A study on the use of chemical pesticides for WWF's meat guides: Methodological and data update

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SYTRA transition of food systems

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About the authors

This study was carried out by Sytra, a research team from the Belgian Université catholique de Louvain (Riera Anton, Antier Clémentine, de Clippele Antoine, Baret Philippe).

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Chapter 1. Introduction

1.1. Context of the study

The current global food system is not sustainable given that its environmental impacts significantly contribute to the crossing of planetary boundaries thresholds. This situation requires to rethink pathways and strategic visions of agriculture, livestock and food systems both locally and globally. Global scenarios converge to two major levers: transitioning towards food diets that include less animal-based products; and moving away from conventional agriculture while promoting agroecological practices.

Consistently with this background, WWF European offices are currently part of the EU-funded project called *Eat4Change*, with the overall objective to shift towards more sustainable diets and food production systems, particularly in livestock production. In addition, the *One Planet Food* project funded by the Swedish PostCode also works towards a similar aim. The deliverables of this study will feed into both of these projects.

Furthermore, in the last years, several WWF European units launched national consumer Meat Guides, looking at how different kinds of animal products (and some vegetal alternatives) affect our planet. As all Meat Guides were developed independently, at a national level, they each take somewhat different aspects into account, in terms of included products, environmental impact categories and assessment methodologies (see section 1.3).

1.2. Objectives and scope

This study focuses on the pesticides use of livestock products, with two main objectives:

1. To review and harmonise the methodology related to the assessment of the pesticides use associated with livestock products;
2. To update and/or assess the pesticides use for a diversity of livestock products, and some vegetal alternatives.

The scope of the assessment can be structured on four levels:

- It focuses on **one environmental impact category**: the use of pesticides;
- It focuses on **six countries**: Sweden (SE), Finland (FI), Austria (AT), France (FR), Estonia (ET) and Belgium (BE);
- It includes **different animal and vegetal products:** beef, pork, poultry, eggs, milk, soy-based products, etc.;
- It considers a certain **degree of differentiation** by including three production systems: organic, conventional and « differentiated » or « certified ».

1.3. General approach of WWF's Meat guides

As shown in Table 1, Sweden was the first country for which a WWF "Meat Guide" was elaborated. It was followed by Finland, Austria and France. Additional guides are on their way for Belgium and Estonia. As mentioned earlier, the scope of this assessment lies on these six countries of interest.

The guides include assessments of the following environmental impact categories (Table 1):

- **Pesticides use**; climate change and biodiversity are included in all country guides;
- Eutrophication; use of antibiotics and animal welfare are additional criteria included in some countries.

These assessments are performed on several animal product categories such as beef, pork, eggs, milk, etc. Some countries include vegetal alternatives and additional animal products such as duck, turkey, game, etc.

Furthermore, product categories are often differentiated per production system: organic, conventional and other national labels (e.g., *Label Rouge* in France).

Table 1. Environmental impact categories included in different WWF Meat Guides.

	Sweden	Finland	Austria	France
First publication	2015	2016	2018	2019
Update(s)	2016, 2019 & 2021	-	2021	2022
Pesticides use	X	X	X	X
Climate change	X	X	X	X
Biodiversity	X	X	X	X
Eutrophication	-	X	X	X
Use of antibiotics	X	-	X	-
Animal welfare	X	-	X	X

Notes: Additional Meat Guides are being prepared in Belgium and Estonia. The included environmental impacts categories for these countries are not known yet.

1.4. Organisation of the report

The following sections of this report are organised as follows:

- Chapter 2 provides a methodological update (variables and calculation methodology);
- Chapter 3 describes the data collection (sources, scope, current status of the assessment);
- Chapter 4 presents the calculation tool which was developed to perform the assessment;
- Chapter 5 provides the results (country-specific and cross-country analysis, product-specific assessments of the pesticide use);
- Finally, Chapter 6 offers a discussion and some recommendations.

Chapter 2. Methodological update

This chapter is related to the first objective stated above. As such, it provides an overview of the indicator, general methodology, calculation steps and necessary inputs used in the context of this study to assess the use of the pesticides associated with animal products. Additionally, section 2.7 reviews the methodologies used in the four existing WWF Meat Guides.

2.1. Choice of the indicator and unit of measurement

The indicator used in the context of this study to reflect the associated level of pesticides (or plant protection products; PPPs) use of a particular product are the amounts of pesticides active ingredients (a.i.) used to produce one unit of food output.

Such an indicator merely reflects the quantities of pesticides used, expressed as active ingredients. However, it does not give an indication on the toxicity of these active ingredients nor on the actual environmental damage that may be induced by the use of these pesticides.

The unit used to measure this indicator is the following: g a.i./kg of edible product.

2.2. General principle

The general principle when assessing the use of pesticides associated to animal products consists in evaluating the quantities of pesticides used during the cultivation of crops used as animal feed.

As a consequence, performing such an assessment relies on the characterisation of two main parameters:

(1) **The pesticides use of feed crops:** i.e., the quantities of pesticide active ingredients used for the pest management of feed crops;
(2) **The feeding practices of the animals:** i.e., the quantities of feed ingredients consumed by each animal, from which an animal-based product will be obtained (meat, eggs, milk, etc.).

2.3. Calculation steps

The overall calculation process requires six inputs (related to the two main parameters introduced above) and can be subdivided in three steps (Figure 1):

1. **Evaluating the pesticides use of feed crops.** The three necessary inputs at this level include: the total use of pesticides per feed crop, the total area of each feed crop and the yields of these feed crops. This allows to calculate the relative use of pesticides of each feed crop, per area (kg a.i./ha) or per volume (g a.i./kg). This constitutes the intermediate output A.
2. **Characterising the feeding practices.** Feeding practices too are represented by three inputs: the feed conversion ratio (FCR), the feed composition and the slaughter and carcass

yields. They allow to calculate the net consumption of each feed ingredient (kg feed ingredient/kg edible product). This constitutes the intermediate output B.

3. **Calculating the relative pesticides use of animal products.** Combining intermediate outputs A and B, it is possible to assess the relative use of pesticides associated with animal productions as a result of their feeding practices.

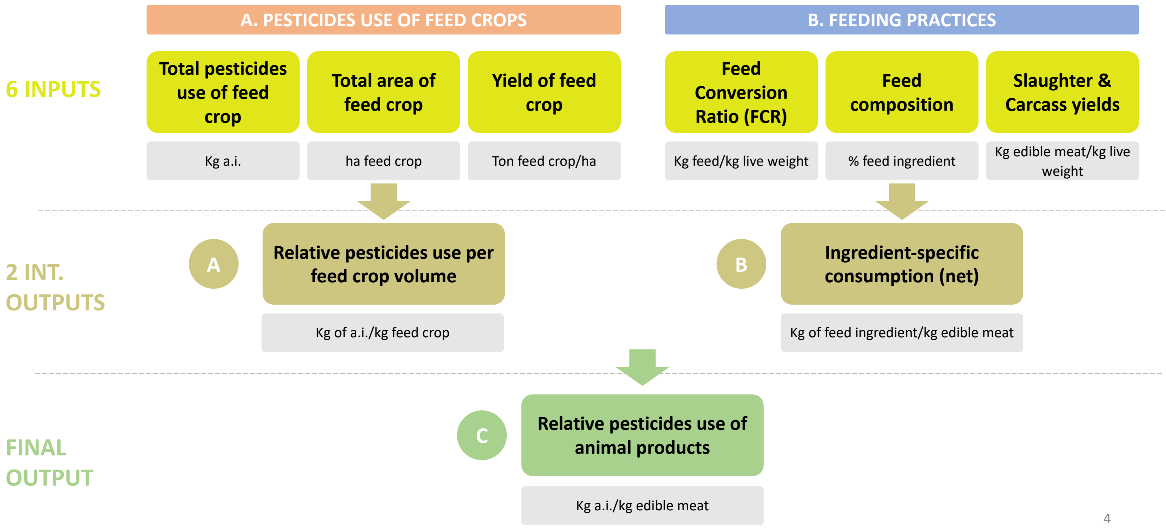

Figure 1. Necessary inputs and calculation steps to assess the relative pesticides use of livestock products.

Note: The calculations should also account for the dry matter contents and transformation yields of different feed ingredients (e.g., amount of raw soy needed per kg of soybean meal).

2.4. Necessary inputs – Feeding practices

This section further details each of the six inputs involved in the calculation.

2.4.1. Input 1 - Feed conversion ratio (FCR)

Reference unit for calculations: kg feed (DM)/kg edible product.

Definition

The feed conversion ratio represents the amount of feed which is necessary to produce one unit of animal output. As such, it can be seen as a measure of the efficiency with which animals convert animal feed into a desired output.

Possible units

Although a feed conversion ratio always reflects the amount of feed consumed per amount of output produced, in practice, it can take several forms and be expressed in different units. This depends on two factors:

(1) How the amounts of feed are expressed:
  - kg feed (humid weight)
  - kg feed DM (dry weight)

(2) How the amounts of output are expressed:
  - kg live weight
  - kg carcass weight
  - kg edible product

As a result, there are six combinations of units in which the FCR can be expressed. Nevertheless, in order to facilitate the calculations and allow for a comparison between products, all FCR values were expressed in one common unit during the calculations: *kg feed (DM)/ kg edible product.*

FCR values found during the data collection process which were expressed in the five other units were converted to the correct unit.

Inclusion of non-productive animals and allocation of impacts

Apart from the FCR unit, the FCR value can also vary depending on the scope of animals which are included in the assessment. Indeed, some FCR values only consider the amounts of feed consumed by the productive animals. Non-productive animals, such as sows or mother hens, which do not lead to a direct production of output are then not considered in the assessment although they also represent an amount of feed consumed and thus have an impact in terms of pesticides use.

In our assessment, non-productive animals were included in the calculations in order to reflect the total consumption of feed and pesticides associated with animal productions. FCR values which initially did not include non-productive animals were corrected.

For bovine systems, this issue is not straightforward as these can lead to two products: milk (and dairy) and beef. Impacts must thus be allocated to one product or to another.

For dairy systems, it was assumed that all consumed feed was affected to the production of milk (or butter or cheese). For cheese, 10 L of milk were assumed necessary for the production of 1 kg. For butter, the ratio was 20 L of milk for 1 kg. These amounts are consistent with previous Meat Guides (Röös et al., 2014; WWF Finland, 2016).

For beef, only the feed consumed by the productive animal was considered. E.g., in the case of beef production from young bulls, only the feed consumed by the bulls was considered. The consumption of feed by the suckler cows was not taken into account. As a consequence, in the case of beef production from culled suckler cows, only their feed consumption was taken into account.

Extensive vs. Intensive

It is worthwhile to note that more extensive production systems (e.g., organic) tend to have higher FCR values. Indeed, as animals in these systems generally live longer lives, they are associated with a greater feed consumption for a similar output level. In comparison, animals in intensive systems live shorter lives, consume less feed and are thus more efficient from that perspective.

As a result, as noted in the French Meat Guide (WWF France, 2019), working with an output-based functional unit (in this case *per kg edible product*; see section 2.4.3) penalises less productive/more extensive systems. Area-based functional units (*per ha*) on the other hand tend to favour more extensive systems, which present lower impacts per unit of area compared with more intensive systems, as noted for example by Halberg et al. (2005). The choice of one functional unit over the other is thus likely to influence the final results when comparing farms and production systems. This is further discussed in section 6.4 (see Figure 24).

In addition, a comparison of production systems should not be based on one single metric but rather on a comprehensive set of indicators covering a diversity of environmental (and socio-economic) themes such as climate change, biodiversity, animal welfare, etc. (as is done in the existing WWF Meat Guides).

2.4.2. Input 2 - Feed compositions

Reference unit for calculations: % of feed ingredient in total feed, expressed in DM contents.

Definition

In order to maintain an acceptable level of complexity in the model, the number of feed ingredients considered in the context of this study was limited to a list of thirteen major ingredients (Table 2). This list was established based on different sources, including national and international animal feed associations (BFA, 2020b; FEFAC, 2019), scientific articles (Hou et al., 2016) as well as technical reports (CELAGRI, 2020; Cuvelier & Dufrasne, 2015).

For each animal product, a specific feed composition was identified, with varying shares of the thirteen ingredients.

Possible units

When considering the composition of a particular feed, it is important to account for the dry matter content (DM) of the different ingredients. Indeed, feed ingredients have varying DM contents. As a consequence, the relative shares of feed ingredients will vary if the feed composition is expressed in humid or in dry terms. This is particularly the case for forage feed ingredients which have lower dry matter contents compared to concentrate feed ingredients, for which DM contents are close to 90%.

Transformation ratios

Additionally, for some feed ingredients a transformation ratio should be accounted for. Indeed, some ingredients are the result of a prior transformation. As such, a greater amount of raw material, or primary crop, is necessary to produce one unit of feed ingredient. In the case of soybean meal, 1,27 kg of soybeans are necessary to produce 1 kg of soybean meal (BFA, 2020a).

Due to limited data availability, it must be noted that the current version of the model does not account for these transformation factors. Indeed, only the previously-mentioned ratio for soybean meal could be found in the literature. LCA databases might contain additional information for other ingredients such as rapeseed meal.

Origin of feed ingredients

It must be noted that in the context of this study, all feed ingredients were assumed to be produced nationally, except for soybean meal which was considered to be imported from Brazil. Complementary considerations and calculations regarding the origin of soy are provided further in the report (see Box 1 and section 6.1).

Table 2. List of thirteen feed ingredients included in the model.

Ingredient category	Ingredients
Forage	Grazed grass
	Grass silage/hay
	Maize silage
	Other forage
Cereals	Wheat
	Maize
	Barley
Protein-rich ingredients	Olea-/proteaginous beans
	Soybean meal
	Sunflower meal
	Rapeseed meal
Others	Sugarbeet pulp
	Vitamins, minerals, etc.

Sources: Based on BFA (2020b); CELAGRI (2020); Cuvelier & Dufrasne (2015); FEFAC (2019); Hou et al. (2016).

2.4.3. Input 3 - Slaughter and carcass yields

Reference units for calculations: kg edible product.

As mentioned earlier, in order to facilitate the calculations and comparisons, the feed conversion values of all products were expressed per kilogram of edible product, which constitutes the functional unit.

However, the initial FCR values found during the data collection process were not always expressed in the desired functional unit as they were sometimes expressed per kilogram live weight or carcass weight. Depending on the initial FCR unit, corrective factors corresponding to the slaughter and carcass yields were applied (Table 3).

Table 3. Corrective factors (slaughter and carcass yields) applied to initial FCR values according to the initial FCR functional unit.

Initial FCR functional unit	Necessary corrective factor(s)	Unit of conversion factor(s)
kg edible product	None	-
kg carcass weight	Carcass yield	*kg edible product/ kg carcass*
kg live weight	Slaughter yield Carcass yield	*kg carcass/ kg live weight* *kg edible product/ kg carcass*

2.5. Necessary inputs - Pesticides use of feed crops

2.5.1. Input 4 – Total pesticides use of feed crops

Reference units for calculations: kg active ingredient (kg a.i.).

For each country, the total use of pesticides on the total area of a specific crop is necessary for the calculations. This constitutes the starting point to characterise the pesticides use of feed crops.

2.5.2. Input 5 – Areas of feed crops

Reference units for calculations: ha.

As a second step, combining the total use of pesticides on a specific crop (i.e., input 4) with the total area of that crop in a considered country allows to calculate the relative use of pesticides per unit of area, which is expressed in kg a.i./ha.

2.5.3. Input 6 – Yields of feed crops

Reference units for calculations: t/ha.

Finally, combining the relative use of pesticides per unit of area (i.e., the result of inputs 4 and 5) with the yields of each crop allows to calculate the relative use of pesticides per unit of output, which is expressed in g a.i./kg feed crop.

This value can either be expressed in humid or dry matter terms. For the calculations, the DM value was used.

2.6. Differentiation of data

As seen above, calculating the relative pesticides use of animal products relies on six categories of input data. This data can be differentiated on three levels:

1. **Product-level**, i.e., differentiating between vegetal (e.g., barley, wheat, soy, etc.) or animal (e.g., beef, eggs, milk, etc.) products.
2. **Country-level**, i.e., differentiating between different countries. In this case, included countries are Sweden, Finland, Austria, France, Belgium and Estonia.
3. **Production system level**, i.e., differentiating between different production systems (e.g., conventional, organic, certified, etc.).

For this assessment, Figure 2 shows the desired level of differentiation for each of the six inputs.

2.6.1. Pesticides use of feed crops

Based on data availability (see Chapter 3 below), the pesticides use of feed crops is differentiated at the crop and country levels but not at the production system levels (i.e without differentiating between various production systems[1]). This means that all conventional[2] feed ingredients were assumed to be grown with similar amounts of pesticides (in one specific country). This is partly because the available data does not allow for such a differentiation. Furthermore, in practice, when buying animal feed, it is not easy to trace the feed ingredients to production systems, except for organic systems. For organic systems and feed ingredients, the pesticides use was considered null given that the use of synthetic pesticides is forbidden (or severely restricted) in organic agriculture.

2.6.2. Feeding practices

On the one hand, similarly to the pesticides use of feed crops, slaughter and carcass yields were differentiated at the product and country levels but not at the production system levels. Indeed, in accordance with experts and based on data availability, it was assumed that slaughter and carcass yields for one product and in one country did not significantly differ across production systems.

On the other hand, FCR and feed compositions were as much as possible differentiated at the production system-level (*conventional – differentiated – organic*), i.e., with a specific value for each assessed product. However, as specific data was not always available for every product, generic values were sometimes used in the calculations. These generic values either related to a country (i.e., country-specific but not production system-specific) or to a production system (i.e., production system-specific but not country-specific).

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[1] Beside the distinction between organic and conventional production systems, more precise typologies of production systems show that the level of pesticide use per kg of crop may vary (see for example (Antier et al., 2018).

[2] i.e., non-organic.

