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Preface

A large amount of food is lost or wasted along the food supply chain. Little is known about the level of food waste generated in the Danish primary production and food industries, and the Danish Ministry of Environment and Food would like to gain more knowledge about food waste taking place along this part of the food supply chain, in order to identify ways to reduce food waste.

Therefore, the Danish Ministry of Environment and Food has requested a study from the Danish Centre of Food and Agriculture at Aarhus University, as part of the agreement between Aarhus University and the Ministry of Environment and Food of Denmark on the provision of research-based policy support, 2017-2020. Scientists at the Department of Food Science and the Department of Agroecology at Aarhus University has conducted the requested study and written this report.

Niels Halberg,

Director DCA – Danish Centre for Food and Agriculture

Summary

This report seeks to establish a foundation for estimating the magnitude of food waste generated in the Danish primary production and food industries and has been prepared at the request of the Danish Ministry of Environment and Food. The five overall food product categories investigated are:

- Meat and meat products, including fish
- Milk and dairy products
- Eggs and poultry
- Cereals and bakery products
- Fruit and vegetables, including potatoes

Currently, the definition of food waste differs, both at a national and international level. Thus, the definitions differ as to, for example, whether edible/inedible parts should be included in the definition and to which extent food waste used for animal feed should be counted as food waste. Therefore, as there is presently no standardised definition of food waste, this report seeks to establish a basis for estimating food waste independently of the potential definition. Sometimes, throughout the report, there is reference to the FUSIONS food waste definition, which is expected to be the common EU definition.

Within each of the five product categories, food waste has been investigated for products that are produced in Denmark in large quantities, according to Statistics Denmark. Food waste has been investigated by a combination of literature research and interviewing key persons from the Danish primary production and food industries on the amount of waste, reasons for waste generation and waste treatments/end destinations of the waste.

We conclude that of the annual production within each food category in both the primary production and food industry, there are rather small percentages that become food waste. The waste that is generated in these steps of the food supply chain is often regarded as inedible parts and/or unavoidable, based on the present production technology, e.g. eggshells, peels from vegetables and entrails from fish and livestock.

In the primary production of animal products, and on a yearly basis, we estimate that 0.013% (34.9 tonnes of LW) of cattle is lost during transportation to the slaughterhouse, and that 0.22 % (591.4 tonnes) of the total Danish cattle production is rejected at the slaughterhouse. For pigs, these values are 0.08% (290 tonnes) and 1.39% (5,150 tonnes LW), respectively. In chicken production, 0.27% of poultry is lost in transportation and 0.9-1.4% is rejected at the slaughterhouse. Of the total milk production, 94.4% is delivered from farm to dairy, and 0.65% is wasted due to medical treatment of the cows. In egg production, around 0.5-1.8% of hen's eggs are wasted, due to cracking in the sorting and packaging process. For fish, around 2.8% of LW is not landed, with the main part being entrails.

In the food industry - besides from the 123,400 tonnes of human edible products - slaughter of cattle in one year produced 134,200 tonnes LW which was not directly edible. Hereof, 8,000 tonnes are used for fodder,

100 tonnes for medicine and 17,400 tonnes of hides used for leather etc. Thus, the actual food waste in relation to the FUSIONS definition was 4,500 tonnes sent to production of biogas and 59,300 tonnes sent to destruction. Slaughter of pigs produced 1,770,000 tonnes of human edible products. Besides, it produced 334,000 tonnes LW not for human consumption. Hereof, 158,000 tonnes were used for fodder and 4,000 tonnes for medicine. Therefore, according to FUSIONS, 152,000 tonnes of waste were sent to DAKA and 21,000 tonnes sent to production of biogas. For chicken meat, 0.23% is wasted. For milk delivered to dairies, around 2-5% is wasted or used as feed instead of food. For eggs, 10% are eggshell waste, 3.6% is wasted from breaking, and 9.4% of the egg mass is wasted in the processing. For fish, the 130,623 tonnes of waste are made up of heads, tails, fins, skin and shells.

In the primary production of plant products, around 3-15% of fruit and berries are wasted due to diseases, damages during harvesting and postharvest losses. For vegetables, around 3-10% are not harvested because of weather conditions and machinery damage. Around 8-20% are lost during postharvest, due to later sorting out as a consequence of blemishes, storage rot and mass loss due to dehydration and respiration. For cereals, there is a 3% mass loss due to respiration and evaporation during drying and storage. In the juice industry, around 30% of all raw materials are wasted as pulp, while in the vegetable industry, 8-50% is production waste from trimming, peeling and usage of inappropriate raw materials, and 0.1-7% is regarded as avoidable waste, caused by quality issues and manufacturing faults. For cereals, approximately 1% of the raw materials are wasted in the industry due to premill cleaning, sorting out of non-malleable substances and damaged packages.

Sammendrag

Hensigten med denne rapport er at skabe grundlag for en vurdering af omfanget af madspild i den danske primærproduktion og fødevareindustri. Rapporten er bestilt af Miljø- og Fødevareministeriet. De undersøgte fem overordnede kategorier af fødevarer er:

- Kød og kødprodukter, inklusive fisk
- Mælk og mejeriprodukter
- Fjerkræ og æg fra høns
- Korn og bageriprodukter
- Frugt og grøntsager, inklusive kartofler

Madspild defineres for nuværende på forskellige måder, såvel nationalt som internationalt. Blandt andet er der forskel på, hvorvidt spiselige/ikke-spiselige dele medregnes, og hvorvidt spild, der går til dyrefoder, betragtes som madspild. Da der endnu ikke er én enslydende definition af madspildsbegrebet, prøver vi i denne rapport at skabe grundlag for en vurdering af omfanget af madspild, uanset definition. Af og til refereres der i rapporten til madspildsdefinitionen FUSIONS, som forventes at blive den fælles EU-definition.

Inden for hver kategori er der valgt produkter, som ifølge Danmarks Statistik produceres i store mængder i Danmark. Madspildet er blevet undersøgt ved en kombination af litteraturstudier og interviews med nøglepersoner fra den danske primærproduktion og fødevareindustri angående årsagerne til spildet og håndtering/slutdestination for dette spild.

Vi konkluderer, at af den årlige produktion inden for hver fødevarekategori i både primærproduktionen og i fødevareindustrien er det en forholdsvis lille procentvis andel, som bliver til madspild. Spildet, der genereres i denne del af fødevarekæden, betragtes ofte som ikke-spiseligt eller uundgåeligt med den nuværende produktionsteknologi, f.eks. æggeskaller, skræller fra grøntsager og indvolde fra fisk og dyr.

I primærproduktionen af animalskbaserede produkter på årsbasis estimerer vi, at 0,013% (34,9 tons levende vægt, LW) fra kreaturer går tabt i transporten til slagteriet, og at 0,22% (591,4 tons) ud af den totale produktion afvises af slagteriet. For svin er disse værdier henholdsvis 0,08% (290 tons) og 1,39% (5.150 tons). For fjerkræ (kylling) går 0,27% tabt i transporten, og 0,9-1,4% afvises af slagteriet. Af den totale mælkeproduktion bliver 94,4% leveret fra gård til mejeri, og 0,65% spildes på grund af medicinsk behandling af køerne. Omkring 0,5-1,8% af ægproduktionen spildes på grund af knæk i ægget under sortering og pakning. Med hensyn til fisk bliver 2,8% af den fangede vægt ikke landet. Størstedelen heraf er indvolde.

I fødevareindustrien producerede slagtning af kreaturer på ét år - ud over 123.400 tons spiselige produkter - 134.200 tons LW, der ikke var af en sådan kvalitet, at de var direkte spiselige for mennesker. Heraf blev 8.000 tons brugt til foder, 100 tons blev brugt til medicin, og 17.400 tons huder blev anvendt til læder m.m. Det egentlige madspild i henhold til FUSIONS-definitionen udgjorde således 4.500 tons, der blev sendt til biogas, og 59.300 tons, der blev sendt til destruktion. Slagtning af svin producerede 1.770.000 tons spiselige produkter.

Derudover blev der produceret 334.000 tons LW, der ikke var af en sådan kvalitet, at det var spiseligt for mennesker. Heraf blev der brugt 158.000 tons til foder og 4.000 tons til medicin. Det egentlige spild ifølge FUSIONS-definitionen udgjorde således 152.000 tons, som blev sendt til DAKA, og 21.000 tons, der blev sendt til biogas. For kyllinger i fødevareindustrien estimeres det, at der er et spild på 0,23%, mens omkring 5% af mælken på mejerierne bliver spildt i produktionen. For æg i industrien består ca. 10% af æggeskaller, mens 3,6% spildes på grund af ægknæk, og 9,4% af æggemassen spildes i forarbejdningsprocessen. For fisk består spildet på ca. 130.623 tons af hoveder, haler, finner, skæl og skaller.

I produktionen af plantebaserede produkter estimerer vi, at ca. 3-15% af alle frugter og bær frasorteres på grund af sygdomme ved høst, høstskader og frasortering under lagring. For grøntsager spildes omkring 3-10% på grund af vejrforhold og skader ved høst. Mellem 8-20% spildes efter høst på grund af beskadigelse, råd og vægttab som følge af respiration og udtørring. For cerealier tabes 3% fra høst til forarbejdning på grund af vandtab ved tørring og respiration under opbevaring. Ved juicefremstilling baseret på frisk frugt og grønt tabes ca. 30% bestående af pulp. I grønsagsindustrien er der et produktionsspild på mellem 8-50% fra trimning og skrælning af produkterne og brug af uegnede råvarer. Estimeret er der et spild på 0,1-7% på grund af kvalitetsstandarder og produktionsfejl, som kunne være undgået. For cerealier er der et spild på ca. 1% i industrien.

Contents

LIST OF ABBREVIATIONS

ADS	Waste Data System in Denmark (Affaldsdatasystemet)
AMS	Automatic Milking Systems
AU	Aarhus University, Denmark
BIP	By-products
CFP	Common Fisheries Policy
COD	Chemical Oxygen Demand
DOA	Dead-on-arrival
EU	European Union – union of 28 countries
EWC	European Waste Codes
FAO	The Food and Agriculture Organization
FLW	Food Loss and Waste (FLW standard)
FSC	Food Supply Chain
FUSIONS	Food Use for Social Innovation by Optimising Waste Prevention Strategies
FW	Food waste
LW	Live weight
MFVM	The Danish Ministry of Environment and Food (Miljø- og Fødevareministeriet)
NACE	Nomenclature of Economic Activities
RYK	Registration and Milk Recording (Registrerings – og Ydelseskontrollen)
SCC	Somatic cell count
SF	Side flow, defined by Hartikainen et al. (2018)
SRM	Special risk material
UN	The United Nations
WRI	World Resources Institute

1. Introduction

Food waste is currently a hot topic, both at a national and an international level and among producers as well as consumers. Today, it is estimated that between 25 and 33% of all food worldwide is lost or wasted (Aschemann-Witzel et al., 2017), with the majority of the loss taking place in developing countries. However, in developed countries, it is estimated that 10% of all food is wasted, the major part hereof (~40%) at the consumer households (Aschemann-Witzel et al., 2017). In EU-28, the FUSIONS project has estimated that food waste amounted to 88 million tonnes in EU in 2012 (Stenmarck et al., 2016). These estimates include both edible and inedible parts associated with food and equal a level of 173 kilograms per year per habitant at EU level. Hereof, 18 ± 3 kilograms originate from the primary production, 33 ± 25 kilograms from the processing and the rest from retail, the food service sector and households (Stenmarck et al., 2016).

In order to prevent and be able to lower the amount of food waste in the future, it is important to have an overview of the food's path 'from field to fork'. Food passes through several steps in the Food Supply Chain (FSC) before it reaches the consumer and in all these steps, generation of waste and losses can occur. The reasons for waste generation might be multiple, depending on the product. Food waste may be assessed in terms of quantities, values and calories, depending on the stance. Due to a growing awareness of resource efficiency, sustainability and the environmental impact by food production, there is an increased focus on reducing and preventing the amount of waste along the production and supply chain. Definitely, there seem to be many good reasons to minimise the amount of food waste, regardless of the stance. The estimates of food waste in the different sectors are rather uncertain, and further studies are needed in order to clarify the magnitude of the waste, not just at a supranational level, but also at a national level. Within the near future, the EU will order member states to track, count and report the amount of food waste generated. Therefore, the Danish Ministry of Environment and Food (MFVM) wishes to have a valid basis for estimation of food waste in the primary production and food industries in Denmark. This includes food from both animal production and plant production. The different food categories included in this report are:

- Meat and meat products, including fish
- Milk and dairy products
- Eggs and poultry
- Cereals and bakery products
- Fruit and vegetables

Only products that are produced in large quantities according to Statistics Denmark will be studied in the present report. Products produced in small quantities or as niche products will thus not be included. Finally, we introduce the Waste Data System (Affaldsdatasystemet (ADS)), which is a database administered by the Danish Environmental Protection Agency under the Ministry of Environment and Food. This database must be considered as an obvious and well-suited tool in the future estimation of food waste since companies already report their waste to this system.

2. Background

2.1. The Food Supply Chain (FSC)

The Food Supply Chain (FSC) is the connected series of activities for the food's path 'from field to fork'. Depending on the product, food passes through several steps in the FSC. In all the steps, it is possible to generate food waste. Figure 1 shows the basic steps of a typical FSC, starting from primary production of plant- or animal-based food and ending with consumption of the food. Primary production of plant-based food can take place in the field, greenhouse or orchard, or wherever the produce has its origin. Typically, following the primary production, there is a period of storage (indicated by a white arrow in Figure 1), which often includes transportation of food to the food processing industry. After processing, the distribution of the food to retail operators or to the food service industry also requires transportation and storage. Thereafter, edible food ends up at the consumption site. An FSC may contain fewer or other steps than outlined in Figure 1, depending on the specific product. Fresh fruits or vegetables from the primary production may e.g. be sold directly to retail, food service or consumers, without entering the food processing step. However, optimal storage conditions along the FSC are pivotal for maintaining a safe and edible food quality in all steps (Zanoni and Zavanella, 2012).

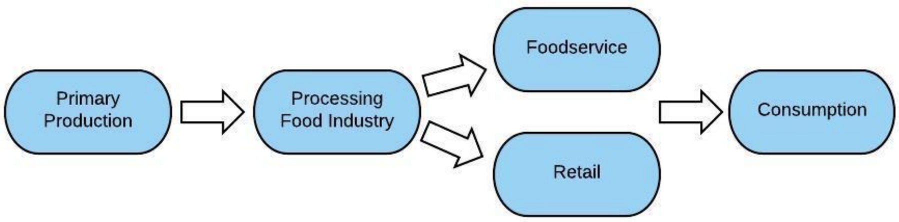


Figure 1. The basic steps of a typical Food Supply Chain (FSC) with food passing through several steps from primary production until consumption. White arrows are indicating a period of storage for the produce, often including transportation.

As mentioned above, food waste may occur in all steps of the FSC, and the possible end destinations for the waste are multiple and depend on the product. The end destinations might be as animal feed, biomaterial, compost, land application or may be refused/discarded or flushed down the sewer. In industrial countries like Denmark, the waste is typically pushed forward in the FSC, whereas in undeveloped countries, the waste occurs to a larger extent in the first steps (Lundqvist, 2008). This may be explained by the use of poor harvesting technologies, lack of proper infrastructure for transportation and poor storage facilities in combination with inappropriate microclimate for storage of fresh fruit and vegetables in developing countries (Lundqvist, 2008). Thus, food is lost early on in the FSC in developing countries, compared to industrial countries. In contrast, the main losses in the developed countries are in the households as mentioned above. Every step or process in the FSC requires resources, e.g. use of water, fuels (if fossil fuels, the activities will contribute to the greenhouse gas emission), land use or labour. Consequently, the longer the food has advanced in the FSC, the more resources have been expended on that particular product.

2.2. Challenges in Defining and Monitoring Food Waste

No doubt, it is challenging to monitor food waste. Several studies have investigated and monitored a large quantity of food waste or food loss along the FSC, although these studies are not directly comparable due to divergent methodologies. The inconsistency with respect to methodology has been addressed by several organisations and in governmental reports as a major challenge in the measurement of food loss and waste. Furthermore, inconsistency in methodology makes it even more complicated to perform systematic comparisons regarding food waste quantities among countries and among different food categories and to evaluate the results in relation to prospective intervention policies. As stated by Lipinski and Robertson (2017), it is challenging to monitoring non-measured food waste, and it is still an open challenge how to define and quantify food waste. In the literature on food waste monitoring, there are several approaches towards estimation and measurement of food waste and although studies can be found in the literature that estimate food waste at EU-level, the results are often divergent because of the different accounting approaches (Caldeira, 2017).

Besides different approaches to the monitoring of food waste, there are also different approaches to defining food waste. A review of existing literature shows that the definitions of food waste that seem generally accepted - and which are referred to and compared in several studies - are the FUSIONS project definition and the FLW (Food Loss and Waste) Standard definition by World Resources Institute (WRI). Furthermore, Hartikainen et al. (2018) have introduced the term *side flow* as a synonym for food waste in their quantification of food waste in the primary production, using the Nordic countries as a case study. The different definitions and systems boundaries will be overall described and compared in the following, with reference to Figure 2 below.

