A study on the use of chemical pesticides for WWF's meat guides: Complementary study for WWF Sweden

Final report – November 2021

Sytra – UCLouvain

Antoine de Clippele

Anton Riera

Philippe Baret

CO-FUNDED BY THE EUROPEAN UNION

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of WWF and other Eat4Change project partners and do not necessarily reflect the views of the European Union.

About the authors

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

Funding

The research was carried out on behalf of WWF Sweden as a follow up to a previous study developed within the context of the EU funded project *Eat4Change*. This deliverable is also aimed to feed into that project.

CO-FUNDED BY THE EUROPEAN UNION

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of WWF and other Eat4Change project partners and do not necessarily reflect the views of the European Union.

Table of contents

Chapter 1. Introduction 5
1.1. Context of the study 5
1.2. Scope of the complementary study 5
1.3. Content of the report 5

Chapter 2. Reminder of methodological steps 7
2.1. Choice of the indicator and unit of measurement 7
2.2. General principle 7
2.3. Calculation steps 7

Chapter 3. Data collection 9
3.1. Scope of assessment 9
3.2. Data sources 10
3.3. Specific vs. generic data 10
3.4. Collected data – Feeding practices 11
3.4.1. Main assumptions 11
3.4.2. Allocation and consideration of non-productive animals in the beef sector 11
3.4.3. Certified production systems 11
3.5. Collected data – Pesticides use of feed crops 14
3.5.1. Available data in Eurostat 14
3.5.2. The case of non-European countries 14
3.5.3. Assumptions and values used for the calculations 15
3.5.4. The case of soybean 15
3.6. Status of assessment 17

Chapter 4. Calculation tool 19
4.1. General functioning 19
4.2. Updates for complementary study 20

Chapter 5. Results 21
5.1. Beef 21
5.2. Broiler 22
5.3. Cheese 24
5.4. Eggs 25
5.5. Lamb 26
5.6. Plant-based products 27
5.7. Pork 29

Bibliography 31

Appendix 1 – Methodology 37
Necessary inputs – Feeding practices 37
Input 1 - Feed conversion ratio (FCR) 37
Input 2 - Feed compositions 38
Input 3 - Slaughter and carcass yields 40
Necessary inputs - Pesticides use of feed crops 41
Input 4 – Total pesticides use of feed crops 41
Input 5 – Areas of feed crops 41

Input 6 – Yields of feed crops 41
Differentiation of data 41
Pesticides use of feed crops 41
Feeding practices 42
Appendix 2 – Input data for feeding practices and pesticides uses 43
Feed conversion ratios 43
Feed consumption of non-productive animals 43
Feed conversion ratios used in the calculations 44
Feed composition 49
Slaughter and carcass yields 53
Pesticides uses of feed ingredients 55

Chapter 1. Introduction

1.1. Context of the study

During the first semester of 2021, a report entitled *A study on the use of chemical pesticides for WWF's meat guides: Methodological and data update* was produced (Riera et al., 2021). The research was carried out on behalf of several WWF European offices and in the context of the EU funded project *Eat4Change* and the Swedish PostCode funded project *One Planet Food*.

Following this initial study and in the context of the re-launch of the updated Swedish Meat Guide, WWF Sweden expressed its interest for a complementary study focusing on a number of additional animal and plant-based products.

1.2. Scope of the complementary study

WWF Sweden provided a list of 87 products which had to be included in the updated Swedish Meat Guide. About half of these products had already been assessed in the first study. The other half were assessed through this complementary study. Additionally, some products which were assessed during the first study were updated in the light of new data collected by WWF Sweden.

Three main tasks were performed:

- **Data update:** Already assessed Swedish products were updated with the new data collected by WWF Sweden.
- **Data collection:** Input data for the 41 new products to assess was collected, including data from new countries of origin not included in the initial assessment (such as Germany, Poland, New Zealand, Brazil, etc.);
- **Calculations and update of the calculation tool:** The calculation tool was updated to account for the new countries of origin;

1.3. Content of the report

This report presents the results regarding the use of chemical pesticides for the additional products which had to be assessed. The following sections are organised as follows:

- Chapter 2 provides a reminder of the methodological steps involved in the calculations;
- describes the data collection for the additional products (sources, scope, calculation hypotheses);
- Chapter 4 presents the calculation tool which was developed and the updates which were performed for this complementary assessment;
- Chapter 5 provides the results, presented per product category;

Chapter 2. Reminder of methodological steps

This chapter provides a reminder of the methodological steps which are necessary to assess the use of chemical pesticides associated with animal products. It is a shortened version of Chapter 2 in the initial report (Riera et al., 2021). More detailed information regarding the necessary inputs is provided in Appendix 1.

2.1. Choice of the indicator and unit of measurement

The indicator used in the context of this study to reflect the level of pesticides (or plant protection products; PPPs) use of a particular product are the amounts of pesticide 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.

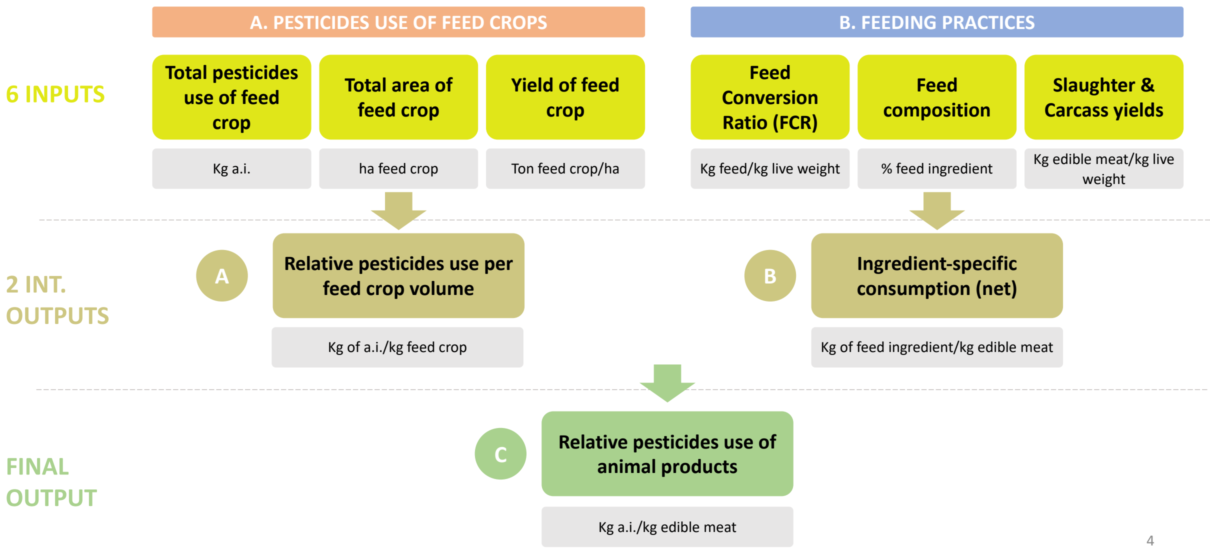

Figure 1. Necessary inputs and calculation steps to assess the relative pesticides use of livestock products.
Note: The calculations should also account for the dry matter contents and transformation yields of different feed ingredients (e.g., amount of raw soy needed per kg of soybean meal).

Chapter 3. Data collection

3.1. Scope of assessment

As noted in point 1.2, this study is based on an initial assessment realised in June 2021. The purpose of this follow-up study was to evaluate 87 animal and plant-based products, of which 41 were not previously evaluated in the original study. In addition, some of the previously evaluated products were updated in the light of new data.

The products range over 20 countries of origin and 8 product categories (Table 1).

Table 1. Countries of origin and product categories included in the list of products to be assessed in the additional study.

20 countries in the list	8 product categories
Belgium (1)	Beef (14)
Brazil (1)	Broiler (15)
Cyprus (2)	Cheese (21)
Denmark (5)	Eggs (8)
EU (8)	Game (1)
Finland (3)	Lamb (9)
France (4)	Plant-based (5)
General (5)	Pork (14)
Germany (5)	-
Greece (3)	-
Ireland (2)	-
Italy (1)	-
Netherlands (4)	-
New Zealand (1)	-
Poland (4)	-
South-America (1)	-
Spain (1)	-
Sweden (34)	-
Thailand (1)	-
USA (1)	-
TOTAL: 87	TOTAL: 87

Notes: Numbers in parentheses refer to the number of products included in each country or product category.

3.2. Data sources

In order to assess the use of pesticides associated with livestock products, a data collection process was necessary to characterise these products with regards to the 6 inputs listed in Figure 1 and in accordance with the defined differentiation level specified in Appendix 1 – Methodology.

This data collection process relied on four data sources:

- **EU-level databases:**
    - Eurostat was the main database which was consulted. It provided the necessary inputs to assess the pesticides use of feed crops for the European countries of interest (Eurostat, 2021b).
- **Non- EU databases:**
    - For the United States of America (USA), a national database on pesticides was used: USGS NAWQA - Pesticide national Synthesis Project (Wieben, 2020).
- **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 from non-European countries.
    - For the inputs related to feeding practices, scientific and grey literature (technical reports) constituted the main data source.
- **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.

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 Appendix 1 – Methodology).

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

3.4.1. Main assumptions

The specific data and calculation inputs related to feeding practices are presented in Appendix 2 – Input data for feeding practices :

- Table 16 presents the feed consumption of non-productive animals;
- Table 17 presents FCR values for the assessed products;
- Table 18 presents feed compositions per product;
- Table 19 presents slaughter and carcass yields.

As much as possible, the calculations were directly based on the feeding practices found in the literature or advised by experts. For many products, the core data was sufficient. However, for some products, it was necessary to make additional assumptions as the original data needed some fine-tuning. These additional assumptions are summarised in Table 2.

3.4.2. Allocation and consideration of non-productive animals in the beef sector

For the production of beef, only the feed consumed by the productive animal was considered (with the exception of USA beef). This implies that the calculations do not include the whole beef system. Rather, only the meat and feed rations of the most representative animal categories in the system, according to data from Moberg et al. (2019), were considered: young bulls in Sweden, bullocks in Ireland and bulls in Germany and Poland.

It was chosen not to include all the animals in the system because this required to estimate and allocate the impacts of suckler and dairy cows, which was not straightforward with the available data: feed rations were provided per year for cows and over the entire lifetime for all other animal categories. Accounting for all animals in the system involved too many assumptions and uncertainties, leading to a general lack of transparency of the calculations. Additionally, as the impacts of suckler cows are distributed over their entire lifecycle and those of dairy cows are mainly allocated to the production of milk, it is likely that including all animals in the system would not significantly change the results.

3.4.3. Certified production systems

Several Swedish products were certified under the *Svenskt Sigill* certification. While no study could be found to define the exact impact of the certifications on the feeding practices or the use of pesticides, assumptions were made to estimate their impact in the calculations, based on the certification rules and exchanges with the certification body (pers. comm., 2021). The main rules for each product category are summarised in Box 1.

Table 2. Presentation of the additional assumptions made in the calculation of some feed rations.