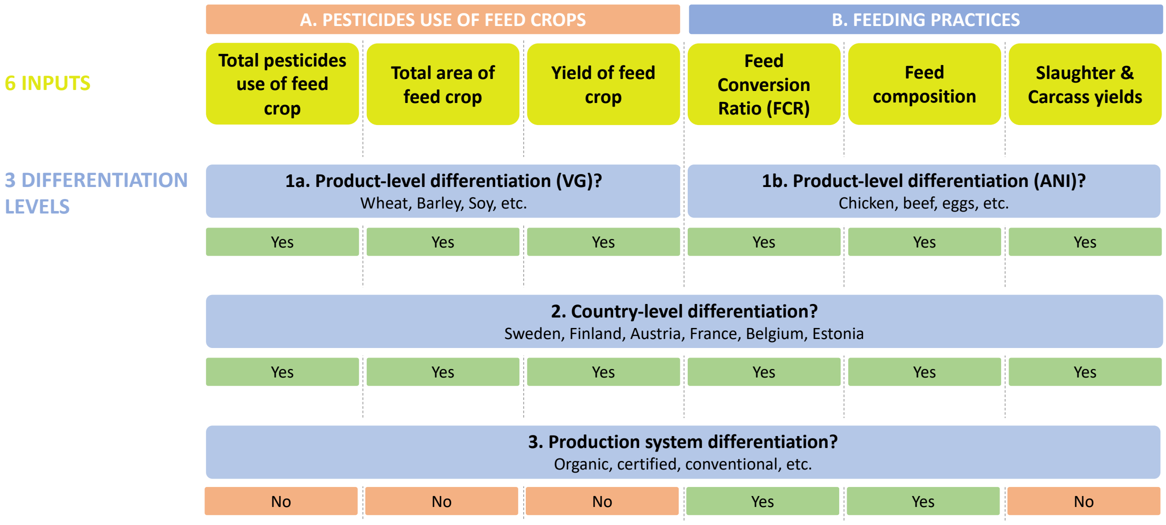

Figure 2. Desired level of differentiation of six inputs necessary to calculate the relative pesticides use of animal products.

2.7. Review of calculation methodology in existing WWF Meat Guides

2.7.1. Comparison of general methodology

All existing Meat Guides use the same indicator, i.e., the amounts of pesticides used to produce one unit of output, expressed in g a.i./kg edible product. In addition, the French Meat Guide also considered the USEtox indicator, which relates to human toxicity.

In essence, the calculation methodology is common to all Meat Guides and follows the general principle explained above. It was first applied by Röös et al. (2014) for the Swedish Meat Guide. For the assessment, the authors looked at the quantities of feed ingredients consumed by each animal product on the one hand and the quantities of pesticides used to produce each feed ingredient on the other hand. The combination of these two parameters then allowed them to evaluate the amounts of pesticides associated with each animal product. The results of this assessment are shown in Figure 3.

The methodologies for Finland and Austria are sensibly similar.

For France, the results were obtained somewhat differently as the quantities of pesticides associated with each animal product were directly extracted from LCA databases. It was thus not necessary to first gather the data related to the pesticides use of feed crops and the quantities of feed crops consumed (although this information is also available in LCA databases). Furthermore, as LCAs consider all processes and materials involved over a product's lifecycle, the potential use of pesticides used for the production of wood for buildings was also included in the assessment. This was not the case for the other assessments.

Table 1
Average total animal feed consumption and consumption of concentrates in production of 1 kg of beef, pork, chicken, egg and cheese (equated to 10 kg milk) and the use of pesticides per kg product in Sweden 2005/2006 (based on Cederberg et al., 2009; Meyer and Cederberg, 2010; SS, 2011).

	Beef	Pork	Chicken	Egg	Cheese
Total amount of feed per kg edible product (excluding roughage) (kg)	4.0	6.8	4.0	2.6	5.1
Amount of soy per kg edible product (kg)	0.20	0.32	0.72	0.25	0.33
Amount of cereals and other feed excluding soy, by-products and minerals per kg of edible product (kg)	3.3	6.1	2.9	2.0	3.8
Pesticide use (g active substance) per kg edible product	1.1 (1.2 incl. pesticide use in roughage)	1.9	1.8	0.82	1.4

Figure 3. Extract from Röös et al. (2014) showing the results of a pesticides use assessment for five animal products in Sweden.

2.7.2. Use of a threshold

It is worth mentioning that all Meat Guides use a three-level traffic light system (*green* – *yellow* – *red*) which allows to classify the products from more to less sustainable. For each environmental impact category, thresholds are defined which determine which colour code applies.

In the case of pesticides use, organic systems are considered as *green* given they do not allow the use of chemical pesticides. The threshold between *yellow* and *red* was set at 1,5 g a.i./kg edible product by Röös et al. (2014). The three following Meat Guides applied the same threshold.

Chapter 3. Data collection

3.1. Scope of assessment

An initial list comprising 215 products was provided by the WWF offices, spanning 27 countries of origin and 12 product categories. Of these, it was agreed that the assessment would focus on 6 countries of origin (Austria, Belgium, Estonia, Finland, France and Sweden) and 8 product categories (beef, broiler, butter, cheese, eggs, milk, plant-based and pork). This resulted in a list of 117 priority products to be included in the assessment (Table 4).

Table 4. Countries of origin and product categories included in the initial list of products to be assessed provided by WWF.

27 countries in initial list	12 product categories in initial list
Argentina (1)	Beef (34)
Austria (24)	Broiler (26)
Belgium (19)	Butter (6)
Brazil (2)	Cheese (36)
Cyprus (2)	Duck (4)
Denmark (5)	Eggs (22)
Estonia (7)	Game (9)
EU (14)	Lamb (18)
Finland (11)	Milk (9)
France (37)	Plant-based (17)
General (17)	Pork (25)
Germany (12)	Turkey (9)
Greece (5)	-
Hungary (3)	-
Ireland (3)	-
Italy (2)	-
Latvia (2)	-
Lithuania (1)	-
Netherlands (7)	-
New Zealand (2)	-
Poland (6)	-
Spain (2)	-
Sweden (27)	-
Thailand (1)	-
UK (1)	-
Uruguay (1)	-
USA (1)	-
TOTAL Initial: 215	TOTAL Initial: 215
TOTAL Priority: 117	TOTAL Priority: 117

Notes: Numbers in parentheses refer to the initial number of products included in each country or product category. Greyed countries and products indicate priority countries and products.

3.2. Data sources

In order to assess the pesticides use of the 117 priority products, a data collection process was necessary to characterise these products with regards to the 6 inputs listed above and in accordance with the defined differentiation level specified in section 2.6.

This data collection process relied on four potential sources (Figure 4):

- **EU-level databases:**
  - Eurostat was the main database which was consulted. It provided all the necessary inputs to assess the pesticides use of feed crops for the six countries of interest.
  - Additionally, the French database Agribalyse was also consulted as it served as the main data source for the elaboration of the French Meat Guide.
- **Scientific and grey literature:**
  - For the pesticides use of feed crops, Eurostat data had to be complemented by literature data for feed crops which are imported crops and hence not included in Eurostat, i.e., soybean meal which was considered to be imported from Brazil.
  - For the inputs related to feeding practices, scientific and grey literature (technical reports) constituted the main data source as there is no EU-wide database which can provide the necessary inputs.
- **Existing Meat Guides:** For the four countries for which a Meat Guide has already been produced (Sweden, Finland, Austria and France), these documents constituted a good starting point to determine the input data used in previous assessments.
- **Contacts with national experts:** Finally, as data on feeding practices was in general rather scarce (at least at the desired level of differentiation), national experts were contacted in each country of interest to validate and complement the data which had been found in the literature.

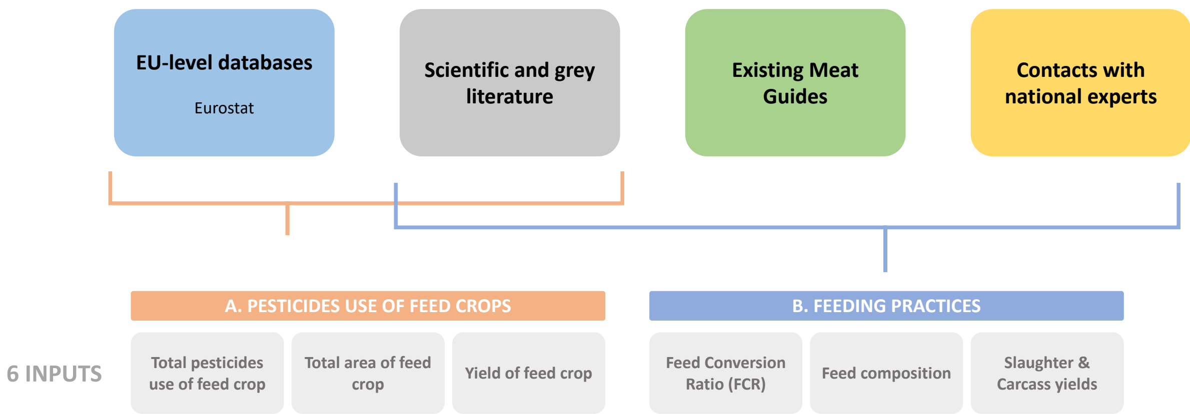

Figure 4. Potential data sources for the characterisation of the six calculation inputs.

3.3. Specific vs. generic data

As far as possible, the assessments and calculations were based on input data which is specific for each product, in accordance with the desired level of differentiation (product – country – production system; see section 2.6).

Nevertheless, the necessary data was not always available. In such cases, generic data was used.

In the case of pesticides use of feed crops, when a country-specific value was missing for a certain feed crop, there were three possibilities: using a value for a similar crop in the same country; using a value for the same crop in a neighbouring country; using the average value of that crop for the available countries.

In the case of feeding practices, when a product-specific input value was missing, a list of generic values could be used as an alternative. These generic values are either specific to the country or to the production system.

3.4. Collected data – Feeding practices

The generic data related to feeding practices are presented in Appendix 1:

- Table 15 presents the feed consumption of non-productive animals;
- Table 16 and Table 17 present generic FCR values, per production system and per country of origin respectively;
- Table 18 and Table 19 present generic feed compositions, per production system and per country of origin respectively;
- Table 20 present slaughter and carcass yields.

3.5. Collected data – Pesticides use of feed crops

3.5.1. Available data in Eurostat

The data regarding the pesticides use of feed crops was derived from Eurostat (Eurostat, 2021c, 2021a), which comprises national statistics on pesticide use for each crop (in kg a.i.).

The period of each data collection covers five years, starting from the first five-year period 2010-2014. The countries are obliged to collect data at least for one reference year out of five years and cover all plant protection treatments associated with the crop. As a result, the frequency and selection of year(s) differ among the countries. For example, some countries collect data only in one year of the five-year period, others each year or every second or third year. Some collect even different crops in different years (e.g., apples in 2011 and potatoes in 2014). Table 5 below provides an overview of the assessment years of the six studied countries.

A wide diversity of pesticides categories is available in the Eurostat database. In this case, six main categories were considered and summed:

- **F**: Fungicides and bactericides
- **H**: Herbicides, haulm destructors and moss killers
- **I**: Insecticides and acaricides
- **M**: Molluscicides
- **PGR**: Plant Growth Regulators
- **Other**: Other plant protection products.

Table 5. National statistics on pesticides use per crop available in Eurostat for six countries of interest.

Country	Last assessment	Previous assessment(s)
Sweden	2017	2010
Finland	2018	2013
Austria	2017	2012
France	2017	2010; 2011; 2012; 2013; 2015; 2016; 2018
Belgium	2017	2012
Estonia	2015	2014

Note: For France, different crops are assessed each year. The last year (2018) is specific to vegetables and fruits.

3.5.2. Assumptions and values used for the calculations

As mentioned in section 2.4.2, 13 categories of feed ingredients were included in the model. For each feed ingredient, it was necessary to find the corresponding crop in Eurostat in order to assign a pesticides use value for each ingredient in each country. For each feed ingredient, a corresponding crop reference in Eurostat was thus defined (Table 7).

For some crops (wheat; barley; rape and turnip), Eurostat provides more than one crop reference, for which the availability of data can vary from country to country. The reference crop was thus adapted accordingly.

It must be noted that for some crops and countries, Eurostat data is missing. In these cases, either values from neighbouring countries or the average value of available countries were used [3]. This is indicated in Table 7.

As a reminder, soybean meal is the only feed ingredient for which the pesticides use value does not come from Eurostat. Indeed, although values for Austrian and French soy are available in Eurostat, an average figure for Brazilian soy was considered given this is the main origin of soy. The case of this feed ingredient and the different values found in the literature are further detailed in Box 1 below.

[3] Eurostat does not provide an EU-wide average value which would cover all member states. Such an average value would thus need to be calculated manually, based on Eurostat data. In the context of this study, when average values are used, these are calculated based on the available values for the six countries of interest.

The corresponding pesticides use values which were used in the calculations are presented at Table 8 per unit of area (kg a.i./ha) and at Table 9 per unit of DM output (g a.i./kg DM crop).

It appears quite clearly that compared to other feed ingredients, soybean meal of Brazilian origin is associated with a significantly higher use of pesticides, especially when results are expressed per unit of output (2,59 g a.i./kg DM, whereas the second highest values do not exceed 0,8-0,9 g a.i./kg DM; see Table 9 and Figure 5). Expressed per unit of area, soybean meal still presents the highest pesticides use, although compared to the rest of feed ingredients, the pesticides use of sugar beet stands out as well (6,5 kg a.i./ha for soybean, 4,2 kg a.i./ha for sugar beet and less than 2,0 kg a.i./ha for all other ingredients). In general, forage crops present the lowest pesticides use values among the considered feed ingredients.

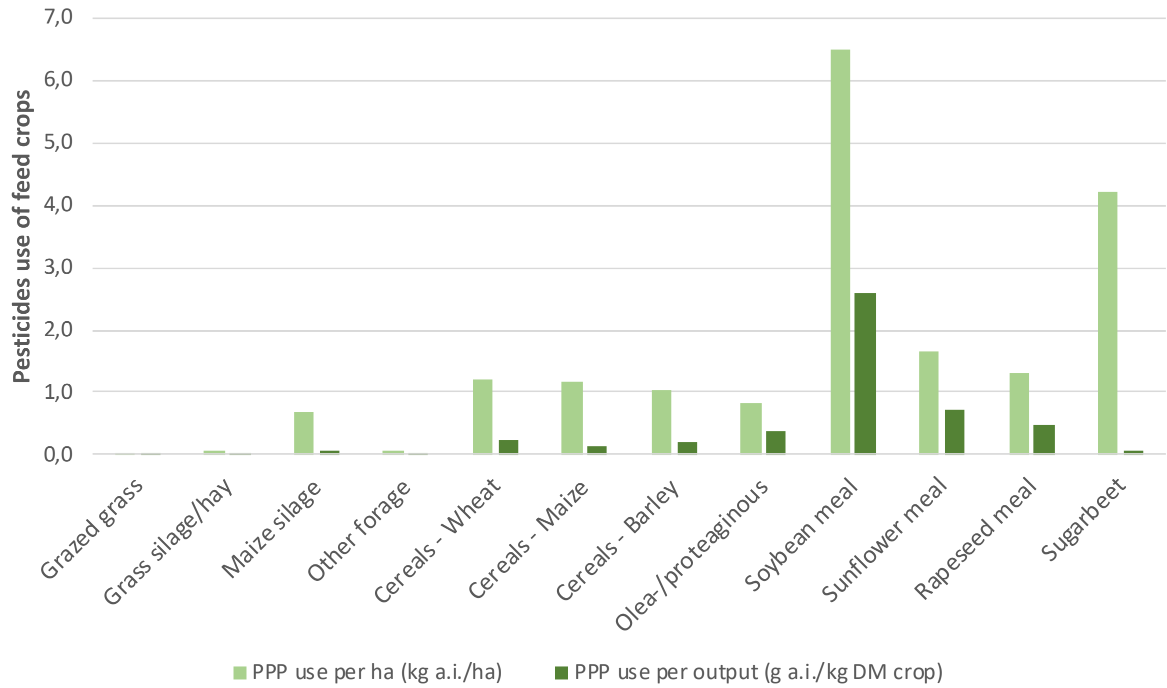

Figure 5. Levels of pesticides uses for different feed crops, per unit of area (kg a.i./ha) and per unit of output (g a.i./kg DM crop).

Notes: The values presented in this figure are average values of pesticides use for different feed ingredients in the six countries of interest. For soybean meal, a Brazilian origin is considered (see Box 1).

Box 1. Pesticides use of soybean in different countries and according to different references.

Unlike all other feed ingredients, soybean meal was not assumed to be produced nationally. Indeed, the EU imports 34 million tonnes of soybean meal annually, of which 13,5 million tonnes (40%) come from Brazil, the first exporter of soy to the EU. It is followed by the USA with 8,5 million tonnes (25% of all EU imports). EU production of soy on the other hand only represents 2,9 million tonnes per year (i.e., less than 10% of EU soybean meal consumption) (BFA, 2020a).

In the light of these numbers, in this study it was considered that all soybean meal comes from Brazil. As Eurostat does not provide any pesticides use value for non-EU crops, a figure had to be found in the literature. For Brazil, three values are compared in Table 6. The values by Pollak (2020) are the ones which were used in the calculations as they are more recent and are an update of the values by Meyer & Cederberg (2010), which were used in previous Meat Guides. The values by Prudêncio da Silva et al. (2010) were also used in previous Meat Guides but were not included in the present assessment as they are less recent and seem rather low.

The table also includes values for EU-countries (Austria and France) and the USA, which allow for a comparison against Brazil and were used to perform a sensitivity analysis (see section 6.1).

Comparing values across countries, Brazil presents significantly higher pesticides use values for soybean (Table 6).

Regarding pesticide categories, it appears that herbicides represent the main substances in terms of volumes of active ingredients. In Brazil, but also in the USA, glyphosate is the main herbicide. In 2011, glyphosate represented just over 80% of the total volumes of herbicides applied on soybean in the USA (Perry et al., 2016). Genetically-engineered varieties can be sprayed with glyphosate during the vegetative phase, thereby increasing the risk of higher residue levels in the harvested soybeans, with residue levels significantly over the accepted amounts in the EU in some cases (Pollak, 2020). Additionally, in order to control glyphosate-tolerant weeds, other herbicide substances such as paraquat or 2,4-D are still used in Brazil, while they are banned in the EU (Pollak, 2020).

Table 6. Pesticide use values for soybean in different countries and according to different references.

Country	Reference [1]	Herbicides per ha	TOTAL PPP per ha	Herbicides per kg	TOTAL PPP per kg
		kg a.i./ha	kg a.i./ha	g a.i./kg	g a.i./kg
Brazil	Prudêncio da Silva et al. (2010)	-	2,5	-	0,9
	Meyer & Cederberg (2010)	4,2	5,8	1,5	2,1
	Pollak (2020) [2]	**4,4**	**6,5**	**1,5**	**2,2**
Austria	Eurostat	0,5	0,6	0,2	0,2
France	Eurostat	1,4	1,5	0,5	0,5
USA	Perry et al. (2016) [3]	1,4	2,1	0,5	0,8

Notes:

[1] The reference years are unknown for Prudêncio da Silva et al. (2010); 2008 for Meyer & Cederberg (2010); 2008-2018 for Pollak (2020); 2017 for Austria and France and 1998-2011 for Perry et al. (2016).