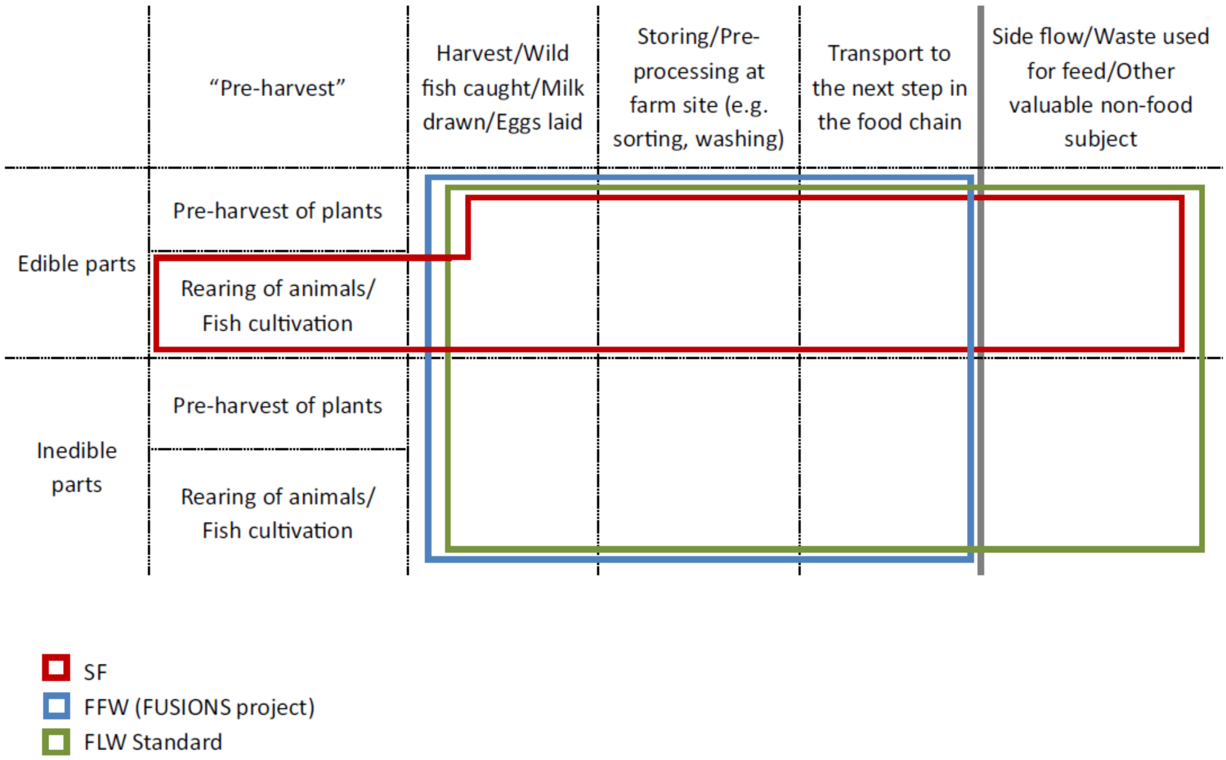


Figure 2. Illustration of the different systems boundaries of SF (side flow), FFW (FUSIONS food waste) and FLW (food loss and waste) standard, (Hartikainen et al., 2018)

FUSIONS was an EU-funded project, running from 2012 to 2016, that among other things made recommendations on how to reduce food waste across the FSC. Their recommendation 1.1 in Stenmarck et al. (2016) was the establishment of a common framework for a food waste definition on EU-level. First of all, FUSIONS define food as:

"*Food means any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be eaten by humans. 'Food' includes drink, chewing gum and any substance, including water, intentionally incorporated into food during its manufacture, preparation or treatment.*"

This food definition thus includes any products ready for harvest or slaughter (including fruits and vegetables not harvested, but ready for harvest) and covers both food and drinks, i.e. both solid and liquid. Based on this food definition, FUSIONS define food waste as follows:

"Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed of, including the following destinations: composting, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea, but not including food or inedible parts of food removed from the food supply chain sent to animal feed or used for the production of bio-based material/biochemical processing".

Summarised, FUSIONS use a definition of food waste which does not include preharvest losses from the rearing of animals/fish cultivation nor the growing phase of plants. Furthermore, waste includes both edible (e.g.

leftovers) and inedible food (e.g. fruit peels). According to the FUSIONS definition, food that is removed from the FSC and sent for animal feed is not counted as food waste. The opposite is the case for the FLW standard (Figure 2), another approach towards monitoring of food waste and losses. The FLW standard was launched by the Food Losses and Waste (FLW) protocol and is commonly used at international level. The FLW standard focuses on where the material removed from the FSC is sent to. The FLW protocol does not as such define what food waste is. It is the users of the standard who decide what makes up the particular definition of waste or loss, based on their quantification goals. The FLW does not in itself include provisions for quantification of loss/waste that occurs preharvest.

The term SF (side flow) used by Hartikainen et al. (2018) has still other definitions and system boundaries than the ones used in FUSIONS and FLW. Thus, inedible parts (not intended for human consumption) of wasted food, e.g. peels and bones, are not included in the food waste ('*side flow')* definition, using the argument that this has originally been considered 'not edible' and is not intended for human consumption. Furthermore, SF includes the rearing phase of domesticated animals, e.g. mortality at farm and during transportation to slaughterhouse, in contrast to the other two definitions, where such mortality is excluded.

Generally, one of the main differences between the definitions found in the literature is from which point in the FSC they start their waste monitoring (Figure 2), what they categorise as waste, loss or by-products, and whether or not to include or exclude edible/inedible food parts. Sometimes, there are even overlaps between the definitions in a single study, which further hinders transparency. As mentioned, there are different approaches in the existing studies to food waste, and this affects the use for specific purposes, depending on the scope of the investigation. Meanwhile, as underlined by several authors, e.g. Azzurro (2016), there is a need for a baseline measurement in order to be able to measure progressions in food waste. A misleading measurement can cause incomplete intervention policies and complicate the design of effective reduction strategies (Caldeira, 2017). As part of achieving the UN Sustainable Development Goals, target 12.3 calls on nations to halve per capita food waste at retail as well as consumer level by 2030, the EU Commission is expected to issue a common definitional framework and methodology to measure food waste. The outcome of the FUSIONS project on food waste is expected to prepare the ground for this, in collaboration with the successor to FUSIONS, the EU research project REFRESH (Resource Efficient Food and dRink for the Entire Supply cHain).

2.3. Definitions and Boundaries in the Present Report

Due to the mentioned challenges regarding food waste definition and methodology, we have not committed to a specific definition of 'food waste' and consequently do not distinguish between food loss and food waste. We find that the collected data in this report can be used and be relevant independently of definition. This report will include data on products produced in large quantities in Denmark, according to Statistics Denmark. Therefore, Danish niche products and products produced in small amounts are included. The starting point is what FUSIONS define as the first step of the FSC, i.e. the moment that

- Crops are ready to harvest
- Eggs are laid
- Animals are slaughtered
- Milk has been drawn from the udder
- Fish have been caught in the net

As can be concluded from the FUSIONS definition on the starting point of the FSC, statements do not include rearing of animals and fish cultivation (which is e.g. included by Hartikainen et al. (2018) in their SF accounting). According to the FUSIONS food waste definition, the first step of the FSC for e.g. beef and pork is when the animal is slaughtered. Food waste can therefore not occur at farm level according to the FUSIONS food waste definition. However, the SF definition also includes food waste during rearing, e.g. mortality at farm level and during transportation to the slaughterhouse, which will be described in the sections about food waste in animal products produced in Denmark. None of the mentioned definitions include 'preharvest' losses of plants, e.g. attack of pests and diseases during the growing of fruit and vegetables. However, if data exist for the step prior to the above stated starting points for both animal- and plant-based products, we have decided to include them since there are ongoing reflections on whether the future common EU system consideration should start when the plants *are ready for harvest* and animals *are ready for slaughter.*

2.4. Waste Data System (in Danish: Affaldsdatasystemet - ADS)

The Waste Data System (in Danish referred to as Affaldsdatasystemet - ADS) is a web-based database, managed by the Environmental Protection Agency under the Danish Ministry of Environment and Food. The database was established in 2010 and gives a description of the quantity of waste generated in Denmark (Toft et al., 2017). Annually, Danish companies report the various types of waste generated, the amount of waste and the waste treatment to the ADS database. Most of the data is publicly available and can be used for statistical purposes. A producer of waste has a company-specific 'P number', which can be translated to a NACE-code. The first digits indicate the line of business, e.g. '01' is for farming and '10' is for food production. The type of waste is stated by an EWC code (European Waste Code), in Danish context called an EAK number. Thus, EAK number 0201 is 'Waste from farming, nursery gardens, aquaculture, forestry, hunting and fishery'. The newest data currently available is from 2016, which is used as reference in the present report, section 6. Data to ADS is reported by the receiver or collector of waste, i.e. not by the waste producer himself. This stands in contrast to the remaining data in this report which are self-reported by the producer. For further information on ADS and how it functions, we refer to Toft et al. (2017) and the homepage 'Affaldsdatasystemet', managed by the Ministry of Environment and Food: http://mst.dk/affald-jord/affald/affaldsdatasystemet/

3. Data Collection

In a review on food waste and resource efficiency in the FSC in a Danish context by Jensen and Bonnichsen (2016), the possibilities for annual measurements of food waste are evaluated. Overall, food waste measurements can be made as 1) Direct, physical measurements (registration of the amount of food waste), 2) Interviews/questionnaires with key operators in the FSC, based upon self-reported data, and 3) Indirect measurements and model estimations based upon data from other studies or other data sources. Direct, physical measurements which provide quantitative data about waste generation in agriculture, greenhouse production and fishery are considered as difficult to obtain, since the process is very labour- and resource-intensive (Jensen and Bonnichsen, 2016). Therefore, measurements using the above types 2 and 3 are preferred. One drawback of this methodology of data collection is the relatively inaccurate results that rely mainly on estimations and self-reported data. However, interviews and questionnaires may give qualitative insights such as causes of waste generation and related problematics.

Data in the present report are based on a combination of literature studies, interviews with key persons from companies/producers that are representative for the Danish situation as well as research-based data. Text and data have been delivered by scientists from Aarhus University within their field of expertise. For some of the fruits and vegetables, data have been divided into organic and conventional production practice. If there are no differences in food waste between the production systems, or if data are missing for the specific food category, only the mean values for each product category will be presented. Furthermore, potential differences in food waste as influenced by differences in cultivars or species within a product have not been accounted for. It is not taken into consideration either whether the products produced in the primary production are exported or whether imported products have been used for processing in the food industry. For the food industry, data are gathered from Danish and international companies within Denmark. Some Danish-owned companies have outsourced their actual production to other countries and are therefore not part of the data in this report.

4. Food Waste in Animal Products Produced in Denmark

Animal products comprise meat and meat products, including fish, milk and dairy products as well as eggs and poultry. The largest meat quantities in Denmark are beef, pork and chicken, so food waste in these three food categories will be the focus area in this report. The majority of eggs produced in Denmark is hen's eggs and this report will only comprise data on food waste in the hen's eggs industry.

4.1. Waste in the Primary Production of Animal Products

4.1.1. Beef

Data on production of beef and veal are derived from slaughtering at slaughterhouses, export of live animals for slaughter and slaughtering at the farms. The total number of cattle slaughtered in Denmark is calculated by the Danish Agriculture & Food Council and published once a year (Landbrug & Fødevarer, 2017b). The numbers from 2006-2016 are given in Table 1. Every week, the slaughterhouses report the number of all approved slaughtering to Landbrug & Fødevarer. Statistics Denmark receives information regarding both the number and the slaughter weight per group of animals. The grouping of the slaughtered animals and the definition of slaughter weight were changed per 1 January 1974 and 1.1 1994 to comply with EU Council Directives 73/132/EEC and 93/24 /EEC as well as Commission Decisions 73/262 and 94/433. The latest change as of 1 January 2009 (EU Regulation (EC) No. 1165/2008) has only resulted in minor changes. Animals under 300 kilograms LW are now considered calves. Until 1994, this limit was 220 kilograms LW.

Number of cattle in Denmark

The existing data from slaughterhouses is not divided into cattle breeds (e.g. Holstein Friesian, Jersey, Hereford etc.), but grouped into whether it is a dairy or a beef breed. This is of importance in relation to mortality etc. at farm level and output of meat at slaughterhouses. In order to estimate the proportion of each group of cattle, we use data from national statistics. In 2016, the cattle population in Denmark amounted to 1,568,300 cattle in total (Landbrug & Fødevarer, 2017b). The total number of cattle in Denmark has been stable at that level for the last decade. The total number of cows in 2016 amounted to 664,800 cows, which can be divided into 571,600 dairy cows (86.0%) and 93,100 (14.0%) beef breed suckler cows (Landbrug & Fødevarer, 2017b). Except for the cows, these numbers are not divided into whether the animals are of dairy breed or beef breed. In Table 1 on number of cattle delivered to slaughterhouses, we have assumed the same percentage distribution between dairy breed or beef breed as for the cows, 86% and 14%, respectively. The table shows that the total slaughtering per year has been relatively stable for the last 10 years, from 493.1 in 2006 to 499.38 in 2016 (1,000 heads).

Table 1. Number of cattle delivered to slaughterhouses, 2006-2016

1,000 heads	***Number of cattle delivered to slaughterhouses per year*** [1)]				**For 2016 data distribution on** [2)]	
	2006	**2014**	**2015**	**2016**	**Dairy breed (86%)**	**Beef breed (14%)**
Cows	194.8	215.5	176.1	200.3	172.3	28.0
Heifers	49.9	46.6	55.9	65.8	56.6	9.2
Steers	6.1	7.5	7.4	5.5	4.7	0.8
Bulls, young	232.4	209.5	215.2	217.4	187.0	30.4
Calves max 300 kg LW	3.8	6.0	5.9	6.7	5.8	0.9
Small calves	0.1	0.1	0.1	0.1	0	0
Total at slaughterhouse	478.1	485.2	460.5	495.8	426.4	69.4
Slaughtering at farm	*6.0*	*6.0*	*4.0*	*4.0*		
Total slaughtering	493.1	491.2	464.5	499.38		
Export	16.4	65.2	46.0	39.8		
Gross production	509.5	556.4	510.5	539.6		

1) Landbrug & Fødevarer (2017b)
2) Own estimate

In the section about waste in food processing, beef breed cattle are further divided into intensive and extensive breeds, represented by Limousine and Scottish Highland cattle. Based on Danish statistics regarding purebred suckler cows from 2013, a distribution between intensive and extensive breeds of 80% and 20%, respectively, was assumed.

Food waste due to mortality at farm and during transportation to slaughterhouse

In the FUSION definition, food waste from livestock production is not included until the livestock are ready for slaughter. However, other food waste definitions (e.g. Hartikainen et al. (2018) also include food waste at farm stage. Therefore, the amount of food waste from on-farm cattle production in Denmark is quantified below.

Every month, SEGES calculate the average mortality for calves, based on the cattle farmers' own registration in the cattle database (in Danish: 'Kvægdatabasen'). Data are divided into dead 'at birth', which also includes dead within the first day, dead 'day 1-30', which means dead during that period in percent of the number of live-born calves and dead 'day 30-180' which means the mortality for calves which are alive by day 30 (Raundal et al., 2018a), see Table 2. In a similar way, SEGES calculate mortality of dairy cows based on the farmers' own registration in the cattle database. Cow mortality is presented in relation to number of cow years (feeding days) in the herd as the sum of cows dead by themselves and cows put down (Raundal et al., 2018b).

Table 2. Mortality for calves and cows at farm level, 2006-2016

Percent of animals [%]	2006	2012	2014	2015	2016	Ref.
Dairy breed						
Cows (% of year cows)	6.2	5.1	5.2	5.0	5.0	2)
Calves – at birth	7.4	6.1	5.8	5.7	5.5	1)
Calves – day 1-30	4.9	4.2	4.3	4.0	3.8	1)
Calves – day 30-180	8.6	7.8	7.7	7.4	7.2	1)
Beef breed						
Cows					*5.0*	*3)*
Calves – at birth	3.7	3.4	2.8	3.0	2.9	1)
Calves – day 1-30	3.5	2.9	2.4	2.8	2.7	1)
Calves – day 30-180	5.1	4.4	3.8	4.,4	4.1	1)

1) *SEGES - Raundal et al. (2018a)*
2) *SEGES - Raundal et al. (2018b)*
3) *Assume the number is the same number as for dairy cows*

Based on data from 2016, the mortality (presented in Table 2) and number of cows in Denmark, and an assumed weight per dead animal, the total number of dead cattle and their total weight were calculated (see Table 3). Annually, the LW from dead cows amounted to 21,000 tonnes and from dead calves to 8,200 tonnes. Calculated per cow per year it amounted to 46 kilograms LW from dead cattle per dairy cow and 32 kilograms LW from dead cattle per beef breed cow.

Table 3. Dead cattle at farm level in Denmark in 2016, total number and LW

Percent of animals [%]	**Dairy breed**	**Beef breed**	**Total**	**Ref.**
Cows				
Total number of cows	571,600	93,100	664,800	1)
Dead, %	5.0	5.0		2)
Dead cows, N	28,580	4,655	33,235	
Dead cows, average LW per animal, kg	653	490		3)
Dead cows, LW total 1,000 tonnes	18.7	2.3	21.0	
Calves				
Total number of born calves per cow per year	*1.09*	*1.08*		*4)*
Total number born	*623,044*	*100,548*	*723,592*	
Calves – dead at birth, %	5.5	2.9		
Calves – dead day 1-30, %	3.8	2.7		
Calves – dead day 30-180, %	7.2	4.1		
Calves – dead at birth, N	34,267	2,916	37,183	
Calves – dead day 1-30, N	22,374	2,636	25,010	
Calves – dead day 30-180, N	40,781	3,895	44,676	
Calves – dead at birth, LW/calf, kg	40	35		
Calves – dead day 1-30, LW/calf, kg	54	48		5)
Calves – dead day 30-180, LW/calf, kg	121	106		6)
Dead Calves, LW total 1,000 tonnes	7.5	0.6	8.2	
LW from dead cows and calves, kg per cow per year	46	32		

1) Landbrug & Fødevarer (2017b)
2) SEGES - Raundal et al., 2018b
3) Pontoppidan and Madsen (2014) (80% Limousin and 20% Highland Cattle)
4) Dairy breed 1.09 calves/cow/year – assuming 40% replacement and the actual CI (calving index) of 397 days (SEGES, 2015) and beef breed (0.9 calves weaned in Highland and 1.0 in Limousin – with the mortality in Table 6 that gives 0.99 and 1.10 born, respectively) (Mogensen et al., 2016).
5) Dairy: 73 and 60 kg assumed at day 30 for bulls and heifers – beef: 67 and 55 kg assumed at day 30 for bulls and heifers assumed dead in the middle of the period.
6) Dairy: 200 and 150 kg assumed at day 180 for bulls and heifers – beef: 175 and 125 kg assumed at day 180 for bulls and heifers assumed dead in the middle of the period.

It was not possible to find numbers from Denmark for mortality of cattle during transportation to the slaughterhouse. The applied number of 0.013% is from data on cattle mortality during transportation in Sweden, which is a weighted average based on studies of both pigs and cattle (Gustafsson et al., 2013, Malena et al., 2007). These numbers fit with the Danish numbers for mortality during transportation of finishers of 0.01%, but are lower than the Danish numbers for sow transportation of 0.07% (Videncenter For Svineproduktion, 2011).