Product	Country	Certification	Calculation hypotheses	Main reference
Beef	Germany	Conventional	Feed ration was based on *bulls* production system	Moberg et al., (2019)
	Ireland	Conventional	Feed ration was based on *bullocks* production system	Moberg et al., (2019)
	Sweden	Indoor	Feed ration was based on *dairy young bulls* production system	Moberg et al., (2019)
	Sweden	Animals on some pasture	Feed ration was based on *suckler young bulls* production system	Moberg et al., (2019), Sigill (Pers. Comm. (2021))
	Sweden	*Svenskt Sigill Klimatcertifierad*	Same diet as 'Animals on some pasture'. Soybean meal in the ration is considered to be imported from the USA.	Moberg et al., (2019), Sigill (Pers. Comm. (2021))
Broiler	Germany	Conventional	Based on average European feeding practices	van Grinsven et al., (2019)
	Netherlands	Conventional	Based on average European feeding practices	van Grinsven et al., (2019)
	Poland	Conventional	Based on average European feeding practices	van Grinsven et al., (2019)
Cheese	All	All[1]	Input of 10 kg of milk for 1 kg of hard cheese and 6.5 kg of milk for soft and semi-hard cheese	Moberg et al., (2019)
	France	Chèvre	Input of 5L of goat milk for 1 kg of cheese	IDELE, (2015)
	Italy	Mozzarella	Input of 8L of milks or 1 kg of mozzarella	Palmieri et al., (2017)
	Sweden	*Svenskt Sigill Klimatcertifierad*	Soybean meal in the ration is considered to be imported from the USA.	Moberg et al., (2019), Sigill (Pers. Comm. (2021))
Lamb	Sweden	Conventional	A range of results is provided. A low-end estimate is based on data which does include pasture. A high-end estimate is based on the assumption that the area of pasture available for animals is entirely treated with pesticides.	Wallman et al., (2011)
Pork	Poland	Conventional	Based on European average feeding practices.	van Grinsven et al., (2019)
	Sweden	Svenskt Sigill Klimatcertifierad	Derived from conventional ration with the part of soybean meal in the ration limited at 5%.	Zira et al., (2021), Sigill (Pers. Comm. (2021))
Plant-based	EU	Mycoprotein	Feed composition of 100% wheat.	Quorn, (2018)

Note: [1] This does not apply to the following products: Mozzarella (Italy) and Chèvre (France).

Box 1. Feeding practices regarding the Swedish certifications of *Sigill*

Svenskt Sigill owns three certifications: *Svenskt Sigill* is the base-level certification. Additionally, *Svenskt Sigill Naturbeteskött* and *Svenskt Sigill Klimatcertifierad* have additional rules, respectively targeted towards natural pasture management and climate.

Specific rules for each certification are detailed in Table 3. This list is not exhaustive as only the rules which have a direct impact on the feeding practices, and thus the use of pesticides, are described. In addition, some rules from the base-level certification (*Svenskt Sigill*) apply across all animal productions:

- At least 70% of the feed must be grown in Sweden;
- At least 30% of the feed must be *Sigill*-certified;
- Soy and palm oil feed must be certified according to RTRS, RSPO or similar.

Table 3. Sigill certification rules related to the feeding practices (Helena Allard, pers. comm., 2021)

Product	Certification	Measures related to the feeding practices
Dairy	*Svenskt Sigill*	At least 50% (DM) of pasture or roughage in the ration.
		On farms with certified milk production, the use of plant protection products on pasture or on ley that are intended for cattle used for milk production are not allowed. Exception at tillage of grassland.
	Svenskt Sigill Klimatcertifierad	No soy from deforested areas (e.g. Brazil).
		At least 70% of grass or roughage in the ration during the year for heifers and 50% for lactating cows.
		At least 60 % of the feed, on an annual basis, shall be produced on the farm or in collaboration with nearby farms. Continuous improvements should be made in order to reach 70%.
Beef	*Svenskt Sigill*	At least 50 % of the feed must consist of roughage.
	Svenskt Sigill Klimatcertifierad	At least 70% of the feed, on an annual basis, shall be produced on the farm or in collaboration with nearby farms.
		70 % of the feed ration must consist of roughage for heifers and steers. 65 % of the feed ration must consist of roughage for bulls.
		No soy from deforested areas (e.g. Brazil).
	Svenskt Sigill Naturbeteskött	Cattle weighing over 250 kg shall be fed with at least 70% (DM) roughage / grazing in the total feeding ration, calculated per barn period and grazing season respectively.
Lamb	*Svenskt Sigill*	At least 50% of the feed for all animals must consist of roughage.
		All lambs must be on pasture at least one month of their life. In practice, all lambs graze during the entire summer (3-4 months at least), do not eat any cereals and are then slaughtered in the autumn. All ewes are on pasture as well during the summer and only eat grass during that period.
	Svenskt Sigill Klimatcertifierad	At least 70% of the feed for the ewes must come from pasture or roughage and 50% for the lambs.
		At least 70% of the feed, on an annual basis, shall be produced on the farm or in collaboration with nearby farms.
		No soy from deforested areas (e.g. Brazil).

	Svenskt Sigill Naturbeteskött	More than half of the grazed pastures must be natural pastures (i.e. pastures which are not ploughed nor fertilised or irrigated).
		Adult animals must graze on natural pasture for at least half of the grazing period. Lambs must graze on natural pasture for at least 4 weeks.
Pork	*Svenskt Sigill Klimatcertifierad*	Maximum 5% of soy coming from deforested areas (e.g. Brazil) in the feed ration.
Broiler	*Svenskt Sigill Klimatcertifierad*	FCR should be of maximum 1,8 kg feed/kg live weight for fast-growing breeds and 2,1 kg feed/kg live weight for slow-growing breeds.
		Maximum 15% of soy in the ration.

3.5. Collected data – Pesticides use of feed crops

3.5.1. Available data in Eurostat

For European countries, data was derived from Eurostat (Eurostat, 2021b, 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 while others do so each year or every second or third year. Some countries collect different crops in different years (e.g., apples in 2011 and potatoes in 2014).

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.

3.5.2. The case of non-European countries

For non-European countries, pesticides data was either found in national databases or in literature.

For the USA, data was derived from the Geological Survey (USGS) database (Wieben, 2020). The pesticides uses were calculated by summing the quantities of the twenty main pesticides used for each crop. Data on USA soybean was included and used as a reference for USA animal products (unlike European countries, for which Brazilian soybean was considered; see section 3.5.4).

For Brazil, the pesticides data was derived from Prudêncio da Silva et al. (2014) except for soybean, for which the values were found in Pollak (2020) (see section 3.5.4).

No data was found for Thailand and New Zealand.

3.5.3. Assumptions and values used for the calculations

As mentioned in the Appendix 1 – Methodology, 13 categories of feed ingredients were included in the model. In general, it was assumed that all feed ingredients were produced nationally, apart from soy (see paragraph 3.5.4).

In the case of European countries, 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 20).

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 [1]. This is indicated in Table 20 in Appendix 2 – Input data for feeding practices.

The corresponding pesticides use values which were used in the calculations are presented in Table 5 per unit of DM output (g a.i./kg DM crop).

3.5.4. The case of soybean

When used as animal feed, soybean meal was in general considered to come from Brazil. As such, it is the only feed ingredient for which a foreign origin was assumed. 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 in the EU. For the USA, it was assumed that American soybean meal was used to feed the animals.

The case of this feed ingredient and the different values of pesticides use found in the literature are further detailed in Box 2 below.

[1] 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 European countries considered in this study.

Box 2. 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 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 4. 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 the previous Swedish Meat Guide. 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.

The table also includes values for EU-countries (Austria and France) and the USA, which allow for a comparison against Brazil. For the USA, two values are compared in Table 4. The value derived from Perry et al. (2016) was used in the initial study. The second value is calculated from the pesticides database of USGS NAWQA for the year 2017. This value was used in the present assessment. Comparing countries, Brazil presents significantly higher pesticides use values.

Table 4. 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
	Wieben, (2020)[4]	-	**3,5**	-	**1,0**

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, France and Wieben (2020); 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).

[4] For Wieben (2020), crop yields for the calculations were derived from US crops yield statistics (USDA, 2020).

Table 5. Values of pesticides uses per unit of dry matter output (g a.i./kg DM feed crop) for twelve feed ingredients in the countries of interest.

Countries	Grazed grass	Grass silage/ hay	Maize silage	Other forage	Cereals - Wheat	Cereals - Maize	Cereals - Barley	Olea- /protea- ginous	Soybean meal - BR	Soybean meal - Other	Sun- flower meal	Rapeseed meal	Sugar beet
Sweden	0,01	0,01	0,01	0,01	0,09	0,15	0,09	0,10	2,59	1,21	0,71	0,23	<0,01
France	0,00	0,00	0,06	0,02	0,38	0,13	0,37	0,84	2,59	1,21	0,71	0,63	0,04
Belgium	0,02	0,01	0,08	0,02	0,39	0,16	0,32	0,41	2,59	1,21	0,71	0,48	0,08
Brazil	-	-	-	-	-	0,69	-	-	2,59	1,21	-	-	-
Cyprus	0,01	0,02	0,06	0,02	1,09	0,15	1,76	0,32	2,59	1,21	0,71	0,42	0,06
Denmark	0,00	0,01	0,02	0,01	0,22	0,15	0,11	0,41	2,59	1,21	0,71	0,28	0,06
Germany	0,02	0,01	0,13	0,02	0,38	0,15	0,44	0,41	2,59	1,21	0,71	0,70	0,08
Greece	0,01	0,01	0,06	0,02	0,27	0,15	0,59	0,41	-	1,21	0,71	0,42	0,06
Ireland	0,01	0,01	0,10	0,03	0,54	0,15	0,44	0,49	2,59	1,21	0,82	1,00	0,06
Italy	0,00	0,01	0,06	0,02	0,12	0,21	0,59	0,41	2,59	1,21	0,71	0,42	0,06
Netherlands	0,02	0,01	0,08	0,02	0,26	0,15	0,22	0,41	2,59	1,21	0,71	0,34	0,06
New Zealand	-	-	-	-	-	-	-	-	-	1,21	-	-	-
Poland	0,01	0,01	0,13	0,02	0,27	0,14	0,18	0,41	2,59	1,21	0,71	0,82	0,04
Argentina	-	-	-	-	-	-	-	-	-	1,21	-	-	-
Spain	0,01	0,01	0,06	0,02	0,27	0,15	0,59	0,41	2,59	1,21	0,71	0,42	0,06
Thailand	-	-	-	-	-	-	-	-	-	1,21	-	-	-
USA	0,08	0,03	-	0,03	0,35	0,48	0,35	1,21	2,59	1,21	-	-	-
General-EU	0,01	0,01	0,06	0,02	0,27	0,15	0,59	0,41	0,40	1,21	0,71	0,42	0,06

Notes:

- 'General – EU' is the average of the pesticide use values of the European countries considered in the study.
- For some crops, some countries do not report all the quantities of pesticides used (e.g. for sugar beet in Sweden, only quantities of Fungicides are reported whereas Insecticides and Herbicides are reported as 'Confidential' and hence not quantified).
- In this table, 'Soybean meal – Other' is considered to be USA soy.

3.6. Status of assessment

Based on the collected data (generic and specific), 53 products were assessed (i.e., input data was collected and a specific result was calculated). Additionally, there are 25 organic products for which the pesticides impact is considered to be zero by definition in the Meat Guides. Adding these products to the 53 assessed products, there is a total of 78 products out of the list of 87 products for which a result is available.

Due to a lack of data, 9 products were not assessed (Table 6).

Table 6. Products for which no results are available in this study.

Products	Total to assess	Not-Assessed	% Not assessed	Missing data
Lamb	9	5	56%	Feeding practices, pesticides uses
Broiler	15	1	7%	Pesticides uses
Beef	14	1	7%	Pesticides uses
Cheese	21	2	10%	Feeding practices
Total	87	9	10%	-

Note: Products which were not assessed are:

- Sigill-certified lamb for Sweden (3); conventional lamb from Ireland and New Zealand;
- Conventional broiler from Thailand;
- Conventional beef from Brazil;
- Conventional halloumi from Cyprus; conventional feta from Greece.

Chapter 4. Calculation tool

4.1. General functioning

To perform the assessment for each product, a calculation tool was developed in an Excel spreadsheet. It consists of six tabs (Figure 2):

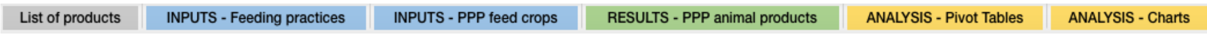

Figure 2. Screenshot of the five tabs included in the calculation tool.

