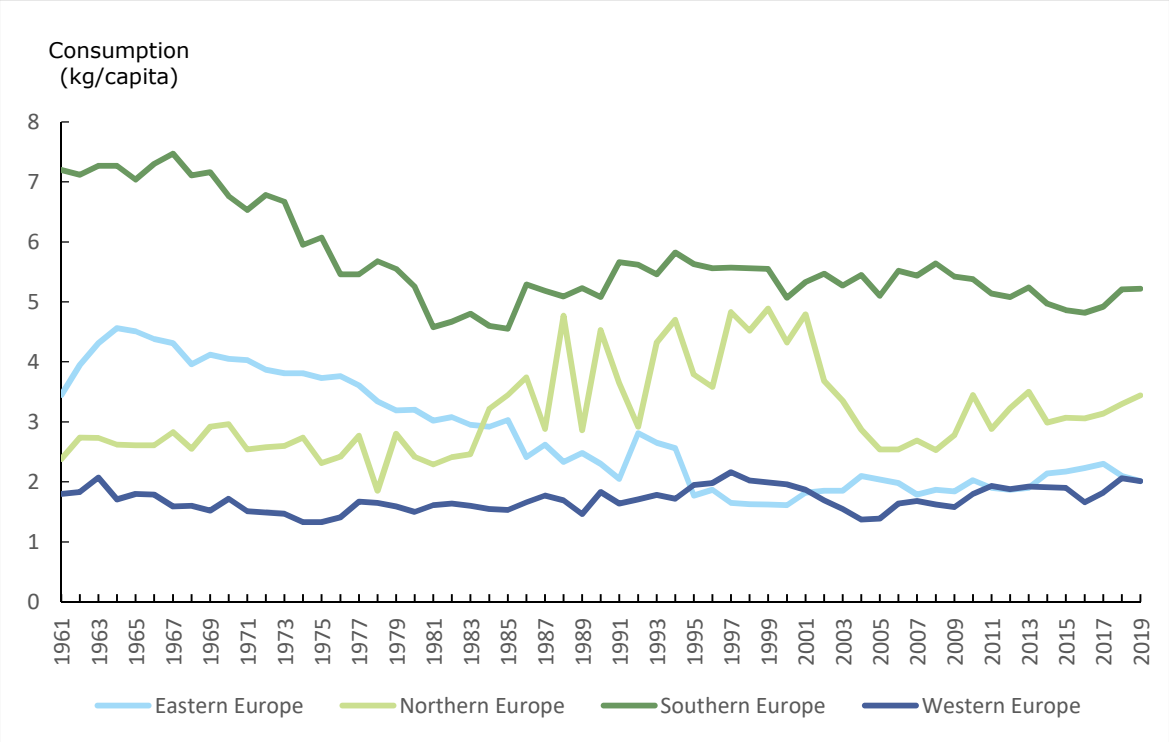

Figure 3. Changes of average grain legume consumption as food in Europe (Source: FAOstat)

Communicating legumes in packaging

Consumers are limited to foods that are available in the market. Furthermore, manufacturers need to provide information regarding animal feed and products origin through the packaging for consumers to make informed choices. We employed the Mitel

[28] European Commission. EU legumes Benefit People and the Planet (accessed August 2022) https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/plants_and_plant_products/documents/factsheet-eu-legumes_en.pdf.
[29] Ibid.

(New Product Development) database to identify which type of processed fish, meat, egg and meat substitute products were introduced in the UK, Germany and Finland markets from 2011 to 2021 and to what extent legumes were mentioned in the packaging of these products. A total of 26,878 new products were introduced, as shown in Table 1. Regarding the market these products were introduced (49% refer to the UK, 42% to Germany and 9% to Finland). The top 10 companies introducing these products are mainly retailers accounting for 40% of the introduced products, see Table 2. Only 12 % of these products are reported as imported, and only 0.81% of the products mention feed type in their packaging. We also searched for the word legumes, peas, beans and soya, as shown in Table 3. Soya was listed in 1.59% of the new products, and almost 88% of these are meat substitutes. Beans and peas were listed in 0.78% and 0.55% of the products, respectively, and all were poultry products targeting flexitarian consumption or used as additional ingredients. Finally, the word legumes was listed in 0.06% of the new products, all except one being meat substitutes.[30]

Table 1. New processed fish, meat, egg and meat substitute products launched in Finland, Germany and The UK from 2011 to 2021.

Sub-category	Frequency	Percent
Meat products	10973	40.8
Fish products	6932	25.8
Poultry products	5616	20.9
Meat substitutes	2254	8.4
Eggs & egg products	1103	4.1
Total	26878	100.0

Table 2. Top 10 companies introducing processed fish, meat, egg and meat substitute products in Finland, Germany and The UK from 2011 to 2021.

Company	Frequency	Percent
Lidl	2350	8.7
Aldi	1955	7.3
Tesco	1164	4.3
Asda	1073	4.0
Waitrose	868	3.2
Sainsbury's	790	2.9
Marks & Spencer	779	2.9
Iceland Foods	662	2.5
Morrisons	656	2.4
Netto Marken-Discount	478	1.8

Table 3. Number of products listing the words feed, soya, beans, peas or legumes in the packaging.

Legumes or feed listed packaging	Frequency	Percent
Soya	427	1.6
Animal feed	217	0.8
Beans	209	0.8
Peas	148	0.6
Legumes	16	0.06

[30] Mitel database, 2021.

Non-GMO soybeans potential

For non-GMO soybean, countries such as Romania, Bulgaria and Moldova are gaining foreign investments into soybean production from multinational commodity traders such as Cargill. [31] These countries put together are estimated to be able to provide 2 million tonnes, representing 5% of EU consumption.[32] France and Italy are the biggest producers of non-GMO soybean in Europe. However, non-GMO soy production is not limited to southern countries. Research indicates that there is agronomic potential to expand into northern Europe, especially in feed use but also as food grade and organic.[33] The general outlook for soybean is favourable, especially considering the growing demand.[34] However, how the future of legumes in food and feed develops is driven by a number of forces. Markets, consumer preferences, science, technology, policy are crucial drivers and are therefore the topic of the following sections.

Markets for feed and food

It is important to understand the markets of the main grain legumes in the EU. As indicated earlier, soybean remains strong, and it is believed that imports are hampering the development of European grain legumes. There are alternatives to imported soybean and levers for improving European grain legumes' position are discussed. The dairy sector is fairly distinct with grain legumes having a smaller role than forage legumes, when considering feedstuffs.

Market segments in feed and food market

The feed market is the most developed market for grain legumes in Europe. Determining factors on the feed market are nutritional content, quality parameters and prices of feed ingredients.[35] Main market segments for legumes from Europe for feed are premium markets such as conventional feedstuff, non-GMO and organic.[36] The main market segments for legumes as food include pulses, processed plant protein products and functional ingredients. Depending on the use in the food sector, legumes are either sold as whole grains or processed into food products such as meat alternatives or processed into functional ingredients in order to fulfil technical or nutritional needs.[37]

Most of the interviewees encourage the production of organic certified grain legumes in Europe, as there is growing interest for organically produced livestock products. In 2018, the amount of dry grain legumes under organic cultivation was estimated at 5% of the

[31] Colsell, S., Mogultay, U., 2019. Soja-Report: wie kann die Eiweißpflanzenproduktion der EU auf nachhaltige und agrarökologische Weise angekurbelt werden? Die Bedeutung eines EU-weiten Eiweißplans. BUND.
[32] Dima, D.C., 2015. Soybean Crop in Romania, Bulgaria and the Republic of Moldova: Current Situation and Perspectives. Agric. Agric. Sci. Procedia., 6, 3-8.
[33] Karges, K., Bellingrath-Kimura, S.D., Watson, C.A., Stoddard, F.L., Halwani, M., Reckling, M., 2022. Agro-economic prospects for expanding soybean production beyond its current northerly limit in Europe. Eur. J. Agron. 133, 126415.
[34] Martin, N., 2015. Domestic soybean to compensate the European protein deficit: illusion or real market opportunity? OCL. 22(5), D502.
[35] Lovett, J., Gent, G., 2000. Market Demands and Research Opportunities: addressing the supply/demand gap for pulses, in: Linking Research and Marketing Opportunities for Pulses in the 21st Century. Springer, pp. 221-233.
[36] Clément, T., Joya, R., Bresson, C., Clément, C., 2018. Market developments and policy evaluation aspects of the plant protein sector in the EU. Brussels: Agrosynergie EEIG for the European Commission.
[37] Ibid.

total production of dry grain legumes in Europe, which is a 1% increase compared to 2014 (4% of total production).[38]

Main grain legumes – EU production and EU internal and external uses

Grain legumes in Europe are either exported or used to make feed or food in Europe. On the feed market, soybean, faba bean, pea and lupin are relevant. Faba bean production in the EU was on average 1.8 million tonnes per year in 2014 to 2018.[39] Since the United Kingdom is the by far largest producer of faba bean, the total production dropped considerably after the withdrawing of the EU. While faba bean is within the EU mainly processed to animal feed, some shares of the production are also exported in international markets to countries such as Egypt where it is used for food.[40] Lupin production is noticeably smaller in the EU with on average 280,000 tonnes produced per year in 2014 to 2018. The main producer is Poland with about 70% of the production.[41] Due to its high protein content, lupin is very attractive as a feed ingredient and mostly used in livestock production. However, there are also lupin based value chains for food and each year new edible food products containing lupins are entering the European market.[42] Field pea is also mostly destined for the feed market but also used in human consumption for example in traditional dishes, but also as a food ingredient for novel products.[43] On average 2.1 million tonnes of field pea were produced per year in 2014-2018 in the EU, which means it was the second most grown grain legume in Europe, after soybean (2.5 million tonnes).[44] Due to the special nutrient composition of soybean – including substantial shares of oil, carbohydrate and protein, the crop allows diverse uses, resulting in market opportunities for whole grain, oil and soybean meal sales.[45] Soybean and soybean meal is the main source of protein in feed rations in the EU and the large volumes needed has resulted in soybean imports of about 35 million tonnes bean equivalents annually.[46] Markets for vegetable oils in Europe consists mostly of rapeseed, soybean, sunflower seeds, maize germs and other oilseeds. Their predominant use lies in food and biodiesel production.[47] It has also been suggested that there is an opportunity to increase the de-fatting capacity of soybeans for human nutrition in Germany.[48] Investment into improving the capacity to process soybeans, would