It has not been possible to find Danish data on the proportion of cattle rejected at arrival at slaughterhouses. From a Swedish study (Strid et al., 2014), it was found that rejection at slaughterhouses is relatively low and mainly comprises rejection of whole animals (0.22% of carcasses inspected). An animal must be healthy and able to stand on all four legs in order to be transported to the slaughterhouse. Animals that have suffered injuries, but which are otherwise healthy, can be slaughtered at the farm, if some specific conditions are met. However, this occurs to a very limited extent and instead, the animal is destroyed even though the meat quality is probably unimpaired (Strid et al., 2014).

On the assumption, that these numbers are accurate and representative for Danish conditions, only 64 cattle will die per year during transportation, which represents a food waste of 34.9 tonnes LW of cattle. Similarly, 1,091 cattle will be rejected at slaughterhouses, which represents a food waste of 591.4 tonnes LW of cattle (Table 4). The Danish Veterinary and Food Administration does not keep statistics on animals that have died during transportation. However, if an animal dies during transportation, it will be registered according to the animal protection regulations in the form of a veterinary control report.

Table 4. Mortality during transportation to slaughterhouses, number of cattle delivered to slaughterhouses and average LW, in the year 2016

	Dairy breed (86%) 1)	Beef breed (14%) 1)	Total 2016
1,000 heads delivered to slaughterhouses (from Table 1)	426.4	69.4	495.8
Mortality during transportation			
Number of dead cattle (0.013%), N per year	55.4	9.0	
Live weight of dead cattle, tonnes per year	29.9	5.0	34.9
Rejected at slaughterhouses			
Number of cattle rejected (0,22%), N per year	938	152	1091
Live weight of rejected cattle, tonnes per year	506.6	84.8	591.4

1) From Table 1 - Landbrug og Fødevarer, 2017b

Dead cattle will be sent to DAKA, a destruction plant, and this 'category 1 waste' can be used as raw material in biogas production, in fertiliser production or burned to generate heat, thus saving coal or oil. When meat and bone meal are burned, the ash can be used in cement production. Fat can be burned, but is mainly used in biodiesel production (DAKA, 2012).

Cattle that die in ways other than by slaughter for human consumption, e.g. killed due to diseases, are seen as 'specified risk material' (SRM), which includes animals, or parts of animals, suspected of being infected with

Transmissible Spongiform Encephalopathies (TSE)/Bovine Spongiform Encephalopathy (BSE). For further information, see By-products Regulation, EU-1069/2009, Article 8 (DAKA Denmark, 2017).

How representative are the data:

By law, each individual animal (cattle) has to be identified by two ear tags, and the farmer has to report all events, like dead, sold or slaughtered, to a central database (Kvægdatabasen). Average mortality for calves and cows at farm (% dead) is reported every month by SEGES (Raundal et al., 2018b, Raundal et al., 2018a), based on registrations in the cattle database. Thus, the number of dead cattle at farm is known with a very high degree of certainty (there could be minor uncertainty regarding stillborn calves). The weight of dead cattle is based on a presumption and standard numbers.

The number of cattle slaughtered in Denmark is reported every week by the slaughterhouses to Landbrug & Fødevarer. Statistics Denmark receives this information on both the number and the slaughter weight per group of animals.

Mortality during transportation (% dead) and rejected (%) at slaughterhouses are not known from Danish slaughterhouses and is in this report based on Swedish studies.

Summary: *In 2016, the cattle population was 1,568,300 cattle in total. On a yearly basis and as a rough estimate, 29,200 tonnes LW of cattle die at farm and 34.9 tonnes LW of cattle die during transportation to slaughterhouses. Annually, 1,091 cattle will be rejected at the slaughterhouses, corresponding to 591.4 tonnes LW of cattle. According to the FUSIONS definition, food waste from livestock production is not included until the livestock are ready for slaughter. Therefore, this food waste will not be induced in food waste accounting according to the EU/FUSION definition. Based on literature studies, we estimate that values are representative for the Danish market for this category.*

4.1.2. Pork

Production figures for pork are derived from slaughtering and export of live animals for slaughter. Number of pigs in Denmark as of 1 January 2016 was according to Statistics Denmark a total of 12.7 million pigs, which is 2.9% less than the year before (Landbrug & Fødevarer, 2017c). Since 2008, the total number of pigs has been stable around 12.0-13.0 million. However, in 2006 and 2007, it was higher (13.5-14.0 million) (Danmarks Statistik, 2016).

The number of pigs in different categories is presented in Table 5 (Landbrug & Fødevarer, 2011, 2013, 2015, 2016, 2017c). In 2016, the distribution of total pigs in groups was based on data from 2,500 farms with pigs. In total, there were 3,294 farms in Denmark with pigs in 2016 (Landbrug & Fødevarer, 2017c).

Table 5. Number of pigs in Denmark from 2010-2016

1,000 heads/year	**2010**	**2012**	**2014**	**2015**	**2016**
Sows					
- Gilts	205	194	199	199	191
- Other pregnant sows	642	595	592	603	586
- Lactating sows	220	206	210	208	205
- Dry sows	40	41	36	36	34
Boars	11	11	11	11	11
Replacement sows for slaughter	9	6	7	7	7
Gilts (< 50 kg)	239	203	221	199	221
Piglets with sows	2,475	2,456	2,569	2,579	2,474
Weaned piglets (< 50 kg)	5,583	5,337	5,313	5,666	5,826
Finishers (>50 kg)	3,449	3,299	3,244	3,201	3,147
Total	12,873	12,348	12,402	12,709	12,702

Table 6 shows the number of pigs slaughtered in Denmark (Landbrug & Fødevarer, 2017c). Further details about distribution hereof, on different groups and their carcass weight, are given by Danmarks Statistik (2018).

Table 6. Pigs slaughtered in Denmark and export of slaughter pigs and sows, 1,000 heads in the years 2000-2016

	2000	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Slaughtering								
Gilts	16.8	9	12	10	12	10	9	9
Sows	398.9	425	489	446	488	513	533	530
Boars	21.8	12	12	11	12	11	9	8
Finishers	20,284.2	19,667	20,360	18,992	18,595	18,323	18,164	17,809
For farmer	17	1	1	1	1	1	1	1
Total at slaughterhouses	20,738.7	20,114	20,874	19,460	19,108	18,858	18,716	18,357
Slaughtered at farms	220	24	24	24	24	24	24	24
Total slaughter	20,958.7	20,138	20,898	19,484	19,132	18,882	18,740	18,381
Rejected	133.3	57	51	42	35	33	36	33
Sent to slaughter	20,872	20,171	20,925	19,502	19,143	18,891	18,752	18,390
Export live pigs	1,455	8,367	8,500	9,562	9,864	11,120	12,133	13,280
- hereof sows and finishers		500	500	500	400	400	300	300
- hereof 30 kg pigs			8,000	9,200	9,700	10,900	12,000	13,200
Total DK pork production	22,413	28,505	29,400	29,100	29,200	30,100	31,300	31,800

Food waste due to mortality at farm and during transportation to slaughterhouses

Based on collected farm data from AgroSoft and Cloudfarms delivered by local farm extension service offices and Danish Crown, SEGES will every year publish numbers for average productivity and mortality at Danish pig farms. Data from 2016 were based on data from 570 sow herds with 435,000 sows per year[1] (43% of Danish sows), 541 herds with piglets and a total production of 12.6 million piglets and 714 herds with finishers and a total production of 5.6 million finishers (31% of Danish production) (SEGES, 2017). At farm level, it is often difficult to know if a dead piglet was stillborn or died just after being born. Therefore, the distribution between 'stillborn' and 'dead before weaning' (Table 7) might be wrong, whereas the total number of dead piglets is indeed valid. Data for dead sows are not given in the mentioned report.

Table 7. Productivity and mortality at farm level, years 2009-2016

	2009	**2012**	**2013**	**2014**	**2015**	**2016**
Litter/sow/year	2.25	2.26	2.25	2.26	2.27	2.27
Live-born piglets/litter	14.2	15.1	15.4	15.6	15.9	16.3
Stillborn piglets/litter	1.9	1.7	1.7	1.7	1.7	1.7
Weaned piglets/sow/year	27.5	29.6	30.0	30.6	31.4	32.2
Dead piglets/sow/year, N	8.72	8.37	8.48	8.50	8.55	8.66
-when born, N	4.28	3.84	3.83	3.84	3.86	3.86
-before weaning, N	4.45	4.53	4.65	4.66	4.69	4.80
Dead pigs after weaning, %	2.6	2.9	2.9	2.9	3.1	3.1
-N dead after weaning/sow/year	0.72	0.86	0.87	0.89	0.97	1.00
Dead and rejected at slaughterhouse, % 1)	4.1	3.6	3.7	3.7	3.7	3.4
Dead sows, %	15.0	13.7			10.5	10.5

1) Hereof 0.18% rejected at slaughterhouse according to data from Danish Crown (2012).

Based on data from 2016, the number of pigs in Denmark (Tables 5 and 6), the mortality (Table 7) and the assumed weight of the dead pigs, total number of dead pigs and weight hereof were calculated and are presented in Table 8.

Dead during transportation: Due to strict regulations on transportation and the short duration hereof (< 3 hours for 95% of the pigs), the number of dead pigs during transportation to slaughterhouses are among the lowest in the world (Videncenter For Svineproduktion, 2011).

Rejected at slaughterhouses: The major part is made up of pigs that the veterinary control has detected as having some kind of illness, and only healthy animals can be used as human food. A minor part is made up of pigs that are euthanised immediately after they arrive due to injuries from the transportation.

[1] *Number of feeding days in a sow herd per year, divided by 365 days*

Table 8. Dead pigs in Denmark in 2016 at farm and during transportation to slaughter and LW hereof

	Number	Dead [%]	Weight per dead pig [kg]	Total LW of dead pigs [1,000 ton]
Dead pigs at farm				
Sows in total	1,016,000	10.5%	234 [1]	24.96
Live-born piglets	37,593,016	37.0/sow/year		
Stillborn piglets	3,920,744	3.86/sow/year	1.5 [2]	5.88
Dead before weaning piglets	4,876,800	4.80/sow/year	1.5 [3]	7.32
Weaned piglets	32,715,200	32.2/sow/year	6.6 [4]	
Dead after weaning	1,014,171	3.1%	6.6 [5]	6.69
30 kg pigs produced	31,701,029		30.8 [4]	
Export of 30 kg pigs	13,200,000		30.8 [4]	
Dead finishers	595,733	3.22% [6]	71.9 [7]	42.83
Total dead at farms	10,514,128			87.68
Dead pigs during transportation to slaughter				
Sows and boars	538,000 total 377 dead	0.07% [9]	234 [8]	0.09
Finishers and gilts	17,905,296 total 1,791 dead	0.01% [9]	112.9 [8]	0.20
Total dead transportation	2,168			0.29
Pigs rejected at slaughterhouses				
Sows and boars	537,623 total 6,505 rejected	1.21% [10]	234 [8]	1.52
Finishers and gilts	17,903,505 total 32,226 rejected	0.18% [10]	112.9 [8]	3.63
Total waste slaughterhouses	38,731			5.15
Total waste DK pork production	10,555,027			93.12

1) LW of dead sows – assumed to be the same as for slaughtered sows: 176.0 kg carcass = 234 kg LW (Danmarks Statistik, 2018)
2) LW of stillborn piglets was assumed to be the same as for live-born piglets; 1.5 kg according to Thorup (2010)
3) These piglets typically die a short time after they are born (Pedersen et al., 2011). Therefore, average birth weight of live-born piglets is used
4) SEGES (2017)
5) These pigs are assumed to die a short time after they have been placed in the weaners stable. Therefore, average weight of weaned piglets is used
6) Of the 3.4% dead and rejected finishers, 0.18% was assumed rejected at slaughterhouse according to data from Danish Crown (2012), personal communication.
7) The time where finishers die is assumed to be evenly distributed during the period. Therefore, an average weight (from 30.8 to 84.9 kg carcass = 112.9 kg LW) of 71.9 kg was used.
8) Same weight as for slaughtered animals, Danmarks Statistik (2018)
9) Videncenter For Svineproduktion (2011)
10) Danish Crown. Personal communication. Data from October 2011 – September 2012

Table 8 shows that the total mortality at Danish pig farms in 2016 was 10.51 million dead pigs at farms and 10.55 million pigs if the mortality during transportation from farm to slaughterhouse and pigs rejected at slaughterhouse is included. This gives a total food waste of 93,120 tonnes LW of pigs. Hereof, 94% of the dead LW is generated at farms, mainly from dead finishers and dead sows as these pigs have a high LW per dead pig. In actual numbers, 8.8 million pigs die before weaning which is 83% of the total numbers of dead pigs.

If the food waste of 93,120 tonnes LW of pigs (dead at farm, during transportation and rejected at slaughterhouses) in 2016 is compared with total amount of LW of slaughtered pigs in Denmark that year - 2,108,300 tonnes - it amounts to 4.4% of the production that ends up as food waste due to mortality (Table 14).

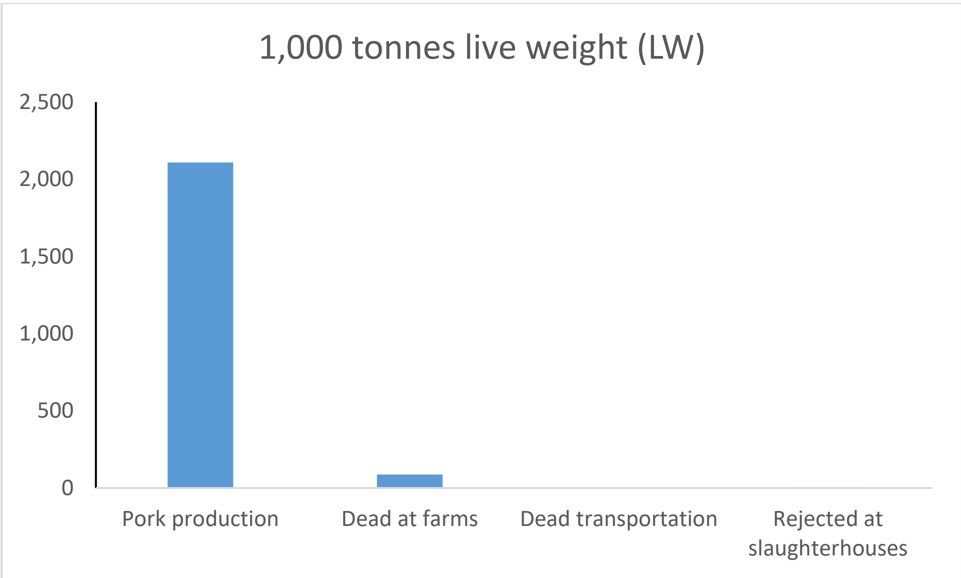


Figure 3. Total pork production in Denmark in 2016, dead pigs at farms and during transportation to slaughterhouses, and pigs rejected at slaughterhouse, all measured as 1,000 tonnes LW.

How representative are the data:

Average mortality (% dead) for piglets (<30 kilograms LW) and finishers (> 30 kilograms LW) at farms is reported every year by SEGES (SEGES, 2017), in 2016 based on farm data from 43% of the sow herds and 31% of the herds with finishers. General average data for dead sows are not given in this yearly report. The national sow mortality rate is based on figures from DAKA for number of sows delivered to destruction and basic figures from Statistics Denmark about the total pig population (Vinther and Jensen, 2018). Therefore, the number of dead pigs, except for sows, at farms is known with a relatively high degree of certainty (even though there is some uncertainty about the distribution between 'stillborn' and 'dead before weaning'). The weight of dead pigs is based on an assumption of age at death, within the interval and standard numbers for weight at that age.

The number of pigs in Denmark are provided by Statistics Denmark. For 2016, the distribution of this total number on groups of pigs was based on data from 76% of the Danish farms with pigs (Landbrug & Fødevarer, 2017c). Meanwhile, number of pigs slaughtered in Denmark are reported every year by Landbrug & Fødevarer, e.g. in the publication Landbrug & Fødevarer (2017c).

Mortality during transportation (% dead) is not reported every year and is in this report based on data from a Danish study from 2011. Finishers rejected (%) at slaughterhouses are known from the above mentioned report published every year as the Danish average (SEGES, 2017), based on data from 31% of the herds with finishers.

Summary: *In 2016, there were 12.7 million pigs in Denmark, and total LW of slaughtered pigs in Denmark in 2016 was 2,108,300 tonnes. Dead pigs at farms amounted to 87,680 tonnes LW, dead during transportation amounted to 290 tonnes LW, and total rejected at slaughterhouse amounted to 5,150 tonnes LW. In summary, this corresponds to 4.4% food waste of the total production of pigs due to mortality. Based on literature studies, we estimate that the values are representative for the Danish market for this category.*

4.1.3. Poultry

The largest by weight amount of poultry meat in Denmark is chicken meat from the annual broiler production of 101.5 million chickens in 2016, corresponding to 154,000 tonnes of poultry (The_Danish_Poultry_Council, 2016). In the primary production, poultry meat can be wasted for different reasons as stated in a French study (Redlingshofer et al., 2017). Discard of poultry along the FSC was identified at primary production level, i.e. from collection of broilers on farm to carcass cutting:

- Mortality at collection/catching of poultry: runted, injured or dead animals at collection or catching, which are not accounted for within total loss at farm stage
- Mortality during transportation prior to slaughtering: total condemnation before slaughtering (*ante mortem* condemnation)
- Condemnation after slaughtering for sanitary reasons: total or partial withdrawal of carcasses or offal after slaughtering (*post mortem* withdrawal)
- Inedible carcass parts (e.g. bone) and other inedible fractions (e.g. feathers), excluding blood
- Discarded, partly edible parts: lack of recovery of edible parts on cuts from small animals (e.g. mechanically separated meat from chicken neck)

The mortality of broilers at farm level, jointly for conventional and organic, was on average 3.2% in 2017 (Dansk Erhvervsfjerkræ, 2018). Furthermore, Redlingshofer et al. (2017) estimate that mortality during transportation (*issue 2*) amounts to 0.33%, while a recent survey covering 95% of all broilers slaughtered from 2011 to 2014 in Denmark found the average dead-on-arrival (DOA) to be 0.27% (Herskin et al., 2016).