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

(2) **INPUTS – Feeding practices:**
   - *No manual entry is needed in this tab* [2].
   - 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* [3].
   - Contains values of pesticides uses of feed crops for a number of countries. Mainly includes European countries (Eurostat), and a few non-European countries.

(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 data contained in the 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.

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

[3] 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.

4.2. Updates for complementary study

For the purpose of this complementary study, the tool was updated on two main points:

- **Countries of origin:** The calculation tool was updated to account for the new countries of origin, both European (e.g. Germany, Italy, Ireland, Poland, etc.) and non-European (e.g. Brazil, USA, Thailand, etc.).
- **Soybean meal:** A new feed ingredient was added to the tool in order to account for the multiple possible origins of soybean meal. The second version of the tool includes two columns: one for Brazilian soy and one for 'other soy' (either from the EU or the USA).

Chapter 5. Results

The pesticide use levels of the products to assess are presented below, per product category. Organic products present a null result by definition and are thus not included in the result sections below.

5.1. Beef

Ten non-organic beef products were assessed. Their results are presented in Table 7 and Figure 3. The average value for this group is 1,99 g a.i./kg edible product, which is above the threshold value.

The four Swedish products are situated below the threshold. The Swedish *Sigill Climate certified* beef presents the lowest overall impact. This can be explained by the absence of Brazilian soybean meal in this system (which is replaced by US soybean meal with a lower impact).

Finnish beef is the only non-Swedish product which is below the threshold. Beef products from all other assessed countries of origin are above the threshold. German beef presents a particularly high value due to high pesticides uses in barley and wheat. USA beef presents the highest value of all assessed products, which can be explained by the fact that USA feed crops appear to be associated with higher pesticides uses than in the EU, and the fact that all animals in the system are included in the assessment (Figure 3).

Table 7. Total pesticides use (g a.i./kg edible product) associated with non-organic beef products.

Country	Product name	PPP TOTAL (g a.i./kg edible product)
Finland	Finland conventional	1,29
Germany	Germany conventional	3,54
Ireland	Ireland conventional	1,91
Poland	Poland conventional	2,14
Sweden	Swedish *Sigill* certified	1,26
	Swedish *Sigill Klimatcertifierad*	1,01
	Swedish certified *Sigill natural pasture*	1,26
	Sweden - animals indoor	1,29
	Sweden - animals on (some) pasture	1,26
USA	USA conventional	4,90
Average		**1,99**

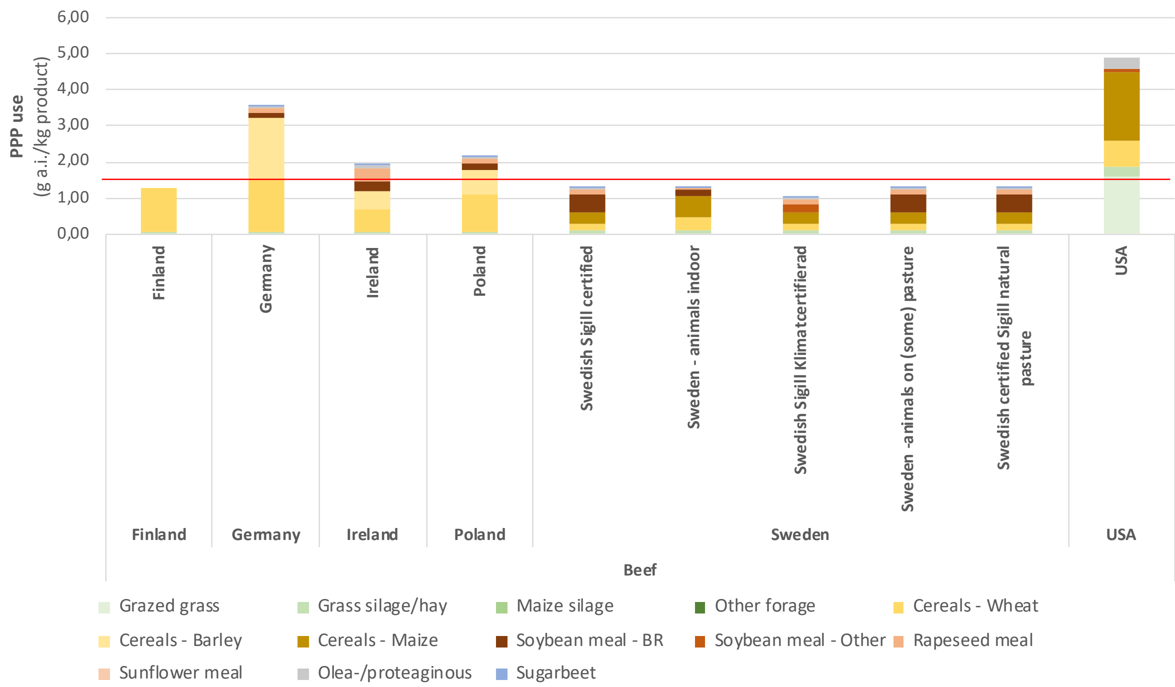

Figure 3. Total pesticides use (g a.i./kg edible product) associated with non-organic beef.

5.2. Broiler

Eleven non-organic broiler products were assessed. Their results are presented in Table 8 and Figure 4. The average value for this group is 2,16 g a.i./kg edible product, which is above the threshold.

In fact, all assessed products present a level of pesticides use which is above the threshold. The highest one is observed for Conventional Brazilian broiler (3,90 g a.i./kg edible product). This is explained by a very high share of soybean meal in its feed (nearly 40% DM).

The French *Label Rouge Auvergne* is the only system which does not use Brazilian soy. Instead, the certification requires the use of French soy, which has a lower impact. This allows to compensate a high FCR value (due to longer lifecycles of the animals in this system).

Swedish systems are just above the threshold They present the lowest results.

In general, the overall pesticides impact of broiler systems is greatly driven by the use of soybean meal (see Figure 4).

Table 8. Total pesticides use (g a.i./kg edible product) associated with non-organic broiler products.

Country	Product name	PPP TOTAL (g a.i./kg edible product)
Belgium	Belgium conventional	2,40
Brazil	Brazil conventional	3,90
Denmark	Denmark conventional	1,81
France	France conventional	2,47
	French *Label Rouge Auvergne*	1,81
Germany	Germany conventional	2,16
Netherlands	Netherlands conventional	2,27
Poland	Poland conventional	2,22
Sweden	Sweden conventional	1,57
	Swedish *Sigill climate certified*	1,57
	Swedish *Sigill certified*	1,57
Average		**2,16**

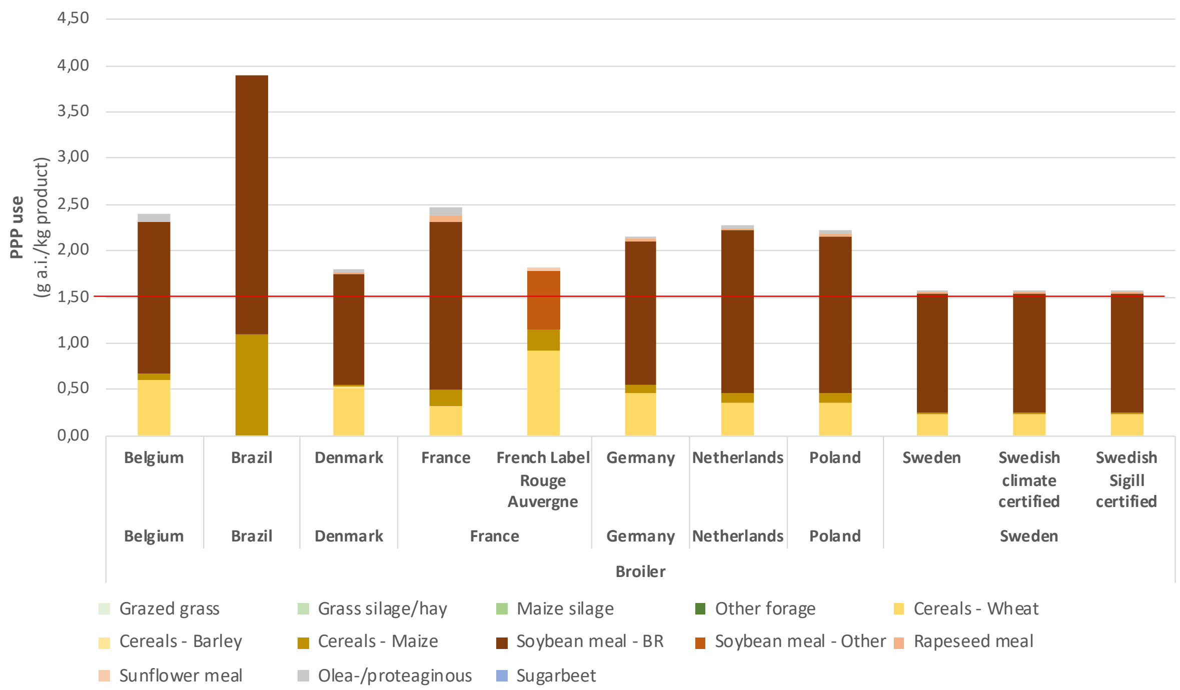

Figure 4. Total pesticides use (g a.i./kg edible product) associated with non-organic broiler in different countries.

5.3. Cheese

Eleven non-organic cheese products were assessed. Their results are presented in Table 9 and Figure 5. The average value for this group is 1,74 g a.i./kg edible product, which is above the threshold.

Within cheese products, there is a difference between hard cheese and soft cheese as the former is assumed to require more milk than the latter (10 L milk/kg cheese vs. 6,5L milk/kg cheese). Within countries, differences between products are explained by this assumption as feeding practices (feed conversion ratio and feed composition) are considered to be the same.

Seven products are situated above the threshold. German cheese (both hard and soft) presents the highest PPP use of all products, followed by Italian mozzarella and Danish hard cheese. This can be explained by relatively important shares of soybean meal in the feed composition (4-6% of DM). Dutch hard cheese and Swedish hard cheese (conventional and *Sigilll certified*) are just above the threshold value (1,61 g a.i./kg edible product). These products contain less soybean meal (2-3% DM).

Four products are situated below the threshold. Danish soft cheese and Swedish halloumi have the same feeding practices as their conventional hard cheese equivalents but they benefit from the fact that they requires less milk than hard cheese. French goat cheese does not require much soybean meal, leading to a low impact. Finally, Swedish *Sigill climate certified* hard cheese benefits from the fact that it cannot use Brazilian soy but uses USA soy instead, thereby limiting its impact.

Table 9. Total pesticides use (g a.i./kg edible product) associated with non-organic cheese products.