[2] The figures by Pollak (2020) are the ones which were used in the calculations.

[3] For Perry et al. (2016), only the per ha value for herbicide use was available. In order to determine the total value, the shares of other pesticides categories were assumed the same as in Pollak (2020). The per kg values were obtained based on FAOSTAT data for soybean yield in the USA over the 1998-2011 period (FAOSTAT, 2021).

Table 7. Main feed ingredients included in the model and corresponding Eurostat crop references in each country of interest.

Countries	Grazed grass	Grass silage/hay	Maize silage	Other forage	Cereals - Wheat	Cereals - Maize	Cereals - Barley	Olea-/proteaginous	Soybean meal	Sunflower meal	Rapeseed meal	Sugarbeet
Sweden	Estonia	Temporary grasses and grazings	Green maize	Plants harvested green from arable land	Common wheat and spelt	Average	Barley	Broad and field beans	Soya BR	Average	Rape and turnip rape seeds	Sugar beet (excluding seed)
Finland	Estonia	Average	Sweden	Sweden	Common winter wheat and spelt	Average	Spring barley	Broad and field beans	Soya BR	Average	Spring rape and turnip rape seeds	Sugar beet (excluding seed)
Austria	France	Average	Green maize	Sweden	Common winter wheat and spelt	Grain maize and corn-cob-mix	Winter barley	Average	Soya BR	Sunflower seed	Winter rape and turnip rape seeds	Sugar beet (excluding seed)
France	Permanent grassland	Temporary grasses and grazings	Green maize	Sweden	Common wheat and spelt	Grain maize and corn-cob-mix	Barley	Broad and field beans	Soya BR	Sunflower seed	Rape and turnip rape seeds	Sugar beet (excluding seed)
Estonia	Permanent grassland	Average	Green maize	Sweden	Common winter wheat and spelt	Average	Spring barley	Broad and field beans	Soya BR	Average	Spring rape and turnip rape seeds	Average
Belgium	Permanent grassland	Temporary grasses and grazings	Green maize	Sweden	Wheat and spelt	Grain maize and corn-cob-mix	Barley	Average	Soya BR	Average	Rape and turnip rape seeds	Sugar beet (excluding seed)

Notes:

- White cells indicate that a country-specific value is available for the feed ingredient. The name in the cell refers to the reference crop in Eurostat for which the value of PPP use was used in the calculations.
- Greyed cells indicate that no country-specific value is available for the feed ingredient. As a result, the cell indicates whether the value of a neighbouring country or the average value (based on the available countries) was used in the calculations.
- For some crops (wheat; barley; rape and turnip), Eurostat provides more than one crop reference, for which the availability of data can vary from country to country. The reference crop was thus adapted accordingly.
- Vitamins and minerals, which are included in the list of potential feed ingredients, are not included in this table as they were assumed not to be associated with any use of pesticides.

Table 8. Values of pesticides use per unit of area (kg a.i./ha) for twelve feed ingredients in six countries.

Countries	Grazed grass	Grass silage/hay	Maize silage	Other forage	Cereals - Wheat	Cereals - Maize	Cereals - Barley	Olea-/proteaginous	Soybean meal	Sunflower meal	Rapeseed meal	Sugar beet
Sweden	0,0087	0,0527	0,0938	0,0503	0,5449	1,1611	0,4079	0,2933	6,5000	1,6478	0,7039	0,1102
Finland	0,0087	0,0776	0,0938	0,0503	0,5531	1,1611	0,7545	0,4873	6,5000	1,6478	0,6130	2,9154
Austria	0,0058	0,0776	0,9522	0,0503	0,8423	0,9522	1,2583	0,8184	6,5000	1,5301	2,1438	7,7637
France	0,0058	0,0207	0,8623	0,0503	2,3936	1,1448	1,9961	1,8664	6,5000	1,7655	2,1869	3,6986
Estonia	0,0087	0,0776	0,2992	0,0503	1,0251	1,1611	0,6323	0,6264	6,5000	1,6478	0,7954	4,2216
Belgium	0,1175	0,1664	1,2840	0,0503	2,8592	1,3862	2,2869	0,8184	6,5000	1,6478	1,8604	6,6203

Notes:

All values are based on Eurostat data except for soybean meal, which is based on Pollak (2020).

Greyed cells indicate that no country-specific value was available for the feed ingredient in Eurostat. As a result, a neighbouring country or the average value was used (see Table 7).

Table 9. Values of pesticides use per unit of dry matter output (g a.i./kg DM feed crop) for twelve feed ingredients in six countries.

Countries	Grazed grass	Grass silage/hay	Maize silage	Other forage	Cereals - Wheat	Cereals - Maize	Cereals - Barley	Olea-/proteaginous	Soybean meal	Sunflower meal	Rapeseed meal	Sugar beet
Sweden	0,0012	0,011	0,01	0,01	0,09	0,13	0,09	0,10	2,59	0,71	0,23	0,00
Finland	0,0012	0,007	0,01	0,01	0,25	0,13	0,26	0,38	2,59	0,71	0,50	0,09
Austria	0,0008	0,007	0,07	0,01	0,20	0,11	0,22	0,39	2,59	0,71	0,82	0,12
France	0,0008	0,003	0,06	0,01	0,38	0,13	0,37	0,84	2,59	0,71	0,63	0,04
Estonia	0,0012	0,007	0,04	0,01	0,22	0,13	0,17	0,24	2,59	0,71	0,41	0,07
Belgium	0,0168	0,007	0,08	0,01	0,39	0,16	0,32	0,39	2,59	0,71	0,48	0,08

Notes:

All values are based on Eurostat data except for soybean meal, which is based on Pollak (2020).

Greyed cells indicate that no country-specific value was available for the feed ingredient in Eurostat. As a result, a neighbouring country or the average value was used (see Table 7).

3.6. Status of assessment

3.6.1. General overview

Based on the collected data (generic and specific), 75 products were assessed so far (i.e., input data was collected and a specific result was calculated). This represents 64% of the 117 priority products and includes both non-organic and organic products (55 and 20 products respectively). Additionally, there are 15 organic products which are part of the priority products but for which no specific data was found (as such, they are not considered as "assessed"). However, their pesticides impact is considered to be zero by definition. Adding these products to the 75 for which data was found, there is a total of 90 products for which a result is available (Table 10).

As appears from Table 11, the status of assessment is lower for some countries (e.g., Estonia) and product categories (e.g., beef). This is can be explained by a generally lower data availability for certain products or because for some countries, the data collection process was limited by the language barrier.

Table 10. Status of assessment of priority products based on data collection and certification. Number of priority products for which an actual assessment was performed and for which a result is available.

Data collection and Certification	Assessment?	Result?	Number
A. Assessed – Organic	Yes	Yes – zero	20
B. Assessed – Non-organic	Yes	Yes – variable	55
C. Not assessed – Organic	No	Yes – zero	15
D. Not assessed – Non-organic	No	No	27
TOTAL Priority products			117
Total 'Assessed' (A+B)			75
Total 'Not assessed' (C+D)			42
Total 'Results' (A+B+C)			90
Total 'No-results' (D)			27

Table 11. Status of assessment of priority products per country of origin and per product category.

Disaggregation	Countries/product categories	To assess	Assessed	%
Per country of origin	Belgium	19	19	100%
	Austria	18	12	67%
	France	28	16	57%
	Finland	9	5	56%
	Sweden	21	13	62%
	Estonia	5	2	40%
	General [1]	17	8	47%
Per product category	Butter	2	2	100%
	Broiler	16	15	94%
	Pork	17	14	82%
	Eggs	17	13	76%
	Cheese	15	9	60%
	Milk	9	5	56%
	Beef	24	9	38%
	Plant-based	17	8	47%
TOTAL	-	**117**	**75**	**63%**

Note: [1] General refers to plant-based (VG) products.

3.6.2. Calculation hypotheses of assessed products

All the calculation hypotheses and input values relative to the feeding practices of the 75 products which were assessed are specified in the separate *Supplementary Material* document (Table S1 for feed conversion ratios and Table S2 for feed compositions).

Chapter 4. Calculation tool

To perform the assessment for each product, a calculation tool was developed in an Excel spreadsheet. It consists of six tabs (Figure 6):

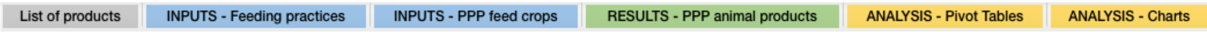

Figure 6. Screenshot of the five tabs included in the calculation tool.

(1) **List of products:**
   - *No manual entry is needed in this tab.*
   - Contains the initial list of 215 products provided by WWF.

(2) **INPUTS – Feeding practices:**
   - *No manual entry is needed in this tab* [4].
   - Contains the generic data regarding feeding practices, which is useful when no specific data is available for certain products.

(3) **INPUTS – PPP feed crops:**
   - *No manual entry is needed in this tab* [5].
   - Contains the Eurostat values of pesticides uses of feed crops for the six countries of interest. Additional values would need to be extracted from Eurostat if other countries were to be included in the assessment.

(4) **RESULTS – PPP animal products:**
   - *Manual entry is needed in this tab.*
   - This is where the entry of input data happens and calculations occur based on the input data.
   - One needs to select whether the calculations are based on specific or generic feeding practices data:
     - *Specific data:* when selecting specific data, the user needs to manually enter the values of the feeding practices inputs in the table. The tool then automatically calculates the outputs based on these values.
     - *Generic data:* when selecting generic data, the tool automatically generates the outputs based on the generic data contained in the second tab (INPUTS – Feeding practices). In this case the user only needs to indicate that the calculations must be based on generic data but no actual entry of data is needed.

[4] Except if the generic data regarding feeding practices needs to be modified or updated (e.g., with more recent/accurate data).

[5] Except if the reference values for certain feed ingredients need to be modified (e.g., to adapt the country of origin of soybean meal).

(5) ANALYSIS – Pivot tables:

- *Manual entry is needed in this tab.*
- This is an interactive tab in which the user can select specific products, product categories or countries of origin. These can then be compared in terms of their outputs (use of pesticides). Results are presented in the form of tables.

(6) ANALYSIS – Charts:

- *Manual entry is needed in this tab.*
- This is an interactive tab in which the user can select specific products, product categories or countries of origin. These can then be compared in terms of their outputs (use of pesticides). Results are presented in the form of charts.

Chapter 5. Results

5.1. Overview of average results (cross-country and cross-product)

Across all countries and products, the average value of pesticides use is 1,74 g a.i./kg edible product when organic products are not included, which is above the threshold of 1,5 g a.i./kg edible product set by WWF (Table 12)[6].

5.1.1. Country comparison

Scope of assessment

Regarding the scope of the assessment, Estonia and Finland present the lowest number of assessed products (3/2 and 5/5 products with/without organic products respectively). For all other countries, more than ten products were assessed when organic products are included[7]. Belgium and France present the highest number of assessed products (19/14 and 20/12 with/without organic products respectively).

Results with and without organic products

When organic products are not included (Table 12), Sweden has the lowest average pesticides use (1,44 g a.i./kg edible product). It is the only country for which the average level of pesticides use is below the threshold of 1,5 g a.i./kg edible product. On the other hand, Finland presents the highest average value (2,87 g a.i./kg edible product).

Given that organic products present a null use of chemical pesticides by definition, all country averages decrease when including organic products. All countries present below-the-threshold average values in this situation, with the exception of Finland for which no organic product was assessed (Table 13).

Two important comments regarding this analysis must be raised. First, it should be noted that such comparisons across countries are not particularly relevant since the number and types of assessed products differ from country to country. Second, the country averages presented here are calculated based on the results of a specific country but are not weighted according to the actual shares of different production systems (e.g., organic) in each country. As a consequence, unless specified otherwise, the country- and product-specific average values presented in the following sections only include non-organic products.

These two points are further discussed in section 6.2.

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[6] This value decreases to 1,06 g a.i./kg edible product when organic products are included, which is below the threshold (Table 13).

[7] Some organic products included here were not actually assessed in terms of data collection but are still included as they present a null result by definition (see Table 10).

Table 12. Cross-country average values of pesticides use for different categories of animal products (g a.i./kg edible product). Organic products not included.

Products	Austria		Belgium		Estonia		Finland		France		Sweden		ALL	
	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product
Beef	1	1,60	4	1,74			1	1,30			2	1,05	**8**	**1,50**
Broiler	1	2,12	2	2,76	1	1,85	1	2,46	3	3,13	3	1,68	**11**	**2,40**
Butter	1	2,93											**1**	**2,93**
Cheese	3	1,47	1	1,14			1	5,80			1	2,40	**6**	**2,29**
Eggs			3	1,41			1	1,06	5	1,50	1	0,93	**10**	**1,37**
Milk			2	0,32					1	0,43			**3**	**0,36**
VG													**5**	**0,35**
Pork	1	1,58	2	2,55	1	2,34	1	3,70	3	2,88	3	1,30	**11**	**2,21**
TOTAL	**7**	**1,80**	**14**	**1,69**	**2**	**1,60**	**5**	**2,87**	**12**	**2,16**	**10**	**1,44**	**55**	**1,74**

Table 13. Cross-country average values of pesticides use for different categories of animal products (g a.i./kg edible product). Organic products included.

Products	Austria		Belgium		Estonia		Finland		France		Sweden		ALL	
	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product	No. products	G a.i./kg edible product
Beef	2	0,80	5	1,39	1	0,00	1	1,30	2	0,00	3	0,70	**14**	**0,86**
Broiler	2	1,06	3	1,84	1	1,85	1	2,46	4	2,34	4	1,26	**15**	**1,76**
Butter	2	1,47											**2**	**1,47**
Cheese	6	0,73	1	1,14			1	5,80			3	0,80	**11**	**1,25**
Eggs	1	0,00	4	1,06			1	1,06	6	1,25	2	0,46	**14**	**0,98**
Milk			3	0,22					4	0,11			**7**	**0,15**
VG													**12**	**0,15**
Pork	2	0,79	3	1,70	1	1,34	1	3,70	4	2,16	4	0,97	**15**	**1,62**
TOTAL	**15**	**0,84**	**19**	**1,24**	**3**	**1,07**	**5**	**2,87**	**20**	**1,30**	**16**	**0,90**	**90**	**1,06**

5.1.2. Product comparison

Scope of assessment

Regarding the scope of the assessment, butter and milk were the least assessed products (2/1 and 7/3 products with/without organic products). Broiler, pork and eggs on the other hand where the most assessed products (15/11, 15/11 and 14/10 with/without organic products respectively).

Results with and without organic products

When organic products are not included, plant-based products (VG) and milk present the lowest average pesticides use values (0,35 and 0,36 g a.i./kg edible product respectively), which are well below the threshold. The average value for eggs is below the threshold too (1,37 g a.i./kg edible product) and that of beef corresponds exactly to the threshold (1,50 g a.i./kg edible product). All other products present average impact levels which are above the threshold. Butter presents the highest average value (2,93 g a.i./kg edible product) but this is based on one single assessment. Broiler and pork come next with 2,40 and 2,21 g a.i./kg edible product respectively (Figure 7).

When organic products are included, broiler and pork remain the only product categories which present average impact levels above the threshold value (1,76 and 1,62 g a.i./kg edible product respectively). All other product averages are below the threshold. The least impacting product categories remain plant-based products and milk (0,15 g a.i./kg edible product each), followed by beef (0,86 g a.i./kg edible product) (Figure 7).

As was the case for the analysis of country averages above, such a comparison of product averages with and without organic products is not particularly relevant since organic products present a null use of pesticides by definition. Including them thus automatically brings the average of a product down. Depending on the number of organic products included in the assessment, the impact on the product average can be greater or smaller. Average values including organic products should thus be weighted according to the shares of production systems.

Range of results

Analysing the range of results (i.e., the maximum and minimum values), it appears that the highest observed impact level is for cheese (5,80 g a.i./kg edible product) and the lowest one for a plant-based product (0,14 g a.i./kg edible product) (Figure 8).

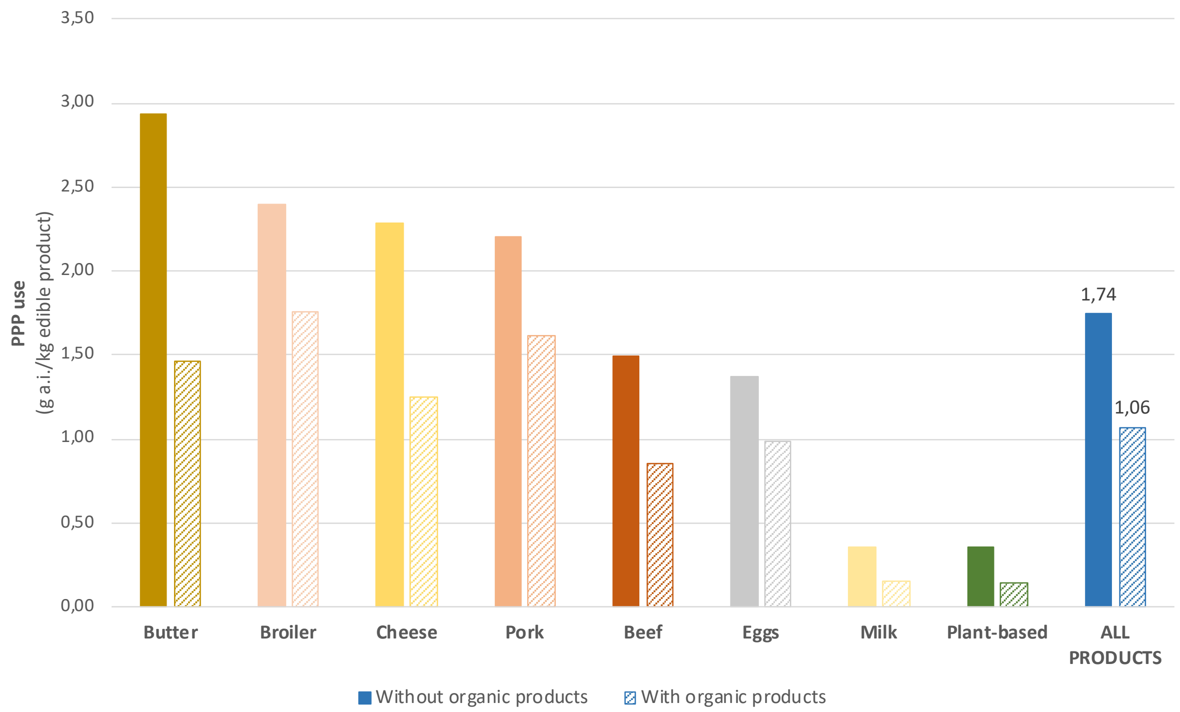

Figure 7. Average pesticides use (g a.i./kg edible product) for different product categories, with and without organic products.

