# Value chains for new food products

# CROPDIVA – D5.1

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# LIST OF ABBREVIATIONS

AT: Austria

BE: Belgium

BOKU: University of natural resources and life sciences Vienna

CH: Switzerland

CZ: Czech Republic

CZU: Czech University of Life Sciences Prague

CROPDIVA: Climate Resilient Orphan croPs for increased DIVersity in Agriculture

FIBL: Research Institute of Organic Agriculture

FINS: Institute for Food Technology of Novi Sad

RS: Serbia

UGENT: Ghent University

VC: Value chain

VCA: Value chain analysis

WBF: Swiss Federal Department of Economic Affairs, Education and Research – Agroscope

WP: Work package

# ACKNOWLEDGMENTS

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# EXECUTIVE SUMMARY


The analysis of 21 value chains in 5 countries for the six crops oats, triticale, hull-less barley, lupin, faba bean and buckwheat in the CROPDIVA project was intended to provide general insights into the structure, development and functioning of value chains of these crops. The case studies on value chains in the feed (9 case studies) and food sectors (19) were based on interviews with the actors in the value chain, with breeders, traders, researchers, advisors, farmers, collection centres, processors and retailers.

The analyses showed a great diversity in the cultivation and use of underutilised crops in the countries considered. The current niche situation of these crops can be explained by past technological developments in the agricultural sector (replacement of horses with tractors, reduced feed demand), the focus of research, breeding and cultivation on main crops, such as wheat, (lock-in, path dependency, standardisation and different transaction costs).

Underutilised crops can contribute to making cropping systems more diverse and resilient with regard to climate change and pests. In that sense, they can play an important role in the transition to a more sustainable agricultural system. The successful development of the cultivation of underutilised crops pre-requisites a concomitant increase of the demand for feed or food products from these crops, which implies amongst others the development of new products. In order to achieve such a change in the agricultural and food system, cross-stage cooperation along the value chain is necessary. The focus of new products should be on food, as this is where the greatest potential for value creation is seen. This assessment is based on the trend towards a more plant-based diet and the vast possibilities for qualitative differentiation in terms of cultivation methods and origin.

The central challenge in building new value chains from underutilised crops are gaps in experience and knowledge. These gaps vary by crop and country. In some cases, breeding efforts are (still) underway for the crops under consideration, but this is rarely the case. Seeds are often imported, which can pose specific challenges in niche markets and implies that the seeds are not ideally adapted to local growing conditions. In agriculture, the cereals oats and triticale have a certain spread in all countries; cultivation practices here are also very similar to the main cereals wheat or barley. More critical gaps in knowledge are found in the crops hull-less barley, the legumes lupin and faba bean, and buckwheat generally and regarding the use of triticale in the food chain. This applies to different stages of the value chain and also affects consumers. Even if they know the crops, they very often lack knowledge of their preparation and use.

The development of products and the establishment of a value chain must be oriented towards the specific local or national framework conditions. These include, for example, the specific underutilised crop, the target market, the length of the value chain, the intended qualitative differentiation, the number of actors. The introduction should take place by means of cooperation along the chain and include actors who are close to the consumer.

# 1. INTRODUCTION

The primary objective of the CROPDIVA project is to increase agrobiodiversity, a prerequisite for stable, ecologically and economically sustainable agrifood systems. Six underutilised but quite promising crops in terms of agrobiodiversity, oats, triticale, hull-less barley, lupin, faba bean and buckwheat, have been intensively researched regarding the following aspects: breeding, agronomic proprieties, the possibility of making new food and non-food products, marketing strategies and implementation in regional value chains. In order to enhance biodiversity by increasing the planted area of these underutilised crops, they should be genetically adapted to the local area and familiar to farmers. The crops should also be promoted to consumers and other agrifood system stakeholders, such as collector centres, food processors, retailers and restaurants. Besides the production of new products, CROPDIVA is focusing on marketing strategies and value chain exploration in order to promote the consumption of and demand for these crops.

Strengthening agrobiodiversity on the consumer's plate is just as important as strengthening it in the field. However, consumer demand may not be the only problem preventing the establishment of new value chains for these so-called underutilised crops. Problems may be logistical or due to a lack of financial resources; therefore, this project explores the existing value chains of products derived from these six crops in order to identify limitations and opportunities for value chain developments.

Specifically, this task of the project aims to analyse food and non-food value chains that can be used as examples during the implementation of new products created within CROPDIVA. Researchers in each of the five participating countries, Austria, Belgium, the Czech Republic, Serbia and Switzerland, therefore carried out between three and five case studies of regional value chains. These cases represent various value chain structures across European regions and the studied examples of underutilised crops. Both upstream processes, such as plant breeding, seed production and agricultural production from the viewpoint of a farm, and downstream processes, such as the logistics of harvested products, storage, processing and sales, were be included in the analysis . The value chains were selected according to their relevance, and transferability will be thoroughly and empirically explored to understand and evaluate their potential for launching new food products. The analysis drew on the food system lock-in concept (Kuokkanen et al., 2017; Magrini et al., 2016; Meynard et al., 2018), transition theory (Geels, 2002; Harich, 2010) and transaction cost theory (Williamson, 1989). The impact of new digital technologies has been given consideration, especially their impact on the food chain (e.g. increased vertical integration, lower transaction costs (Pesce et al., 2019). These concepts and theories build a framework for data collection that is focused on the activities of relevant actors and their intersections within the selected value chains.

The data collection to explore and analyse these value chains was qualitative and mainly consisted of desktop research and interviews with value chain actors. Subsequently, the focus of the analyses was mainly socio-economic and it was based on the organisation and cooperation of the value chain actors, as well as on the various limitations imposed by resource availability and other factors. In addition, the logistical and capacity challenges of companies have also been taken into account, as well as relevant marketing decisions. Finally, socio-economic, political and cultural frameworks have also been analysed, as these can play an important role in all of the above aspects.

Two questions guide this report. The first is developed in the next section: why are underutilised crops not as successful as mainstream crops? In the literature overview, we hypothesise that certain historical events led to the process of path creation and, through reinforcement effects (e.g. economies of scale for mainstream crops), evolved towards lock-in situations. The outcome is a strong dependency on the current path, which is reliance on mainstream crops. Another consequence (and self-reinforcing mechanism) is that transaction costs are too high for underutilised crops, and underutilised crops cannot profit from scale advantages. In addition, some sociocultural and preference factors play a role and might influence the perception of a unique crop, which could also simply be unknown to a large part of the population.

The second question addresses how some underutilised crops managed to become market-established? One hypothesis is that some crops were strongly pushed and that added-value was created in the eye of the consumers. Another hypothes is that well-coordinated private sector organisation or efficient public sector support have played a role in the successful market establishment of some underutilised crop value chains.

The exploration of value chains in this task is linked to other work packages (WP) within the CROPDIVA project. In WP2, a toolbox with which stakeholders can enhance the ecosystem services of cropping systems will be developed. This development must be balanced between the cultural services and the supporting/regulating services. WP3 aims to introduce the selected underutilised crops in various cropping systems, to which this analysis can contribute by identifying both possible obstacles in the development and establishment of the value chain of a niche product and strategies for overcoming these obstacles. Positive examples of established underutilised crop value chains can also contribute to the development of new food and non-food products in WP4. The design of these products will be based on the value chains and market analyses addressed in WP5, which will also contribute to the consumer survey (task 5.2) and form the basis for further work in tasks 5.3 “Development of marketing models” and 5.5 “Formulation of strategic marketing plans and business models”.

This report is structured as follows: first, relying on a literature review, we establish a conceptual and methodological framework.. Then, after the provision of general background information about the crops, the next section describes the methods used for data collection and analysis; the latter is separated into several key value chain analysis steps. In order to better understand the history, regional economic importance and agrifood potential of these six CROPDIVA crops, more specific background information is given for each crop, followed by the summary results of the value chain analyses (by crop). This is followed by a discussion, which includes the limitations of the analyses and recommendations, and a conclusion.

# 2. LITERATURE OVERVIEW

This literature review will serve two final purposes. The first is to set out the theoretical framework, which will form the basis for the discussion and the answers to the underlying questions. A second objective is to build an analytical framework and to review the different chain analysis methods. The framework will allow for a discussion of possible methods of qualitative analysis of the value chains of underutilised crops.

In this section, we review the role of underutilised crops in the agrifood system. First, we briefly discuss synonyms for “underutilised crops” in order to obtain a clearer picture of the various definitions currently in use. Subsequently, we discourse the current state of agrobiodiversity in Europe. We also describe the mechanisms that have led to our current agrifood systems being poorer, in terms of agrobiodiversity, than they were in the past. The third subchapter presents the theoretical framework.

## 2.1 Niche, orphan and underutilised crops

Before establishing a theoretical framework, it is necessary to define the term “underutilised” crop and its uses in the literature. A definition and many usable synonyms can be found in the glossary. However, it is important to note the differences in the scientific literature. Over recent years, different organisations and researchers have started to pay more attention to underutilised crops, including Crop for Future, the recent alliance of Bioversity International with the International Center for Tropical Agriculture (CIAT), the African Orphan Crops Consortium and, of course, the FAO (AOCC, 2018; CFF, 2009; FAO, 2017; International; & CIAT, 2019). Different names and definitions emerged from these varied work and articles, many of which having been conducted in the context of developing countries.. These were summarised by Tadele (2019) and can be seen in It is challenging to group CROPDIVA crops less than one definition. Triticale, for example, can be called an “alternative crop” because of its robustness compared to wheat, but it can hardly be considered a “traditional” crop, as it was only recently bred (in the 20th century). Buckwheat could fall into several definitions, such as "ancient crop", “superfood” or “minor crop”. Different names can be used in an interchangeable manner, depending on the contextual meaning. An appropriate designation for the CROPDIVA crops is “underutilised crop”, as this refers to the underused potential of the crops considered to increase diversity and sustainability of agriculture.

Table 1.

It is challenging to group CROPDIVA crops less than one definition. Triticale, for example, can be called an “alternative crop” because of its robustness compared to wheat, but it can hardly be considered a “traditional” crop, as it was only recently bred (in the 20th century). Buckwheat could fall into several definitions, such as "ancient crop", “superfood” or “minor crop”. Different names can be used in an interchangeable manner, depending on the contextual meaning. An appropriate designation for the CROPDIVA crops is “underutilised crop”, as this refers to the underused potential of the crops considered to increase diversity and sustainability of agriculture.

*Table 1. Different terms given to underutilised crops used in scientific literature. This is a shortened and adapted version of Tadele (2019).*

| Name | Name refers to | Original source |
|---|---|---|
| Abandoned crops | Neglected by research and development | Padulosi (2017) |
| Alternative crops | Options in extreme environments | Padulosi (2017) |
| Ancient crops | Primitive grains, which were not subject to any modern breeding or selection, and which retained characters of wild ancestors | Bouki et al. (2018); Giambanelli et al. (2013) |
| Disadvantaged crops | Unfavoured by research and development | Massawe et al. (2015) |
| Forgotten crops | Little focus on research | FAO (2017) |
| Future smart food | High contribution to future food security | Li and Siddique (2018) |
| Life-style crops | Health-related benefits | Cannarozzi et al. (2014) |
| Local crops | Domestic importance | Padulosi (2017) |
| Lost crops | Genetic erosion of the germplasm | NRC (2006); Vietmeyer et al. (1996) |
| Minor crops | Relative to global (major) crops | Padulosi (2017) |
| Neglected crops | Little focus on science and development | Bermejo and León (1994) |
| Niche crops | Marginal importance in production systems | Padulosi (2017) |
| Orphan crops | Without champions or crop experts | AOCC (2018); Tadele (2009, 2019) |
| Promising crops | For emerging markets | FAO (2017) |
| Superfood | Due to nutritional- and health-related benefits | Provost and Jobson (2014) |
| Traditional crops | Use for centuries or even millennia | Padulosi (2017) |
| Underdeveloped crops | Limited investment | Padulosi (2017) |
| Understudied crops | Due to little scientific research | Tadele and Assefa (2012) |
| Underused crops | Due to little scientific advancement | EcoBusiness (2015) |
| Underutilised crops | Due to little research | Dawson and Jaenicke (2006); Massawe et al. (2015) |
| Wonder plants | Superiority in nutrition- and health-related benefits | EcoBusiness (2015) |

## 2.2 The erosion of diversity in agricultural systems

Producers can and already do use diversification of crop species and varieties in order to cope with environmental and socio-economic changes, in particular climate change (Altieri & Nicholls, 2017; Lin, 2011). Crop diversification might improve the resilience of an agricultural system thanks to, for example, the suppression of pest outbreaks or a buffering of the impacts of climate variability and extreme events (Lin, 2011). The reduction in crop diversity is a major global issue not only for food security but also for human health. Diversifying agri-food systems and diets can improve human health and wellbeing, as well as provide other ecological, economic and social benefits (Dwivedi et al., 2017; Hunter et al., 2016; Nair et al., 2016).

In light of the benefits of agrobiodiversity, it is therefore worthwhile to ask why the agri-food system is not more diversified today and why some crops are still defined as “niche” or “underutilised” crops, even though their potential to contribute to sustainability is great. This interrogation is similar to the question why are underutilised crops not as successful as mainstream crops and why their potential is not fully used?

## 2.3 Theoretical framework

### 2.3.1 Lock-in situation

Many explanations have been given for the disappearance of diversity in the agrifood system. One illustrative explanation has been given for the disappearance of grain legumes in Europe, in particular in France (Jouan et al., 2020; Magrini et al., 2016). First, historical choices led value chain actors to increase returns on adoption; i.e. the more a crop is adopted, the more new adopters have an incentive to adopt this crop. These initial choices were then self-reinforced by mechanisms, eventually creating a path dependency. Reinforcing mechanisms might include economies of scale, learning effects or network externalities (Magrini et al., 2016). Therefore, the more a system is adopted, the lower the costs, in particular the transaction costs and the scale disadvantages, which are both consequences of the initial choices and at the same time act as reinforcing mechanisms.

The ability to import cheap soybeans to use as protein source for livestock production, thanks to trade agreements between Europe and the United States as well as other European policies, has led in turn to the overspecialisation of agrifood systems towards a few mainstream cereals (a lock-in situation; Magrini et al., 2016; Meynard et al., 2018). Alternative crops, especially legumes, have received less attention, which has contributed to uncertainty and knowledge gaps about their cultivation and use for processing. This, in turn, reinforces the initial choice (Magrini et al., 2016). In other words, the mechanisms are self-reinforcing; the underutilised crops are not much grown, so they are not much studied, and because they are not much studied, they are less economically attractive and so are less cultivated by farmers (Meynard et al., 2018).

“Chosen” or major crops, on the other hand, become increasingly valuable for all value chain actors. As summarised by Meynard et al.(2018):

1. “these crops are well known, at both agronomic and technological levels;
2. improved seeds, specific inputs and machinery are proposed by upstream value chain partners;
3. the products of the major crops are easily available for the processors who are interested and match standards recognised by value chains and consumers (since these standards were defined according to the characteristics of these dominant products); and
4. stakeholders in the value chains are involved in tight social networks and are used to working together”.

In turn, the chosen crops, which benefit from scale advantages and low transaction costs, become very dominant in the lock-in system. Economically, this dominance is reflected by comparably higher yields and higher profitability of main crops. Due to low demand of alternative crops, their prices remain low. If a farmer wants to cultivate underutilised crops, this typically goes along with lower profits, i.e. opportunity costs (the foregone profit of not planting a high yield- and high profit-crop).

### 2.3.2 Transaction costs

In our current lock-in system and from a purely economic standpoint, transaction costs are higher for underutilised crops. Transaction costs are both consequences and self-reinforcing mechanisms of the lock-in system, as value chain actors dealing with underutilised crops cannot profit from scale advantages. High transaction costs create barriers for effective functioning of the value chains and represent a strong lock-in mechanism. According to Furubotn and Richter (2005), two ex-ante and two ex-post categories of market transaction costs can be distinguished:

1. Search and information costs (ex-ante),
2. Bargaining and decision costs (ex-ante),

3. Supervision and enforcement costs (ex-post), and
4. Costs for investments in social relations (ex-post).

Transaction costs may be reduced through the use of standards that enhance trade, for example quality standards or the use of standard containers for the transportation of goods (den Butter et al., 2007). These "standards" can represent, in the agrifood system, a few mainstream crops and their related varieties. As non-standard crops, underutilised crops are linked to higher transaction costs because value chain actors must, among other task, search for potential buyers for the crops. Contracting could be a way of decreasing the transaction costs related to underutilised crops, because it is a hybrid mode of market and hierarchy (Ménard, 2004; Meynard et al., 2013). A study by Jouan et al. (2019) aimed to analyse the influence of transaction costs on the economic attractiveness of legumes. Their hypothesis that contracting could decrease transaction costs was partly correct; however, contracting alone was not sufficient to make legumes attractive, mostly because of price uncertainties (Jouan et al., 2019).

In fact, transaction costs can play a role in the governance of a value chain. According to Gereffi et al. (2005) three factors influence global value chain governance: the complexity of transactions, the ability to codify transactions, and the capabilities in the supply base. We believe that the complexity of transactions, which is linked to transaction costs, is relevant to the value chain of underutilised crops.

### 2.3.3 Scale disadvantages of underutilised crops

Scale disadvantages of underutilised crops can include lower market sizes, logistics, storage and transport costs. These disadvantages are the consequences of strategies adopted by cooperatives and brokers of major crops based on economies of scale (Filippi et al., 2008; Magrini et al., 2016; Meynard et al., 2018). They might be linked to the productionist paradigm, which emerged after the Second World War and focused on food security through the maximisation of production. Specialisation of farming systems resulted in investments in large silos, which further disadvantages small-batch underutilised crops (Meynard et al., 2018). The collection of underutilised crops is not widespread; these crops are usually not accepted by all collection centres, which in turn increases transport costs for producers.

### 2.3.4 Transition

The term transition describes processes of change. With regard to agriculture, this refers to changes of agricultural systems and is used with the transition towards more sustainable farming systems (Mottet et al., 2020), agriculture 4.0 and the increasing use of digital and biotechnological innovations (Klerkx & Rose, 2020). Transition also relates specifically to the inclusion of underutilised crops, such as legumes, in cropping or food systems (Ferreira et al., 2021; Mawois et al., 2019). In agricultural research, a lot of attention has been paid in the past to the greater integration of legumes into cropping systems, such as the TRUE[1] project or LegValue[2] project (Balázs et al., 2021; Vasconcelos et al., 2020), or FarmPath[3] project focused on the socio-economic aspects of transition processes (Sutherland et al., 2014) . Another important branch looks at the diversification of cropping systems through rotations, multiple cropping and intercrops, e.g. the DIVERFARMING[4] projectDifferent reviews on transition are available, such as Geels and Schot (2007) on transition pathways or Köhler et al.(2019) concluding that "grand challenges related to sustainability remain unsolved".

[1] TRUE – TRansition paths to sUstainable legume based systems in Europe; https://www.true-project.eu/.

[2] LegValue – Fostering sustainable legume-based farming systems and agri-feed and food chains in the EU; https://www.legvalue.eu/.

[3] FarmPath – Farming Transitions: Pathways towards regional sustainability of agriculture in Europe; https://farmpath.hutton.ac.uk/.

[4] DIVERFARMING – Crop diversification and low-input farming cross Europe: from practitioners' engagement and ecosystems services to increased revenues and value chain organisation; http://www.diverfarming.eu/index.php/en/.

# 3. CROPS INVESTIGATED

The six crops analysed in CROPDIVA are oat, triticale, hull-less barley, lupin, faba bean and buckwheat. Table 2, which is taken from CROPDIVA's proposal, shows the selected crops and their advantages for biodiversity along with some sustainability aspects, the crops' particular quality traits and the food or non-food purposes for each. These crops, which will be detailed in the next sections, were chosen for the project for different reasons. The first is the presence of a large pool of genetic diversity and very specific gene pools. Also, these crops all fit well in a crop rotation because of, for example, their lower fertiliser requirements, nitrogen fixation (by legumes), pollination benefits or ability to provide canopy cover. The crops' adaptations to different geographic conditions and nutritional properties are other reasons for their inclusion. Last, these crops are also expected to cope well with climate change and to resist biotic and abiotic stress.

*Table 2. Characteristics of the CROPDIVA crops. Source: CROPDIVA proposal.*

| Crop | Sustainability and advantages to biodiversity | Quality traits and food/ non-food purposes |
|---|---|---|
| Oats (*Avena sativa* L.) | • Requires fewer nutrients than wheat<br>• High nitrogen use efficiency<br>• Grows well in cool and moist climates<br>• Fewer disease problems than wheat | • Rich in β-glucans and antioxidants, gluten-free<br>• Bakery products, breakfast cereals, probiotic drinks, extruded products (meat substitutes) |
| Hull-less barley (*Hordeum vulgare* L. var. *nudum* Hook. f.) | • Requires fewer nutrients than wheat<br>• Needs less water than wheat | • Rich in β-glucans<br>• Bakery products, pasta, breakfast cereals, sprouted fodder |
| Triticale (x *Triticosecale*) | • Large canopy cover<br>• Strong and profuse roots<br>• High nitrogen acquisition and use efficiency<br>• Good cover crop | • High protein content (e.g. lysine, tryptophan)<br>• Bakery products, breakfast cereals, pasta, extruded snacks, malting/brewing products, silage for feed |
| Buckwheat (*Fagopyrum esculentum*) | • Quick soil cover and weed suppressor<br>• Grows on/rejuvenator for low fertility soils<br>• Extracts phosphorous<br>• Attracts pollinators and other beneficial insects<br>• Loosens topsoil | • Gluten-free, rich in fibre and antioxidants<br>• Bakery products, breakfast cereals, pasta, feed |
| Lupin (*Lupinus* spp.) | • Able to grow in marginal soils<br>• Fixes nitrogen<br>• Can grow in soil with low pH<br>• Attracts pollinators<br>• Protein producer (i.e. reduces the need for import of protein) | • Gluten-free<br>• Bakery products, pasta, beverages, fermentation products, alternative protein source, silage or grain for feed |
| Faba bean (*Vicia faba*) | • Attracts pollinators<br>• Withstands harsh climates<br>• Grows in high salinity or clay soils<br>• Fixes nitrogen<br>• Protein producer | • Rich in proteins<br>• Cooked beans, alternative protein source (meat substitute), high protein feed |

In Europe, production data from the FAO is used to better understand the importance of these six crops and the aggregated category into which they fit. This includes food and feed production data as well as food supply quantities[5] for the six crops. Except for oats, it was challenging to find complete statistics for each crop in all the countries. This data gap illustrates the niche character of these crops.

Table 3 provides FAO data on feed supply in 1,000 tonnes. Corn, wheat and soybeans serve here as references for the other crops. Hull-less barley is aggregated with “barley and barley products”, triticale and buckwheat with “cereals, other” and lupin and faba bean with “pulses, other” (FAOSTAT, 2019).

*Table 3. Feed production (in 1,000 t) for various crops in different countries in 2019 according to FAOSTAT, 2019.*

| FAOSTAT Categories | Wheat and wheat products | Maize (corn) | Barley and barley products | Oats [a] | Cereals, other [b] | Soybeans | Pulses, other [c] and other products |
|---|---|---|---|---|---|---|---|
| *CROPDIVA or Reference Crops* | *Reference* | *Reference* | *Hull-less barley* | *Oats* | *Triticale, buckwheat* | *Reference* | *Faba bean, lupin* |
| **Austria** | 595 | 1,342 | 595 | 59 | 326 | 108 | 28 |
| **Belgium** | 861 | 1,191 | 1,001 | 104 | 93 | 283 | 9 |
| **Czech Republic** | 1,127 | 562 | 458 | 76 | 151 | 1 | 8 |
| **Denmark** | 3,004 | 335 | 2,614 | 231 | 64 | 31 | 65 |
| France | 8,352 | 4,890 | 3,474 | 319 | 2,078 | 116 | 258 |
| **Germany** | 8,981 | 5,965 | 6,174 | 498 | 2,097 | 49 | 176 |
| **Italy** | 1,766 | 11,515 | 1,055 | 193 | 150 | 93 | 86 |
| **Netherlands** | 4,026 | 4,004 | 2,008 | 123 | 154 | -[d] | 20 |
| **Poland** | 1,962 | 2,591 | 2,310 | 644 | 5,820 | 29 | 305 |
| Romania | 494 | 7,292 | 105 | 321 | 270 | 28 | 8 |
| Russia | 14,057 | 8,821 | 9,564 | 2,643 | 1,000 | 1096 | 306 |
| **Serbia** | 367 | 3,482 | 177 | 54 | 102 | 54 | 42 |
| **Spain** | 1,108 | 11,800 | 843 | 424 | 213 | 1 | 61 |
| **Switzerland** | 251 | 306 | 219 | 49 | 47 | 105 | 5 |
| Ukraine | 2,022 | 6,018 | 3,045 | 200 | 8 | 15 | 55 |
| **United Kingdom** | 7,359 | 725 | 3,787 | 310 | 71 | 108 | 491 |
| European Union (27 countries) | 42,763 | 61,433 | 32,514 | 5,009 | 13,271 | 986 | 1,408 |

*Countries in bold are part of this project. [a] Includes both rolled and bran oats. [b] Popcorn, buckwheat flour, buckwheat bran, buckwheat, quinoa, fonio flour, fonio bran, fonio, triticale flour, triticale bran, triticale, canary seed, mixed grains (flour, bran and raw) and preparations. [c] Broad beans, horse beans (faba bean), chickpeas, cow peas, pigeon peas, lentils, bambara beans, vetches and lupines (raw, flour or bran). [d] No data was given.*

Corn is one of the most important feed crops illustrated in table 3. Barley seems to be important as well, but the percentage that represents hull-less barley is quite uncertain, and oats seems to be less important than barley as feed in Europe. In fact, with a few exceptions, the category “Cereals, other” is generally less important than wheat or barley. For legumes, "pulses and others" represent a bit more than twice the feed quantity of the FAOSTAT category soybeans. The differences are less sharp between legumes than between cereal products.

Below, Table 4 provides FAO data on food supply per 1,000 tonnes. Wheat and rye serve as references. Again, hull-less barley is aggregated with “barley and barley products”, triticale and buckwheat with “cereals, other” and lupines and faba bean with “pulses, other” (FAOSTAT 2019). Wheat is much more important than the other categories represented in this table. This further demonstrates the niche

[5] The food supply quantity in kg/capita per year in one country is, according to the FAOStat, calculated by summing the quantity of food produced, the imported quantity and the stocks from the previous year. There is a distinction made between export, feed, seed production, manufacture for food and non-food uses, losses during storage, and available (unused) food supplies. The per capita supply of each food item for human consumption is calculated by dividing the respective quantity of the relevant data by the country’s population.

character of the crops considered, which generally account for only a small percentage of the corresponding FAOSTAT categories.

*Table 4. Food production (in 1,000 t) for various crops in different countries in 2019 according to FAOSTAT, 2019.*

| FAOSTAT Categories | Wheat and wheat products | Rye and rye products | Barley and barley products | Oats [a] | Cereals, other [b] | Soybeans | Pulses, other [c] and other products |
|---|---|---|---|---|---|---|---|
| *CROPDIVA or Reference Crops* | *Reference* | *Reference* | *Hull-less barley* | *Oats* | *Triticale, buckwheat* | *Reference* | *Faba bean, lupin* |
| **Austria** | 778 | 103 | 3 | 16 | 16 | 20 | 8 |
| **Belgium** | 1,138 | 11 | 20 | 2 | 19 | 2 | 2 |
| **Czech Republic** | 905 | 85 | 3 | 21 | 3 | 5 | 7 |
| **Denmark** | 490 | 106 | 0 | 26 | 1 | 1 | 1 |
| France | 7,819 | 29 | 25 | 53 | 16 | 11 | 58 |
| **Germany** | 7,373 | 780 | 19 | 71 | 53 | 81 | 27 |
| **Italy** | 8,736 | 4 | 26 | 14 | 111 | 2 | 133 |
| **Netherlands** | 1,202 | 25 | 39 | 36 | 212 | 16 | 8 |
| **Poland** | 4,079 | 1,113 | 237 | 76 | 57 | 4 | 6 |
| Romania | 2,524 | 23 | 31 | 5 | 16 | 0 | 2 |
| Russia | 20,068 | 817 | 185 | 189 | 6 | 20 | 74 |
| **Serbia** | 982 | 9 | 11 | 3 | 21 | 0 | 2 |
| **Spain** | 876 | 97 | 19 | 20 | 4 | 6 | 3 |
| **Switzerland** | 816 | 7 | 14 | 21 | 8 | 2 | 3 |
| Ukraine | 4,795 | 285 | 91 | 185 | 135 | 1 | 20 |
| **United Kingdom** | 7,507 | 38 | 35 | 16 | 38 | 14 | 91 |
| European Union (27 countries) | 47,186 | 2,736 | 649 | 471 | 584 | 160 | 525 |

*Countries in bold are part of this project. [a] Includes both rolled and bran oats. [b] Popcorn, buckwheat flour, buckwheat bran, buckwheat, quinoa, fonio flour, fonio bran, fonio, triticale flour, triticale bran, triticale, canary seed, mixed grains (flour, bran and raw) and preparations. [c] Broad beans, horse beans (faba bean), chickpeas, cow peas, pigeon peas, lentils, bambara beans, vetches and lupines (raw, flour or bran).*

Table 5 shows the food supply quantity, which serves as a proxy for food consumption, in kilogram per capita for the year 2019. CROPDIVA crops, except for oat, were aggregated with other crops. Hull-less barley is part of the category “barley and barley products”, triticale and buckwheat with “cereals, other” and lupines and faba bean with “pulses, other”. Wheat is by far the most important crop in this category. The importance of other crops is negligible, except perhaps for rye (here as reference) in Austria, the Czech Republic and Germany (11.5, 8 and 9.3 kg/capita per year, respectively) and oats in the United Kingdom (7.4 kg/capita per year). These statistics are based on food supply quantity and not real consumption; the CROPDIVA crops (excepting oat) are only a fraction of those already small quantities. Based upon these data, there can be little doubt that the CROPDIVA crops currently have very little importance in the European agrifood sector. Hence, one major challenge of this task: identifying existing value chains of crops that are consumed in such small quantities.