[38] Kezeya-Sepngang, B., Muel, F., Smadja, T., Stauss, W., Stute, I., Simmen, M., Mergenthaler, M., 2020. Report on legume markets in the EU. Deliverable 3.1 for the EU-H2020 funded project, 'Fostering sustainable legume-based farming systems and agri-feed and food chains in the EU' (LegValue)
[39] Ibid.
[40] Ibid.
[41] Ibid.
[42] Lucas, M.M., Stoddard, F.L., Annicchiarico, P., Frías, J., Martínez-Villaluenga, C., Sussmann, D., Duranti, M., Seger, A., Zander, P.M., Pueyo, J.J., 2015. The future of lupin as a protein crop in Europe. Front. Plant. Sci. 6, 705-705.
[43] Kezeya-Sepngang, B., Muel, F., Smadja, T., Stauss, W., Stute, I., Simmen, M., Mergenthaler, M., 2020. Report on legume markets in the EU. Deliverable 3.1 for the EU-H2020 funded project, 'Fostering sustainable legume-based farming systems and agri-feed and food chains in the EU' (LegValue)
[44] Ibid.
[45] Ibid.
[46] Watson, C.A., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C.F.E., Vanhatalo, A., Zander, P., Murphy-Bokern, D., Stoddard, F.L., 2017. Grain Legume Production and Use in European Agricultural Systems, in: Elsevier, pp. 235-303.
[47] Fediol, 2018. EU Vegetable and Protein meal Industry (accessed September 2021) https://www.fediol.eu/data/Fediol_Brochure_A5%20_FINAL_.pdf.
[48] Value chain German association Mayus, M., Möller, K., Butz, A., Reutlinger, A., Recknagel, J. , Schmid, J., Pabel, T., Krautscheid, H., Paeßens, B., Hahn, V., Lechler, G., Schleihauf, D., Hennig, M. , 2018. Wertschöpfung durch heimische Sojabohnen Landwirtschaftliches Technologiezentrum Augustenberg (LTZ).

potentially stimulate the demand for domestic soybeans and work as a lever for production.[49]

Soybean imports hampering European grain legumes' position

The EU's historically grown dependence on soybean imports that is largely tied to the amount of livestock produced and consumed in Europe, causes today a situation in which grain legumes produced in Europe have to compete with imported soybean in terms of availability, quality and price.[50] Our discussions with actors from livestock and aquaculture value chains have clearly shown that price and availability play a key role when purchasing feed. The main challenge identified was the lack of cost-efficient alternatives to soybean imports used in feed. On the highly competitive market that is currently controlled by major exporting countries such as USA, Brazil and Argentina, European grown legumes are in a difficult position. Therefore, some interviewees stated that on the commodity side, Europe is not able to compete and should turn its attention to valorising grain legumes differently.

Soybean alternatives in northern Europe

In many instances, soybean can be replaced in livestock diets. This market is gaining momentum in countries that are constrained by short growing periods e.g. the Nordics and Baltics.[51] Replacing imported soybean with rapeseed, pea and faba bean, as a source for protein in livestock diets gains attractiveness from being 'locally produced' and as a means to reduce the carbon footprint from transportation.[52] The protein content of these soybean alternatives are generally lower. Pea for instance has only about 24% crude protein in the dry matter compared with soybean with over 40%.[53] To offset the difference in protein content, changes in feed formulations are inevitable to reach nutritional requirements. In aquaculture, animal by-products high in protein can be used together with grain legumes with lower protein contents, according to our interview source. Specialised products such as protein concentrate from faba bean is attractive in aquaculture.

Levers for improving European grain legumes' position

In light of increasing prices for import-soybean and a growing interest in non-GMO soybean, the market for European sourced soybean is expected to grow in Europe. Our interview sources explained that the development of soybean cultivars with traits such as low contents of anti-nutritional factors that are suitable for northern Europe can contribute further to this trend. Facilitating the development of the soybean market in Europe is supported through certification schemes and standards (e.g. Europe Standard,

[49] Ibid.
[50] Lovett, J., Gent, G., 2000. Market Demands and Research Opportunities: addressing the supply/demand gap for pulses, in: Linking Research and Marketing Opportunities for Pulses in the 21st Century. Springer, pp. 221-233.
[51] Stoddard, Frederick. 2020. Legumes in Finland and the world. (accessed September 2021) https://www.ilmastoviisas.fi/wp-content/uploads/2020/11/Stoddard_02112020.pdf
[52] MacPherson, L. 2022. High milk yields without soya? Yes we can. Legume Viewpoints. www.legumehub.eu.
[53] Feedipedia, 2022.

Donau Soya Standard) that intermediary organisations can provide, as seen with Danube Soya.

Forage legumes and their role for dairy

Ruminants are better suited to consume forage legumes and grasses. Our interviews suggest that the dairy sector would benefit from taking the approach of using forages and a minimum amount of supplementary protein for a balanced feeding diet. The dairy sector is starting to question purely production-oriented ways of thinking. It was expressed, that more and more attention is given to reducing emissions, which entails accepting some loss in productivity. Traditionally, forage legumes have been available to cover a large share of protein needs, yet their use is declining.[54] One factor explaining this decline is the availability of relatively cheap synthetic fertilisers.[55] Companies based on grazing and the use forage legumes are able to differentiate themselves from more unsustainable forms of ruminant production systems.

Consumer preferences

The section discusses aspects related to consumer preferences and communication. Consumers are part of the value chain and remain central when determining what can drive up demand for European grain legumes. There were several aspects brought forward in the interviews. Aspects that are considered important include origin and non-GMO labelling. The health and environmental credentials of legumes are also important to communicate.

Importance of provenance

Provenance was widely considered in our discussions, as a key selling point for both food- and animal products. Communicating the use of 'regional' legumes is believed to appeal consumers. There is a great market potential in marketing regional and demand for regional products is growing.[56] As stated by one interviewee "if you have regional animals, then it is just natural that you should have regional feed for all animals". The trend of "re-localization" or "re-connected" modes of producing and providing food is a growing market segment in many parts of the world.[57] Moreover, there is some indication that consumers prefer local feed in food products.[58]

Some of our interviewees were of the opinion that consumers starting to be sensitive towards the origin of feeds, while others emphasised taste and superior quality as the main arguments for buying a meat product. Interestingly, feeding legumes to animals

[54] Rochon, J.J., Doyle, C.J., Greef, J.M., Hopkins, A., Molle, G., Sitzia, M., Scholefield, D., Smith, C.J., 2004. Grazing legumes in Europe: a review of their status, management, benefits, research needs and future prospects. Grass Forage Sci., 59(3), 197-214.

[56] Mayus, M., Möller, K., Butz, A., Reutlinger, A., Recknagel, J. , Schmid, J., Pabel, T., Krautscheid, H., Paeßens, B., Hahn, V., Lechler, G., Schleihauf, D., Hennig, M. , 2018. Wertschöpfung durch heimische Sojabohnen Landwirtschaftliches Technologiezentrum Augustenberg (LTZ).

[57] Kneafsey, M., 2010. The region in food—important or irrelevant? Cambridge Journal of Regions, Economy and Society. 3(2), 177-190.

[58] Profeta, A., Hamm, U., 2019. Do consumers care about local feedstuffs in local food? Results from a German consumer study. NJAS-Wagen J. Life Sc. 88(1), 21-30.

can also enhance taste properties.[59] One interviewee indicated that a premium fish product based on special meals (e.g. regionally sourced) is a potential market to explore further in Europe. This is best executed with known brands. Good examples from other crops include corn-fed chicken or grass-fed dairy.

However, there is a research gap on consumers' willingness to pay for European sourced legumes in feed. Overall, there is a growing societal interest in more regionally and sustainably produced products.

Traceability

The experience from the interviews is that shorter supply chains provide better grounds for traceability. Traceability is related to the transmission of information regarding social and/or environmental aspects of production as well as other legal and quality requirements.[60] A shorter chain is a marketing tool, as indicated by some of the interviewees. Overall, European grain legumes could be supported by developing value chains with an emphasis on traceability.

This could involve the use of block chain technology, with the consumer receiving a QR a code on the packaging with relevant information about the product. The aquaculture company Nireus in Greece have in the past invested in QR technology that provides cooking instructions, recipes, freshness of the product etc.[61] Similarly, BioMar in Norway as part of their sustainability initiatives, informs consumers with the "full story" using QR tags including the feed ingredients and their source.[62]

GMO useful but not main preference

The market for non-GMO is increasingly gaining momentum in Europe, but compared to labels such as domestic origin, non-GMO is not as important.[63] Moreover, if GMO-free becomes the new standard, then there would be no need for labelling, as it would become the default form of production. The discussion suggests that non-GMO is most likely going to modestly affect legume consumption and production in Europe. In a survey looking at consumer perceptions of egg quality in Austria, although GMO labelling was considered important, other determinants such as the housing system, origin, freshness (i.e. expiration date) and price were ranked much higher.[64] However, there are instances, where retailers have stopped offering non-GMO fed poultry products, when the price premium for non-GM IP were too high.[65]

[59] Grabež, V., Egelandsdal, B., Kjos, N.P., Håkenåsen, I.M., Mydland, L.T., Vik, J.O., Hallenstvedt, E., Devle, H., Øverland, M., 2020. Replacing soybean meal with rapeseed meal and faba beans in a growing-finishing pig diet: Effect on growth performance, meat quality and metabolite changes. Meat Sci 166, 108134.

[60] Vallejo, N., Pierre, H. and Asante, R., 2009. The Role of Supply Chains in Addressing the Global Seafood Crisis. UNEP, Nairobi. (UNEP).

[61] Malindretos, G., Vlachos, I., Manikas, I., Chatzimanolakis, M., 2016. Future prospects of sustainable aquaculture supply chain practices, International Conference on Sustainable Design and Manufacturing. Springer, pp. 487-497.

[62] Biomar Group. 2018. Sustainability report 2018.

