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Exploring the Potential and Challenges of *Lathyrus sativus* (Grass Pea) in European Agri-Food Value Chains: A Cross-Country Analysis

Irina Solovieva ^{1,2,*}, Pavlina Miteva-Bölter ¹, Marija Knez ^{3,4}, Ann-Kathrin Bessai ⁵, Eleonora Barilli ⁶, Nadja Kasperczyk ¹, Marija Ranic ^{3,4}, Mirjana Gurinovic ³, Pedro Jose Luna Casado ⁶, Nicolas Alba Morales ⁶, Manuel Sanchez ⁶, Cyril Tisseyre ⁷, Burkhard Schaefer ⁷ and Elena Xoplaki ¹

¹ Center for International Development and Environmental Research (ZEU), Justus Liebig University Giessen, Senckenbergstrasse 3, 35390 Giessen, Germany

² Center for Sustainable Food Systems (ZNE), Justus Liebig University Giessen, Senckenbergstrasse 3, 35390 Giessen, Germany

³ CAPNUTRA, Capacity Development in Nutrition, 11000 Belgrade, Serbia; marijaknez186@gmail.com (M.K.); marijar@imi.bg.ac.rs (M.R.); mirjana.gurinovic@gmail.com (M.G.)

⁴ Centre of Research Excellence in Nutrition and Metabolism, Group for Nutrition and Metabolism, Institute for Medical Research, National Institute of the Republic of Serbia, University of Belgrade, 11000 Belgrade, Serbia

⁵ Bioland, Kaiserstr. 18, 55116 Mainz, Germany

⁶ Solintagro SL, Calle Escritora Rosa Chacel 4 Local 2, 14004 Cordoba, Spain

⁷ ECOZEPT France SAS, Le Barcelone, Bât. 12, 145 Rue Guillaume Janvier, FR-34070 Montpellier, France

* Correspondence: irina.solovieva@agr.uni-giessen.de

Abstract: Modern agri-food systems demand crops that are climate change resilient, support environmental sustainability, enhance dietary diversity and appeal to consumers. This article examines the potential of underutilized crops in meeting these challenges. We take *Lathyrus* as a case study and examine it within the context of European agri-food value chains, with a particular focus on Germany and Spain. The study employs a range of methods—literature review, interviews, field observations, and consumer opinion surveys—to explore its versatility. The findings reveal that *Lathyrus sativus* (grass pea) offers significant benefits: it is adapted to dry climates and tolerates high rainfall. As a nitrogen fixing crop, it can play an important role in crop rotations, reducing the need for fertilization and providing an attractive alternative for organic farmers. Through appropriate processing methods, *Lathyrus* can enhance its beneficial nutritional characteristics. Furthermore, it is well suited for the development of innovative recipes that align with modern culinary trends and meet consumers' expectations across different cultures. To make use of its potential, adaptive cultivation methods and value chain cooperation are needed. Along the value chain, the affordable pricing of *Lathyrus*-based products and clear communication of their nutritional, environmental, and social benefits prove to be most critical.

Keywords: *Lathyrus sativus*; underutilized crops; agri-food value chain; climate change adaptation; farming and processing techniques; consumer preferences; nutritional value; sustainable food systems



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1. Introduction

In recent years, the research on the value of neglected and underutilized crops for achieving food and nutrition security especially in vulnerable regions has been continuously rising [1–4]. The so-called “forgotten gems” are found to have not only high nutritional value but they also reduce the environmental impact of climate change by nitrogen fixation,

improving soil health and conserving biodiversity [5]. Similarly, largely unknown minor crops, grown on a smaller scale and only in specific regions, help preserve local biodiversity, bring economic benefits and contribute towards healthy diets of the local population [6], as well increase climate-resilience of those communities [7]. Recognizing the multifaceted importance of these crops, studies have also focused on investigating the reasons for their reduced cultivation and consumption to bring about strategies for their (re)introduction into the agricultural production and consumption [8].

Lathyrus is a typical “orphan legume” or an underutilized crop in the European conditions [9,10]. It is one of the oldest cultivated crops with a long domestication history (ibid.). Seeds have been found in excavations from India and Turkey dating back to 8000 B.C., as well as in the Balkans. Grass pea (*Lathyrus sativus*, or, *L.sativus*) (in this paper, we use *Lathyrus sativus* and grass pea interchangeably) used to be popular in South Asia (India, Nepal, Bangladesh), many European countries (Italy, Spain, Portugal, France, Poland), and Ethiopia [10,11]. Although long ago *Lathyrus* varieties were used in almost all continents, in present times it is an almost entirely forgotten plant, produced in very small quantities and mainly used as fodder. Grass pea—the variety used for human nutrition—has gained a negative reputation largely due to its association with neurolathyrism, a neurodegenerative disorder caused by a neurotoxin present in the plant [11,12]. Additionally, its nutritional limitations, such as a relatively low content of sulfur-containing amino acids and the presence of antinutritional factors like tannins and phytic acid, have further contributed to its neglect. This has led to a reduced interest for this plant and lack of genetic improvement, resulting in reduced yields both in quantity and eventually quality [9,10]. Addressing these limitations through breeding strategies or processing techniques could help unlock its potential as a valuable crop for food security and sustainable agriculture.

Recognized for their nutritional value and strong potential to address food and nutrition insecurity, research on *Lathyrus* crops is concentrated in low-income regions that face these challenges, such as countries in Africa, South and Southeast Asia [4,7,13–15]. Interest in research on the environmental and nutritional significance of *Lathyrus* crops in the European context is quite high [6,8,16]. The main reasons include high protein content and rich nutritional profile, nitrogen fixing ability typical for all legumes, and relatively high drought tolerance [4,5,8,10,13,15,17,18]. All these factors contribute to the interest in re-introducing this legume into the cultivation. However, to succeed in this, the whole agri-food value chain and multiple actors have to be considered. The studies that summarize such evidence and that can support this effort are scarce, especially for the European conditions. Therefore, this paper explores the potential and challenges of the underutilized *Lathyrus* species focusing on *L. sativus* (grass pea) (this study is a part of the BioValue project. The aim of the BioValue project is to set-up a holistic approach to the analysis of the link among biodiversity, the agri-food value chain, consumers’ preferences and health as well as to support the introduction of underutilized genetically diverse crops in the agri-food value chain throughout Europe) by:

- Investigating the existing experience related to the cultivation of *L. sativus* in the context of Germany and Spain (farming level);
- Studying the processing techniques (industry and home processing);
- Addressing the level of consumption by addressing the consumer preferences related to *L. sativus* and to specific recipes developed with this crop;
- And, finally, analyzing the potential and main challenges of *L. sativus* at every level of the agri-food value chain.

Section 2 of this paper describes the approaches applied to each step of the investigation. Section 3 presents the related results. First of all, the cultivation process is described for the two European countries—Germany and Spain. *Lathyrus* species are quite rare in

Germany and more widespread in Spain, which is why we investigate the experiences related to production of *L. sativus* in the context of these two countries. In the next step, the most relevant processing approaches are presented and discussed from the perspective of the efficient use of the crop benefits and reduction of negative effects for human nutrition. Additionally, the results of consumer preferences are described. Conducting consumer surveys in several countries allows for a broader understanding of regional preferences, cultural differences, and market acceptance, providing valuable insights into the potential for *L. sativus* to meet diverse consumer needs and enhance product development across Europe. Finally, in Section 4 we analyze and discuss the potential and challenges for this crop in agri-food value chains and identify best-practice approaches for each value chain level.

2. Materials and Methods

2.1. Methodological Framework: *Lathyrus sativus* Value Chain Analysis

The study followed a value chain approach structured in three levels namely production, processing, and consumption. This section describes the focus and data collection methods for each of these levels. Findings from all levels were then synthesized to identify potential and challenges within the agri-food value chain for *L. sativus*, providing insights for best-practice recommendations and product development in Europe. This framework ensured that insights from production, processing, and consumption inform each other, creating a comprehensive understanding of *Lathyrus*' role in the agri-food system. While the methodological details for each level are described in the sub-sections below, an overview of the approach is presented in Figure 1.