*Table 5. Food supply quantity in kilogram per capita in the year 2019 for various categories according to FAOSTAT, 2019.*

| FAOSTAT Categories | Wheat and wheat products | Rye and rye products | Barley and barley products | Oats a | Cereals, other [b] | Pulses, other [c] and other products |
|---|---|---|---|---|---|---|
| *CROPDIVA or Reference Crops* | *Reference* | *Reference* | *Hull-less barley* | *Oats* | *Triticale, buckwheat* | *Faba bean, lupin* |
| **Austria** | 87.0 | 11.5 | 0.4 | 1.8 | 1.8 | 1.0 |
| **Belgium** | 99.0 | 1.0 | 1.7 | 0.2 | 1.7 | 0.2 |
| **Czech Republic** | 85.0 | 8.0 | 0.3 | 2.0 | 0.3 | 0.6 |
| **Denmark** | 85.0 | 18.4 | >0.1 | 4.4 | 0.1 | 0.2 |
| France | 120.0 | 0.5 | 0.4 | 0.8 | 0.3 | 0.9 |
| **Germany** | 88.0 | 9.3 | 0.2 | 0.9 | 0.6 | 0.3 |
| **Italy** | 144.0 | 0.1 | 0.4 | 0.2 | 1.8 | 2.2 |
| **Netherlands** | 70.3 | 1.5 | 2.3 | 2.1 | 12.4 | 0.5 |
| **Poland** | 107.7 | 29.4 | 6.3 | 2.0 | 1.5 | 0.2 |
| Romania | 130.0 | 1.2 | 1.6 | 0.2 | 0.9 | 0.1 |
| Russia | 137.6 | 5.6 | 1.3 | 1.3 | >0.1 | 0.5 |
| **Serbia** | 112.0 | 1.0 | 1.2 | 0.3 | 2.4 | 0.2 |
| **Spain** | 97.0 | 0.8 | 0.5 | 0.5 | 0.1 | 4.5 |
| **Switzerland** | 95.0 | 0.8 | 1.6 | 2.5 | 0.9 | 0.4 |
| Ukraine | 109.0 | 6.5 | 2.1 | 4.2 | 3.1 | 0.5 |
| **United Kingdom** | 111.0 | 0.6 | 0.5 | 7.4 | 0.6 | 1.4 |
| European Union (27 countries) | 106.0 | 6.2 | 1.5 | 1.1 | 1.3 | 1.2 |

*Countries in bold are part of this project. [a] Includes both rolled and bran oats. [b] Popcorn, buckwheat flour, buckwheat bran, buckwheat, quinoa, fonio flour, fonio bran, fonio, triticale flour, triticale bran, triticale, canary seed, mixed grains (flour, bran and raw) and preparations. [c] Broad beans, horse beans (faba bean), chickpeas, cow peas, pigeon peas, lentils, bambara beans, vetches and lupines (raw, flour or bran).*

# 4. METHODS

In order to analyse which elements represent a challenge or opportunity for the implementation of a niche food value chain, each partner in this task was asked to identify existing value chains in their respective country. Once these had been selected, each partner collected data through desktop research or interviews. Then, the value chains were mapped and analysed qualitatively according to several elements. This section is divided in three subsections: selection of the case studies, data collection and data analysis.

## 4.1 Selection of the case studies

Based on the literature, the selection of value chains to be investigated was prepared by the task leader. Following this preparatory work, all research partners received guidelines for and participated in a value chain selection workshop. After the workshop, further bilateral discussions took place, which led to the final value chains selection. In parallel, value chain selection was coordinated with other WPs.

Ambiguity regarding the difference between value chain analysis and case study was discussed internally and presented to the research partners by the task leader at the value chain selection workshop. During the presentation, we differentiated between a value chain analysis and a case study (Stake, 1995) in the following manner:

Case study = analysis of one value chain with a main end product
+ facultative branches (e.g. by-product or further processed products)
+ facultative analysis of similar/parallel value chain(s)

Experience of the project participants as consumer and researcher, insights from statistical databases and preliminary desktop research were used for the initial identification of value chains. Research partners were asked to classify their value chains according to multiple criteria defined by the task leader to ensure the chains' diversity and representability:

- Use (food, feed, non-food)
- End products (milk/meat alternatives, raw materials, etc.)
- Value chain length (based on the processing stages and intermediaries)
- Selling channel (Retailer type, on-farm, etc.)
- Product life cycle stage (introduction, growth, maturity, decline)
- Demand/trend
- Origin of raw product (100% national, imported, etc.)

During the selection of value chains, participants discussed whether the value chain analysis should focus on food or should consider both food and feed. The reasons for this were multiple. First, VCs of non-food niche products might be too challenging to find and cover. Also, feed aspects that are relevant for a value chain analysis and implementation are mostly price of feed, yield, nutritional components and feed substitution; marketing and other socioeconomic aspects are less relevant.

The value adding potential is considered to be higher for food than for feed. Furthermore, socioeconomic aspects, like marketing strategies, are much more relevant for food products and the linked VCs. Upgrading a food VC or implementing new food products within a VC is likely to be more difficult than improving a feed VC due to a variety of socioeconomic aspects (demand, trend, price, advertising, framework, etc.). Therefore, it was determined to be important to obtain insights about food value chains.

At the workshop, it was decided that non-food value chains (and in particular feed VCs) should be covered as well. Similarly, the selection of case studies was altered to include an increased focus on non-food (i.e. either feed or use outside the food chain) in order to the follow the general project goals.

Furthermore, the consideration of value chains based on crops that are not within the focus of the CROPDIVA project was also discussed. These so-called "example crops" are formerly underutilised or still underutilised crops that have outgrown their niche and are successful on the market (examples of successful crops grown out of the niche). Example crops could include spelt, poppy seeds and chickpeas (in certain countries). The reasons for considering example crops were various. Perhaps most importantly, investigation of these successful VCs allows actors within this VC to explain the challenges they overcame and how they managed to become successful. CROPDIVA crops might become as important as some of these example crops; therefore, knowing their current challenges would equate to knowing the future challenges of the CROPDIVA crops. The consideration of example crops was also motivated by the fear that some CROPDIVA crops are not established at all in some countries (e.g. hull-less barley). However, at the workshop and in the subsequent discussions, it was decided to only focus on CROPDIVA crops. The example crops (spelt, chickpeas, and poppy) were omitted to ensure a more complete analyses of the six CROPDIVA crops and better reflect the focus of the project in the value chain analyses.

Various discussions followed the VC selection workshop. It was decided that the case studies to be analysed should be extant value chains. A balanced distribution was aimed for in the selection of crops, and each would be analysed by at least three research teams. Bilateral discussion between partners led to some adaptations: gaps for hull-less barley, lupines and faba beans were filled. It was further decided that each partner should perform a value chain analysis of an oats product, which would allow for cross-comparison between all participating countries. The resulting distribution of value chains to be analysed is illustrated in the following table.

*Table 6. Overview of the scope of the value chain analyses performed in this task.*

| Country / Crop | Belgium | Austria | Czechia | Serbia | Switzerland |
|---|---|---|---|---|---|
| **Oat** | food | food | food + feed | food + feed | food |
| **Triticale** | food + feed | | feed | feed | food |
| **Hull-less barley** | | food | food | food | |
| **Lupins** | food + feed | food | | | food + feed |
| **Faba beans** | | food + feed | | food | food + feed |
| **Buckwheat** | food | | food | food | |

## 4.2 Data collection

After selecting value chains and before the beginning of data collection, the value chain boundaries were defined. It was decided that only inputs related to the starting point (agricultural production) should be taken into account; inputs connected to processing enterprises were not relevant and too complex to consider. All intermediate products, as long as they were "on the main chain" (direct line from producer to consumer), were included, but by-products were only analysed if they had a relevant economic value.

Data collection was based first on in-depth desktop research of the selected value chains, followed by key informant interviews.

### 4.2.1 Desktop research

The desktop research was mainly conducted online. Primary, secondary, and tertiary literature were all included in the research. The last, including textbooks, encyclopaedias, guides and newspapers, was useful for understanding the functioning of specific value chains. However, non-scientific literature was probably the most important source of qualitative and quantitative information. For example, company reports or farmers' websites could be used to understand both the size of and the positions of actors in a VC, as well as which services and products they produce.

### 4.2.2 Key informant interviews

The partners had the choice of conducting open, semi-structured or fully structured (closed) interviews, although semi-structured interviews were preferred. On the basis of AFE (n.d.); Hellin (2006); Lesego Herr (2007), guidelines were provided to the partners.

These guidelines were drafted using the three sources listed above with reflection on their relevance for the CROPDIVA's value chain analyses. These interview guidelines, tailored to each type of VC actor, were in the form of possible questions under specific themes. The guidelines were designed in a very open way; the research institutions have very different scientific backgrounds, and it was considered beneficial to allow for adaptation to national specificities. Thus, a certain flexibility of analysis and formulation of questions was given to each research team. Partners were asked to indicate the number of VC actors they interviewed, for each type of actor and VC, and to summarise the main findings regarding constraints/opportunities for the VC and their causes/implications. Very generally, the number of interviews was based on the length of the value chain; it was recommended that a minimum of two interviews for each VC stage should be conducted. For example, at least two farmers or two processing enterprises should be interviewed. If the opinions of the actors of one stage already interviewed for a value chain differed, further interviews were recommended for this analysis. Obviously, if there was only one processor involved in the selected value chain, only that processor need be interviewed.

## 4.3 Data analysis

After the selection of the value chains and in parallel with the data collection, three steps were carried out for the VC analysis: first the mapping of the value chain, then its analysis and finally a synthesis of the VC that summarised the main results. VCs of underutilised crops have unique characteristics, such that some particular elements in the analyses might be of interest. As underutilised crops have high transaction costs due to their small production quantities, it was important to focus especially on input supply, transport/handling/storage infrastructure and processing infrastructure in order to understand whether VC actors are able to adapt to small production quantities.

Another important issue is how to reach consumers, as these crops are not well known and may be more expensive than more popular crops. It was important to understand how consumers obtain these underutilised crops, whether by buying from a large retailer, from specialised shops or by direct sale. Another point of interest was the use of e-commerce platforms to distribute the products. Finally, the utilised marketing strategies were another important aspect of the value chain, as these could be used for the tasks foreseen in CROPDIVA. These analysis steps were based on and adapted from Bellù (2013), Coulibaly et al. (2010), FAO (2014), Issa (2010), Kaplinsky and Morris (2000), and UNIDO (2020).

### 4.3.1 Value chain mapping

The value chain mapping was based on the desktop research but was adapted, if necessary, after the interviews. Value chain mapping was used for both communication (with VC actors) and analysis. It helped to reduce the complexity of a VC in order to capture its main characteristics. Real-world VCs are much more complicated than their mapping, as shown by Kaplinsky and Morris (2000) in Figure 1.

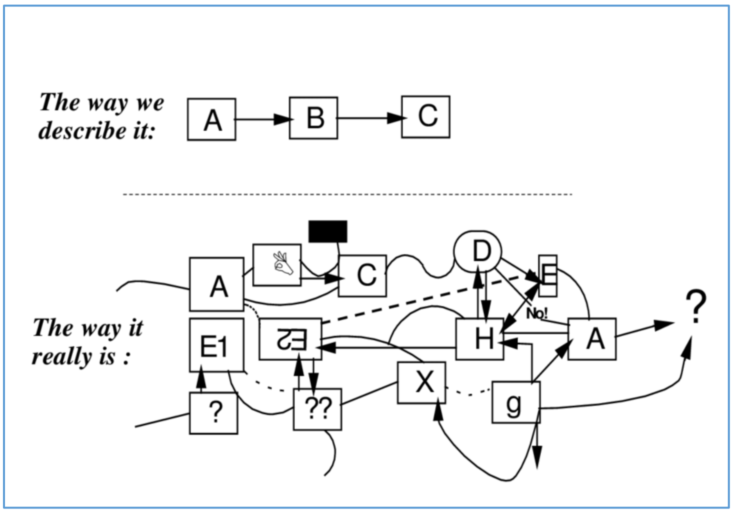


*Figure 1. Value chain mapping: simplicity versus real-world complexity (Kaplinsky & Morris, 2000).*

Value chain mapping started with the identification and mapping of actors. In our report, stakeholder mapping was a better choice than operation or process mapping; this is because we conducted interviews with actors in the VC in order to better identify bottlenecks in the VC and in the overall VC network. In addition, we were less interested in added value or quantification of flows, which would have required mapping of the operations and processes.

After mapping the actors, the relationships between them were established on the basis of product flow. Intermediate products were also mapped for a better understanding of the VC, and by-products were mapped if they were relevant to the VC. An example of a simple mapping of a value chain can be found in Figure 2 (Bellù, 2013).

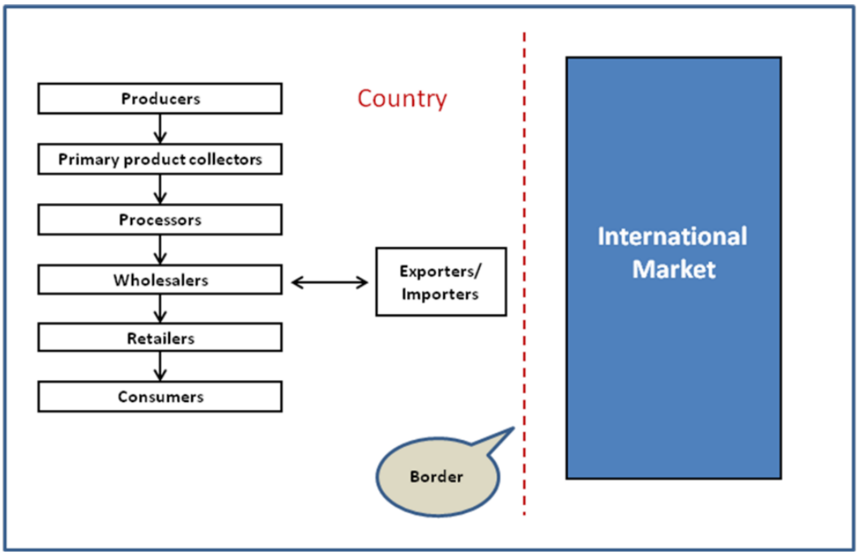


*Figure 2. Simple value chain mapping proposed by Bellù (2013).*

Optional elements were mapped or added if they were particularly relevant. These included the mapping of knowledge and information flows, distinguishable from product flows. The use of digitalisation in the VC as well as any type of vertical coordination/cooperation (e.g. a cooperative association of farmers and collectors) were represented on the map if relevant. A balance was found between clarity and comprehensiveness of the mapping – for example, all seed suppliers were aggregated but separated from fertiliser and crop protection suppliers. With regard to the use of digitalisation, both the use of blockchain for traceability and the use of e-commerce for distribution, important aspects related to VC, were represented on the VC map if relevant.

### 4.3.2 Value chain analysis

After the mapping of the VC, an in-depth analysis was carried out, mainly based on the results of the interviews. The focal points here were the constraints and opportunities of the VC that were reported by the interviewees. The four following main areas of analysis, with different elements, guided the analysis: (i) VC actors' capacities and knowledge, (ii) resources and infrastructure, (iii) market conditions and (iv) framework conditions. These four areas also contained optional elements of analysis that could be reported if appropriate.

The elements of the area of analysis "VC actors' capacities and knowledge", which focused on the actors in the VC, were their knowledge and skills, as well as their level of organisation and cooperation within both their VC stage and the greater chain. In addition, the entry and exit barriers of the VC were also analysed in order to identify challenges and opportunities.

The area "resources and infrastructures" related to the resources and capital available in the value chain and for each actor. The first element of analysis was the availability of inputs, such as locally adapted varieties. In addition, the availability and/or lack of infrastructure were analysed, as this factor can cause problems or costs in transport, storage or handling. Sometimes the infrastructure may be adequate, but the volume and capacity of the infrastructure is too low or skilled labour may be lacking. Value chain financing can be another interesting element of analysis and can play a role in investment and development opportunities.

The analysis of the market conditions included elements such as market structure, which can be used to evaluate the competition or size of a specific market. In addition, identifying the demand, product life cycle stage and trends of a product can also be important for value chain opportunities and challenges. Import and export can play a role in supply and demand and therefore in the price of the product. Many aspects of the product itself, such as packaging, branding, target market segmentation, product pricing strategy, substitution of another product, etc. can be decisive for the success of a value chain. In addition, the means of approaching customers, such as advertising or distribution channels, can influence customer loyalty, curiosity or knowledge.

The framework conditions, i.e. the environment in which the value chain is located is important. Indeed, everything related to institutions, laws and regulations, sometimes resulting in economic incentives, both within the chain and externally, can have an impact on the value chain. An important aspect is the certification of a product, as it allows certain recognition by the customer. This can be organic, Fairtrade or geographic certification. The public sector can also increase demand by buying the products of these underutilised crops and cooking them in hospitals, schools and other public institutions. The culture and tradition of a country can also help to safeguard some crops rooted in local custom. The macro-economic or geographical situation of a value chain can have an impact on, for example, the labour force that can be recruited or the transport costs.

Other optional elements, specific to a whole value chain, can be analysed as well. For example, the use of digital technology, such as blockchain technology or e-commerce, can provide a chain with better traceability or market access. The form of governance of a value chain, characterised by vertical and horizontal linkages, can influence the power differences between actors. Finally, value chains can provide ecosystem services through the production of underutilised crops. After having analysed all the relevant elements, a table and a text synthesis summarise the results and the main challenges and opportunities that have been identified. The results of each analysis are presented, together with a summary of the overall results, followed by a general discussion and a conclusion for each case study.

# 5. OATS

## 5.1 Background

Common oats (*Avena sativa* L.) is a grain belonging to the Poaceae family. Oats is a self-pollinating cereal that can grow to a height of about 60–150 cm. This annual plant is predominantly used for animal consumption, although considerable quantities are used also for human consumption (FAOSTAT, 2019).

### 5.1.1 History and distribution

Some genetic evidence suggests that the ancestor of oats *(Avena sterilis*) came from the Fertile Crescent of the Near East. *Avena sativa*, derived from a domesticated weed, spread to cooler and more favourable areas, leading to the domestication of *Avena sativa* in parts of the Middle East and Europe (Zhou et al., 1999). Oats were therefore mainly cultivated in cool countries, as still seems to be the case (see Figure 3).

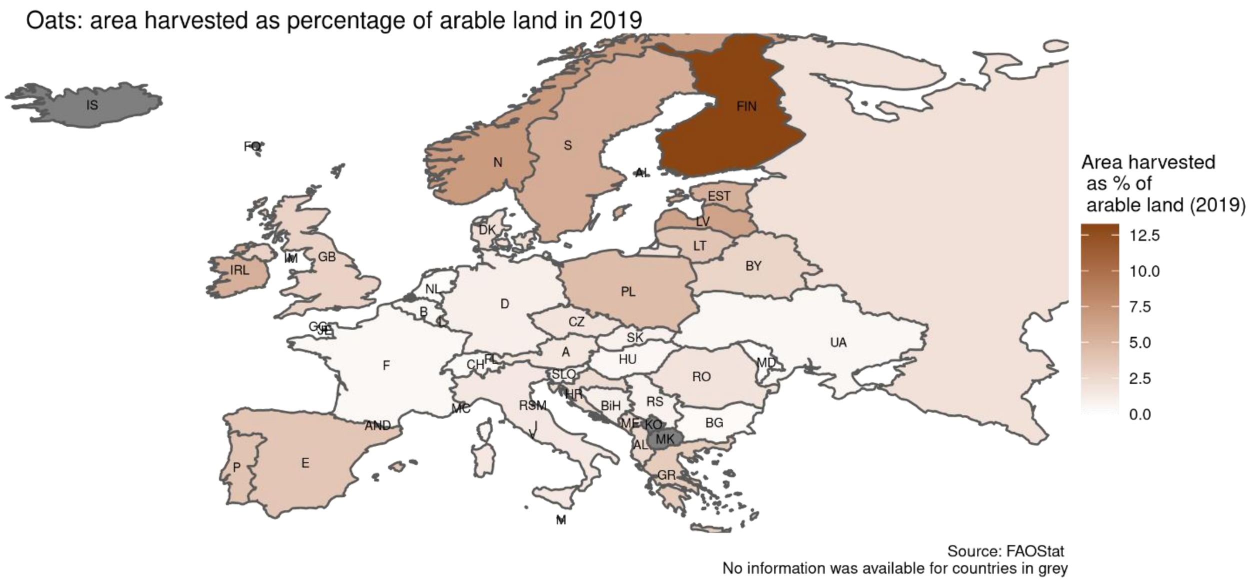


*Figure 3. Area dedicated to the growth of oats as a percentage of the arable area for European countries in 2019.*

In 2019, Russia was the leader in oats production (4.4 million t), followed by Canada (4.2 million t), Poland (1.2 million t) and Finland (1.2 million t; FAOSTAT, 2019). As can be seen in Figure 3, Finland has the highest percentage of oats cultivation area of their arable land.

A closer look at the countries of this task shows that Austria, the Czech Republic and Serbia are quite involved in oats production, but not very much in the trading of oats (Figure 4). As for Belgium and Switzerland, they seem to rely very much on imports.

### 5.1.2 Cultivation

Generally grown as a spring crop, oats can also be grown as a winter crop. Oats prefer moderate climates and low summer temperatures and can tolerate high rainfall better than other cereals. These are several factors explaining the importance of oats in countries with cool and humid summers, like the Scandinavian countries (Welch, 2012).

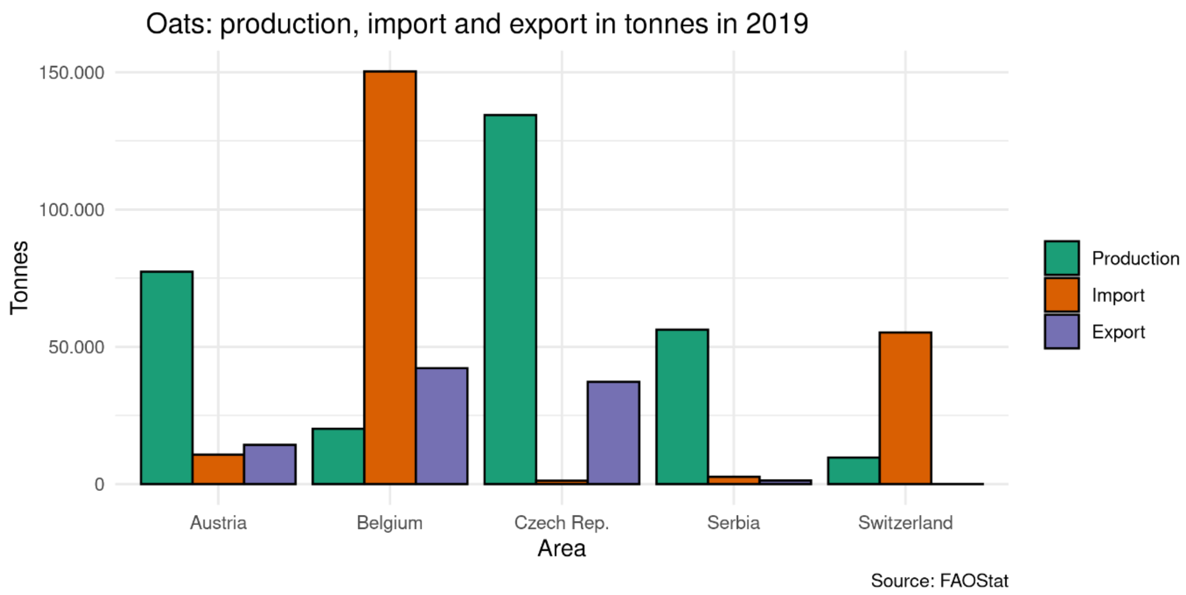


*Figure 4. Oats production, import and export in tonnes in 2019.*

### 5.1.3 Nutrition

The husked grains contain about 48% starch, 5% fat, 11% protein and 17% dietary fibre, of which 3% is β-glucans and 14% is soluble fibre (Sterna et al., 2016). β-glucans are said to lower cholesterol levels and blood glucose concentrations, potentially reducing the risk of cardiovascular disease and diabetes (Cicero et al., 2020; Sima et al., 2018).

Oats are gluten-free but are often contaminated by gluten-containing grains, such as wheat or barley. In addition, they contain avenins, which are similar to the gluten protein of wheat and can sometimes trigger coeliac disease in a minority of people (La Vieille et al., 2016).

### 5.1.4 Uses of oat

Oats, either as whole grain or ground into flour, are often fed to horses and cattle. Oats can also be eaten by ruminants directly in the field, as oats silage or hay. The area cultivated for oats decreased during the 19$^{th}$ century, mainly because oats were then used to feed draught horses, which have since been replaced by machines (Valentine, 2005). In addition, oats were replaced as feed by barley and maize if the climate allowed their cultivation.

For human consumption, oats can be rolled or crushed before use and can be incorporated into cereal mixtures such as mueslis or granola. A well-known preparation is porridge, oats boiled in water or milk. Recently, for vegans and non-vegans alike, oats drinks have become an important substitute for milk. One of the largest producers, Oatly, is now listed on the stock market, and several other food processors and retailers offer their own oats drinks. Oats can be considered globally trendy: Google results for "rolled oats" doubled between April 2020 and April 2021, and searches for "oats milk" increased sevenfold between 2015 and 2020 (Sommerville, 2020).

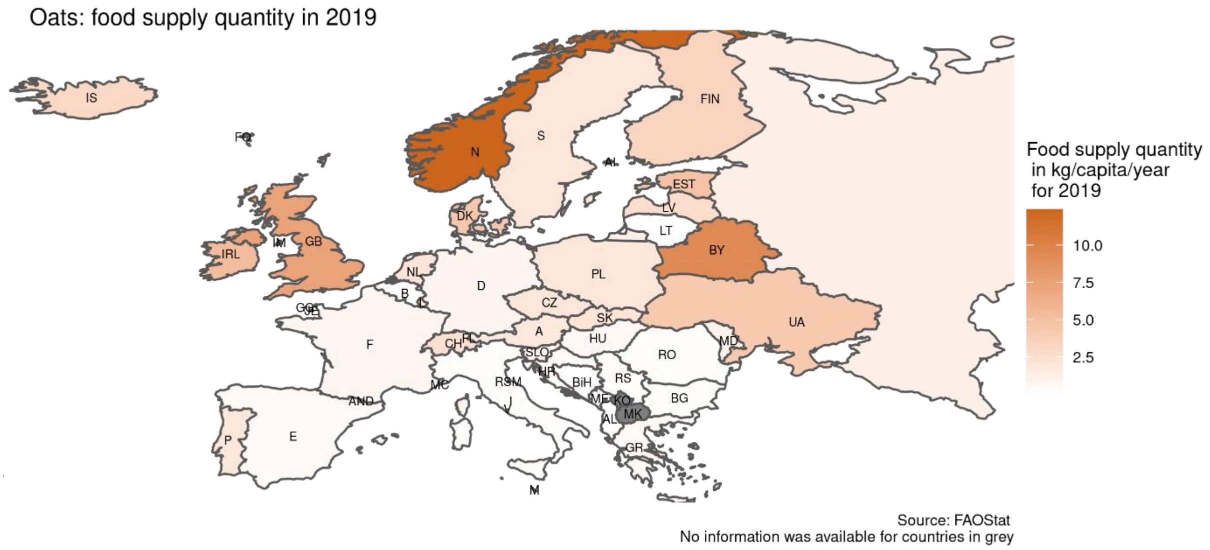


*Figure 5. Food supply quantity of oats (proxy for human consumption) per country in 2019.*

As shown in Figure 5, FAO's indicator of food supply quantity[6], which can serve as a proxy for demand or consumption, indicates that Northern Countries have a higher demand or consumption for oats per capita than do Southern Countries.

## 5.2 Results from the case studies

### 5.2.1 Introduction

Oats value chains were analysed in all the countries involved in this task (Austria, Belgium, the Czech Republic, Serbia and Switzerland). All research countries were involved due to the relatively low effort required to find information and interview partners for oats. Therefore, the oats case studies will allow for an international comparison between all countries. Table 7 shows the interviews performed in the countries of analysis.

*Table 7. Overview of the interviews conducted for oats by each research team.*

| VC actor | BE | AT | CZ | RS | CH | Total |
|---|---|---|---|---|---|---|
| Input suppliers[a] | 2 | 5 | 3 | 5 | 6 | 21 |
| Farmers | 2 | 3 | 3 | 3 | 2 | 13 |
| Collectors | 0[b] | 0[b] | 0[b] | 0[b] | 1 | 1 |
| Processors | 5 | 6 | 4 | 4 | 2 | 21 |
| Feed mills | - | - | 0 | 2 | - | 2 |
| Retail | 0 | 4 | 5 | 2 | 1 | 12 |

*[a] Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
*[b] Not relevant/non-existent/vertically integrated*

Belgian, Austrian and Swiss research teams were looking at food value chains only, while Serbian and Czech research teams additionally included feed value chains in their case studies. Collecting centres

[6] From FAOSTAT. A distinction is made between the quantities exported, fed to livestock, used for seed, manufactured for food and non-food uses, lost during storage and transportation, and available for human consumption. The per capita supply available for human consumption (food supply quantity) is obtained by dividing the respective food supply quantity by the population number and can be used as a proxy for consumption.

are run differently in the different countries and are sometimes integrated with farmers or processors (food or feed). The only exception is Switzerland, where farmers bring their harvests to stand-alone collection centres.

