

The Food and Feed Value Chain of Lupin in Switzerland

CROPDIVA – 5.1

Deliverable Information

Title	The Food and Feed Value Chain of Lupin in Switzerland
Deliverable number	5.1
WP number	5
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Lead beneficiary	WBF (Agroscope)
Type	R: Document, report
Dissemination Level	PU: Public
Due date	June 2022

History of Changes

Version 1.0	Final version (29.06.2022)
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1. THE FOOD AND FEED VALUE CHAIN OF LUPIN IN SWITZERLAND

1.1 Lupin in Switzerland

Whereas lupin cultivation is distributed worldwide, it was never of great importance in Switzerland (Böhler & Dierauer, 2011). One of the reasons for their sparse cultivation (in this country) may have been their toxic alkaloid contents. Alkaloids can be found in various plants, however, regarding lupin consumption, quinolizidine alkaloids (QAs) are a concern due to their adverse effects on human and animal health (Chain et al., 2019). Lupin cultivation started to become interesting for Swiss farmers when low alkaloid contents varieties (sweet lupin) were available, and a crop-related subsidy was paid out (Frick et al., 2002). However, the disease anthracnose, responsible for high reduction in yields, provoked a decline of lupin cultivation (Böhler & Dierauer, 2011). One location of the Swiss centre for agricultural research (Agroscope Reckenholz) published in 2005 a list of recommended varieties (Frick, 2012). Because of their anthracnose resistance, narrowleaf (blue) lupin varieties were highly recommended. In the late 2010s, new white sweet lupin varieties, bred for anthracnose tolerance, were imported to Switzerland. Due to their higher yield potential and anthracnose tolerance, those white lupin varieties are now also interesting for farmers (Arncken-Karutz, 2020). Since 2014, the Swiss organic research institute started breeding white lupin varieties. Table 1 shows the cultivated surface and the average yields obtained for lupin in Switzerland for different years. The cultivated area is still very low.

Table 1. Area cultivated and yield of lupin in Switzerland

Year	2000	2010	2018	2019	2020	2021
Cultivated area (ha)	36	59	163	162	210	304 ^a
Average yields (usable production divided by cultivated area) (kg/a)	-	32.3	28.7	33.9	23.8	- ^b

According to Agristat (2021a). ^a number for 2021 is an estimation (Agristat, 2021b). ^b not available at the time of writing the report.

We could not find one “developed” food value chain to analyse, rather heterogeneous short-value chains with different ways of handling and marketing the lupin post-harvest. We recognize through our interviews that lupin food products are in the introduction stage of their product life cycle (see glossary). In addition, our interview partners were, in general, producing or handling lupin for less than five years (excepting for research organisations). Concerning lupin used as feed, the information we received indicate a marginal use, limited to organic agriculture and diluted in feed mixtures.

Before diving into the results, we would like to mention that CROPDIVA's focus is on narrowleaf (blue) lupin. Through our interviews, we notice that producers were cultivating either narrowleaf or white lupin. Thus, we were not sure before each interview if the interviewee was working with narrowleaf or white lupins, which complicated our analysis. White lupin seems to be more dominant in Switzerland. In this report, we will not always distinguish between narrowleaf and white lupin, since this differentiation in the marketing is currently not relevant. We will only punctually mention some differences and their consequences, if it seems relevant.

1.2 Overview of the interviews completed

Before conducting interviews, we had to research potential interview partners. We collected contact data of lupin producers through press articles and websites. In parallel, we contacted two organic organisations that are involved in lupin research. We obtained the name of a professional responsible for lupin seed trading from a company, who we could interview. Other interview partners, like one organisation linking breeding and seed production, one mill, one feed mill, and one collection centre were indirectly or cross- interviewed. This means that we asked those partners about lupin but also about other CROPDIVA crops.

Table 2. Overview of the number of interviews performed for each VC actor¹.

VC actor	Numbers of interview
Organisation (extension, research, etc.)	4
Organisation linking breeding and seed production	1
Seed trader	4
Producer	5 (3 for food, 2 for feed)
Collector	3
Processor	3
Feed mill	1
Seller (directly to endconsumers)	4

As can be seen in Table 1, we conducted several interviews encompassing various actors along the supply chain. As mentioned already, the upstream part of both feed and food value chains are similar. The same research institutes, seed producers and traders are involved for both feed and food value chain. Whether lupins are used as food (for human consumption) or as animal feed, has no influence on the cultivation of the crop. Two of the five farmers interviewed produced lupin used for feed. After harvest, some producers relied on collection centres whilst other handled their lupin themselves. One collection centre was interviewed. Two other collection centres we interviewed were a part of one feed and one food mill. The feed mill was mostly working in a partnership with collection centres.

Regarding food processors, we interviewed one food mill, one producer processing its lupin itself. Through a cross-interview, we interviewed one food company processing lupin, however the lupin are imported and the processed products sold abroad. Three food producers interviewed sell their lupin and derived products in heterogeneous ways, themselves (on-farm, subscription) or through specialty shops (e.g. ZeroWaste shops). We interviewed one of these speciality shops and in addition, farmers provided us with information about them. Concerning the feed downstream part, we concentrated on the selling of lupin to a feed mill, where feed mixtures are produced.

¹ Please note that we counted the number of interviews for each role taken by one interviewee. For example, if one producer was processing and selling its lupin directly to consumers, one interview with this producer would count as three interviews: one producer interview, one processor interview and one seller interview.

1.3 Results: food

1.3.1 Description of the lupin food value chain

As mentioned already, the organic research institute is currently breeding white lupin. This institute, as well as other research organisations, performs trials with imported lupin varieties. Lupin seeds sold for production are mostly imported to Switzerland. Only one seed multiplication organisation is currently producing lupin seeds from foreign varieties in Switzerland (see figure 1). Seed traders are then reselling those imported or produced seeds to producers. We found heterogeneous ways of selling the harvested lupin by the producers, who were all cultivating lupin for less than 5 years. Some of them did use a collection centre post-harvest; others did dry and handle it on their own. Some let their lupin be processed to lupin coffee or lupin flour. Some farmers sold their lupin (processed or raw) through on-farm direct selling, crop delivery subscription, or through specialty shops (e.g. ZeroWaste shops).