Regarding *issue 4*, inedible carcass parts amount to 23.5%. Assuming a total of 154,000 tonnes of poultry per year, this results in 36,190 tonnes of inedible carcass parts. Meanwhile, offal and edible fractions amount to

2.1%, corresponding to 3,234 tonnes, of which ~30% is used as mechanically separated meat corresponding to 970 tonnes. Finally, ~5.5% is classified at processing as either inedible parts (total of tails and skeleton frame of the breast which are inedible) or as partly edible parts (30% of backs, breast skin and cutting shreds considered unsuitable for human food consumption. Part of it is used as mechanically separated meat) (Redlingshofer et al., 2017).

Regarding *issue 5*, in the Danish broiler production the amount of discarded poultry (not specified according to reason) amounts to 0.9-1.4% at slaughter (Dansk Erhvervsfjerkræ, 2017), while in France, this fraction amounts to 1.07% (Redlingshofer et al., 2017).

It has been concluded that the main problems causing DOA of broilers in Denmark is the temperature of the surroundings during transportation (either very low (<0°C) or high (> 15-20°C) temperatures), higher loading density of the broilers (≤160 cm^2/kilograms) than prescribed in the European Union Council Regulation (2004) and long waiting time at the slaughterhouse (Herskin et al., 2016).

Summary: *In 2016, there were 101.5 million chickens, corresponding to 154,000 tonnes of poultry, in Denmark. Mortality at farm level was, on average, 3.2% in 2017. Mortality during transportation is estimated at 0.27% and inedible carcass parts amount to 23.5%, corresponding to 36,190 tonnes. Amount of discarded poultry (not specified according to reason) amounts to 0.9-1.4% at slaughter, corresponding to between 1,386 and 2,156 tonnes. Based on literature studies, we estimate that the values are representative for the Danish market for this category.*

4.1.4. Bovine milk

According to the FUSIONS food waste definition, the first step of the food supply chain for milk is when milk is drawn from the udder. Food waste may occur at farm level, if not all milk drawn from the udder is delivered for milk processing at the dairy. According to the FUSIONS definition, only food that was originally intended for human consumption, but has been removed from the food supply chain can be defined as food waste. In the case of milk produced at farms, some milk is not delivered to dairies, typically because the milk is contaminated with antibiotics, has a high SCC (somatic cell count) or is planned as feed for calves. In the first case, but not the last, the milk can be counted as food waste according to FUSIONS. In addition, there might be a sale or use within the farm for human consumption. According to Einarson et al. (2013) in Franke et al. (2013), milk planned as feed for calves is unavoidable and a resource on the farm in producing new heifers and bulls, and thus only milk with end destination in the manure can be defined as food waste. In the following, the national milk production at farm level was compared with the amount of milk delivered to dairies, and the reasons for the differences in these numbers were investigated.

The national milk production and amount of whole milk deliveries to dairies are reported every year and published by the Danish Agriculture & Food Council (Landbrug & Fødevarer, 2017a) in dairy statistics based on information from Statistics Denmark and the Danish Dairy Board (Mejeriforeningen). About 10% of the milk production in Denmark is organic (9.3% in 2016) (Landbrug & Fødevarer, 2017a).

This report does not distinguish between the two productions systems: conventional and organic, even though differences in the production systems might create minor differences with regard to the issues investigated. In the organic system, it is required that the calves are fed real cow's milk for 90 days. Also, the increased time (double the conventional) that the milk needs to be retained after medical treatment (SEGES, 2018) could decrease the proportion of the produced milk delivered at the dairy. Based on data from 2016/2017 from 378 organic and 2,276 conventional dairy herds, 93.8% of the produced milk in organic herds was delivered at the dairy. The corresponding number was 94.8% in the conventional herds (Milk Yield recordings by RYK, SEGES (2018)).

Total number of dairy cows in Denmark and their milk production are shown in Table 9. The exact total number of cows in Denmark is known as Danish law requires individual registration of animals in Denmark (Anonymous, 2018a). The national milk production is estimated based on milk production per cow per year from 91% of the cows (513,876 cows in 2016), participating in Milk Yield recording by RYK (SEGES, 2018). It should be kept in mind that there is some uncertainty on these data on milk production, as milk production is only measured for 24 hours, six or 11 times per year. The calculated total milk production based on these measurements is depending on registration of the right data in relation to date at calving and date of dry off.

Based on the above numbers, it was calculated that 95.0% of the milk production was delivered to dairies in 2016, which is in accordance with data from farms with milk yield recording. They reported that the proportion of milk delivered to dairies in 2016 was 94.7% (SEGES, 2018). Similarly, it was found that 94.4% of milk produced was delivered on average for the period from 1 April 2008 to 1 April 2015 (Anonymous, 2015).

Table 9. Milk production at farms, amount delivered to dairies and calculated proportion delivered, %, 2012-2016

	2012	**2013**	**2014**	**2015**	**2016**	**Reference**
Dairy cows, 1,000 heads	579	567	547	570	565	From 1) based on 3)
Milk yield per cow, kg/year[2)]	9,019	9,138	9,663	9,961	10,008	From 1) based on 4)
National milk production, 1,000 tonnes	5,222	5,181	5,286	5,678	5,655	From 1) own calculation
Whole milk deliveries to dairies, 1,000 tonnes	4,929	5,026	5,112	5,277	5,373	From 1) based on 5)
Delivered, %[8)]	94.4	97.0	96.7	92.9	95.0	
Delivered to dairies, %				94.4[9)]	94.7	6+7)

1) *Landbrug & Fødevarer (2017a)*
2) *Milk yield per cow in years as of October, e.g. 2016 is Oct 2015/Oct 2016*
3) *Danmarks Statistik, 2018 (data from 2012-2016), accessed 2018*
4) *SEGES (2018)*
5) *Data from Mejeriforeningen 2017 (data from 2012-2016), cf. Landbrug & Fødevarer (2017a)*
6) *SEGES (2018)*
7) *Anonymous (2015)*
8) *% whole milk delivered/national milk production*
9) *Average 2012-2015*

The destination of milk produced is mainly the dairies. This is the case for around 94.7% of the Danish milk production. The remaining 5.3% can be used for human consumption on the farm, given to calves or thrown away (into the manure).

Looking more detailed into the path of the 5.3% not delivered to dairies, some assumptions must be made as there are no Danish data on the use of the non-delivered milk. However, a Danish questionnaire from 2006 investigated this, with 132 dairy farmers responding (Sørensen, 2008). They found that two out of three herds only use cow milk for milk feeding of the calves and use no milk replacer. A part of this milk was milk from cows with high SCC. 87% of the farms used all such milk for calves. The remaining farms threw it away. Another part was milk from cows that received antibiotic treatment. Twenty-five percent of the farms used all of the treated milk for calves. The remaining farms only used the milk after milk from the first 2-4 milkings was discarded. The rest of this milk for calf feeding was planned for this purpose. The specific proportion between these types of milk used for calf feeding was not given. It has not been possible to find newer data on this subject.

According to national statistics (SEGES, 2015), each cow was treated for a disease by either vet, claw trimmer or farmer 1.08 times per cow per year. If all these cases needed medical treatment with average milk retention for four days (3-5 days, expert statement, 2018), it would affect 1.18% of the milk production. However, it was assumed that treatment of dry cows (cow not lactating) and limb disorders did not require treatment with subsequent milk retention. Thus, there will be only 0.574 cases per cow per year with milk retention, affecting 0.63% of the milk production.

It has been reported that 70% of the antibiotic use for cows is for mastitis treatment (Søgaard, 2016). In 2016, the average occurrence of mastitis was 0.31 cases per cow per year. This level was 0.30-0.35 from 2010-2017 (SEGES, 2018). If the 0.31 mastitis cases account for 70% of all medical treatments, then 100% will be 0.44 cases with medical treatment and subsequent milk retention, thus affecting 0.49% of the milk production. As a rough estimate, we will assume that 0.65% of the milk production ends up as food waste due to medical treatment.

If all calves in all herds were supposed to be fed with cow's milk, it would require 2.1% of the entire milk production (50% heifers: 6 litres per day for seven weeks (147 litres in total), 50% bulls: 6 litres per day for three weeks (63 litres)). Some of this milk comes from the treated cows.

In a Swedish study based on interviews with 17 farmers, it was found that 96.9% of the milk was sent to dairies, 2.5% was fed to calves, 0.3% was used for humans at the farms and only 0.32% ended in the manure well. The main cause for milk waste is antibiotic treatment due to mastitis. Other reasons for milk waste are other cow diseases that give poor milk quality, problems with the cooling system in the milk tank and milk stuck in the tank filter. In another Swedish project, 457 farmers were asked how they handled milk treated with antibiotics (Duse et al., 2012). Eighty percent of the farmers feed milk from treated cows to the calves, while 20% of the farmers did not feed any treated cow milk to the calves.

Similar results were found in Finland by Hartikainen et al. (2014) based on a questionnaire sent to Finnish milk producers, of which nine responded (30%). Food waste was 0.3% of the milk production as a result of milk with antibiotics residues due to antibiotic treatment of the cows.

The rough estimate of 0.65% food waste (Table 10) of primary milk production in Denmark due to medical treatment is higher than the Swedish and Finnish findings of 0.3%.

Table 10. Amount of waste in Danish primary production of milk (tonnes/year), reasons for waste generation and waste treatment, response rate

Food type	Amount produced [1,000 t/year]	Amount delivered to dairies [1,000 t/year]	Waste amount[1)], % (1,000 t/year)	Reasons for waste	Waste treatment
Total milk, national level (2016)	5,655	5,373	**Waste:** 0.65% (37)	Medical treatment of cows	For calves/thrown away (into manure)
			Other use: 4.34% (245)	* for calves * for humans	* feed * food
Total milk, farm level	Recorded at 91% of the farms (RYK) + some farms by AMS	Known at all farms (from payment for dairy)	Not recorded	Known by the farmer	Known by the farmer

1) The difference between amount of milk produced and amount delivered to dairy could either be due to waste or due to other use of the milk – here a rough estimate for amount wasted - no data available

How representative are the data:

The actual amount of whole milk deliveries to dairies is measured data from all farms as reported every year and published by the Danish Agriculture & Food Council (Landbrug & Fødevarer, 2017a), based on information from Danish Dairy Board (Mejeriforeningen). The national milk production is estimated based on samplings of measured milk production at cow level during 24 hours, six or 11 times per year from 91% of the Danish cows (513,876 cows in 2016) participating in Milk Yield recording by RYK (SEGES, 2018). Therefore, there is some uncertainty regarding these data on milk production, and hence also some uncertainty regarding the amount of the milk production that not delivered to dairies, and especially regarding the destination of this milk. There are no existing data on this issue. The reason for some of this milk not being delivered to the dairies is that the milk is contaminated with antibiotics, that the milk has a high SCC or that this milk was planned as feed for calves.

Summary: *An estimated 5,655,000 tonnes of milk were produced in 2016. An average of 94.4% of the milk production was delivered from farm to dairy in the period 2008-2015. The remaining percentage (5.6%) is used for consumption on farms or given to calves. Some of the remaining milk has a high SCC and is not suitable for human consumption, but can be used for feeding of calves or thrown into the manure. As a rough estimate, 0.65% of the milk production (recorded at farm level by RYK) ends up as food waste due to medical treatment of cows. Based on literature studies, we estimate that the values are representative for the Danish market for this category.*

Eggs

In Denmark, the majority of the egg production comes from hen's eggs. Other types of eggs are niche production, e.g. quail eggs. In the following section, the exclusive focus will be on hen's eggs. In 2016, the Danish hen's egg production, which entered authorised egg packaging companies, amounted to 65.66 million kilos (Larsen, 2017), corresponding to 65,660 tonnes. From here, packaging, storage and distribution to retail stores take place. An unknown amount of eggs is sold one-to-one directly from farm to consumer or consumed from own production. In 2002, the Danish Veterinary and Food Administration estimated this at ~10% of the eggs produced or 6.6 million kilograms eggs, corresponding to around 6,600 tonnes.

Within the EU, eggs of class A must fulfil a range of criteria (Commission Regulation, 2003):

Grade A eggs shall have the following minimum characteristics:

Shell and cuticle: normal, clean, undamaged

Air space: height not exceeding 6 mm, stationary; however, for eggs to be marketed as 'extra', the height may not exceed 4 mm

White: clear, limpid, of gelatinous consistency, free of extraneous matter of any kind

Yolk: visible on candling as a shadow only, without clearly discernible outline, not moving appreciably away from the centre of the egg on rotation, free of extraneous matter of any kind

Germ cell: imperceptible development

Odour: free of extraneous odours

Grade B eggs are eggs which do not meet the requirements applicable to eggs in grade A. They may be passed only to approved food industry approved or to non-food industry undertakings (Commission Regulation, 2003). Class B eggs are not allowed for retail sales. Hence, in the grade B category there may be both eggs that are further processed for food or used as non-food.

From a Swedish study in 2011, a total of 3% of eggs produced are downgraded to class B eggs due to different quality issues (Hollstedt, 2011). This amount covers eggs registered in the primary production and at the packaging stations. The reasons for downgrading to class B eggs was in decreasing order: shell cracks due to pressure (61%), pimples on shell (13.6%), cracks due to thin shells (9.8%), deformed shells (6.8%), point holes in shells (5.1%), dirty eggs (2.1%), blood and meat stains (1.6%) (Hollstedt, 2011).

A similar study in Denmark has not been conducted for the last 30-40 years. Approximately 7% of all eggs have previously been estimated to crack (Knækægsprojektet in the 1980s) with 4% at the farms during egg production and egg collection, 1% during transportation and 2% at the packaging stations. Hence, the 4% at the farms have not left the farm/production site. It appears that this percentage has decreased since the 1980s based on the study by Hollstedt (2011) in Sweden and the reported figures in Denmark (Table 11).

Differences must be expected in food waste from eggs on the basis of the different production systems: cages, barn, free-range and organic. Many changes in the Danish egg production systems have taken place during the last 20 years, e.g. change of cage systems from 4-hen cages to enriched cages in 2012, stop of beak trimming of hens in 2014, a decrease from 70% to 40% of eggs produced in cages from 1996 to 2016 and a parallel increase in eggs from organic production from 5% to 25% (Dansk Erhvervsfjerkræ, 2017). These are all factors that are suggested to have an effect on both the mass of egg waste and the reasons for egg waste in the primary production. This statement is, however, not based on data or studies hereof.

Table 11 shows data from a small and a large Danish egg-handling company. The data is from a single year, but considered to be representative for a number of years. A low percentage (0.5-1.8%) of the annual amount produced is wasted. Assuming a yearly egg production of 65,660 tonnes, this amounts to around 330-1,200 tonnes wasted. The reasons for the waste are among others reported to be cracking eggs with holes in the egg sorting and packaging process. The waste can be sold for mink fodder or passed on for biogas production.

Table 11. Shell eggs waste at primary production and packaging stations in Denmark (data from a small Danish company and a large Danish company). Data from 2018.

Food type	Amount produced [kg/year]	Amount wasted [kg (%)]	What is wasted	Where in the production does waste happen	Reason for the waste
Shell eggs (only organic)	611,040	3,036 (0.5%)	Cracked eggs with holes	In the egg sorting and packaging process	Machine errors. Eggs with cracks and other errors. Main reason is manual handling of eggs.*
Shell eggs (all production types)	32,446,300	575,412** 15,298*** (1.8%)	Whole eggs (shell and interior)	At the egg sorting belt and in the packaging in egg trays	Egg are squeezed in the sorting machine or during packaging. Shell is too thin/fragile or already damaged during primary production.

** The eggs are collected in containers and sent to 'combustion company'*
*** Sold for mink feed or biogas production*
**** Waste with no usage*

Summary: *Authorised hen's egg production in Denmark in 2016 amounted to 65,660 tonnes. As estimated based on a Swedish study, 3% of the total eggs produced are downgraded to class B (around 2,000 tonnes). These eggs can be used for processing. Between 0.5 and 1.8% (around 330-1,200 tonnes) of shell eggs are wasted because of cracking in the sorting and packaging process. The waste can be sold for mink fodder or passed on for biogas production. We estimate that values are representative for around 50% of the Danish market for this category.*

4.1.5. Fish

Fish can be caught at sea or produced in aquacultures. Since the aquaculture production in Denmark represents a relatively low percentage of the total fish caught, and since it is still restricted to few species, data on food waste from aquaculture production will not be included in this report. The main part of fish caught at sea is immediately gutted at sea (except for herring and mackerel that are usually landed whole), and internal organs have thus previously been thrown back into the sea. In addition, fish caught in the net might be discarded if they were too small or if the catch was not the species of interest. At present, EU will from 2015 to 2019 gradually be implementing the CFP (Common Fisheries Policy) discard ban of 2013 for all commercial fisheries in the EU. The aim is to eliminate the practice of discarding by introduction of a landing obligation in hope that it will lead to a better utilisation of resources and fewer discards at sea. This result in large amounts of landings which were discarded before the discard ban. It has been estimated that previously around 26% of the total catch was discarded per year (Larsen et al., 2013). No data is available on waste after implementation of the discard ban.

Catches and quotas are given in whole fish - LW - while information on sales quantities are given in landed weight. The difference is the reduction which arises when fish for consumption is cleaned for entrails, filled and iced onboard before landing, i.e. the landed weight (The Danish AgriFish Agency, 2017). Entrails are only utilised to a low extent since it is not currently economically feasible to process entrails for human consumption (Albrechtsen and Becker, 2017). Larger vessels can cut and ensilage entrails and small fishes onboard and sell it for mink fodder. Smaller vessels can store the discarded fractions on ice and sent it to processing on land (Larsen et al., 2013). Fish of size below standard cannot be sold directly for consumption, but are suitable for manufacturing of fishmeal and fish oil. These small fishes are also iced onboard and will be sent to processing on land. However, this typically results in a lower price for the fisherman, compared to fish sent to human consumption. Furthermore, a large percentage of the waste is regarded as inedible for humans, but can be used in pharma, cosmetics and for health foods. Table 12 shows the landed weight and the LW of cod fish, flat fish, herring, mackerel, shrimps and other fish in 2017. It is the difference between the two weights which is assumed to be the amount of waste.

Table 12. Danish vessels' landings of fish for consumption presented as landed weight and LW in tonnes per year. Data from 2017.