[63] Mayus, M., Möller, K., Butz, A., Reutlinger, A., Recknagel, J. , Schmid, J., Pabel, T., Krautscheid, H., Paeßens, B., Hahn, V., Lechler, G., Schleihauf, D., Hennig, M. , 2018. Wertschöpfung durch heimische Sojabohnen Landwirtschaftliches Technologiezentrum Augustenberg (LTZ).

[64] AMA-Marketing, 2016. RollAMA Motivanalyse. https://amainfo.at/fileadmin/user_upload/Konsumverhalten_Ei.pdf

[65] Pascal T, Rodriguez Cerezo E., 2015. Markets for Non-Genetically Modified, Identity-Preserved Soybean in the EU. JRC Science and Policy Report. Luxembourg: Publications Office of the European Union.

Legumes and health claims

Another element brought forward in our interviews is the topic of human diets.[66] While there is still a prevailing preference for animal-based products in many consumer groups, there are also consumers who are increasingly in favour of adopting a flexitarian diet, mainly due to health, environmental and welfare concerns.

The general message from the interview findings on grain legumes as food is that health arguments can motivate consumers to buy legume-based food products. Legumes are in general considered a good source of dietary protein, fiber, complex carbohydrates and minerals. But there are also several examples of legume-based food products that are heavily processed e.g. plant-based versions of mince, nuggets, pies, quiches, vegan cheeses, which raises questions over their healthiness.[67] There is the risk that health claims regarding legume-based products are made prematurely and without sound evidence. European food law does not allow communicating preliminary evidence and therefore using arguments related to health must be scientifically founded.[68] Consolidating health claims are costly for companies. Public institutions could take some of the burden of proof or cost for issuing health claims, paving the way for more alternative proteins into supermarkets.[69]

Communicating the environmental benefit

There was also discussion on the topic of greenhouse gas reductions in relation to legumes, more specifically, the CO_2 savings made from switching to European grain legumes instead of imported soybean. The environmental impact of legumes would benefit from more scrutiny of the entire supply chain, adding to existing research on the environmental impact of legumes on the cropping scale.[70] There is widespread support from our interviews, that the environmental benefit is useful in promoting legumes in the eyes of consumers, but also supplying more grain legumes within the context of public food procurement e.g. canteens.

Quality in feed and food

The livestock and aquaculture sectors are increasingly under pressure to reduce inputs and convert their production systems to include stricter environmental standards related to water, energy and land use. Food companies, animal- and plant-based, are confronted with several standards related to food safety, marketing, novelty and quality.

Standards and certification

Food safety is defined according to the EU Regulation No 178/2002 as part of the general food law. Marketing regulations (1169/2011) and marketing standards are also required and relevant. Businesses based on bringing innovative foods to the market, such as

[66] Sun, Z., Scherer, L., Tukker, A., Spawn-Lee, S.A., Bruckner, M., Gibbs, H.K., Behrens, P., 2022. Dietary change in high-income nations alone can lead to substantial double climate dividend. Nature Food. 3(1), 29-37.
[67] Spector, T., 2020. Spoon-Fed: Why almost everything we've been told about food is wrong. Random House.
[68] Lähteenmäki-Uutela, A., Rahikainen, M., Lonkila, A., Yang, B., 2021. Alternative proteins and EU food law. Food Control. 130, 108336.
[69] Ibid.
[70] Tidåker, P., Karlsson Potter, H., Carlsson, G., Röös, E., 2021. Towards sustainable consumption of legumes: How origin, processing and transport affect the environmental impact of pulses. Sustain. Prod. Consum. 27, 496-508.

Impossible food and Beyond meat, can be subjected to regulations, defined through the EUs regulations on novel foods (1924/2006), GM-foods (1829/2003 and 1830/2003), labelling (1169/2011), health claims (1924/2006) and organic foods (2018/848).[71] To ensure product quality, standards such as BRC or IFS or FSSC 22000 certification can be required by retailers.[72]

In principle, there are several certificates and standards in the value chains that were studied. The main aim with these certificates is to fulfil the requirements of the respective regulations or company policy. The active use of grain legumes of EU origin that are non-GMO certified and/or organic is strong in most cases. Other observed certificates are: ISO 141001, ISO 9001, FSSC 22000, organic and meat products within the geographic indication scheme. For legume-based food there is also separate certification indicating the products' suitability for vegans.

According to our discussions, the quality schemes come at a price. However, higher prices can be justified. For example, in the poultry sector in Austria there was a general fear that feeding non-GMO certified soybean of European origin to layers would affect the sales of eggs. However, even though the change resulted in a small price-increase, the adopted feeding practice did not deter consumers from purchasing such eggs. After all, the overall intention of certification and standards is to encourage market transparency and provides a level playing field, benefiting both consumers and the industry.[73]

Introducing quality standards and certification schemes can become a race to the top with companies searching for more ways to sell their product and appear more responsible than their competition. The example given in one interview is from the poultry sector in Austria where the next opportunity lies in biodiversity improvement e.g. planting trees on poultry farms, having already adopted non-GMO policy for feeding layers. However, a single food category such as eggs can be subjected to a wide range of quality attributes such as quality labels, quality programs (e.g. to reduce salmonella), data banks with health information, traceability of eggs (e.g. single egg printing), and ethical considerations such as no beak trimming. If the aim is to lift the general profile of grain legumes in the minds of consumers, the risk is that legumes get lost in the general noise of certificates and standards.

Trade quality in feed and food

An understanding of the market from the perspective of quality parameters is important when developing the future of grain legumes in Europe. This involves matching products to markets by assessing their quality parameters. Requirements related to conformity, consistency and cost are important variables in the dominant feed industry in Europe.[74]

[71] Lähteenmäki-Uutela, A., Rahikainen, M., Lonkila, A., Yang, B., 2021. Alternative proteins and EU food law. Food Control. 130, 108336.
[72] Hamann, K., Vasconcelos, M., Löhrich, N., Odee, D., Vickers, R., Blazon, N., Trstenjak, M., Toma, L., Maaß, H., Kolmans, A., Tran, F., Bienkowski, D., Iannetta, P., 2019. A map of value chains for legumes used as food. Deliverable 4.1 for the EU-H2020 funded project 'TRansition paths to sUstainable legume-based systems in Europe' (TRUE).
[73] Ibid.
[74] Lovett, J., Gent, G., 2000. Market Demands and Research Opportunities: addressing the supply/demand gap for pulses, in: Linking Research and Marketing Opportunities for Pulses in the 21st Century. Springer, pp. 221-233.

There are no universally applicable quality parameters for trading grain legumes as particular quality requirements are in general based on individual consignments and can vary between buyers. Quality parameters in the food industry are in general considered to be higher than for feed uses (See table 4, annex 2). For food-grade organic soybean in Switzerland, quality specifications includes specific cultivars, protein content, smell, taste, rancidity, appearance of the grains, as well as other contract obligations related to management (removing nighshade plants prior to harvest).[75] If the contamination level is high, then the batch is downgraded to feed. In Germany, the quality criteria for grain legumes in the feed sector is based on quality criteria for cereals (see table 4).

The aim of quality parameters is to ensure an effective and qualitative animal feed. A general challenge in the livestock sector is related to the complexity of animal diets – adequate amounts of nutrients and micro-nutrients have to be included to secure optimal growth in every development stage. The addition of different legumes in feed rations would provide a good balance in terms of amino acids and protein content and could benefit the nutritional value of animal diets. However, individual farmers prefer simplicity, in this case growing one protein source rather than several. While major feed compounders would rather be able to handle a greater variety of feed components (also different grain legumes), they mostly also prefer to stick to the most simple, convenient and reliable protein feed components. Moreover, the strong focus on economic efficiency limits the use to only a small number of feed components.

Another quality parameter that is increasingly discussed within the market and in relation to feed, is the importance of crude protein as a price determining factor. This has to be questioned, since higher crude protein contents in feed only makes sense if correspondingly higher amounts of artificial limiting amino acids are also added.[76] Higher protein contents would lead to a disproportionate level of nitrogen excreted via faeces and urine (and therefore to increased gaseous N losses in the whole subsequent organic manure chain) due to the decreased biological value of the protein.[77] Nevertheless, finding suitable grain legume cultivars with high protein content is a challenge for growers and breeders, especially in the organic sector that has banned the use of synthetic amino acids.[78]

The nutrient content is generally not the main determinant of the market price of grain legumes for human consumption. For food uses, culinary quality is the main determinant of price. This is affected by traits such as the size and shape of the seeds, the colours of the seed coat and kernel, the uniformity and purity of the batch, the flavour of the product etc. The desired quality traits of traders and processors might vary making it important for producers to coordinate with the customer. Further traits contribute to the quality for industrial processing, such as ease and uniformity of dehulling and splitting, energy input for milling to flour, water uptake during cooking along with texture and viscosity after cooking, and of course flavour. The motivation to grow and sell as food grade legumes is in general the higher price for the final product (e.g. meat analogues), given the still higher price margin for these alternative products. Plant-based meat

[75] Klaiss, M., Schmid, N., Betrix, C.-A., Baux, A., Charles, R., Messmer, M.M., 2020. Organic soybean production in Switzerland. OCL. 27, 64.
[76] Mayus, M., Möller, K., Butz, A., Reutlinger, A., Recknagel, J. , Schmid, J., Pabel, T., Krautscheid, H., Paeßens, B., Hahn, V., Lechler, G., Schleihauf, D., Hennig, M. , 2018. Wertschöpfung durch heimische Sojabohnen Landwirtschaftliches Technologiezentrum Augustenberg (LTZ).
[77] Ibid.
[78] Ibid.

alternatives are in general sold at a higher price than mainstream meat products.[79] Exclusive food products protected under geographic origin schemes are sold for a premium price. For example, Fava Santorinis beans (Lathyrus clymenum *L.*) are landraces, prone to crop failures and in general low yielding, which is reflected in the price. However, this is only true for some exclusive varieties, while for the general legume market the lower yields are not always compensated by a higher price.

Food grade grain legumes need to be visually attractive for human consumption. Processing involves more than improving the appearance, it is also connected to enhancing taste properties. This entails some level of separation and cleaning to ensure a high quality end product at the level of primary production. As the seeds get sold to food manufacturing companies, consistent quality is important as adjustments in production to correct any variance in grain legume quality is considered to be a costly and time consuming process. According to our interview source, new plant-based companies are in general surprised at the level of requirements that is needed to get a product into retail, involving costly testing such as shelf-life studies and analyzing ingredients.