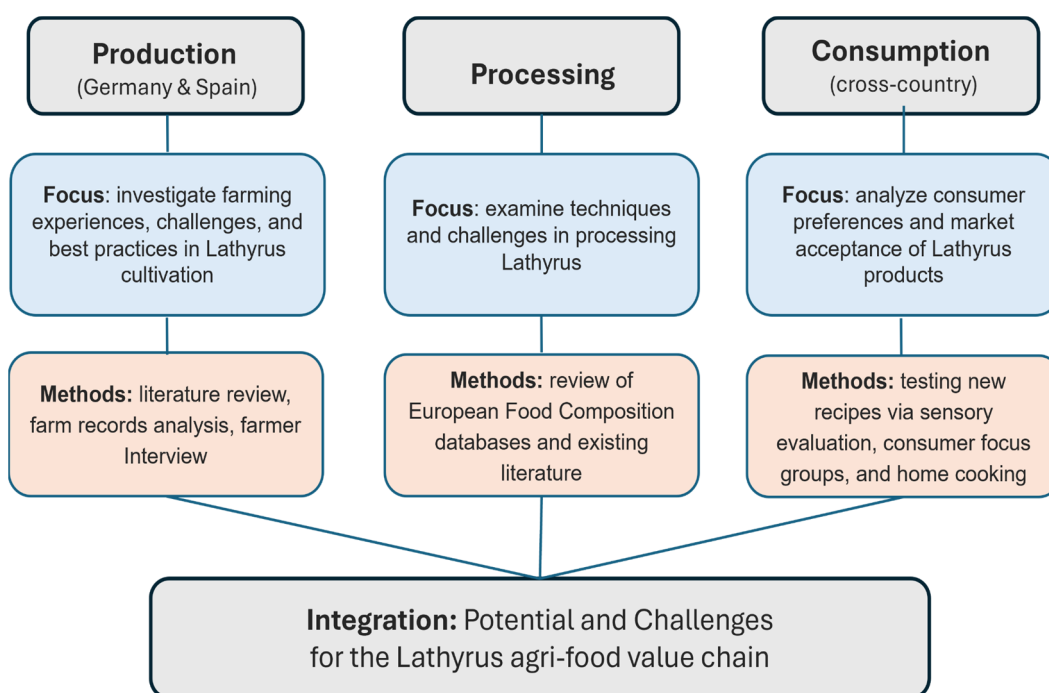


Figure 1. Conceptual and methodological framework for *L. sativus* value chain analysis.

2.2. Production: Farming Level

2.2.1. Literature Review

A literature review was used with the aim to determine the currently relevant farming techniques in the cultivation of *Lathyrus* species. We also focused on relevant agronomic information, such as: a brief plant description; a review of widespread (generally used)

farming practices; ecological effects; crop use. Various literature sources such as journal papers, fact sheets developed by farm advisors, and others were used to collect the necessary details. This information was then used to design the interview guidelines.

2.2.2. Farm Records

Farm records were used to describe the cultivation process for Spain. We analyzed available farm record-based information for the production of *L. sativus* for a farm in Andalusia, Spain.

2.2.3. Farmer Interview

One qualitative semi-structured interview was conducted with a farmer in Germany who grew *L. sativus* under the framework of a small-scale trial. The interview structure was adapted to capture the details of the production process based on farm records from the 2021 season.

The interview questions on the farming processes covered: soil preparation, sowing, fertilization, irrigation, disease and pest control, weed control, harvesting, and crop rotations. The focus was on the resources required and the obtained outcomes, as well as on the factors related to the incorporation of diverse crops and varieties at the farm-level (e.g., crop variety, crop rotation, field size, type of agricultural inputs, etc.).

The goal was to identify specific farming practices and techniques employed by farmers in relation to the production of underutilized crops and to find out how these procedures and techniques chosen by farmers are related to crop diversity decisions.

Apart from gathering the experiences with farming practices, the interview aimed at: the identification of perceived constraints related to crop diversity and to the production of *L. sativus*, and the identification of farmers' current strategies to overcome perceived constraints. The responses to the related open questions were analyzed by applying the thematic analysis approach [19] focusing on perceived constraints related to crop diversity in general, and more specifically to *L. sativus*.

2.3. Processing

Literature review of current processing practices of selected underutilized foods. Information on the food preparation practices associated with *Lathyrus* species was systematically compiled from European food composition databases (i.e., EFSA food composition data, Ciqual in France, and the Serbian Food and Nutrition database) and peer-reviewed studies. Both traditional household methods and industrial processing techniques were identified and classified based on the frequency of use, nutritional and health benefits, ease of use, nutritional enhancement, and sensory improvement. This compilation served as a foundation for refining processing practices of *L. sativus* and developing products that offer enhanced nutritional value.

2.4. Consumption: Recipe Development and Consumer Insights

2.4.1. Development of New Recipes

An important focus of the BioValue project was supporting the creation of the demand among consumers via development of new recipes that would include underutilized crops, especially those that are forgotten. Data from food databases and contributions from the literature review were used to compile a list of commonly consumed dishes made with *L. sativus*.

Traditional cookbooks, food databases, and grey literature were analyzed to develop innovative *Lathyrus*-based recipes, inspiring new combinations and techniques that improve nutritional quality while preserving cultural authenticity.

Selected dishes were prepared by a professional chef and tested by nutrition experts. Spices, taste, aroma levels, and processing methods were adjusted based on insights from initial sensory evaluations. The finalized recipes were analyzed for nutritional content using Serbian food composition databases through DAP (Diet Assess and Plan) software (<https://deltaelectronic.net/dap/efsa/ishrana.php>, accessed on 27 February 2025) [20] and were subsequently subjected to sensory evaluation in five countries across Europe that were a part of the BioValue project.

2.4.2. Sensory Evaluation

The sensory analysis employed a hedonic evaluation to measure consumer satisfaction with the presented products. Participants rated appearance, taste, texture, aroma, mouth-feel, and overall acceptability on a 7-point scale. The seven-point scale is structured as follows: 1 = Dislike extremely, 2 = Dislike a lot, 3 = Dislike, 4 = Neither like nor dislike, 5 = Like, 6 = Like a lot, and 7 = Like extremely). Controlled conditions ensured objectivity, including consent forms, neutral plates, and no interaction among participants. Sensory evaluations of *Lathyrus*-based dishes were conducted during Summer to Autumn 2023 in five locations and countries, namely Belgrade (Serbia), Chania (Greece), Montpellier (France), Izmir (Turkey), and Szekszárd (Hungary), with a total of 156 participants. The sensory evaluation was conducted across the countries where project partners are based, including Serbia, Greece, France, Turkey, and Hungary. This approach ensured that the assessment accounted for cultural and dietary differences, making the results more representative and relevant to diverse consumer preferences. Data from these evaluations were statistically analyzed and reviewed. The participant feedback guided recipe refinement, resulting in the final development of new *Lathyrus*-based recipes.

2.4.3. Focus Groups

To gather qualitative insights into consumer preferences and the acceptance of the developed grass pea recipes, eight focus groups were conducted between May and August 2023 in four countries: France, Greece, Hungary, and Serbia (two per country). A total of 67 consumers took part. Focus groups encouraged open discussions moderated with structured questions. The aim of this exercise was to explore consumer perceptions, preferences, and awareness regarding conventional and underutilized crops. The objective was to assess their understanding of nutritional, environmental, and social aspects, as well as their expectations for product taste, labeling, and distribution channels. This was conducted through structured focus group discussions, where a moderator followed guidelines with open-ended questions to encourage dialogue among participants. Consumers were asked to assess the product's nutritional quality, key factors influencing their perception, and its healthiness. For example, they were asked, "What is most important to you when evaluating the nutritional quality of a product?" and "How would you rate the healthiness of a product?". This qualitative approach allowed for in-depth exploration of consumer attitudes, highlighting areas where additional information and education could support the adoption of underutilized crops. Notes from these discussions were submitted in English and analyzed using MAXQDA 2022 software, a tool for qualitative research.

2.4.4. Home Cooking Tests

The home cooking tests aimed to gather practical feedback on the cooking experience of grass pea recipes shared in France, Greece, Hungary, Serbia, and across Europe through various channels, including food-related websites, social media platforms, and influencers specializing in cooking and recipes. The recipes were translated into local languages and disseminated through these channels. Specifically, the recipes were distributed through websites and applications dedicated to food, cooking, and recipes, as well as social media

platforms focused on food content, such as Instagram, Facebook, and TikTok. Additionally, food influencers who share cooking and recipe content were targeted to amplify the reach. While various channels were contacted, the recipes were successfully shared across 28 different channels in multiple countries, with some channels sharing several recipes. Feedback was collected via comments on different platforms and through an online survey, with the responses analyzed using MAXQDA software.

3. Results

3.1. Farming

3.1.1. General Agronomic Information on *Lathyrus*

L. sativus (grass pea) is adapted to dry climates, although it tolerates high rainfall. It is therefore cultivated in areas with an annual rainfall of 320–1360 mm. Moreover, it is more resistant to waterlogging than many legume species. It is resistant to high temperatures and drought. *Lathyrus cicera* (chickling vetch) is resistant to cold and frost during the early growth stage and is grown as an autumn legume in the Mediterranean zone. It grows even at 2–3 °C. Developed plants can withstand temperatures as low as −12 °C. However, during the flowering period, temperatures just below 0 °C can cause serious damage [21]. The soil requirements for *Lathyrus* species are low. *L. sativus* is adapted to poor soils, but tolerates heavy, clayey soils. It is sensitive to soil acidity. *Lathyrus cicera* is also adapted to poor soils, but not to very wet or waterlogged soils. In general, *Lathyrus* species prefer soils with an alkaline pH [21].