Subcategory	Landed weight[1)] [tonnes/year]	Live weight[1)] [tonnes/year]	Waste amount[2)] [tonnes/year]
Cod fish	28,272	32,887	4,615
Flat fish	27,070	28,845	1,775
Herring	140,878	140,878	0
Mackerel	37,908	37,908	0
Shrimps	5,832	5,940	109
Fish, others	13,350	14,029	679
Total	253,309	260,487	7,178

1) *Statistikbanken (2018b)*
2) *Calculated as the difference between landed weight and LW*

Summary: In 2017, Danish vessels caught 260,487 tonnes LW and landed 253,309 tonnes of fish. The difference (7,178 tonnes corresponding to 2.8%) is mainly waste which is inedible for humans, discard and internal organs which has potential for innovative use in other industries. Based on data from Statistics Denmark, we estimate that the data are representative for the Danish market for this category.

4.2. Waste of Animal Products in the Food Industry

Beef

Food waste generation during transportation from farm to slaughterhouse and rejection of live animals at slaughterhouses was described in section 4.1 for the primary production. In the following, the flow from LW of animals entering the slaughterhouse to food products and by-products/inedible waste leaving the slaughterhouse is described. Most of these organic wastes from slaughterhouses are not edible for humans.

In the project 'Assessment of the total environmental impact of calves and beef', supported by the 'Kvægafgiftsfonden' (2013-14), the Danish Technological Institute (DMRI) carried out a survey of resource consumption and product yields at slaughterhouses for 13 different types of slaughter cattle (Pontoppidan and Madsen, 2014) in order to assess the environmental impact of the entire chain from primary production to beef products leaving the slaughterhouse. In Table 13, we estimate the distribution of the 495,100 units of cattle slaughtered in 2016 (cf. Table 1) on different types of cattle. For each type, LW at slaughter, carcass weight as well as the production of different edible products and by-products and their use, including hides, are shown. Data for dairy breed heifers were not available and the estimates were therefore based on data for young bull calves.

In total, 257,600 tonnes of LW were delivered to slaughterhouses. During slaughtering, this produced 127,800 tonnes of carcasses and 129,800 tonnes of by-products, i.e. products harvested or manufactured from livestock other than carcasses (BIP in Table 13).

In total, 96,100 tonnes of meat without bones could be produced. A total of 25,000 tonnes of other edible products, mainly by-products not from carcasses, were produced as well. These edible by-products may include meat from each the following parts: head, tongue, liver (in particular liver from young animals), heart, thymus, tallow, vein, thick skirt, diaphragm, tripe, udder, omasum, kidney, tail, neck meat, part of lung, throat spleen, testicles, penis, etc. It is important to note that the part of slaughtered animals used for human consumption compared to other uses is globally quite different and varies over time in response to market changes. The data presented here represent a Danish factual situation. It does not resemble global traditions, and market situations especially in Asian or Africa may differ significantly. Edible by-products represent 7-11% of the LW of the animal (Mogensen et al., 2016). Ten percent of bones were assumed used for food production which produced 2,400 tonnes bones for food. Thus, a total of 123,400 tonnes of edible products were obtained from cattle slaughtering in Denmark in 2016.

Besides, 7,900 tonnes potentially edible products were produced which today are mainly used for animal feed/pet feed. These products which might potentially be used for human consumption in some markets outside Denmark, are presently sold for animal feed production in Denmark. Types of by-products included here are liver from old cattle, uterus trachea oesophagus and parts of lung, throat, spleen, testicles and penis. In total, it is estimated that the slaughterhouse by-products in this category represent less than 4% of the LW of the animal (Mogensen et al., 2016).

In total, 45,000 tonnes of by-products like rumen content, fat and a proportion of the blood are used for biogas production in a combined heat and power plant, thus avoiding production of fossil-based heat and electricity. In total, 39,500 tonnes of non-SRM (special risk material) are sent to destruction. This are mainly bones and tallow. In addition, 19,800 tonnes of SRM are sent to destruction. According to the EU regulation, cattle tissues identified as specified risk materials must be properly handled and disposed of. The amount of SRM per head depends on the actual legislation and the risk level, which is low in Denmark compared to other EU member states. The SRM actually constitutes less than 10% of the LW of the animal (Pontoppidan and Madsen, 2014) and includes tonsils and distal ileum for cattle of all ages. For cattle older than one year, additional SRM includes spinal cords, parts of the head, skulls and horns. SRM are presently disposed of in waste incineration plants.

In total, 100 tonnes are used for medicine production. There are different medicines that can be obtained from e.g. animal glands removed from livestock at slaughter: oestrogens, progesterone, insulin, trypsin, testosterone etc. Finally, 4,400 tonnes disappear due to shrinkage.

Besides by-products, 17,400 tonnes of hides are produced every year from the slaughtered cattle, a high-value product used for leather production.

Table 13. Slaughtering of cattle in Denmark in 2016; output of edible products and by-products and utilisation hereof

	Dairy					Highland cattle			Limousin				**DK total**
						Per animal							
	Calf	Young bull	Steer	Heifer	Cow	Young bull	Heifer	Cow	Calf	Young bull	Heifer	Cow	
Age at slaughter, months	8.9	13.5	26.3		65.2	17.9	23.7	91.4	10.5	14.4	20.2	95.4	
Number, N	148,399	44,327	5,500	56,000	172,300	6,275	1,840	5,600	12,550	12,550	7,360	22,400	495,100
kg/animal													**1,000 tonnes**
Live weight	391	458	611	458	653	432	354	436	491	533	504	687	257.6
Carcass	201	237	309	237	297	226	180	211	297	319	292	379	127.8
BIP	190	221	302	221	356	206	174	225	194	214	212	308	129.8
Edible total [1)]	193	222	290	222	294	210	172	204	283	305	276	360	123.4
-Meat without bones	154	176	228	176	218	168	133	155	242	260	228	294	96.1
-Other edible	34.6	40.4	55.2	40.4	71.4	37.6	34.8	45.2	35.5	39.1	42.5	61.6	25.0
-Bones for food	4.4	5.4	7	5.4	5	5.1	4.1	3.5	5	5.4	5.5	5	2.4
By-products total [2)]	167.2	201.1	273.2	201.1	318.6	188.3	162.5	206.9	177.3	193.9	203.8	291.6	116.7
-For feed	10.1	11.8	16.2	11.8	24.1	11	11.7	15.3	10.4	11.4	14.3	20.8	7.9
-For biogas	59.6	69.6	95.2	69.6	132.7	64.7	64.6	83.8	61.1	67.4	78.9	114.4	45.0
-For destruction	71.3	78.2	104.9	78.2	87.9	74.1	59	59.8	78.9	75	77.4	85.1	39.5
-SRM for destruction	17.8	31.6	43.4	31.6	64.2	29.4	22.4	42	18.2	30.6	27.4	62.8	19.8
-Shrinkage	8.2	9.7	13.3	9.7	9.3	9	4.6	5.9	8.5	9.4	5.5	8	4.4
-For medicine	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.1
Hides	30.2	35.2	48.2	35.2	40.2	32.8	19.6	25.5	30.9	34.1	24	34.7	17.4

1) *Edible products are the sum of meat without bones, other edible products and bones for food*
2) *By-products are used for feed, biogas production, sent to destruction and medicine production*

How representative are the data:

Every week, the number of cattle slaughtered in Denmark is reported by the slaughterhouses to Landbrug & Fødevarer. Statistics Denmark receives this information on both the number and the slaughter weight per group of animals. The certainty of these data is assumed to be high. On the other hand, data for the overall utilisation of the LW of animals entering slaughterhouses for food products, by-products and inedible waste are based on the annual result from a project from 2013-14 (Pontoppidan and Madsen, 2014). There may be some variation between years and also between companies in these numbers, especially with respect to the destination and use of the by-products, whether they end up as edible by-products or side flow with other uses.

Summary: *495,100 units of cattle were slaughtered in 2016. This gave in total 257,600 tonnes of LW. Hereof, a total of 123,400 tonnes was edible products (sum of 96,100 tonnes of meat without bones, 25,000 tonnes of other edible products and 2.4 tonnes of bones for food). In total, it also gave 116,700 tonnes of by-products, of which 7,900 tonnes were used for feed and 100 tonnes for medicine. The remaining 91,300 tonnes of by-products were different kinds of waste/by-products used for biogas production (45,000 tonnes) and sent to destruction (59,300 tonnes). Finally, the 17,400 tonnes of hides were used for leather production. We estimate that the values are representative for the Danish market for this category.*

4.2.1. Pork

Food waste during transportation from farm to slaughterhouse and rejection of live animal at slaughterhouses has been described in section 4.1.2. In the following sections, the flow from the LW of animals entering the slaughterhouse to food products and by-products/inedible waste leaving the slaughterhouse is described. Most of these organic wastes from slaughterhouses are not edible for humans.

Total number of slaughtered pigs in 2016 is taken from Table 6 from Denmark Statistics in 2018. They also show the carcass weight of each animal group. Based on production data from 2015, a Danish slaughterhouse has calculated the distribution of the raw pig material and the use hereof (Anonymous, 2018c). This distribution may vary from year to year as it will be dependent on market access and the varying price structure.

The total pork production in Denmark is presented both with and without pigs slaughtered at the farm/for the farmer (Table 14). At-farm slaughtering is responsible for 0.1% of the total number of pigs slaughtered. In the following, the text refers to numbers excluding that production as the utilisation of these pigs are assumed to differ from that of pigs slaughtered at slaughterhouses, however we do not have data from farm slaughtering. The 18.4 million pigs slaughtered at slaughterhouses in 2016 resulted in 1,607,000 tonnes of carcasses produced. As some by-products also are used for human consumption, this adds up to 1,771,000 tonnes. Besides, a total of 158,000 tonnes is used for feed and 4,200 tonnes for pharma production. 152,000 tonnes are used at DAKA and another 21,000 tonnes are used for biogas production.

Landbrug & Fødevarer (2017c) reports that the total pork production in 2016 is 1,517,000 tonnes. This number probably also refers to carcass weight, though it is a bit lower than our calculations.

Table 14. Slaughtering of pigs in Denmark in 2016; output of edible products and by-products and utilisation hereof

	Gilts	**Sows**	**Boars**	**Finishers**	**Pigs for farmer/at farm**	**DK total**	**DK total Excl. pigs at farm [9]**
Number, N [1]	9,000	530,000	8,000	17,809,000	25,000	18,381,000	18,356,000
			kg/animal			**1,000 tonnes**	
Carcass weight[1]	45.0	176.0	175.9	84.9	93.3	1,609.4	1,607.1
Live weight (LW)[2]	59.0	230.6	230.4	111.2	122.2	2,108.3	2,105.3
LW used for human food[3]	49.6	193.9	193.8	93.5	102.8	1,773.1	1,770.5
Pet feed[4]	2.5	9.9	9.9	4.8	5.3	90.7	90.5
Fur feed[5]	1.9	7.4	7.4	3.6	3.9	67.5	67.4
Rendering, DAKA[6]	4.2	16.6	16.6	8.0	8.8	151.8	151.6
Pharma[7]	0.1	0.5	0.5	0.2	0.2	4,2	4.2
Biogas[8]	0.6	2.3	2.3	1.1	1.2	21.1	21.1
Total	59.0	230.6	230.4	111.2	122.2	2,108.3	2,105.3

1) Danmarks Statistik (2018) – data for 2016. Total number slaughtered is excluding rejected pigs
2) Live weight was calculated assuming a fixed relation of 'kg carcass' * 1.31 = 'kg live weight' (Andersen, 1999).
3) Human food mainly consists of all the muscle meat, the major part of the bones, lard, fat and rind and some parts of the blood and by-products such as liver, kidney and heart
4) Pet feed mainly consists of lard, fat, rind, blood and by-products
5) Fur feed same as pet feed
6) For DAKA the waste consists of some bones, some by-products and casings
7) Some casings are used for pharma
8) Some lard, fat and rind and some casings are used for biogas
9) Pigs at farm are pigs slaughtered at slaughterhouse for the farmer or slaughtered at the farm

How representative are the data:

Each year, the number of slaughtered pigs is reported by Statistics Denmark. Here, it is possible to find data on the carcass weight of each animal group, based on a standard relation between LW and carcass weight. The certainty of these data is assumed to be high. Meanwhile, data for the overall utilisation of the LW of animals entering the slaughterhouse in food products, by-products and inedible waste are based on the results from a single year from one big Danish slaughterhouse. This slaughterhouse has calculated the distribution of the raw pig materials and the use hereof (Anonymous, 2018c). This distribution may vary from year to year and between slaughterhouses as it will be dependent on marked access and the varying price structure.

Summary: 18.4 million pigs were slaughtered at Danish slaughterhouses in 2016, corresponding to 2,105,00 tonnes of LW. Hereof, 1,773,100 tonnes were used for human consumption and 158,000 tonnes were used for feed and 4,200 tonnes for pharma production. Of the remaining LW, 152,000 tonnes were sent to destruction and 21,000 tonnes to biogas production. Based on literature studies, we estimate that the values are representative for the Danish market for this category.

4.2.2. Poultry

Chicken account for the biggest amount of poultry produced in Denmark. Other types of poultry are niche production. In this report, only data on chicken will be included. Poultry is handled as raw chicken meat or processed meat. Processed chicken meat covers chicken sausages, fried meatballs, fried fillets and chicken kebab. The food waste amount from a large poultry slaughter plant and processing plant in Denmark, which covers approximately 50-60% of the total annual production, is given in Table 15 below.

Table 15. Poultry products waste in the slaughter and processing industry in Denmark. Data from a Danish company.

Food type	Amount produced [tonnes/year]	Amount wasted [tonnes (%)]	What is wasted	Where in the production does waste happen	Reasons for the waste
Raw chicken meat	70,000	57 (0.08%)	Mixed products of human food quality	Cutting	Waste from production line or trays
Raw chicken meat	70,000	54 (0.08%)	Mixed products of human food quality	Packaging	Waste from production line or trays
Processed chicken meat	26,000	41 (0.16%)	Mixed products of human food quality	Preparation	Waste from production line or trays
Processed chicken meat	26,000	68 (0.26%)	Mixed products of human food quality	Packaging	Waste from production line or trays
Total	96,000	220 (0.23%)			

From Table 15, it can be seen that the percentage of waste from the food industry regarding poultry products is below 1% in the different sections: cutting, packaging, preparation and packaging. In total, the waste makes up 220 tonnes, corresponding to 0.23% of the total production. The waste is assessed as being of human food quality. It has not been possible to find the end destination for this waste.

Summary: Assuming that 96,000 tonnes corresponds to 50%, then the amount of Danish chicken meat, including raw and processed chicken meat, is estimated at 192,000 tonnes/year. In the chicken meat production, below 1% is wasted in the different sections: cutting and packaging of raw chicken meat and preparation and packaging of processed chicken meat. For the company investigated, the total food waste makes up 220 tonnes, corresponding to 0.23% of the total production of raw and processed chicken. The waste generated is assessed as being of human food quality. We estimate that the values are representative for around 50% of the Danish market for this category.

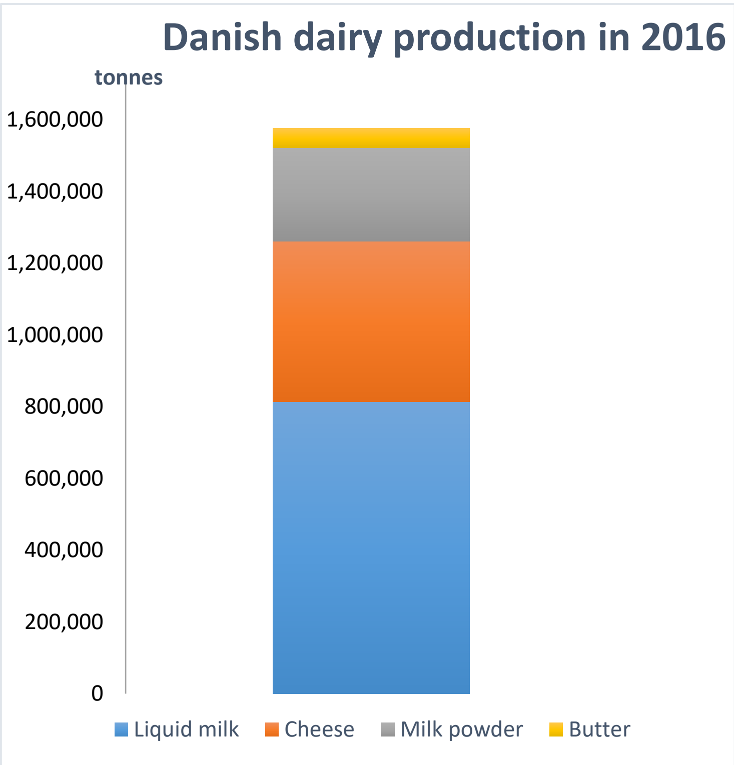
4.2.3. Dairy products

The 5,373,000 tonnes of whole milk delivered to dairies in 2016 can be divided into milk fat and non-fat milk. Milk fat was used for butter (34%), cheese (43%), liquid milk (11%), preserved milk (7%) and other products (5%). Non-fat milk was used for cheese (55%), liquid milk (15%), preserved milk (25%) and other products (5%) (Landbrug & Fødevarer, 2017a).

The total Danish dairy production in 2016 resulted in (graphically illustrated in Figure 4):

- 54,600 tonnes of butter
- 447,700 tonnes of cheese
- 813,500 tonnes of liquid milk259,900 tonnes of milk powder (whole milk powder, skimmed milk powder, whey powder) (Landbrug & Fødevarer, 2017a).

Figure 4. Graphical illustration of the Danish dairy production (tonnes) of liquid milk, cheese, milk powder and butter in 2016.



At the dairy, there is a risk for milk waste, which could be due to:

- Losses due to milk remaining in the pipes and lost during cleaning. These losses are expected to be higher the more different types of products the dairy make
- Surplus products not delivered to shops
- Residues of antibiotics in milk from one farm is contaminating milk from more farms (milk is tested when the milk is collected at the farm, but the test results are not ready prior to mixing at the dairy)

In a report from 1998, it was concluded that the dairy industry has only minimal generation of actual food waste. At the same time, the waste from handling of milk on the dairies was estimated at <1% (Miljøstyrelsen, 1998). To our knowledge, these are the newest data available. A medium sized Danish dairy registered a food waste of 2.3% of the milk delivered in 2017, which was lost in the pipes during cleaning (personal communication, March 2018). This number was estimated based on daily measurement of COD (chemical oxygen demand) in the wastewater from the dairy. At a dairy like this with many different products (> 80), this waste is expected to be higher than at other dairies with a less diverse production.