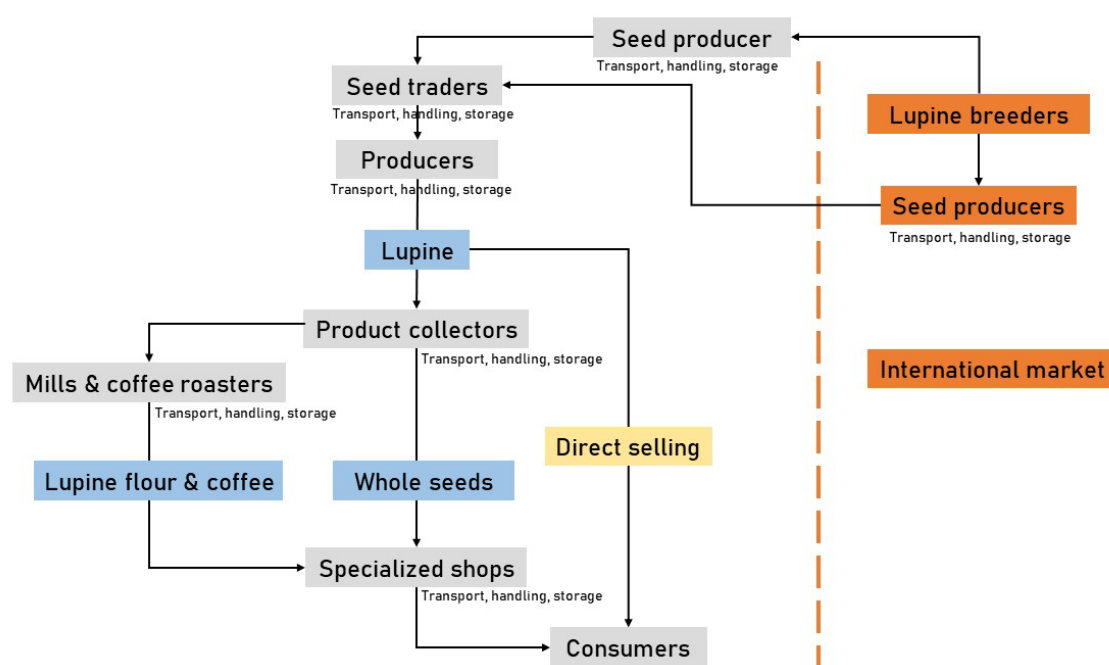


Figure 1. Lupin food value chain mapping.

Table 3 shows different tariff protection on different lupin products (Number: 1209.29XX) and for different usages (BAZG, 2022). According to “tares” - Swiss customs tariff, there is no tariff protection on lupin (BAZG, 2022). Lupin is listed together with vetch under the category “Seeds, fruit and spores, of a kind used for sowing”. There is no explicit category for grain-legumes or for lupin for food production.

Table 3. Overview of the normal tariff protection (duty rates) on lupin and vetch (Together, Number 1209.29XX) for different usages.

Usage	Tariff protection in CHF per 100 kg
Seeds of vetches or lupines, for animal feeding	0.00
seeds of vetches or lupines, for technical purposes	0.00
seeds of vetches or lupines, other	0.00

From BAZG (2022). Retrieved on the 17.06.2022.

1.3.2 Input suppliers (Breeders, researchers, seed producers, seed traders)

The organic research institute breeds white lupin and with other research organisation, perform agronomic trials on white and blue lupins. For now, international seed producers, mainly from Germany and Poland dominate the lupin seed importations in Switzerland. Germany² has been involved for many years in lupin breeding, and lupin is an important protein feed source in Poland³. In addition, lupin cultivation and lupin research are supported in both countries by different programs and projects. In Switzerland, some seed producers affiliated to a seed production organisation are producing lupin seeds. Seed traders make the link between seed producers (foreign and Swiss) and farmers.

VC capacities and organization

Vertical and diagonal linkages

Seed trading companies are giving advice to farmers. They also furnish research organisation with lupin seeds. In general, there is some level of vertical coordination between the different actors. The organic research institute created a lupin innovation network, which reunites different actors of the lupin value chain. This can be understood as a form of diagonal coordination (see Glossary) across the value chain.

Knowledge and technology of actors

In general, interviewees reported some lack of knowledge concerning lupin varieties and cultivation in Switzerland, when compared to other cultures. As an example, mechanisms for anthracnose infection and alternative methods of plant protection against the fungus are not totally known. Our interview partners mentioned the challenges linked to alkaloid contents' variability in lupin. Some interviewees reported that "sweet lupin" varieties might not be enough to guarantee low alkaloid contents for food production, sometimes even feed production.

The lack of knowledge was more important in actors from the conventional sector. One farmer mentioned that their⁴ seed trader did not inform them about the importance of buying an inoculum to enhance the rate of nitrogen fixation, and was not considering alkaloids' variability as an issue.

Entry barriers

One major entry barrier for seed producers mentioned by a seed trader is, besides the current low market size, the absence of tariff protection⁵ on lupin seeds. Without such protection, lupin seeds are much cheaper for importation. Cereal seeds, protected by tariffs, will remain a more attractive option to seed producers than lupins (which are not protected). In addition, lupin seeds multiplication was mentioned as being fastidious compared to cereals multiplication. However, it was reported that importing lupin seeds was not always easy (see resource and infrastructure). Therefore, seed traders and an organisation linking breeding and seed production see potential in national lupin seed production, if this production turns out more reliable than lupin seeds import. Such a case is already observed with protein peas, whose seeds are not tariff protected, however, pea national seed production is profitable, as mentioned by one interviewee.