3.1.2. Farming Practices and Recommendations for *Lathyrus* in Germany and Spain *Lathyrus* in Germany

L. sativus is very rare for German farms, and this crop was not the main focus of the BioValue case study in Germany. There is no official statistical data on this crop and therefore it is difficult to estimate the cultivation area. Currently it is grown on a few organic farms (primarily in Bavaria). It is marketed as whole peas (dry and cooked), flour, and falafel. Still, there is a high interest in this crop as a specie that performs well in any production system with minimal inputs. Therefore, one interview was conducted with a farmer in Bavaria, Germany, who grew *L. sativus* in the framework of a small-scale trial (organic farm). Apart from *L. sativus*, the farmer grew further crops like wheat, spelt, naked oats, millet, and peas.

Soil preparation for *L. sativus* is similar to other legumes, like, for example, green pea. Notably, sowing should take place in uncompacted and well-settled soil. The seedbed must not be too fine, otherwise the nodule bacteria will be impaired. As the cutter bar runs very deep during harvesting, the seedbed should be as even as possible and should not have any protruding stones [22]. In Germany, depending on the weather conditions, soil preparation takes place in mid-March using machinery such as harrows.

Seeding: For Germany, seeding is recommended in the first half of spring (from late March to mid-April). Mixed cropping with cereals is advised to prevent lodging. The interviewed farmer applied intercropping with a grain crop. The number of seeds used depends on the size of the seed and the intended use of the crop. To facilitate fruit harvesting, 125 kg of seed per hectare (ha) is recommended. However, 80 kg of seed per ha can be used when intercropping with grain. The timing of sowing depends on the weather conditions, and usually takes place from late March to mid-April, with machinery such as a precision seeder.

Fertilization: As *L. sativus* binds up to 120 kg of nitrogen per hectare, it does not need any additional nitrogen fertilization and also has a positive effect on the subsequent crop.

Regarding outputs, each ton of grain is estimated to produce 40–90 kg of nitrogen, 20–50 kg of P_2O_5 (phosphorus), and 30–90 kg of K_2O_4 (potassium).

Irrigation: *L. sativus* requires a minimum of 300 mm annual precipitation and is adapted to dry climates. Therefore, no irrigation is required in the German weather conditions. At the same time, this crop is more resistant to waterlogging than other legumes.

Plant protection: Due to the small cultivation area in Germany, no specific diseases have been observed so far. Therefore, little to no plant protection is necessary in the German conditions. The neurotoxin ODAP (ODAP—Oxalyldiaminopropionic acid, neurotoxin found in *L. sativus*) is effective against some pests [23]. However, there is not enough information if there is actual resistance against major pests and diseases and if there are differences in the crop varieties regarding their resistance to diseases and pests in the German conditions.

Weed control: Due to their slow juvenile development, *Lathyrus* species are not very competitive with weeds. Mechanical weed control is applied to address this issue.

Harvesting: The time of harvesting the crop for fruit is determined by the yellowish color of most of the pods and before the lower pods begin to open. Two harvesting methods are used: harvesting the plants, leaving them on the surface of the field to dry and then threshing, or harvesting with the grain harvesters after suitable adjustment. There is no official statistical data on *Lathyrus* in Germany. The interviewed German farmer cultivates *Lathyrus* in the framework of a small-scale trial. Therefore, it was not possible to estimate the average yield in German conditions.

Crop rotations: *L. sativus* is used as a part of intercropping and mixed cropping systems with grains. It is applied before and after grain crops in rotations.

Lathyrus in Spain

In Spain, *Lathyrus* was previously used for different purposes, from animal feed (together with *L. cicera*, using both whole grains to make flour for formulations of compound feed, such as fodder in the form of hay), as soil green manure, or, as a complement to cereals, to human consumption, both mashed (traditionally called “*gachas*”), in soup, boiled in stew, or by directly consuming the green, immature seeds. For instance, in Spain, the surface cultivated decreased from 250,000 ha in 1925 to 636 ha in 2018 [24]. Currently, grass pea is principally grown in the regions of Andalusia, Castilla La Mancha, and Castilla y León [25]. In 2009, the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) assessed the risks of occasional human consumption of grass pea flour and concluded that limited consumption of grass peas, with an ODAP content of less than 0.15%, is not harmful to human or animal health [26].

For the project, farm record-based information on the production of *Lathyrus* was collected from a farm in Andalusia, Spain.

Soil preparation: In Spain, soil preparation methods vary depending on the production model used. In conventional management, deep tillage is not traditionally done; instead, a mouldboard plough is used to bury the remains of previous crops, followed by a couple of passes with a disc harrow to prepare the seedbed. For integrated production, a couple of passes with a cultivator are sufficient for the seedbed preparation. This model also promotes minimum tillage or no tillage, as well as direct sowing. Destruction of stubble by burning is forbidden.

Sowing: In Spain, sowing can occur either from September to October or from February to March. Autumn sowing is recommended in regions where winters are milder (such as Andalusia), allowing for higher grain and forage yields. The number of seeds used depends on the size of the seed and the intended use of the crop. For forage crops, 150–200 kg of seed/ha are recommended, while for grain production it is 140–150 kg of seed/ha. To

facilitate fruit harvesting, 125 kg of seed/ha is recommended in Spain [27]. Sowing is done at a row spacing of 25 cm using common winter cereal seed drills.

Fertilization: As a nitrogen-fixing crop, grass pea requires no additional nitrogen fertilization, making it suitable for low-input production systems.

Irrigation: Usually, no irrigation is applied under normal weather conditions in Spain. However, supplemental irrigation during pod filling may be considered in case of a severe early summer drought (in May), depending on the availability of on-farm resources and access to water.

Disease and pest control: In Spain, *L. sativus* can be sensitive to fungal pathogens as ascochyta blight (*Ascochyta lentis* var. *lathyri*), powdery mildew (*Erysiphe pisi*), rust (*Uromyces pisi* and *U. viciae-fabae*), parasitic weeds like broomrape (*Orobanche crenata*) and field dodder (*Cuscuta campestris*), and insects like black and green aphids (*Aphis craccivora* and *Acyrtosiphon pisum*, respectively).

Weed control: In Spain, chemical treatments can be used in conventional farming, depending on the prevalent weed species affecting the crop. Chemical broadleaf weed control can be done with pea-specific herbicides.

Harvesting: In Spain, harvesting of *Lathyrus* for grain production occurs around June (depending on locality and weather condition of the year), when the grain moisture is below 13% (200–225 days of growth cycle). Yields can vary greatly between 1100 and 1400 kg/ha, and 2600 and 3500 kg/ha. *Lathyrus* for fodder is usually harvested at 50% flowering stage.

Crop rotations: Crops with high nitrogen uptake are typically planted before and after *Lathyrus* (usually wheat, oat, or sunflower).

3.1.3. Potential and Challenges of *Lathyrus* at the Level of Production

This sub-section summarizes the potential and main cultivation challenges of *Lathyrus* based on the information presented above. Additionally, it analyzes the constraints to introduction of *L. sativus* and coping strategies of farmers (based on the farmer interview in Germany).

The main potential of the crop lies in its suitability for a low-input production system. It is well adapted to areas with arid or semi-arid conditions and poor soil. Since it is a nitrogen-fixing crop, no additional fertilization is usually required. Additionally, it has a positive effect on subsequent crops in crop rotation sequences.

No irrigation is needed, although like many legumes, drought during the pod-filling phase can affect yields. Therefore, in the case of early-summer drought, supplemental irrigation during the pod-filling phase can be considered in Spain.

Little to no plant protection methods are necessary under German conditions. In Spain, however, the crop could be affected by several diseases and pests. At the same time, there is extensive experience in disease and pest management due to larger cultivation areas.

Mixed cropping with cereals is recommended to prevent lodging. This can be a challenge since it requires a good choice of support crops. Additionally, careful planning is needed for the pre-processing step of cleaning the harvest.

Lathyrus species are sensible to weeds. According to different studies, mechanical methods have been quite successful. Additionally, there are no legally approved herbicides for this crop in Germany. Some measures can be taken before the field emerges, considering the seed placement depth, to improve the effectiveness of usable herbicides. Other commonly used weeding approaches include:

- Increasing sowing density;
- Rotations with crops that reduce weed presence or with green manure crops;
- Polyculture and mixed cropping.

In Spain, chemical treatments can be applied in conventional farms to control weeds. For example, grass pea is generally susceptible to the parasitic plant *Orobancha crenata* (broomrape); thus, a delayed planting date (such as in spring) and the use of early-maturing varieties are good strategies for broomrape avoidance. Additionally, it is also strongly recommended not to bury harvest remains when dry stems of *Orobancha crenata* are present, to avoid incorporating its seeds, which can cause problems during the growing season.

Uneven ripening can sometimes be a challenge. Lodging can reduce both the quantity and quality of the yield and requires adjustments to the harvesting equipment.

The analysis of constraints based on the qualitative farmer interview confirmed many of the issues summarized above. Most of the constraints for grass pea in Germany identified in the primary data collection are related to the fact that the crop is not well known among German farmers and its cultivation is very rare.