Country	Product name	PPP TOTAL (g a.i./kg edible product)
Denmark	Hard cheese (cow) – Denmark conventional	1,76
	White salad cheese (cow) – Denmark conventional	1,14
France	Chevre (goat) – France conventional	1,05
Germany	Hard cheese (cow) – Germany conventional	3,54
	White salad cheese (cow) – Germany conventional	2,30
Italy	Mozzarella (cow) – Italy conventional	2,15
Netherlands	Hard cheese (cow) – Netherlands conventional	1,61
Sweden	Hard cheese (cow) – Sweden conventional	1,61
	Hard cheese (cow) – Swedish *Sigill climate certified*	1,16
	Hard cheese (cow) – Swedish *Sigill certified*	1,61
	"Halloumi" (Cow) – Sweden conventional	1,24
Average		**1,74**

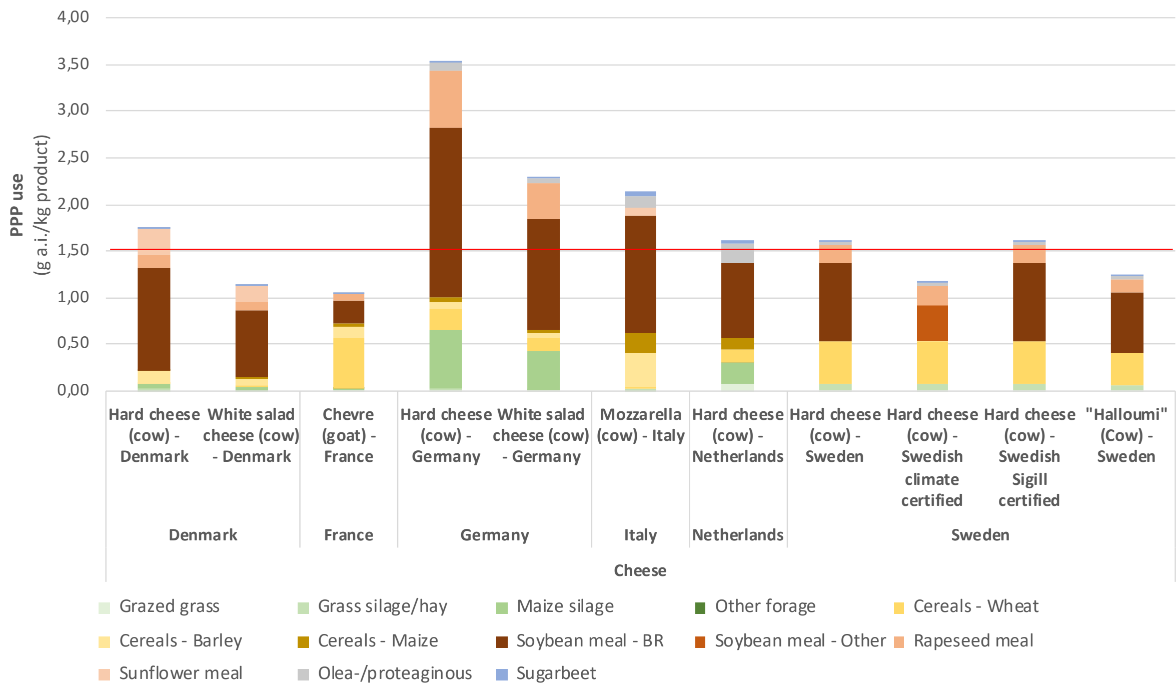

Figure 5. Total pesticides use (g a.i./kg edible product) associated with non-organic cheese in different countries.

5.4. Eggs

Five non-organic egg products were assessed. Their results are presented in Figure 6 and Table 10. The average value for this group is 1,31 g a.i./kg edible product, which is below the threshold.

The Polish conventional system is the only one which presents an impact level above the threshold value (2,29 g a.i./kg edible product), which can be explained by a high feed conversion ratio compared to other egg products. Swedish conventional eggs present the lowest result among assessed products (0,77 g a.i./kg edible product).

As for broilers, the overall impact of egg systems is greatly driven by the use of soybean meal (see Figure 6).

Table 10. Total pesticides use (g a.i./kg edible product) associated with non-organic egg products.

Country	Product name	PPP TOTAL (g a.i./kg edible product)
Denmark	Denmark conventional	1,03
Finland	Finland conventional	1,06
Netherlands	Netherlands conventional	1,38
Poland	Poland conventional	2,29
Sweden	Sweden conventional	0,77
Average		**1,31**

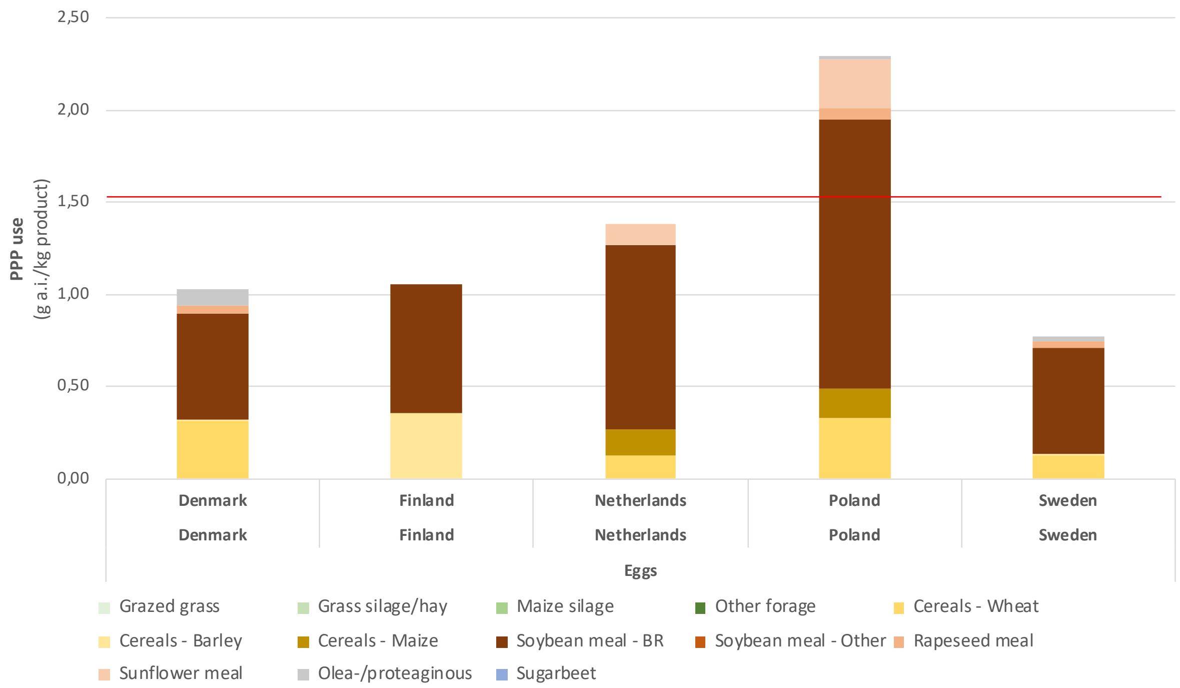

Figure 6. Total pesticides use (g a.i./kg edible product) associated with non-organic eggs in different countries.

5.5. Lamb

One non-organic lamb product was assessed. Its result is presented in Table 11 and Figure 7.

The available data on feeding practices for conventional Swedish lamb is not sufficient to allow for a detailed assessment of its pesticides use. Hence, results are expressed as a range rather than as a specific value: 1,00 g a.i./kg product is a low-end estimate which does not account for the use of pesticides on grasslands (grazed pasture). 2,15 g a.i./kg product is a high-end estimate which assumes that all the grasslands available to lambs is actually grazed and treated with pesticides. In practice, the pesticides use is likely to be closer to the low-end estimate as the majority of Swedish lamb grazes on non-treated grasslands according to experts.

Table 11. Total pesticides use (g a.i./kg edible product) associated with non-organic lamb products.

Country	**Product name**	**PPP TOTAL (g a.i./kg edible product)**
Sweden	Sweden conventional*	1,00-2,15

Note: *The available data does not allow for a detailed assessment of conventional Swedish lamb. 1,00 g a.i./kg product is a low-end estimate which does not account for grasslands and grazed pasture. 2,15 g a.i./kg product is a high-end estimate which assumes that all the grasslands available to lambs is actually grazed and treated with pesticides.

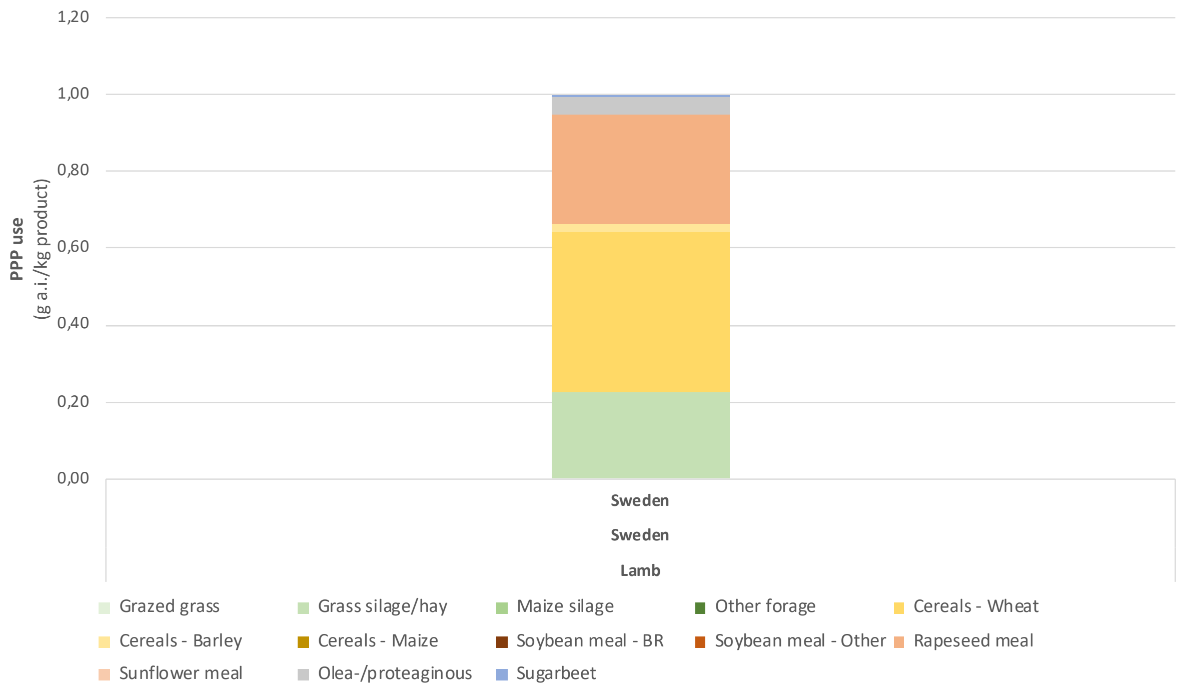

Figure 7. Total pesticides use (g a.i./kg edible product) associated with non-organic Swedish lamb.

Note: The figure presented in this chart (1,00 g a.i./kg edible product) is a low-end estimate which does not account for the use of pesticides on grasslands (grazed pasture). 2,15 g a.i./kg product is a high-end estimate which assumes that all the grasslands available to lambs is actually grazed and treated with pesticides.

5.6. Plant-based products

Four non-organic plant-based products were assessed. Their results are presented in Table 12 and Figure 8. The average value for this group is 0,33 g a.i./kg edible product, which is well below the threshold.

In this group, each product is assumed to be constituted of one single "feed ingredient": olea-/proteaginous beans for legumes conventional legumes, wheat for *Quorn* and *Seitan* and soybeans for conventional tofu. For all products (including soybean-based products), a European origin is assumed.

Of the five assessed non-organic products, tofu presents the lowest impact level (0,14 g a.i./kg edible product) while Quorn presents the highest impact level (0,47 g a.i./kg edible product).

Table 12. Total pesticides use (g a.i./kg edible product) associated with non-organic plant-based products.

