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Grain legumes on the Swedish market: origin and pesticide use in the production

Ida Ekqvist, Elin Röös, Pernilla Tidåker

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Ida Ekqvist
Ida.ekqvist@gmail.com

Elin Röös
Elin.Roos@slu.se

Pernilla Tidåker
Pernilla.Tidaker@slu.se

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Foreword

The mapping of origins of grain legumes on the Swedish market and parts of the review was performed by Ida Ekqvist as a project course at SLU. The study was later extended with a more in-depth literature review covering pesticide use in grain legume production. Elin Röös, Georg Carlsson and Pernilla Tidåker have been supervisors to this student project. The report was completed thanks to funding from the Formas project *New Legume Food*.

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Abstract

Production of food contributes heavily to the total negative environmental impact caused by human activities. A change towards a more plant-based diet is needed to cope with these challenges, and grain legumes could play an important role in such a transition. Pesticide use in agriculture imposes negative pressure on ecosystems and poses risks to organisms. Most of the grain legumes consumed in Sweden today are imported, but there is potential to increase domestic production and consumption. This report maps the origin of grain legumes on the Swedish market and explores use of pesticides in cultivation of imported grain legumes consumed in Sweden and in Swedish grain legume production. The report begins with an inventory of the origins of grain legumes sold in Sweden, followed by review of the literature on pesticide use in grain legume production worldwide but particularly in China and Canada, which are important countries of origin for grain legumes consumed in Sweden. The results indicate lower pesticide use in conventionally grown legumes in Sweden than in production of imported conventional equivalents and, above all, a higher degree of transparency due to existing monitoring that includes pesticide use intensity for legumes. Studies that include impact assessment of pesticide use in grain legume cultivations are scarce. There is clearly a need for more data and for a harmonized model to assess the toxicological impacts of pesticide use.

Contents

Introduction

Activities within the food system contribute heavily to the total negative environmental impacts caused by human activities, and have been identified as one of the main drivers of biodiversity loss, climate change, freshwater use, and disturbance of the phosphorus and nitrogen cycles. Animal production is responsible for a large share of these negative environmental impacts (Willett *et al*., 2019). A change towards a diet containing less animal products and more plant-based foods has been shown to be one of the most effective ways to cope with these challenges (Röös *et al*., 2017). Grain legumes have the potential to play an important part in transition towards a more sustainable and healthy diet (Röös *et al.,* 2018). This is mainly due to their high content of proteins and dietary fiber (Nadathur, Wanasundara, & Scanlin, 2017) and beneficial agronomic characteristics, including nitrogen fixation. Most of the grain legumes consumed in Sweden today are imported, but there is increasing interest in domestically grown beans, peas, and lentils in Sweden.

One agricultural activity imposing negative environmental pressure within the food system is pesticide use. The use of pesticides has reduced crop losses and enhanced the productivity of agricultural systems over the past few decades, by protecting crops from pest, diseases, and competition from weeds. However, pesticide use is increasing globally (Zhang, 2018) and is causing severe damage to ecosystems, resulting in biodiversity loss and toxicity symptoms in human and animals (Bergmann, 2019). A recent study showed that use of agrochemicals (including pesticides) is the second largest driver of the rapid global decline in insect species (Sánchez-Bayo & Wyckhuys, 2019).

Most countries have legislation setting maximum residue limits (MRL) for food and feed, in order to regulate pesticide use, enable trade, and protect human health. The MRL is defined by the European Food Safety Authority (EFSA) as "*the upper legal level of a concentration for pesticide residues in or on food or feed based on Good Agricultural Practices (GAP) and to ensure the lowest possible consumer exposure*" (EFSA, 2011). Good Agricultural Practices (GAP) include a number of principles to promote sustainable agricultural production, taking into account economic, social, and environmental aspects and resulting in safe and healthy products (FAO, 2016). Included in GAP are regulations concerning pesticide residue limits and storage of pesticides. Furthermore, when complying with GAP standards, farmers are obliged to use integrated pest management and keep detailed records of farm practices (Global G.A.P, 2018). The GAP standards are implemented on national level, together with a voluntary certification scheme intended for business-to-business relations, and are thus not directly visible to consumers. A growing number of retailers and supermarket chains in the European Union (EU) are demanding that their suppliers be certified against a private food safety standard such as GlobalGAP (Liu, 2007). In 2010, more than 40 retail chains in Europe required their suppliers to have GlobalGAP certification (Fiankor *et al.,* 2017). Thus certification facilitates trade, but it does not provide farmers with the possibility to market added values in their production.

Although MRLs are partly based on agricultural practices in accordance with the GAP principles, the legislation on MRL for various substances differs between countries and regions. In general, the EU has the lowest MRLs, and also relatively strict legislation concerning substances approved for use in pesticides (Handford, Elliott, & Campbell, 2015). The EU pesticide legislation is harmonized across the member countries (*ibid.).* Developing countries typically have less strict pesticide legislation, due to lack of the resources and expertise needed to implement and enforce pesticide regulations (Liu & Guo, 2019).