² Lupin cultivation trials were already initiated in 1779 by Frederick the Great. Later, between 1927 and 1931, German plant breeder Reinhold von Sengbusch found lupin with low alkaloid levels and laid the foundations for lupins development into usable crops. Collaborative projects financed by the German Federal Ministry of Agriculture and Food focuses on lupin breeding, like InnoLuteus project and LupiSmart (Böhme, 2020).

³ In Poland, lupin represents the largest acreage and quantities of fodder legumes for grain in 2019. The Polish Ministry of Agriculture and Rural development took different measures and financed multi-annual programmes in order to enhance national protein production, e.g. "Action Plan to use alternative protein sources for GM soybean protein in animal nutrition" (IAFE-NRI, 2021).

⁴ In this text, "their" is used as a singular gender-neutral third-person pronoun.

⁵ The main Swiss agricultural markets are mostly protected by tariffs. This also applies to seed imports (OECD, 2015).

Resource and infrastructure

Inputs availability

Seed traders and one organisation linking breeding and seed production reported difficulties to obtain desired seeds varieties. Late delivery of imported lupin seeds were mentioned, which required having reserves of seeds. In addition, some of the seed traders had to sell to some farmers another variety than the one they had requested. Inoculum availability was reported as being challenging in recent years. In general, seed traders are aware of this challenge and recommend farmers to order their lupin seeds as soon as possible.

Existing and required infrastructure

One seed trader that was interviewed mentioned that they would be interested to have partners producing lupin seeds in Switzerland. They wish they could start agronomic trials with lupin varieties, because they, along with some farmers, are interested in lupin production. However, they do not have capacities for this, because their cultivated surface is already fully used, as their focus is on cereals and other crops.

Market conditions

Market trends and demand

Interviewees reported being asked for lupin and seeing a real interest for lupin cultivation by farmers. Seed traders reported being aware of the trends mostly through their clients.

Market size

One seed trader reported not being sure if lupin seed selling would be profitable for them. In fact, they mostly see the potential to attract new clients through the fact that they sell lupin. For example, one farmer might buy lupin from them, and then choose to buy seeds from other crops at the same time.

Distribution channels

The seed traders we interviewed are delivering the seeds directly to the clients. This allows for a personal relationship between the clients and the seed traders.

1.3.3 Producers

Motivations behind lupin cultivation were various: diversifying crop rotation, replacing soybean and/or faba bean, landscape quality, and/or just curiosity. Producers were very heterogeneous in the way they handled and marketed their lupin post-harvest.

VC capacities and organization

Horizontal und diagonal linkages

The producers interviewed were often reporting not knowing other farmers that were producing lupin, implying an absence of horizontal linkage. One farmer reported having been recently called for advice by other farmers interested for lupin production. It seems that farmers were quite isolated regarding lupin production. However, they knew about a lupin innovation platform recently created by the organic research organisation, which aims to reunite different VC actors, in order to develop lupin value chains.

Knowledge and technology of actors

Producers reported no need for other machinery to cultivate lupins. Nevertheless, they reported the great lack of knowledge concerning lupin cultivation, and described performing “learning by doing”. Producers reported mainly a lack of advice about weed control. Only one had previous experience

thanks to their apprenticeship, where lupin was grown as feed for cows. One farmer mentioned not being aware of the importance of buying an inoculum to enhance the rate of nitrogen fixation.

Resource and infrastructure

Inputs availability

As already reported in part 1.2.4, seed availability was challenging for farmers. Some reported having to accept another variety than the one ordered. Producers were aware that they had to order seeds soon enough. One farmer reported having changed the seed trader, in order to get certainty about receiving the lupin seeds variety wanted.

Logistical issues with transport, storage, handling, and required infrastructure

The need for a better network of collection centres was reported. One producer had to drive a long way to reach a collection centre taking his good; another had to contact three collection centres, and only the third one accepted his lupin. In general, farmers but also research institutes mentioned the need for a better network of lupin collection, in order to have more efficient value chain. Some farmers that did not produce enough tonnage for collection centre (see: 1.2.6 Collection centres) rented or possessed a drying and/or cleaning machine.

Market conditions

Distribution channels

Lupin food producers used different distribution channels. Raw lupin and lupin products (coffee, flour) (see part 1.2.7 Processors) were sold by farmers through on-farm direct selling and through cereal subscription or to other sellers, like “ZeroWaste” specialty shops (see part 1.3.5 Food sellers). Some producers mentioned that some collection centre did not take their lupin, because they would not accept low volumes of lupin.

Framework conditions

Regulatory & institutional environment

The biggest problem related to lupin is the alkaloid content. As for now, there is no regulation of alkaloid content, only two recommended thresholds for food and feed. In fact, some farmers reported not testing their lupin for alkaloid content. Other did test it, but had to send samples to Germany and it was reported to be very expensive. For many VC actors it was unclear if there is the possibility to test for it in Switzerland. Two researchers confirmed that there is the possibility to test the alkaloids content in Switzerland. Some farmers fear that some sweet lupin variety might exceed this threshold, since alkaloid content is very variable.

Role of public sector (support, policies, etc.)

In Switzerland, farmers get direct payments for growing legumes for feed purposes, which is a reason for producers to cultivate lupin for feed. As of the first of January 2023, farmers will get this direct payment also for legumes grown for food purposes. Some interviewees were thinking that this would be an incentive to push legume cultivation. Other interviewees were mentioning other factors that should be addressed first, otherwise this new direct payments directive will not have any impact on legume cultivation. They mention, for example, the lack of knowledge about cultivation, the underdeveloped collection network and the missing of sales opportunities. Another person mentioned that some farmers are already registering their surface of legume grown for food, and not feed, as eligible for direct payment. Farmers might not know that this direct payment is only for feed purposes, as for now (and before 2023). If the legume ends in the feed or food channel would not be controlled. Hence, for this interviewee, this new direct payment will not be an important driver for farmers that are

already producing food legumes (and hypothetically already obtaining those direct payments direct for feed legumes).