Country	Product name	PPP TOTAL (g a.i./kg edible product)
General (EU)	Legumes conventional	0,35
	Quorn conventional	0,47
	Seitan conventional	0,38
	Tofu/Tempeh (soy)	0,14
Average		**0,33**

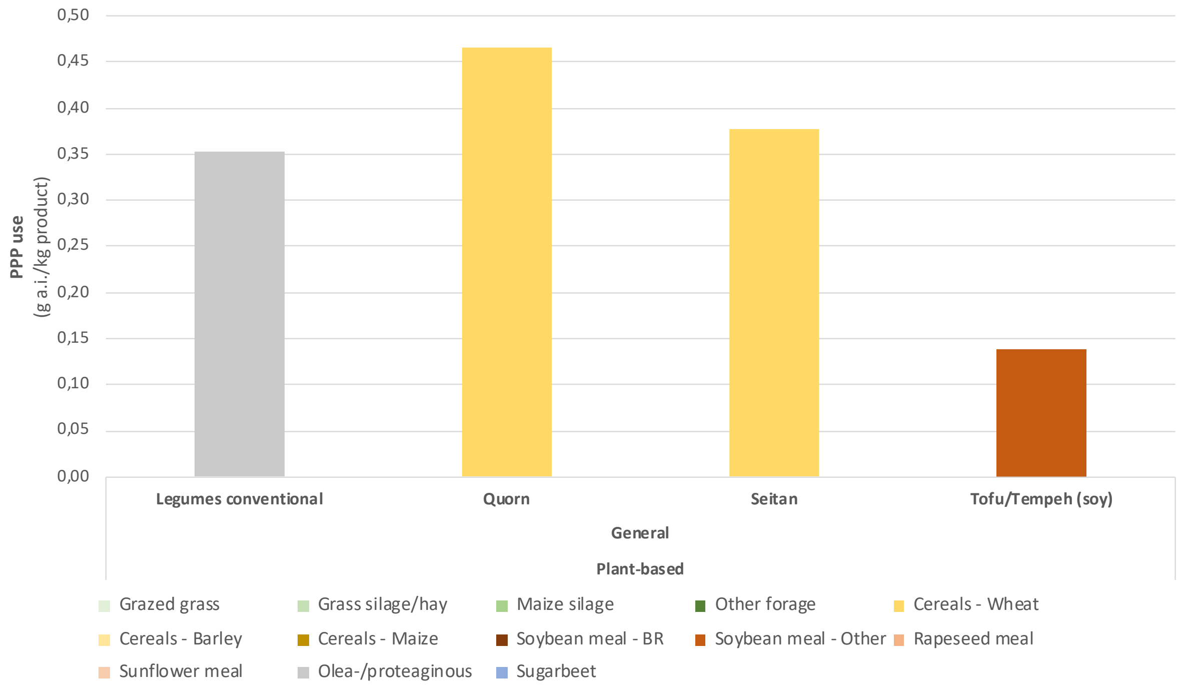

Figure 8. Total pesticides use (g a.i./kg edible product) associated with non-organic plant-based products

5.7. Pork

Ten non-organic pork products were assessed. Their results are presented in Table 13 and Figure 9. The average value for this group is 2,14 g a.i./kg edible product, which is above the threshold.

Of the assessed non-organic products, only one presents an impact level which is just below the threshold: Swedish climate certified pork (1,48 g a.i./kg edible product respectively). This is due to the fact that its feed ration contains slightly less soybean meal (maximum 5% is allowed by the certification) compared to other Swedish pork systems.

All other pork products present impact levels which are above the threshold, although Swedish conventional and Sigill-certified pork are very close (1,55 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.

Table 13. Total pesticides use (g a.i./kg edible product) associated with organic and non-organic plant-based products.

Country	**Product name**	**PPP TOTAL (g a.i./kg edible product)**
Denmark	Denmark conventional	1,69
Finland	Finland conventional	3,70
Germany	Germany conventional	1,97
Italy	Italy conventional	2,95
Netherlands	Netherlands conventional	2,49
Poland	Poland conventional	1,95
Spain	Spain conventional	2,08
Sweden	Sweden conventional	1,55
	Swedish *Sigill climate certified*	1,48
	Swedish *Sigill certified*	1,55
Average		**2,14**

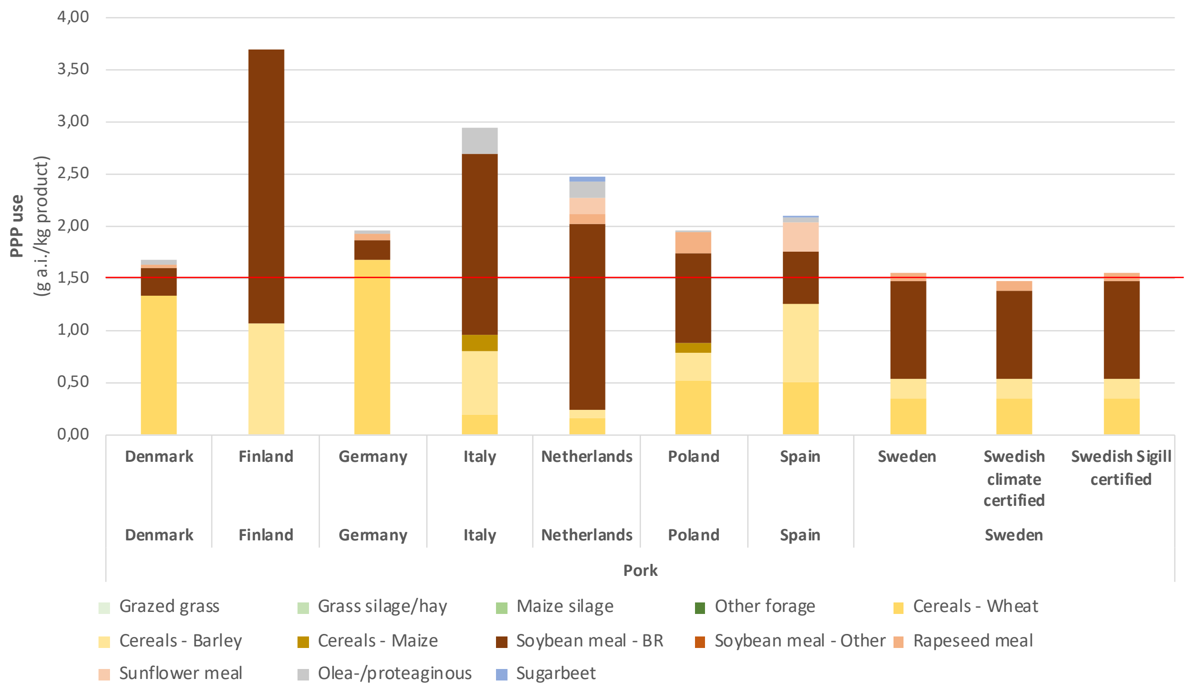

Figure 9. Total pesticides use (g a.i./kg edible product) associated with non-organic pork in different countries.

Bibliography

Antier, C., Petel, T., & Baret, P. (2018). Creating the conditions for a transition towards more sustainable farming systems: A participatory approach with prospective scenarios. *IFSA Conference. Theme 5 - Sustainable Agrifood Systems, Value Chains and Power Structures.*

BFA. (2020a). *Durabilité—Soja durable.* Belgian Feed Association (BFA).

BFA. (2020b). *Rapport statistique de l'industrie belge de l'alimentation animale 2019.* Belgian Feed Association (BFA).

Cederberg, C., Sonesson, U., Henriksson, M., Sund, V., & Davis, J. (2009). *Greenhouse gas emissions from Swedish production of meat, milk and eggs 1990 and 2005.* SIK - Institutet för livsmedel och bioteknik.

CELAGRI. (2020). *L'alimentation des bovins.* Cellule d'information agriculture (CELAGRI).

Chambres d'Agriculture. (2013). *Valorisation de viande et des produis transformés à base de porcs. Découpe pour la vente directe.*

Clune, S., Crossin, E., & Verghese, K. (2017). Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production, 140,* 766–783. https://doi.org/10.1016/j.jclepro.2016.04.082

Cuvelier, C., & Dufrasne, I. (2015). *L'alimentation de la vache laitiere—Aliments, calculs de ration, indicateurs d'évaluation des déséquilibres de la ration et pathologies d'origine nutritionnelle* (Livret de l'agriculture, p. 105).

Dalgaard, R., Schimdt, J. H., & Cenian, K. (2016). *Life cycle assessment of milk—National baselines for Germany, Denmark, Sweden and United Kingdom 1990 and 2012.* Arla Foods. https://lca-net.com/files/Dalgaard-et-al-2016-Life-cycle-assessment-of-milk-National-baselines-for-Germany-Denmark-Sweden-and-United-Kingdom-2012.pdf

Damaziak, K., Riedel, J., Gozdowski, D., Niemiec, J., Siennicka, A., & Róg, D. (2017). Productive performance and egg quality of laying hens fed diets supplemented with garlic and onion extracts. *Journal of Applied Poultry Research, 26*(3), 337–349. https://doi.org/10.3382/japr/pfx001

Dekker, S. E. M., de Boer, I. J. M., Vermeij, I., Aarninck, A. J. A., & Groot Koerkamp, P. W. G. (2011). Ecological and economic evaluation of Dutch egg production systems. *Livestock Science 139,* 109–121.

ERM, & UGent. (2011). *Toepassen van de Carbon Footprint methodologie op Vlaamse veehouderijproducten.* Environmental Resources Management (ERM) & Universiteit Gent (UGent).

Ertl, P., Steinwidder, A., Schönauer, M., Krimberger, K., Knaus, W., & Zollitsch, W. (2016). Net food production of different livestock: A national analysis for Austria including relative occupation of different land categories / Netto-Lebensmittelproduktion der Nutztierhaltung: Eine nationale Analyse für Österreich inklusive relativer Flächenbeanspruchung. *Die Bodenkultur: Journal of Land Management, Food and Environment, 67*(2), 91–103. https://doi.org/10.1515/boku-2016-0009

Eurostat. (2021a). *Statistics on crop production in EU standard humidity.* https://ec.europa.eu/eurostat/databrowser/view/APRO_CPSH1__custom_756089/default/table?lang=en

Eurostat. (2021b). *Statistics on pesticide use in agriculture.* https://ec.europa.eu/eurostat/databrowser/view/aei_pestuse/default/table?lang=en

FAOSTAT. (2021). *Statistics on soy yield in USA.* Food and Agriculture Organisation of the United Nations (FAO).

FEFAC. (2019). *Annual Report 2018-2019.* The European Feed Manufacturers' Federation (FEFAC).

Halberg, N., van der Werf, H. M. G., Basset-Mens, C., Dalgaard, R., & de Boer, I. J. M. (2005). Environmental assessment tools for the evaluation and improvement of European livestock production systems. *Livestock Production Science, 96*(1), 33–50. https://doi.org/10.1016/j.livprodsci.2005.05.013

Hou, Y., Bai, Z., Leschen, J. P., Staritsky, I., Sikirica, N., Ma, L., Velthof, G., & Oenema, O. (2016). Feed use and nitrogen excretion of livestock in EU-27. *Agriculture, Ecosystems and Environment, 218*, 232–244.

IDELE. (2015). *Observatoire de l'alimentation des chèvres laitières françaises.* Institut de l'élevage. https://idele.fr/?eID=cmis_download&oID=workspace://SpacesStore/2b91bf50-f754-491d-bc76-32093b4aafc9

IDELE, & CNE. (2019). *Les chiffres clés du GEB. Bovins 2019. Productions lait et viande.* Institut de l'élevage (IDELE) & Confédération Nationale de l'Elevage (CNE).

IFIP. (2016). *La production de porcs Label Rouge, une perspective dans le contexte 2015 ?* Institut du porc (IFIP).

ITAVI. (2015). *Performances technqiues et coûts de production en volailles de chair, poulettes et poules pondeuses.* Institut Technique de l'Aviculture (ITAVI).

Koch, P., & Salou, T. (2020). *Agribalyse: Rapport méthodologique, Volet Agriculture. Agribalyse V3.0.* ADEME.

Lamnatou, Chr., Ezcurra-Ciaurriz, X., Chemisana, D., & Plà-Aragonés, L. M. (2016). Environmental assessment of a pork-production system in North-East of Spain focusing on life-cycle swine nutrition. *Journal of Cleaner Production, 137,* 105–115. https://doi.org/10.1016/j.jclepro.2016.07.051

Loveday, D., & Ferguson, K. (n.d.). *Rob Holland, Director Center for Profitable Agriculture.* 12.

Malagutti, L., Colombini, S., Pirondini, M., Crovetto, G. M., Rapetti, L., & Galassi, G. (2012). Effects of phytase on growth and slaughter performance, digestibility and nitrogen and mineral balance in heavy pigs. *Italian Journal of Animal Science, 11*(4), e70. https://doi.org/10.4081/ijas.2012.e70

Meyer, D. E., & Cederberg, C. (2010). *Pesticide use and glyphosateresistant weeds: A case study of Brazilian soybean production.* SIK - Institutet för livsmedel och bioteknik.