Pesticide residues in foods consumed in the EU are monitored through national control programs in each member state and in Iceland and Norway, and through an EU coordinated control program reports every third year. The EU control program is based on 11 different categories of foods that each country must analyze, but grain legumes are not included (EFSA, 2018). Each EU member state specifies which food products to include in its national control program. All analytical results for pesticide residues from each country are then reported to EFSA. The national control program for pesticide residues in Sweden is risk-based and requires 60% of the samples to be taken from 20 different kind of foods identified as most important concerning the risk to consumers (Jansson & Fogelberg, 2018).

Life Cycle Assessment (LCA) is a commonly used method to assess the environmental impact of chosen impact categories during the whole life cycle of a product (Baumann & Tillman, 2004; Poore & Nemecek, 2018). The toxicological impact on organisms and ecosystem of substances used within a system is one impact category that can be assessed by LCA. The impact category for toxicity is usually divided into human toxicity and ecotoxicity. Ecotoxicity is often further divided into terrestrial toxicity and aquatic toxicity (Baumann & Tillman, 2004).

Toxicity is a rather complicated impact category, partly due to the wide range of substances used and the variety of impact these substances have (*e.g.*, carcinogenic, endocrine disruptive, etc.). Further, the pathways and degradation rate of a substance must be taken into account when calculating the characterization factors[1] used to assess the toxicity of a substance. Considering the wide range of substances used in society today and the vast amount of data needed to assess the impact of a substance, it may be necessary to compromise on the accuracy of each characterization factor, in order to include as many substances as possible (Baumann & Tillman, 2004). With these uncertainties in mind, several studies highlight the importance of interpreting the results of toxicological assessment with great care (Nordborg *et al.,* 2014; Notarnicola *et al.*, 2017; Cederberg *et al.*, 2019).

Different ways of modeling pesticide emissions lead to different results in the toxicological impact assessment, which results in low comparability across LCA studies (Bennet, 2012; Notarnicola *et al.*, 2017). The toxicity impact of pesticides has been frequently excluded from LCA studies, due to the lack of a satisfactory and coherent model (Silva *et al.*, 2010; Romero-Gámez *et al.*, 2012; Nordborg *et al.*, 2014). Further development is therefore needed (Rosenbaum, *et al.*, 2015).

Against this background, the aim of this report was to map the origin of grain legumes on the Swedish market and explore the use of pesticides in cultivation of imported grain legumes consumed in Sweden and in Swedish grain legume production.

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[1] All substances in a LCA study are multiplied by a substance-specific characterization factor that reflects the relative environmental impact of each substance. This makes it possible to quantify the total toxicological impact of a product or a service. Characterization factors are also used in other impact categories.

Material and methods

An inventory of grain legumes sold in Swedish supermarkets was performed, to map the origin of grain legumes consumed in Sweden. National trade statistics were not used in the inventory, since they are not a reliable data source for identifying the country of origin of foods imported into Sweden. This is because the declared exporting land may not be the land where the food was grown, but the country e.g., where it was packed.

The inventory was carried out in spring 2019, by visiting 10 supermarkets in Uppsala and Stockholm representing the largest supermarket chains in Sweden. Information on origin was searched for on the packaging of all dry and canned grain legumes available in the supermarkets. If the origin of the product was not stated on the packaging, the information was sought through email contact with the company marketing the product. The information obtained was compiled and used to identify the main countries of origin of grain legumes currently sold in Sweden. Based on this information, two importing countries (Canada, China) were selected for in-depth analysis. Information about pesticide use in these two countries was acquired through a literature search and through contacts with relevant authorities and stakeholders. In addition, data on pesticide residues in grain legumes were included in the analysis, as an indicator of high pesticide use.

A literature study was conducted (see *Appendix* 1) to collect information about pesticide use in grain legume production and how it is included in LCA. The scope of this literature search was not limited to LCA studies of legumes with an impact assessment of pesticide toxicity, since these studies are scarce. Thus it also included other studies providing data on actual pesticide use per hectare, to give an indication of pesticide use in different regions of the world. The use of herbicides, fungicides, and insecticides expressed as kg active ingredient per hectare gives very limited information on the toxicity impact of pesticide use, since substances have different properties and have effects in different amounts. However, this metric was included in the present study, since it can serve as an indicator of potential impact and is often the only measure available (Cederberg *et al.,* 2019). Studies reporting on pesticide residues in different grain legumes were also included, as an additional indicator of high and harmful pesticide use.

Method description for the literature study

The literature study was conducted based on a number of keywords (presented below) in different combinations. The databases used were mainly Web of Science and the SLU library search tool Primo. Google Scholar was used on a few occasions when an article that was considered interesting was not available in the other two databases.