Another Danish dairy found a similar level of food waste of 2.51% of the milk delivered in 2017/2018, assumed lost in the pipes during cleaning (Anonymous, 2018b). This number was though to account for the unexplained remnant looking at the total amount of milk delivered and its use. Again, at a dairy like this with a high number of different products, a higher waste from cleaning is expected due to several changes in production compared with other dairies with a less diverse production. Besides, another 0.04% of the milk delivered was wasted as it was delivered with defects (could be wrong taste, content of antibiotic etc.). Finally, 0.13% of the milk that has been soured, but not sold in time ends up as feed instead. Other types of milk (not soured) which were not sold in time, but still sufficiently fresh was recycled and used for cheese production (0.19% of delivered milk). In addition, some of the buttermilk (corresponding to 2.72% of milk delivered) was sold for feed instead of food. Here, there is probably a potential for increasing the utilisation of delivered milk for human consumption (Anonymous, 2018b). The numbers on utilisation of milk delivered to this dairy are summed up in Table 16.

Table 16. Utilisation of amount of milk delivered (Anonymous, 2018b) with milk delivered as baseline, %

Category	**[%]**
Milk delivered	100.00
Utilised for human consumption	94.60
Wasted in pipes during cleaning	2.51
Wasted due to defects in the delivered milk	0.04
Milk planned to be sold for human consumption (soured milk), but sold as feed	0.13
Milk planned to be sold for human consumption (not soured milk), but returned for cheese production	0.19
Buttermilk sold for feed	2.72

Large amounts of whey are produced in the production of cheese. Earlier, it was considered a by-product that was returned to the farms and used for feed. However, today this has turned into a highly valued product for humans.

How representative are the data:

Data on the amount of whole milk delivered to dairies and its use in different forms of dairy production are given every year (Landbrug & Fødevarer, 2017a). These numbers are assumed to represent the total milk production and to be data of high certainty. Data for food waste at the dairies are based on data from only two dairies. The certainty of these data is assumed to be high. Due to the high number of dairy products produced at these dairies, their estimates of 2.3-2.5% waste from cleaning of the pipes are expected to be higher than for other dairies with a less diverse production.

Summary: *5,373,000 tonnes of whole milk were delivered to dairies in 2016. Most of the milk was utilised for human consumption (5,082,858 tonnes) as liquid milk, cheese, milk powder or butter. It is estimated that maximum 2.3-2.5% (123,579-134,325 tonnes) was wasted in the handling (lost during cleaning of the pipes) at the dairy, 0.04% (2,149 tonnes) was wasted due to defects in the delivered milk. Maximum 2.72% (146,145 tonnes) of the buttermilk was sold for feed instead of food. We estimate that the data are representative for around 50% of the Danish market for this category.*

4.2.4. Eggs

As described in section 4.1.5., eggs for further processing in the food industry can be either grade B eggs or eggs purchased directly for processing. Best 'before date' is 28 days after laying of eggs. In Denmark, it is mandatory to store eggs at refrigerated temperatures (5>T<12°C), which means that a low amount is wasted from retail stores (Danish Regulation no. 1354, 2017).

In egg processing, all shell eggs are broken and separated from the calcified eggshell, which make up ~8-10% of the weight of the egg. Eggshells are regarded as inedible parts of food and are discarded to be used in bio-materials processing or burned for heating/energy production. In Table 17, the waste from a Danish egg processing company shows that ~4% is used for biogas production and ~9% is not used for any other purpose.

Table 17. Egg waste in the processing industry in Denmark (data from a large Danish company).

Food type	**Amount produced [kg/year]**	**Amount wasted [kg, (%)]**	**What is wasted**	**Where in the production does waste happen**	**Reason for the waste**
Shell eggs received from packaging to egg breaking process	4,802,021	480,202 (10%)	Shells, which make out ~ 10% of total egg weight	Breaking of shell eggs for production of liquid egg mass	Removal of parts not suitable for human consumption
		172,218* (3.6%)	Shells and egg mass	From breaking and throughout the process	The production process
		452,045** (9.4%)	Egg mass	From breaking and throughout the process	The production process

* Used for biogas production
** Wasted without use

Summary: *A Danish egg processing company produced 4,802,021 kilograms eggs in a year (from packaging to egg breaking process). Egg shells make up around 8-10% of the weight of an egg and are regarded as inedible waste. The shells can be used in bio-materials processing or be burned for heat/energy production. Around 3.6% of the eggs were wasted due to breaking in the production process and instead used for biogas production. 9.4% of the egg mass was wasted without use. We estimate that the values are representative for around 50% of the Danish market for this category.*

4.2.5. Fish

Waste generation from fish production is often included in data on meat production and usually not handled separately, which makes it difficult to extract relevant data solely on fish from other food waste accountings. After landing, fish can be processed in the industry for the manufacture of e.g. frozen products, marinated, canned or smoked fish. Cutaways in the processing of fish can be used for feed, processed for fishmeal or extracted to produce fish oil. Most of the waste consists of heads, fins, tails and shells which are not directly suitable for human consumption. Instead, most of this fraction is sold as feed for minks or used for production of fish oil and fishmeal.

According to Albrechtsen and Becker (2017), in the manufacture of herring fillets around 35% of the whole fish makes up the actual filet, while the remaining 65% consists of heads, tails, fins, entrails and skin. This remaining fraction is disposed of for mink feed, for processing at a fishmeal factory or for fish oil extraction. Table 12 shows that with 140,878 tonnes of herring landed in 2017 and 65% of this weight being inedible, the created waste was 91,570 tonnes. For mackerel in the food industry, Albrechtsen and Becker (2017) report that 41% of the whole mackerel goes to fillets, 31% is press cake from where oil has been extracted, 12% mackerel oil, 12% loss from boiling and 4% sludge. Oil and press cake are used for feed and sludge for biogas production. Landed weight of mackerel in 2017 was 37,908 tonnes (Table 12), so the fraction that did not consist of actual fillets, amounted to 22,366 tonnes. Utilisation in the shrimp production is 32% (Albrechtsen and Becker, 2017) and with a landed weight of 5,832 tonnes of shrimps (Table 12), this would generate 3,965 tonnes of waste, consisting of mainly shrimp shells, where some of the waste is used in meal production. The utility from cod fish is around 55% (Albrechtsen and Becker, 2017). Assuming this is a good estimate on cod fishes generally, the landed weight of cod fishes in 2017 of 28,272 tonnes (Table 12) would generate 12,722 tonnes of waste.

Summary: *In 2017, the landed weight was 140,878 tonnes of herring, 37,908 tonnes of mackerel, 5,832 tonnes of shrimps and 28,272 tonnes of cod fishes. The estimated waste generation from the Danish fish industry of shrimps, cod fishes, herring and mackerel in 2017 is 130,623 tonnes. The waste consists of heads, tails, fins, entrails, skin and shells, where some is used for oil extraction or fishmeal production. Based on literature studies, we estimate that the values are representative for the Danish market for this category.*

5. Food Waste in Plant-Based Products in Denmark

Plant-based food products produced in Denmark include cereals, fruit and vegetables, potatoes and products based on these raw materials. The largest quantities of cereals produced for human consumption are wheat, whereas smaller amounts of rye, barley and oat are produced as food. Large quantities of fruit produced in Denmark comprise apples, pears, berries such as sour cherries, blackcurrants and strawberries. The most important vegetables produced in Denmark comprise carrots, onions and to a minor extent head cabbages, tomatoes and cucumber (see Figure 6 and Table 19). In contrast to animal products, fresh plant-based products are still alive and are metabolically active after harvest, having respiration and turnover of metabolic compounds, shortening the shelf life and lowering the overall quality (Edelenbos et al., 2010).

5.1. Waste in the Primary Production of Plant-Based Products

In the present context, the primary production of plant-based products refers to farming of cultivated species of fruit, vegetables, potatoes and cereals in fields, orchards and greenhouses.

Fruit and vegetables are classified based on culinary use and not on whether they are fruits and vegetables in a botanical context. This brings e.g. tomatoes and cucumbers into the vegetable category. Examples of plant-based products in the primary production are apples, pears, carrots and wheat. Fruit and vegetables are used for fresh consumption and minimal processing or are heat treated, while cereals are primarily used for further processing into flour, flakes and as an ingredient in beer production. A more holistic approach to food waste in the plant-based category would include the growth phase of plants from seed until maturity as well as losses in the field before the plants are mature for harvest, but due to limited resources and no available data, this part has been excluded from the report.

5.1.1. Fruits and berries

The fruits considered are apples, pears, strawberries, blackcurrants and sour cherries, since these are the main horticultural crops in Denmark. Figure 5 shows the yield of these fruits in 2016/2015. Exact values can be found in Table 18 below.

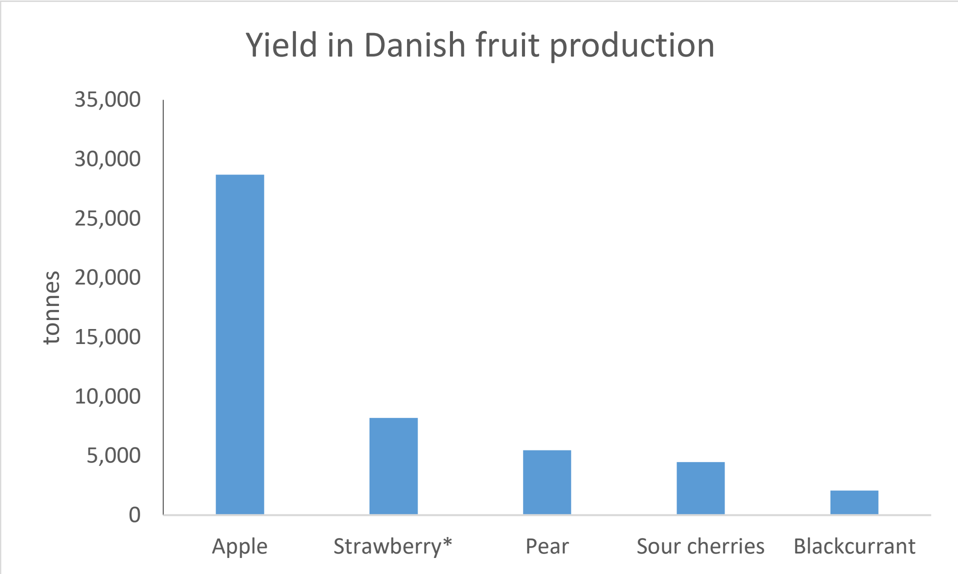


*Figure 5. Graphical illustration of yield (tonnes) in Danish fruit production in 2016 for selected fruits. *Data for strawberry production is from 2015, the newest data available. Data from Statistikbanken (2018c). Exact values can be found in Table 18.*

In recent years, an increasing part of the fruit production has either changed or is being converted to follow the guidelines for organic production. Table 18 shows the share of organic areas in fruit and berry production in 2017. It can be seen that percentagewise, the organic areas of the total area are 43% for blackcurrants, 27% for apples and 8% for pears and strawberries. Note that even though 27% of the areas with apples are organic, it does not necessarily mean that 27% of the total production by weight is organic, since there is typically a lower yield in organic production.

Table 18. Data on total yield in tonnes/year in 2016, (Statistikbanken, 2018c). Total cultivated area and share of organic area in hectare (ha) and share of organic area in percentage of the total area of fruit and berry produced in Denmark. Data from 2017 (Landbrugsstyrelsen, 2018)

Fruit and berries	Total yield [tonnes/year]	Total area [ha]	Organic area[1)] [ha]	Organic [% of total area]
Apples	28,701	1,444	387	27
Strawberries	8,205[2)]	1,191	94	8
Pears	5,466	303	23	8
Sour cherries	4,469	659	28	4
Blackcurrants	2,074	578	248	43

1) Sum of fully converted area and area under transformation to certified organic production
2) The production in 2015, no data available for 2016

Apples and pears

There are several reasons for food waste in the fruit production. Some of the most important are:

- *Accidental drop during harvest:* Dependent on year and variety, it is estimated that accidental drop during harvest amounts to less than 1% of the harvested volume. It is no longer economically feasible to gather dropped fruits for juicing, and there might also be a food safety issue due to fungal mycotoxin production. It should be noted that while these fruits are lost for human consumption, they are eaten by birds, mice, earthworms and other soil dwelling organisms, whereby the overall biodiversity of the orchard is improved
- *Rot:* Fruits with rot have no alternative uses and are always left in the field or sorted out during grading. The amount of rotten fruit will differ significantly depending on variety and climate conditions (increasing in rainy summers). Based on a three-year average of all apples delivered to one large Danish cooperation, it is estimated that 2% is lost due to rot. The prevalence for rotten fruit is generally larger in organic production due to the lack of fungicides in the production. The Danish production of organic apples, however, is small and fruits are not stored as long time as conventional fruit. Only about 1% of organic fruits is currently discarded due to rot.
- *Scab:* The amount of scab-diseased fruit depends on weather conditions during the growing period and on choice of variety. In conventional production, scab is generally controlled by fungicides, and scab-diseased fruits will be of minor importance in the production. In larger commercial organic orchards, where approved fungicides are used, less than 1% of the fruit is discarded due to apple scab. In unsprayed organic production, a 10-15% loss is a realistic estimate (based on trials conducted at AU). Fruits infected by scab can be utilised for juice.
- *Insects:* In general, insect attacks are more unpredictable than diseases, and growers can be surprised by a sudden insect infestation that did not pose a problem during the previous seasons. A range of insects are capable of inflicting major damage during the fruit development, but around harvest time, the most troublesome are larvae from different tortrix species with the codling moth as the most predominant. These larvae inflict damage to either the interior of the fruit or cause superficial damage to the fruit skin. The damage may not be large in size, but it is an entry point for rot diseases, and fruits with broken skin are not accepted for fresh consumption sale. In experiments conducted by the Department of Food, Aarhus University, at conventional grower's orchards, damage levels of up to 15% have been recorded in severe cases. Based on a three-year average of all apples delivered to one large Danish cooperations, it is estimated that 3% is lost due to insects. These fruits will, however, be reutilised for juice. In general, organic fruits suffer from higher insect infestations levels because of the few and less effective insecticides that are available, but fruits delivered to the cooperation show about the same amount of superficial damage as the conventional fruit.

Furthermore, there are some quality requirements that have to be complied with for fruits for fresh consumption. If the fruits do not meet these requirements, they might be used for other purposes such as juice production. Apples and pears have to meet variety-specific size and colour requirements and be free of blemishes on the skin (russet, frost damage). Most cooperations also enforce quality standards, e.g. internal quality like sugar content and firmness that may lead to fruits being rejected for fresh consumption. Healthy fruit that falls short of these requirements is a dead end for the grower and is therefore continuously minimised by optimisation of cultural practices. Still, it is estimated that a relatively high proportion of the apples used for juicing are juiced because they fail to meet the quality requirements. The majority of these fruits will initially be left in the orchard and later picked directly for juicing. Some losses of fresh-consumption fruits may also be encountered when fruits cannot be sold prior to the end of their optimal storability. Particularly early ripening varieties are characterised by a short storability and are subject to high losses because their sales window is short and shifts from year to year due to climatic conditions. The amounts lost vary from year to year and are highly dependent on general market conditions (amount of fruit in long-term storage, harvest size of southern hemisphere fruit and extent of the new harvest of similar fruit in neighbouring countries). Generally, apples that cannot be sold for fresh consumption will be utilised for juice production. The market for discarded pears for juicing is small, as these fruits have a low acid content, making the juice bland.

Summary: *In Denmark 28,701 tonnes of apples were produced in 2016. It is estimated that about 80-85% (22,961-24,396 tonnes) of the production is sold for fresh consumption, about 12-17% (3,444-4,879 tonnes) is used for juice production and 3-5% (861-1,435 tonnes) is lost as food waste. The pear production was 5,466 tonnes in 2016. It is estimated that 95% (5,193 tonnes) is sold for fresh consumption and 5% (273 tonnes) is lost as food waste. We estimate that the values are representative for 70% of the Danish market for this category.*

Sour Cherries

In the last 10 years, the sour cherry production has been through structural changes, and the acreage has decreased from 1,600 hectares to 659 hectares in 2017. During the structural down-sizing, an estimated 10-30% of the fruits were left on the trees due to prices being below the cost of harvesting. Today, the remaining conventional production has increased focus on high-quality products like pitted fruit and wine and less on juice production. Only a small proportion (20 ha) of the remaining production is converting to organic production because of difficulties in growing this crop organically.

There are two main reasons for food waste during sour cherry production, harvesting and attack by diseases and pests:

Harvesting: Sour cherries are harvested by machine, and the time of harvest is a compromise between waiting for the majority of the fruits to ripen with a sufficient sugar content and accepting that the first mature fruits fall of due to wind and being overripe. It is estimated that about 2-4% of the harvest is lost just prior to the harvest. During the harvest, about 3-5% of the fruit is lost, depending on the type of machinery, because fruits are shaken off the trees and fall outside the sail that is catching the fruits, or fruits are unripe and cannot be shaken off the tree.

Diseases and pests: Monilia, grey mould and colletotrichum rot are rot diseases that affect sour cherry berries during ripening. The extent to which berries are affected varies from season to season and depends largely on weather conditions and the availability of fungicides. In the conventional production, rot diseases can currently be successfully controlled by fungicides in contrast to the organic production, where no efficient fungicides or other control measurements are available.

Cherry fruit flies are the main pest on sour cherries, causing losses around harvest. The fruit is infested while the berry is still unripe, but as the fruit matures, so do the fly maggots, reaching full maturity at harvest. Cherry fruit fly infestation has previously been a reason for rejects at the processing factory, but with the effective insecticides currently available and with focus on the problem, it is no longer estimated to cause rejects, based on personal communication with a larger, Danish company handling sour cherries. In organic production on the other hand, the cherry fruit fly cannot be controlled by the control measurements currently allowed.