### 5.2.2 Situation in the research countries

In **all research countries**, oats have a long history of cultivation, during which they were mainly used as horse feed, especially before the Second World War. Although a decline in oats cultivation is observable in all countries, consumption by humans has recently grown. Oats and derived products are therefore known by consumers and are not often considered “niche” by food processors and retailers. However, cultivation of oats for food is still “niche” in some countries, which rely heavily on import. These include Belgium, Switzerland and, to a lesser extent, Serbia. Regarding animal feed, oats value chains are generally mature and have reached a saturation point in Serbia, where production has even declined.

In **Belgium**, a steady decline in oats production has been reported. Although oats have recently experienced growth in organic cultivation, this production is only present in one region of the country (Wallonia). Belgian production is limited to feed purposes, and about 90% of the oats used for food production are imported. Regarding food processing and consumption, oats are mainly used in cookies, granola bars and plant-based dairy alternatives. A growing interest among Belgian consumers in oat-based drink alternatives represents an area of potential expansion for oats production.

In **Austria**, the self-sufficient rate of oats production is calculated at 86%. About two-thirds of overall production is used as animal feed. The organic sector appears quite interested in oats, as about 40% of oats cultivation is organic. Various products are already available to consumers, and several actors expect a growth of the oats market due to trends such as veganism and growing health and environmental consciousness in the Austrian food market. Still, oats cultivation in Austria has been reported to be decreasing over recent decades, which reduces domestic oats availability and could therefore be a limiting factor for market expansion of domestic production.

In the **Czech Republic**, oats represent a low proportion of land dedicated to cereals. Czech production is stable; two-thirds of the production is used mainly as feed for animals, and about one-quarter is exported. In the food sector, oats products are not well known, and human consumption is lower than in other European countries. Products sold in Czechian retail stores are very limited (mostly flakes), but the market segment is slowly developing, and innovative oats products could be marketed successfully and find a niche, which shows consumer interest in oat-based products.

In **Serbia**, as possibilities for exportation and livestock production have decreased, oats have become less attractive to farmers. In fact, the Serbian market is limited to feed production for farmers. The feed value chain shows a significant level of vertical coordination and organisation between actors. Regarding oats destined for human consumption, almost all oats and oats products (flakes, flour, etc.) are imported by food processors and retailers, and these importations have increased in the last few years. The food value chain is not coordinated between the up- and downstream sectors; however, use of domestic oats could be targeted with prior efforts dedicated to improvement of quality od oats produced by domestic farmers.

In **Switzerland**, oats are heavily imported for both the food and feed sectors. This is because imported oats are cheaper than domestic production and are of higher quality (when coming from Scandinavian countries). In retail stores, various imported oats products can be found by consumers. Key players in both the organic and conventional sectors are conscious of oats market growth (especially the oats drink market), and they are trying to set up a food value chain to produce Swiss oats products by coordinating production with food processing and production.

### 5.2.3 Inputs

Research institutes in the Czech Republic and in Serbia and a company in Austria are breeding oats varieties. In contrast, Belgian and Swiss farmers are using foreign varieties, mainly from Germany but also from the United Kingdom, the Czech Republic and France. Seeds are domestically propagated based on foreign breeds in Switzerland and Austria. Belgian farmers only produce seeds to a very small extent. In each research country, around five to eight oats varieties are registered on the variety list.

The Serbian oats seed market is shrinking due to a decline in cattle production, low demand for export, farmers' utilisation of their own seeds and the negative impacts of fluctuating prices and yields on profitability. In addition, the market is small enough to curtail widespread breeding efforts. In Austria, farmers propagating seeds are doing some agronomic trials, but there is no obvious breeding or research interest. In Switzerland, varieties are being tested by various actors involved in the seed market.

Cultivation technology and seed quality assurance systems exist in all of the countries under consideration. However, national oats breeding, which further adapts this cereal to a given location, only exists in Austria, the Czech Republic and Serbia. In the three other countries considered, oats seed is imported from abroad, which implies a certain dependence. In this case, national cultivation could be improved through site-adapted breeding and innovative breeding and selection methods could accelerate breeding progress. The increasing demand for oats for human consumption, a result of the growing market for milk alternatives, could favour intensified oats breeding.

### 5.2.4 Farmers

Generally, the interviewed farmers consider oats to be an easy crop to grow. In all countries, due to oats' historic importance, cultivation experience exists. Oats has potential as a spring crop for diversifying crop rotation and for suppressing weeds. It is often cultivated with fewer inputs than other mainstream cereals and in marginal areas, for example at higher elevations. The low cultivation requirements of oats and its use as both a catch crop and a mixed crop explain the importance of oats in organic farming.

However, oats deliver a lower yield and fetch lower market prices in all research countries than do other mainstream cereals; i.e. a farmer planting oats instead of a more profitable crop incurs opportunity costs. This double disadvantage applies to both feed and food oats. Therefore, oats is generally not attractive to farmers with the exception of organic farmers. Other exceptions include farmers that use the feed on-farm and Czechian vertically integrated farms and food processing plants.

Regarding oats used for human consumption, Austrian farmers report an increase in demand and in quality requirements from downstream actors. For Swiss and Serbian farmers, reaching the quality parameters threshold (mainly the hectolitre weight or test weight) is challenging.

Oats production is often concentrated in specific regions – this is the case in Austria, Belgium and Serbia. This observation can partly be explained by site conditions (primarily soil and precipitation). Such agglomeration offers specific advantages for further specialisation. Regional concentration of oats production supports quick dissemination of ideas and innovations, provides access to specific production inputs (e.g. advice, machinery) and offers favourable purchase and sales channels with lower logistic costs.

Farmers generally already own the necessary machinery and equipment as a result of the similarity between the cultivation techniques of oats and other cereals. Due to the long cultivation tradition, there is also a certain, possibly locally concentrated, experience with oats cultivation in all countries. Oats therefore have fewer niche cultivation characteristics than other crops. This situation and the dynamic demand with high value-added potential due to the use of oats in dairy alternatives offer good starting points for expanding oats cultivation and thus crop diversity. If there is a corresponding demand and higher prices that compensate for the low yields per hectare compared to other crops, oats cultivation can be expanded in the short term.

### 5.2.5 Collectors

As mentioned above, only Swiss collecting centres are not integrated with other oats value chain stages. Small batches of oats (and underutilised crops in general) are more costly and challenging to handle, as Swiss collection centres are more adapted processing large batches of mainstream crops. However, for oats, there is the possibility of increasing (to a certain extent)[7] hectolitre or test weight at the collection centre stage by passing them multiple times in a de-awner machine, which could be essential for farmers to avoid food declassification to feed quality.

In the other research countries, collection centres are integrated on farms, with food/feed processors, or sometimes within retail. In addition, food oats are sometimes directly imported to food processors and retailers, so that no collection centres are involved. In Serbia, collection centres and feed mills are integrated to collect oats. As feed oats production is declining in Serbia, Serbian farmers and collection centres might struggle to find a buyer or producer, which is why a website was designed by a private company to connect value chain actors together.

For collection centres, oats is a standard crop that is mainly used for feed; the required infrastructure, knowledge and experience already exist. The Swiss example shows that such an existing feed value chain can easily be transformed for food use. The importance of cooperatives in the European agricultural sector, some of which are active at different stages of the food chain (inputs, collection, processors and retailers), can promote cross-stage coordination to build a new value chain.

### 5.2.6 Food processors

In many food-processing companies in the research countries, oats are imported from abroad. In general, knowledge and technology is mostly available for oats processing, as it is similar to other cereals. The quality of domestic oats would be challenging for food processors, especially when compared to Scandinavian oats, because of the less adapted climate in the research countries and, in Serbia specifically, the use of uncertified and self-produced seeds by farmers. Currently, Serbian and Austrian research teams point to the need for investment in product innovations (e.g. protein extracts from oats as meat alternative) in order to broaden the oats products market segment. Some product innovations were mentioned: an Austrian company is producing oats whiskey and a Czechian one a fermented product made from germinated oats.

In general, competition in the oats food-processing sector is high, preventing or complicating entry into the market. In Austria and the Czech Republic, a few companies are already dominant. In Serbia, regarding domestic oats products, a monopolist is dominating the oats market. However, that monopolist would have difficulties with imported oats products, as foreign companies can better position their brand name on the market. A similar situation can be identified in the Swiss market for oats drink, where a domestic oats drink is in competition with other drinks produced with foreign oats by a few other Swiss companies or by international companies. Currently, it seems that organic imported? oats drinks are more attractive to consumers than are Swiss domestic oats drinks (conventional); however, the latter came later on the market. In Serbia, not only the business-to-consumer market but also the business-

[7] The hectoliter weight is a measure of specific weight or density and is used as an indicator of grain quality (Burke et al., 2001). The collection center can increase this post-harvest number by cleaning the oats repeatedly, which can be accomplished (to an extent) by passing them multiple times through a de-awner machine.

to-business market is important for oats because the confectionary industry, which is very important in Serbia, buys significant quantities of oats products.

Different certifications are important in various countries. Downstream actors target the gluten-free certification; however, contamination with other gluten-containing crops could be challenging to avoid. The importance of organic certification varies among countries. The food producers in Serbia are not organically certified. This is also the case in the Czech Republic due to mistrust by consumers towards the organic label. In Austria and Switzerland – countries with higher GDP per capita – organic certification seems more important for marketing oats products.

Food processors are an important interface between agriculture and trade or end consumers, primarily because processors can develop new products. The prerequisites for this are acceptance and the value added by the food trade/retail sector. The observed trends (such as health, vegetarian food and the prioritisation of buying local products) as well as the special characteristics of oats offer promising starting points for this development.

### 5.2.7 Feed processors

The Czech and Serbian research teams investigated national feed value chains. However, Czechian oats used for feed are not involved in any processing but instead most of the crop is directly used on farms. Serbian feed companies vertically integrate the collecting, processing and retailing stages (collection centre, feed mill and retailing). As Serbian feed mills are currently producing feed mixtures, those mills are already well equipped with developed technology. Feed processors cooperate with research centres to test new products. A decline in cattle production has reduced feed demand; however, selling feed mixture is still more competitive, thanks to value addition, than is selling raw materials. Feed mixtures in Serbia are sold through feed company distribution centres or specialised retail establishments, sometimes online. The market is characterised by perfect competition, and supply and demand are stable.

### 5.2.8 Retailers

Wholesalers and retailers do not consider oats to be an underutilised crop, and consumers can very easily find many different oats products in shops. The research teams described a large variety of oats products retailers: large retail chains, food health stores, bakeries, online business, etc. Retailers are forecasting a growth in demand for oats products. Wholesalers are mainly relevant in longer value chains or when imported oats are used.

In the Czech Republic, oats flakes are mainly offered in conventional stores, while special high quality flakes (organic and oriented toward consumers) are found in smaller shops in urban areas. Austrian wholesalers reported an increased demand for oats, mainly from bakeries and pastry shops. However, fluctuating quantities and prices in the Austrian oats market as well as the difficulty of motivating farmers to produce oats are considered obstacles to further establishment of domestic oats in the food market.

Communication and marketing strategies are quite similar between the countries and revolve around trends such as veganism, vegetarianism, lower meat consumption, growing health and environmental consciousness and naturalness. For domestic oats products, regionality is an important marketing strategy. Organic certification for oats was found to be less important in Serbia and the Czech Republic. In addition to communication strategies, positioning oats products in departments devoted to health foods attracts consumers.

In Switzerland, the high prices of oats drinks on market shelves are viewed critically by value chain actors, especially domestic farmers. High prices are perhaps justified for niche products, as they must overcome scale disadvantages and marketing costs; however, this can prevent a further demand increase.

Oats are present in different forms in the retail sector in all of the participating countries. Current trends (milk alternatives, emphasis on health, etc.) promote the expansion of the range of oats in the retail sector. Although establishing a domestic oats supply can be challenging due to quality and quantity fluctuations, positive price signals could mitigate this challenge.

### 5.2.9 Summary

In the research countries, oats was identified as a crop known by consumers and by the food and feed downstream sectors. However, ensuring the quality and/or price of domestic oats is challenging for food processors, wholesalers and retailers, so they rely heavily on imported oats. Increasing domestic production to replace imported oats could be a first step toward fostering oats cultivation. This could enhance agrobiodiversity, capture regionality and sustainability trends, and satisfy the expected market demand growth for this crop.

Various actors are already relying on the origin of oats as a marketing strategy, for example with the Swiss oats drink. However, challenges related to increased production and the integration of oats in existing value chains must still be overcome. In order to increase production, farmers need stronger motivation to grow oats; to accomplish this, profitability should be closer to that of other mainstream cereals. Both reported yields and prices were too low in the research countries.

The Czech and Serbian breeding programs target yield enhancement (is it already a target of Czech breeders), whilst all countries can attempt to meliorate cultivation practices and increase research and trials to identify the best-adapted varieties. Farm-gate prices comparable with those of mainstream cereals could be achieved by increasing demand for such domestic products; however, the food processing and retailing sectors need to encourage interest in domestic oats utilisation. In fact, quality issues could challenge integration of domestic oats in current food value chains. These issues are mainly linked to the climate and/or marginal growing conditions of the research countries. In Serbia, a specific challenge is the use of non-certified and self-produced seeds by farmers. Czechian and Serbian breeding programs could play an important role, as could farm trials in all the research countries.

Another issue related to the food oats value chain in Serbia is the crucial lack of coordination between actors. Enhancing connections (perhaps through internet platforms, as mentioned above for Serbian feed actors) is important for the integration of domestic products in domestic food processing and retailing companies. A good example is the cooperation exhibited by key players from the Swiss food market upon the introduction of the Swiss oats drink; the connections and influence of the agricultural cooperative, together with the experiences and marketing power of one of the most important dairy processing companies, allowed the quick introduction of a domestic oats drink. Swiss oats prices increased afterwards.

In addition, research in Serbia and Austria points to the need to invest in product innovations (e.g. protein extracts from oats as meat alternative) in order to broaden the oats market.

Trends such as veganism, vegetarianism, lower meat consumption, growing health and environmental consciousness, naturalness, regionality, organic production and nutrients content should be used in order to foster demand for oat products. One limitation of marketing towards the gluten-free market is the presence of avenins, which are similar to gluten, in oats. However, the gluten form in oats is problematic for only very few coeliac patients (Londono et al., 2013). Nevertheless, gluten contamination from machines and infrastructures used for other cereals is much more challenging for coeliac people. It is very important that the positive contribution of oats to all the above-mentioned trends be accounted for and communicated clearly to consumers.

We suggest that, in general, value chain actors should coordinate amongst themselves and try to enhance domestic production and quality in order to integrate existing food value chains and capture current oats market growth with domestic production. To accomplish this, the most important goal is to increase farmers' profitability, as other parts of these value chains are already experienced with imported oats. Enhancing yields and quality could be a first step towards higher profitability for farmers. However, breeding efforts are slow, and breeding programs are not present in all countries. Therefore, prices could be increased to raise farmers' profitability. To do this, product differentiation could be targeted by proposing domestic oats products, like the Swiss oats drink. Consumers are generally already familiar with oats, so this crop's healthy reputation can be used to differentiate it from other cereal products, which could in turn increase prices for farmers. Higher profitability for farmers would increase production, and the resulting scale advantages could be beneficial to all value chain stages.

Regarding the feed value chain, it seems that the market has reached maturity in the Czech Republic and Serbia. Czechian farmers primarily use the oats they grow on their own farms, while in Serbia, the feed value chain for oats is well coordinated. Even though cattle production is declining, feed mixtures with domestic oats are still profitable for the feed sector. Perhaps the decline in livestock production and decreased need for feed could be coupled with the integration of domestic oats in food value chains. The coupling of the food sector with the well-organised feed sector could be beneficial for value chain organisation. One solution could be optimised oats segregation into lots with higher test weight for processing into food products and lots with lower quality (smaller seed) intended for feed production. Nevertheless, quality is an important factor that should be given priority.

# 6. TRITICALE

## 6.1 Background

Triticale (×*Triticosecale*) is a cross between wheat (*Triticum aestivum*) and rye (*Secale cereale*). It is mainly grown in Europe as a feed grain. Total production in Europe was over 15 million tonnes in 2019. In comparison, its import and export share is very low, with about 636,000 tonnes exported and 470,000 tonnes imported for all European countries.

### 6.1.1 History and distribution

The first triticale hybrids were created towards the end of the 19th century in Scottish and German laboratories (Stace, 1987). At first, the hybrids were not fertile because the number of chromosomes between the parents is not compatible. At the beginning of the 20th century, the discovery of colchicine, a chemical molecule that can force the duplication of chromosomes, enabled the crossed triticale to be fertile (Blakeslee & Avery, 1937).

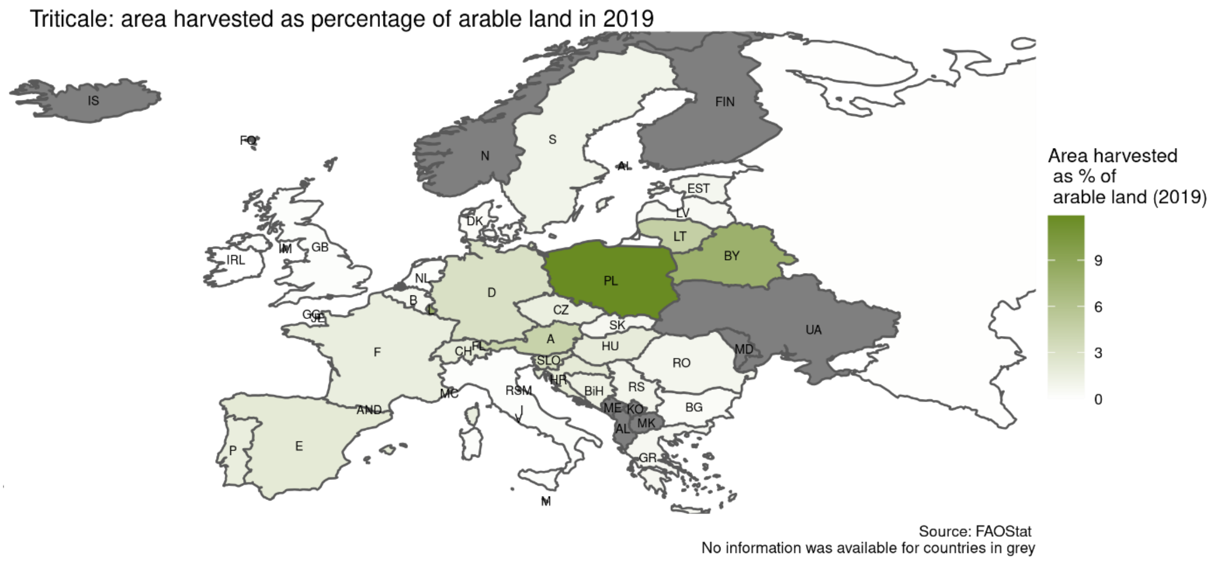


*Figure 6. Area dedicated to the growth of triticale as a percentage of the arable area for European countries in 2019.*

Poland is the country with the highest proportion of triticale growing area and has the world's highest production with 6.08 million tonnes in 2019 (see Figure 6). The second-most important producer in Europe is Germany with 2.04 million tonnes; Belarus produces 1.54 million tonnes, and France produces 1.2 million tonnes (FAOSTAT, 2022)

Triticale has some importance in each country of this task (see Figure 7). It is also apparent that the crop is not really present on the markets; rather, it is used for animal feed directly on-farm.

### 6.1.2 Cultivation

Triticale is grown like wheat and rye and can be used as a winter or spring cereal. The properties of rye, such as resistance to fungal diseases and (a)biotic stress tolerance, are some advantages of triticale. As a cross between two cereals with different growing areas, triticale is adapted to various and diverse environments. It is a robust cereal with high grain potential, good nutritional quality and tolerance to frost (Arseniuk, 2015).

### 6.1.3 Nutrition

Triticale whole grain flour consists of 73% carbohydrates, 15% fibre, 13% protein, 10% water and 1.8% fat (Zhu, 2018). Like its two parents, triticale contains gluten. The protein content is similar to that of wheat, but its lysine content is slightly higher, and the digestibility of its starch is reportedly higher than that of other cereals (Mergoum et al., 2009).

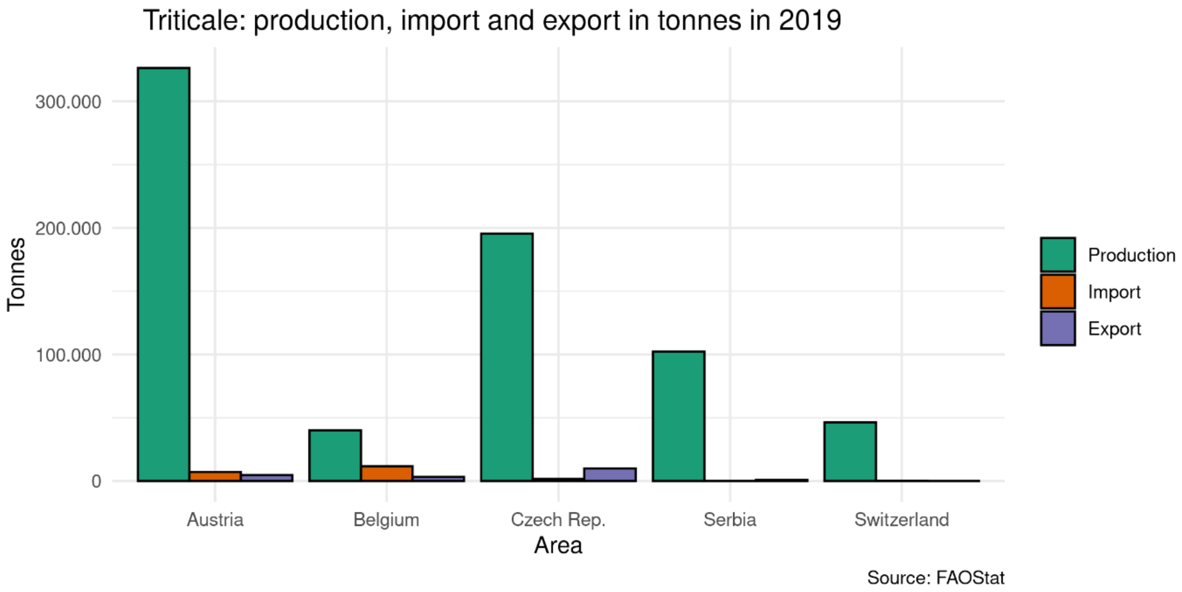


*Figure 7. Triticale production, import and export in countries of this task for the year 2019.*

### 6.1.4 Use of triticale

Triticale is mainly used for animal feed, as the advantages are numerous. It can be used as animal feed grain, forage or both, but also as grazing forage, cut forage, hay or silage (Mergoum & Gómez-Macpherson, 2004). Its amino acid composition fulfils the requirements of both monogastrics and poultry.

Triticale is not commonly used for human consumption, but its high lysine content and nutritional value may be of interest to communities relying on cereals in their diets (Mergoum & Gómez-Macpherson, 2004). Triticale could be consumed, like wheat and rye, in the form of pasta, noodles, breads and other baked products.

According to Peña (1996), several factors prevent triticale from being consumed by humans on a large scale: grain compositional factors, region-specific grain preferences of consumers, competitiveness with other grains and various economic, marketing and processing aspects. In addition, improving agronomic traits and disease resistance has clearly been a breeding goal for triticale, to the detriment of grain colour and bread-making quality (Peña, 1996).

## 6.2 Results from the case studies

### 6.2.1 Introduction

Value chain analyses for triticale were conducted in Belgium, the Czech Republic, Serbia and Switzerland. Research teams from Belgium, the Czech Republic and Serbia looked at feed value chains in their respective countries, while the Swiss research team investigated a single food value chain. In addition to the feed value chain, the Serbian research team looked at a non-food or "green energy" value chain, namely biogas production. Whilst established feed production was identified in these four research countries, a small-scale commercialisation of a triticale food product was only reported in Switzerland.

*Table 8. Overview of the interviews conducted for triticale by each research team.*

| VC actor | BE | CZ | RS | CH | Total |
|---|---|---|---|---|---|
| Input suppliers[a] | 3 | 7 | 3 | 5 | 18 |
| Farmers | 1 | 4 | 3 | 1 | 9 |
| Collectors | 0[b] | 0[b] | 0[b] | 2 | 2 |
| Processors | 7 | 2 | 2 | 2 | 13 |
| Retail | 0[b] | 2 | 0[b] | 2 | 4 |

*[a] Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
*[b] Not relevant/non-existent/vertically integrated*

Table 8 reports the number of interviews conducted by each research team. It should be noted that for feed value chains, high-level vertical integration was observed (in the collecting, processing and retailing stages), which explains the lack of interviews with specific collectors and retailers.

### 6.2.2 Situation in the research countries

In **Belgium**, commercialisation and product development is inexistent in the food sector. Triticale has only been used for limited editions of bread mixes, for which quality assurance was challenging. Triticale production for feed purposes is rather stable to slowly declining. It is frequently grown by organic Belgian farmers and used as ensilage or feed mixtures for animal production. Historically, farmers grew it for their animals and to sell the surplus to feed mills. However, most farmers have shifted production towards wheat, which is more profitable and delivers higher yields. Belgian feed mills partly rely on imports of triticale to produce feed mixtures.

In the **Czech Republic,** the value chain of triticale for feed purposes is stable, functioning and mature. It is a conventionally grown crop of minor importance when compared to wheat and barley, and therefore, there is no detailed commodity balance information on its use. Self-sufficiency in triticale production is higher than 100%, meaning enough is produced to export small quantities. Triticale production for feed purposes seems to be linked to livestock production, and the current decrease in Czech livestock production has reduced interest in growing triticale.

In **Serbia,** the area in which triticale is cultivated has increased, in fact nearly doubled, in the last 10 years. This is in contrast with the rather stable to declining cultivation interest in Belgium and the Czech Republic. The reason for this increase in triticale production is the Serbian government's support for production of green energy from renewable sources, which began in 2017. Triticale is used on large farms for biogas production. On smaller farms, triticale is grown as a low-input cleaning crop to suppress weeds in marginal lands, and it is also used to feed animals (fresh, ensiled, dried or ground in a mixture). Triticale grains are also sold to feed mills to be incorporated in feed mixtures. The decrease of livestock production in Serbia has not directly affected the production of feed mixtures, which remain in demand and are more profitable than primary agricultural material thanks to the value added by processing. Triticale imports have tended to increase whilst exports have decreased over the last five years. As about 80–90% of the imported triticale comes from Russia, the current Ukraine–Russia war will probably also impact Serbian triticale supply to some extent.

In **Switzerland**, triticale is mainly used for feed, and the area of cultivation has remained stable throughout the last few years; niche production in the food sector has also been identified. Breeders from a private biodynamic institution created a triticale variety for mixed use as food and feed. This triticale variety is higher in protein, provides lower yield than other varieties and is currently used by bakeries for producing bread. The breeders could in fact recruit interested farmers, collection centres, mills and bakeries. The market size is small; however, artisanal bakeries have successfully baked and marketed triticale bread.

### 6.2.3 Inputs

The breeding and seed supply situation is very different amongst the research countries. In Belgium, no breeding was reported and seed suppliers are dependent on imports, but Belgian demand for triticale seeds is slowly decreasing as farmers shift to wheat production. The lack of adapted varieties with sufficient yields and resistance has further reinforced the demand decrease in Belgium.

In the Czech Republic, breeding activity has been terminated, and two Czech varieties are being maintained. However, all 10 of the varieties recommended by a national institute are foreign varieties. The main source countries for seed importation are Poland, Germany and the Netherlands. Demand for triticale seeds is decreasing due to a decline in livestock production and – similar to Belgium – a shift to wheat because of higher wheat market prices.

In Serbia, various research and breeding institutes are working with triticale. Of the four key triticale varieties (75% of market share), two are of Serbian origin, while the others are from France and Croatia. Smaller Serbian breeding companies have the rest of the market share (25%). Breeding institutes and seed suppliers are producing the seeds, and the same breeders and suppliers are involved in both the feed and green energy value chains.

In Switzerland, one biodynamic private institute is breeding feed varieties and has released a food (bread) variety that is currently being produced in the country. However, this variety is not registered on the Swiss varieties list but is instead considered a “niche variety”. This designation, effectively a penalisation, is due to its lower yield; yield is the most important parameter for Swiss triticale registration. Therefore, this niche variety cannot be exported, and its cultivation area is restricted.

Triticale is less in demand in two of the countries surveyed, where farmers tend to instead grow wheat. However, cultivation technology and experience with this cereal cross is available in all countries. The primary use as a feed grain limits the value added by processing, which is estimated to be higher in the food sector. Seed breeders and multipliers should focus their resources; under the given conditions, intensified triticale breeding seems difficult.

### 6.2.4 Farmers

In Belgium, the Czech Republic and Serbia, farmers produce triticale for livestock feed. It is either directly used on farms (fresh, ensilage or in a mixture) or is sold to a feed mill for feed mixture production. A link between decreasing interest in triticale and more attractive wheat prices was identified in Belgium and the Czech Republic. In addition, decline in triticale production was found to correlate to a decrease in livestock production in the Czech Republic. In Serbia, the use of triticale shifted from feed production to green energy production and is increasing thanks to government support. It is mostly large Serbian farms that are involved in green energy production, which is vertically integrated with farming. The biogas that these large farms produce is used to produce electricity for the Serbian state. Small Serbian producers are still using triticale to feed animals.

Except in Belgium, triticale is considered a low-input robust crop that is resistant to drought and better adapted to marginal conditions than is wheat. In Belgium, triticale varieties have delivered insufficient yields and are prone to disease. Belgian farmers growing triticale are often organic certified and grow the crop in sandy soils. In Switzerland, the bread triticale variety used in the food sector was created for organic farms to replace wheat in marginal locations. However, regarding the value chains in Belgium and the Czech Republic, food triticale is less attractive to farmers than is wheat or spelt. Swiss farmers growing food triticale reported an interest in triticale's robustness and carefree cultivation. The desire to contribute to diversity and cooperate with the private institute was also reported to be important to those farmers.