Criteria for inclusion for articles were:

- fully accessible without charge
- written in English or Swedish
- published after 1995
- peer-reviewed article published in a scientific journal

Relevant statistics and reports from authorities were also searched for, and used when deemed relevant.

The keywords used were: *Legume, pea, beans, pulses, Pisum sativum, lentils.* The keywords were used in all relevant combinations with one or more of the following words: *Production, pesticide, LCA, crop protection, plant protection, weed management, herbicide use, pesticide use, toxicity, Canada, China, pesticide residues.*

Results

Inventory of origin

The inventory of country of origin of grain legumes imported to Sweden is presented in Table 1 and Figures 1 and 2. Dry and canned legumes were included. Semi-finished foods and ready-made meals were not included, due to scarcity of data on origin. A total of 126 packs of dried and canned beans, peas, and lentils were scrutinized. Information concerning country of origin was found for 114 of these packs, either through the declaration on the packaging or through contact with the company marketing the product.

A common response by companies to inquiries about product origin was that the country of origin varies based on available supply. Most of the brands declared the country of origin on the packaging, sometimes with several countries to cover variation in country of origin. Some of the brands that did not declare origin on the packaging provided the necessary information on inquiry, while others replied that they could not specify any origin at all due to large variation. A few companies did not answer at all. A summary of the inventory can be found in *Appendix 1*.

Table 1. Number of times a country was stated as country of origin for a sample of dried or canned grain legumes available in supermarkets in Sweden 2019. Products are subdivided into total, organic, and conventional

Country	Total	Conventional	Organic
Argentina	5	4	1
Canada	24	14	10
China	48	13	35
Ethiopia	1	1	0
France	4	2	2
Italy	14	2	12
Madagascar	1	1	0
Mexico	1	1	0
Myanmar	1	1	0
Poland	4	2	2
Russia	1	1	0
Spain	2	1	1
Turkey	15	1	14
USA	18	16	2
Sweden	7	6	1
Peru	1	1	0
Ukraine	1	1	0
Egypt	2	2	0

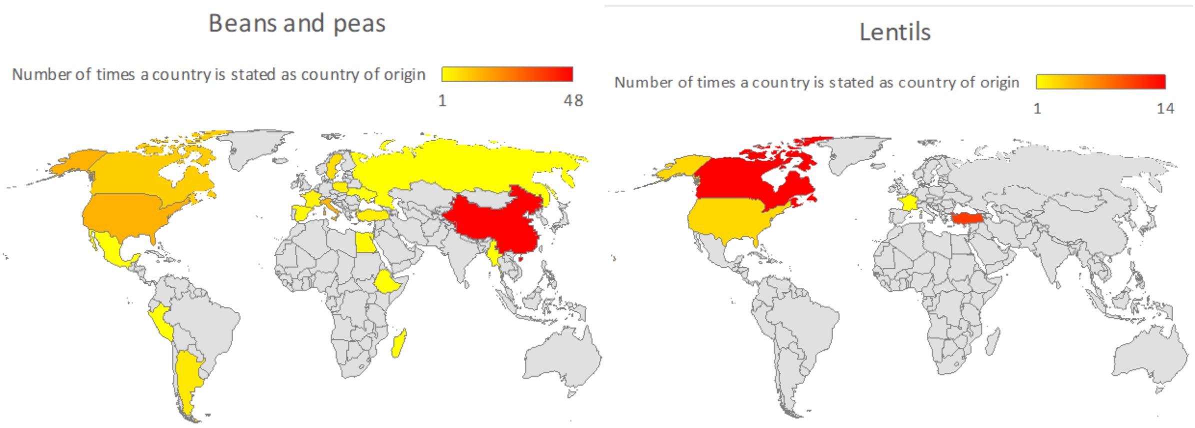

Figure 1. Number of times a country was declared as the country of origin on (left) samples of dry or canned beans and peas and (right) samples of dry or canned lentils sold in Swedish supermarkets in spring 2019. The information was taken from the packaging when available. When no origin was declared on the packaging, the company marketing the product was contacted.

Figure 2. Map showing countries of origin (as stated on product packaging or declared by the relevant company) of dry and canned grain legumes found in supermarkets in Sweden. The density of the dots gives a rough indication of the main regions where the legumes are cultivated.

Since more than one country of origin was often declared per product, the actual origin of a specific product remained unknown. Thus the results of the inventory show how many times a country was stated as the country of origin for a product, not how many times a product actually originated from a country. Both organic and conventional grain legumes were included in the study, as shown in Table 1.

The inventory showed that China was the single most common country of origin of grain legumes found in supermarkets in Sweden. The second most frequent declared country of origin was Canada, from which most of the products were lentils. The inventory also showed that almost all lentils found in stores were imported from Canada and Turkey. All lentils from Turkey were organic, as were 50% of lentils from Canada. Most of the grain legumes investigated that had China as the stated country of origin were organically grown (73%).