Constraint 1: Climatic conditions were mentioned as an important constraint. Main climate-related constraint is connected to the changing precipitation patterns, namely that precipitation is available mainly in winter and often there is lack of precipitation in summer. This constraint is valid not only for *L. sativus* but also for other arable crops. As mentioned above, lack of precipitation during the pod filling phase can result in reduced yields.

Possible coping strategies: Growing intercrops and cover crops for a longer period to cover soil can reduce evaporation and help keep the moisture collected during the winter months and cope with the decreased water availability during the growing season. Among the mentioned approaches was also adjusting the cropping season based on the rainfall by, for example, sowing earlier to use the winter and early-spring precipitation best.

Constraint 2: Lack of information on cultivation techniques suitable for German conditions is another constraint reported for *L. sativus*.

Possible coping strategies: Here, the farms can rely on small-scale trials and the experience of other farmers. Connection to the knowledge networks and specialized social networks plays an important role here. For the policy, this means that not only knowledge creation (e.g., through supporting breeding and agronomic research that includes new crops and varieties), but also knowledge transfer and communication are of crucial significance.

Constraint 3: The constraint related to the choice of the support crop for *L. sativus* is connected to the previous point but also includes further issues connected to the value chain linkages that play an important role. The information based on experience in the German conditions is missing on what crop is most suitable in combination with *L. sativus* from the perspective of productivity, yield quality, and consequent effort for processing. Related experiments are currently being conducted in the context of pilot studies in WP7 of the BioValue project; the results will be documented and disseminated at the end of the project.

Possible coping strategies: Mentioned coping strategies showed that farmers rely on gathering experience from small-scale trials, testing different combinations at small farm plots, and collecting information on the experiences of other farmers. Careful planning is important for the right choice of supporting crops depending on the possibilities for post-harvest processing available in the region and on the final use of the crop.

Constraint 4: A connected challenge is the issue of clearing the harvest for the use for food—separating the grains in the case of mixed cultures can become an issue and requires the availability of specific clearing infrastructure.

Constraint 5: The challenge of setting quality standards for the entire value chain of *L. sativus* is another important issue. Since the crop is new, the standards have not yet been clearly identified or communicated.

Possible coping strategies: Co-operation along the value chain can be an approach to tackling the issue of standards. Collaboration between the processors and farmers can

create more transparency in a value chain. Processors should provide clear information about the quality and characteristics of the raw product they require.

3.2. Processing

Among *Lathyrus* species, *L. sativus* (grass pea) is most commonly used for human nutrition. It is utilized in various ways across different regions, reflecting local culinary traditions and agricultural practices. In India, grains are sometimes boiled whole but are primarily processed through dhal mills to produce split dhal, the most common retail form [28]. In Ethiopia, popular methods include soaking and boiling seeds into ‘nifro’, sprouting followed by boiling, and roasting soaked seeds to make ‘kollo’ [29]. Grass pea flour is used for unleavened bread, sauces like ‘shiro wott’, or mixed with other legumes and cereals [30].

The main challenge is that raw grass pea contains toxic amino acids (β -ODAP) that can cause neurotoxicity in the case of frequent consumption. Therefore, proper processing is essential to reduce this risk. Processing methods, such as soaking, fermentation, boiling, roasting, germinating, extrusion, and autoclaving, significantly reduce toxicity and improve nutritional value (Figure 2).

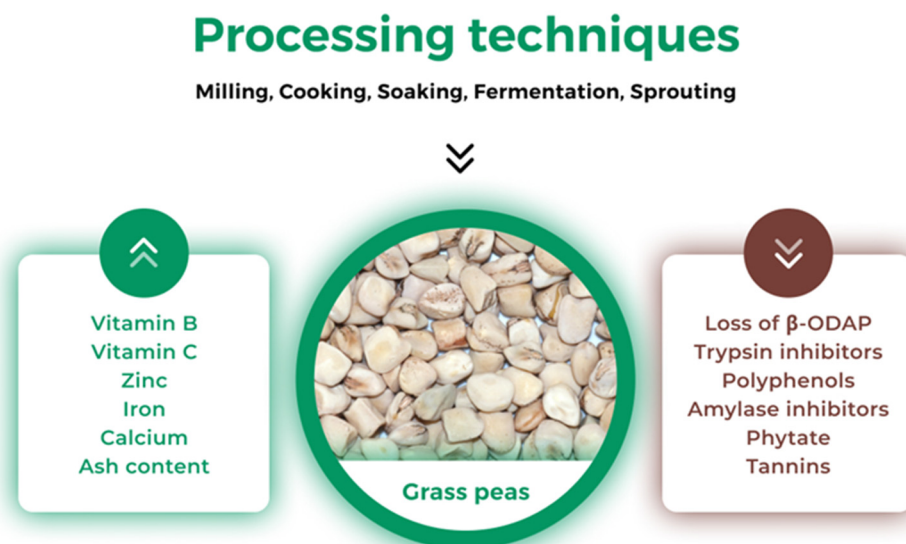


Figure 2. Variations in nutritional composition of grass pea during processing.

Extended soaking reduces β -ODAP, antinutritional factors, and enzyme inhibitors, soaking in boiling water reduces β -ODAP by 65–70% and trypsin inhibitors and polyphenols by 42–48% and 30–37%, respectively [31]. Similarly, boiling enhances sensory appeal and tenderness while significantly reducing β -ODAP levels [32]. Pre-soaking combined with ordinary or pressure cooking effectively reduces antinutritional factors [33]. Cooking for 20 min is optimal for reducing β -ODAP content, with higher temperatures showing increased reductions [34]. The processing methods significantly influence the nutrient composition and mineral content of grass pea seeds. Traditional preparation methods, such as roasting, boiling, and unleavened bread preparation, effectively reduce antinutritional factors like phytate and tannins, with phytic acid content decreasing by 33%, 30%, and 70%, respectively [35]. Similarly, β -ODAP levels decreased by 12% after roasting and 38% after boiling, while mineral content, including zinc, iron, and calcium, increased. Protein content rose by 9% and 10% for roasted and boiled seeds, respectively, accompanied by increased fat and reduced ash content [35].

The preparation of sauces, such as ‘shiro wott’, proved to be the most effective method for reducing antinutrients, with a 47% reduction in β -ODAP, 83% in tannins, and 74% in phytate, along with an 8% increase in protein content [35].

Fermentation enhances the color, texture, and flavor of grass pea while increasing protein digestibility and reducing heat-stable antinutritional factors like phytate. Fungal fermentation with *Rhizopus oligosporus* and *Aspergillus oryzae* decreased β -ODAP levels by 80% in high-toxin varieties and by 97% in low-toxin varieties [36]. Germination similarly improves digestibility, reduces antinutrients, and hydrolyzes proteins into essential amino acids and absorbable polypeptides [37]. It also enhances the availability of vitamins B and C and reduces polyphenol content.

Extrusion lowers antinutrient levels, reduces viscosity in cereal gruels, and enhances nutrient density [38]. Autoclaving and roasting milled grass pea reduced β -ODAP content by up to 50% and 30%, correspondingly compared to raw seeds [39]. Additionally, fermentation and germination processes effectively destroyed enzyme inhibitors, reducing amylase inhibitors by 71% and trypsin inhibitors by 66% [31].

In summary, processing techniques such as milling, cooking, soaking, fermentation, and sprouting are used to enhance the nutritional profile of grass peas while reducing antinutritional factors. These methods increase the content of essential nutrients like Vitamin B, Vitamin C, zinc, iron, calcium, and ash content (see Figure 2 above). Simultaneously, they help reduce harmful compounds such as β -ODAP, trypsin inhibitors, polyphenols, amylase inhibitors, phytate, and tannins, making grass peas a safer and more nutritionally valuable ingredient for food products.

3.3. Consumption—Recipe Creation and Consumer Feedback

3.3.1. Creation of New Recipes

One new dish buckwheat and grass pea stew with eggplant, and one innovative food product grass pea and chickpea flour crackers were developed in the framework of the BioValue project. *Lathyrus*-based dishes focus on the nutritional benefits of grass pea, which is rich in proteins, fibers, and essential micronutrients. Combining grass pea with other ingredients enhances its nutrient profile, while processing techniques like soaking and fermenting help preserve and boost its nutritional value [40].

Based on sensory evaluation feedback, *Lathyrus*-based recipes were refined to improve sensory appeal and overall acceptability. Adjustments to ingredients, cooking methods, and flavor profiles were made in response to participant suggestions (described in Section 3.3.2). These refinements resulted in recipes with enhanced sensory characteristics and higher overall desirability.

In addition, the novelty of *Lathyrus*-based products extends beyond their sensory attributes. The integration of grass pea flour into food products enhances their nutritional value, offering unique bioactive compounds. Grass pea, along with other underutilized plants such as lentils and buckwheat, contain specific prebiotic fibers not commonly found in mainstream foods [39]. These fibers resist digestion in the small intestine and are fermented by gut bacteria in the colon, producing short-chain fatty acids that improve digestion, immune function, and reduce inflammation [41].