Triticale cultivation is of low importance in all countries. In some cases, the area used to grow triticale is declining because wheat is being grown there instead or because the demand for triticale as animal feed has declined as a result of decreasing livestock numbers. Olny in Serbia, triticale production is increasing. Wheat has both price and yield advantages over triticale. Its primary use as a feed grain limits value creation. In organic farming, the robustness and cultivation possibilities on less fertile sites seem to contribute to interest in the crop. Increasing political efforts to reduce the use of plant protection products include requirements for crop rotation diversity; this could promote triticale as a robust cereal capable of replacing wheat in the future. However, if the decrease in livestock numbers continues, the demand for feed, triticale's primary use, could also decline.

### 6.2.5 Collectors

Collection centres are integrated with feed mills within the feed value chains and are not necessary for green energy production (direct use on-farm in production plants). In Switzerland, however, it was necessary to identify collection centres capable of accepting small batches of food triticale. As it is a special variety, it cannot be mixed with other triticale varieties; this results in higher handling costs for collection centres, which are more adapted to handling large batches of mainstream crops. It was reported that Swiss collection centres would adapt and begin to accept to smaller batches; however, this trend is unclear and requires more investigation.

### 6.2.6 Feed processors

In the Belgian, Czechian and Serbian feed value chains, farmers deliver triticale grains to feed mills (when it is not used on-farm). In those three countries, mills have the necessary knowledge and adequate infrastructure to process feed mixtures. Generally, triticale can be processed like wheat. In the Czech Republic and Serbia, the network and vertical cooperation between actors is very important. Serbian feed mills invest in extensive media marketing or rely on established cooperation to sell the feed mixtures they produce.

In Serbia, feed mills generally sell through their network of distribution centres or through specialised shops. The distribution centres also sell pesticides, seeds, etc., illustrating the strong level of vertical and horizontal cooperation between actors. The Serbian feed market is characterised by perfect competition, feed prices are based on supply and demand and the market position of feed mixtures is stable. In the Czech Republic, relationships between feed mills and farmers are tighter (no intermediates), as the mixture based on farmers' recipes is bought back by the farmers. Only a small percentage of feed mixture is put on the market at all. Belgian feed mixtures from mills are sold to distributors or directly to farmers.

Society's demands on the agricultural sector in terms of pesticide use, fertilisation and related objectives, such as climate protection and biodiversity, could influence the feed market. The extent to which triticale will be affected by or benefit from these possible changes is difficult to assess.

### 6.2.7 Food processors

After harvest, Swiss food triticale is milled into flour and sold to artisanal bakeries. Milling is similar to that for other cereals. Triticale, parented by rye, is subject to infection by the ergot disease, which represent a threat to consumers. A change in the EU regulation regarding ergot sclerotia and ergot alkaloids thresholds could impact the use of triticale as food. In addition, monitoring ergot alkaloids (at present only sclerotia levels are measured) might be analytically difficult, according to Lattanzio et al. (2021), for Italian food commodities. Analytical and regulatory challenges linked to ergot alkaloids should be further researched.

A few Swiss artisanal bakeries are using triticale flour to bake bread. A variety of methods are used, including scalding the dough, using sourdough or yeast starters, mixing it with other cereals and using it “pure”. Bakeries agree that triticale flour is difficult to work with and cannot currently be used for industrial baking due to the stickiness of the dough and the lack of soft, wheat-like properties. The triticale variety being used is bred from rye and hard wheat, which has inferior baking qualities compared to soft wheat. The baking challenges related to triticale bread are an entry barrier for the industry, which would ensure that the bread remains only a niche product in artisanal bakeries and limit its availability to curious consumers. In Belgium and the Czech Republic, companies encountered similar challenges, and this explains the lack of food products based on triticale. Triticale could have more potential if integrated into tortillas or crackers (Pérez et al., 2003; Vaca-García et al., 2011).

### 6.2.8 Retailers

Swiss bakeries sell the triticale bread to health shops or directly to consumers. Proximity with consumers is important (e.g. by organising baking workshops), as it allows bakers to inform consumers about triticale. In fact, people familiar with the agricultural sphere see triticale as feed (rather negatively), and those unfamiliar with agriculture often do not know about it at all. Thus, there is a crucial need to inform consumers about triticale and choose a bespoke bread name to market triticale bread. Positive marketing aspects of triticale bread, as reported by bakers and their consumers, are the long shelf life and the nutty triticale-typical taste (not just a mix of rye and wheat). Although some current trends, such as regional consumption or sustainability concerns, are favourable toward triticale bread, the trend of consuming “ancient grains” like spelt or emmer is unfavourable for the rather “recently bred” triticale.

Informing consumers could be done, as planned by one Swiss baker, through use of a QR code on the bread packaging. By scanning the code, consumers get information about the value chain, enhancing transparency and traceability. In addition, organic certification is quite important to successfully targeting a clientele with a higher willingness to pay for “alternative” products like triticale bread.

### 6.2.9 Summary

Serbian and Swiss research institutes are involved in triticale breeding. Seed supply (importation or domestic production) is relatively stable in the research countries. Triticale feed value chains were characterised as quite organised and mature – or even declining. However, triticale can still be considered an underutilised crop in all the research countries because it is produced in much lower quantities than those of mainstream crops. Similar use of triticale and wheat in feed mixture processing make it rather easy to integrate into the coordinated feed sector. The decline in livestock production and more attractive wheat prices (opportunity costs) are linked to a decline in triticale utilisation. The positive characteristics of triticale, including robustness, drought resistance, low-input cultivation and high-lysine content, appear insufficient to maintain or increase triticale cultivation. Only government support for green energy production is making triticale attractive for large-scale farms in Serbia, where the cultivation area is even increasing.

In Switzerland, breeders created a niche for triticale in the food sector. There were reported attempts to use triticale as food in other countries, but they were unfruitful. It is unclear what parameters are allowing Swiss actors to succeed in such marked contrast to actors in Belgium and the Czech Republic. The organic sector might play a role: it allows for more diverse cropping and has a niche sector. The organic sector is better adapted to handling smaller batches, and actors' intrinsic motivation, which is linked to higher interest and/or meaningfulness, may be higher. On one hand, one can speculate that the Swiss bread variety better allows for bread production than do other triticale varieties. However, that variety cannot be exported because of its registration as a "niche variety" in Switzerland. On the other hand, triticale bread baking seems to be possible only in artisanal bakeries, which, in contrast to industrial bakeries, can adapt their production on a case-by-case basis.

However, even for artisanal bakeries using the Swiss variety, baking triticale bread remains a challenge due to unfavourable dough properties. An easy solution is to blend the dough with wheat, but this can reduce marketing possibilities by altering the taste or shelf life. Another solution is to reduce the knowledge gap between quality parameters (like falling number or sedimentation value) and possible food sector applications. Additionally, understanding the relationship between quality parameters and triticale genes could be beneficial to meliorating baking properties. Marketing triticale bread is currently as challenging as baking it. Careful attention should be paid to consumers' perceptions of triticale. Consumers might negatively perceive triticale as feed crop or associate it with genetically modified organisms, since triticale is a "human-made" breed.

The Swiss study represents the only case in which triticale is used as food. This analysis points to multiple factors that are relevant to the implementation of a new food chain: the triticale variety was bred by a biodynamic breeder; in the organic sector, greater crop diversity is part of the cropping system; the organic processing sector is used to dealing with smaller batches; and the motivation to grow a triticale variety for use in baking, as well as to actually bake the bread, is probably to a large extent intrinsic (based upon interest and meaningfulness). This framework, supported by good networking and communication among stakeholders, can promote new products from underutilised crops.

The greatest assets for increasing triticale use as food are probably the well-developed downstream segments of the feed value chains and triticale's similarity to other cereals, which allows farmers and primary processors (mills) to handle it in a very similar fashion. Some countries have breeding programs, and the seed supply seems stable. Challenges to increasing use are, as mentioned above, related to secondary processing (like bread baking) and marketing (perceptions of triticale). To address the challenges in processing triticale, on the one hand breeding should focus more on the suitability of triticale for bread making. On the other hand, processing techniques could be further developed. However, triticale's positive characteristics should be employed to offset these negative perceptions and increase interest in the crop. For example, the taste and shelf life of triticale bread can be promoted, as can sustainability aspects related to triticale (low-input, resistant to drought, low requirements, etc.), especially in comparison to wheat.

# 7. HULL-LESS BARLEY

## 7.1 Background: Hull-less barley

Hull-less or naked barley (*Hordeum vulgare* L. var. *nudum Hook*. f.) is a variety of domesticated barley belonging to the Poaceae family. Its main feature is a hull that is much easier to remove. This imparts superior dietary quality because fewer nutritious layers are lost in processing (Aldughpassi et al., 2016). It is considered an ancient grain for human consumption, but the fact that the hull is easy to remove makes hull-less barley an interesting option for use as pig and poultry feed. Several other uses of hull-less barley as whole grain or in value-added products have also been considered (Bhatty, 1999a, 1999b).

Since hull-less barley is not differentiated from other barley types in production statistics, we refer in this section to the statistical category as simply barley (for example, when we discuss barley's importance in Europe). It is important to note that the share of hull-less barley in the barley data presented is probably very small.

### 7.1.1 History and distribution

Barley (*H. vulgare*) is thought to have been domesticated in the Fertile Crescent and to be the ancestor of wild barley, *Hordeum spontaneum*. The mutation causing barley to be hull-less would have occurred after the domestication of *H. vulgare*. The cultivation of hull-less barley is said to be almost as old as that of hulled barley, but it is less common because it gives lower yields and because breeding has been neglected in Europe, especially in contrast to Asia (Dickin et al., 2011; Siebenhandl-Ehn et al., 2011).

Hull-less barley production is much higher outside Europe, and this is reflected in the lack of statistics on hull-less barley cultivation in Europe. The highest production identified is in Canada, with 800,000 t on about 325,000 ha in 1998 (Bhatty, 1999a).

### 7.1.2 Cultivation

Hull-less barley is grown in the same way as barley, as a winter crop or spring crop. It is known for its great adaptability to unfavourable climates and soils; for example, it can grow in both the Himalayan Mountains and in the dry lands of North Africa (Aldughpassi et al., 2016).

### 7.1.3 Nutrition

In general, hull-less barley contains 13–18% protein, 60–70% starch, 4–8% β-glucan, 12–17% total dietary fibre and 3–6% soluble fibre. In comparison with hulled barley, hull-less barley contains more protein, more starch and more total and soluble β-glucan, and it has a higher content of limiting amino acids, like lysine and threonine, than are present in wheat or hulled barley (Bhatty, 1999a, 1999b). Found in oats as well, β-glucans are said to lower cholesterol levels and blood glucose concentrations, potentially reducing the risk of cardiovascular disease and diabetes (Sima et al., 2018). Hull-less barley is considered to be the richest grain source of β-glucans (Aldughpassi et al., 2016).

### 7.1.4 Uses as food and feed

Hull-less barley can be consumed as flakes, as porridge, as entire grains in soup, in bread, etc. Generally, it can replace barley in all food and feed products.

Hulled barley is often used for feed, particularly where maize does not grow well. However, hull-less barley is less common as feed in other parts of the world than it is in Canada. There, hull-less barley is primarily used to feed monogastric animals like swine and poultry (Bhatty, 1999a). Multiple studies seem to show that the hulls could decrease the energy and protein digestibility, conferring an advantage over hulled barley (Bleidere & Gaile, 2012; Darroch et al., 1996; Thacker et al., 1988).

## 7.2 Background: Barley

Since hull-less barley is not differentiated in production statistics, we often refer in this section simply to barley[8]. In general, barley is similarly used for feed, malting and brewing. Figure 8 shows the harvested area of barley in Europe in 2019. Ireland leads the way in arable land allocation. Barley trade with partner countries is generally very low, which may explain the direct use of each country's production in the form of feed and/or malted, brewed or distilled products.

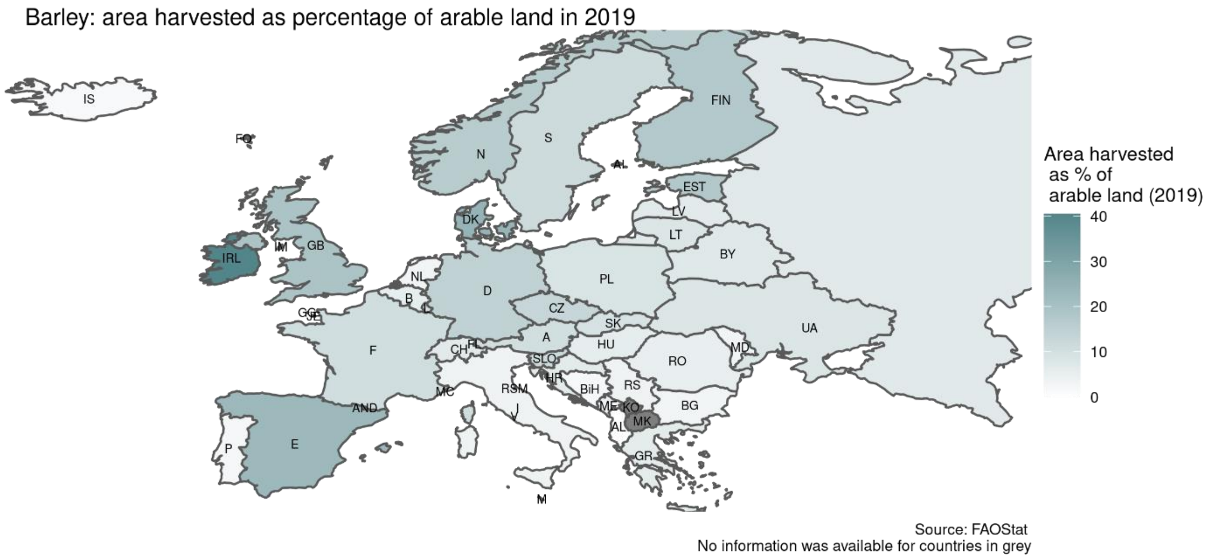


*Figure 8. Area dedicated to the growth of barley as a percentage of arable land in Europe in 2019.*

[8] One might well question the validity of using barley as a reference, since hull-less barley will probably only account for a small proportion of the total.

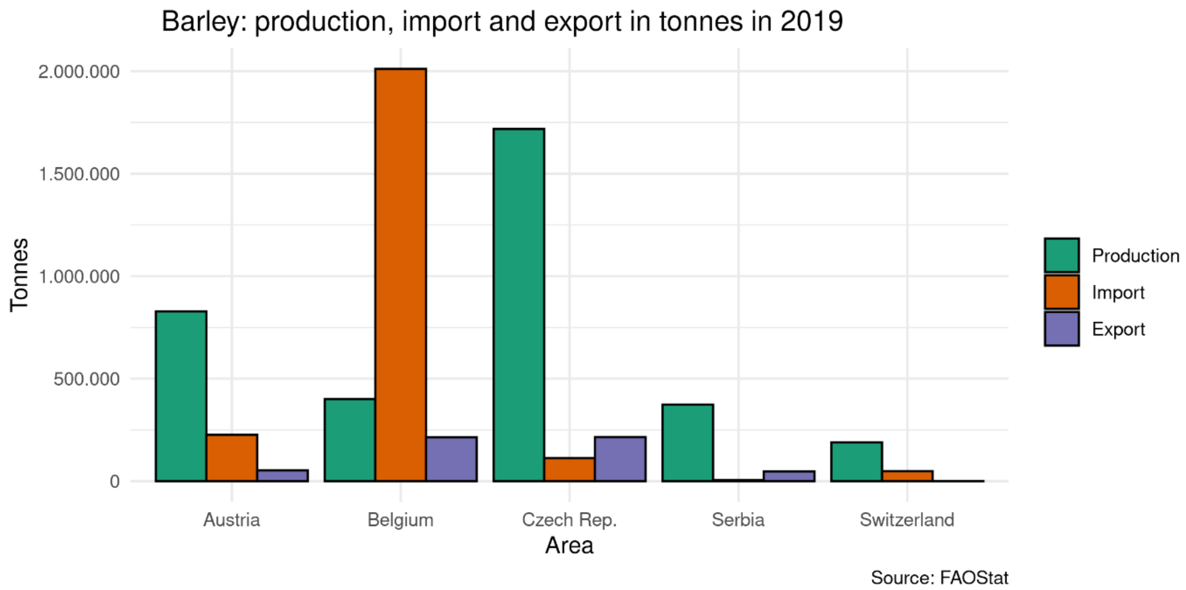


*Figure 9. Barley production, import and export for the five countries of this task in 2019.*

### 7.2.1 Uses of barley as food

In Europe, barley consumption has greatly decreased, being replaced by wheat or rice. Currently, it is mainly employed for feed (70%) and for malting, brewing and distilling (21%); less than 6% is grown for human consumption (the rest, 3%, is used for biofuel production; Tricase et al., 2018). However, barley for human consumption remains very important in other parts of the world, like Northern Africa or Asia (Baik & Ullrich, 2008). Barley consumption in Europe is very low, as can be seen in Figure 10, but there has been a clear renewal of interest in barley because of its nutritional properties.

Barley can be used as a whole grain, as pearled grain or as different flour types. Barley for human consumption can be integrated into different preparations, such as bread, pasta, noodles, tortillas, cookies and flakes. In Korea, it is used as a rice substitute and for the production of sauce and paste similar to those based on soybeans. In Middle Eastern and North African countries, barley is often pearled and used in soups, flat bread and porridge. In Western countries, it is often cooked in stews, soups or baby foods (Arendt & Zannini, 2013).

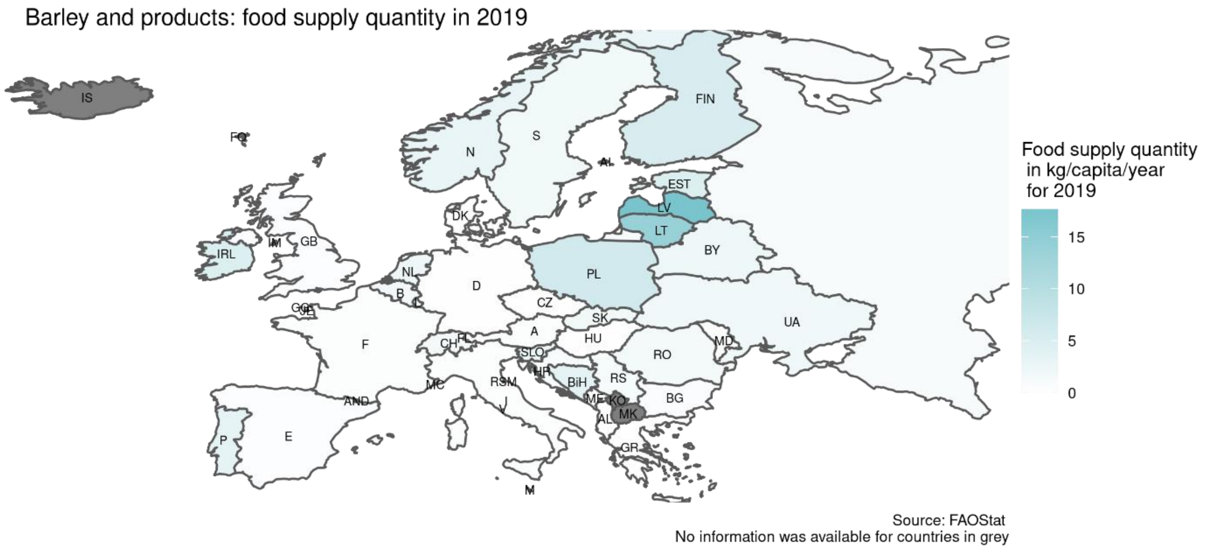


*Figure 10. Barley food supply quantity (proxy for consumption or demand) in kg/capita per year for European countries in 2019.*

Barley is well known for its usage in production of beverages. It was the first cereal used for beer brewing and can be used to produce whisky and other alcoholic beverages. For this, barley is used in the form of malt, which is also used in baked products, soft drinks, desserts, etc. Malt can be used to give colour, flavour and/or sweetness to products (Arendt & Zannini, 2013). Another beverage known in Europe is *caffè d'orzo,* which is a coffee-like mixture of malt and water. Similarly, barley tea is enjoyed in Asian countries.

## 7.3 Results from the case studies

### 7.3.1 Introduction

Value chain analyses for hull-less barley were conducted in Austria, the Czech Republic and Serbia. It is important to note that hull-less barley is generally very rare in Europe, including in the countries just mentioned. This is reflected in the lack of national cultivation statistics in Austria and the Czech Republic and in the lack of information for consumers on Serbian barley products, whether made with hulled or hull-less barley. The lack of national cultivation statistics for hull-less barley might be because it is a subspecies of barley, and perhaps Austrian and Czech national statistics do not differentiate their statistics between subspecies. Consequently, research teams were only able to conduct a limited number of interviews. Table 9 shows the number of interviews conducted by the research team in each of those three countries.

*Table 9. Overview of the interviews conducted for hull-less barley by each research team.*

| VC actor | AT | CZ | RS | Total |
|---|---|---|---|---|
| Input Suppliers[a] | 0 | 5 | 2 | 7 |
| Farmers | 3 | 2 | 1 | 6 |
| Collectors | 0[b] | 0[b] | 0[b] | 0 |
| Processors | 5 | 4 | 2 | 11 |
| Wholesale/Retail | 5 | 2 | 2 | 9 |

*[a] Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
*[b] Not relevant/non-existent/vertically integrated*

In Austria, there is no breeding program or large-scale seed production; thus, the research team was not able to conduct interviews with input suppliers. The collection centre stage is not relevant for hull-less barley, as producers handle their small harvests themselves.

### 7.3.2 Situation in the research countries

Hull-less barley is, as already mentioned, very niche in Austria, the Czech Republic and Serbia. Nonetheless, differences in the agricultural importance of hull-less barley can be identified. In **Austria**, farming trials have been attempted for breeding purposes. However, the produced breeds were not satisfactory, leading to a decrease in interest and cessation of the trials. No other research activities were identified. Few Austrian farmers are still producing hull-less barley, and the demand is low and stable. The majority of the inputs (seeds and products) are imported from German wholesalers and food processors. At each value chain stage (producer, food processor, wholesaler and small retailers), companies sell hull-less barley directly to consumers. Some retailers were solely relying on German hull-less barley (wholesalers) while others, smaller businesses or farmers, were selling domestic hull-less barley.

Breeders and researchers in the **Czech Republic** were the most interested in hull-less barley and aim to build a value chain. Two varieties were bred and are licensed by one research institute. This institute, as a value chain initiator, started or became involved in various food processing projects, including bread, puffed bread and pot barley. However, none of these products achieved any resonance in the private sector for commercialisation. Currently, only a few farmers produce hull-less barley, and no processing is available. Hull-less barley can be bought in small stores and health shops, but the origin of that barley is uncertain and probably foreign.

**Serbia** is the most advanced of the three countries regarding research and commercialisation of hull-less barley, although it has no tradition of growing hull-less barley. Serbian breeding programs by research institutes were successful at breeding three varieties in the 1990s. One large producer was identified; however, information on smaller producers was not available. Multiple companies are involved in processing. Products such as grain, flakes, porridge preparation, flour, semolina, pasta and bread are offered on the Serbian market and, thanks to a popular private nutrition program, ready-to-bake mixtures containing hull-less barley can be found in the retail sector. Due to their high β-glucan content, the health benefits of hull-less barley products could be emphasised with a health claim; however, this is not used in practice for marketing purposes. It is surprising that, for example, the ready-to-bake mixtures are not designated by such a health claim. In any case, as mentioned, consumers are not able to determine if the products are made with hull-less or hulled barley. The products are produced in small quantities and their availability is spatially variable. According to Serbian trade statistics, only small quantities of hull-less barley are imported from France and Hungary. In addition, small quantities are exported to Montenegro, North Macedonia and Bosnia and Herzegovina.

### 7.3.3 Inputs

In Serbia and the Czech Republic, research institutes were involved in breeding hull-less barley varieties. In Austria, on the other hand, hull-less barley producers need to rely on imported seeds from Germany. Czech producers are to some extent using German hull-less varieties, which are of higher yield than Czech seeds. Austrian and Serbian producers partly propagate their seeds themselves. In Serbia, self-propagation would hamper domestic breeding and seed production endeavours. Nevertheless, three new Serbian varieties are expected to be released in the near future, and some research has also been conducted in that country on the agronomic and food properties of hull-less barley. All research on this underutilised crop is bolstered by its similarity in cultivation, harvesting, processing, etc. are similar to those used for mainstream cereals.

### 7.3.4 Farmers

In general, only a few farmers were identified as producers of hull-less barley, almost certainly due to lack of sales opportunities in the three countries. Yields of hull-less barley are lower than those of hulled barley, and quality issues can be challenging. As hull-less and hulled barley prices are comparable, except perhaps for some Austrian farmers, harvesting lower quantities is not attractive. Opportunity costs and risks are hence important and might explain why producers are not cultivating hull-less barley.

In the Czech Republic, domestic market size was reported to be too small for producers. International trade is a target for at least one food company; however, the international market generally deals in very large quantities, and there are insufficient organic producers. In Austria and the Czech Republic, organic certification seems to be an important prerequisite to finding sales markets for hull-less barley.

### 7.3.5 Collectors

As hull-less barley is not produced in large quantities in the three countries, collection centres are not relevant in any of these value chains. The harvested products are sorted and cleaned by the producers themselves. The lack of collection centres can be crucial in building up a value chain based on underutilised crops.

### 7.3.6 Processors

Except for in Serbia, there were no industrial or artisanal companies involved in hull-less barley processing, although some pilot projects from research institutes had been conducted in the Czech Republic. These utilised hull-less barley to make bread, puffed bread and pot barley; however, no commercialisation emerged from these projects. Explanations for this disappointing result were lack of interest from companies or/and lack of organic producers able to deliver high-quality hull-less barley in large quantities. In Austria, some food processors, including a brewery, stopped producing hull-less barley products. Production was primarily halted due to flavour issues, although there were also quality concerns.

In Serbia, primary processors (responsible for dehulling and milling) have been challenged by a fraction of hull-less barley grains that do not dehull well. The unhulled hull-less barley grains require additional dehulling; however, the soft hull remnants do not sufficiently protect the grain during this step. Thus, the grains are broken into several parts, which lowers their quality and reduces the interest of secondary processors. In Serbia, almost all processors are using domestic hull-less barley in parallel with industrially dehulled barley.

### 7.3.7 Retailers

Some Austrian retailers have been importing hull-less barley products from Germany, whilst others buy domestically. One wholesaler who imports from Germany sells it to small retailers, mainly health shops. Domestic hull-less barley can be found at farm shops, and some small shops retail hull-less barley as groats. However, the origin of these groats is unknown, and they are likely to be imported. In Serbia, as in Austria and the Czech Republic, no large retail chains were selling hull-less barley, although Serbian consumers can buy it in certain bakeries or health shops.

Demand for hull-less barley is reported to be low, and it is unclear to many value chain actors how much growth hull-less barley products will experience in the long term. However, interesting potential marketing aspects could be helpful, such as health and environmental consciousness, regionality, veganism and wheat substitution. The β-glucan content is particularly important for marketing since this offers an unique selling proposition. β-glucan content is higher in hull-less barley because dehulling is not necessary. Only a gentle polishing of the hull-less grain is needed, which preserves nutrients. In general, it is possible to designate products with a health claim if they contain β-glucan in the amount present in hull-less barley products (Harland, 2014). In Serbia, however, health claims are not utilised in practice in the marketing of the products. In general, there is a lack of health benefits promotion, of recipes and cooking tips for hull-less barley. It is still an unknown crop to the general population and is not traditionally used in the three countries. Unfortunately, no form of hull-less barley promotion or advertisement was identified.

### 7.3.8 Summary

The hull-less barley value chains appear to be immature. The lack of national statistics reflects this classification as well as the knowledge gaps of consumers on barley products. The public sector seems more involved in Serbia and the Czech Republic, in which some level of research or breeding was identified, than in Austria. Serbian and Czech varieties are bred, while Austrian hull-less barley producers rely on imported seeds from Germany. In the Czech Republic, however, food development research on hull-less barley does not seem to have reached the private sector for large-scale commercialisation.

Yields of hull-less barley are lower than those of hulled barley, reducing the attractiveness of the crop. This yield disadvantage can be reduced or compensated for by higher prices, as is the case in Austria. The general demand for hull-less barley is low in all markets included in this task, and this lack of demand has caused farms to give up on growing it. Hull-less barley is mostly sold in health shops or in farm shops instead of in large supermarkets. Marketing potential is nonetheless significant, mainly because of the β-glucan content of hull-less barley. However, not enough promotion of the health claim has been done, which explains why consumers and other value chain actors are not aware of the health and other benefits.

Prior attempts to establish a market for barley, as recorded in the analyses, started from individual stages of the value chain. A coordinated attempt to establish barley on the market across several stages could not be identified in the countries under consideration. In light of the experiences so far in processing hull-less barley (Agu et al., 2009; Kinner et al., 2011; Meints et al., 2021), such a coordinated approach would help to address the challenges at the production stage and significantly aid in providing information on the benefits (Bhatty, 1999a) and uses of barley to processors and consumers.

# 8. LUPIN

## 8.1 Background

Narrow-leaved or blue lupin (*Lupineus angustifolius* L.) is a species of lupin belonging to the Fabaceae family. This legume is rich in protein and is a potential meat alternative and its symbiosis with certain bacteria, which allow legumes to fix nitrogen in the soil, makes lupin a good candidate to replace soybeans in animal feed. Lupin production, still minor in Europe, amounted to just under 400,000 tonnes in 2019. In comparison, just less than 11,700,000 tonnes of soybeans were produced in the same year in Europe (FAOSTAT, 2022).