Pesticide use associated with imported grain legumes sold in Sweden

China

China is the largest user of pesticides globally, using more than 30% of global agricultural chemicals on only 9% of the world's cropland (Wu *et al*., 2018). The average use of pesticide per hectare in China is two- to seven-fold higher than in other regions of the world *(ibid.).*

National statistics in China only present total pesticide use for the whole country, and no data on pesticide use per region or for different crops are available (Ministry of Agriculture of the People's Republic of China, 2015). It has been reported that the average use of pesticides in China in 2009 was 14 kg/ha (Li, Zeng & You, 2014)[2] and that the average use of active ingredients in pesticides in 2010 was 18.7 kg/ha (Zhang *et al.,* 2015). This made China the third largest consumer of pesticide per hectare in the world in that year *(ibid.)*. However, pesticide use is reported to vary widely between different regions of China, from a highest use rate of

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[2] The study by Li, et al. (2014) does not specify whether the amount of pesticide per hectare refers to active ingredient.

64.3 kg/ha to a lowest rate of 2.2 kg/ha *(ibid.).* Several studies have reported overuse and low use efficiency of pesticides (and chemical fertilizers) in China (Li *et al*., 2014; Zhang *et al*., 2015; Wu *et al*., 2018; Zhang, 2018; Liu & Guo, 2019). This has led to pollution of soil and water and to presence of pesticide residues in fruit and vegetables (Chen *et al*., 2011; Zhang *et al*., 2018).

China has long been a leading producer of peas, faba beans, mung beans, and adzuki beans (Li *et al.,* 2017). The average yield of pea and bean crops in 2014 (most recent available statistics) was 1,730 kg/ha (Ministry of Agriculture of the People's Republic of China, 2015). Since 1985, beans from the provinces of Heilongjiang and Yunnan have been an important export product to Europe and other parts of the world *(*Li*, et al.,* 2017*).* Pesticide use in these two provinces in 2009 was within the range 5-12 kg/ha according to a study by Li *et al*. (2014), which gives an indication of pesticide use in grain legume production in China.

The legislation on MRLs for vegetables (including grain legumes) in China is not fully enforced, and there is a lack of monitoring of pesticide residues in vegetables from China (Yu, *et al*., 2018). It has also been reported that the technology used for detecting pesticide residues in food is lagging behind in China compared with other countries (Liu & Guo, 2019).

In the latest report from EFSA on pesticide residues in food, China was one of the countries of origin most frequently exceeding the MRLs for different food products (EFSA, 2018). Three studies that investigated pesticide residues in vegetables (including grain legumes) in different periods and in different regions in China all concluded that conventionally grown grain legumes are among the most critical food crops as regards pesticide residues (Chen *et al*., 2011; Qin *et al*., 2016; Yu *et al*., 2018). In one study that monitored vegetables grown in north-western China between 2011 and 2013, the detection rate of pesticide residues exceeding the MRL was highest in cowpeas (26.7% of samples). The same study found that, of the 40 vegetable samples that exceeded the MLR, 72.5% contained residues from banned pesticides (Yu, et al., 2018). Another study that monitored pesticide residues in western China found similar results, with cowpea being the product in the vegetable category that most frequently contained pesticide residues exceeding the MRL and one of the crops that most frequently contained multiple pesticide residues. Beans were also relatively frequently (25% of samples) found to contain insecticides, confirming findings in another study where pesticide residues were present in 30% of kidney bean samples analyzed and 45% of cowpeas samples (Yu-feng, Xiao, & Feng-shan, 2017). A study investigating pesticide residues in vegetables in eastern China 2006-2009 identified legumes as the crop with the highest incidence of pesticide residues (18.9% of samples). Further, grain legumes were found to be the most critical of foods included in an assessment of the potential health risk of exposure to pesticide residues in foods (Chen, *et al*., 2011). A more recent study investigated 12 types of vegetables from 15 provinces in China and found that cowpea had the second highest detection rate of pesticide residues (71.4% of samples) (Xu, *et al.,* 2018). It is worth mentioning that those studies used the MRLs that apply in China, which are in general set slightly higher than those in the EU. The vegetables investigated in the studies cited were not organically grown.

In several studies, pesticide overuse in China has been attributed to lack of regulation and to lack proper knowledge and education among farmers on how to use pesticides in an efficient way (Li *et al*., 2014; Qin *et al*., 2016). One study found a significant correlation between farm size and pesticide use, with small farms using more pesticides per hectare (Wu, *et al*., 2018). China has a considerably higher proportion of small farms than most other countries in the world, with as many as 98% of households that run a farm in China having less than two hectares of farmland *(ibid.)*

Information concerning agricultural production in China for the export market was sought in this study through contact with food retailers and importers in Sweden. The responses indicated that Chinese producers that sell their agricultural produce to the European market often have certification in place to ensure food safety and quality, such as GAP and Good Manufacturing Practices (GMP), since this is often a requirement from European supermarket chains and food retailers. Several of the big brands that market grain legumes in Sweden state that they carry out spot-checks to analyze pesticide residues in some of their products[3].