Summary: *In Denmark, 4,469 tonnes of sour cherries were produced in 2016. It is estimated that about 90-95% (4,022-4,245 tonnes) of the production is sold as frozen, processed or juiced fruit. It is estimated that between 5 and 10% (223-447 tonnes) is lost, either prior to harvest or during harvest because of machinery, unripe fruits and attacks by diseases and pests. We estimate that the values are representative for 70-80% of the Danish market for this category.*

Blackcurrants

During the last five years, the production of blackcurrants has been through a devastating pricing crisis that has resulted in a decrease in production area from 1,888 hectares in 2013 to only 578 hectares. in 2017. The crisis was triggered by oversupply in Europe, causing prices to drop below production costs. As a consequence, an estimated 15% of the blackcurrants have not been harvested in the years 2013-2016, but left on the bushes to rot. A majority of growers have chosen to grub the plantings and convert to grain production, while most of the remaining plantings are under conversion to organic production. At present, the organic production is too low to meet the demand for blackcurrants, and therefore prices are significantly higher than before. However, during the three-year transformation process to certified organic production, berries can only be sold as conventional produce, at a price that may be too low to carry the costs of harvesting. Consequently, food waste due to harvest abstaining may still occur in 2018.

Besides, food waste in blackcurrant production may occur during harvesting and due to attack by diseases.

Loss during harvest: Blackcurrants are harvested by machine and the harvest date is a compromise due to large variability in maturity between the first and the last berries of the raceme. Fruits can be lost during harvesting due to berries falling off just prior to harvest, berries being dropped by the machine (amount depending on type of machine) or berries remaining on the bushes because they are unripe and harder to shake off. Overall, it is estimated that 5-6% of the harvest is lost in this way.

Diseases: Grey mold and mildew may affect the flowers and berries and will often lead to fruit falling of prematurely, affecting the yield prior to harvest. Diseased berries present on the bushes at harvest will be included in the harvest and may therefore reduce the quality of the product, but will not result in actually discarding of the fruits.

Summary: *In Denmark, the quantities of blackcurrants produced have decreased significantly during latter years. In 2016, the yield was 2,074 tonnes. Blackcurrants are sold as frozen or juiced fruit. It is estimated that between 5 and 8% (104-166 tonnes) is lost during and after harvest due to harvesting procedures and attack by plant diseases. We estimate that the values are representative for around 80% of the Danish market for this category.*

Strawberries

The strawberry production is rapidly undergoing a transformation from a traditional field production to a highly in-put protected production. Protected production includes both plastic tunnels in the fields as well as almost year-round production in regular greenhouses. The biggest production losses are encountered in the open field production (15%), less in tunnels (5%) and least (2-3%) in green-house production. In 2015, the production of strawberries was 8,205 tonnes (Table 18). Food waste during strawberry production might occur during harvesting and due to a high disease incidence during production, as described below.

Loss during harvest: Strawberries are hand-picked, and accidental losses during the picking process are very low. However, towards the end of the picking season, it may be decided that picking is no longer economically feasible, and the last 2-3% of the yield may not be harvested.

Diseases: On-farm waste in the strawberry production is mainly related to the occurrence of grey mold rot (*Botrytis*), but other rot diseases such as leather rot, black rot and anthracnose are also troublesome and may lead to production losses as well as rendering the fields unusable for future strawberry production.

Grey mold is an omnipresent pathogen. The extent to which it affects strawberry production is determined by weather conditions and production systems. It is far more prevalent in outdoor production and is the driving force behind a steady increase in tunnel and indoor strawberry production. In outdoor production, *Botrytis* can be controlled to a certain level by the use of fungicides, but in extremely wet summers, fungicides may not suffice to keep the problem under control. In 2017, it was very wet during harvesting and between 10 and 50% was lost on-farm. In recent years, the control of *Botrytis* has been jeopardised by the occurrence of multi-resistant strains of *Botrytis* that are resistant to all fungicides currently registered against *Botrytis* in Denmark.

Botrytis infections as well as other rot diseases may in their early stages not be recognisable at picking, and infected fruit may be harvested and spread the disease to adjacent fruit in the package. This is the main cause for fruit rejection by sales outlets.

Rotten fruit is continuously removed during the picking season to avoid spread from diseased to healthy fruit. Rotten fruit is destroyed preferably away from the field, and there are currently no alternative uses for rotten fruit as eating them constitutes a health risk.

Mildew is another disease that may affect strawberries. In outdoor production, it is mainly a disease on the leaves, but in indoor production it is the main disease and may also affect fruits.

Pests: A range of insects attack strawberries, and the majority may affect yield prior to harvest. Capsids may cause deformed fruit that cannot be sold for consumption. The most worrisome pests are, however, slugs and snails that eat berries when ripe or leave slime on the berries. Losses are generally kept at a minimum with the use of pesticides.

During peak harvest, prices may drop to a level where it is no longer economically feasible to market the fruit and carry the expenses for picking and selling. Such instances happen.

Summary: *In 2015, 8,205 tonnes of strawberries were produced. It is estimated that between 2 and 15% (164-1,231 tonnes) of the production is lost during and after harvest, depending on the weather conditions and production system. We estimate that the values are representative for 50-60% of the Danish market for this category.*

5.1.2. Vegetables

Vegetables are a very diverse group of food, consisting of many different species and varieties, grown in open fields, covered with plastic, or produced in plastic tunnels or greenhouses. From a culinary perspective, vegetables are regarded as part of a main meal and include many different types, such a root crops, bulbs, stems, leafy, flower and fruit vegetables. In the present report, table potatoes are included in the vegetable category, but are handled separately. Figure 6 shows the yield in Danish vegetable production in 2017 with the main crops presented. Notice that even though green peas for human consumption are actually a great crop in Denmark (15,411 tonnes in 2017), it is not considered in this report, since it is mainly frozen, and the waste is considered as being very low.

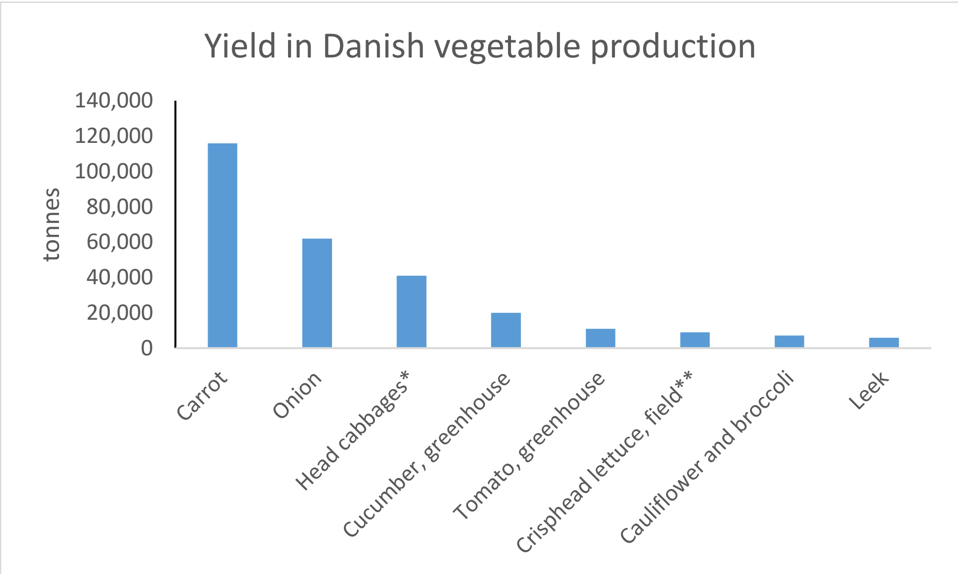


*Figure 6. Graphical presentation of yield (tonnes) in Danish vegetable production of selected vegetables in 2017. *Cabbages cover white, red and pointed. **Value from 2015, newest data available. Data from Statistikbanken (2018c). Exact values can be found in Table 19.*

In Denmark, more than 30 different vegetable species are cultivated in open fields, and several species are grown in greenhouses, with tomatoes and cucumbers being the largest cultures. Each of these species can be grown in several ways, e.g. directly sown in the field or transplanted in the field after cultivation in the greenhouse. Furthermore, vegetables are grown both conventionally and organically, following specific organic guidelines. Thus, 44% of the area with carrots, 77% of the area with cucumbers in greenhouse and 44% of the area with tomatoes in greenhouse are grown organically (Table 19).

Table 19. Data on total yield in tonnes/year in 2017 (Statistikbanken, 2018c). Total cultivated area and share of organic area in hectare (ha) and share of organic area in percentage of total area of vegetables produced in Denmark, data from 2017 (Landbrugsstyrelsen, 2018).

Vegetable	Production [tonnes/year]	Total [ha]	Organic[1)] [ha]	Organic [% of total area]
Carrot	115,846	2,294	1,010	44
Onion	61,900	1,477	250	17
Head cabbages (white, red, pointed, savoy)	41,050[2)]	764	179	23
Cucumber, greenhouse	20,000	13	10	77
Tomato, greenhouse	10,900	16	7	44
Crisphead lettuce, field	8,975[3)]	757	216	29
Cauliflower and broccoli	7,070	819	196	24
Leek	5,798	333	46	14

1) Sum of fully converted area and area under transformation to certified organic production

2) No data for production of savoy cabbage, therefore not included in this number

3) Value for 2015, newest data available

Many species of vegetables are harvested at commercial maturity, i.e. at a maturity stage demanded by consumers, while the vegetables are still growing actively. Therefore, the storability is generally short, depending on the type of product, unless the products are quickly cooled and stored at low temperatures. This applies to many leafy greens (e.g. lettuce), flower vegetables (e.g. broccoli) and fruit vegetables (e.g. cucumber). Other vegetable crops may be harvested fully mature and stored for several months at low temperatures (e.g. head cabbages and root crops). In cold storage, mass losses take place because products are partly dehydrated due to evaporation and respiration. In preparation of sale, the products are trimmed and may be sorted out and eventually discarded due to diseases which develop over time. In summary, there are huge variations in the waste of vegetables after harvest, as the levels depend on product type, production system and storage conditions.

In the field, the waste of products may happen in different ways, and the amount of waste varies significantly. Some vegetable crops harvested in open fields are not harvested because the weather conditions are unfavorable for harvest of the crop. Low temperature during growth may either delay the crop development or directly result in lack of growth, whereas high temperature may result in faster growth and overproduction. Other vegetable crops will not be harvested because of overproduction and low prices or lack of proper timing in relation to market needs.

In 2017, 61,900 tonnes of onions were produced in Denmark (Table 19). The numbers in 2017 were higher than in previous years, 2015 and 2014, with around 52,000 tonnes (data not shown). Five large Danish producers of onions were contacted, and they all generally reported a small share of onions not being harvested. A few reported that on average 3-4% of their cultivated area was not harvested due to weather conditions, and a single record in 2017 amounted to 9% of the cultivated area that was not harvested. After harvest, the discarded amount was in the range of 8-14%, up to 20% for organic onions. The reason for discarding was rot, cracking and mechanical injuries during harvest. Some producers spread the waste on the fields, others sent it to biogas or a combination of both.

It has not been possible to get data from producers of carrots on waste from the primary production in Denmark, but this issue has been investigated by Hartikainen et al. (2017). They found that waste of carrot by weight was distributed as follows: 10% left in the field, 61% used for animal feed, 25% composed and 4% in the category 'other'. The reasons for waste generation were quality issues, pests, diseases and difficulties in harvesting the crop from fields.

As mentioned, there is a large variation in waste amount from vegetable production, not only from year to year, but also from season to season. This is seen in e.g. greenhouse tomato production, where you often see both winter and summer production and thus experience a large variation. The main reasons for discarding tomatoes are deformed fruits and fruit sizes which do not fit the purchasers' needs or EU-regulations. This proportion is roughly estimated at 0.5% of the total production. Some of the tomatoes can be sold as class II products, and some will pass on to processing in the industry for e.g. ketchup production. Another scenario is the case where the retailer and the processor have a contract to have a specific amount delivered, but the retailer has a surplus production. This surplus has to be distributed in time through other channels which may be a challenge and cause a waste if it doesn't succeed.

There has been a widespread perception that each year, some crops would not be harvested if the crop did not fulfil marketing standards. The general impression based upon contact to 12 farmers and/or cooperations in this project indicates that this is not the case. Everything is harvested, if weather conditions permit it, and will afterwards be sorted according to marketing standards, where produce that does not fulfil the standards may be sent to further processing, sold at reduced price, or discarded.

Summary: *Since vegetables are metabolically active, there is a huge variation in food waste along the FSC, depending on several factors, e.g. the product type, the cultivation system (e.g. organic vs. conventional), weather conditions, year to year and seasons to season variations as well as harvest machinery and storage conditions. Generally, data and information on waste in the Danish primary production of vegetables are scarce, and it is difficult to obtain data. We got some data on onions, tomatoes and carrots. A rough estimate is that around 3-10% is not harvested because of machinery and weather conditions, and discard after harvest amounts to around 8-20% caused by e.g. injuries and rot. We estimate that the values are representative for around 30-40% of the Danish market for this category.*

Potatoes

In 2017, production of potatoes for table potatoes amounted to 566.9 million kilograms, corresponding to 566,900 tonnes, while starch amounted to 1353.9 million kilograms, corresponding to 1,353,900 tonnes (Statistikbanken, 2018a). In total that gives 1,920,800 tonnes of potatoes. As for vegetables, there are large variations in the potato production from year to year and from farmer to farmer. One farmer was not able to harvest 52% of his cultivated area compared to 2% for another farmer the same year. The reasons in both cases were poor weather conditions and accompanying difficulties with harvesting machinery. Out of the total, a minimum of 7% in conventional production and 12% in organic production is wasted due to stones, soil, weeds, mechanical injuries, infection by larvae and/or potato black scurf. This waste is going back to the field or used for animal feed, depending on the type of waste. It is estimated that around 8-13% is further wasted in storage due to storage rot and weight loss from respiration and evapotranspiration. The waste percentage depends on the storage facilities and storage management, on the raw material quality at harvest and the storage conditions and storage duration (Edelenbos et al., 2010).

Summary: *In 2017, 1,920,800 tonnes of potatoes were produced, which includes potatoes for table and for starch. A minimum of 7% in conventional production and 12% in organic production is wasted due to stones, soil, weeds, mechanical injuries and disease. It is estimated that around 8-13% is further wasted in storage due to rot and weight losses from evaporation and respiration. We estimate that the values are representative for around 30-40% of the Danish market for this category.*

5.1.3. Cereals

The average cereal grain harvest in Denmark is about 10 million tonnes (Table 20), with wheat and barley being the two major cereals. Most Danish produced grain is used for feed, typically 70-80%. However, in 2016, 249,000 tonnes of wheat, 85,000 tonnes of rye and 38,000 tonnes of oat were ground into flour, groats etc. (Table 21). Production of cereals used for food is often associated with specific quality requirements as well as a high price in order to meet the standards required for high flour yield, bread making etc. Cereals for human consumption only account for approximately 6, 15 and 13% of the total production of wheat, rye and oats, respectively. Cereals not fulfilling the requirements for human consumption are used for feed. In general, all cereals can be and are used for feed. Therefore, the actual food waste according to the FUSIONS food waste definition is negligible, since discarded cereals are, as mentioned, used for animal feed.

Table 20. Production of different cereals (for both human consumption and animal feed) in Denmark in different years, Statistikbanken (2018d).

	Production (1,000 tonnes) in different years				
	2013	**2014**	**2015**	**2016**	**2017**
Cereals (grain) total	9,085.1	9,764.4	10,023	9,130.2	9,999.2
Winter wheat	3,997	5,082.6	4,957.7	4,116.7	4,761.3
Spring wheat	148.2	70.7	71.6	84.8	72.8
Rye	526.8	677.8	771.7	577.2	723.2
Triticale	74.4	95.9	81.8	56.2	60.5
Winter barley	677.4	789.9	805.2	678.3	846
Spring barley	3,272.5	2,757.7	3,050.8	3,271.3	3,146.3
Oats and dredge corn	313.2	216.9	231.4	301.9	350.2

Table 21. The utilisation of the total Danish and imported cereals in 2016, Statistikbanken (2018e). The balance for crop year concerns the period from 1/7 the displayed year to 30/6 the following year. Two dots mean either that a figure is not applicable or that there are no available data. Figures for the latest two calendar years and latest crop year are provisional.

Utilisation (1,000 tonnes) for Danish and imported cereals in 2016					
	Wheat	**Rye**	**Triticale**	**Barley**	**Oats and dredge corn**
Production less waste	4,075	560	54	3,831	293
Imports	234	17	18	37	33
Stocks, primo	3,946	529	32	2,922	206
Seeds for sowing	110	18	2	133	11
Exports	957	17	0	690	21
Grinding for flour, groats etc.	249	85	..	..	38
For manufacturing	11	..	..	310	..
Stocks, ultimo	3,382	379	6	3,063	251
Used for feeding	3,546	606	96	2,594	211

A major part of the produced barley in Denmark is malting barley. As for bread wheat, a higher price can be obtained if the barley fulfils the requirements of maltsters and can be sold as malting barley for use in Denmark or exported. If the barley does not fulfil the requirements for malting, it is used for feed. The Danish production of malting barley was approximately 1.2 million tonnes in 2017 (personal communication, 2018). The amount of wheat and barley used in Denmark for manufacturing (cereals used in breweries, malt houses and distilleries) was 321,000 tonnes in 2017 (Table 21). Two Danish operated malting plants are malting 150,000 tonnes of barley/year and 120,000 tonnes/year, respectively. Rootlets are a by-product in the malting process. The amount is estimated at 0.4% (1,125 tonnes) and used for biogas production (personal communication, April 2018).

Statistics Denmark operates with a 3% shrinkage in the tables describing the production (Table 20) and utilisation of cereals (Table 21). This difference covers the estimated loss in the handling process from harvest to utilisation, caused by a respiration and evaporation. The exact loss is not measured and the applied correction of 3% is used by Statistics Denmark, based on experience.

Summary: *In Denmark, cereals are mainly grown for animal feed. In 2016, 249,000 tonnes of wheat, 85,000 tonnes of rye and 38,000 tonnes of oat were used for grinding for flour, groats etc. The estimated 'waste' in the handling process from harvest to processing is made up of an experience-based 3% shrinkage. We estimate that the values are representative for more than 80% of the Danish market for this category.*

5.2. Waste of Plant-Based Products in the Food Industry

The plant food industry handles and processes raw materials from fruit and vegetable production. The food categories of processed plant-based products are very diverse and comprise many different raw materials. Except for minimally processed plant-based products, one or several preservation step(s), e.g. heat treatment and/or freezing, are involved in the processing. The majority of these processing steps will inactivate enzymes and/or slow down enzyme activity, leading to a more stable product with a prolonged shelf life. A prolonged shelf life will in itself reduce waste as the usage period is extended due to a lower degree of deterioration of the plant-based product (Belitz et al., 2009).