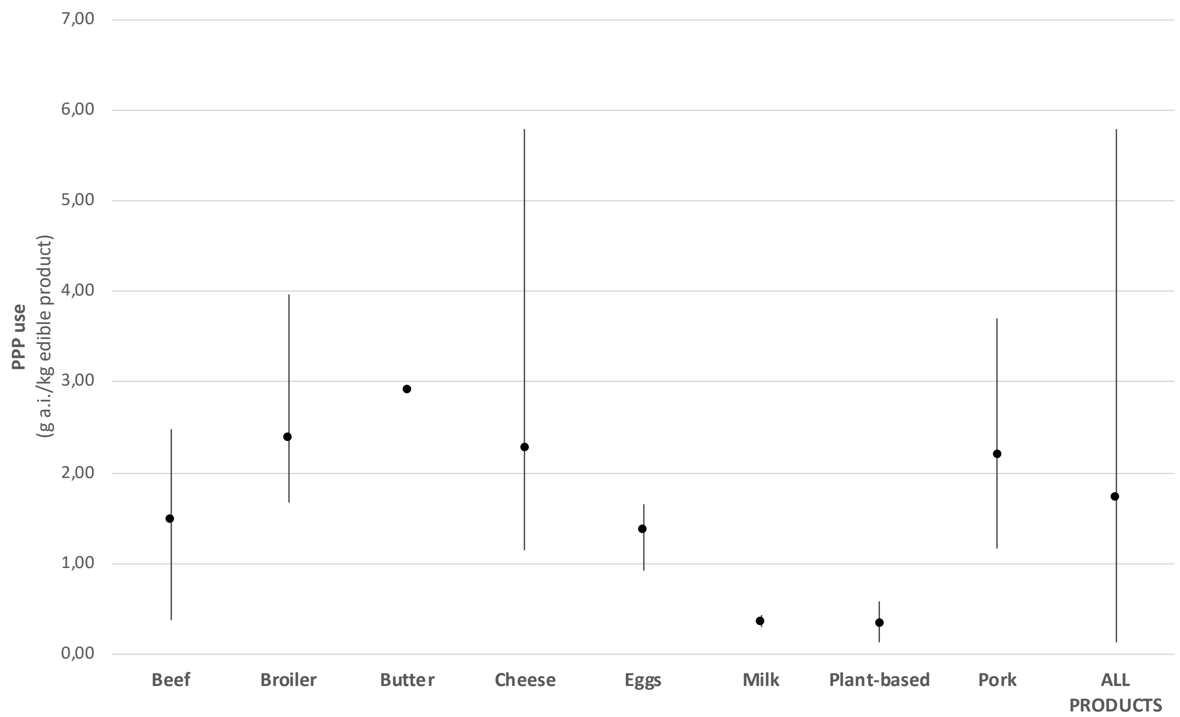

Figure 8. Maximum, minimum and average pesticides use values (g a.i./kg edible product) for different animal and plant-based product categories. Organic products not included.

Note: Based on 55 non-organic products.

Contribution of soybean meal

Given the important impact of soybean meal (see Figure 5), it is interesting to look at the relative contribution of soybean meal in the average impact of each product category. On average, across all assessed non-organic products, soybean meal represents 61% of the total pesticides use. More specifically, the impact levels of broiler and eggs seem particularly driven by soybean meal (75% and 71% of total impact respectively). The impacts of milk seem closely related to soybean meal too (74% of total impact) but this is based on only three assessments. Furthermore, the average value for this group is much lower than that of broilers and eggs, and well below the threshold. Beef and butter are the only product categories for which the share of soybean meal in the total impact is lower than 50% (45% and 27% respectively). However, for butter, this is based on one single assessment (Figure 9).

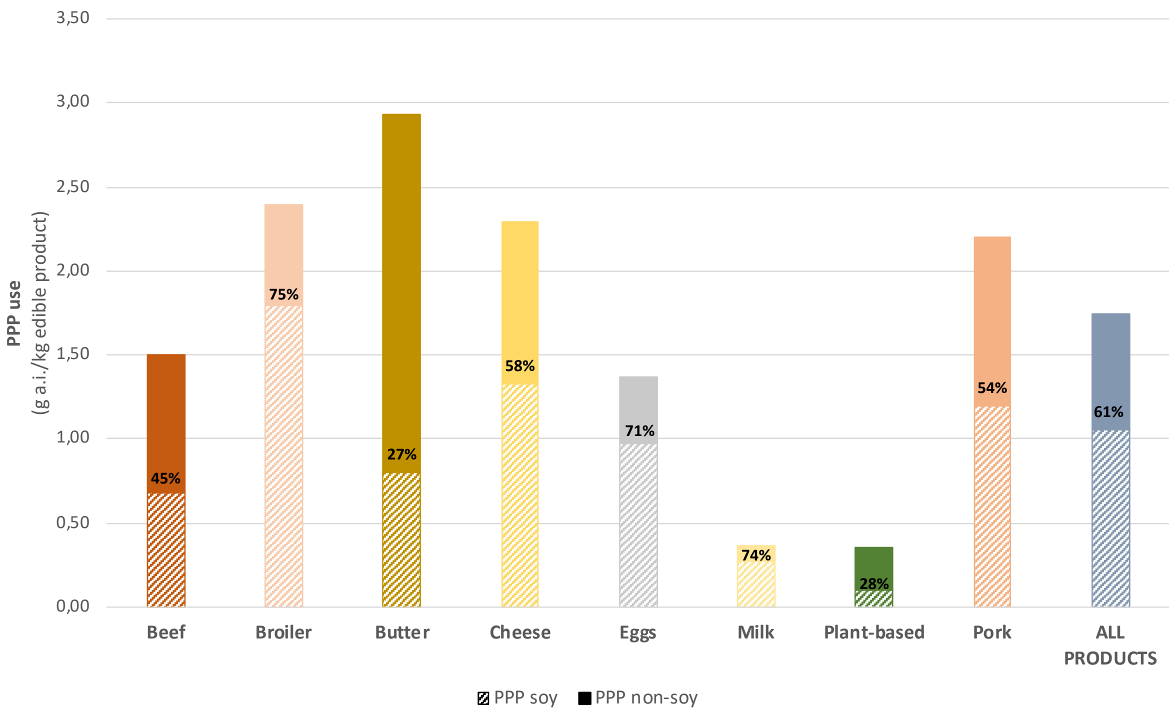

Figure 9. Share of soybean meal in average pesticides use (g a.i./kg edible product) of different product categories. Organic products not included.

Note: Based on 55 non-organic products.

5.2. Country-specific results

The following sections provide a closer overview for each country of origin. Only non-organic products are presented in the charts as organic products present a null result by definition.

5.2.1. Austria

Fifteen products were assessed for Austria, of which eight are organic and present a null value. The results of the seven non-organic products are presented in Figure 10.

Excluding organic products, the country-average[8] use of pesticides for the assessed animal products in Austria is 1,80 g a.i./kg edible product, which is above the threshold of 1,5 g a.i./kg edible product (Table 21 in Appendix 2)[9].

Butter presents the highest value whereas the lowest values are observed for cheese. These are exactly half that of butter given that the model assumes that 1 kg butter=20L milk and 1 kg cheese=10L milk. This holds true for all cheese types, which explains why cream cheese, gouda and mozzarella present the same results (Figure 10 and Table 21 in Appendix 2).

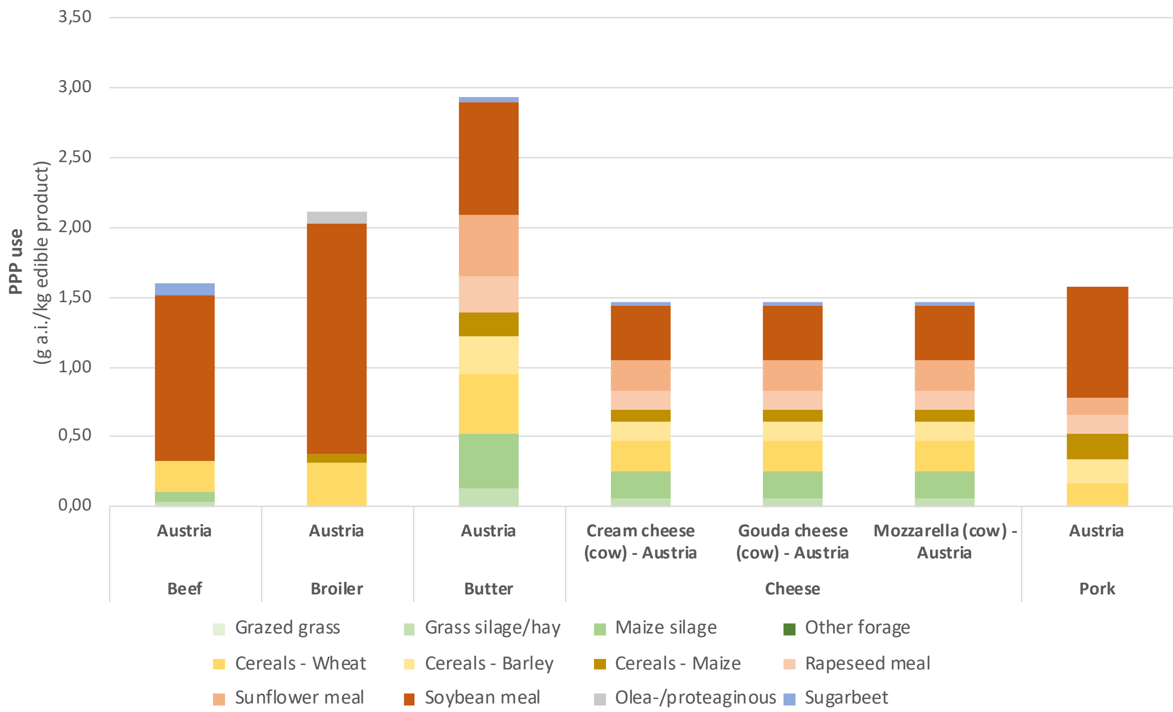

Figure 10. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in Austria.

[8] It should be noted that the country averages presented here are not weighted according to the shares of different production systems in each country.

[9] The country average is reduced by half and below the threshold when organic products are included (0,84 g a.i./kg edible product).

5.2.2. Belgium

Nineteen products were assessed in Belgium, of which five are organic and present a null value. The results of the fourteen non-organic products are presented in Figure 11.

Excluding organic products, the country-average use of pesticides for the assessed animal products in Belgium is 1,69 g a.i./kg edible product, which is above the threshold of 1,5 g a.i./kg edible product (Table 22 in Appendix 2)[10].

Broiler and pork present the highest average values whereas the lowest values are observed for milk (Figure 11 and Table 22 in Appendix 2).

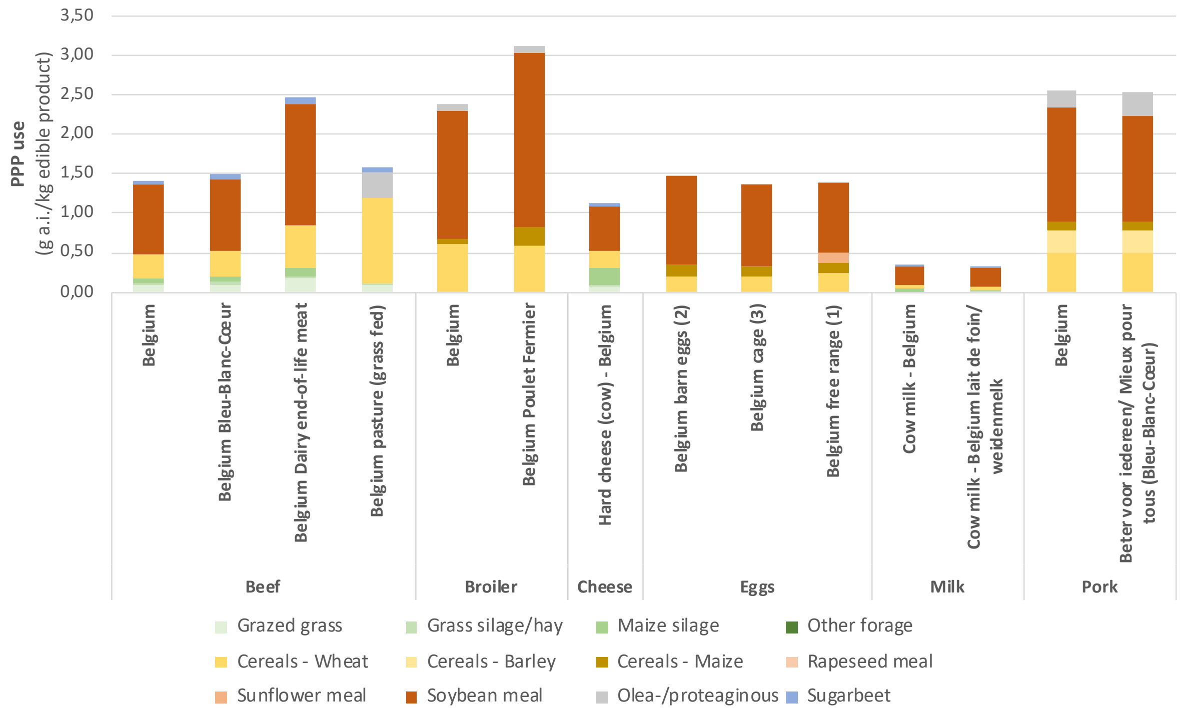

Figure 11. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in Belgium.

5.2.3. Estonia

Only three products were assessed in Estonia, of which one is organic (beef) and presents a null value. The results for the two non-organic products are presented in Figure 12.

Conventional Estonian broiler (1,85 g a.i./kg edible product) is above the threshold while conventional Estonian pork (1,34 g a.i./kg edible product) is below the threshold. The country-average amounts 1,60/1,07 g a.i./kg edible product without/with organic products (Table 23 in Appendix 2).

[10] When organic products are included, the country average decreases to 1,24 g a.i./kg edible product.

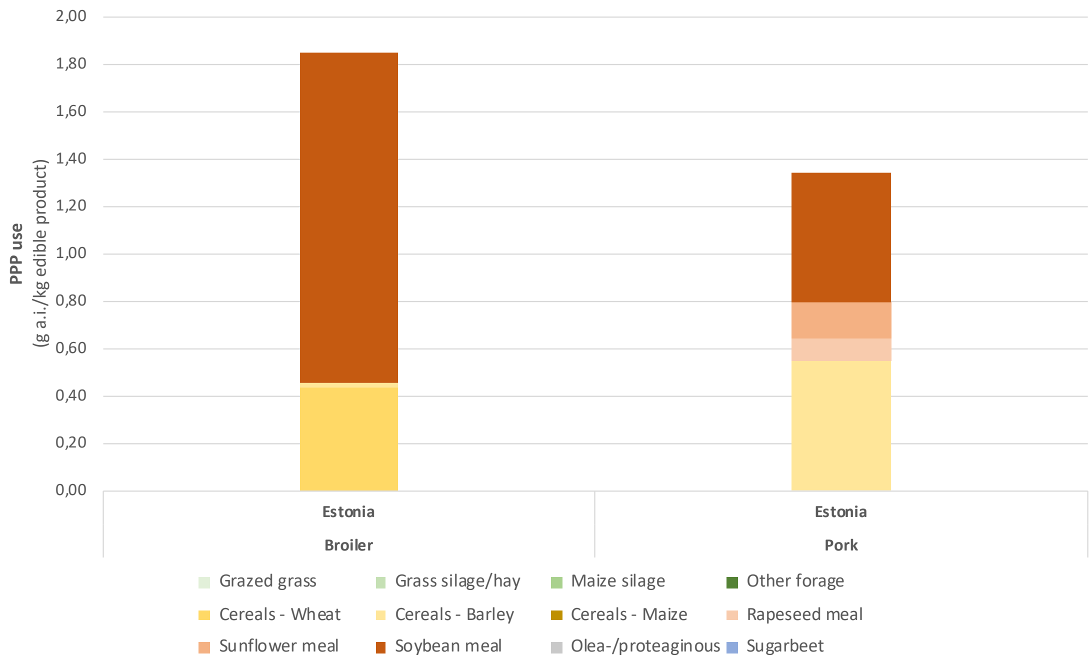

Figure 12. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in Estonia.

5.2.4. Finland

Only five products were assessed in Finland, of which none are organic and present a null value.

Cheese presents the highest value (5,80 g a.i./kg edible product) while beef presents the lowest one (1,30 g a.i./kg edible product). The country-average is of 2,87 g a.i./kg edible product, which is above the threshold (Figure 13 and Table 24 in Appendix 2).

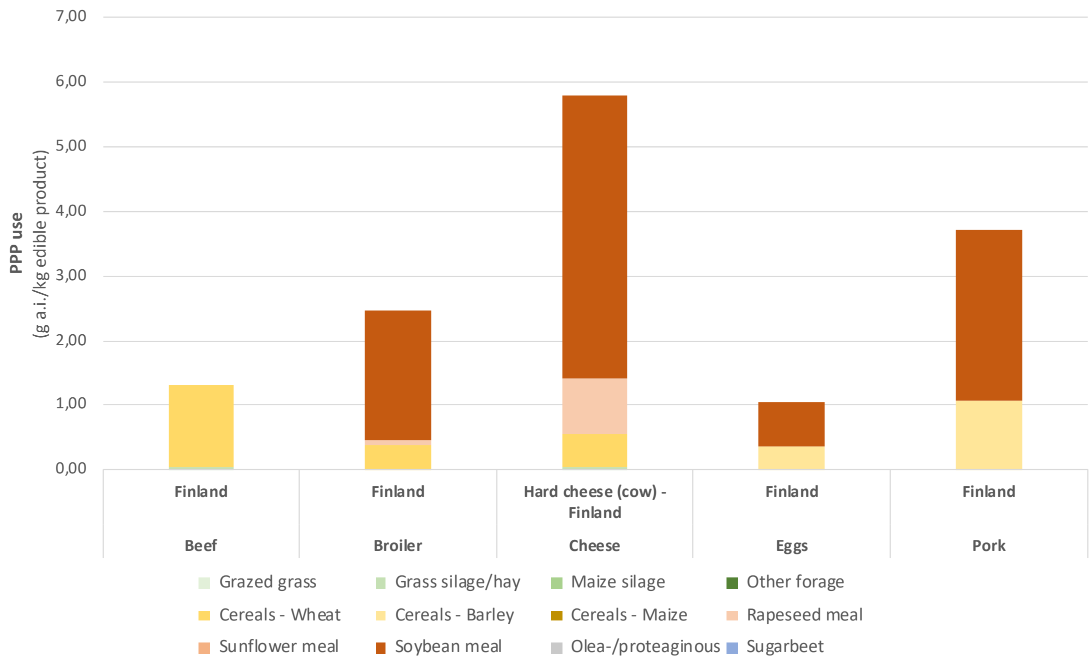

Figure 13. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in Finland.