Canada

Canada does not report national statistics on pesticide use in kg/ha (Statistics Canada, 2019). In this study, data on pesticide use in Canadian grain legume production were requested from Canadian authorities, advisory organizations, and associations connected to grain legume production or pesticides, but with little success.

Unlike China, grain legumes in Canada are usually produced on large farms and farm size has grown considerably in recent decades (Statistics Canada, 2019). The average size of farms growing grain legumes was 1,070 hectare in 2011, and the average area of grain legume cultivation per farm was 178 hectares (Bekkering, 2014). Most grain legumes in Canada are grown in the provinces of Saskatchewan, Manitoba, Alberta, and Ontario. In 2011, Saskatchewan accounted for 79% of grain legume production in Canada. Most peas, lentils, and chickpeas are grown in Saskatchewan, while Ontario has the largest area of dry beans (*ibid.*).

Data on pesticide use in Canada in kg/ha are scarce. One study reported that average herbicide use for soybean cultivation in Ontario in 2008 was 1.7 kg/ha active ingredient (McGee, Berges, & Beaton, 2010). This is slightly higher than the value in inventory data for Canadian soybean included in a LCA study, where the application rate was 1.19 kg/ha active ingredient of total pesticides (Pelletier, Arsenault, & Tyedmers, 2008). Another study showed that pesticide use was higher on average on Canadian farms with grain legumes than on farms with field crops, and that most of the farmers who grow grain legumes also grow other crops (Bekkering, 2014).

In a national survey in 2017, a vast majority of farms in Canada (93%) reported use of herbicides (Statistics Canada, 2019). In Manitoba, 61% of the farms with field crops reported fungicide use, while in Ontario insecticide use was reported by 35% of field crop producers (*ibid.*). A sharp increase in glyphosate use has been seen in Canada, largely due to the use of genetically modified glyphosate-tolerant crop varieties, including soybean (McGee *et al.*, 2010; Wilson, 2012). Another contributing cause to the high use of glyphosate may be pre-harvest use, when glyphosate is used to kill the growing crop in order to synchronize crop harvest (at latest three days before harvest). This form of use is recommended by the

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[3] The information was obtained through personal communication with Marie Engberg at Axfood konsumentkontakt, Karin Amnå at ICA Sverige AB and Helene Rehnberg at Di Luca & Di Luca AB.

authorities in the main legume production provinces (Saskatchewan Ministry of Agriculture, 2019; Manitoba Ministry of Agriculture, 2019). The per-hectare dose of glyphosate for pre harvest use recommended by the authorities is 0.74-4.3 kg/ha active ingredient. Since 2011, farmers in Canada have faced problems with glyphosate-tolerant weeds, which could be assumed to be a consequence of the relatively high use of glyphosate in Canada (University of Saskatchewan, 2016).

In a recent report from EFSA concerning pesticide residues in food consumed in the EU, lentils were the individual food with the highest incidence of glyphosate residues (38% of samples), while soybeans were in third place (16%) and dry peas in fourth place (12%) (EFSA, 2018). Pod peas was one of the foods in which multi-pesticide residues were most commonly found (more than 50% of samples) (*ibid*).

In the most recent Swedish national control program from 2016, 19 samples of dried lentils were analyzed. Pesticide residues were found in five of these samples, but at low levels that were below the MRLs (Jansson & Fogelberg, 2018).

Pesticide use in Sweden

Swedish agricultural statistics keep track of pesticide use (specifying fungicides, herbicides, and insecticides) per hectare in different types of crops. Yearly monitoring data on pesticide use per hectare in peas and beans are available (Jordbruksverket, 2018). A more detailed report on pesticide use, including kg/ha data for different kinds of beans and peas, was issued recently by Statistiska Centralbyrån (2018).

Several studies have found relatively low pesticide use in Sweden compared with other EU member countries and the rest of the world (including all crops) (Wivstad, 2005; Cederberg *et al.*, 2019) and a low incidence of pesticide residues in food produced in Sweden (EFSA, 2018; Jansson & Fogelberg, 2018). This is particularly true in the case of fungicides and insecticides, where Sweden has one of the lowest use rates in the EU (Cederberg *et al.,* 2019). This is consistent with the data on Swedish pesticide use in grain legumes presented in *Appendix* 2. It can be partly explained by the lower pressure from insects and fungi in Sweden due to the cooler climate (Nordborg et al., 2017) and partly to the type of crops grown in Sweden. An additional explanation may be that preventive plant protection methods, such as varied crop rotations, are used to a larger extent.