1.3.4 Collection centre

We interviewed one collection centre, as well as one feed mill and one food mill that also acted as collection centres. The interviewee of the feed mill could give us even more information about collection centres, since they are working with different collection centres. Additionally, we have some information from farmers' interviews.

VC capacities and organization

Horizontal linkage

The collection centre we interviewed was not taking lupin anymore, because only a few farmers were producing lupin. However, this collection centre recommended their clients (farmers) another collection centre nearby, which is known to collect bigger lupin quantities. Other collection centres were recommending the interviewed collection centre, because it was taking another niche crop. Hence, for the interviewee, there is some collaboration between collection centres regarding niche crops.

Entry barriers

Bitter alkaloids are one entry barrier, since they could contaminate other products. In addition, collection centres would not know how to handle them and do not know how (and how often) they should test alkaloids content. Besides possible alkaloids contamination, another entry barrier is the allergic nature of lupin. Hence, there would be the need to declare it. Alternatively, collection centres would need to separate it from other crops in their machines to ensure that their products have no allergens and no alkaloids contamination, which could represent some costs.

Resource and infrastructure

Volume & capacity of facilities

The low production volume of lupins in Switzerland is accompanied by challenges for the collection points: minimum quantities of 3-8 t are required to fill drying machines (in general, for bigger collection centres). With small batches, there is also the risk of mixing with other products during collection, storage and processing. This is not dramatic when working with large quantity, but when a small batch of lupin is mixed with larger batches of other crops, the lupin might be too "diluted" with the other crops.

1.3.5 Food processors

We interviewed one mill and one farmer that made lupin flour. Through a cross-interview, we obtained information from a food company processing lupin for a German company (outsourcing of the processing in Switzerland). In addition, we interviewed a researcher expert for food processing, in particular with lupin. To produce flour, the dried lupin is first cleaned from impurities and foreign seeds. Then, the lupin is dehusked and milled. We heard reports of another farmer who supplied their lupins to a coffee roaster, but we decided to focus our attention only on lupin flour.

VC capacities and organization

Knowledge and technology of actors

Two farmers and one mill mentioned that there is a general concern by food processors about alkaloid contents, justified by the absence of testing possibilities. In addition, two farmers were told by processors that lupin would be sticky in their machines. One farmer producing lupin flour reported that a good dissipation of the heat generated by the grinding process is important to avoid stickiness. To

sum up, the lack of alkaloid testing possibilities and the missing milling experience were reported. However, if testing alkaloid content for farmers could be expensive, testing alkaloid contents would not be more expensive than other common quality and safety tests regularly conducted by food processors, according to one interviewee.

Besides this, one interviewee mentioned that there is the possibility to roughly determine the alkaloid content of seeds using UV light. UV light could make a substance in the lupin seed fluorescent, there is to some extent a positive correlation between alkaloids and fluorescent substance in the seed. This UV light method is a quick, easy and cheap way of controlling alkaloid contents; it would never replace a proper quality and safety control.

Another possibility to deal with bitter alkaloids is to store them and mix high and low alkaloid harvests from different years. However, lupin must be very dried before storage and important quantity of lupin are required. Processed as flour, it could become rancid and bad, because of high protein and fat content, according to one interviewee.

Food processors can correct the bitter taste of alkaloids by adding spices (as long as the safety limit is not exceeded). One interviewee mentions that this correction with spices is mostly usable for meat alternatives. For milk alternatives, it would be more difficult to cover the bitter taste with spices and other ingredients.

Entry barriers

Bitter alkaloids (because of both health dangers and bitter taste) are important entry barriers. Two interviewees mentioned that there is the possibility to avoid alkaloid concerns by making protein isolates from lupin. However, the investment costs are high and hence prohibitive. Lupin protein extraction generates with by-products, which would need to be used for ethics and sustainability reasons. In addition, a generous quantity of lupin would be necessary so that the investments would pay off. According to one interviewee, Switzerland is too small for providing enough lupin for such a processing facility. Another interviewee mentioned that there is the possibility of “watering” lupin for extracting alkaloids. Watering strategy would require some investments as well and it is an additional step in the lupin processing. It is already used and might have more potential than protein extraction, because the costs are still lower and the entirety of the lupin is used, not only the protein.

Besides alkaloids, one entry barrier is the fact that lupin is an allergen. Hence, there would be the need to declare this. Alternatively, food processors would need to separate it from production to ensure that their products have no allergens, which represent some costs.

Market conditions

Products

According to preliminary results of a survey of Swiss consumers regarding lupin, lupin products minimally processed would be more desired, like lupin grit or flour, than meat or cheese alternatives. One interviewee reported that hummus or spreads would be interesting products for the food industry, since colour and size parameters are less important parameters for the final product.

1.3.6 Food sellers

As “food sellers”, we include any VC actors that sell lupin directly to the end consumers, in our example, three farmers and many retailing shops. Some farmers sell their products on-farm or through a cereal subscription. In addition, some work with “ZeroWaste” shops or other specialty shops. We interviewed

one of those shops, and in addition, we report farmers' opinions based on direct marketing of lupin seeds and lupin flour.

VC capacities and organization

Vertical linkage

Two farmers collaborating with specialty or "ZeroWaste" shops reported having a good collaboration with these shops. In two cases, the initiative was coming from the shops. In another case, the contact came from the producer. One interviewee mentioned that this collaboration was a source of reliability for them.