### 8.1.1 History and distribution

Known since the Neolithic period, lupin was domesticated and used by the first civilisations around the Mediterranean region (Cowling, 2001). It is frequently found in wild forms in many regions, but the Mediterranean region is still one of the major centres of agricultural lupin diversity today (Cowling, 2001).

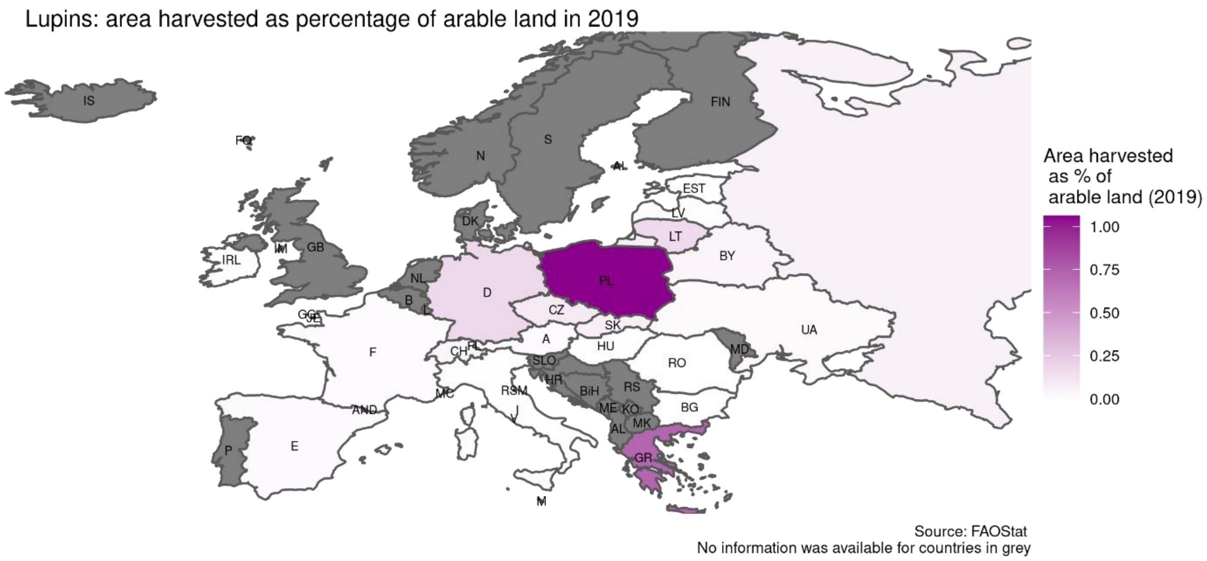


*Figure 11. Area dedicated to the growth of lupin as a percentage of arable land for European countries in 2019.*

In 2019, the area under lupin cultivation as a percentage of arable land was highest in Poland and Greece; however the area is still low, and it represents in fact less than 1.5% of arable land (Figure 11). Focusing on the production and import/export data of countries in this task, the Czech Republic produced around 3000 tonnes in 2019, making it the most important producer, while production quantities in Switzerland and Austria were both below 500 tonnes (there is neither FAO data nor 2019 import/export data for Belgium and Serbia; see Figure 12).

### 8.1.2 Cultivation

Lupin is a legume planted around March to April in the northern hemisphere and harvested in August. It is a cool-season crop that is tolerant to spring frosts. Lupin prefers medium-heavy to deep sandy soils. It thrives in the same growing areas as maize (Böhler & Dierauer, 2011). As a legume, it combines with bacteria of the genus *Bradyrhizobium* to fix nitrogen in the soil, making lupin an interesting crop to include in a crop rotation (Pueyo et al., 2021).

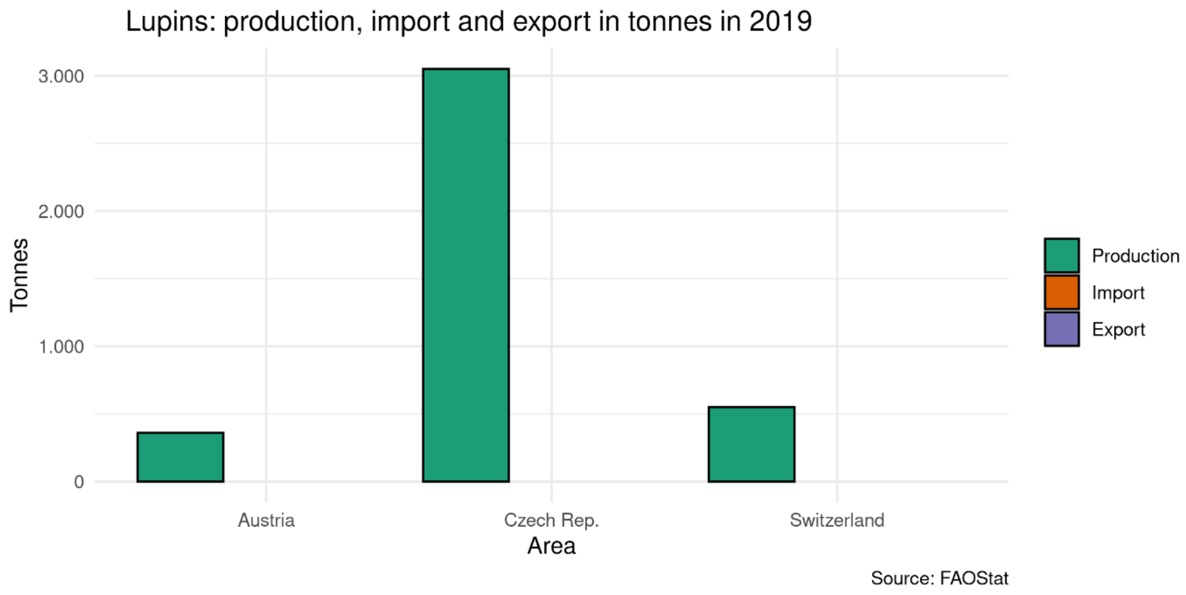


*Figure 12. Lupin production, import and export for three countries of the task for 2019. Data about trade and for Belgium and Serbia were not available.*

### 8.1.3 Nutrition

*L. angustifolius* varieties are a good source of nutrients, and on average the 906 g/kg dry matter consists of about 33% protein, 6.8% fat, 14% fibre, 3.7% ash, 42.5% nitrogen-free extract and 0.065 % alkaloids (Sujak et al., 2006). Lupin, in general, is rich in threonine, lysine and tryptophan, but has low methionine content and only small amounts of other sulphur-containing amino acids (Mukisira, 1994). The presence of anti-nutrients, such as alkaloids, protease inhibitors, lectins and saponins, may have a detrimental effect but may also have medicinal properties (Knecht et al., 2020). Some people may be allergic to lupin, for which reason it has been declared an allergen (Smith et al., 2004).

### 8.1.4 Use of lupin

Thanks to its protein content, lupin is mostly used as animal feed. It would be able to replace soybean for this purpose, although breeding efforts regarding yield stabilisation, resistance to biotic and abiotic stresses, biochemical structure associated with seed quality and late maturing should be made to increase its potential as an alternative protein source (Abraham et al., 2019). *L. angustifolius* can be grazed green or as stubble (after harvest of the seed) by ruminants, but it could also be used as silage or hay (Heuzé et al., 2019).

Lupines are very popular in South America, where they are eaten in the form of ceviche, known in Ecuador as “Cevichochos”. Cooked and pickled, lupin seeds can also be eaten as a snack or appetiser, like olives or pickles. In this form, they are called “Tremoços” in Portugal. In Europe and Australia, lupin flour is sometimes added to wheat flour to improve taste and create a richer, creamier colour.

Lupines are often used in vegan alternatives to meat and dairy products, and new products based on lupines have emerged in recent years, such as lupin ice cream or lupin drink. The market for sweet lupines (sweet because alkaloid-free and therefore suitable for human consumption) is expected to grow from 2022 to 2032, according to a report by Future Market Insights (2021).

## 8.2 Results from the case studies

### 8.2.1 Introduction

Value chain analyses for lupin were conducted in Austria, Belgium and Switzerland. Research teams from Belgium and Switzerland looked at both food and feed value chains, while the Austrian research team investigated only a food value chain. Table 10 reports the number of interviews performed by each research team.

*Table 10. Overview of the interviews conducted for lupin by each research team.*

| VC actor | AT | BE | CH | Total |
|---|---|---|---|---|
| Input suppliers[a] | 1 | 4 | 9 | 14 |
| Farmers | 1 | 3 | 5 | 9 |
| Collectors | 0[b] | 0[b] | 3 | 3 |
| Processors | 5 | 4 | 4 | 9 |
| Retail | 0[b] | 3 | 4 | 7 |

[a] *Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
[b] *not relevant/non-existent/vertically integrated*

In the three countries, lupin cultivation and commercialisation of food products is marginal. Only a few producers are cultivating lupin; production seems to be much more important in the organic sector. However, this study identified interest from farmers, food processors and researchers.

### 8.2.2 Situation in the research countries

In **Austria**, legume production has declined in recent years, and lupin is only marginally produced, although it was grown on a larger scale during the 2000s. This decline is explained by the disease anthracnose, by low productivity driven by seasonal variability and by low prices, which are the result of EU policies favouring soybean importation. There has recently been a resurgence of interest in this crop thanks to new sustainability trends and the breeding of anthracnose-tolerant and -resistant varieties. Lupin cultivation is mostly located in Upper Austria, where pedo-climatic conditions are more favourable (sufficient precipitation and acidic soils) and it is a governmentally subsidised crop that is sometimes called “the soybean of Mühlviertel” (a part of Upper Austria). The research team investigated value chains of processed products, such as lupin coffee and a spicy sauce. Other available products include lupin yoghurt, lupin coarse meal and lupin sugo.

In **Belgium**, no registered farmers produce lupin, and no large-scale commercial value chains were found. However, researchers identified several food and feed processing companies that use lupin from imported sources. One food processing company integrates lupin into bread mixes, which are sold to bakeries. Another uses lupin as a meat alternative and sells it to local and organic stores. The feed processing company integrates Australian lupin into lupin-based feed components, which are sold throughout Europe.

In **Switzerland**, lupin became important in the 2000s because of the breeding of sweet varieties and the implementation of a crop-related subsidy. However, the emergence of anthracnose and the related drastic declines in yield almost entirely halted lupin cultivation. As in Austria, the introduction of anthracnose-tolerant and -resistant varieties enabled Swiss lupin cultivation to resume. Still, no large commercial food value chain was identified, and only a few Swiss farmers are currently producing lupin. Regarding the feed value chain, the organic sector is fostering demand for Swiss protein, which has encouraged lupin cultivation. Lupin seems more important in the organic sector for both the food and feed value chains.

### 8.2.3 Inputs

In all three countries, lupin varieties are imported from other countries, mainly Germany, Poland and France. In Switzerland, an organic research institute began breeding white lupin; however, commercialised varieties are not expected to be released for at least 10–15 years. In Switzerland, only very few seed producers are propagating lupin seeds and most are imported. In Austria and Switzerland, few issues relative to seed supply reliability were mentioned, although farmers in both countries do not always receive their preferred varieties. In Switzerland, deliveries of lupin seeds were sometimes too late in the season, and inoculum[9] availability has been challenging in recent years. Swiss seed production could enable a reliable seed supply for Swiss farmers; however, tariff protection for legume seeds is different from that of cereal seeds (and much lower), so legume seed production is not attractive to Swiss seed producers.

Very little lupin research has been conducted in Belgium and Austria. In addition to breeding white lupin, the Swiss organic research institute is also conducting agronomic trials and marketing research and has recently established an innovation network with different value chain actors who are interested in lupin.

### 8.2.4 Farmers

As mentioned above, no registered Belgian farmers are currently producing lupin. Swiss and Austrian farmers seem to face similar challenges and share common characteristics. They are interested in the sustainability and agro-environmental benefits of lupin, such as its nitrogen fixation. However, these farmers are confronted with issues regarding cultivation, for example weed control, harvest timing or weather variability, which increase uncertainty about obtainable yields. In Austria, seed quality is an issue due to impurities and low germination rate, and the variability of alkaloid content in sweet lupines is another challenging issue. Swiss farmers who directly market their lupin were unsure if there were testing possibilities in Switzerland. Some farmers sent their lupin to Germany for testing and noted the associated costs. In Austria, value chain actors complained that they have to wait so long for the test results.

Austrian and Swiss farmers also face similar post-harvest issues. Austrian collection centres do not want to handle small batches of a crop, so they refuse to collect lupin. Swiss farmers are to some extent better off than their Austrian colleagues, as there are a few Swiss collection centres that collect lupin. Some Swiss and Austrian farmers need to invest or rent appropriate machines for drying and cleaning the lupin themselves (or outsource the process), which can be a limiting factor for farmers.

The public sector has some level of importance in the Austrian and Swiss markets. As mentioned, lupin is a subsidised crop in Austria, and in Switzerland: direct payments are paid for the cultivation of legumes (payment per hectare). In Switzerland, that direct payment is currently only granted for legumes destined to be used as animal feed, but this will change on 1 January 2023, when it will begin to be paid for legumes used for food production. However, this economic incentive will not be decisive if other challenging matters are not resolved.

In the Swiss feed sector, not only the public sector but also the organic one is incentivising farmers to produce lupines. Since 2022, all feed used for ruminants on organic farms must be of Swiss origin. Consequently, the organic sector has organised a redistribution of prices. In a transparent manner, a deduction will be made from the reference price for all Swiss organic feed grains; feed lupin and soybean

[9] Inoculation of plants and growth media (e.g. soils) with non-pathogenic microorganisms, e.g. mycorrhizal fungi (Mycorrhiza) or Rhizobium. The latter are soil bacteria that live in symbiosis with leguminous plants and can bind atmospheric nitrogen.

are granted an incentive premium. This focus on national production must be seen in the context of the trend towards sustainable, local agriculture and the closing of cycles. A strengthening of these approaches and the corresponding design of agricultural policy framework conditions can fundamentally change the growing conditions for underutilised crops.

For farmers, lupin cultivation is very challenging due to weather variability, limited knowledge and research and a lack of adapted varieties – except, to some extent, in Switzerland. A lack of sales opportunities and collecting centres willing to accept lupin are other reasons for low cultivation in these countries. A few Austrian and Swiss farmers have found niche markets thanks to contacts with food processors (only in Austria) or with specialised shops ("ZeroWaste", organic, local, health shops), but demand quantities are low. Dealing with alkaloids, which can impart a bitter taste, and the related uncertainty about testing possibilities are additional challenges that require further attention.

### 8.2.5 Collectors

Collection centres are not relevant in Belgium, as no production is happening. In Austria, the cooperatively managed collection centres are not willing to collect lupin because the quantities being produced are too small. Some Swiss collection centres collect lupin, but the low production volume leads to similar challenges related to collection – a minimum quantity is in general required to fill drying machines (at least for bigger collection centres). With small batches, there is also the risk of commingling with other products during collection, storage and processing. This issue is not as relevant when working with large quantities, but when a small batch of lupin is mixed with larger batches of other crops, the former might get too "diluted".

Bitter alkaloids are a significant challenge for collection centres because they can contaminate other products. In addition, collection centres generally do not have essential knowledge about handling alkaloid content or testing for it. Besides possible alkaloid contamination, another challenge is the allergic nature of lupin, which must be clearly declared. Alternatively, collection centres can separate lupin from other crops in their machines to limit contamination with allergens and alkaloids, the process for which can incur additional costs.

### 8.2.6 Feed processors

One important Swiss organic feed mill meliorated transport distance challenges by cooperating with different collection centres. This demonstrates a higher degree of vertical coordination between feed value actors than is evident in Belgian and Austrian markets, and that cooperation enables a more expansive distribution of collection centres across Switzerland and a higher collection capacity for the feed mill. Swiss organic standards are increasing demand for local protein; hence, feed mills are processing Swiss lupin into organic feed mixtures.

To produce feed components, one Belgian feed mill relies on imported Australian lupines due to their superior and more stable nutritional quality; however, price volatility and logistics issues are challenging for the mill. After arriving by boat, the Australian lupines are cleaned and processed before being sold to European feed companies. The main advantage of using lupin in feed is its high protein content; its low iron content would also be beneficial to the marketing of some types of meat. This is because a high iron content in feed leads to the final product having a deeper red colour (for some types of meat, such as veal, this is undesirable). However, iron undernutrition for the purpose of obtaining whiter meat is controversial, as it is detrimental to, for example, the calf's health (Gygax et al., 1993).

Overall, the presence of alkaloids and the allergen declaration are not problematic for the production of feed mixture. Lupin makes up only a small percentage of feed mixtures, in which it is diluted with other crops. Recommended alkaloid thresholds are also lower for animals than for humans.

### 8.2.7 Food processors

In general, use of lupin in the Austrian, Belgian and Swiss food industry is novel. Austrian food processors already produce multiple lupin products, including coffee, spicy sauce, coarse lupin and sugo (for chili or soup). Austrian food processors are challenged by volume and quality fluctuations caused by a decrease in Austrian cultivation and weather variability, which influences lupin quality. The organic association BioAustria registers farmers offering lupin in order to connect up- and downstream sectors. Overall, Austrian food processors did not find processing lupin to be challenging.

In Switzerland, however, milling lupin into flour was considered relatively difficult, as the fat content of the lupin was reported to make it sticky in the milling machines. These processing difficulties might be more related to the process itself than the national company involved. Processing lupin into, for example, lupin coffee is not challenging, as the process is very similar to that for regular coffee.

Bitter alkaloids remain a challenge, not only for farmers but also for other value chain actors. For example, Austrian food processors complained about the waiting times before receiving their alkaloid test results. Reducing alkaloid content, besides breeding even sweeter varieties, is possible at the food processing level. Production of protein isolates[10] is an option; however, this is rather costly and high volumes are required to be profitable. Watering the lupines is another option that has already been implemented in other countries. This is less expensive than isolating protein, and all parts of the lupin are used. In any case, further investments are also required for watering lupines.

Alkaloids are challenging not only because they can pose a danger to human health and are weather variable but also because they taste very bitter. For processed products, such as meat alternatives or spreads, that bitterness can be balanced by using spices. For other products, like lupin coffee, lupin drink or sweet products, masking the bitter taste is more difficult. Spread and hummus are cheap products that require neither high-quality lupines (regarding colour, grain size or form, etc.) nor advanced technology.

It is required by law (regulation (EU) No 1169/2011) that the allergenic nature of lupin is declared. Some food companies refuse to include lupin in their production because it is listed as an allergen. They fear the additional costs needed to maintain the allergen safety of lupin-free products.

For companies, obtaining certain certifications can be very beneficial. Some Austrian food processors, for example, target the organic, vegan and/or gluten-free certification to improve their marketing capabilities.

### 8.2.8 Retailers

Austrian retailers of lupin products are various: supermarkets, drug stores, organic stores, farm shops, health food stores and restaurants. In Belgium, only organic food stores sell lupin. Swiss consumers can find lupin products in organic shops, small shops, "ZeroWaste" shops and farm shops.

The advantageous marketing characteristics of lupin products, such as regional production, high-protein content and plant-based origins, are in line with the high-protein, vegan, vegetarian, local and sustainable trends. It can be certified gluten-free, vegan and organic. Lupin coffee is caffeine-free and can be locally grown. Lupin also has some advantages over soybean: it is considered a local crop ("Northern soybean") and is not associated in the media with unsustainable practices (e.g. deforestation

[10] Isolated protein obtained by separating the protein from protein concentrate. Protein isolate is produced industrially in large quantities, mainly from soy (soy protein isolate) and milk (casein; whey protein).

in the Amazon) or, due to certain molecules, with cancer risks[11]. However, consumers lack knowledge about lupin and how to prepare and cook it properly.

### 8.2.9 Summary

Overall, lupin has great potential because of its high protein content and the agro-environmental benefits of its cultivation. However, its importance is still marginal in the three research countries for reasons that are manifold and concern all stages of the value chain.

Breeding is currently only occurring in Switzerland (resulting varieties are expected to be available in 10–15 years), so the varieties used in the three countries are not those that are best adapted to the area. In addition, seed supply is not reliable. Farmers get other varieties than those they asked for and deliveries sometimes arrive late. Also, research is still scarce, meaning farmers lack the knowledge necessary for successful cultivation. Weed control and harvest timing are challenging, and lupin displays significant weather variability. Uncertainty about yields and lupin quality is challenging for farmers, which reduces the crop's attractiveness.

Lupin quality is directly related to alkaloid content, which is challenging to measure and weather-dependent. If weather reduces lupin quality, it is declassified to feed, which jeopardises profitability for the farmer. Different aspects can play a role in decreasing alkaloid levels, including breeding and food processes. However, these solutions require investment and might be costly. As different value chain actors are concerned by the alkaloids issues, a strategic planning and coordination of the actors should be required. Testing for alkaloids is sometimes time-consuming or costly, so improved coordination and cost distribution could enable more efficient handling. For example, it should be decided at which stages alkaloid levels will be tested, as well as how and how often, in order to minimise costs and maximise food safety and quality.

After harvest, farmers must either find a collection centre or rent or invest in machines for drying and cleaning. Collection centres may refuse lupin because of alkaloid content, the allergen declaration or because the harvest volume is too small. Lack of pre-processing of lupin is a limiting factor for farmers; organising into collectives or buying machines collectively is an option for overcoming this limiting factor. Localised lupin cultivation (e.g. in Upper Austria) is an opportunity for farmers to organise themselves horizontally.

Food processing companies face challenges related to upstream issues. The quality and quantity of lupin fluctuates in Austria. The demand for high quality lupins often exceeds the supply. Belgian food processors rely on imports, which might represent an opportunity for domestic lupin cultivation development. However, this would require adapted varieties and further education regarding lupin cultivation. Regarding processing, it seems that success depends mostly on the type of final product. For example, processing lupin into lupin coffee seems less challenging than into lupin flour. In general, further research and development should address potential inexperience with lupin and the lack of adequate technology for its processing.

Feed mills are less impacted by challenges related to quality issues or high alkaloid contents, as lupin can be diluted in feed mixtures. For the Belgian feed mill included in this task, this is because they import Australian lupines, which are of superior and more stable quality. Australian lupines are, however, subject to price fluctuations and logistics issues, representing another potential inroad for Belgian cultivation. Swiss feed mills, because of new organic regulation for ruminants' nutrition, face more issues related to the availability of Swiss organic protein crops.

[11] Isoflavones in soybean have oestrogenic properties, and they have been blamed for lowering testosterone levels in men and raising the risk of breast cancer in women. However, soybean seems, rather, to protect against cancer risk, but the reasons behind this have not been clearly elucidated (Brown, 2019).

Various research projects and demonstration projects have dealt with the cultivation and use of lupines in feed and food. For example, a network of demonstration farms in northern Germany developed business strategies for the use of lupines over a period of five years (Koch & Schrage, 2019). The aim was to demonstrate the successful cultivation and utilisation possibilities of this demanding protein crop. The results were incorporated into the recently completed “Supporting the production and use of grain legumes” (www.legumestranslated.eu/). In Northern Germany, a company processes 2000 t of lupin seed yearly and is looking for lupin farmers (Gesellschaft zur Förderung der Lupine, 2021). These are just two examples of many recent projects in the field of legumes. When developing products based on lupines, the results from former and ongoing projects should be analysed and considered, with a special focus on countries that were not covered by this analysis. Overall, the public sector is incentivising lupin cultivation in Switzerland and Austria, and these incentives might be a first step towards enhanced lupin utilisation. However, many issues need to be addressed before this becomes a reality. Another marketing-related issue faced by retailers is the lack of consumer awareness of this crop. Consumers must be informed about lupin and know how to prepare it or have convenient products available if they are to buy it. On a positive note, the marketing potential for lupin is significant: not only does it have a better reputation than does soybean, but also it responds to current vegan, vegetarian, sustainable, regional and high-protein trends.

# 9. FABA BEAN

## 9.1 Background

Faba bean (*Vicia faba*) is an annual legume species also known as fava bean, horse bean, broad bean, etc., depending on the subspecies[12]. It belongs to the Fabaceae family and can fix atmospheric nitrogen in the soil through symbiosis with bacteria. According to FAOSTAT, faba bean production amounted to more than 1.5 million tons in 2019, making faba bean the third-most produced legume in Europe, behind soybean and pea (Kezeya Sepngang et al., 2020). Just under 500,000 tonnes were exported and 250,000 tonnes were imported by all European countries in 2019.

### 9.1.1 History and distribution

Faba bean is thought to be one of the founder crops of the Near East; however, its wild ancestors are unknown (Kosterin, 2014). Faba bean was a common crop in Europe in the Middle Ages (Die Ottonenzeit, 2020). This is because of its low cultivation requirements, high nutritional value and the storability of the dried beans. The cultivation of garden beans and potatoes displaced the faba bean, so that today it is mainly used as a fodder crop in Europe and around the world. Exports outside the European Union are mainly destined for the food market in Egypt and the fish feed market in Norway (Kezeya Sepngang et al., 2020).

Looking at the arable area dedicated to faba bean production on Figure 13, Lithuania leads (2.5%), followed by the United Kingdom (2.25%) and Latvia (1.9%).

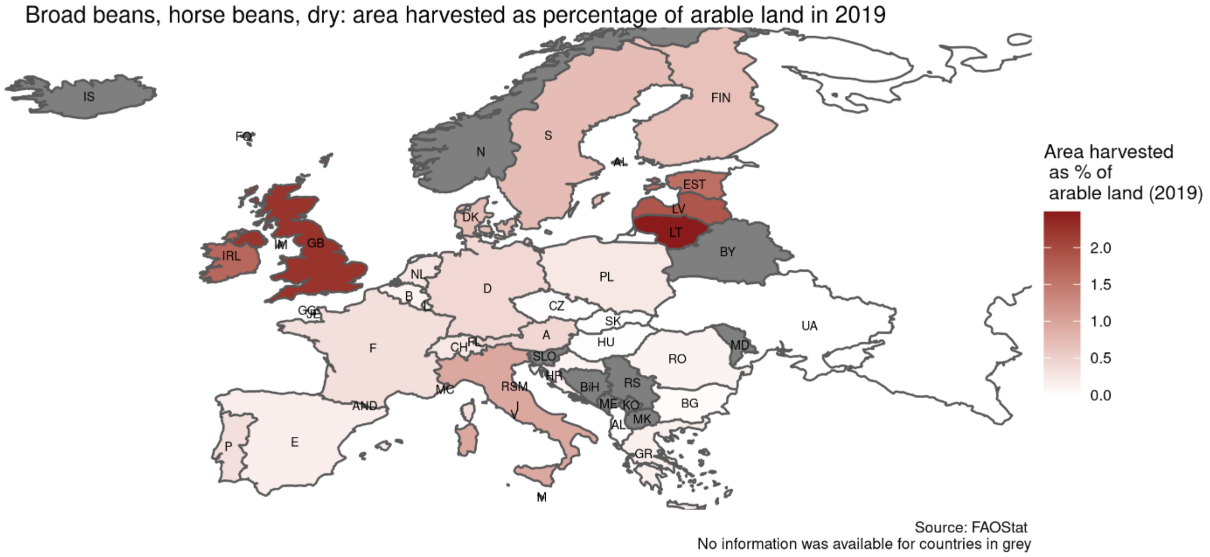


*Figure 13. Area dedicated to the growth of faba bean as percentage of arable land for European countries in 2019.*

In absolute production value, the United Kingdom ranks first, with a production of about 600,000 tonnes per year from 2014 to 2018. France, Lithuania and Germany follow with an average of about 215,000

[12] In this report, we will use the general name from the proposal, "faba bean". Bean size is useful for distinguishing between Vicia faba var. minor, horse beans or field beans, which produces smaller seeds mainly used as feed and V. faba var. major, broad beans, which produce large seeds that are mainly used for human consumption (Heuzé et al., 2021).

tonnes per year, 170,000 tonnes per year and 145,000 tonnes per year, respectively (Kezeya Sepngang et al., 2020).

Focusing on the countries in this task and on Figure 14 below, we can observe a great disparity between the different countries. Austria and Switzerland seem to be more focused on faba bean production, which does not seem to be as important in Serbia and the Czech Republic. For Belgium, the quantity produced, imported and exported is about the same.

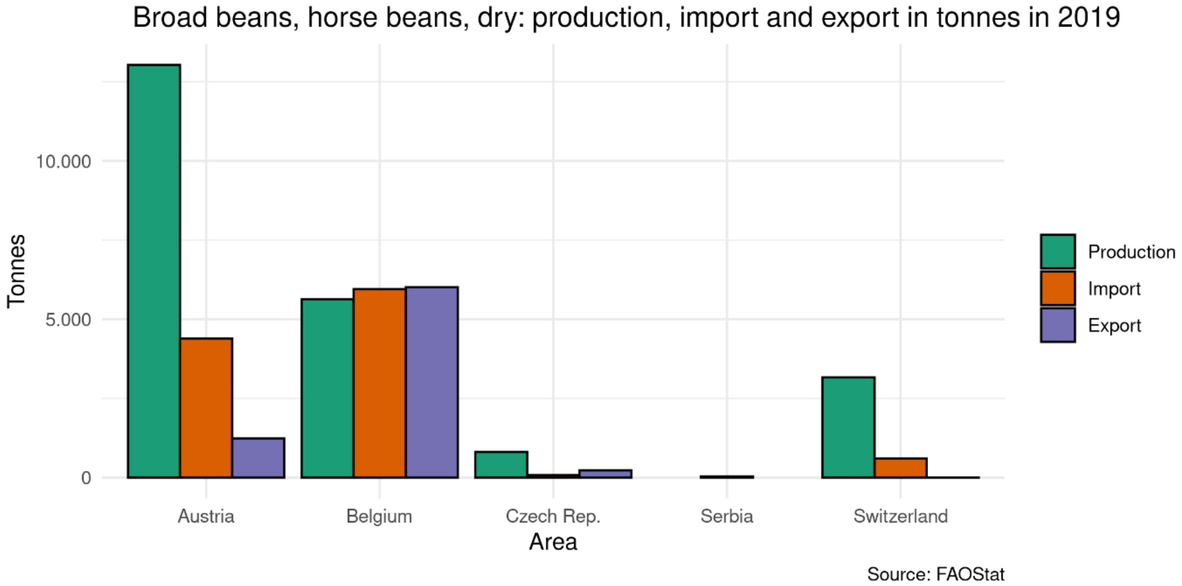


*Figure 14. Faba bean production, import and export for the countries of this task for the year 2019. Trade data was not available for Serbia.*

### 9.1.2 Cultivation

Faba bean can be sown as a winter or spring crop. As a legume, faba bean fits well into a crop rotation with cereals. It prefers heavy, calcareous soils and does not have high expectations regarding climate (Dierauer & Böhler, 2009). Faba bean likes 700 to 1000 mm of rainfall distributed over the growth season and can also be cultivated well on saline soils or previously flooded areas (Die Ottonenzeit, 2020; Muehlbauer & Tullu, 1997).