L. sativus and other legumes, pulses, and pseudocereals, when used in gluten-free products, offer superior nutritional value compared to traditional gluten-free cereal flours [40]. They are rich in fibers, proteins, minerals, and antioxidant compounds, making them beneficial additions to gluten-free bakery items [11]. Combining gluten-free cereal and *Lathyrus* flours enhances amino acid profiles and boosts protein content, while pseudocereal flours offer additional nutrients like proteins, dietary fibers, micronutrients, and polyphenols, further enriching the product.

3.3.2. Results from the Sensory Evaluation Exercises

The sensory evaluation of the *Lathyrus*-based dish showed varying responses across different countries, reflecting cultural and dietary preferences. In Serbia, the dish was generally well received, with most respondents rating its appearance, taste, texture, and aroma positively. The highest rating for overall acceptability was 'love it', with only a small number of participants rating it negatively, showing a strong preference for the sample. In Greece, participants were more neutral, with most respondents expressing indifference across all characteristics. The texture of the dish received the most negative feedback, with several participants rating it as 'dislike it', leading to an overall 'neutral' reception of the dish. In France, similar to Greece, a large portion of respondents expressed neutral opinions, especially for appearance, flavor, aroma, and mouthfeel. Texture again received neutral feedback, with a significant number of 'neither like nor dislike it' ratings. The overall response was one of indifference, as most participants rated the overall acceptability as 'neutral'. In Hungary, the response was more positive, with a considerable number of respondents rating the dish as 'love it' for taste and texture, and 'like it a lot' for appearance, aroma, and mouthfeel. A majority of Hungarian participants expressed a favorable opinion, with 81% rating overall acceptability positively, highlighting the dish's appeal in this region. In Turkey, the responses were mixed, with many participants rating texture, aroma, and mouthfeel as neutral. Taste was rated as 'dislike it' by 30% of respondents, and appearance received a more positive rating, with 40% of participants expressing a preference. Overall acceptability was also rated neutral by a third of the respondents, indicating a general lack of enthusiasm towards the dish.

In summary, the sensory evaluation of the *Lathyrus* based dish revealed clear regional differences in consumer preferences. Serbian participants provided the most favorable evaluations for taste, texture, aroma, overall acceptability, and mouthfeel, while Hungarian participants rated appearance the highest. The dish's texture received the highest ratings from participants in both Serbia and Hungary. In contrast, respondents from France and Turkey provided lower evaluations across all categories. Nevertheless, the dish was appreciated by all participants, with overall feedback remaining positive. These findings suggest that cultural and dietary differences play a significant role in shaping consumer preferences, with some regions displaying more openness to alternative dishes like this one.

The main recommendations from the panelists feedback for the Buckwheat and grass pea stew with eggplant include offering cheese options like mozzarella or cheddar based on personal preference, and adding seasonings such as black pepper, cumin, mint, garlic, salt, basil, or lemon to taste. Additional suggestions include baking the dish before serving, pairing it with fresh vegetables like green pepper or cucumber, and ensuring proper coordination of cooking times for ingredients with varying textures, such as shorter cooking for buckwheat and longer for grass peas. The combination of buckwheat and peas was highlighted as both interesting and unusual, with participants expressing interest in continuing to use it in the future.

The crackers, made from grass pea and chickpea flour and seasoned with dandelion, generated curiosity due to their unconventional components. While most consumers recognized the ingredients, some struggled to identify them, particularly in Serbia. In France, the product was mainly perceived as an alternative snack, while in Serbia and Hungary, it was met with mixed opinions on taste and texture. Consumers in Serbia found it to have a distinctive flavor, noting a strong pea taste but a mild dandelion flavor, whereas France and Hungary described the taste as too neutral or lacking in spice. The taste received mixed reviews, with many describing it as too neutral, bitter, or unappealing, especially in Hungary and Serbia. In contrast, French participants found it pleasant and appetizing. In Hungary, the product was viewed as too rich and unmarketable. Texture

was largely criticized across all countries, described as chewy, dry, and crumbly, however, Serbia offered a rare positive remark on the texture. Despite the negative feedback on taste and texture, the crackers were appreciated for their appearance and practicality, particularly in France, where it was seen as a potential pre-sport snack. Consumers across all countries highlighted the cracker's nutritional value, noting its high protein content, suitability for physical exercise, fiber content, and its gluten-free nature (notably in France and Greece). The use of legumes, like chickpeas, as a flour substitute was positively received, though some French participants suggested adding a second vegetable protein source to improve the amino acid profile.

Suggestions for improvement focused on making the crackers crunchier and thinner or enhancing their flavor profile with more spice options, including regional variations. While the product's appearance was generally well received, some participants found it less appealing. Many comments on the crackers emphasized issues with texture, particularly their dryness and the difficulty in chewing and nibbling. During the trial phase, various preparation methods and dough consistencies were tested, revealing that using only chickpea and grass pea flour results in a dry texture. To enhance the eating experience, participants in the sensory evaluation recommended pairing the crackers with accompaniments such as sour cream, tzatziki salad, or dipping them in a drink like yogurt.

To optimize the recipe, several adjustments have been proposed based on feedback; increasing salt and oil to enhance flavor and moisture, incorporating garlic or aromatic spices to improve aroma, and modifying cooking times, temperatures, or ingredient ratios to achieve a desirable texture and reduce hardness. Moisture and texture can be further enhanced by adding ingredients such as olive oil or sauces. Crunchiness may be improved by extending baking times or incorporating crisp ingredients. Additionally, adjusting ingredient ratios and increasing the tomato quantity could refine taste and balance flavors. Blending grass pea flour with other flours may result in a milder taste and smoother texture. These modifications aim to enhance the overall sensory appeal of the product, making it more suitable and attractive to a wider audience.

3.3.3. Focus Groups, Consumers Perception

The focus group discussions on crackers revealed several key insights, with consumers generally perceiving them as a convenient and satisfying snack. Notably, French consumers also regarded crackers as a healthy option. Discussions on *Lathyrus*-based recipes revealed a consistent interest in new products across countries, despite a strong attachment to conventional foods due to familiarity with taste, appearance, preparation methods, and affordability. While consumers demonstrated a good understanding of nutritional benefits, awareness of environmental and societal impacts was less prominent, and the broader concept of cultivated biodiversity was rarely mentioned.

It is important to mention that no significant differences were observed between countries regarding any of the examined parameters. Consumers showed a strong interest in the nutritional and environmental benefits of the crackers, highlighting their gluten-free, high-protein content and use of sustainable ingredients like legumes. However, they clearly emphasized the need for clear labeling, especially concerning the product's origin, environmental impact, and social aspects. Consumers suggested better communication strategies, including tastings and online information, to increase understanding and trust in the product's benefits. Finally, discussions revealed that crackers could appeal to a health-conscious, environmentally aware audience, with potential for broader distribution in supermarkets, health food stores, and organic markets.

Participants emphasized the need for more information on *Lathyrus* crops, including their unique characteristics such as taste, cooking methods, and nutritional, environmental,

and social benefits. Suggested communication channels included online platforms, points of sale, and tasting events to address skepticism and build trust. Provenance, tradition, and natural agricultural practices were particularly valued. Consumers expressed a preference for paying the same price for the product, with any willingness to pay a premium primarily driven by taste.

Environmental benefits were also emphasized, particularly those linked to the use of legumes, though participants noted the importance of explaining cultivation practices to maximize understanding. Social aspects were less frequently addressed, with comments mainly focusing on ingredient origin, production processes, and the objectives of stakeholders involved.

3.3.4. Brief Overview of Home Cooking Test Results

The home cooking test results revealed a division of opinions across countries, with *Lathyrus*-based dishes receiving varied feedback that reflected diverse consumer perspectives while also highlighting some common themes. The general opinion on the recipe was positive, with thirty-six positive comments and only three negative ones. Positive feedback highlighted satisfaction with the dish, with remarks such as ‘good recipe’, excellent and interesting dish’, and ‘love the recipe’. Many found it to be filling and suitable for various meals, such as breakfast, lunch, or dinner. A few mentioned making it multiple times or that their children enjoyed the dish. Several consumers appreciated the originality of the recipe, with 4 describing it as ‘very original’ or ‘a change’. Some users expressed eagerness to try the dish, including those who love eggplants and peas or who wanted to explore similar recipes. However, 1 person from France did not find the recipe interesting and felt that some of the peas were undercooked and the buckwheat overcooked. Regarding taste, the dish received positive comments and only two rather negative ones. The positive remarks included descriptors like ‘very tasty and delicious’, and ‘surprisingly delicious’. One Hungarian noted that the peas helped mask the taste of eggplant, which was appealing to those who were not fond of it. Three Hungarian consumers commented positively on the buckwheat’s taste, and its fit with Hungarian cuisine, while one French person noted that buckwheat had a distinctive taste. On the other hand, two French respondents found the dish somewhat bland and lacking in flavor. In terms of appearance, the dish received mainly positive, but also some neutral, and negative comments. Positive feedback praised its appetizing look, color, and visual appeal, with some describing it as ‘outstanding’ or ‘looks incredible’. However, one Greek respondent found the appearance unremarkable, though they suggested that adding ingredients like cherry tomatoes could improve its color. On the other hand, some participants from Serbia, Hungary, and France felt the appearance was less appealing and needed work to make it more appetizing. Finally, regarding texture, participants from France and Serbia praised it, calling it ‘excellent’, ‘superb’, and noting the variety of textures from the different ingredients. A Hungarian participant found it ‘light’, which they appreciated. However, one French person commented that while the texture was generally good, the dish was a bit dry.