Market conditions

Marketing communication and distribution channels

Consumers' knowledge about lupin as food in Switzerland seems to be limited. Producers selling directly to clients reported having to explain about lupin cultivation, preparation and cooking required. Interviewees mentioned that direct selling was the best way to promote lupin to their clients. Still, farmers reported wishing for more communication and advertising about lupin and legumes in general. One reported feeling a growing interest from the media. The shop interviewed tries to promote lupin through their restaurant by cooking it in their menus.

According to two interviewees, lupines have the advantage of a better reputation in the media than soya, for three reasons. The first is that lupin is not portrayed as a deforestation culprit in the media, nor is it linked to the controversial import of soya for animal feed. In the media, soy is sometimes criticized for its hormonal effects and cancer risk, as it contains high levels of isoflavones, which are thought to act as oestrogens in the body⁶ (Brown, 2019). Lupin would not be associated with hormonal effects and cancer risk in the media.

Products

The ZeroWaste shop interviewed reported selling good amount of lupin coffee. Lupin coffee would be a local and caffeine-free alternative of coffee that is much appreciated by their clients. The ZeroWaste shop would like to offer other products like tofu and tempeh, however, there is no Swiss company producing it in a "ZeroWaste" way (not packed in plastic). However, raw lupins would come last in the shop's legume category: chickpeas would be the most sold, followed by kidney beans and soybeans, and then lupins.

1.4 Results – feed value chain

The next results are concerning the feed value chain. There are similarities between both chains, mostly regarding the upstream processes. The feed value chain we focus on is about feed mixtures containing some percentage of lupin.

1.4.1 Description of the lupin feed value chain

The upstream part of the value chain (Breeding until producer) is similar for both feed and food sectors, as can be seen in figure 2. We then chose to focus on a feed mill (specialized in organic farming) that is buying the lupin from the farmers directly. This feed company is working with partner collection

⁶ Soybean's isoflavones have oestrogenic properties. They have been blamed for lowering testosterone levels in men and for raising the risk of breast cancer in women. However, soybean seems rather to protect against cancer risk, but reasons behind it are not totally elucidated (Brown, 2019).

centres, in order to cover a greater area of collection. The harvested lupin is then processed and mixed with other compounds to a feed mixture. The feed company sells the mixture to clients, mostly organic dairy farms.

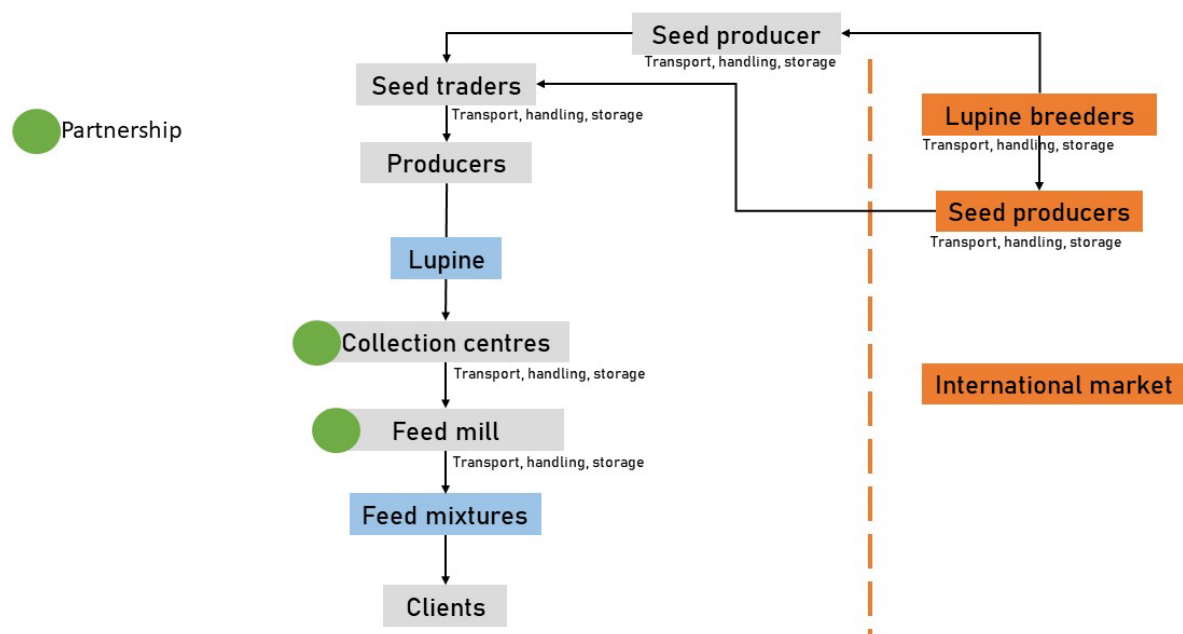


Figure 2. Lupin feed value chain mapping.

1.4.2 Input suppliers (Breeders, researchers, seed producers, seed traders)

This part is similar to the corresponding part 1.3.2, “Input suppliers” of the food value chain. Since lupin is marginally used in Switzerland, there are no important differences between food and feed varieties bred and produced.

1.4.3 Producers

The elements are similar to the part 1.3.3. “Producers”. The only difference are the distribution channels and certification, as can be seen below.

Market conditions

Distribution channels

For feed, lupin was sold to feed mill through collection centres (see 1.2.8 Feed mill), instead of being dry and/or processed by the farmers themselves. One conventional farmer reported that their lupin has been refused by two collection centres, before being accepted by a third one. One organic farmer did not have such problem and could deliver it to the collection centre he knew.

Framework conditions

Certification

New directives from “BioSuisse” were adopted, and 100 percent “BioKnospe”⁷ (organic) feed for ruminants as of 1.1.2022 should be from Switzerland (BioSuisse, 2022). Hence, the organic feed sector is asking for protein crops such as lupin. BioSuisse is even encouraging lupin cultivation by giving a

⁷ Bio Suisse is the leading private organic organisation in Switzerland and established the national organic brand Knospe (German word for bud).