### 9.1.3 Nutrition

On average, faba beans contain 86.6% dry matter, which is 40–48% starch, 25–33% protein, 7–11% fibre and 1% fat (Heuzé et al., 2021). As a source of fibre, vitamins and minerals, faba bean has multiple health benefits (Ofuya & Akhidue, 2005). As with legumes, the sulphur amino acids (methionine and cysteine) and tryptophan contents are low, while the levels of leucine, lysine, aspartic acid, arginine and glutamic acid are high; the latter are generally low in cereals (Boye et al., 2010). The complementarity of grains and legumes in vegetarian and vegan diets is therefore significant (Mayer Labba et al., 2021).

Faba bean contains the alkaloids vicine and convicine, which can cause “favism” in people genetically deficient in a particular enzyme (Arese & De Flora, 1990; Mayer Labba et al., 2021).

### 9.1.4 Uses of faba bean

Faba bean can be used as hay, silage, or straw, or sometimes as green manure (Muehlbauer & Tullu, 1997). Feed varieties should be low in tannins, in vicine and convicine and in trypsin inhibitors (Heuzé et al., 2021). For ruminants, faba bean seeds are generally easy to digest, and they appear able to replace rapeseed feed contents without affecting the milk production or milk composition of dairy cows. Pigs appreciate faba bean, which is rich in protein and energy, although the anti-nutrient content may present a problem (Heuzé et al., 2021).

Faba bean can be used in aquaculture, e.g. for feeding salmonids such as rainbow trout or Atlantic salmon. Depending on the species of fish, the variety of faba bean and its processing, faba bean can make up 15–35% of the feed mixture (Heuzé et al., 2021).

In the human diet, faba bean is a staple food in Egypt, China, Ethiopia and other countries in North Africa and the Middle East. *Ful medames*, stewed faba beans, are often eaten for breakfast and supper or in sandwiches in the Middle East. Faba beans can also be eaten as *falafel* or *taamia* (bean cakes), or sprouted and made into soup (*fool nabet*; Askar, 1986).

In Italy, faba beans are sometimes eaten with pecorino cheese on May 1st in a meal called *Fave e pecorino*. In Sicily, they are eaten as a soup called *maccu*. More generally, faba beans seem to have been or remain a well-known ingredient in many cuisines, such as those of South America, Asia and Europe, and they can be eaten steamed or boiled, fried, roasted like peanuts, in soups, mashed, in falafels, etc. Faba beans can also be processed and incorporated into products such as bread, pasta and meat alternatives (Verni et al., 2019).

## 9.2 Results from the case studies

### 9.2.1 Introduction

Value chain analyses for faba bean were conducted in Austria, Serbia and Switzerland. Research teams in Austria and Switzerland looked at both food and feed value chains. Table 11 reports the number of interviews conducted by each research team.

*Table 11. Overview of the interviews conducted for faba bean by each research team.*

| VC actor | AT feed | AT food | RS | CH | Total |
|---|---|---|---|---|---|
| Input suppliers[a] | 3 | 1 | 2 | 7 | 13 |
| Farmers | 4 | 1 | 2 | 3 | 10 |
| Collectors | 1 | | 0[b] | 3 | 4 |
| Processors | 3 | 1 | 2 | 7 | 13 |
| Retail | 4 | 1 | 2 | 3 | 10 |

*[a] Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
*[b] Not relevant/non-existent/vertically integrated*

### 9.2.2 Situation in the research countries

Use of faba bean as feed has a long tradition in **Austria**. In the last 30 years, however, the harvested volume has declined by 70%. Austrian faba bean is mainly cultivated in Lower Austria and Upper Austria, though the area dedicated to its growth has also decreased in recent decades. Measures to strengthen Europe's self-sufficiency by encouraging the cultivation of protein-rich crops have fostered faba bean cultivation. Since faba beans are mainly cultivated organically – in 2019, the organic share of the Austrian faba bean cultivation area was 79.2% (BMLRT, 2021) – diseases (especially nanoviruses transmitted by aphids) and droughts have resulted in a sharp decline in organic faba bean cultivation. Additionally, the emergence of soybean has led to a competitive situation. In past years, little or no breeding of faba bean was conducted, and breeding progress is particularly lacking regarding resistance to nanoviruses. The value chain for faba beans as feed is relatively short due to the small market in Austria, noticeably shorter than the oats or lupin value chains. Seeds are imported, mainly from

Germany or France, because there is no Austrian seed company that produces faba bean seeds. Only a few farmers propagate the imported faba bean seeds, mainly for their own use. Up to now, faba bean products have been rare in supermarkets and available only in health food and specialty stores. However, starting in autumn 2022, new faba bean meat substitutes will be produced and listed in Austria.

In **Serbia**, faba beans are an ingredient in traditional dishes and thus part of the gastronomic tradition. Although once in wide use, after the Second World War faba bean was largely displaced by the common bean. Faba bean breeding is not currently being conducted, and farmers usually propagate their seeds themselves. Therefore, there are no downstream actors available in Serbia.

In **Switzerland**, there is also well-documented use of the faba bean up to the first half of the twentieth century. The crop was used in both human nutrition and as animal feed. Due to the growing importance of other crops and increasing international trade, the faba bean was gradually displaced. In a publicly supported project, old varieties from a seed bank were used to revive cultivation in the mountainous region of Grisons[13]. The beans are processed into semolina or flour, which is then used for the most part in upscale dining and to a lesser extent marketed in specialty stores.

### 9.2.3 Inputs

Austria, Serbia and Switzerland all rely on imports of faba bean seeds from France and Germany, where breeding is performed. In Serbia, faba bean breeding ceased in 2007. It is expected that seed demands will somewhat decrease due to competition from other legume crops, such as soy in Austria and Switzerland and lupin in Switzerland. An exception could be the organic seed market.

Import of seeds can be challenging due to the small national markets, which was cited as a reason for supply difficulties. Strict private organic standards in Austria do not allow the import of seeds sterilised by electron treatment, which in Germany is applied to faba bean seeds.

Furthermore, legal requirements for establishing a value chain on a non-licensed old variety can be challenging (Swiss case study), and the required registration has been reported to be complex and costly. However, the re-cultivation and maintenance of old varieties is currently being supported by a public program and a foundation dedicated to the preservation of the genetic diversity of plants and animals in Switzerland.

Public measures related to the breeding or researches of faba bean are marginal. In the current ERA-NET project ProFaba (https://www.suscrop.eu/projects-first-call/profaba), multiple European partners cooperate to develop improved faba bean breeding practices and varieties.

Seed propagation in Switzerland and Austria is no longer being performed, but private propagation is relevant in Austria and Serbia and for the Swiss food value chain. For most underutilised crops, propagation of seeds is disadvantaged in Switzerland, as the propagation of main crops is protected by tariffs. This makes the establishment of domestic faba bean propagation economically unattractive.

### 9.2.4 Farmers

Faba bean cultivation is a long-standing tradition in Europe. The general agricultural contributions of legumes, such as improving soil conditions via nitrogen fixation, diversifying standard crop rotations and producing plant-based protein, also apply to faba beans. This is common knowledge among farmers. However, the low competitiveness of faba beans compared to other legumes has resulted in decreasing cultivation in Austria and only slow growth (due to organic farmers) in Switzerland. The profitability of

[13] Grisons (Graubünden) is a Swiss canton situated in the East of the Swiss Alps.

faba bean cultivation is challenging because of the small market as well as because of the yield level and yield variation. Since demand from the downstream chain is low, faba beans are often used directly as fodder within agriculture.

In organic farming, the importance of faba beans is higher. First, organic cropping systems require higher crop diversity. Faba beans require a long cultivation period of about five years, which favours their integration into organic crop rotations. Second, closing nutrient cycles is more important in organic farming. In Switzerland, for example, the private organic standard requires a domestic protein supply for organic ruminants, which makes faba bean an attractive option. However, faba bean's susceptibility to nanoviruses, pests and weed competition can be challenging for organic farmers.

Public support for faba bean cultivation exists in Austria and Switzerland. This support can compensate for the disadvantage of economic inefficiency compared to other crops.

Faba bean's susceptibility to drought has been criticised in light of Europe's increasingly dry summers. This could be a critical issue in the expansion of faba bean cultivation.

Increasing the area of organic cultivation and measures to diversify crop rotations and crop diversity could support faba bean cultivation. Further, intensified breeding (for yield, uniform maturity of beans, disease resistance, etc.), advice to fill farmers' knowledge gaps (regarding, for example, cultivation and weed control) and more significant direct payments were all suggested as methods for encouraging faba bean cultivation.

### 9.2.5 Collectors

Collection centres are not active in the collection, processing or cleaning of faba beans in Austria, Serbia or Switzerland. A large part of the harvest is used internally as feed. When faba beans are marketed, they are usually sold directly to a feed mill, which prepares and processes the beans into compound feed.

### 9.2.6 Feed processors

Faba beans are used in animal feed. Like other legumes, they serve primarily as a source of protein, and they are in close competition with other protein sources. Relevant factors in this competition include the protein content, the structure of the amino acids and undesirable antinutritive ingredients. The latter limit the usability of faba beans, especially for monogastric animals, such as chickens or pigs. Finally, the price of faba beans plays a decisive role in whether this crop is used as a component of a compound feed.

The faba beans are mostly delivered directly from farmers to feed mills, where they are ground. The bean's tough shell makes processing difficult.

In Austria and Switzerland, faba beans are often cultivated organically. Therefore, they are ideally used in organic feed. Demand for domestic organic ruminant feed in Switzerland has increased due to a change in BioSuisse's guidelines: ruminants must be fed only with 100% BioSuisse feed (concentrate and basic feed).

Due to the limited supply of faba beans in Austria (for more on this, see the chapter Farmers), supply is secured via contracts, and faba beans are imported from EU countries.

Only small proportions of faba beans are used in feed mixtures; their use is restricted due to antinutritive ingredients. Compared to other legumes, faba bean seems to be at a disadvantage. In Austria, for example, soybeans are heavily used, while in Switzerland pea utilisation outstrips that of faba bean (Agroscope & HAFL, 2016). This is justified by the more advantageous cultivation and feed properties of these crops. As faba beans are highly susceptible to summer drought, climate change could pose an additional challenge. Under these circumstances, it may be difficult to position faba bean more strongly as a component of compound feeds.

### 9.2.7 Food processors

The trend toward plant-based meat alternatives is increasing food processors' interest in legumes, such as soybeans, peas, lupines and faba beans. In Austria, various players with different products were considered for this purpose. In Switzerland, a specific food chain was studied in which faba beans from mountain farming were primarily used in gastronomy as well as marketed in smaller specialty stores.

In Austria, one food processor ceased processing faba beans due to problems related to pests and quality issues. Another processor, the biggest in Austria, uses imported faba bean protein concentrate and press cake from the EU to produce a meat substitute product. A third processor, a mill that focuses on legumes, has a decade of experience processing Austrian faba beans into flour and granules, which are then sold to a processor that produces baking aids.

The processing of faba bean raw materials into food products for direct consumption offers great value-added potential. Faba bean has been used in the production of sliced sausage because of its neutral flavour (after the removal of any bitterness) and to provide a different texture than that of competitors, like peas and green beans. In the fall of 2022, this product, the marketing for which will focus on sustainability, will be launched in two major supermarket chains. This processor is currently searching for Austrian sources of protein extracts from faba bean.

The Swiss case represents a rather short but unique food chain. Based on the idea of reviving old food traditions and faba bean varieties, cultivation of a variety from a seed bank was started in the mountainous canton of Grisons. The raw product is processed by a mill that specialises in small quantities of quality labelled products (organic, biodynamic, mountain farmed, etc.). The mill breaks the hull and grinds the beans into chunks, semolina or flour. This processing can be performed with standard equipment.

The next processing step is performed by cooks in around 20 restaurants across Switzerland, who use the faba beans in dishes such as hummus, falafel and preparations similar to risotto or polenta. This direct contact between the cook (processor) and the guest (consumer) allows for communication of little-known advantages of faba beans (sustainability, flavour, etc.) as well as information about the crop’s history, food culture and traditional uses.

These are promising examples of a short, processing-extensive food chain (Switzerland) and longer, processing-intensive food chains (Austria), each of which offers high value-added potential. Given the trend towards meat alternatives and the possibility of integrating other characteristics desired by consumers to a greater extent in the future (such as regional supply, mountain farming, health, and sustainable food production), this represents a promising initial situation. Based on these interesting projects, it is conceivable that regional or national demand will increase and create positive incentives for other actors to join the currently underdeveloped faba bean value chains.

### 9.2.8 Retailers

Faba beans are a niche retail product. Currently, only small quantities of faba bean semolina or flour are sold, e.g. in specialty or health shops. The bitterness of faba beans is a challenge to retail growth, as is consumers’ unfamiliarity with the crop, its farming and eating traditions and its preparation, which will require costly marketing to overcome. The current situation, however, also offers growth potential. The use of faba beans in processed meat alternatives contributes to public awareness, and simple processing techniques have enabled the direct marketing of ground faba beans (as semolina and flour) by farm shops. The history and former intensive use of the faba bean allows retailers to link consumers to those traditions with their products.

### 9.2.9 Summary

The analyses of different faba bean value chains show certain challenges at the seeding, farming and processing stages. Despite its widespread use in earlier times, faba bean is currently a rather marginal underutilised crop in the countries considered. Here, experience and knowledge in other countries (e.g. Germany[14] or France) could be used to catalyse international cooperation and knowledge exchange.

Breeding is not present in any of the countries analysed, which requires the import of seeds. In view of the scarce breeding resources and immense challenges of arable farming (climate change, plant protection, biodiversity and food security, to name a few), the establishment of national faba bean breeding programs currently seems to make little sense; intensified cooperation with established breeders in other European countries would be more appropriate. Existing supplier relationships should be maintained in order to guarantee a supply of seed that is well adapted to national cultivation conditions.

Given attractive prices and stable and reliable sales markets, the number of farmers who grow faba beans will increase. The potential for value creation is seen mainly in processing for human consumption, less so in the market for animal feed. Challenges include the water demand during blossom and the long cultivation period.

Switzerland's success at reviving and marketing a lesser-known crop through the gastronomic channel is a good example of how to reintroduce a product on a regional level. Consideration in the kitchen - usually by discerning restaurateurs - reflects a certain value. The consumer can taste the product and can directly ask questions about its origin, history or preparation, and they may also be able to purchase the raw ingredient in the restaurant. Similar opportunities to communicate with and inform customers are also offered by the sale of faba bean products in direct farm marketing and in delicatessen stores.

For the faba bean, the decisive factor is whether it brings special properties for processing or for end consumers. Direct marketing by farmers, which experienced a boost in various countries during the COVID-19 crisis, can offer sales potential for semolina or flour made from faba beans. The use in meat substitute products could also offer great potential. According to the Austrian analysis, products made from faba bean have a specific texture and a neutral taste, making it a useful ingredient in many products and recipes. Overall, faba bean is well suited to current trends, such as vegan and vegetarian products and sustainable and regional food.

[14] For example, the German protein crop strategy aims to reduce competitive disadvantages of domestic protein crops (legumes such as faba bean, pea and lupin species), close research gaps and test and implement necessary measures in practice (BLE, 2022).

# 10. BUCKWHEAT

## 10.1 Background

Buckwheat (*Fagorpyrum esculentum*) is a plant of the family Polygonaceae, often referred to as the rhubarb or sorrel family. It is cultivated for human consumption but also as feed or cover crop, and it is called a “pseudocereal” because it produces seeds with content of starch and other constituents similar to those of true cereals making it suitable for processing similar to cereals. Despite the similarity of the names and in nutritional profile and uses, buckwheat is not related to wheat.

### 10.1.1 History and distribution

Buckwheat is thought to have originated in southern China, more precisely in the Himalayan foothills (Ohnishi, 1998). Its domestication soon followed, and cultivation spread to Korea and Japan. By the 14th century, it was being grown in Europe. From Europe, buckwheat spread to North America with the help of immigrants (Campbell, 1997).

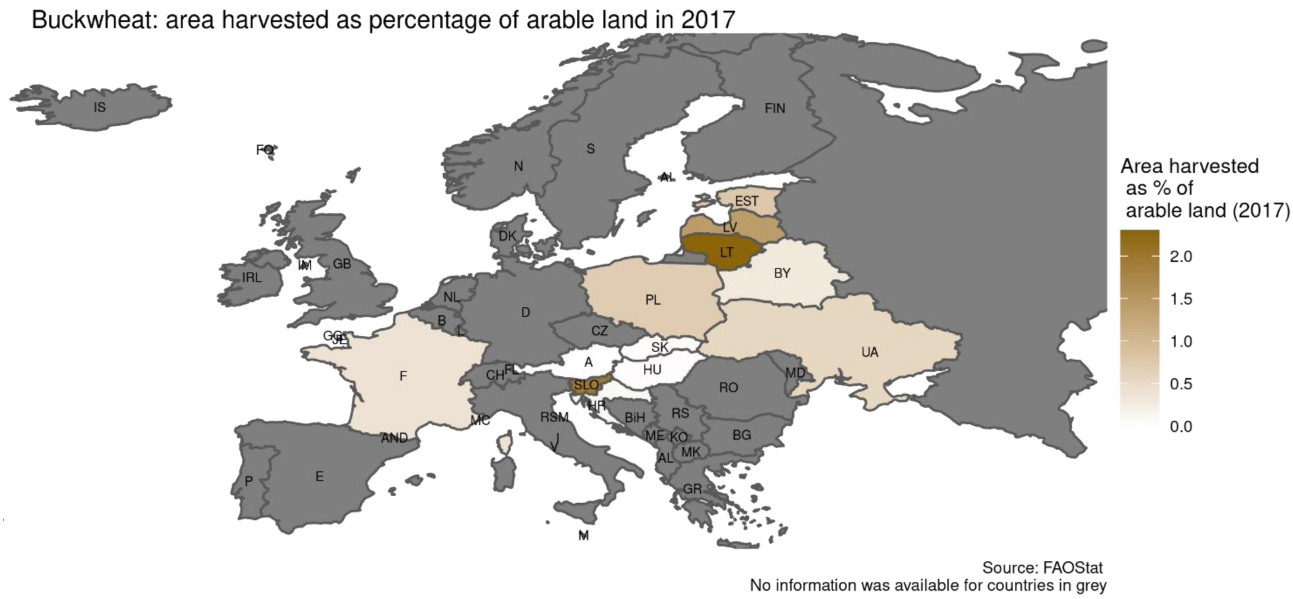


*Figure 15. Area dedicated to the growth of buckwheat as percentage of arable land for 2017[15].*

Production of buckwheat is currently very important in Russia and China, with over 892,000 and about 504,000 tonnes, respectively, produced in 2020 (FAOSTAT, 2020). Its importance in Europe is minimal; therefore, FAO statistics do not give the number of hectares cultivated or total production for all countries in most recent years. Figure 15 shows the area dedicated to the growth of buckwheat as a percentage of arable land for 2017. Buckwheat production does not seem to be well documented, and complete information could not be found for recent years for the countries of this task, as can be seen in the Figure 16. For the Czech Republic and Austria, some information about production in 2017 has been found; According to the official statistics the Austrian buckwheat production was equal to 0 tonnes (no official data for either country, only “FAO data based on imputation methodology”). For the other researched countries (Belgium, Serbia and Switzerland), only import and export data was available. It is clear that the countries are mainly importing buckwheat, except the Czech Republic, which seems to be more

[15] Data from 2017 was used because data from more recent years were lacking for some countries.

involved in production and trading, with a total estimated production of 2,262 tonnes distributed on 887 hectares in 2017 (FAOSTAT, 2020).

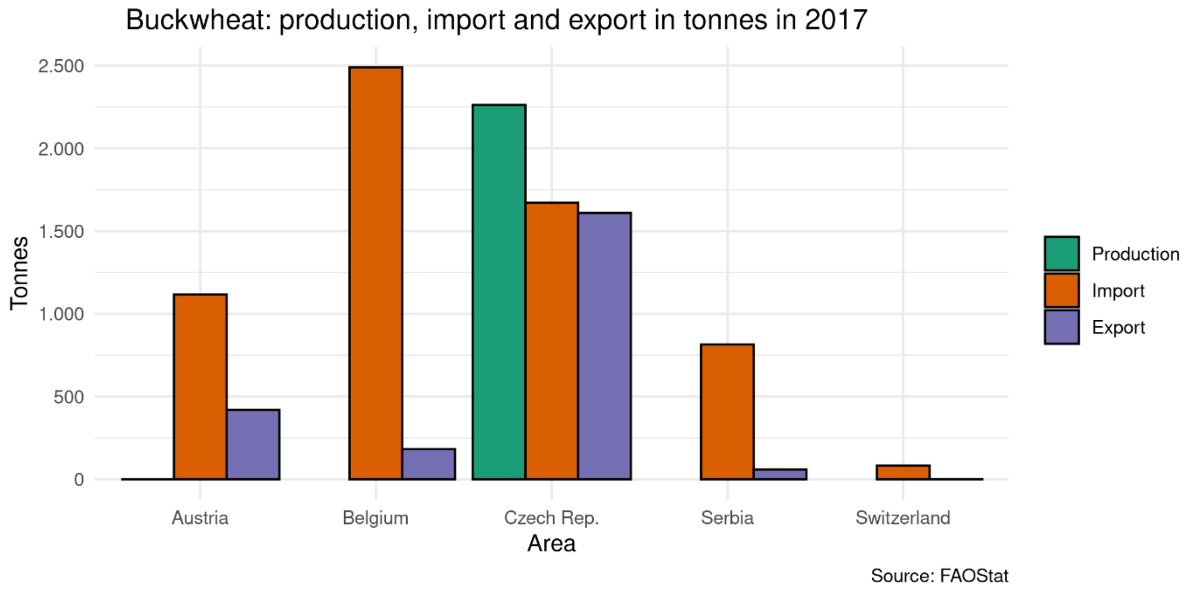


*Figure 16. Buckwheat production, import and export for the countries involved in this task for 2017.*

### 10.1.2 Cultivation

Buckwheat is adaptable to extreme cold, lack of water, and varying climatic conditions. As a short-season crop, it does not tolerate excess nitrogen well and prefers well-drained, low-fertility and acidic soils (Luitel et al., 2017; Rodríguez et al., 2020). Buckwheat is popular with pollinators, and their presence helps to increase yield. Beekeepers could have an interest in buckwheat because of its late flowering, which occurs when other nectar sources are scarce (Campbell, 1997). However, buckwheat cultivation also presents certain challenges, notably reduced seed shattering, a determinate growth habit, synchronised flowering and reduced plant height for better lodging resistance (Campbell, 1997). Buckwheat can be grown not only for grains but also as a cover crop or "green manure", for erosion control, and as cover and feed for wildlife.

### 10.1.3 Nutrition

Buckwheat is rich in starch, which makes up between 60 and 70% of the grain. The protein content is between 11% and 14%, which makes buckwheat a comparatively high-protein gluten-free grain. The amino acid profile is also balanced, with high levels of lysine, arginine and aspartic acid. The lysine content of cereals is generally very low, which makes buckwheat a unique alternative (Rodríguez et al., 2020). Buckwheat contains several important phytochemicals, including the flavonoid rutin, which is sometimes erroneously referred to as Vitamin P.

### 10.1.4 Uses of buckwheat

Buckwheat has multiple uses. It is an ancient grain and was considered a traditional peasant food in many cultures. In Korea and Japan, it is typically consumed in the form of noodles. As it is difficult to make gluten-free pasta, making *soba* noodles has become an important tradition in Japanese culture. *Pizzocheri* is buckwheat pasta produced in Northern Italy and Eastern Switzerland, although it is better known in Europe in the form of pancakes, crêpes or bread.

In France, buckwheat, also known as *blé noir* (black wheat) due to its colour, is experiencing a certain revival. The area dedicated to cultivation has risen from 30,900 hectares in 2012 to 74,883 in 2017, with production rising from 105,000 tonnes to 263,485 in the same period (FAOSTAT, 2017). In 2010, buckwheat from Brittany was even officially granted a Protected Geographical Indication (PGI) (eAmbrosia, 2010).

In Eastern Europe and Western Asia, buckwheat is even more important. In fact, its importance is so great in those areas that Russia, Belarus, Ukraine and the Eurasian Economic Union decided during some critical months of the COVID-19 crisis to ban buckwheat exports (FAO, 2021a, 2021b, 2021c; Global Trade Alert, 2020). According to Kashintseva (2010), *grechka* (Russian for buckwheat) represented about 20% of the cereal consumption in Russia in 2009, where it is consumed as *blini* (Russian for pancake) or as *gretschnewaja kascha* (Russian for buckwheat porridge), among other dishes. Similar traditional meals are appreciated in other Slavic countries.

Buckwheat is also consumed in the form of gluten-free beer, whisky, *shōchū* (a Japanese distilled beverage) or tea. Buckwheat husks can be used to stuff cushions and poufs. In addition, green buckwheat leaves are used in cooking and alternative medicine, and buckwheat honey is known for its strong taste and dark colour.

## 10.2 Results from the case studies

Food value chain analyses for buckwheat were conducted in Belgium, the Czech Republic and Serbia. Buckwheat food value chains considered products like buckwheat pasta in the Czech Republic and ready-to-bake mixes in Belgium. A wide range of buckwheat products is available in Serbia. Below, Table 12 shows the number of interviews conducted by each research team in the participating countries.

*Table 12. Overview of the interviews conducted for buckwheat by each research team.*

| VC actor | BE | CZ | RS | Total |
|---|---|---|---|---|
| Input suppliers[a] | 1 | 6 | 3 | 10 |
| Farmers | 1 | 4 | 3 | 8 |
| Collectors | 1 | 0[b] | 0[b] | 1 |
| Processors | 3 | 2 | 4 | 9 |
| Retail | 1 | 2 | 2 | 5 |

*[a] Includes researchers, advisors, extension services, breeders, input suppliers, seed producers and traders.*
*[b] Not relevant/non-existent/vertically integrated*

### 10.2.1 Situation in the research countries

There is a tradition of growing buckwheat in Europe, and the research countries are no exception. However, the current buckwheat market varies widely among the research countries.

In **Belgium**, domestic production is very negligible, but Belgian consumers are familiar with buckwheat products (Linssen et al., 2019). One region called Limburg, where buckwheat has a history of cultivation and use, recently acknowledged buckwheat as an official regional product. In Limburg, restaurants and gastronomes are already producing specialties like buckwheat pancakes and buckwheat sausages. Belgian trade of buckwheat is significant, as buckwheat and buckwheat flour are imported in large amounts. Food companies are processing buckwheat flour into diverse products, like ready-to-bake mixes. Interestingly, Belgium exports about half of its imported buckwheat, and the export values of buckwheat have risen over recent years. Buckwheat products are mostly sold in speciality shops, such as organic stores.

In the **Czech Republic**, buckwheat production is mainly located in Morava, a mountainous area in the east of the country; there has been a decline of the area under cultivation. Low interest is due to low yields and the energy required for drying. The Czech Republic has a negative trade balance and imports a large amount of buckwheat. Cheap imports from Poland, Italy, Russia and Ukraine are difficult for domestic farmers to compete against. Also, subsidies for non-food usages of buckwheat and for meadows in places where buckwheat used to be grown, have reduced domestic production, which is of course not favourable for the integration of domestic buckwheat over foreign buckwheat by food processors and retailers. Food processors are producing a wide range of buckwheat products; however, most of them are made with imported buckwheat. Consumption has slightly increased in the last 20 years but only makes up a small part of the health food product range.

In **Serbia**, buckwheat cultivation is grown in the mountains and in the Pannonian Plain, and some organised associations were identified. Historically grown mostly in Slovenia in the former Yugoslavia, buckwheat is experiencing a renaissance in Serbia that began in the early 21st century, mainly because of its nutritional value. In fact, a large variety of buckwheat products is available for consumers. However, domestic buckwheat is not well integrated into the downstream parts of the value chain, mostly because of quality issues due to poor post-harvest handling (inadequate drying and no cleaning of the harvest). No official statistics were found about buckwheat cultivation. The current downstream portions of buckwheat value chains rely heavily on imports, 80–95% of which come from Russia. Therefore, the current Ukraine–Russia conflict could have an impact on the availability of buckwheat in Serbia; this could foster demand for domestic production.

### 10.2.2 Inputs

Currently, there are no buckwheat breeding programs in Belgium or Serbia, although one of the four varieties previous bred in Serbia is still in use because of the high yields it provides. In the Czech Republic, two breeding companies are still active and are focusing on increasing abiotic stress tolerance and technological seed processing value. In total, five Czech varieties are available to Czech farmers.

Buckwheat seeds are sold for grain production but also as green manure. In the Czech Republic, in addition to those bred and propagated domestically, other imported varieties are available to farmers. However, Czech food processors prefer domestic varieties, which are easier to clean and have small- to medium-sized grains that are better suited to the processing machines. Surprisingly, buckwheat does not appear on the Czech List of Plant Varieties. Nevertheless, it is subject to quality control and can still be exported (which is an exception to the rule, as this generally only applies to varieties on the list).