5.2.5. France

Twenty products were assessed in France, of which eight are organic and present a null value. The results for the twelve non-organic products are presented in Figure 14.

Excluding organic products, the country-average use of pesticides for the assessed animal products in France is 2,16 g a.i./kg edible product, which is above the threshold of 1,5 g a.i./kg edible product (Table 25 in Appendix 2)[11].

Broiler and pork present the highest average values whereas the lowest values are observed for milk (Figure 14 and Table 25 in Appendix 2).

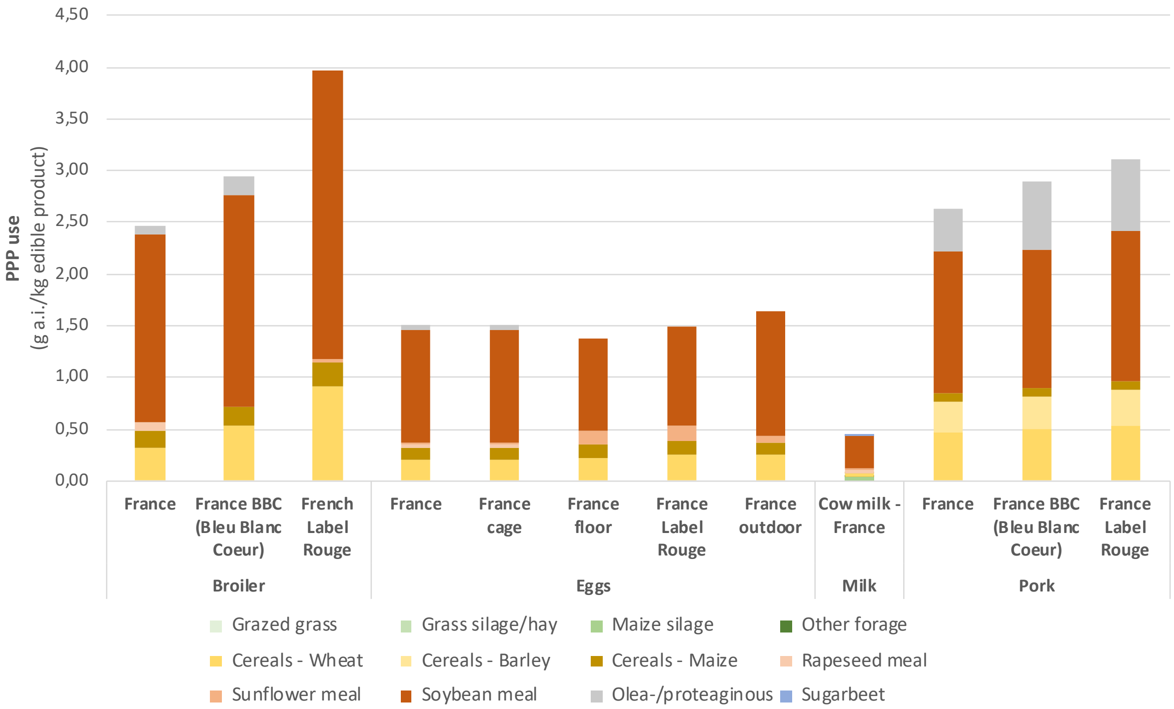

Figure 14. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in France.

[11] When organic products are included, the country average decreases to 1,30 g a.i./kg edible product, which is below the threshold.

5.2.6. Sweden

Sixteen products were assessed in Sweden, of which six are organic and present a null value. The results for the ten non-organic products are presented in Figure 15.

Excluding organic products, the country-average use of pesticides for the assessed animal products in France is 1,44 g a.i./kg edible product, which is just below the threshold of 1,5 g a.i./kg edible product (Table 26 in Appendix 2)[12].

Conventional cheese presents the highest value whereas the lowest value is observed for certified natural pasture beef (Figure 15 and Table 26 in Appendix 2).

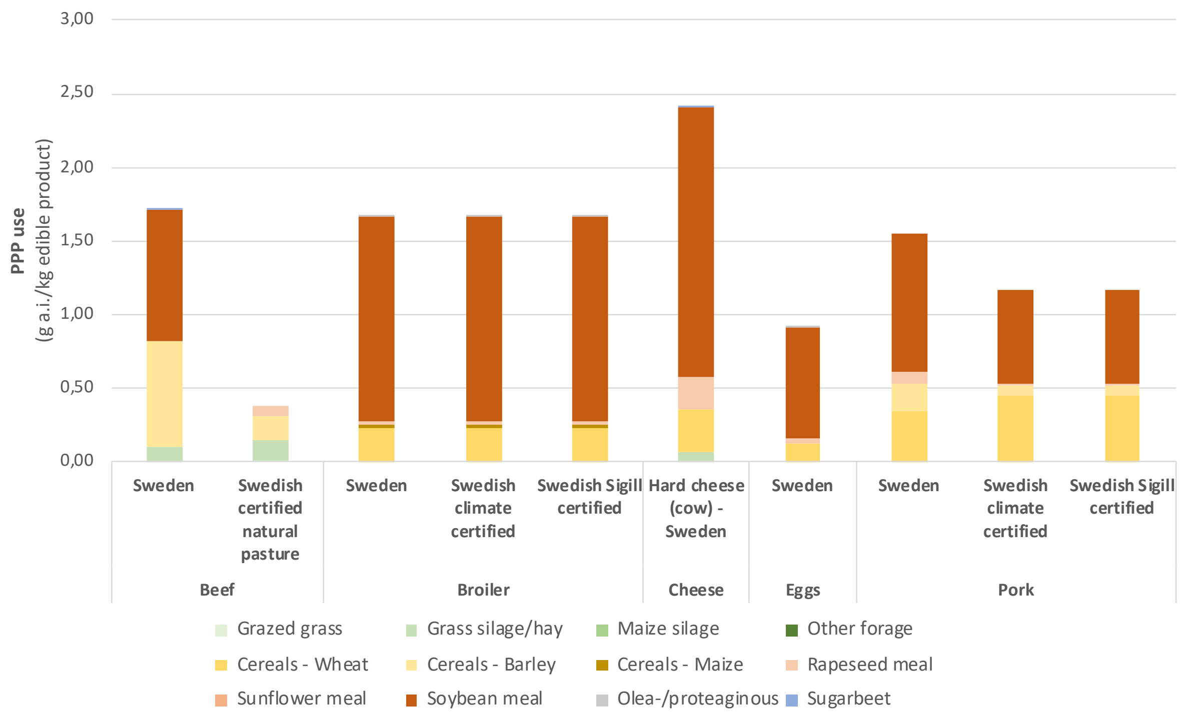

Figure 15. Total pesticides use (g a.i./kg edible product) associated with different non-organic animal products in Sweden.

[12] When organic products are included, the country average decreases to 0,90 g a.i./kg edible product.

5.3. Product-specific assessments

The following sections analyse in more detail each product category. Only non-organic products are presented in the charts as organic products present a null result by definition.

5.3.1. Beef

Fourteen beef products were assessed, of which six are organic and present a null pesticides use by definition. The results for the eight non-organic beef products are presented in Figure 16.

The average value for this group when organic products are excluded is 1,50 g a.i./kg edible product, which corresponds exactly to the threshold value (Table 27 in Appendix 3)[13].

Four products are situated below the threshold and four above. The Swedish certified natural pasture beef presents the lowest overall impact. This can be explained by the absence of soybean meal in this system. This is also the case for Finnish beef and Belgian grass-fed beef but the lower impact due to the absence of soy is partly compensated by higher shares of wheat. Belgian dairy end-of-life meat present the highest impact, which is explained by a higher FCR value compared to other products (Figure 16).

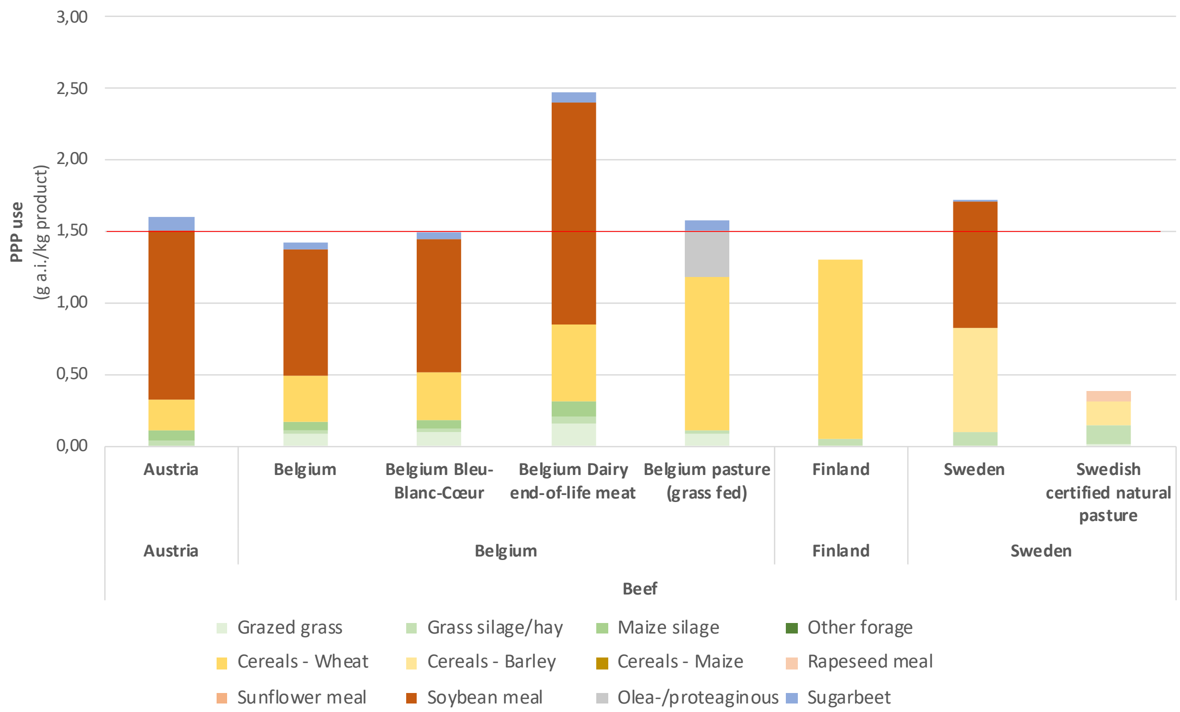

Figure 16. Total pesticides use (g a.i./kg edible product) associated with non-organic beef in different countries.

[13] The average decrease to 0,86 g a.i./kg edible product when organic products are included.

5.3.2. Broiler

Fifteen broiler products were assessed, of which four are organic and present a null PPP use by definition. The results for the eleven non-organic broiler products are presented in Figure 17.

The average value for this group when organic products are excluded is 2,40 g a.i./kg edible product, which is above the threshold (Table 28 in Appendix 3)[14].

In fact, all assessed products present a level of pesticides use which is above the threshold. The highest one is observed for the French *Label Rouge* system (3,97 g a.i./kg edible product). This system, and other extensive systems such as the Belgian *Poulet Fermier* or the French *Bleu Blanc Coeur*, are penalised by higher FCR values which are the result of longer lifecycles in these systems. On the other hand, Swedish systems present the lowest results (1,68 g a.i./kg edible product).

In general, the overall pesticides impact of broiler systems is greatly driven by the use of soybean meal (see Figure 9).

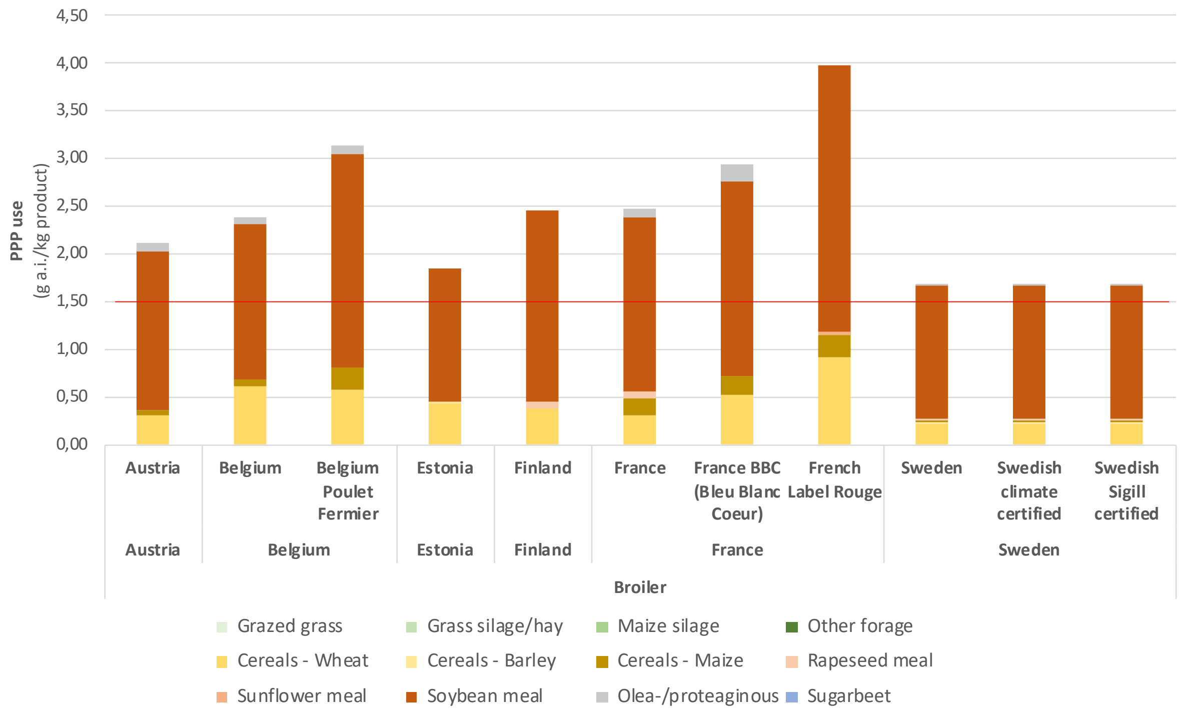

Figure 17. Total pesticides use (g a.i./kg edible product) associated with non-organic broiler in different countries.

[14] The average decreases to 1,76 g a.i./kg edible product when organic products are included, which is still above the threshold.

5.3.3. Butter & Cheese

Thirteen butter and cheese products were assessed (two and eleven respectively), of which six (one and five) are organic and present a null PPP use by definition. The results of the seven non-organic butter and cheese products are presented in Figure 18.

The average value for this group when organic products are excluded is 2,38 g a.i./kg edible product, which is above the threshold (Table 29 in Appendix 3)[15].

Four products are situated below the threshold while three products are situated above. Finnish cheese presents the highest PPP use of all products (5,80 g a.i./kg edible product). This is explained by a relatively important share of soybean meal in the feed composition in comparison with other products from the group (13% of DM). On the other hand, Belgian cheese presents the lowest PPP use (1,14 g a.i./kg edible product). Austrian products all present the same value (same calculation hypotheses) and the impact for Austrian butter is exactly twice that for Austrian milk. This is explained by the fact that 1 kg of butter requires 20L milk while 1kg cheese requires 10L milk. Hence, the results for these two groups are directly related to those of milk products (see section 5.3.5 below).

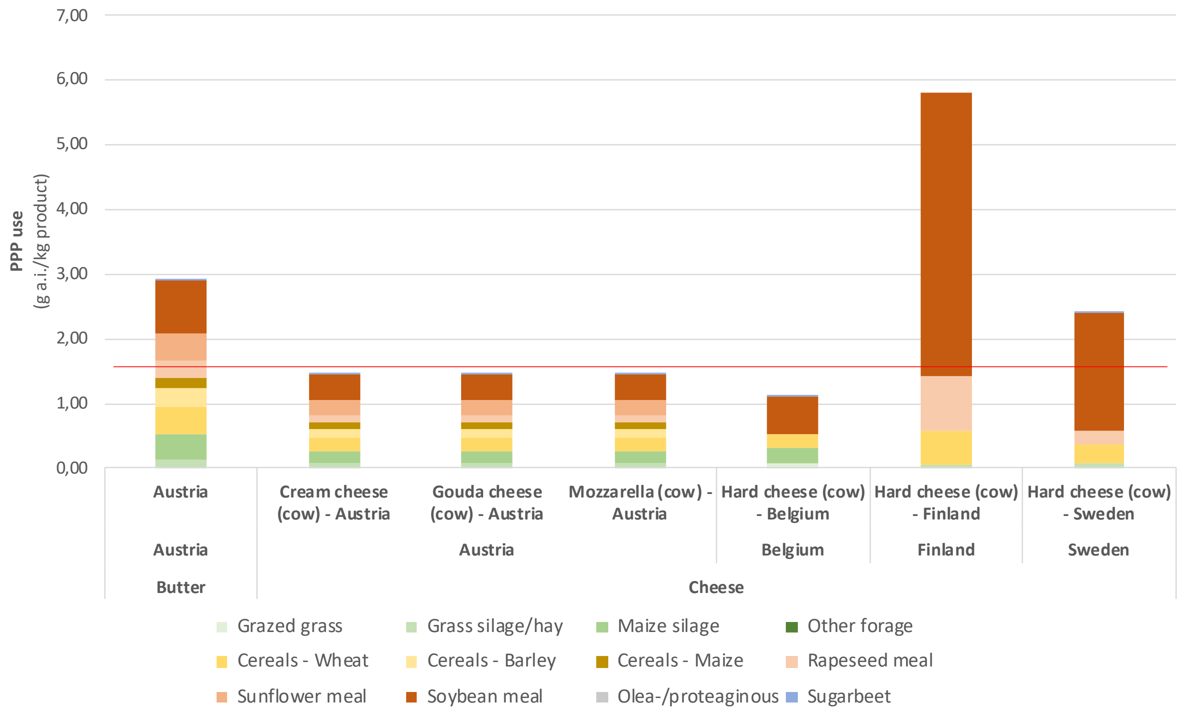

Figure 18. Total pesticides use (g a.i./kg edible product) associated with non-organic butter and cheese in different countries.