“promotional contribution” on feed lupin and soybean (BioSuisse, 2021). This promotional contribution is rather important and contributes to increase profitability of lupin production for organic farmers.

1.4.4 Collection centre

The elements mentioned were similar than for part 1.3.4, “collection centres” of the food value chain. Challenges are dealing with small quantities, mixing of small batches with bigger ones, high transaction costs for small batches, distance of collection centres, etc. However, there is a different level of organisation than for the food value chain. The processor and seller of this feed value chain, a feed mill, is organising itself and works in partnership with collection centres. This partnership is discussed below in the “vertical linkage” part.

VC capacities and organization

Vertical linkage

Concerning the feed value chain, the collection centres are partners of the feed mill and consequently there is a higher level of vertical integration than for the food value chain. Producers can bring their lupin to collection centres that are partners of the feed mill. The feed mill is responsible to pay the farmers directly, and the collection centres charge the feed mill with the handling and storage costs. However, the feed mill reported that not all their partner collection centres were taking lupin, because of the elements mentioned above and in part 1.3.4, “collection centres” of the food value chain.

1.4.5 Feed mill (Processor and seller)

The feed mill, after having collected the lupin from the partner collection centres, processes lupin into organic feed mixtures. New directives from “BioSuisse” were adopted, and 100 percent “BioKnospe”⁸ (organic) feed for ruminants as of 1.1.2022 should be from Switzerland (BioSuisse, 2022). The new directives explain the interest and use of lupin in organic feed mixtures. Lupin in feed mixtures was reported marginal in the conventional sector, as imported soybean is the most important protein source. This same feed mill then sells the feed mixtures containing the lupin, mostly to organic dairy farms.

VC capacities and organization

Vertical integration

As mentioned in part 1.3.4 (Collection centres), the feed mill has a partnership with collection centres. This is, according to the interviewee, a win-win situation: collection centres perform handling and storage and are paid for their services by the feed mill. For the feed mill, this allows for a better distribution of collection centres across Switzerland, and a higher capacity of collection as well.

Market conditions

Distribution channels

As a feed mill, they deliver themselves almost all order from clients. This delivery is important and allows for more contact between the mill and the clients. This contact was said to be necessary to keep clients and to stay competitive. Feed mill process and sell feed mixtures containing lupin for different reasons. Besides the new BioSuisse directives, producers need protein crops from Swiss origins, and lupin has a great potential to deliver protein on Swiss territory.

Framework conditions

Regulatory & institutional environment

⁸ Bio Suisse is the leading private organic organisation in Switzerland and established the national organic brand Knospe (German word for bud).

The concern about alkaloid content is not that relevant when using lupin milled as fodder. In fact, sweet lupin is diluted in feed mixtures and hence, there is a little chance to exceed recommended alkaloid thresholds. Another concern is the fact that the feed mill must respect organic regulations. New for 2022 in the organic sector is that 100% of the raw material used for feeding ruminants must be from Swiss origin and organic. This creates a great demand for organic lupin and other grain legumes, and for this interviewee, the surface for lupin cultivation could clearly be expanded in Switzerland.

Certification

The interviewee reported that organic certification was very good for them, as they could expand in Switzerland. They have become organic specialists, which allows them to position a specific market segment in the Swiss feed market.

1.5 Discussion

Through our interviews, we discovered different aspects regarding lupin production in Switzerland. First, lupin production is rather depending on foreign lupin seeds. Then, the food value chains are heterogeneous with regard to the downstream aspects. In addition, some farmers play different roles in the food value chain: for example, that of a collection centre (when cleaning and drying the harvest on farm), of a processor, and/or of a seller. This indicates a low involvement of the downstream sector, but also the possibility for farmers to sell lupin directly to end consumers or to other clients like zero waste shop.

The feed value chain shows a greater level of organisation. The interviewed feed mill is responsible for producing feed mixtures, and because of a high demand for Swiss protein crops, lupin is wanted. The higher development of the feed value chain over the food one is reflected in national statistics. Lupin can only be recorded for its usage as feed in the national cultivation statistics “Agricultural Policy Information System” (BLW, 2022) and it seems that it is not difficult to integrate lupin into the value chain of feed mixtures. However, feed mixtures containing lupin seem to be mainly used in the organic sector.

In fact, lupin has no tradition in Switzerland, and as mentioned by an interviewee, researchers have shown for now the most interest in lupin value chain(s). Research institutes are breeding or testing lupin, and they created a lupin innovation network as well. One could say that there is a “push strategy” from researchers; however, the rest of the food value chain is not as mature. A form of indirect “change resistance”, linked to the risk aversion of many actors, could partially explain the current underdeveloped state of lupin value chain, despite research push strategy (Harich, 2010). In addition, the underdeveloped state of lupin value chain(s) could be seen as a form of path dependence (preference for cereals, imported soybean, etc.), resulting in a missing institutional framework and a lock-in situation (Magrini et al., 2016).

In the next part, we will discuss the different past and future challenges linked to lupin food and feed value chains. Past challenges or successes were mostly achieved by “isolated” VC actors, for example producers selling lupin to their clients or to specialized shops, as we mentioned before. Still, the current challenges are various and concerning each actor of the value chain, as can be seen in table 2 and as we will discuss in the next pages.

1.5.1 Past challenges & successes of the value chains

Anthraxnose tolerance

A major and specific issue regarding lupin cultivation is the disease anthracnose, which could cause total yield losses. This challenge was overcome by the breeding of white lupin tolerant in other countries. The importation of those varieties allowed for higher yields (because white lupin is better adapted in Switzerland and provides higher yields than narrowleaf lupin, but old white lupin varieties were not tolerant to anthracnose), which resulted in higher adoption levels among farmers.