In Serbia, seeds are either propagated by one seed company or by farmers or seeds are imported from abroad. In Belgium, there is no seed production and all seeds are imported. In both countries, the demand for buckwheat seeds is reported to be low (domestic seed production in Serbia is insufficient even to meet this low demand). In Belgium, low yields are the main reason for limited interest in buckwheat; in Serbia, farmers sometimes bypass the domestic seed market, choosing instead to: use certified seeds for many years, and sow harvested seeds, until the crop loses its properties; import seeds from Russia, Ukraine and Sweden; or propagate autochthonous seeds, which are sometimes sold online.

No research efforts were identified in Belgium. In the Czech Republic, research is being conducted and the breeding of new varieties is ongoing. Although Serbian buckwheat research has been conducted (on, for example, optimisation of the production of bread and pasta), it does not appear to have targeted current issues encountered by domestic value chain actors (like purification, dehulling or milling issues). This misfocus is mainly due to the lack of relationships with value chain actors.

### 10.2.3 Farmers

In general, buckwheat production is located in well-defined regions, like the Czech Morava mountains, the Serbian Pannonian plain or the Belgian Limburg region. Buckwheat is easy to grow organically, and it withstands poor soils and requires fewer inputs and less care than many other crops. Czech farmers cultivate buckwheat to diversify their crop rotation. Business relationships with processors and direct payments (for landscape quality) are also important incentives for farmers.

Barriers for cultivation for Czech and Serbian farmers are similar and concern the post-harvest steps. In both countries, prices are low compared to mainstream crops. In addition, cleaning and drying the harvest is challenging but necessary for harvest quality. Not all Serbian and Czech farmers possess a drying machine. In the Czech Republic, farmers sometimes cooperate and provide drying and cleaning services to other farmers. Organic Czech farmers must rely on one organic product processing company (PRO-BIO) for drying and cleaning organic buckwheat. In Serbia, the situation is different. Large producers are generally equipped with drying and cleaning machines, allowing them to more easily handle their post-harvest buckwheat. Small Serbian producers, however, must use simple, less adequate techniques for drying (like turning the buckwheat over with shovels on a concrete surface). Grains prepared this way are not always fully dried and can be microbiologically unsafe for humans. In addition, the harvest is not cleaned and many impurities, like weed seeds, can be found within it, resulting in low quality and a lower product price. Sometimes large Serbian farms provide drying and cleaning services to small farmers.

In the Czech Republic, direct payments for landscape quality can be obtained, and these are attractive to many farmers. Mixtures containing buckwheat can be sown in nectar-bearing biozones or to support the climatic and ecological aspects of farming, and the EU financially supports these practices.

### 10.2.4 Collectors

As already mentioned, Serbian and Czech farmers handle the buckwheat post-harvest steps themselves or make use of the services of another farmer who is equipped to dry and clean the harvest. An exception is a single organic food processing company that collects organic buckwheat from Czech farmers.

In Belgium, one collecting centre plays a pivotal role in the importance of buckwheat in the country. This centre imports Demeter and organic-certified buckwheat and then sells it to organic shops or larger food processors. This collection centre, as an intermediary, is attractive to small organic shops that cannot bargain with the dominant wholesaler.

### 10.2.5 Food processors

In general, food processing companies in the research countries use imported buckwheat. The only exception is the Czech Republic, where some food processors use domestic buckwheat. Czech buckwheat, of small to medium size, better suits the Czech food processors' machines. One Czech mill, which has been processing buckwheat in the traditional way for more than 100 years, has a very diverse portfolio of buckwheat products and can serve as an illustrative example of processing in the Czech Republic, encounters a variety of challenges. Their storage and production capacities are limited; however, they are currently building infrastructure to account for these limitations. This mill removes the hulls mechanically, which is more costly than thermal dehulling but preserves more of the nutritional content. In contrast, imported buckwheat is thermally dehulled, making it less expensive.

The decline in Czech buckwheat production is challenging for the mill and for other companies willing to use domestic buckwheat. In addition, direct payments for landscape quality (buckwheat grown in crop mixtures or as non-food in "greening or honey belts") and the ability to export harvested buckwheat as seeds for use in greening mixtures sold to Germany both reduce the amount of domestic buckwheat available for food purposes. Therefore, the mill has begun to make contracts directly with farmers in order to secure sufficient amounts of the domestic harvest. The mill is also involved in knowledge transfer via media articles and educational events.

In Belgium, mills and bakeries are involved in buckwheat food processing. Milling firms, however, import buckwheat for their flour mixes; since they need only small quantities, on-site processing is considered inefficient. These flour mixes contain various grains and are marketed to consumers as a healthier, artisanal option. Buckwheat flour makes up something like 1–5% of the total mix. Belgian milling firms no longer offer gluten-free products, as it has become too difficult to meet allergy standards or those products do not fit within their marketing strategies. The milling firms generally import buckwheat from larger supplier companies in the Netherlands, as buying from small suppliers can be problematic due to food safety and quality standards (e.g. metal detection in triage, cross-contamination when working with allergens, certification). Flour mixes containing buckwheat are then sold to artisanal and industrial bakeries, which can order flour with a tailored percentage of buckwheat.

Serbian food processing relies on buckwheat imports. Primary processors, often wholesalers, dehull and mill the buckwheat, and then secondary processors use buckwheat flour to produce various foodstuffs. Different levels of vertical integration were reported, including seed production, farming, dehulling and milling for pasta making. Several companies are, as in Belgium, producing ready-to-bake mixes that can be sold to the 5,000 bakeries in Serbia. These companies have a strong position in the market and a good distribution network, so barriers to entry are high for other companies. In general, Serbian food processors rely on imports because domestic supply is linked to different issues: it is delivered in small batches and the quality is insufficient (impurities, microbiological safety, grain size, grain maturity, etc.). Imported buckwheat tends to be of superior and more uniform quality for the same price, and trade synergy exists with Russia: trucks transport Serbian apples to Russia and come back filled with Russian buckwheat.

### 10.2.6 Retailers

In Belgium, where buckwheat products are sold in bakeries, the grey colour conferred by buckwheat is associated by consumers with artisanal-quality products; about 10% buckwheat creates a product with a pleasant appearance. Marketing is currently targeting the trend toward “ancient grains”, and packaged products come with additional information for consumers.

In the Czech Republic, domestic, organic and/or gluten-free buckwheat products are sold in health and specialised shops. Imported buckwheat products, which are significantly less expensive are sold in specialised shops, as well as in retail chains. Regarding marketing, core target groups in the Czech Republic are mothers with young children, individuals with coeliac disease and elderly people.

In Serbia, consumers can purchase buckwheat in health shops, in bakeries and in retail chains. The health shop market is divided into a network of chain retail locations and small businesses. The health supply shops are often integrated with wholesale and possess a competitive advantage over the smaller private businesses.

In the three research countries, no marketing activities by private actors in the value chains were identified. However, buckwheat consumption is promoted in Serbia and the Czech Republic, mostly through media articles, recommendations and recipes. The bitter taste of buckwheat is related to wrong cooking and requires information and education of consumers in order not to limit consumer acceptance.

### 10.2.7 Summary

There are no buckwheat breeding programs in Serbia and Belgium; however, research and breeding for new varieties are both ongoing in the Czech Republic. Although some research about buckwheat has been performed in Serbia, it appears not to target current issues. In Belgium, seeds are imported, while in the Czech Republic and Serbia, they are produced. In Serbia, however, farmers often rely on other sources of seed (import and/or on-site propagation), which bypasses national seed production and leads to a potentially lower-quality harvest.

Buckwheat production is typically located in well-defined areas, some of which are traditionally known for buckwheat cultivation. In Serbia, it seems that buckwheat producers could profit from advice on which seeds should be used, fertilisation and general production technology. Buckwheat cultivation is more prevalent in organic farming, and organic certification seems very important in Belgium and the Czech Republic. If farmers in these countries want to enter the buckwheat market, it may be advantageous to comply with organic standards in order to enter existing value chains.

The lack of rigorous cleaning and drying of the harvest in Serbia makes it harder to link downstream and upstream parts of the value chain. Large Serbian farms can rely on their own equipment; however, smaller farmers need to either use low-technology methods to handle their buckwheat, lowering harvest quality, or to rely on larger farms. In the Czech Republic, where farmers generally cooperate to dry and clean the buckwheat, a single organic food company is still involved in the post-harvest drying and cleaning processes.

In these three countries, buckwheat processing is widely available, and various products can be found. However, the buckwheat that is processed is usually imported from other countries, except in the Czech Republic, where both domestic and foreign buckwheat are present. Some Czech processors favour domestic buckwheat, as their machines are better adapted to its smaller-sized grains. However, a decline in production for food and increased use as non-food (due to EU subsidies and exporting harvest within greening mixtures) makes it challenging for food producers to use domestic buckwheat. In addition, thermally treated, imported buckwheat (of lower nutritional quality) is cheaper than domestic, mechanically treated buckwheat, further challenging any Czech farmers and food processors who wish to grow and use domestic buckwheat.

The lack of collection centres was identified as one cause for the low integration of domestic buckwheat in existing Serbian value chains. There is a lack of coordination between farmers and food processors, resulting in Serbian food processors being drawn to the advantages of importing higher-quality buckwheat. Utilisation of certified seeds by farmers and the presence of collection centres (or stronger horizontal cooperation among farmers) to aggregate batches and homogenise quality could be necessary to convince food processors to use domestic buckwheat. Dependence on Russia for imports and the current Ukraine–Russia conflict might also shift interest towards domestic production. To encourage sufficient Serbian production, profitability for farmers should be comparable to that of mainstream crops.

Overall, buckwheat consumption is well established in the three countries for which data was available, as it can be found in bakeries in Belgium and Serbia and in a range of shops and retail chains in all three countries. It appears that consumers are generally familiar with buckwheat but not with the details of its use, such as its health benefits and how to prepare buckwheat pasta. Hence, promoting and informing consumers about domestic buckwheat and special buckwheat products could help to increase demand, as could ensuring that buckwheat's bitter taste is taken into account when processing and crafting products for consumers. The gentler mechanical dehulling could be used for market differentiation in the Czech Republic, and gluten-free and organic certifications could aid a marketing push. However, gluten-free certification might be challenging to obtain, due to contamination issues.

The Czech family mill mentioned above solved this problem by exclusively processing buckwheat; however, this is probably not realistic for other companies. In addition, the health benefits of buckwheat deserve further promotion to consumers. The trend towards "ancient grains" may already be fully exploited in Belgium, but it could eventually be extended to other products (and other countries) for further market differentiation.

# 11. DISCUSSION AND CONCLUSIONS

## 11.1 Theoretical framework

### 11.1.1 Path dependency and lock-in

The analyses of underutilised crop value chains in this report provide good examples of lock-in. Lock-ins can be identified at different levels of the value chains. Plant breeding for the crops and countries considered in this study usually no longer takes or never took place at all. As a result, seeds have to be imported from other countries and may not be ideally adapted to local growing conditions. As a result, the yields of underutilised crops do not match those of main crops and profitability is lower. Trade in underutilised crops is subject to uncertainties (e.g., alkaloid limits for lupines), few established trade chains and less standardization than for main crops. In food processing, there are specific challenges (e.g., dehulling buckwheat in Serbia or its grain size in the Czech Republic) that increase processing costs.

The focus of agriculture on certain main crops, such as wheat, is explained by historical decisions and developments. For the underutilised crops considered, important developments were, for example, the development of synthetic fertilizers (reduced the incentive to integrate legumes into the crop rotation), of motors (reduced the demand for oats for horses) and the increasing international exchange (import of proteins for animal feed). The focus on main crop types goes hand in hand with a corresponding standardization and the development of economies of scale or reduced transaction costs. These developments are in part mutually reinforcing, further concentrating the focus on a few crops. The following graph illustrates this lock-in for plant breeding.

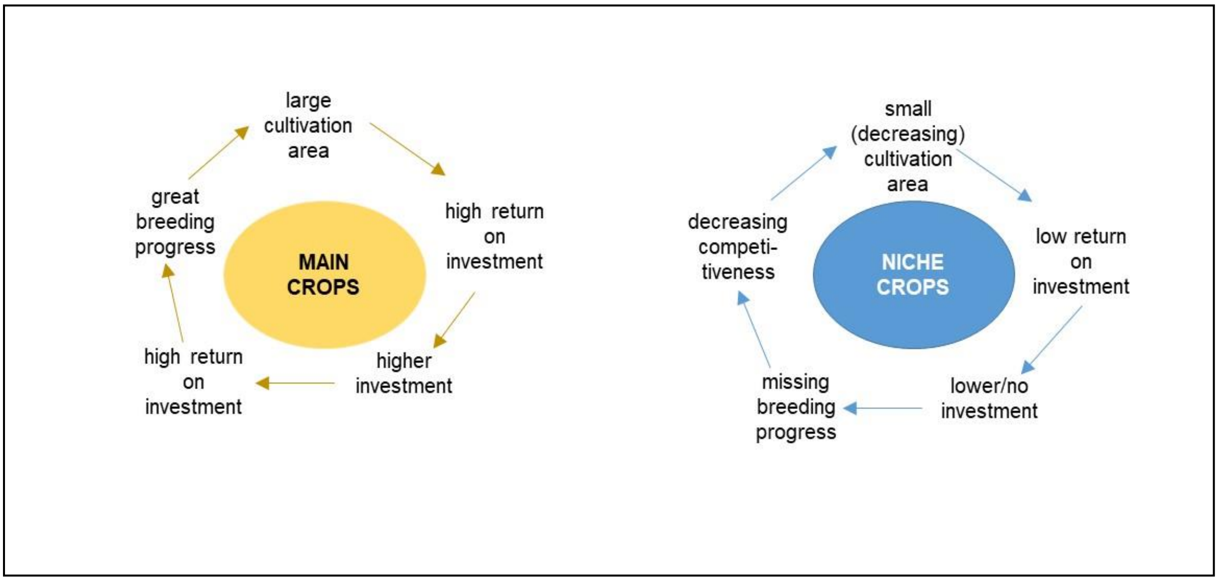


*Figure 17. Driving forces in plant breeding for main and underutilised crops (FOAG, 2015).*

Breaking out of this cycle is associated with typical innovation risks. This applies to plant breeding, which takes a gamble and an investment risk when establishing new breeding areas. Finally, breeding underutilised crops is associated with various market risks. There are also increased risks for farmers when entering production of an underutilised crop: an increased production risk (yield, quality) due to a lack of knowledge or experience, as well as market risks (sales, price).To break out of this circle, increased demand (e.g. due to new food trends), strategic management and joint assumption of the risks or governmental interventioncan offer ways out.

### 11.1.2 Transaction costs

Closely linked to the lock-in are increased transaction costs in the production and marketing of underutilised crops. Knowledge and experience gaps of value chain actors result in increased search and information costs (ex-ante transaction costs). An example of this is obtaining the desired varieties when importing seeds. These challenges, as well as tmissing knowledge in extension services, ultimately increase decision-making costs. For consumers, it is also difficult and laborious to get food products from underutilised crops and it is more demanding to prepare such food. We have also observed increased ex-post transaction costs for the underutilised crops considered. Uncertainties in thresholds (alkaloid) and also lack of standards as well as trade practices can contribute to increased supervision and enforcement costs in case of dispute. Certain case studies have shown that once relationships are established, they can be very stable in the face of the shared challenges of building a value chain for an underutilised crop. The specific relevance of transaction costs were highlighted by Jouan et al. (2019). For legumes, they detected higher transaction costs compared to wheat due to high asset specificity – degree to which human, financial and materials can be adapted to other purposes – and uncertainties.

### 11.1.3 Transition

In view of the challenges of a lock-in situation and the associated risks and increased transaction costs, the question arises as to possible solutions. In the case studies various approaches, also described in the literature, emerged.

The cooperation between important market players in building the value chain of the Swiss oats drink shows the potentials. The cooperation of different actors from different levels and the coordination of the value chain (Le Bail et al., 2014) supported by intensive marketing made it possible to establish this value chain in a short time. However, the example of naked barley in the Czech Republic must also be mentioned, which could not be brought out of its underutilised despite cooperation between research, extension, plant breeding and food processing. It seems important to involve stakeholders who can assess the needs of consumers at an early stage. These can be processors or retailers.

Morel et al. (2020) identified three settings in which crop diversification innovation takes place. First, "changing from within" the dominant food system; production is mainly conventional and primarily targeted at commodity markets. Second, "building outside" the dominant food system; production is rather organic and targeting local markets with small-scale value chain actors. Third, "playing horizontal" focuses on the farm level and possibilities of horizontal cooperation and exchange to diversify cropping systems. For the assignment to a category, the cultivation strategy (temporal or spatial crop diversification, with intercrop), the type of value chain (local, commodity market, farmer feed market) and the type of farming are taken into account (Morel et al., 2020). The analyses on which this report is based offer examples of successful value chains as well as starting points for future development and possible new foods according to Morel et al.'s categorisation.

For established crops, such as oats or triticale, which have a tradition of cultivation or a certain spread in agriculture, the linkage to existing value chains and actors, i.e. crop diversification and new food products from within the mainstream food system, lends itself. The Swiss oats drink example is a good example for such a case. Existing production and processing of buckwheat in the Czech Republic and Serbia – even if the raw materials are of organic origin – could also be further developed in this setting, since the value chains include food processors that use imported buckwheat (i.e., traded commodity).

Less common crops are often first cultivated in organic farming for agroecological (extended crop rotation, closing nutrient cycles) and other reasons. Such transition outside the dominant food system seems evident for crops such as hull-less barley, legumes (faba bean, lupin) and buckwheat.

The organic sector can also play an important role in the transformation of the food system (cf. also above on "setting"). Its experience in building up the organic market and value chains offers interesting starting points. The organic farming system is based on a greater diversity of cultivation and crops, which is reflected in the high organic shares of certain crops (e.g., lupins or oats in Austria). There is often a greater openness to farm and process new, less widely grown crops. Organic actors often are intrinsically motivated (e.g., the triticale bread food chain or the faba bean food chain in Switzerland). Consumers of organic products, finally, are often also more open to alternative and plant-based food products; underutilised based food products are often sold in organic shops (e.g., buckwheat in Belgium, the legumes lupin and faba bean in Austria, triticale bread in Switzerland).

Furthermore, there is experience in trading and processing with small quantities and fluctuating availability. Umbrella organisations of organic agriculture, unlike the conventional sector, often also have a cross-level organisational structure. This seems to be linked to a certain size and level of development of the organic food market (such as Austria or Switzerland). This allows for cross-stage coordination of a value chain as well as of value creation. In the Swiss organic legume market, for example, there is a kind of cross-subsidisation through target prices and additional premiums (compensatory contribution ) for faba beans and lupins) (Brunner, 2022; Joder, 2022).

Finally, the value-added potential is high. Examples of this are the lupin VC in Austria or the faba bean VC in Switzerland. Triticale bread - i.e. the use of a cereal that was previously mostly used as animal feed for baking bread - was also produced via the organic route. Strict organic standard, however sometimes restrict market development (e.g., ban on the import of irradiated lupin seeds by Bio-Austria or specifications, e.g., by Bio Suisse, on the degree of processing, which is often very high in the case of plant-based protein isolates).

The horizontal cooperation at farm level ("playing horizontal", Morel et al. (2020)) can be a relevant strategy to establish underutilised products as fodder. Regarding the crops analyzed, this could especially be relevant for triticale or the legume crops, faba bean and lupins.

Change resistance (Harich, 2010) is the tendency of a system to continue its current behaviour even though there are valid reasons and incentives to change it. For the transition of the food system, the question arises in this context as to which actors in the value chain are decisive here. Who has the power to change (market governance) and to which incentives do these actors react? It is furthermore important to couple the relevant systems properly (such as the human system with the environmental system) (Harich 2010).

There is probably no single relevant actor when building a value chain for food or feed from underutilised crops. In principle, it seems important to have a certain degree of networking and cooperation across several stages of the chain. In Europe, agricultural cooperatives in some countries often have an important role in the supply of inputs as well as the purchase of agricultural products. They can therefore play an important role in establishing and expanding a value chain.

Furthermore, food processors can play an important role here. They are the link between the food trade, which is in contact with the end consumers, and the suppliers of the raw materials. Food processors and their development departments can also play an important role as innovators in the development of new foods. The development of the plant-based food market offers room for innovation; the Austrian analysis of the oats chain points to the relevance of innovation by food processors and the Serbian analysis of naked barley points to untapped potential in the cooperation between public research and food processing companies. In Germany, for example, there are interesting research-induced developments concerning the processing of lupins, which, however, have not yet spread to or influenced the countries under consideration.

A better coupling of the environmental and human systems could be achieved by internalising positive and negative externalities. This would be an area of action for agricultural and food policy. Underutilised crops contribute to the diversity of cultivation; at the same time, the productivity per unit area is generally lower than for the main ,crops which put underutilised crops at a disadvantage (FOAG, 2015). Finally, international cooperation and coordination (division and specialisation of labour) in breeding can be used to promote underutilised crops. The challenges in plant breeding are great and resources must be used efficiently (ECPGR, 2021).

## 11.2 Value chain

In this section, the results of the case studies of value chain analyses of underutilised crops will be synthesized for the different levels of the value chain. The final section will consider some overarching issues, relevant for the establishment of new food and feed value chains, covering potential contributions of digitalization and cooperation.

### 11.2.1 Research

Research can play an important role in the further development of these underutilized crops. The research need relates not only to breeding, cultivation, food processing, food technology and nutritional aspects but also to the contribution of these crops to ecosystem services provision and resilient farming systems. . Public research actors are important in breeding, cultivation, nutrition and ecosystem services research, while private research has a greater role to play in food technology and processing. According to Mazzucato's much-noted ideas (Mazzucato, 2013) the state can play an important role in fostering the development of underutilised crops as the bearer of research and innovation risks.

In breeding, the aim is to better exploit the yield potential, to increase quality and to reduce certain susceptibilities of the crops to diseases or pests – these aspects were mentioned across different crops and countries. Research on cultivation provides the basis for a better understanding of the challenges of cultivation as well as the contribution of underutilised crops to diverse and resilient farming systems. Basically it is important to close the existing gaps in knowledge and to transfer the knowledge gained to advisory services and ultimately communicate it to the farming community.

In the field of food technology and processing as well as nutrition, it is important to optimize processing (e.g., some percentage of hull-less barley according to the Serbian case study requires de-hulling which negatively affects product quality) and to maintain the quality of raw products as far as possible and to process them into healthy food. The underutilised crops under consideration can make a contribution to a healthy diet; it is important to increase consumers' knowledge of this contribution.

### 11.2.2 Agricultural extension

Lack of knowledge is a core problem and challenge for underutilised crops. Knowledge gaps exist at various levels, from breeding to cultivation to processing and finally to consumers. Extension as a mediator between research and practice can  if the knowledge bases exist - contribute to closing these knowledge gaps.

Frequently mentioned were gaps in knowledge and lack of experience at the agricultural level. These are less relevant for the cereals under consideration than for the other crops. There are gaps in knowledge about cultivation techniques, such as the choice of varieties or fertilisation, but above all about plant protection. In the organic sector, there is in part broader experience with certain underutilised crops.

### 11.2.3 Breeding

Underutilised crops have a hidden potential that needs to be developed through breeding. At the same time, underutilised crops present certain fundamental challenges in cultivation (tolerance to abiotic stress, yield stability, adaptation to local growing conditions) that need to be addressed. For all crops considered, either yield or quality or both aspects were deemed to be in need of improvement in order to compete in economic terms with the mainstream crops. This setting points to considerable resource requirements that the breeding development of underutilised crops demands.

In the countries covered by this analysis, there is little breeding for the crops considered. If there is breeding, the intensity of breeding for the crops is rather low, partly limited to organic varieties. Seeds are often imported from abroad, hence, the varieties are not locally adapted. While the national exchange of seed and information was partly mentioned positively, a strategy could be to further develop and stabilise the international trade relations as well as to intensify the technical exchange.

### 11.2.4 Seed supply/wholesale

The varieties developed by plant breeders are propagated and processed by multipliers. The seed then reaches farmers via the seed trade. The distinction between plant breeding and seed distribution/trading was not always clear-cut in the case studies.

In the case of the less widespread crops hull-less barley, faba bean and lupin, there were various reports of challenges in obtaining the desired varieties on time (especially in the case of lupin in Austria and Switzerland) and in required quality (use of irradiated faba bean seed is not allowed in Austria according to private organic standards). Further quality issues were mentioned comparing national seed (lower yields of hull-less barley in Czech Republic) with imported seed. If seed is imported from abroad, this usually also means that no or only few cultivation trials take place in the country. This can be accompanied by gaps in knowledge in extension services (national varieties of main crops are often tested in growing trials at several locations in a country and their properties are analysed). The border protection of Swiss agriculture also affects the seed market. For example, legume seeds are less protected than seeds of the main cereal crop, wheat; this makes domestic propagation less attractive.

Seed suppliers (seed sellers) in Europe often are integrated in agricultural cooperatives. These cooperatives often cover different levels of the value chain: they supply farmers with inputs such as seeds as well as fertilisers and plant protection products; on the other hand, they buy the agricultural products from the farmers and may even process them themselves. This cross-stage function of agricultural cooperatives can be important in building a value chain, as different stages can be coordinated and controlled.

In the case of faba beans, in some cases (Serbia, Switzerland), recourse is made to old landraces that are propagated by the farmers themselves. This can be a good selling point, as it is possible to emphasise originality and tradition in marketing. However, the use of non-certified seed is associated on the one hand with low demand and thus little incentive to establish seed production. On the other hand, this can be associated with fluctuations in harvest and quality (in the case of hull-less barley and oats in Serbia).

The fact that the countries under consideration are rather small in terms of area in comparison to other European countries seems to be shaping this overall picture. The most frequently mentioned import countries for seeds were Germany (oats, triticale, hull-less barley, lupin, faba bean), France (oats, faba bean), and Poland (triticale, lupin, buckwheat) – each with a larger agricultural area and correspondingly larger seed markets.

### 11.2.5 Farmers

At the level of agriculture, a differentiation is first necessary. It is important to distinguish between, on the one hand, better-known or more widespread crops such as the cereals oats, triticale, and, partly also, the pseudo cereal buckwheat and, on the other hand, less widespread crops such as hull-less barley, lupins and faba beans. Oats and triticale, for example, are more or less well-known, but primarily produced and used as animal feed. Here it would be interesting to increase the value added in order to be able to pay higher prices, so that the willingness to cultivate these crops increases and subsequently larger areas are cultivated. The knowledge about the cultivation of these two cereals is available, as are the machines and equipment required for cultivation. However, mainstream crops are more demanded, because they generate higher profit for farmers.

In contrast, there are major gaps in knowledge about the less widespread crops such as faba beans, lupins and hull-less barley, and in some cases also buckwheat (cf. also the chapter on extension above). Lock-in mechanism result in high transaction costs and lacking knowledge. This relates to the details of cultivation, such as soil requirements (mentioned in Austria for lupin), fertilisation (Serbia: buckwheat), plant protection (Austria and Switzerland: anthracnose in lupin). In the case of underutilised crops, knowledge is often also lacking on the part of agricultural advisors.

The economic viability of the underutilised crops considered is a fundamental challenge. The prices of feed grains are typically lower than those for grains for human consumption and, above all, the yields are mostly lower than for main crops such as wheat. Lack of experience in cultivation increases the risks, both in terms of price (quality, such as the hectoliter weight of oats) and yield, which ultimately results in greater variability in final output.

A reason for lower yields is unexploited breeding potential. Challenges in pest and disease management increase yield risk and variability. Fluctuating yields are particularly challenging in small-volume markets such as underutilised crops. Here, crop fluctuations can more often lead to an undersupply or oversupply. This makes the management of such markets more difficult.

In addition to the harvest volume, the price is essential for profitability. Since certain underutilised crops have so far been used primarily as fodder (oats, triticale, legumes) and the producer prices of fodder are generally lower than those of food, the initial situation is challenging. Higher value can usually be added to food than to feed (Jouan et al., 2019). When marketing underutilised crops as food, it is then important to clearly differentiate these products from the mainstream crops by making their specific attributes (for instance organic and regional production) and benefits (e.g. health and environmental benefits) clear to customers. The sale of food products from underutilised crops in farm shops allows farmers to increase their added value. Short food chains with low processed products (e.g. flours, semolina) are particularly suitable for this purpose.

Currently, the markets for the crops considered are often dominated by imports. Oats are imported from northern countries and buckwheat is imported from Poland, Ukraine (into Czech Republic) or from Russia (into Serbia). Large food processors' use of underutilised products often relies on imports.

It is difficult for farmers to sell underutilised products because there are no buyers in certain regions (market risk). In some cases, farmers dry and prepare the harvested crop themselves (e.g., buckwheat in Serbia or faba bean in Switzerland). This requires investments that can be reduced through cooperation with other farms. If the distance to the buyers is very long, this increases the logistics costs.

Further risks arise in sales, as for certain anti-nutritive substances there are either no limit values (e.g. for alkaloid in lupins in Switzerland, where there are only recommendations or guideline values) or different strict limit values (ergot alkaloid in triticale). This also increases transaction costs.

Farmers' motives to cultivate the crops considered are manifold. The extension of crop rotation is an important agronomic reason. A broader crop rotation serves preventive crop protection and can contribute to weed suppression (this was mentioned about oats and buckwheat). The low demands or low cultivation intensity of certain crops is also mentioned as an argument. Increasingly, the receipt of direct payments is also linked to more diverse crop rotations. Specific direct payments as concrete monetary (extrinsic) incentives also encourage the use of buckwheat as an intercrop (greening mix), which has boosted production in Czech Republic, or of triticale as an energy crop (Serbia). Finally, there are intrinsic motives, such as an interest in crops grown in the past or a contribution to a more diverse landscape, which motivate farmers to grow underutilised crops.