Infrastructure

In the wider literature, it has been suggested that a concrete barrier for the legume production in Europe is related to the lack of processing facilities.[80] Incorporating more infrastructure in Europe to support legume production and processing is needed. The question of processing infrastructure is a chicken-and-egg situation. The lack of investment into legume-based infrastructure (pre-treatment and processing) is partly due to the low production levels. Yet, increasing processing capacity, higher density of collection plants as well as mobile toasting facilities, these are all examples that would further encourage the expansion of grain legume production in Europe.

Processing infrastructure

Infrastructure for cereal production is very established in many parts of Europe but the same cannot be said for grain legumes. Furthermore, legume production is not uniform across Europe. Bigger feed mills show a general preference for larger grain quantities, making it challenging for small producers to find nearby processors that want to process smaller quantities. Mobile toasting was discussed in the interviews. The process of toasting deactivates the anti-nutritional compounds in soybean (e.g. trypsin inhibitors) by heat, particularly useful in pig and poultry production.[81] However, our interviews indicated that there is some doubt whether mobile toasting is a cost effective solution, due to the often long distances between processor and grower. Moreover, mobile toasting can encounter bureaucratic obstacles, as seen in Germany.[82] Nevertheless, most interviewees stated that investment into processing is needed.

[79] Kezeya-Sepngang, B., Muel, F., Smadja, T., Stauss, W., Stute, I., Simmen, M., Mergenthaler, M., 2020. Report on legume markets in the EU. Deliverable 3.1 for the EU-H2020 funded project, 'Fostering sustainable legume-based farming systems and agri-feed and food chains in the EU' (LegValue)

[80] Magrini, M.-B., Anton, M., Cholez, C., Corre-Hellou, G., Duc, G., Jeuffroy, M.-H., Meynard, J.-M., Pelzer, E., Voisin, A.-S., Walrand, S., 2016. Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecological Economics. 126, 152-162.

[81] Lindner, C., Schmelzer, E., 2020. Recommendations for using soy-based feedstuffs for poultry production. OK-Net Ecofeed Practice Abstract.

[82] Mayus, M., Möller, K., Butz, A., Reutlinger, A., Recknagel, J. , Schmid, J., Pabel, T., Krautscheid, H., Paeßens, B., Hahn, V., Lechler, G., Schleihauf, D., Hennig, M. , 2018. Wertschöpfung durch heimische Sojabohnen Landwirtschaftliches Technologiezentrum Augustenberg (LTZ).

Quality variability

Another processing related challenge is connected to grain quality variability. In one interview, it is reported that soybeans were delivered to a feed mill from different parts of Europe and the mill ended up with seeds of varying quality. The issue had to be solved through trial and error as there was limited practical knowledge available at the time. Similarly, a tofu producer experienced how raw materials from new suppliers required additional adjustments in the food processing stage. At worst, poor quality resulted in production delays and additional costs. In our interview, centralizing processing activities in one infrastructure unit has been suggested as a means to improve quality. The less hands that are involved the better the end result. It is therefore suggested that attention is needed to ensure a consistent quality to meet market requirements.

Processing capacity for plant-based foods

The often high price of plant-based foods is in general considered a negative aspect.[83] Price reduction is dependent on automatisation and economies of scale to ultimately reduce production costs for legume-based food products.[84] As stated by one interviewee, "innovations are coming from small companies but execution is coming from bigger players…scaling up for example European wide". Investment into ingredient and manufacturing is needed to scale up legume-based food innovations in Europe, for promising legume-based food products.

Networks

Building partnerships and collaboration is important to encourage the wider use and production of European legumes. It can take many forms and can involve different stakeholders. In supply-chain research there are essentially two forms of collaboration: either vertical or horizontal. Vertical involves collaborating with customers and internally across functions, whereas horizontal involves collaborating with competitors and non-competitors, for example, by sharing manufacturing capacity. We take a broader approach by looking at the impediments to change as well as the agents or institutional framework that drive change and demand.

Fear of change

The discussion revealed that that there is some degree of inertia in the livestock sector. Livestock producers can show a fear of experimenting with new feed rations, according to our interview sources. This fear is not based on price or rational facts but is more subjective i.e. the fear that something could go wrong. Learning and peer networks can prove to be invaluable in addressing softer matters related to cognitive barriers to change.[85]

[83] Elzerman, J.E., van Boekel, M.A.J.S., Luning, P.A., 2013. Exploring meat substitutes: consumer experiences and contextual factors. Br. Food J. 115(5), 700-710.
[84] Kezeya-Sepngang, B., Muel, F., Smadja, T., Stauss, W., Stute, I., Simmen, M., Mergenthaler, M., 2020. Report on legume markets in the EU. Deliverable 3.1 for the EU-H2020 funded project, 'Fostering sustainable legume-based farming systems and agri-feed and food chains in the EU' (LegValue)
[85] Mawois, M., Vidal, A., Revoyron, E., Casagrande, M., Jeuffroy, M.-H., Le Bail, M., 2019. Transition to legume-based farming systems requires stable outlets, learning, and peer-networking. Agron for Sustain. Dev. 39(1).

Decisive agents

It became apparent from our interviews that certain actors play a greater role in implementing change. There are in general key economic agents that drive the demand for grain legumes.[86] From our interviews, downstream actors can play an important role in encouraging changing feeding practices. For example, milk processors are important due to their relationship to supermarkets. The dialogue between the milk processor and retailer feeds back to the dairy farmer.

In another example from Austria, the main retailers of the country decided in 2013 to sell only domestic eggs in their stores. The commitment to sell only fresh Austrian eggs made it economically feasible to introduce regional non-GMO soybean feed into the country's domestic egg production. Without this agreement, the additional costs accrued from adopting regional feed sources would have been infeasible. Moreover, the agreement avoided the scenario of having expensive domestic eggs and cheaper non-domestic eggs on the market, which would have negatively affected the sales of the certified non-GMO domestic eggs. This case illustrates the role of incumbent actors in taking a supportive stance in favour of European grain legumes.

Encouraging farmers to adopt more grain legumes as part of a "greening" initiative can also be supported by private investments. For example, the Resilient Dairy Landscape project in the UK involves a group of farmers, a processor and a water company, that together explore the "trade-offs between farmers' livelihoods, the natural environment and the stable supply of reasonably priced dairy products".[87] The project evaluated Landscape Enterprise Networks in the UK, and found that farmers planted four times faster hedgerows under a privately funded scheme, than publically funded agri-environment alternatives.[88] Although the project is not about legume production, it serves as a source of inspiration and highlights the potential of private funded schemes to encourage environmental practice, as well as the principal of what value actors attribute to the system as a whole. Central to this is the involvement of downstream actors (e.g. dairy company) with close connection to consumers and the rest of the value chain.

Production contracts

Contract production is a way to formalize collaboration between sellers (e.g. growers) and buyers (feed company). There is normally a level of uncertainty in relation to the price, volume, quality and market of the legumes, so a contract helps to address such issues. These contracts are believed to reduce transaction costs i.e. costs related the process of negotiation, verification and information searching.[89] Production contracts can set payments based on a function of tonnage, area under cultivation, quality parameters, price fixing as well as stipulate penalties in case of any breaches.[90] The production contract as a mechanism for collaboration is a strong facet of many of the value chains interviewed, with one observed exception.

[86] Clément, T., Joya, R., Bresson, C., Clément, C., 2018. Market developments and policy evaluation aspects of the plant protein sector in the EU. Brussels: Agrosynergie EEIG for the European Commission.
[87] Resilient Dairy Landscapes. Homepage (accessed 1.3.2022) https://www.resilientdairylandscapes.com/
[88] Coyne, L., Kendall, H., Hansda, R., Reed, M. S., & Williams, D. J. L., 2021. Identifying economic and societal drivers of engagement in agri-environmental schemes for English dairy producers. Land Use Policy, 101, 105174.
[89] Jouan, J., Ridier, A., Carof, M., 2019. Economic Drivers of Legume Production: Approached via Opportunity Costs and Transaction Costs. Sustainability. 11(3), 705.
[90] Ibid.

Based on the experience of one aquaculture value chain representative, collaboration with farmers in the form of contracts can be complicated if the communication between farmers and mills is inadequate. The example given is based on a project set-up between an aquaculture company and producer organisation to source local non-GMO soybean as feed for fish. The project quickly ran into difficulties due to the lack of a legal framework between the buyer (company) and the producer organisation (cooperative). The buyer was prompted to sign individual contracts with each individual producer, adding costs related to processing, storage and distribution. Moreover, there was general communication failure with the producers that misunderstood the terms for remuneration in relation to the required quality requirements (e.g. moisture, purity). This case illustrates the importance of having effective legal frameworks to support contracts.

Buyers play a central role in stating their expectations. Committing to the welfare of all participants in the value chain is considered important. Businesses or producer organisations can take a pro-active stance in ensuring that it buys or ensures that growers receive a "fair price". In the cases we observed, this has involved the use of producer organisations and value-added products. As one interviewee stated "guaranteed price - guaranteed offtake. This is the added value, it is from farmer's hand, and we communicate it and consumer is paying for it, appreciates it, and recognizes that this system is contributing to sustainable development".

Collaboration over organisation borders

For legumes as food, networks involving different actors in the value chain are seen as important for promoting the consumption of grain legumes. This assumes some level of multi-actor collaboration in raising awareness around grain legumes in the minds of consumers, but also in the industry, e.g. hotel, restaurant and catering (HoReCa), as legume-based food companies are not in the position to do it alone.

Science and technology

This section provides an overview of the science and technology related matters discussed in our interviews. In general, establishing the sustained production of grain legumes in Europe requires the full support of the knowledge and innovation system.[91] Aspects discussed include using technology to reduce the price of protein concentrates for feed in aquaculture and developing new cultivars through breeding.