According to a recent study, the typical pesticide dose per hectare in Sweden is 1.1 kg active ingredient for peas and 0.9 kg active ingredient for faba beans (Krüger Persson, 2019). This is in line with the Swedish national statistics for pesticide use, which report a per-hectare dose of 0.99 kg active ingredient for peas and 1 kg active ingredient for faba beans (Statistiska Centralbyrån, 2018). Glyphosate was the most commonly used herbicide in Sweden in 2016 (Jordbruksverket, 2018). However, unlike in China and Canada, glyphosate is not permitted for use in growing food crops in Sweden.

The findings on pesticide use in grain legume production in different countries and for different crops are compiled in *Appendix 2*.

Assessment of toxicological impacts of pesticide use in legumes

Only a few LCA studies of grain legumes have included pesticide use. In several of these studies, pesticide use was included in the inventory data but toxicity was not assessed (Pelletier et al., 2008; Poore & Nemecek, 2018)**.** Some studies that included both the amount of pesticides and the impact category toxicity only included production and transport of pesticides in the calculations, and excluded the effect of application of pesticides in the field (Silva *et al*., 2010; Romero-Gámez *et al*., 2012). This was reported to be due to lack of a satisfactory calculation model. In the LCA studies that included actual use of pesticides in the calculation of toxicological impact, a variety of characterization factors and calculation models were used (Abeliotis *et al*., 2012; MacWilliam *et al*., 2014; Nordborg *et al*., 2014, 2017; Elhami *et al*., 2017). The current scarcity of LCA studies that include pesticide use in grain legume production, together with poor comparability of the existing results, make it difficult to get a clear picture of the environmental impact of pesticide use across different countries and cropping systems.

The only published study found in the present search that compared ecotoxicity impact of grain legumes produced in different geographical areas was an LCA study that included assessment of freshwater ecotoxicity impact of pesticide use in peas cultivated in Sweden and soybeans cultivated in Brazil. The results showed that soybeans from Brazil had a significantly higher impact than peas from Sweden, due to higher pesticide use and to use of more toxic substances in soybean plantations in Brazil (Nordborg *et al.,* 2017).

Discussion

The findings presented in this report indicate lower pesticide use in conventional legume production in Sweden and, above all, a higher degree of transparency due to existing monitoring that includes pesticide use intensity in grain legumes. The cooler climate is probably one explanation for the low pesticide use in grain legume production in Sweden. Moreover, compared with countries that grow grain legumes in large and more intensively managed monocultures (e.g., soybeans in Brazil and the U.S.), the lower use of pesticides in grain legumes in Sweden can be explained by a more diversified and less intensive cropping system and the use of crop rotation (Meyer & Cederberg, 2010). Like Sweden, both Canada and China commonly use crop rotation in the production of grain legumes (Bekkering, 2014; Li *et al*., 2017). Interestingly, in China crop yields are approximately half those of peas and beans in Sweden, which may be partly explained by soil and climate conditions and possibly also by the varieties of grain legumes used.

The high level of glyphosate residues found in lentils is probably explained by the relatively high use of glyphosate in Canada, since almost all inventoried lentils originated from Canada or Turkey. Whether exposure to glyphosate residues in food causes any health risk for humans is debated. EFSA states that glyphosate should not be classified as a carcinogenic substance, while the World Health Organization's cancer research unit (International Agency for Research on Cancer, IARC) concluded in 2015 that glyphosate is a possible carcinogen (Portier, et al., 2016). A number of studies indicate that glyphosate is toxic to several organisms in different ecosystems (Motta et al., 2018; Richmond, 2018).

The incidence of MRL transgression in domestically produced grain legumes in China is relatively high and these products often contain multi-residues. However, it should be noted that the studies reviewed here applied the Chinese MRL and that the food products included were collected on the domestic market. Since the EU has a slightly lower MRL, these products might not be permitted for export to the EU. Furthermore, many large retailers in the EU require their suppliers to be certified against a private certification such as GAP, to ensure food safety and quality. This means that the pesticide use described for China may not be representative of the use for the grain legumes found in Swedish supermarkets, since farming practices may differ between products traded domestically and products exported to the European market.

It is worth mentioning that the impact of implementation of GAP standards on pesticide use in agricultural production seems to vary. One study that investigated the impact of public GAP standards on pesticide use in Southeast Asia concluded that the farmers complying with the GAP standards did not use less or fewer hazardous pesticides than farmers who did not adhere to the standards (Schreinemachers, *et al.*, 2012). This was partly explained by the lack of options available to farmers to handle the pest situation and to over-rapid program expansion.

Furthermore, legumes are not among the main food categories in the EU control program that monitors pesticide residues in foods consumed in the EU (EFSA, 2018). The low sample frequency may therefore not give a representative picture of the status of pesticide residues in imported legumes. Additionally, China is one of the countries of origin most frequently exceeding the MRLs for foods consumed in Europe, according to the pesticide residue monitoring program in the EU (EFSA, 2018). Taken together, this indicates an increased risk of pesticide residues in Chinese grain legumes available on the Swedish market.