Moberg, E., Walker Andersson, M., Säll, S., Hansson, P.-A., & Röös, E. (2019). Determining the climate impact of food for use in a climate tax—Design of a consistent and transparent model. *The International Journal of Life Cycle Assessment, 24*(9), 1715–1728. https://doi.org/10.1007/s11367-019-01597-8

Mogensen, L., Kristensen, T., Nielsen, N. I., Spleth, P., Henriksson, M., Swensson, C., Hessle, A., & Vestergaard, M. (2015). Greenhouse gas emissions from beef production systems in Denmark and Sweden. *Livestock Science, 174,* 126–143. https://doi.org/10.1016/j.livsci.2015.01.021

Nguyen, T. L., Hermansen, J., & Mogensen, L. (2010). Fossil energy and GHG saving potentials of pig farming in the EU. *Energy Policy, 38,* 2561–2571.

Palmieri, N., Forleo, M. B., & Salimei, E. (2017). Environmental impacts of a dairy cheese chain including whey feeding: An Italian case study. *Journal of Cleaner Production, 140,* 881–889. https://doi.org/10.1016/j.jclepro.2016.06.185

Perry, E. D., Ciliberto, F., Hennessy, D. A., & Moschini, G. (2016). Genetically engineered crops and pesticide use in U.S. maize and soybeans. *Science Advances, 2*(8). https://doi.org/10.1126/sciadv.1600850

Pollak, H. (2020). *Pesticide footprint of Brazilian soybeans. A temporal study of pesticide use and impacts in the Brazilian soybean cultivation.* Master's thesis - Chalmers University of Technology.

Prudêncio da Silva, V., van der Werf, H. M. G., Soares, S. R., & Corson, M. S. (2014). Environmental impacts of French and Brazilian broiler chicken production scenarios: An LCA approach. *Journal of Environmental Management, 133,* 222–231. https://doi.org/10.1016/j.jenvman.2013.12.011

Prudêncio da Silva, V., van der Werf, H. M. G., Spies, A., & Soares, S. R. (2010). Variability in environmental impacts of Brazilian soybean according to crop production and transport scenarios. *Journal of Environmental Management, 91*(9), 1831–1839. https://doi.org/10.1016/j.jenvman.2010.04.001

Quorn. (2018). *Sustainable future of food – production of first class protein alternative for a balanced diet.* Quorn. https://assets.ctfassets.net/uexfe9h31g3m/71sdVt68rSUyy0KuOW2Ky0/785a424ffd50dc187f2581b21813c79a/Sustainable_future_of_food.pdf

Riera, A., Antier, C., & Baret, P. (2019). *Study on livestock scenarios for Belgium in 2050.* https://sytra.be/wp-content/uploads/2020/04/UCLouvain_Study_Livestock_Belgium_v191028.pdf

Riera, A., Antier, C., de Clippelle, A., & Baret, P. (2021). *A study on the use of chemical pesticides for WWF's meat guides: Methodological and data update.* Sytra - Earth and Life Institute - UCLouvain.

Röös, E., Ekelund, L., & Tjärnemo, H. (2014a). Communicating the environmental impact of meat production: Challenges in the development of a Swedish meat guide. *Journal of Cleaner Production, 73*, 154–164. https://doi.org/10.1016/j.jclepro.2013.10.037

Röös, E., Ekelund, L., & Tjärnemo, H. (2014b). Communicating the environmental impact of meat production: Challenges in the development of a Swedish meat guide. *Journal of Cleaner Production, 73*, 154–164. https://doi.org/10.1016/j.jclepro.2013.10.037

Rotz, C. A., Asem-Hiablie, S., Place, S., & Thoma, G. (2019). Environmental footprints of beef cattle production in the United States. *Agricultural Systems, 169*, 1–13. https://doi.org/10.1016/j.agsy.2018.11.005

Rougher, C., Elfrink, E., Tjek Lap, & Balkema, A. (2015). *LCA of Dutch pork, assessment of three pork production systems in the Netherlands.* https://doi.org/10.13140/RG.2.1.4933.4644

Thomassen, M. A., van Calker, K. J., Smits, M. C. J., Iepema, G. L., & de Boer, I. J. M. (2008). Life cycle assessment of conventional and organic milk production in the Netherlands. *Agricultural Systems, 96*(1), 95–107. https://doi.org/10.1016/j.agsy.2007.06.001

USDA. (2020). Crop Production 2019 Summary. *Crop Production*, 124.

van Grinsven, H. J. M., van Eerdt, M. M., Westhoek, H., & Kruitwagen, S. (2019). Benchmarking Eco-Efficiency and Footprints of Dutch Agriculture in European Context and Implications for Policies for Climate and Environment. *Frontiers in Sustainable Food Systems, 3*, 13. https://doi.org/10.3389/fsufs.2019.00013

Viaene, J. (2012). *Overzicht van de Belgische pluimve- en konijnenhouderij in 2010-2011*. Verbond voor Pluimvee, Eieren en Konijnen (VEPEK).

Wageningen UR. (2013). *Kwantitatieve Informatie Veehouderij (KWIN-V) 2013-2014* (p. 418). Wagenin UR, Livestock Research.

Wallman, M., Cederberg, C., & Sonesson, U. (2011). *Life cycle assessment of Swedish lamb production: Version 2*. SIK - Institutet för livsmedel och bioteknik.

Wieben, C. M. (2020). *Estimated Annual Agricultural Pesticide Use by Major Crop or Crop Group for States of the Conterminous United States, 1992-2017 (ver. 2.0, May 2020)* [Data set]. U.S. Geological Survey. https://doi.org/10.5066/P9HHG3CT

Winkler, T., Schopf, K., Aschemann, R., & Winiwarter, W. (2016). From farm to fork – A life cycle assessment of fresh Austrian pork. *Journal of Cleaner Production*, *116*, 80–89. https://doi.org/10.1016/j.jclepro.2016.01.005

WWF Austria. (2018). *WWF Austria's Meat Guide*. WWF.

WWF Finland. (2016). *WWF Finland's Meat Guide*. WWF.

WWF France. (2019). *Viande—Manger moins, manger mieux*. WWF, CIWF France, Quantis.

Xue, L., Prass, N., Gollnow, S., Davis, J., Scherhaufer, S., Östergren, K., Cheng, S., & Liu, G. (2019). Efficiency and Carbon Footprint of the German Meat Supply Chain. *Environmental Science & Technology*, *53*(9), 5133–5142. https://doi.org/10.1021/acs.est.8b06079

Zira, S., Rydhmer, L., Ivarsson, E., Hoffmann, R., & Röös, E. (2021). A life cycle sustainability assessment of organic and conventional pork supply chains in Sweden. *Sustainable Production and Consumption*, *28*, 21–38. https://doi.org/10.1016/j.spc.2021.03.028

Appendix 1 – Methodology

Necessary inputs – Feeding practices

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

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., 2014a; 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 0) 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.

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).

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

14). 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 in the report (see section 0).

Table 14. 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 – Brazil Soybean meal – Other 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).

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 15).

Table 15. 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*

Necessary inputs - Pesticides use of feed crops

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.

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.

Input 6 – Yields of feed crops

Reference units for calculations: kg/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.

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 10 shows the desired level of differentiation for each of the six inputs.

Pesticides use of feed crops

Based on data availability (see Chapter 3), 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[4]). This means that all conventional[5] 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.

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).

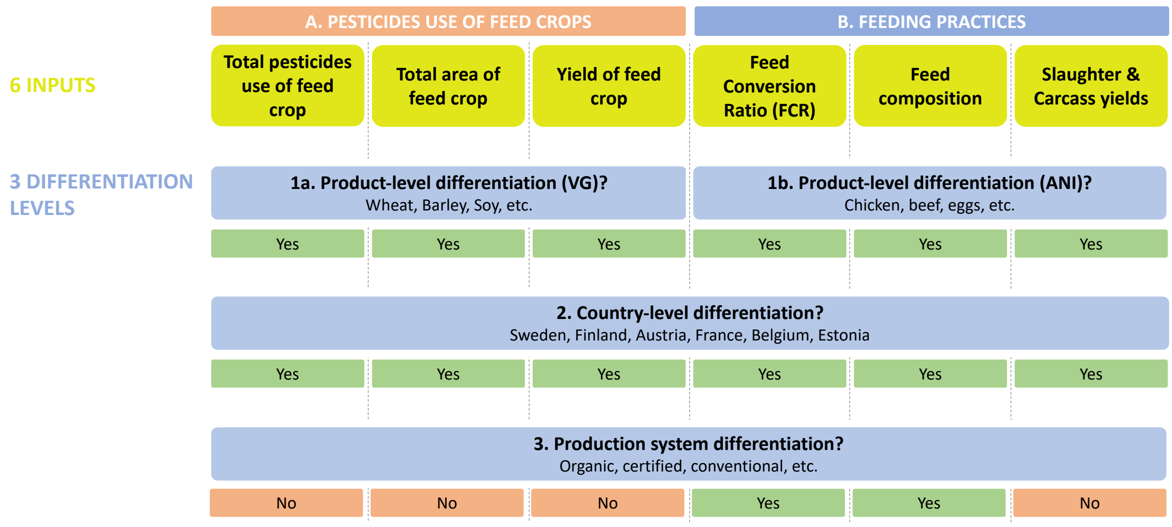

Figure 10. Desired level of differentiation of six inputs necessary to calculate the relative pesticides use of animal products.

[4] 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).

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

Appendix 2 – Input data for feeding practices and pesticides uses

Feed conversion ratios

Feed consumption of non-productive animals

Table 16. 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).

Feed conversion ratios used in the calculations

Table 17. Values of FCR used in the calculations for the assessed products (continued on the following pages).

Country	Product	Category	Certification	Data type	Source FCR	Reference FCR value	Reference FCR Unit	Non-prod. Animals?
Finland	Beef	Conventional	Finland	Generic - country	WWF (2016) FI Meat Guide	12,50	kg feed (DM)/kg edible product	Not included
France	Beef	Conventional	France	Generic - system	Based on Rabeux & Elias (2015); Hubrecht et al. (2013) and Buron et al. (2018)	6,20	kg feed (DM)/kg live weight	Not included
Germany	Beef	Conventional	Germany	Generic - country	Moberg et al., (2019)	13,17	kg feed (DM)/kg carcass weight	Not included
Ireland	Beef	Conventional	Ireland	Generic - country	Moberg et al., (2019)	21,77	kg feed (DM)/kg carcass weight	Not included
Poland	Beef	Conventional	Poland	Generic - country	Moberg et al., (2019)	13,17	kg feed (DM)/kg carcass weight	Not included
Sweden	Beef	Conventional	Sweden - animals indoor	Specific	Moberg et al., (2019)	13,13	kg feed (DM)/kg carcass weight	Not included
Sweden	Beef	Conventional	Sweden -animals on (some) pasture	Specific	Moberg et al., (2019)	10,15	kg feed (DM)/kg carcass weight	Not included
Sweden	Beef	Differentiated	Swedish certified Sigill natural pasture	Specific	Moberg et al., (2019)	10,15	kg feed (DM)/kg carcass weight	Not included
Sweden	Beef	Differentiated	Swedish Sigill certified	Specific	Moberg et al., (2019)	10,15	kg feed (DM)/kg carcass weight	Not included
Sweden	Beef	Differentiated	Swedish Sigill Klimatcertifierad	Specific	Moberg et al., (2019)	10,15	kg feed (DM)/kg carcass weight	Not included
USA	Beef	Conventional	USA	Generic - country	Rotz et al., (2019)	22,30	kg feed (DM)/kg carcass weight	Included
Belgium	Broiler	Conventional	Belgium	Specific	ITAVI, (2015)	1,70	kg feed/kg live weight	Not included
Brazil	Broiler	Conventional	Brazil	Generic - country	Prudêncio da Silva et al., (2014)	1,86	kg feed/kg live weight	Included