Protein concentrate prices

The raw material for feed is commonly seen as the highest cost in aquaculture production.[92] Considerable opportunity lies in using more grain legumes as prices for fish meal are very high.[93] Protein concentrates of good quality allow for more flexibility in fish feed but are expensive to produce.[94] Our interviewee suggested that protein concentrate

[91] De Visser, C.L.M., Schreuder, R., Stoddard, F., 2014. The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives. OCL. 21(4), D407.
[92] Ernst & Young. 2017. The Norwegian aquaculture analysis 2017.
[93] Blaufuss, P., Trushenski, J., 2012. Exploring Soy-Derived Alternatives to Fish Meal: Using Soy Protein Concentrate and Soy Protein Isolate in Hybrid Striped Bass Feeds. N. Am. J. Aquac. 74(1), 8-19.
[94] Moniruzzaman, M., Damusaru, J.H., Won, S., Cho, S.-J., Chang, K.H., Bai, S.C., 2020. Effects of partial replacement of dietary fish meal by bioprocessed plant protein concentrates on growth performance,

from faba would be desirable in the aqua feed market. Thus, finding inexpensive solutions to produce faba bean concentrate is considered useful. In one study air classification technology was used to produce faba bean concentrate – a technology considered to be relatively inexpensive.[95]

Cultivar development

The overall message communicated in the interviews is that developing cultivars for different climatic zones and with good nutritional profiles remains important. This is connected to improving the profitability of grain legumes. Another aspect brought forward in the interviews, is the importance of old cultivars as a source for genetic diversity.

Legume breeding programmes are limited and often focussed on short-term breeding goals using elite germplasm with little time for lengthy pre-breeding.[96] Public institutions play an important role in pre-breeding activities exploiting landraces and wild relatives by making the germplasm publically available.[97] Climate change is posing new challenges for breeding legumes, hence a sense of preparedness is important and ensuring that legume production is resilient. Investing in the future is important yet private and public funding into breeding programmes is currently low in Europe, and this affects the competitive edge of farmers.[98]

Policy

This section provides an overview of the policy measures that could increase the production and consumption of legumes in Europe, according to our analysis of the interviews. The measures to stimulate production ranges from the introduction of a carbon tax on imported soybeans, or nitrogen fertilizer, a ban on GMOs, as well as policy that supports animal production systems, that have a smaller environmental impact. Direct support in the form of subsidies is suggested to encourage production. To increase the consumption of grain legumes in human diets, it is suggested that consumers need more guidance with consuming healthier foods.

The first policy measure suggested in our interviews is to implement a carbon tax on imported soybeans or nitrogen fertiliser. However, others show a general concern that a tax or any other added cost would increase food prices for consumers. The questions about "at what cost" is problematic. When promoting more legumes for human consumption, policy has to take into consideration the "true cost" of animal production but also acknowledge differences in animal production systems. This means developing mechanisms to support animal production systems that are aligned to better environmental and ethical practice, as well as supporting crop production for human consumption. However, whether grain legumes should be fed to animals or to what extent is a source of contention. For

hematology, nutrient digestibility and digestive enzyme activities in juvenile Pacific white shrimp, Litopenaeus vannamei. J. Sci. Food Agric. 100(3), 1285-1293.

[95] De Santis, C., Crampton, V.O., Bicskei, B., Tocher, D.R., 2015. Replacement of dietary soy- with air classified faba bean protein concentrate alters the hepatic transcriptome in Atlantic salmon (Salmo salar) parr. Comp Biochem Physiol Part D Genomics Proteomics 16, 48-58.

[96] Rubiales, D., Annicchiarico, P., Vaz Patto, M.C., Julier, B., 2021. Legume Breeding for the Agroecological Transition of Global Agri-Food Systems: A European Perspective. Front. Plant Sci. 12.

[97] Ibid.

[98] Ferreira, H., Pinto, E., & Vasconcelos, M. W. 2021. Legumes as a cornerstone of the transition toward more sustainable agri-food systems and diets in Europe. Front. Sustain. Food Syst., *5*.

instance, soybean currently used in fish feed, could be eaten by humans, but animal by-products are not an option for human consumption, according to one interview source.

Investments are needed in processing facilities to support legume production in Europe. The aim is to provide the means to invest in storage and improved sorting.[99] A starting point would be to increase processing units, preferably at convenient places e.g. at the same place where farmers deliver their cereals. Another opportunity lies in expanding the extrusion of raw soybeans in animal feed mixes, according to our interview sources. Extrusion is an effective technology to de-activate anti-nutritional factors and improve the digestibility of amino acids in poultry and pig diets.[100] Investment into processing systems is needed to unlock the potential of home-grown grain legumes and develop domestic markets.

Another goal discussed is reducing EU's protein deficit. Since the livestock industry is main the driver for grain legume consumption in Europe, increasing European legume production remains essential to close the protein deficit in Europe.[101] This leads some of the interviewees to suggest long-term (5-10 year) support to producers, for example in the form of higher subsidy per hectare for legume production. Another measure suggested would be a EU-wide ban or restriction on GMO crops. Currently at least 17 countries in the EU have restricted or banned the use of GMOs.[102] There is debate to what extent a ban on GMO is compatible with WTO rules.[103] Contradictive opinions on the merits of GMO emerged in our discussions. Many see GMO as a means to innovate legume crops, while others question their usefulness. From a legume breeding perspective, GMOs are seen as a way to innovate but it would require changes in public preferences and regulations.[104]

As for feed, opportunities lie in creating demand for indigenous crops, by looking at the nutritional credentials of grain legumes and demonstrating to livestock producers the advantages of substituting imported proteins. Domestic demand can also be encouraged as seen in Switzerland, where the organisation BioSwiss has implemented a policy stipulating that all feed for ruminants must be of Swiss origin both as roughage and concentrated feed after 2022.[105] In Luxembourg, organic farmers were more accustomed to cultivating grain legumes than conventional farmers.[106] This suggests that the preconditions for demanding 100% domestic grain legumes as feed is relatively speaking easier to implement in organic production due to their experience in cultivating legume

[99] Meynard, J.-M., Charrier, F., Fares, M.h., Le Bail, M., Magrini, M.-B., Charlier, A., Messéan, A., 2018. Socio-technical lock-in hinders crop diversification in France. Agron. Sustain. Dev. 38(5), 54.
[100] Mariscal-Landín, G., Lebreton, Y., Sève, B., 2002. Apparent and standardised true ileal digestibility of protein and amino acids from faba bean, lupin and pea, provided as whole seeds, dehulled or extruded in pig diets. Animal Feed Science and Technology. 97(3-4), 183-198.
[101] Martin, N., 2014. What is the way forward for protein supply? The European perspective. OCL. 21(4), D403.
[102] European Commission. Restrictions of geographical scope of GMO applications/authorisations: EU countries demands and outcomes (accessed 10.3.2022) https://ec.europa.eu/food/plants/genetically-modified-organisms/gmo-authorisation/gmo-authorisations-cultivation/restrictions-geographical-scope-gmo-applicationsauthorisations-eu-countries-demands-and-outcomes_en

[103] Punt, M.J. and Wesseler, J., 2016. Legal but costly: an analysis of the EU GM regulation in the light of the WTO trade dispute between the EU and the USA. World Econ., 39(1), pp.158-169.
[104] Rubiales, D., Annicchiarico, P., Vaz Patto, M.C., Julier, B., 2021. Legume Breeding for the Agroecological Transition of Global Agri-Food Systems: A European Perspective. Front. Plant Sci. 12.
[105] Klaiss, M., Schmid, N., Betrix, C.-A., Baux, A., Charles, R., Messmer, M.M., 2020. Organic soybean production in Switzerland. OCL. 27, 64.
[106] Zimmer, S., Liebe, U., Didier, J.-P., Heß, J. 2016. Luxembourgish farmers' lack of information about grain legume cultivation. Agron. Sustain. Dev. 36, 2.

crops. In comparison, conventional farmers often have little experience, and are often cultivating grain legumes for the first time.

In a recent survey looking at consumer attitudes towards plant-based foods in the EU, reports that many consumers in Europe have recently adopted a flexitarian diet but lack guidance (preparation skills) and general information about plant-based foods.[107] In our interviews, it also became apparent that supporting education and awareness about the role of legumes in cropping systems is important to raise their profile among consumers.

Workshop results

Each group formulated a range of steps that they perceived necessary for their transition pathways (Supplementary table, see Annex 4). The two pathways of the groups to more legumes in feed and food varied in terms of the majorly included sphere of action – while in group 1 policy prevailed in group 2 agronomic related steps were in focus, although the groups were not intentionally organized along thematic lines.

Group 1

Since the feed sector is by-far the largest consumer of legumes in Europe[108], this sector is addressed by several policy measures formulated by Group 1:

Campaigns promoting European legume farming is the first step needed. Measures for increasing consumers' understanding of and preferences for European legume farming is a promising tool for supporting environmental and health concerns in society. [109] [110] The group envisages an improvement in legume awareness through a Europe-wide origin certification for feed as well as food value chains. While non-profit organizations (e.g. Round Table on Responsible Soy Association (RTRS) or Proterra) are exemplary actors in the context of origin certification, the European Union is considered the main institution needed to introduce standards on origin certification. This would place the responsibility for certification, not in the intermediate private-public space of non-profit organizations anymore, but in the public sector with the political entity of the European Union.