However, there is for now only a tolerance and no resistance to anthracnose in white lupin. Current disease management relies on planting pathogen-free seed and chemical control (Alkemade et al., 2021). The latter is considered problematic and is not possible in organic agriculture. Hence, breeding for resistance appears as probably the most sustainable approach. As the tolerance/resistance in white lupin is polygenic and not controlled by single dominant genes (like in narrowleaf lupin), breeding anthracnose tolerant/resistant white varieties remains challenging (Alkemade et al., 2022). In addition, two highly virulent strains have been shown to be able to overcome resistance of “advanced white lupin breeding material” (Alkemade et al., 2021). In short, if white varieties can tolerate anthracnose better than before, anthracnose seems to remain a challenge for white lupin breeders and producers.

Demand for food and feed exists

Similar to other niche crops, there are always some consumers curious about new products. In fact, some farmers are successfully selling lupin directly to their consumers or to specialized shops. The interest of specialized shops shows that some demand is present for lupin; however, lupin is still a niche crop and a niche food product.

As for the feed value chain, there is a demand for lupin, in order to integrate it in feed mixtures. The knowledge and the machinery of feed mills are already sufficient, which is a great perspective in order to increase lupin cultivation. There is definitively some interest for both food and feed value chains. However, lupin will remain a niche crop, if current and future challenges, which are discussed in the following section, are not resolved and anticipated for.

Table 1. Summary of the challenges, strategies and potential benefits for each value chain actor.

VC actor	Main challenges/opportunities (order: most important first)	Strategies undertaken/to undertake	Potential & benefits for the actor in the VC chain
Input suppliers (Breeders, researchers, seed producers, seed traders)	<ul style="list-style-type: none"> Reliability of seed supply Alkaloid contents 	<ul style="list-style-type: none"> Ordering seeds timely, establish relations with foreign seed producers Varieties should be very low in alkaloids, if used for food Need to give good advice to producers 	<ul style="list-style-type: none"> Seed trader: lupin as side business could help attract new clients The more reliable for lupin supply, the better for keeping clients
Producers	<ul style="list-style-type: none"> Quality: alkaloid level Seed supply: they do not always get the wanted variety Not enough knowledge about cultivation, e.g. weed control Lack of collection centres network and of sales opportunities Yield level and variability 	<ul style="list-style-type: none"> Find sales opportunities and be sure that the varieties is adapted for what is planned Order soon enough, show interest for lupin seeds by seed traders Find a way to gather knowledge from other farmers or researchers (networking, demonstration farms, etc.) Find and convince collection centre to take their goods, or work with other farmers 	<ul style="list-style-type: none"> Lupin is advantageous in crop rotation Diversification of earnings
Collection centres	<ul style="list-style-type: none"> low tonnages (for existing infrastructure and processes) Motivation or willingness to work with lupin reported as low Alkaloid and allergen contents are to be dealt with 	<ul style="list-style-type: none"> Convince farmers to bring their goods together to reach an higher tonnage Recognize potential of lupin and increase willingness to work with lupin 	<ul style="list-style-type: none"> Diversify their products Attract new clients specially looking for a collection centre accepting lupin
Processors	<ul style="list-style-type: none"> “Stickiness” of lupin might be challenging Alkaloid and allergen contents are to be dealt with 	<ul style="list-style-type: none"> More experience with lupin processing might be needed 	<ul style="list-style-type: none"> Interest to work with another product Diversification of the processed products
Feed mill	<ul style="list-style-type: none"> Organic standards (BioSuisse) increase the demand for Swiss protein 	<ul style="list-style-type: none"> Try to convince farmers to produce lupin for feed 	<ul style="list-style-type: none"> Less reliance on import for feed mixtures
Sellers	<ul style="list-style-type: none"> Clients do not know lupin and how to use it 	<ul style="list-style-type: none"> Direct selling is already allowing direct marketing to the consumers There is still a need to promote legume and lupin in general 	<ul style="list-style-type: none"> Diversity of products offered might attract new clients that know about lupin

1.5.2 Current and foreseen challenges and chances of the value chains

Seed availability

For lupin specifically, seed availability seems to be challenging, because it relies on imports. Swiss farmers often did not get the variety they wanted, or got the seeds eventually too late in the season. As it might be common for niche crops as well, breeders, seed producers and seed traders might have less interest in niche crops. This is because the market size is small and hence, economies of scale are hard to achieve and profits' are small (lock-in situation). Additionally, establishing a market requires establishing contacts, finding customers, clarifying quality issues (alkaloid levels), and forecasting demand and hence, results in high transaction costs. National seed production could be an alternative for reliability, but at the moment it is disadvantaged relative to other crops (especially cereals) due to differences in tariff protection of imports. In addition, lupin seed output is relatively low when compared with cereals seed production.

Alkaloid content

As stated by different interviewees, alkaloids content is still a big issue specific to lupin. Because lupin production is small, and because there is no regulation but only a threshold recommendation, there was never any incentive to implement an alkaloid control system, for example, at collection centres. Consequently, farmers and other VC actors fear that this might be a problem in the future, since some “sweet” lupin varieties are not stable or “really sweet”. Variability in alkaloid content of sweet lupin varieties and uncertainty about future regulation are reasons that make lupin cultivation and processing for food very uncertain. Unclear legal or health requirements regarding alkaloids might be a specific barrier of entry, due to increased transaction costs.

In fact, this problem specific to lupin can be solved through breeding (“extra sweet” lupin or “stable sweet” varieties) or through processing (“watering” or “protein isolation”). Our interviewees reported that breeding should be the option to go, as processing might be too costly (e.g. protein isolate). Additionally, farmers would then have the possibility to sell their lupins directly, and would not have to rely on processing to be sure it is safe for consumers. It was reported that some very low alkaloid contents varieties from Poland have the drawback to have low vitality, and hence they need for example the support of a cereal crop (mixed cropping). However, as breeding is in general a slow process, there might be need to collaborate along the value chains to handle the alkaloid contents. Value chain actors could for example split the costs of alkaloid testing and think about a potential system for controlling alkaloid values at different levels of the stage.