Further, the current pesticide regulations in the EU do not take into account the risk of multi-residues in foods; it does not matter how many different types of pesticide residues a sample contains, as long as each individual substance in a sample is below the MRL and is in compliance with the legislation (EFSA, 2018). This can be associated with risks, since complete knowledge of the synergies between substances is currently lacking (Svingen & Vinggaard, 2016). It is argued that the legislation on chemical risk assessment should include the so-called cocktail effect (Svingen & Vinggaard, 2016). As an example, a study has shown that substances used in fungicides can increase the toxicity of common insecticides by up to 50-fold (Cedergreen *et al.*, 2017). However, regardless of the risks associated with consumption of pesticide residues in food, detection of residues is an indication of a high level of pesticide use, which is known to cause damage to surrounding ecosystems and to pose a risk to farmers handling the pesticides. Furthermore, the absence of pesticide residues in food does not guarantee optimal use of pesticides, since if they are used early in the cultivation the substances may degrade and leave no residues in the food, but the pesticide may still have caused damage to ecosystems and farmers.

The lack and inconsistency of available statistics and monitoring concerning pesticide use in general, and pesticide use in legume production in particular, made it difficult to assess pesticide use in production of grain legumes imported to Sweden in the present study. This shortage of data is also reported in other studies (Nordborg *et al*., 2017; Notarnicola *et al*., 2017; Cederberg *et al*., 2019). Furthermore, LCA studies that include pesticide use in grain legume cultivation are scarce and there is clearly a need for a harmonized method to assess the toxicological impacts of pesticide use. However, this and other studies indicate relatively low pesticide use in Sweden in general and also in cultivation of grain legumes.

Conclusions

An inventory of the country of origin stated on the packaging of dry and canned grain legumes sold in Swedish stores showed that China was the single most common declared country of origin, particularly for organic products. The second most frequently declared country of origin was Canada. In contrast to Sweden, there are no national statistics on the intensity of pesticide use in Chinese or Canadian grain legume production. However, heavy pesticide overuse in Chinese agriculture in general has been reported, partly due to lack of regulation and knowledge among farmers. The average use of pesticide active ingredient per hectare is reported to be more than 10-fold higher in China than in Sweden. China is one of the countries of origin most frequently found to exceed the MRLs for food products consumed in Europe.

A majority of the lentils consumed in Sweden originate from Canada or Turkey. Glyphosate is frequently used in grain legume production in Canada, resulting in problems with glyphosate-tolerant weeds. Lentils are the food item with the highest incidence of glyphosate residues among foods consumed in the EU, according to EFSA.

There is a scarcity of LCA studies that include the toxicological impact from pesticide use in grain legume production and there is no harmonized method for assessing toxicological impacts. This, and the lack of available statistics and monitoring of grain legumes produced outside Sweden, make it difficult to compare pesticide impacts of different grain legumes consumed in Sweden. However, there are strong indications that replacing conventionally grown imported grain legumes with organically and/or domestically produced grain legumes would reduce pesticide use considerably and provide a higher level of transparency on production methods.

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Appendix 1 - Overview of country of origin of grain legumes sold in Sweden

BEANS AND PEAS	Coop (PL)	Änglamark (el	Favorit eko	Go Green	Kung Markatta	Urtekram	Risenta	Zeta	ICA i love eko	Saltå Kvarn	ICA (PL)	Eldorado	Garant	Garant eko	Seva n
Black beans				Sweden (d)	China*	China* (d)	China	N/A	USA*, China*	China* (d)	Argentina, China	USA, Canada (d)	China	USA, China*	
Black Eye												Madagascar, Peru (d)			
Borlotti beans			China * (d)	Sweden (d)	China*	China* (d)		N/A		Italy*	Canada, China			Italy * Canada* (d)	
Butter beans						China *, N/A* (d)									
Brown beans	USA, Canada			Sweden (d)											
Cannellini beans								N/A	China*, Argentina*		Argentina			China *	
Chickpeas	Russia	Italy *	Italy*/Spain*/	Canada (d)	Italy*, Turkey* (d	Italy *	France	N/A	in EU*	Italy*(d) ,Turkey*	Mexico, Italy	Italy, France, Argentina, Ukra	USA, China, Ca	Italy * Turkey* (d)	Egypt
Edamame beans															
Green peas				N/A*											
Mung beans				Myanmar (d)	x (d)					China* (d)		China (d)			
Kidney beans	China, USA	China *	China* (d)	Sweden (d)	China* (d)	China *, N/A (	China, USA	N/A	China*	Italy* China* (d)	China, USA	China, USA (d), China, USA	N/A	China * , China* (d)	
White beans	USA, Canada	China *	China* (d)	Sweden (d)	China*, China* (	China* (d)	USA	N/A	China* (d)	Italy* China* (d)	Canada (ICA basic)	Ethiopia, Canada (d), USA		China*(d)	
White beans large		China *		N/A *	China*		Poland, China		China*, Polan	China*(d), USA *	China, Poland, Turkey		N/A	China*, Poland *	
Soy beans					China*		Canada			China* (d					
Pinto beans												USA (d)			
Yellow peas				Sweden (d)					Sweden* (d)						
Fava beans															Egypt
bonbönor															Spain
LENTILS															
Black lentils (beluga)					Canada* (d)	Canada *	Canada						Canada, USA		
Green lentils			Canada*/Turkey* (d)	Canada (d), N/	Turkey* (d)	Turkey *	USA		Turkey*, Cana	France*		USA, Canada (d)		Canada*, Turkey* (d)	
Red Lentils			Canada*/Turkey*(d)	Canada (d), N/	Turkey* (d)	Turkey*	Canada		Turkey *(d)	Turkey* (d)		Canada (d)		Turkey* (d)	
Puy lentils						Canada *									