The group calls for policy on non-GMO or at least a standardization of GM/ non-GMO regulations across Europe by the European Commission. As a drastic step, Group 1 see value in implementing stricter regulation on non-GMO feed in the European Union. Livestock production in Europe is highly dependent on imported plant protein, such as soybean meal, which mainly originates from GM cultivars.[111] A ban on all feed products containing GM materials would create economic opportunities for European grown feed

[107] Bechtold, K-B., Spahic, A., Sommer, L., Nosten, P., Alexandre, M., Jaczniakowska-McGirr, S., Perez-Cueto, A., Faber, I., De Steur, H., Schouteten, J., Rini, L. 2021. What consumers want: a survey on European consumer attitudes towards plant-based foods, with a focus on flexitarians. European Union's Horizon 2020 research and innovation programme, No 862957.
[108] Clément, T., Joya, R., Bresson, C., Clément, C., 2018. Market developments and policy evaluation aspects of the plant protein sector in the EU. Brussels: Agrosynergie EEIG for the European Commission.
[109] Hamann, Karen 2020. Facilitating the EU market demand for legume-grain and -fodder as feeds. Deliverable 4.3 for the EU-H2020 funded project, 'TRansition paths to sUstainable legume-based systems in Europe' (TRUE).
[110] Balázs, B., Kelemen, E., Centofanti, T., Vasconcelos, M. W., Iannetta, P. P.M. 2021a. Integrated policy analysis to identify transformation paths to more sustainable legume-based food and feed value-chains in Europe. Agroecology and Sustainable Food Systems.
[111] de Visser, C.L.M., Schreuder, R., Stoddard, F. 2014. The EU's dependency on soya bean import for the animal feed industry and potential for EU produced alternatives. OCL. 21:D407.

sources, including legumes.[112] Not as drastic, but also addressing regulations on GM crops, is the proposition to standardize GM/ non-GMO regulations across Europe. So far, the European Union provides a legal framework, which still leaves the chance for member states to make territorially differing decisions.[113]

The group calls for a market-based policy to make home-grown legumes as feed financially more rewarding as part of a greening measure within the Common Agricultural Policy. Three previous CAP instruments recognise the benefits of legumes from an environmental point of view: the green direct payment or greening, agri-environmental-climate-measure and voluntary coupled support.[114] The group participants see options to stress local legumes as feed in one of these instruments in particular. The use of local grown legumes in feeding livestock could be included within the green direct payment scheme that includes the possibility to grow legumes on ecological focus areas (Regulation (EU) No. 1307/2013, Art. 46) or as a part of crop diversification (Regulation (EU) No. 1307/2013, Art. 44).[115] This step would expand the impact from crop production to include their use in livestock farming.

Group 1 also calls for concrete policy measures for calculating the environmental impacts of feed raw materials. The positive environmental effects of including legumes in the cropping system and the reduction of greenhouse emissions is described in the scientific context.[116] This needs transparent assessment and should be communicated to the wider public. The group calls for standardized methods for assessing environmental performances that improves the comparability between products. The European Commission's project on Product Environmental Footprinting Category Rules (PEFCR) is important in this context.

The food sector is subject to several policy-related steps by the participants. In addition to guiding food consumption choices through information tools, the group calls for a regulatory policy and economic incentive to increase consumption. As a regulatory policy, the participants suggests to prioritize European legumes or animal products fed with European in public food procurement e.g. cafeterias in schools or the army. This pro-legume procurement policy takes form within national governments or local authorities, partly also directed by the EU. A clear focus on European legumes and a higher integration of pulses in menus is in line with public dietary guidelines and healthcare recommendations.[117] Moreover, introducing more legumes in a familiar institutional setting e.g. schools, public hospitals, childcare facilities, etc. can potentially improve the

[112] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

[113] Christiansen, A.T, Adersen, M.M., Kappel, K. 2019 Are current EU policies on GMOs justified? Transgenic Res. 28, 267–286.

[114] European Commission, 2018. Report from the Commission to the Council and the European Parliament on the development of plant proteins in the European Union. European Commission: Brussels, Belgium. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0757

[115] European Union 2013. Regulation (EU) No. 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No. 637/2008 and Council Regulation (EC) No. 73/2009. Official Journal of the European Union L 347:608–670

[116] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

[117] Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., et al. 2019. Food in the anthropocene: the EAT–lancet commission on healthy diets from sustainable food systems. Lancet 393, 447.

general acceptability and desire to consume European legumes among different demographics.[118]

Some participants suggest that conventional food products should be labelled as originating from inside or outside the EU - similarly as it is already done with organic products. Since the origin of food is one of the most important factors affecting food choices[119] and there is a high consumer preference for local food,[120] the consumption of European legumes could be promoted by this measure.

The group suggests a scorecard on the environmental performance of food products. European legumes have considerable environmental benefits[121], which raises the profile of legume products. In this context, participants highlight the trend of shifting consumer preferences and behaviour - particular concerning diets - providing further support for this measure.

Many European countries have introduced carbon taxes in recent years which vary in rate, scope and the sectors included.[122] The group participants suggested that the European Commission introduces a substantial EU-wide carbon tax in the agri-food sector until 2025. The agricultural sector contributes to 10% of the EU's total GHG emissions.[123] Carbon saving efforts need to be increased if the Green Deal's objective to make Europe carbon-neutral by 2050 (EU Green Deal) is to materialize. Diverse crops and livestock activities add to the total emission, including considerable contributions stemming from synthetic fertilizers.[124] Due to the high potential for fertilizer savings of legume-supported systems,[125] their economic attractiveness would increase with the introduction of a carbon tax in the agricultural sector. However, the probability that climate change policies would lead to significant changes in legume production is limited due to the prevailing political inertia.[126]

Besides changes in crop consumption either in the feed or food sector, the participants formulated also policy-steps addressing crop production. These are either directed at the topic of breeding, crop analysis or IPCC methodologies for greenhouse gas inventories.

[118] Hamann, Karen 2018. Public and Private Procurement. Deliverable 4.4 for the EU-H2020 funded project, 'TRansition paths to sUstainable legume-based systems in Europe' (TRUE).
[119] Eurobarometer, EFSA 2019. Food Safety in the EU. Special Eurobarometer Wave EB91, 3.
[120] Feldmann, C., Hamm, U. 2015. Consumers' perceptions and preferences for local food: A review. Food Quality and Preference, 40, 152-164.
[121] Ditzler, L., van Apeldoorn, D. F., Pellegrini, F., Antichi, D., Bàrberi, P., Rossing, W. A. H., 2021. Current research on the ecosystem service potential of legume inclusive cropping systems in Europe. A review. Agron. Sustain. Dev. 41 (2), 504.
[122] Matthes, F., 2020. Pricing Carbon – An important instrument of ambitious climate policy. Retrieved from: https://www.boell.de/sites/default/files/2020-09/The%20Pricing%20of%20CO2.pdf
[123] European Environment Agency, 2021. Greenhouse gas emissions from agriculture in Europe. (accessed on 29.3.2022) https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-agriculture

[124] FAO, 2020. Emissions due to agriculture. Global, regional and country trends 2000–2018. FAOSTAT Analytical Brief Series No 18. Rome.
[125] Stagnari, F. et al. 2017. Multiple benefits of legumes for agriculture sustainability: an overview. Chem. Biol. Technol. Agric. 4(2), 1-13.
[126] Balázs, B., Kelemen, E., Centofanti, T., Vasconcelos, M. W., Iannetta, P. P.M. 2021b. Policy Interventions Promoting Sustainable Food- and Feed-Systems: A Delphi Study of Legume Production and Consumption. Sustainability 2021, 13, 7597.

Breeding efforts in legume crops have been neglected for decades.[127] While breeding progress in cereal crops increased their technical and economic performances steadily, legumes still need genetic improvements to compete with cereal crops. Fewer than 400 new cultivars were publically registered in the year 2015, 150 for beans, compared to nearly 2500 new wheat cultivars in the same year.[128] The group participants suggested the implementation of measures that would provide a return on investment for legume breeders. The relevant actor for this step are national governments or the European Commission. However, participants do not only see the option for increased competitiveness through breeding efforts – legumes would become more common in the event of a ban of pesticide use on other crops (e.g. cereals).

In the step concerning crop analysis, the European Commission is seen as an important actor for the introduction of European standards for lab methods analysis and quality control of legumes traded in Europe. All grain legume species provide high-quality protein.[129] However, they also contain anti-nutritional factors (ANFs) which affect nutrient digestibility and livestock performance when used as feed.[130] The composition can vary considerably in crops depending on for example the environmental conditions during cultivation, which is why analysis and quality controls of legumes are essential. Common European standards could ease the indispensable analysis processes and decrease the prevalent barrier of ANFs in legumes.

Another step that is indirectly addressing European legume crops is the need to revise the IPCC reporting requirements for national GHG inventories. Land use change induced emissions from abroad should be included in national emissions inventories. This would have strong consequences in the figures in light of the EU's large imports of soybean and soybean products that are associated with land use changes in South-America.[131]

In addition to this strong focus on policy-related steps, the participants formulated steps for technological progress in engineering issues. This includes the development of cheap rapid tests for analysing ANFs in legumes as well as analysing cultivars on their specific strengths and weaknesses for specific uses, providing increased insight in legumes' compositions. The development of environmental-friendly weed management technologies could be an important step in the context of making grain legume cultivation more sustainable and thereby increase their presence in sustainable agriculture even more. Since grain legumes' competitiveness against weeds is limited, [132]herbicide applications are needed which reduces the overall sustainability of legume production.

[127] Magrini M-B, Anton M, Chardigny J-M, Duc G, Duru M, Jeuffroy M-H, Meynard J-M, Micard V and Walrand S 2018. Pulses for Sustainability: Breaking Agriculture and Food Sectors Out of Lock-In. Front. Sustain. Food Syst. 2:64.

[128] Magrini M-B, Anton M, Chardigny J-M, Duc G, Duru M, Jeuffroy M-H, Meynard J-M, Micard V and Walrand S 2018. Pulses for Sustainability: Breaking Agriculture and Food Sectors Out of Lock-In. Front. Sustain. Food Syst. 2:64.

[129] Murphy-Bokern, D. Peeters, A. Westhoek, H. 2017. The Role of Legumes in Bringing Protein to the Table. In: Murphy-Bokern, D., Stoddard, F., Watson, C. (Eds.), Legumes in cropping systems. CABI, Oxon.

[130] Watson, C. and Stoddard, F. 2017. Introduction – Perspectives on Legume Production and Use in European Agriculture. In: Murphy-Bokern, D., Stoddard, F., Watson, C. (Eds.), Legumes in cropping systems. CABI, Oxon.

[131] Boerema, A., Peeters, A., Swolfs S., Vandevenne F., Jacobs S., Staes J., Meire, P. 2016. Soybean Trade: Balancing Environmental and Socio-Economic Impacts of an Intercontinental Market. PLoS ONE 11(5): e0155222.

[132] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.

The group attempted to identify a major trigger that would increase the production and consumption of European legumes. Technological innovation, changes in attitudes, climate change or the formulation of a decisive policy are all potential levers. Considering the output from the group and the design of their pathway, the role of policies became apparent. However, due to wide range of suggestions and the observed discussion, it is also evident that not a single step or policy could solve the situation and realize the vision. Societal trends such as changing consumer behaviours, as well as sudden events and shocks such as the prohibitions of pesticides in other crops or the Amazon fires also play a role and create opportunities for European legume-related developments. The uptake of different sectors in the formulated policies showed the perceived need to not only stress production focused policies, but to build a mixed policy approach involving agriculture and food policies that creates incentives along the value chain. What is essential in such a mix is policy integration in order to create strong linkages between the measures and prevent inconsistencies.[133] A crucial question in this context of aligning multiple interactions is addressing the role of different actors. In our workshop, the European Commission is an important instigator and emphasis is set for policy on a European level.