In summary, participants generally appreciated the novelty and recognized the nutritional and environmental benefits of *L. sativus*, viewing it as an underutilized crop with potential. Many were open to trying new recipes incorporating it. Taste and texture received mixed reviews; some participants found the unique flavor appealing, while others were less enthusiastic. Price concerns were raised, especially in Greece and Hungary, and suggestions for improving the dish include adding more spices, vegetables, or cheese. Despite varying cooking methods and ingredient textures, some participants found the recipes easy to prepare, while others struggled to locate specific ingredients such as buckwheat and grass peas, especially in France and Hungary. This difficulty in sourcing ingredients was cited

as a main reason for not making the dish more frequently. Nonetheless, the ingredients, particularly grass pea, were recognized for their culinary versatility, ability to enhance texture and flavor in different dishes, and their nutritional benefits, alongside their potential environmental advantages. Participants also recommended considering seasonality and accessibility, and some suggested enhancing the dish with additional accompaniments to improve the general experience.

Overall, the dishes were considered innovative, interesting, and tasty. However, their future success will depend on effectively addressing the identified challenges and further aligning the products with consumer preferences. This includes ensuring accessibility to these underutilized plants, providing comprehensive information on their nutritional benefits, utilization, and cooking methods, as well as offering additional suggestions for their integration into everyday culinary practices.

4. Discussion

The interest for studying *L. sativus* in a European context is quite high [6,8,18]. However, the reintroduction of this legume into the cultivation needs a holistic approach to agri-food value chain considering multiple stakeholders. While the studies that summarize such evidence and that can support this effort are scarce for the European conditions, our results are a first attempt to apply this approach on this underutilized crop.

Based on the farming practices observed in cultivation of *L. sativus* in Germany and Spain, it is possible to emphasize the potential of this crop to comply with environmentally friendly production approaches [5,6,10,11,21,42]. This refers primarily to the climate and soil adaptability of this crop, as well as its alignment with sustainable agronomic practices:

Resilience in arid conditions: *L. sativus* is well adapted to arid or semi-arid regions, making it a valuable option for farmers in areas with low rainfall [43,44]. This resilience opens up opportunities in regions where other crops might struggle under water stress.

Soil flexibility and fertility benefits: The crop's ability to thrive on poor soils, including heavy, clayey soils, reduces the need for intensive soil amendments [43,44]. Its nitrogen-fixing capacity (binding up to 120 kg of nitrogen per hectare) not only reduces the reliance on synthetic fertilizers but also improves soil fertility for subsequent crops, making it an excellent option in crop rotation sequences [23,42,44].

Minimal and no-tillage options: The potential for minimal or no tillage systems helps conserve soil structure and organic matter [24,27]. This is especially relevant in systems where conservation agriculture is a priority.

Mixed cropping systems: In Germany, *L. sativus* is often intercropped with cereals to prevent lodging [23,42], while in Spain, associations with legumes and cereals are used in organic systems. Such mixed cropping enhances biodiversity and can improve overall field resilience.

Intrinsic pest management: The presence of the neurotoxin ODAP, which can deter some pests [23], reduces the need for extensive chemical plant protection measures.

Low fertilizer requirement: With its nitrogen-fixing ability, *Lathyrus* species can contribute to sustainable nutrient management, lessening the farmer's reliance on external nitrogen sources [23,42].

Mechanization flexibility: In regions like Germany, harvesting is adapted for combine harvesters, suggesting that with proper adjustments, the crop can fit into existing mechanized farming systems [42]. This makes *L. sativus* a practical option in modern, technology-driven agricultural operations.

However, while having many opportunities and being pretty adaptable, *L. sativus* faces few challenges as well, which relate to their specific agronomic needs and limited cultivation history in the case of Germany. Main challenges are related to the specific soil

demands, water availability during the pod filling phase, the pest and disease pressures that have been observed in Spain, harvest and post-harvest management and the knowledge and infrastructure gaps. In addition to only identifying them, we provide here suggestions on how to overcome them:

Soil pH sensitivity: Although the crop is tolerant of poor soils, it requires an alkaline environment and is sensitive to soil acidity. Farmers must monitor and, if necessary, amend soil pH to optimize growth.

Water management concerns: While *Lathyrus* thrives under dry conditions, certain varieties (e.g., *L. cicera*) do not perform well in very wet or water-saturated soils. In Spain, supplemental irrigation might be needed in case of early-summer droughts during critical stages like pod filling, which demands additional on-farm resources and water management strategies. In Germany, to compensate for the inadequate precipitation patterns, using intercrops and cover crops can help conserve winter moisture and reduce evaporation during the growing season, addressing the water availability challenge.

Weed control: *Lathyrus* is sensible to weeds. Apart from mechanical weed control, further commonly used weeding approaches are: increasing the sowing density; rotations with crops that reduce the presence of weeds or a green manure crop; polyculture and mixed crops.

Fungal pathogens and parasitic weeds: In Spain, *L. sativus* is vulnerable to fungal diseases (e.g., downy mildew, powdery mildew, rust) and parasitic weeds such as *Orobanche crenata* and field dodder. This necessitates specific strategies such as adjusting planting dates, selecting early maturing varieties, and careful residue management (e.g., not burying infected dry stems).

Insect pests: Based on the observations in Spain, Aphids (both black and green varieties) can affect the crop, potentially requiring targeted pest management, especially under conventional farming systems.

Limited localized research: In regions like Germany, there is a noted lack of comprehensive information on cultivation techniques specifically tailored to local conditions. Farmers often rely on small-scale trials and shared experiences, which can slow the adoption of best practices on a larger scale. Nevertheless, farmers can leverage small-scale trials and tap into specialized social and knowledge networks to share experiences and refine cultivation techniques. But most importantly, increased investment in breeding and agronomic research (as supported by projects like BioValue) can generate tailored cultivation guidelines for German conditions.

Mixed cropping complexities: When grown in mixed cropping systems, separating *L. sativus* grains from other crops for food use can be challenging, which underscores the need for effective post-harvest processing methods and value chain cooperation. Development or the adaptation of post-harvest processing infrastructure tailored for mixed cropping systems could address the grain separation challenge, potentially spurring innovation in this area. In regions, where the practice with this crop is low, experiments and pilot projects offer the opportunity to identify the best support crops, thereby enhancing productivity and easing post-harvest processing challenges.

Quality standards and collaboration along the value chain: Establishing uniform quality standards along the entire value chain—from cultivation to market—remains a challenge. Collaborative efforts among farmers, processors, and other stakeholders can lead to the creation of clear quality standards, which will help integrate *L. sativus* into the market and strengthen the entire value chain.

It is obvious that a successful introduction and adoption of *L. sativus* depends on a seamless integration of sustainable farming practices, adequate processing techniques, and adaptability to consumer preferences. When consumers are educated about *Lathyrus'*

nutritional benefits and versatility, and when innovative recipes create a demand for *Lathyrus*-based products, farmers are incentivized to produce the crop and adjust their practices accordingly, and processors are incentivized to invest in techniques that preserve the crop's quality and unlock its potential for value-added products.

In this study, *L. sativus* has proven to be a promising candidate for the development of innovative food products, aligning with contemporary culinary trends and consumers' increasing interest in diverse, sustainable, and nutritious alternatives. The development of *Lathyrus*-based recipes, combined with the positive outcomes from sensory evaluations and consumer perceptions, highlights its potential as a versatile and valuable ingredient.

The use of *L. sativus* in food products enhances their nutritional value by providing bioactive compounds and prebiotic fibers that support gut health [45]. Grass pea is also a rich source of proteins, minerals, and antioxidants, offering superior nutritional benefits compared to conventional gluten-free flours [40].

The feedback from focus groups further highlighted the growing consumer interest in the nutritional and environmental benefits of alternative crops like *L. sativus*. This suggests that there is a significant opportunity for communication strategies to emphasize these aspects, particularly via digital platforms, which could link consumers to detailed product information, including its sustainability, processing, nutritional value, and farming practices [46]. In a world increasingly concerned with the ecological impact of food systems, *L. sativus* could position itself as a key player in sustainable agriculture, provided that its environmental and social benefits are effectively communicated to consumers. However, several important points emerge from this work that deserve further consideration.