[15] The average decrease to 1,28 g a.i./kg edible product when organic products are included, which is below the threshold.

5.3.4. Eggs

Fourteen eggs products were assessed, of which four are organic and present a null PPP use by definition. The results for the ten non-organic eggs products are presented in Figure 19.

The average value for this group when organic products are excluded is 1,37 g a.i./kg edible product, which is below the threshold (Table 30 in Appendix 3)[16].

The French outdoor system is the only one which presents an impact level above the threshold value (1,65 g a.i./kg edible product). The results for French conventional (cage) and *Label Rouge* systems are very close to the threshold (1,50 and 1,49 g a.i./kg edible product). On the other hand, Swedish and Finnish systems present the lowest impact levels (0,93 and 1,06 g a.i./kg edible product respectively).

Here too, the overall impact of eggs systems is greatly driven by the use of soybean meal (see Figure 9).

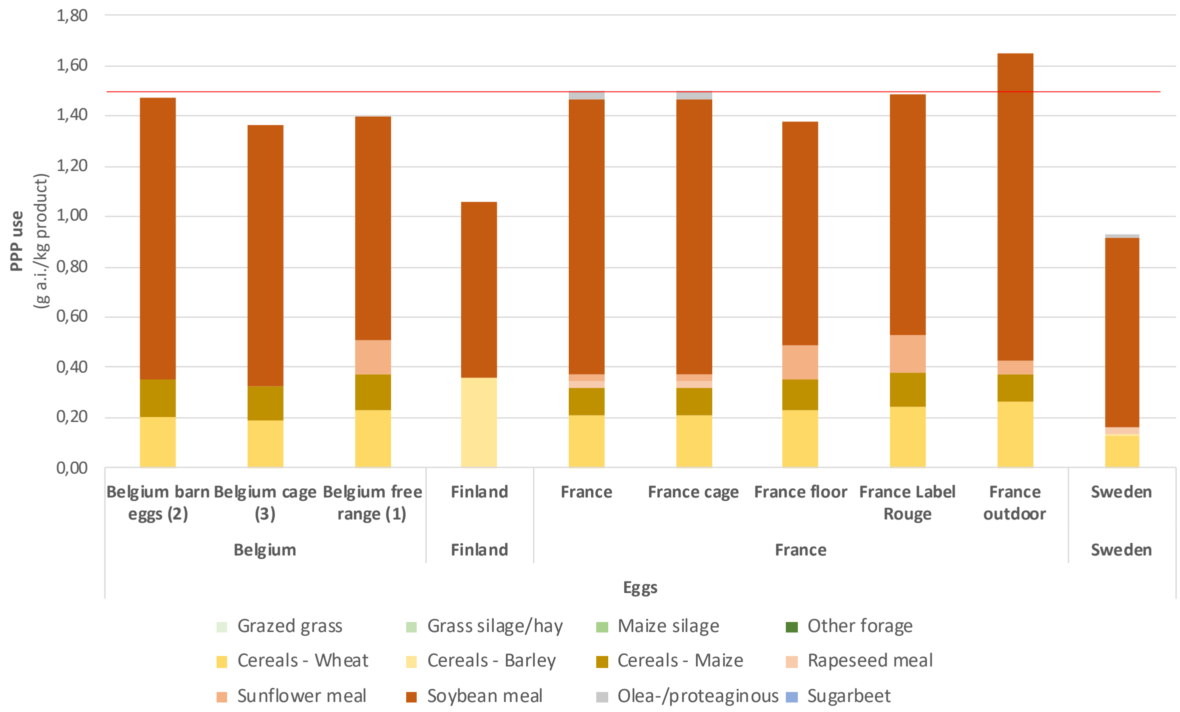

Figure 19. Total pesticides use (g a.i./kg edible product) associated with non-organic eggs in different countries.

[16] The average decrease to 0,98 g a.i./kg edible product when organic products are included.

5.3.5. *Milk*

Seven milk products were assessed, of which four are organic and present a null PPP use by definition. The results for the three non-organic eggs products are presented in Figure 20.

The average value for this group when organic products are excluded is 0,36 g a.i./kg edible product, which is well below the threshold (Table 31 in Appendix 3)[17].

Of the three assessed non-organic products, French conventional milk presents the highest value (0,43 g a.i/kg edible product) while Belgian hay milk (lait de foin/weidenmelk) presents the lowest value (0,31 g a.i./kg edible product).

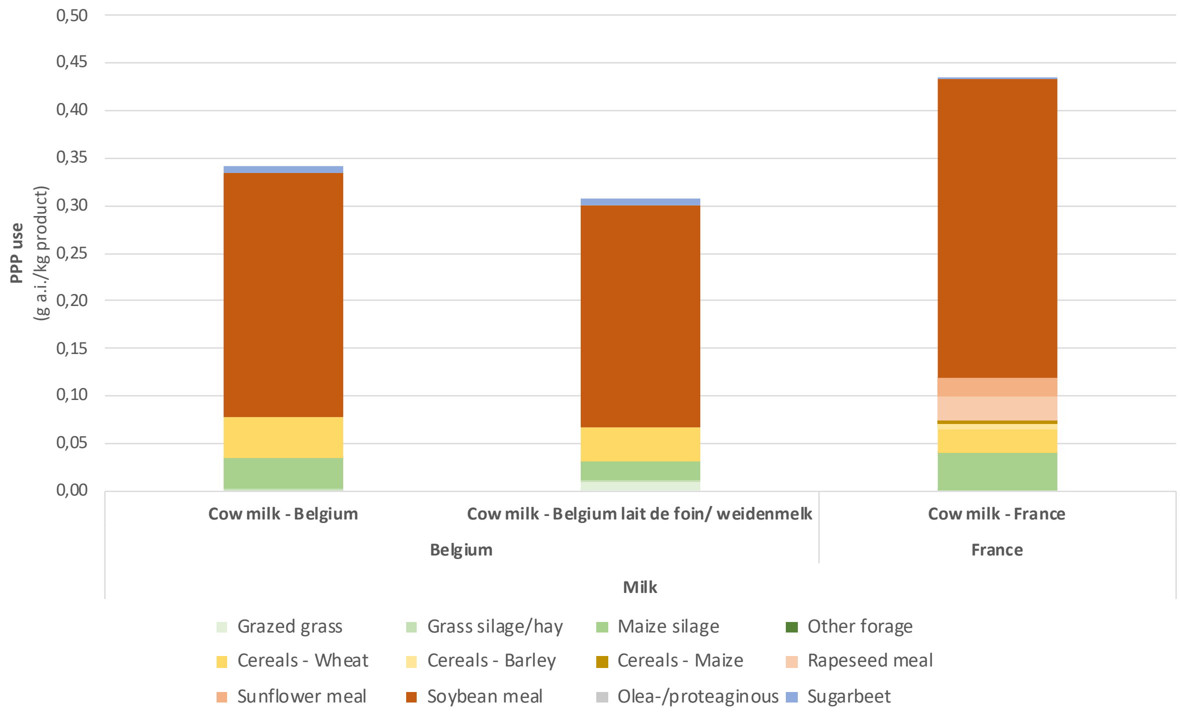

Figure 20. Total pesticides use (g a.i./kg edible product) associated with non-organic milk in different countries.

[17] The average decrease to 0,15 g a.i./kg edible product when organic products are included.

5.3.6. Plant-based products

Twelve plant-based products were assessed, of which seven are organic and present a null PPP use by definition. The results for the five non-organic plant-based products are presented in Figure 21.

The average value for this group when organic products are excluded is 0,35 g a.i./kg edible product, which is well below the threshold (Table 32 in Appendix 3)[18].

In this group, each product is assumed to be constituted of one single "feed ingredient": olea-/proteaginous beans for Härkis and conventional legumes, wheat for Seitan and soybeans for conventional soybeans and tofu. In the case of soybean-based products, an EU-origin is assumed for the soybeans (unlike soybean meal which is considered to come from Brazil).

Of the five assessed non-organic products, tofu presents the lowest impact level (0,14 g a.i./kg edible product) while Härkis presnts the highest impact level (0,59 g a.i./kg edible product).

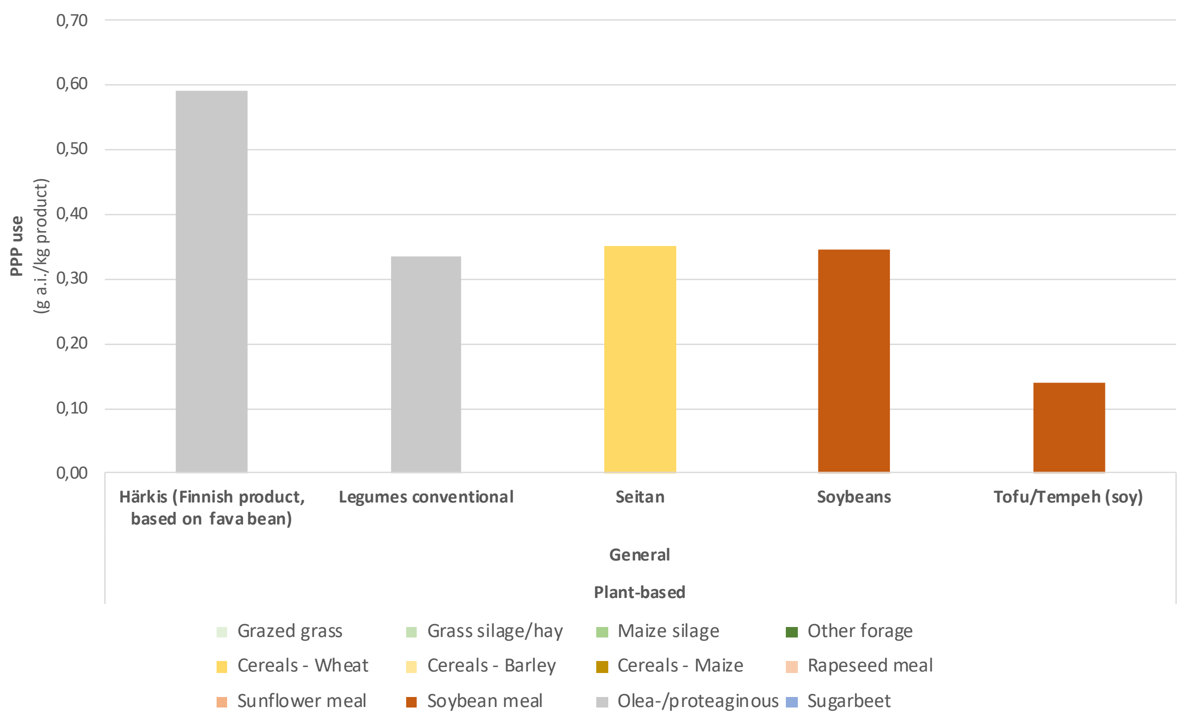

Figure 21. Total pesticides use (g a.i./kg edible product) associated with non-organic plant-based products.

[18] The average decrease to 0,15 g a.i./kg edible product when organic products are included.

5.3.7. Pork

Fifteen pork products were assessed, of which four are organic and present a null PPP use by definition. The results for the eleven non-organic eggs products are presented in Figure 22.

The average value for this group when organic products are excluded is 2,21 g a.i./kg edible product, which is above the threshold (Table 33 in Appendix 3)[19].

Of the eleven assessed non-organic products, only three present an impact level which is lower than 1,5 g a.i./kg edible product: Swedish climate certified pork, Swedish *Sigill* certified pork and Estonian conventional (1,17; 1,17 and 1,34 g a.i./kg edible product respectively). All other pork products present impact levels which are above the threshold, although Swedish conventional pork and Austrian conventional pork are very close (1,55 and 1,58 g a.i./kg edible product). Finnish conventional pork presents the highest impact level (3,70 g a.i./kg edible product), which is explained by high shares of soybean meal.

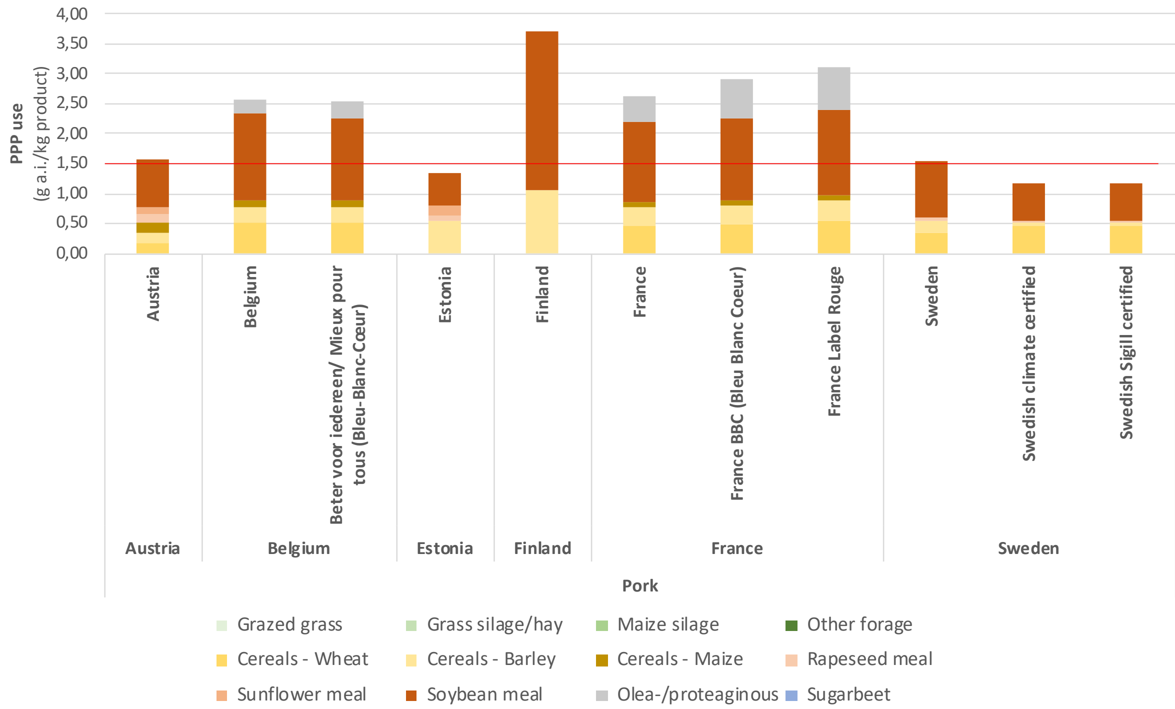

Figure 22. Total pesticides use (g a.i./kg edible product) associated with non-organic pork in different countries.

[19] The average decrease to 1,62 g a.i./kg edible product when organic products are included, which is still higher than the threshold.

Chapter 6. Discussion and recommendations

6.1. Sensitivity analysis – Origin of soy

The importance of soybean meal, and more specifically of Brazilian soybean meal, in the pesticides use of animal products has already been mentioned several times throughout this report (see Box 1, Figure 5 and Figure 9). Although, the current European feed industry remains highly dependent on imports of Brazilian soybean meal (see Box 1), moving towards other sources of soybean meal (and protein sources) could represent a significant shift in terms of the sustainability of animal feed.

In the present study, the baseline model assumes that all soybean meal used as animal feed is imported from Brazil (soy used for plant-based products such as tofu is assumed to be of EU-origin). All results presented in Chapter 5 follow this hypothesis. Additionally, two alternative scenarios were considered: (1) importing soybean meal from the USA rather than from Brazil; and (2) moving towards locally produced, EU-sourced soy. In all three scenarios, 100% of the soybean meal used in animal feed is considered to come from the same origin (soy used for plant-based products is always considered to be of EU-origin).

The results of these scenarios are presented in Figure 23.

As presented in Chapter 5, the results of the baseline scenario lead to an average level of pesticides use of 1,74 g a.i./kg edible product for 55 non-organic products, with a maximum impact level of up to 5,80 g/kg edible product.

In the US-sourced scenario, the average impact across the 55 assessed non-organic products decreases to 1,06 g a.i./kg edible product (i.e., a 39% decrease against the baseline scenario). The maximum value in this case represents 2,93 g a.i./kg edible product.

Finally, in the EU-sourced scenario, the average impact across the 55 assessed non-organic products decreases to 0,86 g a.i./kg edible product (i.e., a 51% decrease against the baseline scenario). The maximum value in this case amounts 2,25 g a.i./kg edible product.

These results confirm the importance of moving towards alternative sources of soybean meal and the great impact of this feed ingredient in the total pesticides use of animal products. Whereas in the baseline scenario, the average value across the 55 assessed products is above the threshold of 1,5 g a.i./kg edible product, both scenarios lead to average values which are below the threshold. Furthermore, the results presented in this section exclude organic products. Including them would bring the scenario averages further down.