Group 2

While the vision for increasing European sourced legumes in feed and food was the same for Group 2, the designed pathway differed in its focus. The group directed the majority of steps on production-related or engineering changes - either on the farm or processing level.

The introduction and widespread adoption of small-scale equipment for on-farm processing of home-grown legumes is a necessary pre-requisite for increasing production. The processing of soybean before feeding is indispensable due to presence of ANFs. The participants therefore agree that small-scale processing would address the lack of nearby processing facilities and could foster regional value chains.

Currently, commodity trading clearly dominates feed markets, hindering the uptake of regional legumes.[134] There is strong support for specific contracts for the production of feed between farmers and processors/collectors. Mutually agreed prices creates security and encourages production.

Many steps referred concomitantly to the feed and food sector in Group 2. Participants see a need to inform consumers about the origin of animal feed. Simple labelling with attributes such as "home-grown feed" or "EU-grown feed" in order to promote EU legumes would be useful to inform the public and guide food choices. Sudden events and shocks e.g. the destruction of the rainforest, droughts or other disasters in the major feed-producing regions can support the efforts to abandon imported feed.

[133] Balázs, B., Kelemen, E., Centofanti, T., Vasconcelos, M. W., Iannetta, P. P.M. 2021a. Integrated policy analysis to identify transformation paths to more sustainable legume-based food and feed value-chains in Europe. Agroecol. Sustain. Food Syst. 45:6, 931-953

[134] Clément, T., Joya, R., Bresson, C., Clément, C., 2018. Market developments and policy evaluation aspects of the plant protein sector in the EU. Brussels: Agrosynergie EEIG for the European Commission.

Premium value chains (e.g. food) ensures higher economic returns and provide competitiveness to locally or European produced grain legumes.[135] In order to support the direct consumption of legumes, this group see a benefit in increasing the diversity of legume-based foods. Moreover, the increase of such products could promote legume consumption since many consumers lack knowledge on how to prepare legumes. [136]

Similarly to Group 1, the members of Group 2 agree that the positive environmental attributes of legumes increases their attractiveness in agriculture. The climate crisis as well as national and EU-wide initiatives to go carbon neutral further increase their attractiveness. Participants envisage more opportunities to grow a wider array of legume crops in cooler climates and achieve higher yields, which would increasingly make northern regions of Europe larger suppliers of grain legumes in the future compared to southern Europe. Legumes crops such as lentil in southern Germany, chickpea in Central Europe, narrow-leafed lupin in the Nordic region, and soybean in Central Europe are rarely grown in these regions but could flourish in the future.[137]

The group acknowledges the need for increasing breeding efforts for legumes and call for improved cultivars. Interestingly, there is also mention of a more liberal policy on genetic improvement allowing easier access to and acceptance of 'GM'. Aligning the European Commission's set of rules on GM with the opinion from the European Food Safety Authority (EFSA) and other scientist would speed up genetic improvements in legumes. In another step, participants see the continued need to improve resistance to and/or management of pests, diseases and weeds as new stresses appear with climate change. Legume crops are already very susceptible to a wide range of diseases, pests and weeds. The participants acknowledges that farmers require more information about cultivating legume crops. The group perceives extension services and demonstration projects as a means to address issues related to cultivation.

The group calls for the formation of local working groups to identify what is done in a region and what is needed to grow and sell more legumes, specifically focusing on the evaluation of available information and infrastructure and the development of marketing concepts for special products. Such efforts could foster locally tailored solutions, which is highly relevant for legumes since the suitability of different legume crops vary between regions.[138]

The participants also see the chance to strengthen the position of legumes in Europe through discussions with value chain actors on how to decrease environmental pressures through agriculture, particularly referring to healthy nitrogen and phosphorus balances. As legume crops have the ability to fix nitrogen in the soil (BNF), they allow for reductions in nitrogen fertilisation. In addition, legumes can solubilize soil phosphorus, which can improve the phosphorus uptake of crops.[139] The group also discussed the effect

[135] Ibid.
[136] Ibid.
[137] Watson, C., Reckling, M., Preissel, S., Bachinger, J., Bergkvist, G., Kuhlman, T., Lindström, K., Nemecek, T., Topp, C., Vanhatalo, A., Zander, Z., Murphy-Bokern, D., Stoddard, F. 2017. Grain legume production and use in European agricultural systems. Adv. Agron. 144, 235–303.
[138] Döring, T. F., 2015. Grain legume cropping systems in temperate climates, in: De Ron, A., M. (Eds.) Grain legumes. Springer, New York, pp. 401–434.
[139] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

of legumes on biodiversity in light of a wider trend for the inclusion of legumes in biodiversity management plans.

Synthesis of workshop and interviews

Three broad areas emerged as important for transitioning towards an increased production and consumption of legumes. These are

1. production and consumption (as food for humans);
2. harnessing the power of networks; and
3. using differentiation strategies in value chains to support consumption.

All of these can be applied together for inducing a transition that increases the production and consumption of European legumes.

Production

Conventional livestock and aquaculture producers that want to use more European legumes are dependent on the availability of non-GMO commodity production and have to consider the price of grain legumes. Addressing the European protein deficit through EU-grown legumes will inevitably require vast amounts of regional legume production to substitute the currently imported soybean. Increasing production ultimately requires scaling up to achieve low prices and large volumes based on large-scale farming enterprises across Europe. However, it is unclear whether affordable food prices can be maintained in a setting increasingly defined by stricter standards e.g. carbon emission reductions and limited pesticides use. In line with Ricardo's laws of comparative advantage, farmers in Europe are concentrated on growing cereals largely because they grow well, in other words cereals capture the resources efficiently, generating high yields.[140] To make legumes profitable and competitive at farm level, improving their efficiency to capture resources remains central.

Simple production-related subsidies are not capable of inducing long-lasting changes, yet they remain important to incentivise production. Connected to improving farmers' profitability is the development of cultivars through focused breeding activities, institutional improvements such as suitable contracts for production, the empowerment through local knowledge provision on crop production and connecting practices to market requirements, the provision of agri-technological solutions for pest and weed issues in legume cropping or the introduction of small-scale processing equipment. It should be acknowledged that the uptake of novel crops is slow and gradual, as it also involves demonstrating their benefits to farmers that have little or even no experience of growing legumes.

Consumption of grain legumes as food

The change of consumption patterns of is best addressed either through educational campaigns or a range of information provision tools that allow consumers to make knowledge-based choices. There is still room to diversify plant-based food products made from grain legumes as well as providing guidance on adopting a plant-based diet by

[140] Murphy-Bokern. 2022. Developing legume-supported cropping systems in Europe: have we forgotten something? Annals of Applied Biology, in press.

improving people's culinary skill-set. This is partly connected to the dietary trend that is moving towards increasing plant-based consumption, placing emphasis on flexitarian diets and reducing meat consumption. However, it is important to recognise the heterogeneity of consumers' preferences (e.g. regarding meat consumption, flavours). Any recommendation or strategy that might follow needs to consider this.

Networks and key actors
Connecting supplier (e.g., producers) and buyer (e.g., processors) is also a matter of providing the grower with specific market requirements. This involves networking and establishing suitable platforms to facilitate business relations.

There are key actors that facilitate change. This includes sourcing managers but also retailers that can make important decisions to support European feed use, as seen in the Austrian case. Retailers are not only focused on price, but also on organisations' and consumers' interests, when deciding what to put on their shelves. As shown in the case of UK, retailers are important when deciding what production strategies (e.g., feeding strategy) their linked supply chain should follow (e.g., livestock producers).

Moreover, local working groups are needed to identify what is done in a region and what is needed to grow and sell more legumes, specifically focusing on the evaluation of available information and infrastructure and the development of marketing concepts for special products. Such efforts could foster locally tailored solutions, which is highly relevant for legumes since the suitability of different legume crops varies between regions.

Lastly, producers ensure the availability of grain legumes yet their bargaining power is often small. Ensuring their economic outcomes through fair production prices is essential. Producers could organise into larger cooperatives in order to achieve higher prices in the negotiation process with potential buyers.

Value creation through differentiation
As stated by one interviewee "All we know is [the] price of everything and value of nothing''. The value-chains addressed in this report gain their distinctiveness from having a strong preference for using European legumes. These value chains differentiate themselves based on their strong regionality and/or sustainability. Focusing on the environmental and resource impacts of legumes is clearly seen as a chance to encourage a legume-supported agrifood system, particularly in light of current trends either in society or EU policy, encouraging carbon zero or biodiversity conservation and actions to stall deforestation. Legumes are valued for their health (as food for human consumption), their environmental credentials, and often the geographical origin i.e. where they have been grown. In many of the value chains the role of producers is mentioned assuring the consumer that the welfare of all value chain participants is important. In the case of producers, this can take the form of ensuring a fixed production price or a guaranteed top-up on the market price, which can also improve farmers' profitability. Besides the price factors, consumers buy products mainly for their superior taste, but also their ethical, health and environmental credentials. Livestock and food producers are able to capitalise on these credentials and differentiate themselves from the competition.

Conclusions

To increase grain legume production and consumption in Europe, there is a need to focus on the transformative power of key actors in adopting change. Niches destabilise current structures creating new trajectories for development. The niches observed in this report are value chains that include legumes as feed or food. In these cases, legumes are favoured for their local, environmental, health (plant-based food) related credentials.

According to transition theory, niches usually have distinct objectives, either to 'fit-and-conform' or 'stretch and transform' the prevailing regimes.[141] The objective in *fitting and conforming* is to persuade society that the niche is able to become competitive on regime criteria. For large users of feed materials, two important criteria are identified: price and availability. Some of the interviews reported a general concern over Europe's ability to supply enough raw materials and at the same time remain competitive as a non-GMO production region in the world, without affecting consumer prices for animal and fish products. Europe gains its distinctiveness from other global markets with its strong non-GMO profile and "greening" policies. However, stricter standards add costs to production. To maintain a level of competitiveness legumes have to be profitable at the farm level. Breeding programmes are central in improving the resource capture of legumes (especially carbon through photosynthesis). This suggests that legume production is more likely to increase if it fits and conforms to the rules of competition.