While *Lathyrus*-based products were generally well received, consumer acceptance was influenced by various factors, including flavor profiles, texture, and overall familiarity [47]. This raises the question of how to better align the sensory characteristics of *Lathyrus*-based foods with consumer expectations. Additionally, the development of *Lathyrus* products should be informed by regional preferences and dietary habits, as cultural acceptance is crucial for widespread adoption [48,49].

On the other hand, the challenges surrounding the integration of *L. sativus* into agri-food value chains must not be overlooked. Such are consumer familiarity, the utilization of suitable processing methods, ensuring ingredient availability, and scaling up production to meet market demands [50].

Future research should explore *Lathyrus*' role in dietary diversification, food security, and sustainable agriculture, while also considering consumer preferences and market trends. Moreover, effective packaging, branding, and marketing strategies will be essential for reaching the target audience and ensuring the success of *Lathyrus*-based products in the EU market.

5. Conclusions

L. sativus offers a unique blend of advantages—such as its ability to grow in challenging environments, its contribution to sustainable nutrient management, and its suitability for low-input farming systems. However, realizing these benefits at the farming level requires addressing challenges related to weed management, harvest timing, and robust agronomic practices tested in various environmental contexts. By integrating localized research, adapting cultivation methods to specific climatic and soil conditions, and fostering cooperation along the value chain, farmers can better leverage the opportunities offered by *L. sativus* while mitigating its inherent challenges. At the same time an integrative approach is needed to successfully introduce *L. sativus* in the agri-food value chain. Not only are considerations on farming level needed, but also on processing and consumption levels.

The study showcases the potential of *L. sativus* as a versatile ingredient of innovative food products, plant-based diets, and functional foods. Through the creation of new recipes, such as *Lathyrus*-based stews and crackers, the study demonstrated its culinary appeal across diverse consumer groups. Sensory evaluation data revealed positive consumer acceptance, with preferences for improved taste, texture, and nutritional profiles. The importance of ensuring product availability at a reasonable price, emerged as a key finding from the work conducted with consumers. Focus group discussions further emphasized the importance of clear communication on the nutritional, environmental, and social benefits of *Lathyrus*-based products. Overall, the findings suggest that *L. sativus* holds promise in meeting modern consumer expectations while contributing to agri-food value chains, particularly through sustainable farming and processing practices.

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References

1. Li, X.; Siddique, K.H.M. Future Smart Food: Harnessing the potential of neglected and underutilized species for Zero Hunger. *Matern. Child Nutr.* **2020**, *16*, e13008. [[CrossRef](#)] [[PubMed](#)]
2. Mudau, F.N.; Chimonyo, V.G.P.; Modi, A.T.; Mabhaudhi, T. Neglected and Underutilised Crops: A Systematic Review of Their Potential as Food and Herbal Medicinal Crops in South Africa. *Front. Pharmacol.* **2022**, *12*, 809866. [[CrossRef](#)]
3. Ojuederie, O.B.; Igwe, D.O.; Ludidi, N.N.; Ikhajiagbe, B. Editorial: Neglected and underutilized crop species for sustainable food and nutritional security: Prospects and hidden potential. *Front. Plant Sci.* **2024**, *14*, 1358220. [[CrossRef](#)] [[PubMed](#)]

4. Samal, I.; Bhoi, T.K.; Raj, M.N.; Majhi, P.K.; Murmu, S.; Pradhan, A.K.; Kumar, D.; Paschapur, A.U.; Joshi, D.C.; Guru, P.N. Underutilized legumes: Nutrient status and advanced breeding approaches for qualitative and quantitative enhancement. *Front. Nutr.* **2023**, *10*, 1110750. [[CrossRef](#)]
5. Odeku, O.A.; Ogunniyi, Q.A.; Ogbale, O.O.; Fettke, J. Forgotten Gems: Exploring the Untapped Benefits of Underutilized Legumes in Agriculture, Nutrition, and Environmental Sustainability. *Plants* **2024**, *13*, 1208. [[CrossRef](#)] [[PubMed](#)]
6. Mattas, K.; Nastis, S.A.; Michailidis, A.; Tsakiridou, E.; Spyridon, K. Unveiling the hidden gems: Minor crops as catalysts for sustainable development, biodiversity conservation, and economic resilience. *Sustain. Dev.* **2024**, *32*, 4748–4757. [[CrossRef](#)]
7. Feldman, A.; Ho, W.K.; Massawe, F.; Mayes, S. Bambara Groundnut is a Climate-Resilient Crop: How Could a Drought-Tolerant and Nutritious Legume Improve Community Resilience in the Face of Climate Change? In *Sustainable Solutions for Food Security*; Sarkar, A., Sensarma, S., vanLoon, G., Eds.; Springer: Cham, Switzerland, 2019; pp. 151–167. [[CrossRef](#)]
8. Knez, M.; Ranic, M.; Gurinovic, M.; Glibetic, M.; Savic, J.; Mattas, K.; Yercan, M. Causes and Conditions for Reduced Cultivation and Consumption of Underutilized Crops: Is There a Solution? *Sustainability* **2023**, *15*, 3076. [[CrossRef](#)]
9. Cullis, C.; Kunert, K.J. Unlocking the potential of orphan legumes. *J. Exp. Bot.* **2017**, *68*, 1895–1903. [[CrossRef](#)]
10. Knez, M.; Ranić, M.; Gurinović, M. Underutilized plants increase biodiversity, improve food and nutrition security, reduce malnutrition, and enhance human health and well-being. Let's put them back on the plate! *Nutr. Rev.* **2024**, *82*, 1111–1124. [[CrossRef](#)]
11. Lambein, F.; Travella, S.; Kuo, Y.-H.; Van Montagu, M.; Heijde, M. Grass pea (*Lathyrus sativus* L.): Orphan crop, nutraceutical or just plain food? *Planta* **2019**, *250*, 821–838. [[CrossRef](#)]
12. Ramya, K.R.; Tripathi, K.; Pandey, A.; Barpete, S.; Gore, P.G.; Raina, A.P.; Khawar, K.M.; Swain, N.; Sarker, A. Rediscovering the Potential of Multifaceted Orphan Legume Grass Pea—A Sustainable Resource With High Nutritional Values. *Front. Nutr.* **2022**, *8*, 826208. [[CrossRef](#)] [[PubMed](#)]
13. Cheng, A.; Raai, M.N.; Zain, N.A.M.; Massawe, F.; Singh, A.; Wan-Mohtar, W.A.A.Q.I. In search of alternative proteins: Unlocking the potential of underutilized tropical legumes. *Food Secur.* **2019**, *11*, 1205–1215. [[CrossRef](#)]
14. Ikhajagbe, B.; Ogwu, M.C.; Ogochukwu, O.F.; Odozi, E.B.; Adekunle, I.J.; Omage, Z.E. The place of neglected and underutilized legumes in human nutrition and protein security in Nigeria. *Crit. Rev. Food Sci. Nutr.* **2022**, *62*, 3930–3938. [[CrossRef](#)] [[PubMed](#)]
15. Popoola, J.O.; Ojuederie, O.B.; Aworunse, O.S.; Adelekan, A.; Oyelakin, A.S.; Oyesola, O.L.; Akinduti, P.A.; Dahunsi, S.O.; Adegboyega, T.T.; Oranusi, S.U.; et al. Nutritional, functional, and bioactive properties of african underutilized legumes. *Front. Plant Sci.* **2023**, *14*, 1105364. [[CrossRef](#)]
16. Knez, M.; Mattas, K.; Gurinovic, M.; Gkotzamani, A.; Koukounaras, A. Revealing the power of green leafy vegetables: Cultivating diversity for health, environmental benefits, and sustainability. *Glob. Food Secur.* **2024**, *43*, 100816. [[CrossRef](#)]
17. Katoch, R.; Tripathi, A. Rice bean (*Vigna umbellata*): A promising legume with unexplored potential. In *Neglected and Underutilized Crops*; Academic Press: Cambridge, MA, USA, 2023; pp. 647–680.
18. Tan, X.L.; Azam-Ali, S.; Goh, E.V.; Mustafa, M.; Chai, H.H.; Ho, W.K.; Mayes, S.; Mabhaudhi, T.; Azam-Ali, S.; Massawe, F. Bambara Groundnut: An Underutilized Leguminous Crop for Global Food Security and Nutrition. *Front. Nutr.* **2020**, *7*, 601496. [[CrossRef](#)]
19. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101.
20. Gurinović, M.; Milešević, J.; Kadvan, A.; Nikolić, M.; Zeković, M.; Djekić-Ivanković, M.; Glibetić, M. Development, features and application of DIET ASSESS & PLAN (DAP) software in supporting public health nutrition research in Central Eastern European Countries (CEEC). *Food Chem.* **2018**, *238*, 186–194.
21. Papakosta-Tasopoulou, D. *Special Agriculture: Cereals and Legumes (Ειδική γεωργία: Σιτηρά και ψυχανθή)*; Σύγχρονη Παιδεία; Synchroni Paideia: Thessaloniki, Greece, 2012; 760p, ISBN 9789603571056.
22. Landwirtschaftliches Zentrum Liebegg. *Steckbrief Eiweisserbsen*; Landwirtschaftliches Zentrum Liebegg: Gränichen, Switzerland, 2022.
23. Artenportrait Startclim 2020. Infoblatt: Speiseplatterbse. *StartClim*. Available online: https://www.arche-noah.at/media/artenportrait_speiseblatterbse.pdf (accessed on 27 February 2025).
24. Nadal, S.; Fernandez-Aparicio, M.; Cordoba, E.M.; Gonzalez-Verdejo, C.I. *Guía de Cultivo de la Almorta. Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible*; Formato Digital (e-Book); Instituto de Investigación y Formación Agraria y Pesquera: Córdoba, Spain, 2020; p. 27.
25. MAPAMA. 2024. Available online: <https://www.mapa.gob.es/es/estadistica/> (accessed on 27 February 2025).