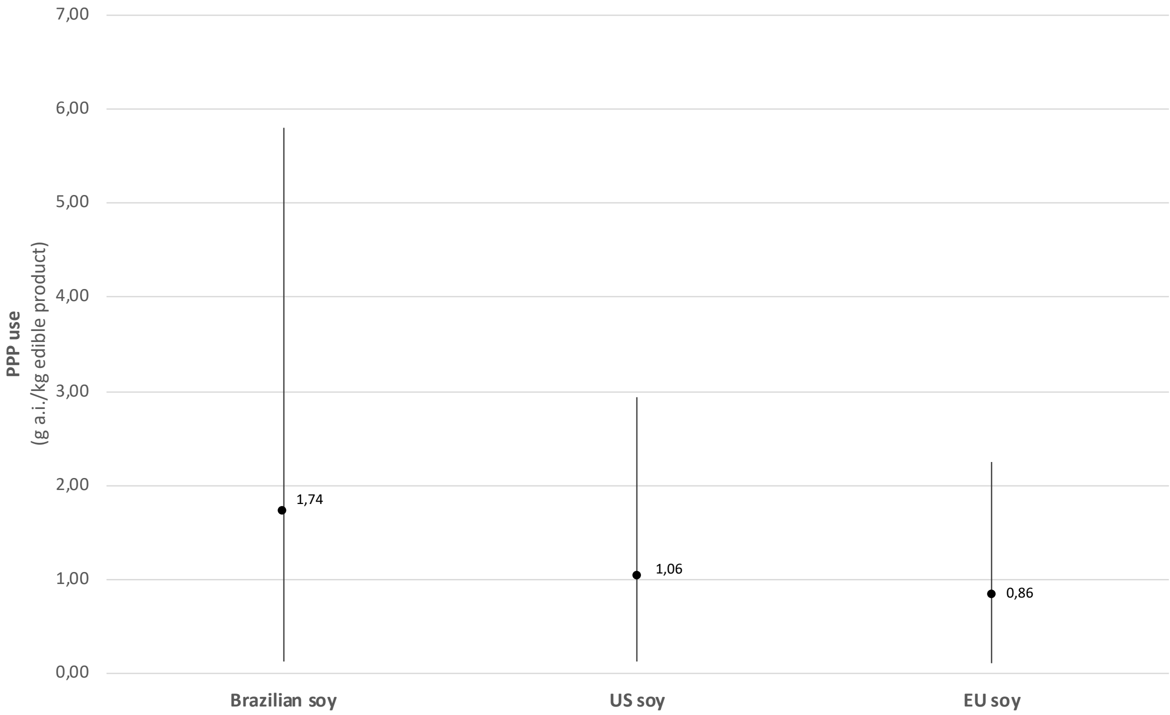

Figure 23. Maximum, minimum and average pesticides use values (g a.i./kg edible product) for different animal and plant-based products according to the origin of soybean meal. Organic products not included.
Note: Based on 55 non-organic products.

6.2. Country averages and organic agriculture

It has already been mentioned that comparing the country-average values presented in section 5.1.1 is not particularly relevant since the number and types of assessed products differ from country to country. Furthermore, the country averages presented before are calculated based on the results of a specific country but are not weighed according to the actual shares of different production systems, such as organic agriculture, in each country.

Hence, comparing the shares of organic agriculture in the countries of interest might give an indication of how the country averages might be affected. As presented in Table 14, organic agriculture represents a significant share of the total utilized agricultural area in Austria, Estonia and Sweden (over 20%). For these countries, the country-average levels of pesticides use is likely to be more favourably affected than for countries in which organic agriculture still represents smaller shares (such as Belgium, France and to a lesser extent, Finland).

Table 14. Share of organic agriculture in six countries of interest (% of organic area in total utilised agricultural area in 2019).

Country of interest	Share (%) of organic area in total utilised agricultural area in 2019
Austria	25,3%
Belgium	6,9%
Estonia	22,3%
Finland	13,5%
France	7,7%
Sweden	20,4%

Source: Eurostat (2021b)

6.3. Threshold value

WWF Meat Guides use a traffic light colour system to help consumers differentiate between sustainable (green), less sustainable (yellow) and not sustainable (red) products. In order to affect a colour to each product, thresholds need to be set. These were set by Röös et al. (2014) as they carried out the first Meat Guide assessment for WWF Sweden. In the case of pesticides, a green light was given to organic products given that they are associated with a null use of pesticides. Additionally, a threshold of 1,5 g a.i./kg edible product was used to differentiate between yellow and red products.

All following WWF Meat Guides and the results presented in this study refer to the same threshold values. Based on the results of this study, no specific recommendations or considerations stand out which would suggest to modify the set values. Indeed, in each product category there are organic products which would be given a green light, non-organic products which are below the threshold value and which would be given a yellow light as well as non-organic products which are above the threshold value and which would be given a red light. Broilers are the only exception for which all non-organic products are above the threshold (see 5.3.2). According to the results presented in this study, broiler products are thus either green (organic) or red (non-organic). Furthermore, the average value across all non-organic products is of 1,74 g a.i./kg edible product, which is rather close to the threshold value of 1,5 g a.i./kg edible product.

Although the above elements seem to go in the direction of maintaining the threshold value at 1,5 g a.i./kg edible product, it is worth to reflect on some more general considerations regarding the implications of a threshold value. Indeed, setting a fixed cut-off value implies that products leading to very similar impact levels might end up in different categories. This is for example the case of Belgian *Bleu Blanc Coeur* beef which presents a results of 1,49 g a.i./kg edible product and thus classifies as yellow, while Belgian grass-fed beef presents an impact of 1,58 g a.i./kg edible product (i.e., an increase of just 6%) and classifies as red. On the contrary, Swedish certified natural pasture beef presents an impact level of 0,38 g a.i./kg edible and thus classifies in the same category as Belgian *Bleu Blanc Coeur* (yellow), while presenting a 75% lower result (see section 5.3.1).

6.4. Choice of the indicator and functional unit

It has already been mentioned throughout the report that some limitations are associated with the indicator and the functional unit used in the study.

First, as mentioned in section 2.1, considering the use of pesticides does not reflect on the toxicity of the used pesticides nor on the actual environmental damage that may be induced by the use of these pesticides. A more comprehensive assessment should thus include a wider set of indicators.

Second, as explained in section 2.4.1, working with an output-based functional unit (*per kg edible product*) tends to penalise extensive systems and favour intensive systems. This bias could be nuanced by also presenting the results with an area-based functional unit (*per ha*), which tends to favour extensive systems. Using these two functional units would allow for a better and more accurate understanding of the pesticides use of animal products.

As an example, Figure 24 presents the pesticides use of non-organic beef products expressed per unit of area (*per ha*) rather than per unit of output (*per kg edible product*). It appears that within a country, more extensive systems present lower pesticides use values per hectare compared to conventional alternatives (e.g., Belgian grass-fed beef vs. more conventional Belgian alternatives). On the contrary, when expressed per unit of output, the Belgian grass-fed system presents a higher impact than the conventional Belgian alternatives (see Figure 16).

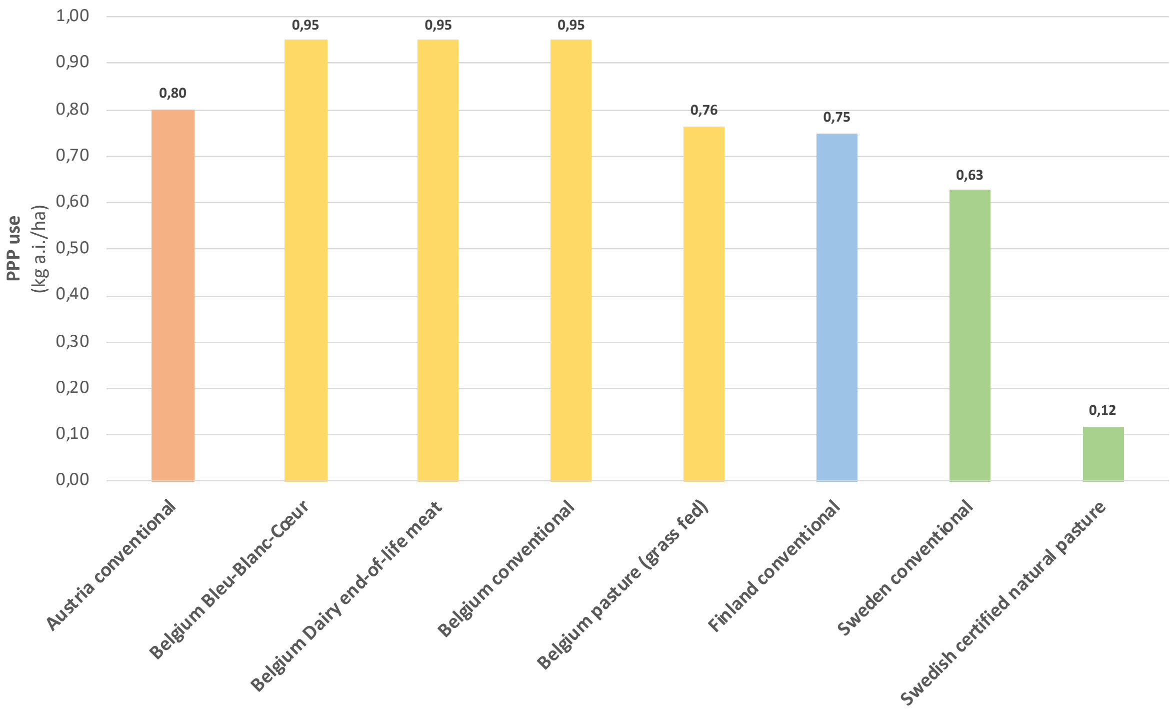

Figure 24. Total pesticides use per hectare (kg a.i./ha) associated with non-organic beef products

Third, the used functional unit (*per kg edible product*) allows to compare products across different product categories. However, it does not reflect on nutritional differences between product categories (beef, pork, milk, plant-based alternatives, etc.). A complementary functional unit taking these differences into account, e.g., the protein contents of the different products (*per kg edible protein*) would allow to increase the level of detail of the presented results.

Although these additional indicators would increase the overall accuracy of the results, it must be kept in mind that this might come at a certain cost in terms of communicating a clear message towards consumers, especially in the context of WWF's Meat Guides.

6.5. Missing data

As mentioned in sections 3.1 and 3.6, a list of 117 priority products was established starting from an initial list of 215 products.

Regarding the 117 priority products, a result could be produced for 90 products (including non-assessed organic products which have a null result by definition). No results were produced for the 27 remaining priority products due to a lack of specific data. Ideally, collecting additional specific data would be necessary to assess the pesticides impacts of these products. However, if no specific data can be collected for these products, a result could still be generated based on the generic data included in the calculation tool (relative to the country of interest or to the production system).

Regarding the remaining 98 non-priority products, these include product categories (duck, game, lamb, turkey) and countries of origin (Argentina, Denmark, New Zealand, Portugal, etc.) which are currently not assessed. Including them in the assessment would thus require additional data collection, both in terms of specific and generic data.

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Appendix 1 – Generic data for feeding practices

Feed conversion ratios

Feed consumption of non-productive animals

Table 15. Generic feed consumption values of non-productive animals per product category.

Product	**Source**	**Feed consumption by non-productive animals** kg feed (DM)/kg product
Broiler	Based on ITAVI (2015); Viaene (2012); Wageningen UR (2013)	0,16
Eggs	Based on ITAVI (2015); Viaene (2012); Wageningen UR (2013)	0,28
Pork	IFIP (2016)	0,42
Milk	Personal communication with BE expert (2018)	0,55
Beef	None considered in the calculations	0,00
Cheese	Personal communication with BE expert (2018)	5,45
Butter	Personal communication with BE expert (2018)	10,91
Plant-based	None	0,00

Note: Results are expressed per kg live weight for boiler and pork and per kg edible product for all other categories (eggs, milk, cheese and butter).

Generic FCR values – per production system

Table 16. Generic FCR values per production system for different product categories.

Product	Source	Category	FCR	Unit
Broiler	ITAVI (2015) & Pers. Comm.with BE experts (2018)	Conv	1,7	kg feed/kg live weight
		Diff	2,4	kg feed/kg live weight
		Org	2,6	kg feed/kg live weight
Eggs	Wageningen UR (2013) & Pers. Comm. with BE experts (2018)	Conv	2,0	kg feed/kg edible product
		Diff	2,3	kg feed/kg edible product
		Org	2,4	kg feed/kg edible product
Pork	Nguyen et al. (2010) & Pers. Comm. with BE experts (2018)	Conv	2,7	kg feed/kg live weight
		Diff	2,7	kg feed/kg live weight
		Org	3,3	kg feed/kg live weight
Milk	For Farmers (n.d.)	Conv	1,1	kg feed (DM)/kg edible product
		Diff	1,5	kg feed (DM)/kg edible product
		Org	1,7	kg feed (DM)/kg edible product
Beef	Based on Buron et al. (2018); Hubrecht et al. (2013) ; Rabeux & Elias (2015)	Conv	6,2	kg feed (DM)/kg live weight
		Diff	6,5	kg feed (DM)/kg live weight
		Org	7,5	kg feed (DM)/kg live weight
Cheese	For Farmers (n.d.)	Conv	11,0	kg feed (DM)/kg edible product
		Diff	15,0	kg feed (DM)/kg edible product
		Org	17,0	kg feed (DM)/kg edible product
Butter	For Farmers (n.d.)	Conv	22,0	kg feed (DM)/kg edible product
		Diff	30,0	kg feed (DM)/kg edible product
		Org	34,0	kg feed (DM)/kg edible product
VG[1]	Lindenthal et al. (2018) ; WWF Austria (2018)	Conv	0,4	kg feed/kg edible product
		Diff	0,4	kg feed/kg edible product
		Org	0,4	kg feed/kg edible product

Notes:

- Conv = Conventional; Diff = Differentiated; Org = Organic.
- Products highlighted in grey do no not include the feed consumption by non-productive animals. It is however included in non-highlighted values.
- Values for cheese and butter are directly related to those of milk given that it is considered that 1kg cheese corresponds to 10L milk and 1kg butter corresponds to 20L milk.
- [1] The reference plant-based (VG) product considered here is tofu.

Generic FCR values – per country of origin

Table 17. Generic FCR values per country of origin for different product categories (continued on next page).

Product	Country	Source	FCR	Unit
Broiler	Belgium	ITAVI (2015) & Pers. Comm. with BE experts (2018)	1,70	kg feed/kg live weight
	Austria	Hou et al. (2016)	2,18	kg feed (DM)/kg carcass weight
	France	ITAVI (2015)	1,70	kg feed/kg live weight
	Estonia	Pers. Comm. with ET expert (2021)	1,52	kg feed/kg live weight
	Sweden	Moberg et al. (2019)	3,00	kg feed/kg carcass weight
	Finland	WWF Finland (2016)	3,00	kg feed/kg edible product
Eggs	Belgium	Wageningen UR (2013) & Pers. Comm. with BE experts (2018)	2,00	kg feed/kg edible product
	Austria	Hou et al. (2016)	2,50	kg feed (DM)/kg edible product
	France	ITAVI (2015)	2,17	kg feed/kg edible product
	Estonia	Hou et al. (2016)	2,30	kg feed (DM)/kg edible product
	Sweden	Röös et al. (2014)	2,60	kg feed/kg edible product
	Finland	WWF Finland (2016)	2,10	kg feed/kg edible product
Pork	Belgium	Nguyen et al. (2010) & Pers. Comm. with BE experts (2018)	2,70	kg feed/kg live weight
	Austria	Winkler et al. (2016)	4,00	kg feed/kg carcass weight
	France	IFIP (2016)	2,51	kg feed/kg live weight
	Estonia	Pers. Comm. with ET expert (2021)	2,60	kg feed/kg live weight
	Sweden	Moberg et al. (2019)	4,20	kg feed/kg carcass weight
	Finland	Hou et al. (2016)	3,20	kg feed (DM)/kg live weight
Milk	Belgium	For Farmers (n.d.)	1,10	kg feed (DM)/kg edible product
	Austria	FAO et al. (2014)	1,00	kg feed (DM)/kg edible product
	France	IDELE et al. (2019)	0,80	kg feed (DM)/kg edible product
	Estonia	Hou et al. (2016)	1,00	kg feed (DM)/kg edible product
	Sweden	Sasu-Boakye et al. (2014)	0,72	kg feed (DM)/kg edible product
	Finland	WWF Finland (2016)	1,30	kg feed (DM)/kg edible product
Beef	Belgium	Based on Buron et al. (2018); Hubrecht et al. (2013) ; Rabeux & Elias (2015)	6,20	kg feed (DM)/kg live weight
	Austria	Ertl et al. (2016)	11,54	kg feed (DM)/kg carcass weight
	France [1]	Based on Buron et al. (2018); Hubrecht et al. (2013) ; Rabeux & Elias (2015)	6,20	kg feed (DM)/kg live weight
	Estonia [2]	Mogensen et al. (2015)	6,15	kg feed (DM)/kg live weight
	Sweden	Mogensen et al. (2015)	6,15	kg feed (DM)/kg live weight
	Finland	WWF Finland (2016)	12,50	kg feed (DM)/kg edible product
Cheese	Belgium	For Farmers (n.d.)	11,00	kg feed (DM)/kg edible product
	Austria	FAO et al. (2014)	10,00	kg feed (DM)/kg edible product
	France	IDELE et al. (2019)	8,00	kg feed (DM)/kg edible product
	Estonia	Hou et al. (2016)	10,00	kg feed (DM)/kg edible product
	Sweden	Sasu-Boakye et al. (2014)	7,20	kg feed (DM)/kg edible product

	Finland	WWF Finland (2016)	13,00	kg feed (DM)/kg edible product
Butter	Belgium	For Farmers (n.d.)	22,00	kg feed (DM)/kg edible product
	Austria	FAO et al. (2014)	20,00	kg feed (DM)/kg edible product
	France	IDELE et al. (2019)	16,00	kg feed (DM)/kg edible product
	Estonia	Hou et al. (2016)	20,00	kg feed (DM)/kg edible product
	Sweden	Sasu-Boakye et al. (2014)	14,20	kg feed (DM)/kg edible product
	Finland	WWF Finland (2016)	26,00	kg feed (DM)/kg edible product
VG[3]	General	Lindenthal et al. (2018) ; WWF Austria (2018)	0,40	kg feed/kg edible product

Notes:

- Products highlighted in grey do no not include the feed consumption by non-productive animals. It is however included in non-highlighted values.
- Values for cheese and butter are directly related to those of milk given that it is considered that 1kg cheese corresponds to 10L milk and 1kg butter corresponds to 20L milk.
- [1] No data was found for French beef. Hence the same value as for Belgium was used.
- [2] No data was found for Estonian beef. Hence the same value as for Sweden was used.
- [3] The reference plant-based (VG) product considered here is tofu.

Feed composition

Generic feed composition values – per production system

Table 18. Generic feed composition data per production system for different product categories (continued on next page).