Country	Product	Category	Certification	Data type	Source FCR	Reference FCR value	Reference FCR Unit	Non-prod. Animals?
Denmark	Broiler	Conventional	Denmark	Specific	Moberg et al., (2019)	3,00	kg feed/kg carcass weight	Included
Finland	Broiler	Conventional	Finland	Generic - country	WWF Finland, (2016)	3,00	kg feed/kg edible product	Included
France	Broiler	Conventional	France	Specific	ITAVI, (2015)	1,70	kg feed/kg live weight	Not included
France	Broiler	Differentiated	French Label Rouge	Specific	ITAVI, (2015)	3,10	kg feed/kg live weight	Not included
Germany	Broiler	Conventional	Germany	Generic - country	van Grinsven et al., (2019)	1,61	kg feed/kg live weight	Not included
Netherlands	Broiler	Conventional	Netherlands	Generic - country	van Grinsven et al., (2019)	1,65	kg feed/kg live weight	Not included
Poland	Broiler	Conventional	Poland	Generic - country	van Grinsven et al., (2019)	1,65	kg feed/kg live weight	Not included
Sweden	Broiler	Conventional	Sweden	Generic - country	Moberg et al., (2019)	3,00	kg feed/kg carcass weight	Included
Sweden	Broiler	Differentiated	Swedish climate certified	Generic - country	Moberg et al., (2019)	3,00	kg feed/kg carcass weight	Included
Sweden	Broiler	Differentiated	Swedish Sigill certified	Generic - country	Moberg et al., (2019)	3,00	kg feed/kg carcass weight	Included
Sweden	Broiler	Organic	Sweden organic and KRAV	Generic - country	Moberg et al., (2019)	3,00	kg feed/kg carcass weight	Included
Denmark	Cheese	Conventional	Hard cheese (cow) - Denmark	Generic - country	Dalgaard et al., (2016)	10,50	kg feed (DM)/kg edible product	Included
Denmark	Cheese	Conventional	White salad cheese (cow) - Denmark	Specific	Dalgaard et al., (2016)	6,83	kg feed (DM)/kg edible product	Included
Finland	Cheese	Conventional	Hard cheese (cow) - Finland	Specific	WWF Finland, (2016)	13,00	kg feed (DM)/kg edible product	Included
France	Cheese	Conventional	Chevre (goat) - France	Specific	IDELE, (2015)	7,90	kg feed (DM)/kg edible product	Included

Country	Product	Category	Certification	Data type	Source FCR	Reference FCR value	Reference FCR Unit	Non-prod. Animals?
Germany	Cheese	Conventional	Hard cheese (cow) - Germany	Generic - country	Dalgaard et al., (2016)	11,80	kg feed (DM)/kg edible product	Included
Germany	Cheese	Conventional	White salad cheese (cow) - Germany	Specific	Dalgaard et al., (2016)	7,67	kg feed (DM)/kg edible product	Included
Italy	Cheese	Conventional	Mozzarella (cow) - Italy	Specific	Palmieri et al., (2017)	7,62	kg feed (DM)/kg edible product	Included
Netherlands	Cheese	Conventional	Hard cheese (cow) - Netherlands	Generic - country	van Grinsven et al., (2019)	11,53	kg feed (DM)/kg edible product	Included
Sweden	Cheese	Conventional	"Halloumi" (Cow) - Sweden	Specific	Moberg et al., (2019)	6,84	kg feed (DM)/kg edible product	Not included
Sweden	Cheese	Conventional	Hard cheese (cow) - Sweden	Specific	Moberg et al., (2019)	10,53	kg feed (DM)/kg edible product	Not included
Sweden	Cheese	Differentiated	Hard cheese (cow) - Swedish climate certified	Specific	Moberg et al., (2019)	10,53	kg feed (DM)/kg edible product	Not included
Sweden	Cheese	Differentiated	Hard cheese (cow) - Swedish Sigill certified	Specific	Moberg et al., (2019)	10,53	kg feed (DM)/kg edible product	Not included
Denmark	Eggs	Conventional	Denmark	Generic - country	Röös et al., (2014)	2,60	kg feed/kg edible product	Included
Finland	Eggs	Conventional	Finland	Generic - country	WWF Finland, (2016)	2,10	kg feed/kg edible product	Included
Netherlands	Eggs	Conventional	Netherlands	Generic - country	Dekker et al., (2011)	2,31	kg feed/kg edible product	Not included
Poland	Eggs	Conventional	Poland	Generic - country	Damaziak et al., (2017)	3,96	kg feed/kg edible product	Not included
Sweden	Eggs	Conventional	Sweden	Generic - country	Röös et al., (2014)	2,60	kg feed/kg edible product	Included
Sweden	Eggs	Organic	Swedish organic and KRAV	Generic - country	Röös et al., (2014)	2,60	kg feed/kg edible product	Included

Country	Product	Category	Certification	Data type	Source FCR	Reference FCR value	Reference FCR Unit	Non-prod. Animals?
Sweden	Lamb	Conventional	Sweden	Specific	Wallman et al., (2011)	18,48	kg feed (DM)/kg carcass weight	Included
General	Plant-based	Conventional	Legumes conventional	Specific	WWF Austria, (2018)	1,00	kg feed/kg edible product	Included
General	Plant-based	Conventional	Quorn	Specific	Quorn, (2018)	2,00	kg feed/kg edible product	Included
General	Plant-based	Conventional	Seitan	Specific	WWF Austria, (2018)	1,62	kg feed/kg edible product	Included
General	Plant-based	Conventional	Soybeans	Specific	WWF Austria, (2018)	1,00	kg feed/kg edible product	Included
General	Plant-based	Conventional	Tofu/Tempeh (soy)	Specific	WWF Austria, (2018)	0,40	kg feed/kg edible product	Included
General	Plant-based	Organic	Seitan organic	Specific	WWF Austria, (2018)	1,62	kg feed/kg edible product	Included
General	Plant-based	Organic	Soybeans organic	Specific	WWF Austria, (2018)	1,00	kg feed/kg edible product	Included
General	Plant-based	Organic	Tofu/Soy/Tempeh organic	Specific	WWF Austria, (2018)	0,40	kg feed/kg edible product	Included
Denmark	Pork	Conventional	Denmark	Specific	Moberg et al., (2019)	4,40	kg feed/kg carcass weight	Included
Finland	Pork	Conventional	Finland	Generic - country	Hou et al., (2016)	3,20	kg feed (DM)/kg live weight	Included
Germany	Pork	Conventional	Germany	Specific	Moberg et al., (2019)	4,40	kg feed/kg carcass weight	Included
Italy	Pork	Conventional	Italy	Generic - country	Malagutti et al., (2012)	3,05	kg feed (DM)/kg live weight	Not included
Netherlands	Pork	Conventional	Netherlands	Specific	Rougher et al., (2015)	2,66	kg feed/kg carcass weight	Not included
Poland	Pork	Conventional	Poland	Generic - country	Nguyen et al., (2010)	3,00	kg feed/kg live weight	Not included

Country	Product	Category	Certification	Data type	Source FCR	Reference FCR value	Reference FCR Unit	Non-prod. Animals?
Spain	Pork	Conventional	Spain	Generic - country	Lamnatou et al., (2016)	3,30	kg feed/kg carcass weight	Not included
Sweden	Pork	Conventional	Sweden	Specific	Zira et al., (2021)	2,67	kg feed/kg live weight	Included
Sweden	Pork	Differentiated	Swedish climate certified	Specific	Zira et al., (2021)	2,67	kg feed/kg live weight	Included
Sweden	Pork	Differentiated	Swedish Sigill certified	Specific	Zira et al., (2021)	2,67	kg feed/kg live weight	Included
Sweden	Pork	Organic	Sweden organic and KRAV	Specific	Zira et al., (2021)	3,38	kg feed/kg live weight	Included

Notes:

- This table only includes products which were assessed in the complementary study. Organic products are not included either as their result is zero by definition.
- Values for cheese and butter are directly related to those of milk given that it is considered that 1kg cheese corresponds to 6,5 or 10L milk and 1kg butter corresponds to 20L milk.

Feed composition

Table 18. Assumptions and calculation inputs regarding feed compositions for assessed products (continued on following pages).

Product	Country	Category	Certification	Source	Dry weight / Humid weight	Forage total	Cereals total	Olea-/proteaginous	Protein rich total	Sugarbeet	Others (vitamins, minerals…)
Beef	Finland	Conventional	Finland	WWF Finland, (2016)	Dry weight	60%	40%	0%	0%	0%	0%
	Germany	Conventional	Germany	Moberg et al., (2019)	Dry weight	56%	41%	1%	1%	0%	0%
	Ireland	Conventional	Ireland	Moberg et al., (2019)	Dry weight	90%	8%	1%	1%	0%	0%
	Poland	Conventional	Poland	Moberg et al., (2019)	Dry weight	56%	41%	1%	1%	0%	0%
	Sweden	Conventional	Sweden - animals indoor	Moberg et al., (2019)	Dry weight	57%	41%	0%	1%	0%	0%
	Sweden	Conventional	Sweden -animals on (some) pasture	Moberg et al., (2019)	Dry weight	60%	29%	2%	6%	2%	1%
	Sweden	Differentiated	Swedish certified Sigill natural pasture	Moberg et al., (2019)	Dry weight	60%	29%	2%	6%	2%	1%
	Sweden	Differentiated	Swedish Sigill certified	Moberg et al., (2019)	Dry weight	60%	29%	2%	6%	2%	1%
	Sweden	Differentiated	Swedish Sigill Klimatcertifierad	Moberg et al., (2019)	Dry weight	60%	29%	2%	6%	2%	1%
	USA	Conventional	USA	Rotz et al., (2019)	Dry weight	82%	17%	1%	0%	0%	0%
Broiler	Belgium	Conventional	Belgium	BE Feed company (2018)	Humid weight	0%	65%	7%	20%	0%	8%
	Brazil	Conventional	Brazil	Prudêncio da Silva et al., (2014)	Humid weight	0%	57%	0%	39%	0%	4%
	Denmark	Conventional	Denmark	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
	France	Conventional	France	Koch & Salou, (2020)	Humid weight	0%	68%	3%	26%	0%	3%
	France	Differentiated	French Label Rouge	Koch & Salou, (2020)	Humid weight	0%	76%	0%	20%	0%	3%
	Germany	Conventional	Germany	van Grinsven et al., (2019)	Dry weight	0%	70%	2%	24%	0%	4%

Product	Country	Category	Certification	Source	Dry weight / Humid weight	Forage total	Cereals total	Olea-/proteaginous	Protein rich total	Sugarbeet	Others (vitamins, minerals…)
Broiler	Netherlands	Conventional	Netherlands	van Grinsven et al., (2019)	Dry weight	0%	70%	2%	24%	0%	4%
	Poland	Conventional	Poland	van Grinsven et al., (2019)	Dry weight	0%	70%	2%	24%	0%	4%
	Sweden	Conventional	Sweden	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
	Sweden	Differentiated	Swedish climate certified	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
	Sweden	Differentiated	Swedish Sigill certified	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
	Sweden	Organic	EU organic	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
	Sweden	Organic	KRAV	Moberg et al., (2019)	Humid weight	0%	77%	3%	16%	0%	5%
Cheese	Denmark	Conventional	Hard cheese (cow) - Denmark	Dalgaard et al., (2016)	Humid weight	87%	6%	0%	6%	1%	0%
	Denmark	Conventional	White salad cheese (cow) - Denmark	Dalgaard et al., (2016)	Humid weight	87%	6%	0%	6%	1%	0%
	France	Conventional	Chevre (goat) - France	IDELE (2015)	Dry weight	68%	26%	0%	2%	2%	2%
	Germany	Conventional	Hard cheese (cow) - Germany	Dalgaard et al., (2016)	Humid weight	88%	5%	1%	6%	1%	0%
	Germany	Conventional	White salad cheese (cow) - Germany	Dalgaard et al., (2016)	Humid weight	88%	5%	1%	6%	1%	0%
	Italy	Conventional	Mozzarella (cow) - Italy	Palmieri et al., (2017)	Dry weight	52%	24%	4%	8%	12%	0%
	Netherlands	Conventional	Hard cheese (cow) - Netherlands	van Grinsven et al., (2019; Thomassen et al., 2008)	Dry weight	77%	12%	5%	3%	4%	0%
Cheese	Sweden	Conventional	"Halloumi" (Cow) - Sweden	Moberg et al., (2019)	Dry weight	56%	31%	3%	7%	2%	1%