*Table 1. Summary of results of the inventory of country of origin for grain legumes sold in Sweden. Countries marked with a * are found on organic products, the rest are conventional products. Countries followed by (d) are named on dried grain legumes, the rest are canned legumes*

Appendix 2. Summary of the studies reviewed that include data on pesticide use in grain legume production

Kolumn1	Country	Pesticide	Herbicide	Insecticide	Fungicide	Yield (kg)	Reference
Pea	France	3.2				4111 (DM)	Werf, Petit, & Sanders, 2005
Common bean (Gigantes)	Greece	1.7	1.1	0.41	0.19	2800	Abeliotis, Detsis, & Pappia, 2012
Common bean (Plake)	Greece	0.96	0.3	0.34	0.32	1150	Abeliotis, Detsis, & Pappia, 2012
Soybeans	Brazil	2.5				2791	Silva, Werf, Airton, & Soares, 2010
Soybeans	Brazil	2.1				2535	Silva, Werf, Airton, & Soares, 2011
Lentils	Iran	5.1	2.07	3.05		2024	Elhami, Khanali, & Akram, 2017
Soybeans	Canada	1.2				2380	Pelletier, Arsenault, & Tyedmers, 2008
Soybeans	Brazil	3.8	3.2	0.3	0.26	3030	Nordborg, Berndes, & Cederberg, 2013
Soybeans	Brazil	1.9	1.4	0.3	0.26	3030	Nordborg, Berndes, & Cederberg, 2014
Soybeans	Brazil	5.7	4.1	1.1	0.54	2800	Meyer & Cederberg, 2010
Faba beans (spring)	France	2.9	1.7	0.09	1.07	5070	Poore & Nemecek, 2018
Faba beans	France	3.1	1.8	0.19	1.15	5070	Poore & Nemecek, 2018
Chickpeas	Australia	6.4				1884 (DM)	poore & Nemecek, 2018
Lentils	Canada	1				1413	Poore & Nemecek, 2018
Faba beans	France	3.1				4224	Poore & Nemecek, 2018
Faba beans	France	1				4400	Poore & Nemecek, 2018
Faba beans	Germany	1				3050	Poore & Nemecek, 2018
Lupin	Belgium	5.8				2633	Poore & Nemecek, 2018
Lupin	Germany	2				2645	Poore & Nemecek, 2018
Lentils	Turkey	1				1249	Poore & Nemecek, 2018
Spring peas	France	2.1 - 3.8				4100-5300 *	Poore & Nemecek, 2018
Winter peas	France	2.8 - 4.3				3734- 5300 **	Poore & Nemecek, 2018
Peas	France	3	0.57	0.24	2.19	3810	Poore & Nemecek, 2018
Peas	France	4.2	1.72	0.25	2.23	4600	Poore & Nemecek, 2018
Peas	France	5.0				3970 (DM)	Poore & Nemecek, 2018
Peas	France	2.1				3349 (DM)	Poore & Nemecek, 2018
Peas	France	5.7				4176	Poore & Nemecek, 2018
Peas	France	3.2				4110 (DM)	Poore & Nemecek, 2018
Peas	France	2.0				4260	Poore & Nemecek, 2018
Peas	Germany	2.0				3050	Poore & Nemecek, 2018
Peas	Sweden	1.1	1.1	0.045		3400	Krüger Persson, 2019
Peas	Sweden	0.99	0.97	0.02		3450	Jordbruksverket, 2018
Peas	Sweden	0.94	0.86	0.08		2500-3100	Flysjö et. al 2008
Faba beans	Sweden	1	0.99	0.06	0.17	3590	Statistiska Centralbyrån, 2018
Peas	Sweden	0.99	0.99	0.05			Statistiska Centralbyrån, 2018
Faba beans	Sweden	0.88				3810	Krüger Persson, 2019

Review of studies that include inventory data on pesticide use in grain legumes. All values in kg active ingredient/hectare.

*Data originally from five different studies.
** Data originally from three different studies.
DM = Dry matter (when data on wet yield were not available).