A possible starting point for the development of new food products and the establishment of new value chains is the spatial concentration of agricultural production of underutilised crops. This is the case for legumes in Austria (especially lupine, but also faba bean in Upper Austria) as well as for buckwheat in the Czech Republic and Serbia. The concentration of the cultivation of underutilised crops allows a focus on these regions, where experience in cultivation and, possibly also in collection and processing, already exist.

### 11.2.6 Collection centers / wholesalers

Farmers sell their products to other farmers (especially fodder), directly to food processors (this only applies to larger or very large farms) or - this is probably the rule in Europe - to collection centres. In these collection centres, the products are collected (many smaller batches are brought together), cleaned, if necessary, dried, and thus prepared for resale in larger batches. These functions of collection centers already indicate the relevance of economies of scale (decreasing per unit costs with increasing production quantity): the more uniform (standardised) the goods to be collected are, the lower are the costs of collection and processing as well as the costs of exchange, i.e. the transaction costs. Small batches are unattractive because small silos are needed, the risk of commingling is greater with small quantities (and a larger number of crops), and the effort required for separation is greater (this is particularly important for crops with allergens, such as lupin, or for gluten-free production). Here, the organic sector has concrete experience (separation, small batches) and is predestined for collection and processing of underutilised crops in the food chain.

This stage of the value chain seems to be structured differently in the countries considered; this can partly be explained by the average farm size (which is highest in the Czech Republic, while Austria and Switzerland have relatively small average sizes).

Collection centres play an important role in linking agricultural production and industrial processing in most of the countries considered. The lack of a collection point can be a key problem for a value chain (e.g. buckwheat in Serbia). As a rule, this stage of the food chain is integrated into larger, often cooperative enterprises. Integration offers advantages in the coordination of a value chain across stages.

### 11.2.7 Feed processor

The production of animal feed consists of the processing (milling, crushing, squeezing) of agricultural raw products or by-products from the food industry or raw material processing (e.g. rapeseed press cake). The feed mill for processing agricultural raw products can easily be integrated into the collection centres or vice-versa. Economies of scale and standardised feed products also play an important role in feed production (similar to the collection centres). Important are nutrients such as protein, starch, minerals, etc., of raw materials. Origin or regional production usually receives less attention. There are therefore limits to the added value. Limits of anti-nutritional substances and contaminants (e.g.

mycotoxins) are often less strict than in food production. The procurement costs of the raw materials play an important role as the price competition is very high on the feed market. Customers of the feed mills are farmers who purchase feed for their animals.

Some of the crops considered are established as fodder crops, such as triticale or oats. Declining livestock numbers in Czech Republic and Serbia explains the reduced demand for triticale and oats. This development could be further intensified as a result of the general trend towards plant-based meat substitutes and increasing efforts to reduce nutrient surpluses (nitrogen and phosphorus) originating from animal husbandry (e.g. in the Netherlands or Switzerland).

On the other hand, the demand for domestic feed, especially protein feed, could be stimulated by the closing of nutrient cycles and the renunciation of feed imports. Examples of this are Donau-Soja (based in Austria and with an office in Serbia) or the requirement of the Swiss organic association Bio Suisse that ruminants may only be fed with Swiss feed. The existing technologies and knowledge for processing the underutilised crops under consideration are available or can easily be transferred.

### 11.2.8 Food processor

Food processing is the link between the agricultural upstream stages of the food chain and forms the interface to the consumer (in the case of bakeries) or to wholesalers or food retailers. In the innovation process and the development of new food products, this stage of the value chain and the research and development work are of central importance.

The structure of this stage is very diverse. This diversity concerns the size of the company, where the spectrum ranges from small artisanal bakeries that process triticale flour into bread to large industrial bakeries to multinational companies with many subsidiaries. The marketing, from own brands to private labels, and the marketing activities are correspondingly diverse as are the specific challenges.

The availability of raw materials is an important criterion for food processors. This refers to the quantity and the required quality. Variations in the quality of the initial product (e.g. for buckwheat in Serbia) require a certain amount of leeway for adjustments of the formulation. Existing international trade flows have a certain volume and established standards that ensure general availability of specific qualities as well as adaptable trade volumes. The same reliability does not exist for underutilised crops. Contracts are used to secure supplies and there exist also other examples of cooperation (e.g. buckwheat in Czech Republic, triticale in Serbia, lupin in Austria). This reduces uncertainties for both sides and lowers transaction costs.

The processing of underutilised crops is sometimes accompanied by specific challenges. For example, hull-less barley has the problem that some individual husks have to be removed after all. This step partially destroys the grains, which affects the quality. Baking triticale is associated with dough stickiness, which makes industrial processing almost impossible. To what extent these challenges are due to the lock-in situation, whether they can be solved by breeding, technically or otherwise, cannot be assessed. When developing new products, it is important to identify major pitfalls at an early stage, to assess their solvability and to estimate the resources required to find a solution. Establishing such a value chain requires investment by food processors, not only in technological processes and equipment but also in market research.

Lacking consumer knowledge and acceptance of new products and resulting low demand can represent a major risk for processors. Triticale, e.g., faces the challenge that consumers are not familiar with this cereal. The name is unfamiliar and sounds novel, which makes some people worried about a new variety that has been bred using genetic engineering. Other consumers who know triticale as a feed grain consider it to be of inferior quality.

New food products need to address consumers' needs and expectations. Current trends in nutrition (more plant-based, health, allergen-free) and sustainability are relevant. Underutilised crops can become an attractive solution for consumers. However, this requires coherent communication and smart marketing. When using novel technologies for food processing, the perception of these technologies by consumers needs to be taken into account (Giordano et al., 2018).

Finally, the close link between food processing and food retailing must be pointed out. Processors should involve retailers at an early stage of product development or even develop something together. Reference was also made to other possible partners, such as research, which should be involved in the development.

### 11.2.9 Retail (in a broader sense)

The case studies also cover a broad spectrum in terms of trade or contact with the end consumer. Farmers who market their products themselves, restaurateurs who use underutilised crops in the kitchen and serve them to their guests, smaller and larger organic, zero waste and health shops and finally large, nationally important retailers were interviewed. In all these channels, food from underutilised cultures can be bought and consumed - partly in parallel online.

The actors at the end of the value chain are in direct exchange with consumers and can perceive trends at an early stage. Retailers can be considered as gatekeeper between producers and consumers (Lang, 2003 "Food industrialization"). This is generally true for both smaller and larger shops, with different framework conditions applying in each case.

In small shops and direct sales, there is an opportunity to provide information/explanations to consumers on the underutilised products, their history/tradition, preparation and possibly health or environmental benefits. These are usually differentiated premium products (origin, production process, etc.) with or without a label. The quantities traded tend to be smaller and the value chains less mature in small shops and direct sales.

Large food retailers sell underutilised crops in medium and larger quantities (e.g. oatmeal or buckwheat in Serbia). Examples of relatively new products are oats drinks and plant-based meat alternatives, in which underutilised products are used on a larger scale. Here, less direct communication is possible, but considerable resources flow into marketing.

### 11.2.10 Consumer

Consumers are at the end of the food chain. As their expectations and preferences regarding underutilised cultures are collected in a separate survey (task 5.2, which is the object of a separate deliverable), this was not analysed in depth in the present task. However, as already mentioned previously, underutilised cultures offer many possible points of contact with current trends. Legumes with a high protein content are suitable for vegan and vegetarian products. This segment is currently experiencing strong growth. Oats, hulls-less barley and buckwheat can satisfy the need for natural and healthy nutrition. Aspects such as origin (regional origin, mountain farming) or organic or biodynamic production play a major role in countries where food expenditure accounts for a smaller share of disposable income. In this setting, there are good and diverse starting points for bringing underutilised products closer to consumers.

## 11.3 Overarching issues

In this section, further points that are relevant for different stages of the value chain or across stages will be addressed.

### 11.3.1 Digitalisation

Digitalisation is important in the marketing of underutilised products via online shops, sales platforms or social networks. There were various mentions and examples of good practices here (e.g. buckwheat in Serbia and Czech Republic). Online trade can reduce transaction costs and also help to reduce spatial distance. In this way, online marketing can be useful in building a value chain.

In addition, online platforms for exchange and networking have been documented in several countries. These platforms serve the exchange between actors of the same stage, as well as the networking of different stages (Lupin in Astria and Switzerland). Such platforms can help to better master the above-mentioned challenges in cultivation, the supply of raw products and marketing.

The application of blockchain technology in the agricultural and food sector is often mentioned in connection with traceability. This can help build customer trust and loyalty (Mika et al., 2021).Finally, digital technologies can also help to close knowledge gaps, especially among consumers, by providing additional information on origin, production methods or preparation via QR codes. In this way, digital applications can contribute in various ways to raising awareness of underutilised crops and promoting their cultivation (Hedberg et al., 2021).

### 11.3.2 Cooperation

The great importance of cooperation for the development of new products based on the underutilised crops under consideration is mentioned and emphasised in many case studies. There are examples of this both horizontally, i.e. between the actors in one stage of the value chain, and vertically, i.e. across different stages.

Cooperation covers different aspects: exchange of price information at producer level (e.g. Austrian oats chain), cooperation between value chain actors with research institutions (e.g., Serbian oats chain), improvement of breeding (different value chains), coordination of entire or parts of value chains (e.g. the Swiss oats and the faba chain), ensuring the supply (e.g. Austrian hull-less barley and lupin value chain). Cooperation in building a value chain seems to be a key success factor (Schäfer, 2019), especially during initiation.

## 11.4 Limitations of the study

The 21 case studies on food and feed value chains of the underutilised crops oats, triticale, hull-less barley, faba bean, lupin and buckwheat aimed to identify examples or references for the implementation of new food products. This approach drew on concepts such as food system lock-in, transition and transaction cost theory.

The approach and its theoretical framework deem to be generally appropriate. Case studies rely on the willingness to participate and to share relevant, partly sensitive business or market information and expectations. Such willingness was not given equally across countries and value chain actors. Based on the analysed cases, we have the impression that the willingness to participate and share knowledge and experiences decreases (i) the larger a company or a market segment is and (ii) the more downstream an actor is. Farmers and breeders generally were rather open compared to large food processors or retailers.

The number of interviews in the countries involved differs; this can be explained by (i) different lengths of the supply chains (number of actors involved), (ii) the willingness of experts contacted to provide information and (iii) the development stage of a supply chain. Although the selection of value chains was prepared and discussed during a workshop, the resulting case studies could not equally contribute to this task's objective. This classification can partly be explained by the framework discussed and developed within this task to select the value chains, such as the focus on the CROPDIVA crops and the distribution of crops across countries, which both, limited the case study choice. If a broader perspective on value chains of other crops (so-called “example crops”, see glossary) such as chick peas, spelt, linseed or poppy seeds could have contributed more to the objectives of the present task stays open.

Finally, case studies are qualitative studies. The variability within the 21 case studies, which were conducted in five countries and for six crops, is considerable. The different expertise of the partners involved, who either have a specification in socio-economics or food science, adds a further diversity due to the different backgrounds and perspectives.

This analysis was carried out in the first half of 2022. The political and economic impact of the conflict in Ukraine certainly influenced some of the expert talks, while others took place before the war broke out. Global agricultural markets, especially the grain market, were strongly influenced by the war. In some countreis, some agri-environmental measures were abrogated or postponed in favour of food production. These developments could further increase the focus on high food production (e.g. calories) per area unitarea production in the future. This could have an inhibiting effect on the cultivation of underutilised crops, which usually reach lower yields or nutrients per hectare than mainstream crops, such as wheat. This scenario may not be adequately reflected in the present analyses due to the time period in which the expert interviews took place. In addition, the COVID-19 pandemic situation affected consumer behaviour during the lockdowns in European regions. The impact and the perception of the pandemic situation most probably influenced the expert talks as well. It remains open to which extend the pandemic situation has an impact on their positions on underutilised crops.

## 11.5 Implications for further project work

Certain patterns emerge from the analyses that should be taken into account when developing new products from underutilised crops and implementing them in new or existing value chains.

The value added is greater in the food sector than in the feed sector. In order to compensate for the economic disadvantages of underutilised crops compared to main crops, a certain added value is required. To exploit this, the products should offer a specific benefit (often called "added value") to the consumer. This can be achieved through qualitative differentiation, e.g. organic production, regional origin, preservation of old cropcow varieties, health benefits or specific sustainability aspects.

- ➢ New products should be introduced in the food market (rather than in the feed sector).
- ➢ Qualitatively differentiate new products by labels such as organic, origin, etc.

Across the analysis we detected different gaps of knowledge and experience. These gaps apply to different actors of value chains. It is important to close these gaps by research, advice and education.

- ➢ Knowledge gaps must be identified and should be closed as far as possible.

The importance of cooperation and communication along the value chain when introducing new products also became clear in the analyses. Essential seem to be actors that are close to the end consumer, such as food traders or processors and gastronomy. They are best placed to assess the market potential of new products and also to identify trends at an early stage. Finally, consumers' knowledge gaps can be addressed through direct communication and marketing.

- ➢ Cooperate and exchange with other value chain actors, ideally those who are close to end consumers.
- ➢ Direct contact and exchange with consumers can help to reduce or eliminate prejudices and knowledge gaps (use, preparation of hitherto little-known foods).The integration of gastronomic actors and nutritionists into the value chain can also be helpful.

An international exchange as well as a certain specialization and division of labour is a good way to achieve breeding and research. Research on niche crops is costly and certainly cannot be intensified in parallel in different countries for resource reasons.

- Cooperate and exchange with other research actors internationally in order to be able to focus scarce research funds.

Experience with niche cultures is partly concentrated spatially. This may be due to the production and market conditions at the location or certain traditions. Such agglomeration can be used as a starting point to promote the development of "lighthouses". From regional focal points, the cultivation of underutilised crops could then be expanded.

- Use agglomerations as starting points to increase the production and usage of underutilised crops.

The development of a value chain should be very well prepared. In this area, there is extensive experience and literature on different levels (breeding, cultivation, processing, marketing), on certain countries or crops. This existing knowledge should be evaluated and taken into account with regard to the specific situation.

- Consult existing literature on a case-specific basis (regarding crop, country, farming type, type of value chain).

# 12. SYNTHESIS

The analysis of 21 value chains in 5 countries for the six crops oats, triticale, hull-less barley, lupin, faba bean and buckwheat in the CROPDIVA project was intended to provide general insights into the structure, development and functioning of value chains of these crops. These findings shall serve both the development of new products from the niche cultures considered in WP 4 and the further work steps in WP 5, the consumer survey and the development of marketing models.

The case studies on value chains in the feed (9 case studies) and food sectors (19) were based on interviews with the actors in the value chain, with breeders, traders, researchers, advisors, farmers, collection centres, processors and retailers.

The analyses showed a great diversity in the cultivation and use of underutilised crops in the countries considered. The current niche situation of these crops can be explained by past technological developments in the agricultural sector (replacement of horses with tractors, reduced feed demand), the focus of research, breeding and cultivation on main crops, such as wheat, (lock-in, path dependency, standardisation and different transaction costs). In some cases, despite national production, the processing of underutilised crops is based on imports (e.g. oats, which are imported on a large scale from Nordic countries).

Underutilised crops can contribute to making cropping systems more diverse and resilient with regard to climate change and pests. In that sense, they can play an important role in the transition to a more sustainable agricultural system. The successful development of the cultivation of underutilised crops pre-requisites a concomitant increase of the demand for food products from these crops, which implies amongst others the development of new food products. In order to achieve such a change in the agricultural and food system, cross-stage cooperation along the value chain is necessary. The focus of new products should be on food, as this is where the greatest potential for value creation is seen. This assessment is based on the trend towards a more plant-based diet and the vast possibilities for qualitative differentiation in terms of cultivation methods and origin.

The central challenge in building new value chains from underutilised crops are gaps in experience and knowledge. These gaps vary by crop and country. In some cases, breeding efforts are (still) underway for the crops under consideration, but this is rarely the case. Seeds are often imported, which can pose specific challenges in niche markets and implies that the seeds are not ideally adapted to local growing conditions. In agriculture, the cereals oats and triticale have a certain spread in all countries; cultivation practices here are also very similar to the main cereals wheat or barley. More critical gaps in knowledge are found in the crops hull-less barley, the legumes lupin and faba bean, and buckwheat generally and regarding the use of triticale in the food chain. This applies to different stages of the value chain and also affects consumers. Even if they know the crops, they very often lack knowledge of their preparation and use.

The development of products and the establishment of a value chain must be oriented towards the specific local or national framework conditions. These include, for example, the specific underutilised crop, the target market, the length of the value chain, the intended qualitative differentiation, the number of actors. The introduction should take place by means of cooperation along the chain and include actors who are close to the consumer.

# ANNEX – GLOSSARY

This glossary builds a common and harmonised understanding of terms related to task 5.1, Value Chain Analysis. It is greatly inspired by Coulibaly et al. (2010), Gereffi et al. (2005), Pesce et al. (2019) and UNIDO (2020).

## Blockchain technology

Definition from Pesce et al. (2019): "Blockchain is a registry of transactions shared by all the stakeholders via the internet. It is a means of data storage that is transparent, secure and not under the control of a central body. The Blockchain saves several transactions, with a non-reverse option. However, it is impossible to delete or change past transactions. It is a peer-to-peer technology, which operates in a decentralised way through nodes. The technology is secured because the information is encrypted. Blockchain can thus enhance trust because of the transparency of the transactions made. It also fosters collaborative and shared economy"

Blockchain can be used to ensure traceability and transparency and to reduce transaction costs. Please consult Pesce et al. (2019) to find out more about the uses of blockchain technologies in the agrifood sector.

## Certification

A certification is a label that is allowed to be used only if a product meets certain standards, which are regulated and controlled by a third party. This third party, the certifier/certification body, controls and enforces that a product, a process or a service meets specific requirements/standards. Obtaining a certification is considered to be beneficial to producers and/or processors. In addition to fairtrade and organic certification, examples of existing certifications from the EU-Quality Schemes are:

- Protected designation of origin (PDO)
- Protected geographical indication (PGI)
- Traditional speciality guaranteed

See Quality schemes explained | European Commission (europa.eu).

## Collection centre

Collection centres, product collectors or primary crop collectors are used to collect the harvests of local farmers. Besides aggregating the production of the local farmers, they are responsible for cleaning and drying the harvested crops.

## CROPDIVA crop

Refers to the six crops of interest for the project: oats, triticale, hull-less barley, lupin, faba bean and buckwheat. These crops are considered underutilised in the European context (might be subject to exceptions).

## Diagonal linkage

Please note that this is not an established economic term. In this context, diagonal linkage or actors' cooperation describes the larger analysis of both vertical and horizontal linkage together, the larger analysis of how actors are organised across and within the value chain levels. The analysis of diagonal linkages is relevant to understanding the general cooperation, innovation and knowledge flows of a value chain.

### Downstream

Setting the starting point at farm production, downstream refers to what happens in the value chain as soon as the product leaves the farm (collection by collecting centre, processing, wholesaling, retailing, catering, etc.).

### E-Business

E-Business is the exchange of information and purchase of products and services between businesses using the internet (Pesce et al., 2019).

### E-Commerce

E-Commerce is the online purchase of goods and services from the internet by consumers (Pesce et al., 2019).

### Example crop

Refers to a crop that was once underutilised (see item "underutilised crops"). One example in Switzerland is the crop spelt, which can now be found in almost all shops and bakeries in the form of flour, pasta or bakery products.

### Infobox: horizontal linkage, coordination and integration.

- Horizontal linkage

Refers to the level of organization between individuals/firms that occupy the same level in the VC. There might be no linkage, horizontal coordination or horizontal integration.

- Horizontal coordination

Any form of formal or informal partnership between actors within the same VC level.

An example of high horizontal coordination is a farmers' cooperative. A medium horizontal coordination could be "joint marketing" by different cheese factories to promote cheese consumption.

- Horizontal integration

This is the merging of two companies/individuals occupying the same VC level or the acquisition of one firm by another on the same VC level.

### Label

A label is any claim made on a food product, which can be regulated or not by third parties. If a label is linked to production standards and controlled by third parties, it is considered a certification (See item "certification").

### Long value chain

Based on UNIDO (2020), the definition of "long" for a VC could be:

- an increased physical distance between the farmer and final consumers;
- an increased number of steps connecting the farmer to final consumers;
- a decrease in cultural and social proximity between farmers and consumers.

As something "long" is always relative to something short, and also context-dependent, we suggest in this task (5.1) counting the number of processing stages/actors and intermediaries between farmers and consumers. This count should be compared with that of other VCs to define VC "length". Calling a VC "long" is here only qualitative, and counting the stages is just a proxy for social distance. Geographic locations of production, processing and consumption are other qualitative criteria that should be taken into account when assessing value chain "length".

## Mainstream crop

Refers to a crop that is massively produced and/or consumed; compare to marginalised crops (see item "underutilised crops"). In Europe, the mainstream crops are generally (national exceptions are possible) wheat, potatoes and rice.

## Market structure

Market structure is used to classify markets' differences based on the nature and degree of competition. It also describes the number of buyers and sellers present in a market and, implicitly, the consequences on market competition. In fact, depending on market competition, bargaining power, as well as barriers for entry/exit, can be either low or high for buyers and sellers. Here is a general classification of market structures:

- Perfect competition: many buyers and many sellers on the market. All the producers sell a similar product but lack price influence over their products. Barriers for entry/exit are very low.
- Oligopoly: many buyers and a small number of firms, which own more than 40% of the market share, selling differentiated or identical products. In order to attract many buyers, their competitive strategy is based on the other firms.
- Oligopsony: Many sellers but only a few buyers on the market. The oligopsonists have some control over the price and their competitive strategies are based on their competitors. This is common in agriculture, where there are many producers and comparatively few buyers.
- Monopoly: many buyers and only one selling company. With no competitor, the monopolist has a lot of influence on the price. This sole product seller is often an owner of resources, patents, copyrights or licenses, or, where initial set up costs are high, the only company capable of an investment of that size. Barriers of entry/exit are very high.
- Natural monopoly: economies of scale cause efficiency to increase continuously with the size of the firm, so that a monopoly emerges "naturally". Examples are railways and telecommunication and utility companies. Many barriers of entry.
- Monopsony: Many sellers but only one buyer on the market. Similar to the monopolist, the monopsonist has significant influence on price.

Please consider that some nuances exist in-between and that the market structures do not represent the entire reality of a market.

## Product life cycle

Refers to the length of time after a product is introduced in a market. After product development, there are generally four stages of a product life cycle: introduction, growth, maturity and decline. Knowing the life stage of a product is important for making decisions, adapting the marketing strategy, reducing/increasing the price, handling competition, designing new packaging, etc.

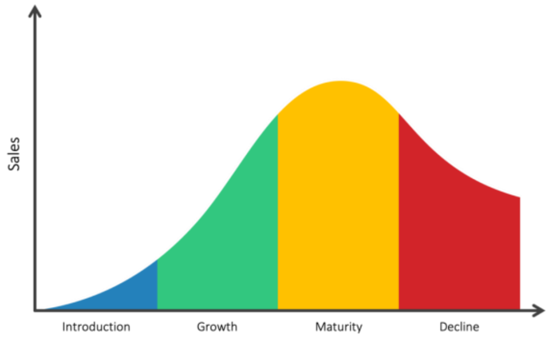


*Figure 18. Product life cycle. Source: Business-to-you. https://www.business-to-you.com/product-life-cycle/. Consulted on the 11.11.2021.*

## Selling channel

Refers to the method used to sell products to consumers. Examples are farmers' markets, retail shops, E-commerce (see item "E-commerce"), restaurants, etc.

## Short value chain

Based on UNIDO (2020, pp. 4–5), the definition of "short" for a VC could be:

- a reduced physical distance between the farmer and final consumers;
- a reduced number of steps connecting the farmer to final consumers;
- an increase in cultural and social proximity between farmers and consumers.

As something "short" is always relative to something long, and also context-dependent, we suggest counting the number of processing stages/actors and intermediaries between farmers and consumers. This count should be compared with that of other VCs to define VC "length". Calling a VC "short" is here only qualitative, and counting the stages is just a proxy for social proximity. Geographic locations of production, processing and consumption are other qualitative criteria that should be taken into account when assessing value chain "length".

## Starting point

Reference point to describe what is "downstream" and what is "upstream" in a value chain. For task 5.1, we chose to set the starting point at the farm level.

## Supply chain/supply chain management

A supply chain differs slightly from a value chain, although both are used to describe the production and distribution of products. However, a supply chain refers more to the management, logistics and costs optimisation of a chain, while the value chain perspective is oriented towards the market development process, product value enhancement in the eyes of the consumer, and overall value addition at each step of the chain. See Feller et al. (2006) for further details.

## Transaction costs

Costs that, at each stage of the VC, are not linked to production and marketing expenses. Examples for transaction costs are market research costs, costs related to searching out market information and business partners, market screening costs, negotiations costs, monitoring costs, contract enforcement costs, transport and logistics costs for distributing goods, etc.

Market inefficiencies, e.g. low market transparency, a lack of standards and deficiencies in the business environment, can result in high transaction costs. Through market organisation and improved value chain coordination, transaction costs can potentially be decreased.

## Underutilised crops

Synonyms are neglected, underused, orphan, abandoned, lost, local, minor, traditional, alternative, niche, or underdeveloped crops. An underutilised crop is a wild, semi-domesticated or cultivated non-commodity crop that has been marginalised in mainstream agriculture (Padulosi, 2017). A discussion of the terms employed is conducted in the chapter Literature.

## Upstream

Setting the starting point at farm production, upstream refers to what happens in the value chain before the product leaves the farm (breeding, input supplying, machinery use, counselling, etc.). See items "Starting point" and "Downstream" for more information.

## Value chain governance

Governance refers to the vertical coordination and the power asymmetry levels between actors in a value chain. Based on Gereffi et al. (2005), one can distinguish five different forms of governance: market, modular, relational, captive and hierarchy relationships. Please refer to Gereffi et al. (2005) for more information on governance forms.

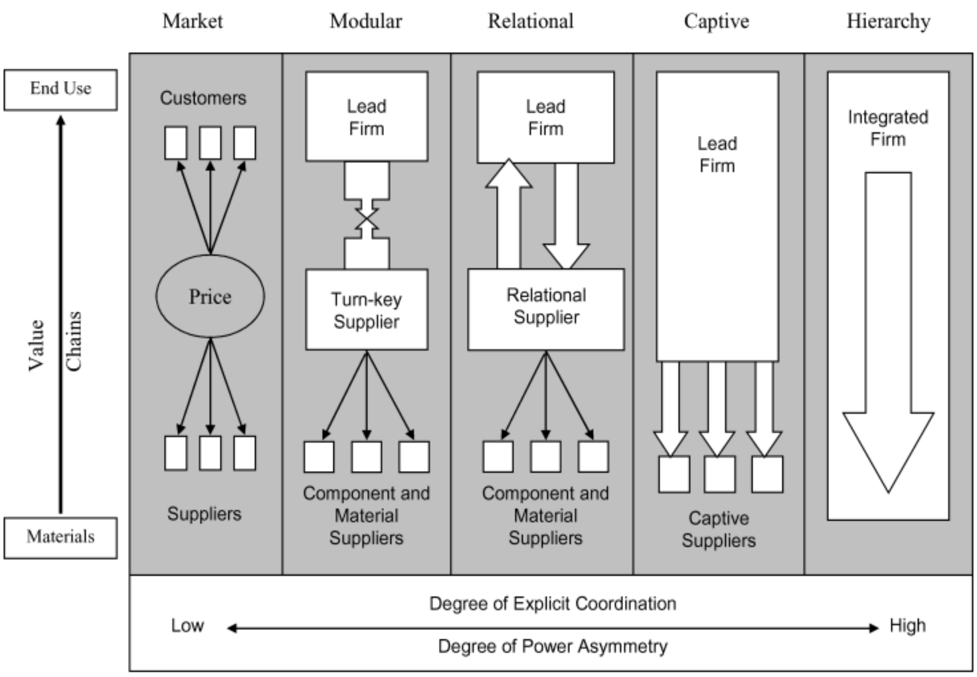


*Figure 19. From Gereffi et al. (2005). The five governance forms are represented graphically and ordered by level of power asymmetry & explicit coordination.*

## Value chain map/value chain mapping

The value chain map is a visual representation of the value chain. VC actors are represented, as are different output(s), such as the produced crop and the end-product delivered to consumers. Links between actors and output(s) are drawn in order to map physical exchange of products.

## Infobox 2: Value chain actor, operator and supporter/support service provider.

- Value Chain actor

VC actors are all individuals, companies and public agencies related to a value chain. Value Chain actors can be divided into value chain operators (1.25) and value chain supporters/providers of support services (1.26).

- Value Chain operator

Operators of a VC are VC actors that own any form of the product at a stage of the VC. Examples of operators include breeders, producers, small and medium enterprises, industrial companies, retailers and wholesalers and exporters/importers.

- Value Chain supporter/support service provider

Value chain supporters provide VC support services and represent the common interests of the VC actors. In contrast to VC operators, they never own the product but rather help the VC to be more successful. Examples include research and development, farming counselling and marketing

## Infobox 3: Vertical linkage, coordination and integration.

- Vertical linkage

This refers to the level of organisation between two VC actors from different levels of the value chain. Their relationship can be regulated through oral agreements and/or written contracts. There could be no particular linkage, vertical coordination or vertical integration.

For the classification of vertical linkage levels according to coordination and power asymmetry levels, see item "value chain governance".

- Vertical coordination

Represents any form of formal or informal partnership between actors of different VC levels. An example of vertical coordination is the coordinated work and informal agreements between a local bakery and cereal farmers.

- Vertical integration

Represents the merging or acquisition of another firm from across the value chain. A seed supply company that starts to collect crop output because of the acquisition of a collecting centre is an example of vertical integration.

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