The objective in stretching and transforming is to develop the consensus in society that the "rules of the game" need to undergo some changes. From a production point of view, it could be about re-defining the economic competitiveness of cropping systems, maybe by revising understanding of optimum yield across a cropping system. The non-market outputs of grain legumes related to their environmental credentials are not well recognized.[142] This transformative agenda involves some level of systems-thinking that looks at the contributions of crops and supply chain activities to the system as a whole, whether it is about improving biodiversity, the livelihoods of farmers or the climate impact of food products. All of this would mean a larger shift in consumers' behaviour, but given the current changes and uncertainties in world food markets, there is a huge potential for a more regionalized sustainable agricultural production.

[141] Smith, A., Raven, R., 2012. What is protective space? Reconsidering niches in transitions to sustainability. Res. Policy. 41(6), 1025-1036.

[142] Zander, P. Amjath-Babu, T.S., Preissel, S., Reckling, M., Bues, A., Schläfke, N., Kuhlman, T., Bachinger, J., Uthes, S., Murphy-Bokern, D., Stoddard, F., Watson, C.A. 2016. Grain legume decline and potential recovery in European agriculture: a review. Agron. Sust. Dev. 36, 1–20.

Annex 1

Interview guide

Research question: How to increase the proportion of regional legumes in European value chains? An analysis of sector-level knowledge and outlook on pathways for transition.

Sub-questions:

- What are the opportunities? By 'opportunities' we mean what circumstances make it possible for something to happen?
- What are the challenges?
- How can we overcome them?

Included sectors: poultry, pig meat, aquaculture, soya and cool-season grain legumes, plant derived food, dairy and beef

I. Description of the value chain(s)
These questions address the first part of the interview: describing value chains in the respective technical areas/ sectors

Core functions of value chain

Please describe a value chain involving European-grown grain legumes in your technical area. What does it look like?

- How many production stages? (length of value chain)

II. Multi-level perspective on challenges and opportunities
In order to approach challenges and opportunities connected to the described value chain, we want to apply a multi-level perspective - hence we want to focus on various angles of the value chain in the following. We will explore different challenges to legume value chains by looking at markets, costumer preferences, technology, infrastructure, networks, and policy.

1. Markets and customer preferences

- What market opportunities can you identify in terms of integrating grain legumes in your technical area?
- What are the main market challenges to include European grain legumes in this value chain?
- What customer preferences do you consider as challenges or opportunities for increasing the use of European grain legumes?
- What recommendations would you give to overcome these challenges?

2. Technology and science

- What are the main technological opportunities in your described feed and/or food value chain?
- What are the challenges?

- How would you overcome these?
- Which science related questions would you like to solve?

3. Infrastructure and networks

- What is the motivation for having the value chain collaboration you have described earlier?
- Describe any opportunities for improving collaboration with other companies/organizations or other actors in general?
- Are there any challenges in terms of infrastructure (e.g. processing) and/or value chain collaboration?
- How would you overcome these?

4. Policy

- What kind of policy would create a favourable environment for businesses to use more European legumes?
- Are there any policies and regulations that constrain the use of more regional legumes in your sector?
- How would you change them?

5. Outlook

- What is your vision for grain legumes?

Annex 2

Table 4. The general quality requirements of food and feed grade faba bean and pea in Germany.[143]

Feed	Food
General requirements: - Humidity: below 15% - Contamination: less than 2% (all organic and inorganic foreign constituents, seeds of other species including foreign grains than the seeds to be examined as well as damaged and eaten grains) - Shrivelled, broken grain: max. 10% - Pest population (free from living pests) - Organic goods: pesticides below 0.01 mg / kg according to BNN guidelines	*General requirements:* - Moisture: 15% - Contaminants: Under 2% - Shrivelled or broken grains: 5 to 10% - Pests: Free from living and dead pests - Pitting: individual limits (additional) - Free from pesticides (additional) - Free from mold (additional)
- Value-added ingredients such as crude protein (isolated cases) Anti-nutritional factors: - The most important antinutritive ingredients in field bean are vicin/covicin and tannins, although there are varieties that are low in vicin/covicin or tannin-free. - While tannins can be disadvantageous when used in pig feed, vicin and covicin are undesirable in poultry feed. Here it is important to consider the recommended limits in the ration. - If the cultivated legumes are to be marketed, it is recommended to discuss the choice of variety with the buyer before sowing the legumes. - Other anti-nutritive ingredients such as lectins, protease inhibitors and oligosaccharides do not play a role in practice so far.	*Example of consignment for Emsland-Stärke GmbH in Germany for yellow-seeded pea (Pisum sativum) grain feed pea:* - Stocking: max. 2 % - black peas (rich in tannin): max. 1 % - green peas as admixture in yellow peas: max. 10 % - broken peas: max. 10 % (half peas do not count as broken peas) - Moisture: max. 15 - free from mould - free from live and dead animals - Fluazifop-P-butyl (Fusilade Max), Haloxyfop (Gallant Super), Tebuconazole (Folicur) are not used.
	Other possible quality parameters *Sensory requirements* - Appearance typical of the species odour and taste typical for the species without foreign odour and taste, pure, not musty or mouldy - Shape, colour, grain size - for yellow peas: proportion of green peas - Uniform variety, if applicable - Consistency (cooked) Quality parameters - Weight (thousand grain weight or per 100 grains) - Discolouration - Clumping
	Product-specific chemical requirements - Ingredients: crude protein content, tannin, vicin/covicin, ...

[143] DemoNetErbseBohne. Qualitet. (accessed 10.11.2021) https://www.demoneterbo.agrarpraxisforschung.de/index.php?id=351

	- Water content - Heavy metal content (lead, cadmium, mercury) - Residues of pesticides and fumigants, heavy metals and mycotoxins: Requirements according to German food law and EU food law
	Microbiological requirements, for example - Total bacterial count - Enterobacteriaceae - Escherichia coli - Yeasts - Moulds - Salmonella - Staphylococcus aureus
	Further technofunctional parameters can describe the utilisation and processing properties of the raw material: - Cooking behaviour, cooking time, water absorption before cooking - Swelling capacity/water binding - Particle size - Texture - Protein composition - Lipid composition - Starch content and composition - Oil binding - Protein solubility - Emulsifying capacity, emulsion stabilisation - Luminosity - Chromaticity - Whippability - Enzyme activity - Baking properties

Annex 3

The workshop was organized in a two-step procedure: there was an introducing phase with a presentation by the facilitators in order to achieve a common understanding of the current situation of grain legumes in Europe. Then a phase of group work followed. In this second phase the exercise was introduced to the participants. A common vision of "Increasing European sourced legumes in feed (aquaculture, dairy and beef, pig meat, poultry) and food" was fixed and the guiding question "What steps are needed to include more European legumes in value chains" was presented. Participants were invited to refine the steps or actions needed in terms of relevant actors, sectors, scale (local, national, etc.) and timing (focused on the period from 2020 to 2030). Additionally, further relevant factors for the vision such as trends, sudden events and shocks could also be added to the pathways.

Each group formulated a range of steps that they perceived necessary for their transition pathways (Supplementary Annex 4, table 5). The two pathways of the groups to more legumes in feed and food varied in terms of the majorly included sphere of action – while in group 1 policy prevailed in group 2 agronomic related steps are in focus. In the following section the results of the interviews and workshop are presented. Although the interviews and workshop forms the basis of the presented results, additional research articles or documents have been used to elaborate some of the ideas brought forward by the interviewees and workshop participants.

Annex 4

Table 5. Supplementary table: Overview of the steps discussed in the workshop

	Policy	Engineering	Production
Crop	Implement measures (aids?) to achieve ROI for legume breeders. Otherwise on the long-term, the hybrid bred crops will better performing in comparison	Analysing varieties for their specific strengths and weaknesses for specific uses in order to make the best use of them	More information and demonstrations of legume crops
	European standards for lab methods for analysis/quality control of legumes	Support for development of environmental friendly weed management technologies (mechanical and chemical).	Local working groups to identify what is done in the region and what is needed to grow/sell more legumes (information, infrastructure, marketing concepts for special products)
	Revising IPCC reporting requirements for national GHG inventories so that Land use change induced emissions abroad are also considered. By that all measures to reach the Paris climate goals need reconsideration.	Improved cultivars	Role of legumes in nutrient balancing re: water, air, nitrate, phosphate
	Sensible policy on genetic improvement	Continuing need for resistance and/or management of pests, diseases, weeds as new stresses appear with climate change	
Feed	Prepare policy on GM free feed	Cheap rapid tests for analysing antinutritional factors in legumes	
	Recognise the use of local grown legumes in feeding livestock as a Greening measure within the CAP	Small-scale equipment for on-farm processing of home- grown legumes	

Legumes Translated (Translating knowledge for legume-based farming for feed and food systems) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817634

	Consensus about legume effects on C footprints and resilience to climate change. European project on Product Environmental Footprinting Category Rules (PEFCR; carbon and many other metrics) of feed raw materials		
	Production of feed needs specific contracts		
Feed, food	Standard Europe origin certification (like. Proterra, RTRS) among food and feed value chain. Promote European legumes (incl. soy) farming among consumers.		High quality legumes (price is not as important)
	Standardise GM/non-GMO regulations across Europe		Moving towards carbon zero
	Inform consumers about animal feed origin of the commercial meat		Climate change may give opportunities: growing more in cooler climates and we may need to feed regions that used to feed us
Food	Public food procurement (cafeteria, schools, army etc) should define a mandatory rule for preferring European legumes or animal products fed with European legumes.	Increased diversity of easy legume-based foods	Focus on added value products
	Information about origin of components as we have it already with organic food also for conventional (at least EU / non-EU) or giving the country of origin outside EU.		
	Create a scorecard for food products for their environmental performance as there is for diet.		
	Introduction of a substantial carbon tax also in the agri-food sector.		
	Promotion of EU legume content to make it a selling point. Simple food labelling (Homegrown feed, EU-grown feed, etc).		

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