This alkaloid problem is not that relevant for feed. Feed mixtures contain a small percentage of sweet lupin and the recommended threshold for animal is lower than for human.

Collection centres: network and infrastructure

Crops with small production volumes pose a challenge to collection centres for a variety of reasons: some drying machine or other collection centres' infrastructure are working with a minimum amount of tonnage. Therefore, some collection centres refuse lupin because the quantities harvested by one farmer are too small. In addition, there is a possibility that crop residues will be mixed with the lupin seeds. Lupin is an allergen and has bitter alkaloids, and both aspects are entry barriers that should be accounted for.

A larger number of crops collected can also result in higher transaction costs and less economies of scale. Therefore, not all collection centres are willing to take lupin for drying and cleaning. As one farmer reported, only the third collection centre he went to accepted his lupin. The small number of collection

centres accepting lupin increases search and transportation costs. This finally might decrease farmers' interest in cultivating lupin.

Sales opportunities, promotion and marketing

Knowledge of the crop and of lupin as a foodstuff among the general population seems limited, including in Switzerland. This seems to be the case for lupin, as farmers reported to have to inform their clients. The consequence of this “invisibility” is of course the lack of sale opportunities for farmers, so that only a few can find “their niche” to sell their products. This is not the case for the feed value chain, since lupin, as “Swiss protein” is demanded.

Thus, the lack of sale opportunities for food is linked to the fact that lupins are not known by end consumers and therefore not in demand. Other elements could play a role, for example the lack of interested processors and retailers. Processors might lack sufficient knowledge and experience with lupin (reported “stickiness”), and the alkaloid and allergen challenge can play a role too (transaction costs). For retailers it is not attractive to sell raw lupins, as it is a difficult product, which consumers might not know how to prepare. Hence, finding a way to accommodate low alkaloid contents could trigger food processors to produce special lupin products that might be more appealing to retailers, as they would be easier to prepare for consumers. Of course, prices must be adequate for all actors of the value chain. Opportunities for marketing could be the fact that lupin has ecological benefits and is not badly described by the media, as it is the case for soybean (See part 1.3.6, Food sellers). Hence, presenting lupin as an alternative to soybean could contribute to enhance demand for it.

Certification and public sector

The production of organic lupins provides access to the organic feed market. In the conventional sector, there is the possibility to rely on imported soybean to feed animals with enough protein. However, organic regulation requires Swiss feed, which creates a demand to meet. As a niche food product, organic certification could be interesting, because of the “promotional contributions”. One farmer was successful in the conventional sector, selling their lupin on-farm and to a specialized shop.

The direct payment for feed legume is, besides the organic promotional contribution of BioSuisse, a good incentive for all farmers to grow lupin. As for 2023, it is unclear how much the change regarding this direct payment (legumes for human consumption will be included in the payment) will affect legume production. One can of course expect a higher interest by farmer for legumes, but other challenges mentioned should be prioritized, for lupin cultivation and consumption to expand.

As said at the beginning of the discussion, lupin cultivation was more “pushed” by research organisation, than “pulled” by consumers. Research institutes might be very helpful in different ways, like breeding Swiss varieties or making agronomic trials, besides consumer studies. In fact, a certain support of the public sector might have great benefits for lupin value chains. The best example is the creation of the lupin innovation platform and the work of different researchers to encourage lupin cultivation, but also foster innovation towards processing and product development. However, in the end, the demand of the consumers will be determinant for the further development of the food value chain. In addition, the demand for Swiss organic protein fodder could be a driver of increased lupin cultivation as well.

1.5.3 Limitations

We conducted many interviews and could obtain different perspectives on the importance of lupin in Switzerland. However, the distribution of our interviews was slightly biased towards scientific organisations and producers. The upstream part of the value chain, as well as the research

organisations, seem to have more interest in lupin than the downstream part, as for now. Reasons for the low representation of the downstream sector in our report and in the lupin value chains are various. First, the network of collection centres seems to be challenging for both feed and food value chains. Infrastructure of collection centres is designed for large trade volumes and producers might not want to produce high tonnages without sale guarantees. In fact, organic feed lupin producers seem to be better off regarding sale opportunities when compared to producers cultivating lupin for food usage. Different reasons can be mentioned: alkaloid and allergens content is not a risk for feed mixtures production, organic Swiss protein crop are in demand, feed mills seem to have required machinery and experience to handle lupin (for more information, see part 1.4.5 Feed mill). For the food value chain, the lack of processors and/or retailers interested in lupin can be explained by different reasons: lack of knowledge, fear of alkaloid and allergens contents, lack of consumer demand for lupin products, risk aversion. Consequently, current lupin food producers and sellers are restricted to distribution channels that are very close to the consumers, in order to promote lupin consumption and share advice for preparation.

1.6 Synthesis

Overall, lupin value chains are very young and at their introduction stage in Switzerland. Research organisations are involved in food value chain creation (“push” strategy) and the new direct payments for the cultivation of lupin will certainly contribute to enhance interest for lupin cultivation. However, challenges must be overcome for both upstream and downstream value chain parts. For example, inputs suppliers need to ensure reliable seed importation (or production) to decrease seed traders’ and farmers’ uncertainty about seed availability. Farmers’ knowledge about lupin cultivation should be greatly improved, in order to ensure low variability of the yields. Collection centre should organise themselves and collect lupin. Processors might want to experiment and research more about potential usages of lupin as a food product. Of course, the demand for lupin should as well be increased, by marketing it or promoting it to the consumers.

In the end, willingness to increase lupin production will require some work at all stages of the value chain. Research is needed, for example regarding alkaloid contents and food product development. In parallel, network of collection centres and interest from processors and retailers need to be built, depending on their willingness, consumers demand, and upstream coordination, together with research organisations. This situation can be a good starting point to further expand lupin cultivation and usage in Switzerland.

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