26. Navarro, A.A.; Palomar, J.F.C.; Hernández, T.O.; Olivier, A.P.; Ortiz, J.C.; Conde, F.R.; Jubete, F.F.; de los Mozos Pascual, M.; Vioque, R.S.; Cobos, P.D.; et al. Report of the Scientific Committee of the Spanish Agency for Food Safety and Nutrition (AESAN) on the Occasional Human Consumption of Grass Peas (*Lathyrus sativus*). AESAN-2009-012. 2009. Available online: <https://onerecord.id/Record/IOS16997.807534/Preview> (accessed on 27 February 2025).
27. López-Bellido, L. Grain Legumes for Animal Feed. In *Neglected Crops: From a Different Perspective*; Hernando Bermejo, J.E., León, J., Eds.; Plant Production and Protection Series No 26; FAO: Rome, Italy, 1994; pp. 273–288. Available online: https://hort.purdue.edu/newcrop/1492/legume_animal.html (accessed on 27 February 2025).
28. Pratap, A.; Mehendi, S.; Pandey, V.; Malviya, N.; Katiyar, P. Pre- and Post-harvest Management of Physical and Nutritional Quality of Pulses. *Biofortif. Food Crops* **2016**, *2016*, 421–431.
29. Urga, K.; Fufa, H.; Biratu, E.; Gebretsadik, M. Effects of blanching and soaking on some physical characteristics of grass pea (*Lathyrus sativus*). *Afr. J. Food Agric. Nutr. Dev.* **2006**, *6*, 1–17. [[CrossRef](#)]
30. Tekle-Haimanot, R.; Abegaz, B.M.; Wuhib, E.; Kassina, A.; Kidane, Y.; Kebede, N.; Alemu, T.; Spencer, P.S. Pattern of *Lathyrus sativus* (grass pea) consumption and beta-N-oxalyl- α - β -diaminopropionic acid (β -ODAP) content of food samples in the lathyrism endemic region of northwest Ethiopia. *Nutr. Res.* **1993**, *13*, 1113–1126.
31. Shiwani Srivastava, S.K. Effects of Processing on the Reduction of β -ODAP (β -N-Oxalyl-L-2,3-diaminopropionic acid) and Anti-Nutrients of Khesari Dhal, *Lathyrus sativus*. *Sci. Food Agric.* **1996**, *71*, 50–58.
32. Padmajaprasad, V.; Kaladhar, M.; Bhat, R.V. Thermal isomerisation of β -N-oxalyl-L- α , β -diaminopropionic acid, the neurotoxin in *Lathyrus sativus*, during cooking. *Food Chem.* **1997**, *59*, 77–80. [[CrossRef](#)]
33. Bishnoi, S.; Khetarpaul, N. Effect of domestic processing and cooking methods on in-vitro starch digestibility of different pea cultivars (*Pisum sativum*). *Food Chem.* **1993**, *47*, 177–182.
34. Dessie, T.; Yami, A.D.N.; Peters, K. Evaluation of Processing Methods on the Feeding Value of Grass Pea to Broilers. *Int. J. Poult. Sci.* **2003**, *2*, 120–127. [[CrossRef](#)]
35. Gobezie, G. Effects of Traditional Food Processing Methods on Nutrient Compositions and Anti-Nutritional Factors of Grass Pea (*Lathyrus sativus*, L.) Foods Consumed, in Ethiopia. *Natl. Acad. Digit. Repos. Ethiop.* **2010**. [[CrossRef](#)]
36. Yigzaw, Y.; Gorton, L.; Solomon, T.; Akalu, G. Fermentation of seeds of teff (*Eragrostis tef*), grass-pea (*Lathyrus sativus*), and their mixtures: Aspects of nutrition and food safety. *J. Agric. Food Chem.* **2004**, *52*, 1163–1169. [[CrossRef](#)]
37. Ahmed, F.A.-R.; Abdel-Rahim, E.A.-M.; Abdel-Fatah, O.M.; Erdmann, V.A.; Lippmann, C. The changes of protein patterns during one week of germination of some legume seeds and roots. *Food Chem.* **1995**, *52*, 433–437.
38. De Muelenaere. Extrusion: A First and Third World Tool. In *Technology and the Consumer, Proceedings of the SAAFoST Tenth Biennial Congress and a Cereal Science Symposium*; Natal Technikon Printers: Durban, South Africa, 1989; Volume 1, pp. 22–44.
39. Girma, A.; Tefera, B.; Dadi, L. Grass Pea and Neurolathyrism: Farmers' perception on its consumption and protective measure in North Shewa, Ethiopia. *Food Chem. Toxicol.* **2011**, *49*, 668–672.
40. Barone, M.; Tulumello, R. *Lathyrus sativus*: An Overview of Chemical, Biochemical, and Nutritional Features. In *Lathyrus sativus and Nutrition*; SpringerBriefs in Molecular Science; Springer: Cham, Switzerland, 2020; pp. 1–23. [[CrossRef](#)]
41. Arslan, M.; Gökkaya, M.E.H.M.E.T.; Çetin, E.; Erkamaz, T.; Yol, E. Diversity for Fatty Acid and Organic Acid Contents in Mutant Grass Pea (*Lathyrus sativus* L.) Genotypes. *Legume Res.* **2023**, *46*, 541–547. [[CrossRef](#)]
42. Böhm, H.; Dauber, J.; Dehler, M.; Gallardo, D.A.A.; de Witte, T.; Fuß, R.; Höppner, F.; Langhof, M.; Rinke, N.; Rodemann, B.; et al. Fruchtfolgen mit und ohne Leguminosen: Ein Review. *J. Kult.* **2020**, *72*, 489–509. [[CrossRef](#)]
43. Almeida, N.; Rubiales, D.; Vaz Pato, M. Grass Pea. In *Grain Legumes. Handbook of Plant Breeding*; De Ron, A., Ed.; Springer: New York, NY, USA, 2015; Volume 10, pp. 251–265. [[CrossRef](#)]
44. Campbell, C.G. Grass pea. *Lathyrus sativus* L. Promoting the Conservation and Use of Underutilized and Neglected Crops. In *Promoting the Conservation and Use of Underutilized and Neglected Crops*; Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute: Rome, Italy, 1997; Volume 18.
45. Enneking, D. The nutritive value of grasspea (*Lathyrus sativus*) and allied species, their toxicity to animals and the role of malnutrition in neurolathyrism. *Food Chem. Toxicol.* **2011**, *49*, 694–709. [[CrossRef](#)] [[PubMed](#)]
46. Goufa, M.; Makeroufas, E.; Gerakari, M.; Sarri, E.; Ragkos, A.; Bebeli, P.J.; Tani, E. Understanding the potential to increase adoption of orphan crops: The case of *Lathyrus* spp. cultivation in Greece. *Agronomy* **2024**, *14*, 108. [[CrossRef](#)]
47. Günden, C.; Atakan, P.; Yercan, M.; Mattas, K.; Knez, M. Consumer response to novel foods: A review of behavioral barriers and drivers. *Foods* **2024**, *13*, 2051. [[CrossRef](#)] [[PubMed](#)]
48. Günden, C.; Atis, E.; Salali, E.; Gunden, C.; Atiş, E.; Salali, H.E. Underlying Food Values Influencing Food-Related Behaviors of Consumers in Turkey. 2023. Available online: <https://www.researchgate.net/publication/377330332> (accessed on 10 February 2024).

49. Laureati, M.; De Boni, A.; Saba, A.; Lamy, E.; Minervini, F.; Delgado, A.M.; Sinesio, F. Determinants of consumers' acceptance and adoption of novel food in view of more resilient and sustainable food systems in the EU: A systematic literature review. *Foods* **2024**, *13*, 1534. [[CrossRef](#)]
50. Tuorila, H.; Hartmann, C. Consumer responses to novel and unfamiliar foods. *Curr. Opin. Food Sci.* **2020**, *33*, 1–8. [[CrossRef](#)]

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