Product	Category	Source	Grazed grass	Grass silage/ hay	Maize silage	Other forage	Cereals Total [1]	Olea-/proteaginous	Soy-bean meal	Sun-flower meal	Rape-seed meal	Sugar-beet	Others (vit...)
Broiler	Conv	BE Feed company (2018)					65%	7%	20%				8%
	Diff	BE Feed company (2018)					70%	5%	20%				5%
	Org	BE Feed company (2018)					65%	4%	26%				5%
Eggs	Conv	BE Feed company (2018)					68%		20%				12%
	Diff	BE Feed company (2018)					66%		15%	8%			11%
	Org	BE Feed company (2018)					66%		15%	8%			11%
Pork	Conv	BE Feed company (2018)					65%	12%	13%				10%
	Diff	BE Feed company (2018)					65%	18%	12%				5%
	Org	BE Feed company (2018)					67%	15%	14%				4%
Milk	Conv	Boonen et al. (2015)		27%	38%	5%	10%		9%			9%	2%
	Diff	Boonen et al. (2015)	36%	26%	17%	2%	6%		6%			6%	1%
	Org	Faux et al. (2019)	42%	41%			14%	3%					
Beef	Conv	CELAGRI (2020)	49%	29%	7%		7%		3%			5%	
	Diff	Faux et al. (2019)	37%	31%			20%	6%				6%	
	Org	Faux et al. (2019)	37%	31%			20%	6%				6%	
Cheese	Conv	Boonen et al. (2015)		27%	38%	5%	10%		9%			9%	2%
	Diff	Boonen et al. (2015)	36%	26%	17%	2%	6%		6%			6%	1%
	Org	Faux et al. (2019)	42%	41%			14%	3%					

Butter	Conv	Boonen et al. (2015)		27%	38%	5%	10%		9%			9%	2%
	Diff	Boonen et al. (2015)	36%	26%	17%	2%	6%		6%			6%	1%
	Org	Faux et al. (2019)	42%	41%			14%	3%					
VG [2]	Conv	Lindenthal et al. (2018)							100%				
	Diff	Lindenthal et al. (2018)							100%				
	Org	Lindenthal et al. (2018)							100%				

Notes:

- Conv = Conventional; Diff = Differentiated; Org = Organic.
- Products highlighted in grey are expressed in humid weight terms. Non-highlighted values are expressed in dry weight terms.
- Values for cheese and butter are directly related to those of milk given that it is considered that 1kg cheese corresponds to 10L milk and 1kg butter corresponds to 20L milk.
- [1] Only the total share of cereals is presented here. This category is made up of wheat, maize and barley.
- [2] The reference plant-based (VG) product considered here is tofu.

Generic feed composition values – per country of origin

Table 19. Generic feed composition data per country of origin for different product categories (continued on next page).

Product	Country	Source	Grazed grass	Grass silage/ hay	Maize silage	Other forage	Cereals Total [1]	Olea- /protea ginous	Soy- bean meal	Sun- flower meal	Rape- seed meal	Sugar- beet	Others (vit…)
Broiler	Belgium	BE Feed company (2018)					65%	7%	20%	0%	0%	0%	8%
	Austria*	Koch & Salou (2020)					68%	3%	22%		3%		3%
	France	Koch & Salou (2020)					68%	3%	22%		3%		3%
	Estonia	Pers. Comm. with ET expert (2021)					73%		19%				8%
	Sweden	Moberg et al. (2019)					77%	2%	15%		2%		4%
	Finland	WWF Finland (2016)					60%		30%		5%		5%
Eggs	Belgium	BE Feed company (2018)					68%	0%	20%	0%	0%	0%	12%
	Austria*	Koch & Salou (2020)					63%	2%	20%	1%	2%		11%
	France	Koch & Salou (2020)					63%	2%	20%	1%	2%		11%
	Estonia*	Moberg et al. (2019)					65%	5%	13%		6%		11%
	Sweden	Moberg et al. (2019)					65%	5%	13%		6%		11%
	Finland	WWF Finland (2016)					75%		15%				10%
Pork	Belgium	BE Feed company (2018)					65%	12%	13%	0%	0%	0%	10%
	Austria	Winkler et al. (2016)					76%		7%	4%	4%		10%
	France*	Winkler et al. (2016)					76%		7%	4%	4%		10%
	Estonia	Pers. Comm. with ET expert (2021)					75%		5%	5%	5%		10%
	Sweden	Moberg et al. (2019)					94%		4%		1%		1%
	Finland	WWF Finland (2016)					80%		20%				
Milk	Belgium	CELAGRI (2020)	36%	26%	10%	2%	9%		9%			7%	1%
	Austria	FAO et al. (2014)		59%	19%		16%		1%	2%	1%	1%	1%
	France	FAO et al. (2014)	13%	15%	45%	3%	8%		9%	2%	3%	1%	1%

	Estonia*	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Sweden	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Finland	WWF Finland (2016)	6%	49%			16%		13%		13%		3%
Beef	Belgium	CELAGRI (2020)	49%	29%	7%		7%		3%			5%	
	Austria*	CELAGRI (2020)	49%	29%	7%		7%		3%			5%	
	France*	CELAGRI (2020)	49%	29%	7%		7%		3%			5%	
	Estonia*	Mogensen et al. (2015)		50%			46%		2%			2%	
	Sweden	Mogensen et al. (2015)		50%			46%		2%			2%	
	Finland	WWF Finland (2016)		60%			40%						
Cheese	Belgium	CELAGRI (2020)	36%	26%	10%	2%	9%		9%			7%	1%
	Austria	FAO et al. (2014)		59%	19%		16%		1%	2%	1%	1%	1%
	France	FAO et al. (2014)	13%	15%	45%	3%	8%		9%	2%	3%	1%	1%
	Estonia*	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Sweden	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Finland	WWF Finland (2016)	6%	49%			16%		13%		13%		3%
Butter	Belgium	CELAGRI (2020)	36%	26%	10%	2%	9%		9%			7%	1%
	Austria	FAO et al. (2014)		59%	19%		16%		1%	2%	1%	1%	1%
	France	FAO et al. (2014)	13%	15%	45%	3%	8%		9%	2%	3%	1%	1%
	Estonia*	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Sweden	Sasu-Boakye et al. (2014)		52%			25%		6%		7%	8%	2%
	Finland	WWF Finland (2016)	6%	49%			16%		13%		13%		3%
VG[2]	General	Lindenthal et al. (2018)							100%				

Notes:

- Products highlighted in grey are expressed in humid weight terms. Non-highlighted values are expressed in dry weight terms.
- Values for cheese and butter are directly related to those of milk given that it is considered that 1kg cheese corresponds to 10L milk and 1kg butter corresponds to 20L milk.
- No data was found for products marked with an asterisk (*). Hence the values of other countries were used (see matching references to identify the countries used as proxies).
- [1] Only the total share of cereals is presented here. This category is made up of wheat, maize and barley.
- [2] The reference plant-based (VG) product considered here is tofu.

Slaughter and carcass yields

Table 20. Slaughter and carcass yields per country of origin for different meat products

Product	Country	Source	Slaughter yield (kg carcass/kg live weight)	Carcass yield (kg meat/kg carcass)	Total losses (kg meat/kg live weight)
Broiler	Belgium	Riera et al. (2019)	72%	72%	52%
	Austria	Ertl et al. (2016)	72%	68%	49%
	France	Riera et al. (2019)	72%	72%	52%
	Estonia	Riera et al. (2019)	72%	72%	52%
	Sweden	Cederberg et al. (2009)	70%	72%	50%
	Finland	WWF Finland (2016)	72%	80%	58%
Pork	Belgium	ERM & UGent (2011)	79%	80%	63%
	Austria	Winkler et al. (2016)	78%	80%	62%
	France	Chambres d'Agriculture (2013)	79%	81%	64%
	Estoni*a	ERM & UGent (2011)	79%	80%	63%
	Sweden	Zira et al. (2021)	59%	59%	35%
	Finland*	ERM & UGent (2011)	79%	80%	63%
Beef	Belgium	ERM & UGent (2011)	67%	81%	54%
	Austria	Ertl et al. (2016)	67%	76%	51%
	France	IDELE & CNE (2019)	54%	68%	37%
	Estonia*	Clune et al. (2017); Mogensen et al. (2015)	50%	70%	35%
	Sweden	Clune et al. (2017); Mogensen et al. (2015)	50%	70%	35%
	Finland*	Clune et al. (2017); Mogensen et al. (2015)	50%	70%	35%

Notes:

- No data was found for products marked with an asterisk (*). Hence the values of another country were used (see matching references to identify the countries used as proxies).

Appendix 2 – Country-specific results

Austria

Table 21. Total pesticides use (g a.i./kg edible product) associated with different animal products in Austria.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**1,60* / 0,80****
Austria conventional	1,60
Austrian organic	0,00
Broiler	**2,12* / 1,06****
Austria conventional	2,12
Austria organic	0,00
Butter	**2,93* / 1,47****
Austria conventional	2,93
Austria organic	0,00
Cheese	**1,47* / 0,73****
Cream cheese (cow) - Austria	1,47
Cream cheese (cow) – Austria Organic	0,00
Gouda cheese (cow) - Austria	1,47
Gouda cheese (cow) – Austria Organic	0,00
Mozzarella (cow) - Austria	1,47
Mozzarella (cow) – Austria Organic	0,00
Eggs	**0,00**
Austria organic	0,00
Pork	**1,58* / 0,79****
Austria conventional	1,58
Austrian organic	0,00
Country-average	**1,80* / 0,84****

Note: * Average values without organic products / ** Average values with organic products.

Belgium

Table 22. Total pesticides use (g a.i./kg edible product) associated with different animal products in Belgium.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**1,74* / 1,39****
Belgium conventional	1,42
Belgium Bleu-Blanc-Cœur	1,49
Belgium Dairy end-of-life meat	2,48
Belgium organic	0,00
Belgium pasture (grass fed)	1,58
Broiler	**2,76* / 1,84****
Belgium	2,39
Belgium organic	0,00
Belgium Poulet Fermier	3,13
Cheese	**1,14**
Hard cheese (cow) - Belgium	1,14
Eggs	**1,41* / 1,06****
Belgium barn eggs (2)	1,47
Belgium cage (3)	1,36
Belgium free range (1)	1,40
Belgium organic (0)	0,00
Milk	**0,32* / 0,22****
Cow milk - Belgium	0,34
Cow milk - Belgium lait de foin/ weidenmelk	0,31
Cow milk - Belgium organic	0,00
Pork	**2,55* / 1,70****
Belgium	2,56
Belgium organic	0,00
Beter voor iedereen/ Mieux pour tous (Bleu-Blanc-Cœur)	2,55
Country average	**1,69* / 1,24****

Note: * Average values without organic products / ** Average values with organic products.

Estonia

Table 23. Total pesticides use (g a.i./kg edible product) associated with different animal products in Estonia.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**0,00**
Estonian state certified grassland beef (+ EU organic)	0,00
Broiler	**1,85**
Estonia conventional	1,85
Pork	**1,34**
Estonia conventional	1,34
Country average	**1,60* / 1,07****

Note: * Average values without organic products / ** Average values with organic products.

Finland

Table 24. Total pesticides use (g a.i./kg edible product) associated with different animal products in Finland.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**1,30**
Finland conventional	1,30
Broiler	**2,46**
Finland conventional	2,46
Cheese	**5,80**
Hard cheese (cow) – Finland conventional	5,80
Eggs	**1,06**
Finland conventional	1,06
Pork	**3,70**
Finland conventional	3,70
Country average	**2,87**

Note: * Average values without organic products / ** Average values with organic products.

France

Table 25. Total pesticides use (g a.i./kg edible product) associated with different animal products in France.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**0,00**
French organic beef	0,00
French organic beef	0,00
Broiler	**3,13* / 2,34****
France conventional	2,47
France BBC (Bleu Blanc Coeur)	2,94
France organic	0,00
France Label Rouge	3,97
Eggs	**1,50* / 1,25****
France conventional	1,50
France cage	1,50
France floor	1,38
France Label Rouge	1,49
France organic	0,00
France outdoor	1,65
Milk	**0,43* / 0,11****
Cow milk - France	0,43
Cow milk – France organic	0,00
Goat milk – France organic	0,00
Sheep milk – France organic	0,00
Pork	**2,88*/ 2,16****
France conventional	2,62
France BBC (Bleu Blanc Coeur)	2,90
France Label Rouge	3,12
France organic	0,00
Country average	**2,16* / 1,30****

Note: * Average values without organic products / ** Average values with organic products.

Sweden

Table 26. Total pesticides use (g a.i./kg edible product) associated with different animal products in Sweden.

Products	TOTAL PPP use (g a.i./kg edible product)
Beef	**1,05* / 0,70****
Sweden conventional	1,72
Swedish certified natural pasture	0,38
Swedish organic and KRAV	0,00
Broiler	**1,68* / 1,26****
Sweden conventional	1,68
Swedish organic and KRAV	0,00
Swedish climate certified	1,68
Swedish Sigill certified	1,68
Cheese	**2,40* / 0,80****
Halloumi (cow) – Swedish organic	0,00
Hard cheese (cow) – Sweden conventional	2,40
Hard cheese (cow) – Swedish organic	0,00
Eggs	**0,93* / 0,46****
Sweden conventional	0,93
Swedish organic and KRAV	0,00
Pork	**1,30* / 0,97****
Sweden conventional	1,55
Swedish organic and KRAV	0,00
Swedish climate certified	1,17
Swedish Sigill certified	1,17
Country average	**1,44* / 0,90****

Note: * Average values without organic products / ** Average values with organic products.

Appendix 3 – Product-specific results

Beef

Table 27. Total pesticides use (g a.i./kg edible product) associated with beef in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Austria	**1,60* / 0,80****
Austria conventional	1,60
Austrian Organic	0,00
Belgium	**1,74* / 1,39****
Belgium conventional	1,42
Belgium Bleu-Blanc-Cœur	1,49
Belgium Dairy end-of-life meat	2,48
Belgium organic	0,00
Belgium pasture (grass fed)	1,58
Estonia	**0,00**
Estonian state certified grassland beef (at the same time EU organic)	0,00
Finland	**1,30**
Finland conventional	1,30
France	**0,00****
French organic beef	0,00
French organic veal	0,00
Sweden	**1,05* / 0,70****
Sweden conventional	1,72
Swedish certified natural pasture	0,38
Swedish organic and KRAV	0,00
Product average	**1,50* / 0,86****

Note: * Average values without organic products / ** Average values with organic products.

Broiler

Table 28. Total pesticides use (g a.i./kg edible product) associated with broiler in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Austria	**2,12* / 1,06****
Austria conventional	2,12
Austrian Organic	0,00
Belgium	**2,76* / 1,84****
Belgium conventional	2,39
Belgium organic	0,00
Belgium Poulet fermier	3,13
Estonia	**1,85**
Estonian conventional	1,85
Finland	**2,46**
Finland conventional	2,46
France	**3,13* / 2,34****
French conventional	2,47
France BBC (Bleu Blanc Cœur)	2,94
France organic	0,00
French Label Rouge	3,97
Sweden	**1,68* / 1,26****
Sweden conventional	1,68
Swedish organic and KRAV	0,00
Sweden climate certified	1,68
Swedish Sigill certified	1,68
Product average	**2,40* / 1,76****

Note: * Average values without organic products / ** Average values with organic products.

Butter & Cheese

Table 29. Total pesticides use (g a.i./kg edible product) associated with butter and cheese in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Butter - Austria	**2,93* / 1,47****
Austrian conventional	2,93
Austrian organic	0,00
Cheese - Austria	**1,47* / 0,73****
Cream cheese (cow) – Austria conventional	1,47
Cream cheese (cow) – Austria organic	0,00
Gouda cheese (cow) – Austria conventional	1,47
Gouda cheese (cow) – Austria organic	0,00
Mozzarella (cow) – Austria conventional	1,47
Mozzarella (cow) – Austria organic	0,00
Cheese - Belgium	**1,14**
Hard cheese (cow) - Belgium	1,14
Cheese - Finland	**5,80**
Hard cheese (cow) - Finland	5,80
Cheese - Sweden	**2,40* / 0,80****
Halloumi (cow) – Swedish organic	0,00
Hard cheese (cow) - conventional	2,40
Hard cheese (cow) - organic	0,00
Product average	**2,38* / 1,28****

Note: * Average values without organic products / ** Average values with organic products.

Eggs

Table 30. Total pesticides use (g a.i./kg edible product) associated with eggs in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Austria	**0,00**
Austrian organic	0,00
Belgium	**1,41* / 1,06****
Belgium barn eggs (2)	1,47
Belgium cage (3)	1,36
Belgium free range (1)	1,40
Belgium organic (0)	0,00
Finland	**1,06**
Finland conventional	1,06
France	**1,50* / 1,25****
France	1,50
France cage	1,50
France floor	1,38
France Label Rouge	1,49
France organic	0,00
France outdoor	1,65
Sweden	**0,93* / 0,46****
Sweden	0,93
Swedish organic and KRAV	0,00
Product average	**1,37* / 0,98****

Note: * Average values without organic products / ** Average values with organic products.

Milk

Table 31. Total pesticides use (g a.i./kg edible product) associated with milk in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Belgium	**0,32* / 0,22****
Cow milk - Belgium	0,34
Cow milk - Belgium lait de foin/ weidenmelk	0,31
Cow milk - Belgium organic	0,00
France	**0,43* / 0,11 ****
Cow milk – France	0,43
Cow milk - France organic	0,00
Goat milk - France organic	0,00
Sheep milk - France organic	0,00
Product average	**0,36* / 0,15****

Note: * Average values without organic products / ** Average values with organic products.

Plant-based (VG)

Table 32. Total pesticides use (g a.i./kg edible product) associated with plant-based products.

Country and products	PPP TOTAL (g a.i./kg edible product)
Plant-based	**0,35* / 0,15****
Chickpeas organic	0,00
Härkis (Finnish product, based on fava bean)	0,59
Legumes conventional	0,34
Legumes organic	0,00
Seitan	0,35
Seitan organic	0,00
Soy products organic	0,00
Soybeans	0,35
Soybeans organic	0,00
Tofu/Soy/Tempeh organic	0,00
Tofu/Tempeh (soy)	0,14
Wheat based products organic	0,00
Product average	**0,35* / 0,15****

Note: * Average values without organic products / ** Average values with organic products.

Pork

Table 33. Total pesticides use (g a.i./kg edible product) associated with pork in different countries.

Country and products	PPP TOTAL (g a.i./kg edible product)
Austria	**1,58* / 0,79****
Austria conventional	1,58
Austrian Organic	0,00
Belgium	**2,56* / 1,70****
Belgium conventional	2,56
Belgium organic	0,00
Belgium Beter voor iedereen/Mieux pour tous (Bleu Blanc Coeur)	2,55
Estonia	**1,34**
Estonian conventional	1,34
Finland	**3,70**
Finland conventional	3,70
France	**2,88* / 2,16****
French conventional	2,62
France BBC (Bleu Blanc Cœur)	2,90
France Label Rouge	3,12
French organic	0,00
Sweden	**1,30* / 0,97****
Sweden conventional	1,55
Swedish organic and KRAV	0,00
Sweden climate certified	1,17
Swedish Sigill certified	1,17
Product average	**2,21* / 1,62****

Note: * Average values without organic products / ** Average values with organic products.