Product	Country	Category	Certification	Source	Dry weight / Humid weight	Forage total	Cereals total	Olea-/proteaginous	Protein rich total	Sugarbeet	Others (vitamins, minerals…)
	Sweden	Conventional	Hard cheese (cow) - Sweden	Moberg et al., (2019)	Dry weight	56%	31%	3%	7%	2%	1%
	Sweden	Differentiated	Hard cheese (cow) - Swedish climate certified	Moberg et al., (2019)	Dry weight	56%	31%	3%	7%	2%	1%
	Sweden	Differentiated	Hard cheese (cow) - Swedish Sigill certified	Moberg et al., (2019)	Dry weight	56%	31%	3%	7%	2%	1%
Eggs	Denmark	Conventional	Denmark	Moberg et al., (2019)	Humid weight	0%	65%	10%	16%	0%	9%
	Finland	Conventional	Finland	WWF (2016) FI Meat Guide	Humid weight	0%	75%	0%	15%	0%	10%
	Netherlands	Conventional	Netherlands	Dekker et al. (2011)	Humid weight	0%	64%	0%	24%	0%	12%
	Poland	Conventional	Poland	Damaziak et al. (2017)	Dry weight	0%	63%	1%	27%	0%	8%
	Sweden	Conventional	Sweden	Moberg et al., (2019)	Humid weight	0%	65%	10%	16%	0%	9%
	Sweden	Organic	EU organic	Moberg et al., (2019)	Humid weight	0%	65%	10%	16%	0%	9%
	Sweden	Organic	KRAV	Moberg et al., (2019)	Humid weight	0%	65%	10%	16%	0%	9%
Lamb	Sweden	Conventional	Sweden	Adapted from Wallman et al. (2011); grazed grass not included	Dry weight	72%	17%	2%	4%	4%	0%
Plant-based	General	Conventional	Legumes conventional	WWF (2018) AT Meat Guide	Humid weight	0%	0%	100%	0%	0%	0%
	General	Conventional	Quorn	Quorn communication (2017)	Humid weight	0%	100%	0%	0%	0%	0%
	General	Conventional	Seitan	WWF (2018) AT Meat Guide	Humid weight	0%	100%	0%	0%	0%	0%
	General	Conventional	Tofu/Tempeh (soy)	WWF (2018) AT Meat Guide	Humid weight	0%	0%	0%	100%	0%	0%

Product	Country	Category	Certification	Source	Dry weight / Humid weight	Forage total	Cereals total	Olea-/proteaginous	Protein rich total	Sugarbeet	Others (vitamins, minerals…)
Pork	Denmark	Conventional	Denmark	Moberg et al., (2019)	Humid weight	0%	94%	2%	3%	0%	1%
	Finland	Conventional	Finland	WWF (2016) FI Meat Guide	Humid weight	0%	80%	0%	20%	0%	0%
	Germany	Conventional	Germany	Moberg et al. (2019)	Humid weight	0%	94%	2%	3%	0%	1%
	Italy	Conventional	Italy	BE Feed company (2018)	Humid weight	0%	65%	12%	13%	0%	10%
	Netherlands	Conventional	Netherlands	Rougher et al. (2015)	Dry weight	0%	28%	11%	35%	26%	0%
	Poland	Conventional	Poland	van Grinsven et al. (2019)	Dry weight	0%	84%	0%	12%	0%	4%
	Spain	Conventional	Spain	Lamnatou et al. (2016)	Humid weight	0%	80%	2%	14%	0%	3%
	Sweden	Conventional	Sweden	Zira et al., (2021)	Humid weight	0%	90%	0%	10%	0%	0%
	Sweden	Differentiated	Swedish climate certified	Zira et al., (2021)	Humid weight	0%	90%	0%	10%	0%	0%
	Sweden	Differentiated	Swedish Sigill certified	Zira et al., (2021)	Humid weight	0%	90%	0%	10%	0%	0%
	Sweden	Organic	EU organic	Zira et al., (2021)	Humid weight	0%	87%	6%	7%	0%	0%
	Sweden	Organic	KRAV	Zira et al., (2021)	Humid weight	0%	87%	6%	7%	0%	0%

Notes: Only the main categories of ingredients (forage, cereals, olea-/proteaginous, protein rich feed, sugarbeet and others) are presented in the table. Each of these categories is made up of different ingredients as described in point 3.5.3.

Slaughter and carcass yields

Table 19. Slaughter and carcass yields per country of origin for different meat products

Product	Country	Category	Source	**Slaughter yield** (kg carcass/kg live weight)	**Carcass yield** (kg edible meat/kg carcass)	**TOTAL Losses** (kg edible meat/kg live weight)
Beef	Austria	All	Ertl et al., (2016)	67%	76%	51%
	Belgium	All	ERM & UGent, (2011)	67%	81%	54%
	Estonia*	All	Clune et al., (2017); Mogensen et al., (2015)	50%	70%	35%
	Finland*	All	Clune et al., (2017); Mogensen et al., (2015)	50%	70%	35%
	France	All	IDELE & CNE, (2019)	54%	68%	37%
	Germany	All	Clune et al., (2017); Xue et al., (2019)	-	70%	38%
	Ireland	All	Moberg et al. (2019) ; Clune et al. (2017)	-	70%	49%
	Poland	All	Moberg et al. (2019) ; Clune et al. (2017)	-	70%	49%
	Sweden	All	Clune et al., (2017); Mogensen et al., (2015)	50%	70%	35%
	USA	All	Loveday & Ferguson, (n.d.)	63%	66%	42%
Broiler	Austria	All	Ertl et al., (2016)	72%	68%	49%
	Belgium	All	Riera et al. (2019)	72%	72%	52%
	Brazil	All	Prudêncio da Silva et al., (2014)	75%	77%	57%
	Denmark	All	Moberg et al. (2019) ; Clune et al. (2017)	-	77%	54%
	Estonia	All	Sytra (2018)	72%	72%	52%
	Finland*	All	WWF Finland, (2016)	72%	80%	58%
	France	All	Sytra (2018)	72%	72%	52%
	Germany	All	Xue et al. (2019)	-	-	58%

	Netherlands*	All	Sytra (2018)	72%	72%	52%
	Poland	All	Clune et al. (2017)			54%
	Sweden	All	Cederberg et al., (2009)	70%	72%	50%
Lamb	Sweden	All	Moberg et al. (2019) ; Clune et al. (2017)	-	66%	43%
Pork	Austria	All	Winkler et al., (2016)	78%	80%	62%
	Belgium	All	ERM & UGent, (2011)	79%	80%	63%
	Denmark	All	Moberg et al. (2019) ; Clune et al. (2017)	-	59%	43%
	Estonia*	All	ERM & UGent, (2011)	79%	80%	63%
	Finland*	All	ERM & UGent, (2011)	79%	80%	63%
	France	All	Chambres d'Agriculture, (2013)	79%	81%	64%
	Germany*	All	Xue et al. (2019)	-	80%	62%
	Italy*	All	Malagutti et al. (2012), Chambres d'agriculture (2013)	83%	81%	67%
	Netherlands*	All	ERM & UGent, (2011); Rougher et al., (2015)	81%	80%	65%
	Poland*	All	Xue et al., (2019)	-	80%	62%
	Spain*	All	Lamnatou et al. (2016), Chambres d'agriculture (2013)	79%	81%	64%
	Sweden	All	Zira et al., (2021)	59%	59%	35%

Note: No specific data was found for some products (with an *). Hence the values of another country were used (see matching references to identify the countries used as proxies). It must also be noted that Clune et al., (2017) uses the same yields for different countries.

Pesticides uses of feed ingredients

Table 20. Main feed ingredients included in the model and corresponding crop references in each country of interest (continued on following pages).

Countries	Grazed grass	Grass silage/hay	Maize silage	Other forage	Cereals - Wheat	Cereals - Maize	Cereals - Barley	Olea-/proteaginous	Soybean meal – BR	Soybean meal - other	Sunflower meal	Rapeseed meal	Sugarbeet
Sweden	Average	Temporary grasses and grazings	Green maize	Plants harvested green from arable land	Common wheat and spelt	Average	Barley	Broad and field beans	Soya BR	Soya USA	Average	Rape and turnip rape seeds	Sugar beet (excluding seed)
France	Permanent grassland	Temporary grasses and grazings	Green maize	Average	Common wheat and spelt	Grain maize and corn-cob-mix	Barley	Broad and field beans	Soya BR	Soya USA	Sunflower seed	Rape and turnip rape seeds	Sugar beet (excluding seed)
Belgium	Permanent grassland	Temporary grasses and grazings	Green maize	Average	Wheat and spelt	Grain maize and corn-cob-mix	Barley	Average	Soya BR	Soya USA	Average	Rape and turnip rape seeds	Sugar beet (excluding seed)
Brazil	-	-	-	-	-	Maize	-	-	Soya BR	Soya USA	-	-	-
Cyprus	Average	Lucerne	Average	Average	Common wheat and spelt	Average	Barley	Other dry pulses and protein crops n.e.c.	Soya BR	Soya USA	Average	Average	Average
Denmark	Estonia	Average	Green maize	Sweden	Common winter wheat and spelt	Average	Spring barley	Average	Soya BR	Soya USA	Average	Winter rape and turnip rape seeds	Estonia
Germany	Belgium	Average	Green maize	Average	Common winter wheat and spelt	Average	Winter barley	Average	Soya BR	Soya USA	Average	Winter rape and turnip rape seeds	Sugar beet (excluding seed)

Greece	Average	Average	Average	Average	Average	Average	Average	Average	Soya BR	Soya USA	Average	Average	Average
Ireland	Permanent grassland	Average	Green maize	Plants harvested green from arable land	Common winter wheat and spelt	Average	Barley	Broad and field beans	Soya BR	Soya USA	Rape, turnip rape, sunflower seeds and soya	Winter rape and turnip rape seeds	Average
Italy	France	Average	Average	Average	Durum wheat	Grain maize and corn-cob-mix	Average	Average	Soya BR	Soya USA	Average	Average	Average
Netherlands	Belgium	Average	Green maize	Average	Common winter wheat and spelt	Average	Spring barley	Average	Soya BR	Soya USA	Average	Rape and turnip rape seeds	Sugar beet (excluding seed)
Poland	Average	Average	Germany	Average	Common winter wheat and spelt	Grain maize and corn-cob-mix	Spring barley	Average	Soya BR	Soya USA	Average	Winter rape and turnip rape seeds	Sugar beet (excluding seed)
Spain	Average	Average	Average	Average	Average	Average	Average	Average	Soya BR	Soya USA	Average	Average	Average
USA	All forage (pasture, alfalfa and other hay)	All forage (pasture, alfalfa and other hay)		All forage (pasture, alfalfa and other hay)	Wheat	Corn for grain	Wheat	Soybean	Soya BR	Soya USA			
General - EU	Average	Average	Average	Average	Average	Average	Average	Average	Average	Soya USA	Average	Average	Average

Notes:

- For some crops, no data was available. 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;
- There are two columns for the soybean meal. This allows to take into account the different origins of the soybean in the ration;
- 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.