For fruits and vegetables, the most common types of processed products (Figure 7) include frozen products (e.g. berries, peas, beans and sweet maize), canned products (e.g. pears, peaches, peas, sweet maize and apple purée), pickled vegetable products (e.g. olives, gherkins and beetroots), heated products (e.g. fruit jams) and dried products (e.g. raisins, apples).

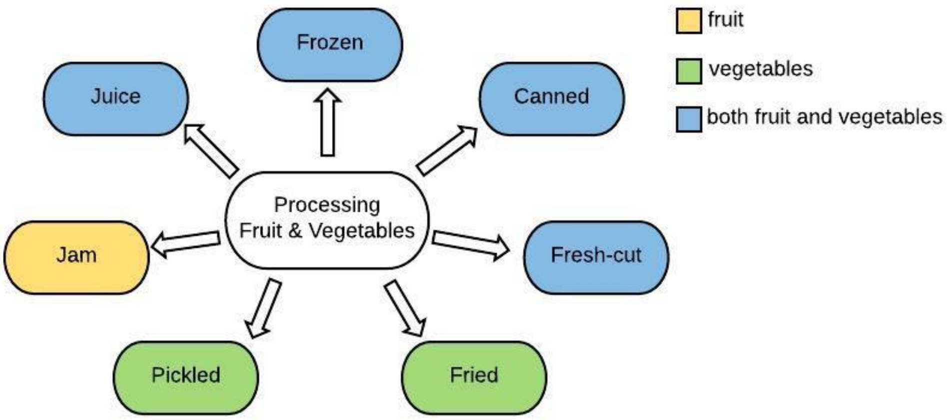


Figure 7. The various processing methods for fruit and vegetables in the food industry.

In Denmark, fruits and vegetables are commercially frozen, canned, fresh-cut, fried, pickled, made into jam or juiced, mostly in small amounts for the home market. However, the market for minimally processed fruits and vegetables is growing, with the products being produced close to the end-users. Minimally processed fruits and vegetables are not subjected to any heat treatments, so the products are metabolically active. Therefore, these products have a short shelf life and may easily be wasted in the FSC (Edelenbos, 2015). Minimally processed vegetables are raw vegetables that are trimmed and washed, often cut or shredded, spin-dried and packaged in plastic materials having specific gas transmission properties. The most common processed potato products produced in Denmark are French fries and potato chips which are subjected to frying and either frozen (French fries) or stored dried (potato chips). Furthermore, vacuum-packed, precooked potatoes are manufactured, especially for the catering and food service sector. Danish fruits and berries are mainly processed into juice and jams (Figure 7) and discarded, but still edible, fruits and berries may be used for the processing of these goods.

Postharvest fruit decay caused by microorganisms brought in from the orchard may result in market-end losses. Processing ensures a supply of safe, nutritious foods to consumers throughout the year. The main wastes generated by the fruit and vegetable industry are organic materials, see below description of juice and other fruit-based beverages. It has not been possible to obtain data on jam, but the waste is expected to be minor since the industry often receives semi-manufactured, frozen fruits/berries which are ready for use.

5.2.1. Fruit and vegetable juices and beverages

The data in Table 22 are obtained from a big Danish juice manufacturer and show that the waste from juicing varies between 30 and 50% for the most dominant raw materials, with an estimated average of 37%. However, the food waste depends on the raw material. A rather high share of the raw materials is Danish, with citrus being the raw material that is imported. The food waste from juice production comprises mainly pulp which is used as animal feed.

Table 22. Waste in Danish juice production using apples, carrots, beetroots and citrus.

Raw material for juice manufacturing	**Total production/year**		**Total food waste/year***		**% estimated food waste of total**
	[tonnes/year]	% weight distribution of raw materials	[tonnes/year]	% weight distribution of food waste	
Apples	1,040	32.5	364	31.0	35.0
Carrots	1,560	48.8	520	44.2	33.3
Beetroots	78	2.4	31.2	2.7	40.0
Citrus	520	16.3	260	22.1	50.0
Total	**3,198**	**100**	**1,175**	**100**	**36.7**

Besides the big juice companies, all large Danish fruit cooperations, including apple producers, have their own juice-processing factories. The same applies to a handful of independent, large growers. They reuse the majority of apples discarded from the orchards for juice production, with exception of rotten fruits. Overall, it is estimated that between 15 and 17% of the produced apples are juiced, based on numbers for 2015, 2016 and 2017 gained from a large Danish, fruit-handling company. With an apple production of 28,701 tonnes (cf. Table 18), around 4,600 tonnes of apples are used for juice production. In accordance with data from the big companies (Table 22), the juice production generates 70% juice and 30% pulp, i.e. the dry matter of the fruit, including kernels. At present, the pulp is not reused for human consumption, but is deposed off via biogas production. The pulp is thus currently handled as non-edible waste. Attempts have been made to use the pulp for animal feed but this approach was discontinued due to hygiene demands that made it too laborious for smaller cooperations to handle. A few attempts have been made to utilise the pulp for human consumption, in the form of a dried fibre-rich food supplement, but this is still very small-scale. However, other uses may be a possibility in the future.

Sour cherries are produced in quite big quantities in Denmark as described in section 5.1.1. A negligible part of the sour cherries goes to fresh consumption, while the major part goes to frozen loose (pitted) cherries. The remaining part is processed for wine or cherry sauce. When fruits are pressed for juice and wine production, a non-edible pulp consisting of fruits stones and fruit dry matter is generated. At present, the pulp is not reused, but is disposed of via biogas production. It has not been possible to find data on waste from this production.

Regarding blackcurrant that is also produced in Denmark as described in section 5.1.1 a part of them are also processed as blackcurrant juice. Once the berries have been delivered to the processing plant, losses are few. Impurities like leaves and twigs can be removed mechanically. Blackcurrants sold as frozen berries need to be of a superior quality, but potential rejects may be utilised for juicing as are relatively few green or diseased berries. Again, pulp is generated from juice production and goes for biogas production. It has not been possible to gain data on waste from this production.

Innovative use of the waste might be a future possibility, e.g. extraction of high-value health food, since the skin of the berries contains a high number of bioactive compounds that may benefit the human health. Also, blackcurrant oil may be processed from the seeds.

Summary: *15-17% of the apple production is juiced, generating a fraction of pulp, which varies between 30 and 50%. The pulp is used for animal feed in the big juice companies, whereas the pulp from the smaller fruit cooperation is mainly disposed of via biogas production. We estimate that the values are representative for 70-80% of the Danish market for this category. It has not been possible to gain data on waste from the processing of sour cherries and blackcurrant.*

5.2.2. Vegetables

As shown in Figure 7, vegetables that are minimally processed can be sold as ready-to-eat or ready-to-use products or as frozen, canned, pickled or fried products. As described above, heat treatment preserves vegetables so their shelf life is prolonged and the food waste reduced in contrast to fresh-cut products that have a short shelf life (Belitz et al., 2009)

Processed, heat-treated vegetable and potato products

The production waste from heat-treated products varies from 8.8% to 18.3% (Table 23). The production waste is due to trimming, peeling and waste during processing. Waste for heat-treated vegetable products also includes evaporation. Very little has to be trimmed away for cucumbers (the stem-end) prior to heat treatment, giving a waste percentage of 8.8%. For white cabbage, it is 12.0% in one factory and for red cabbage, 18.3% in another factory (Table 23). Depending on the final product, more or less of the cabbage core can be used for processing. The quality of the raw materials and storage conditions before processing also influence the waste percentage as the trimming loss increases with longer storage time under non-optimal storage conditions due to removal and waste of the outer leaves (Edelenbos et al., 2010). From Table 23 it can be seen that 15% of the heat-treated beetroot is wasted. This value is low, since the manufacturer boils the beetroots prior to peeling, thus minimising the peeling loss.

The waste of processed potato products, such as French fries, vacuum-packed precooked potatoes and potato chips varies from 16-58%, depending on the initial raw material quality and the processed product (Table 23). Potatoes delivered for processing of chips are washed and sorted by another company. Therefore, some of the waste from production is pushed backwards in the FSC and is not fully reflected in the values. The fact that some industries are subcontractors to larger, specialised industries is becoming more common within the potato, root crop and onion sector. The high waste percentage of boiled potatoes (58%) and French fries (45%) is due to the initial quality of potatoes used for processing, where the entire harvested crop is used for processing. In the chips production, only suitable raw materials are delivered for processing. Non-suitable raw materials are used either for other food products, for starch production or animal feed. Thus, different strategies are reflected in the waste values. The waste was 40% for tomatoes because of removal or loss of pulp during processing. The avoidable waste in processing varies from less than 0.1% to 7% (Table 23).

Minimally processed vegetables

Data for production and food waste for minimally processed vegetables and potatoes are shown in Table 23. Compared to heat-treated vegetables, the food waste during production of minimally processed vegetables is much higher as explained above.

The waste of fresh-cut beetroots is 40% because of high peeling losses. Some of the waste from production in the fresh-cut industry is also pushed backwards in the FSC because subcontractors deliver e.g. trimmed carrots ready for peeling. All waste in Table 23 includes waste from trimming, cutting, washing, centrifugation and packaging. In general, the waste is 20% or higher for all coarse vegetables (carrots, beetroots, leeks, white cabbage and red cabbage) and lower for the salad vegetables (pointed cabbage, broccoli, cauliflower, crisp head lettuce and cucumber).

Table 23. Waste from processed vegetables, divided into production-waste and avoidable waste, tonnes/year

Subcategory	Total raw material (2016) [tonnes/year]	Waste amount [tonnes/year]	Waste percentage [%]	Production waste* [%]	Avoidable waste** [%]	Usage of waste
Ready-to-eat heat-treated vegetables						
Beetroots	2,320	355	15.3	14.8	0.5	Back to field
Red cabbage	2,720	498	18.3	18.1	0.2	Back to field
Cucumbers, sliced	1,508	158	10.5	10.0	0.5	Back to field
Cornichons	382	34	8.8	8.4	0.4	Back to field
Gherkins/pumpkins	527	56	10.6	10.1	0.4	Back to field
White cabbage	3,000	360	12.1	12.0	0.1	Bio combustion
Potatoes, boiled	22,000	12,760	58.0	51.0	7.0	Animal feed
Potatoes, French fries	41,000	18,532	45.0	38.0	7.0	Animal feed
Potatoes, chips	17,500	2,800	16.0	11.0	5.0	Animal feed
Fresh-cut and vegetables						
Potatoes, peeled	3,000	1,000	33.3	30.0	3.0	Animal feed
Carrots	2,133	489	22.9	22.3	0.7	Animal feed
Beetroots	113	45	39.8	33.9	5.9	Animal feed
Leeks	91	23	24.9	22.7	2.2	Animal feed
White cabbage	212	90.0	42.5	40.5	2.0	Animal feed
Red cabbage	32	10.5	32.8	25.0	7.8	Animal feed
Pointed cabbage	38	7.3	19.2	14.2	5.0	Animal feed
Broccoli	92	8.0	8.7	5.3	3.4	Animal feed
Cauliflower	18	3.4	18.9	13.3	5.6	Animal feed
Crisphead lettuce	447	58	13.0	12.1	0.9	Animal feed
Tomatoes	69	27	39.7	35.4	4.3	Animal feed
Cucumbers	93	6.0	6.5	4.3	2.2	Animal feed
Onions, peeled	not stated	.	30.0	25.0	5.0	Bio combustion
Onions, sliced or diced	not stated	.	14.1	14.0	<0.1	Bio combustion
Total	97,295	37,320				

* Due to trimming, peeling and waste in processing. Waste from heat-treated products also includes evaporation of water

** Losses due to unsuitable raw materials for processing and/or manufacturing faults

Only a few fruit products are manufactured as minimally processed products. Fresh-cut apples are one of them. Production of fresh-cut apples is around 33 tonnes per year, starting from a raw material amount of 47 tonnes. Therefore, the waste amounts to 14 tonnes (29.8%), all categorised as production waste and mainly generated by peeling.

Summary: *Many different vegetables are processed for ready-to-eat, heat-treated products or fresh-cut, ready-to- eat or ready-to-use products. In 2016, the total amount of raw materials of the most dominant, minimally processed vegetables was 97,295 tonnes, generating a food waste was 37,320 tonnes/year. The production waste is caused e.g. by trimming and peeling during processing. Estimates of production waste varies between 8 and 50%. The trimming and peeling loss varies depending on the type of vegetables, the parts used and the applied processing technology. Our estimates of the avoidable waste vary between 0.1 and 7%. Industries state that <0.1-7% of the avoidable waste is due to unsuitable raw materials for processing and manufacturing faults. We estimate that the values are representative for 70-80% of the Danish market for this category.*

5.2.3. Cereals

Cereals provide the basis for a long range of products, such as bread, biscuits, cakes, cookies etc. (Belitz et al., 2009) and beer. The aim of milling is to obtain flour which can be used for baked products, such as bread. This is mostly done with wheat and rye, while oat is used for flakes and barley for beer production.

The use of wheat, rye and oat for grinding for flour, groats etc. amounted to 249,000, 85,000 and 38,000 tonnes, respectively, in 2016 (Table 21) for a total of 372,000 tonnes. Waste in the mill industry in the grinding of wheat, rye and oats for flour, groats etc. can be divided into three fractions: premill cleaning and sorting of non-malleable foreign substances, such as stones, straw, foreign seeds, ergot etc., packet damage and floor sweepings. In total, these fractions represent approximately 1% of the received cereals. The packet damage and floor sweeping fractions are used for feed - unless hygienic requirements are not fulfilled - or for biogas production (personal communication).

Loss and waste in the processing of baked food is limited in the big industrial bakeries as most waste in the baking process is recycled in the bakery or used for feed. Some of the processed and packed bread is discarded at the bakeries before retail and distribution due to overproduction. The discarded bread is used for feed, but it has not been possible to find exact quantities.

Summary: *Waste in the cereal industry is quite low, with approximately 1% (3,720 tonnes) waste of the received cereals. The food waste from the cereal industry is mainly used for animal feed. We estimate that values are representative for around 75% of the Danish market for this category.*

6. Waste in 'Affaldsdatasystemet' (ADS)

In this section, the amounts of waste found in the Danish 'Affaldsdatasystemet', ADS, are shown. Table 24 shows the relevant NACE codes in the ADS system (see section 2.4 for a short description of ADS) and the waste registered for each of the NACE codes. The total amount of waste from the relevant NACE groups is 1,236,299 tonnes/year. However, waste in ADS comprises several product types not included in our data, including waste from products that are not considered in this report. Since it is not clear where the counting starts and ends, and what is counted as waste, it is both misleading and difficult to compare values at the present stage,

Table 24. NACE codes and waste generation within the line of business, newest data available from 2016

NACE codes	**2016 [tonnes]**
01 Plant and animal production, hunting and related services	615,220
03 Fishery and aquaculture	6,012
10 Processing of food	614,967
Total (sum of above)	1,236,199

Table 25 shows the most relevant EAK numbers and the waste registered for each EAK number in combination with fraction E02 food waste from the ADS. However, the food waste in the ADS system comprises several products not included in our data, including waste from imported food products and waste from e.g. forestry, which cannot be defined as *food* waste. Furthermore, our data include only part of the food waste, since we have only been dealing with the food categories produced in large quantities. Therefore, it is not possible to make a valid estimate of the total food waste based on our data that is comparable to the ADS values.

Table 25. Data from Waste Data System (ADS) in relation to waste from primary production, relevant EAK numbers given. Data from 2015

EAK number(s)	**Category**	**Waste [tonnes/year]**
020101 020102 020103	Waste from agriculture, nursery gardens, aquaculture, forestry, hunting and fishery	80,467
020201, 020202	Waste from processing of meat, fish and other foods of animal origin	47,180
020303	Waste from processing of fruit, vegetables, cereals, edible oils, cacao, coffee, tea, tobacco and tinned food, production of yeast and yeast extracts and production and fermentation of molasses	178
020502	Waste from production of dairy	3,550
Total (sum of above)		131,375

7. Discussion

In the literature, different definitions of food waste are used which complicates a comparison of waste among countries, sectors and periods. According to FUSIONS, the highest contributor of food waste is households which account for 46.5% of EU food waste, whereas the primary production accounts for 9.1%. Note that the FUSIONS definition of food waste includes preharvest losses and inedible parts, such as peels of fruit and bones from animals. Some waste from production and processing is unavoidable. On one hand, the food waste in the Danish primary production and food industries for animal products is well-documented since slaughterhouses and farmers keep close track of their in/output of animals. For both plant-based and animal-based products, there seem to be great efforts to ensure an effective resource utilisation.

7.1. Perspectives on Data Collection

In a previous study, Mogensen et al. (2013) presume that under Danish conditions, food waste from the primary production (farming as well as greenhouse production) is very low and therefore inconsiderable. This report has confirmed that the food waste in the primary production and the food industries- and in particular, in the animal food production - is by percentage indeed quite low while the food waste in the plant food production - and in particular in the raw fruit and vegetable primary production - is higher.

Food waste and production practice

The data in this report show differences in food waste among animal products and plant-based products and also among heated and processed plant-based products and raw and processed plant-based products. In general, the food waste in the animal sector is low and very consistent from year to year. The variation in food waste for raw plant-based products, which is generally higher than for animal products, may be due to differences in the properties of the two food categories. Plant-based products are quite uncontrollable and hard to handle due to the biological nature of raw fruits and vegetables which easily deteriorate, depending on the product properties and the environmental conditions. Raw plant-based products have metabolic activity, such as respiration, and will eventually become senescent, rotten and die. This affects the shelf life and hence the amount of food waste in the FSC. However, as stated in the report, several factors will influence the duration of the shelf life of these products, such as the product type, season, climate and cultivation practice as well as the storage conditions.

Another factor concerns the animal production and handling units which are often very effective and have large units with many animals or a large volume of animal products coming in and out. Data from slaughterhouses and yield in milk production are e.g. relatively easy to find, because the producers already report these data. In contrast, the units producing and handling plant-based products on the Danish market are typically smaller. Here, data are not that easily accessible, because the units do not necessarily report the data or the data are sparse. Production practice (conventional versus organic) seems to influence the amount of waste in such a way that organic practice for some food products, e.g. carrots, can lead to more waste in the FSC steps (primary production and food industry) considered in the present report. This waste can be ascribed to the restricted use of pesticides in organics production and that fruit and vegetables thus bring more diseases along from the field into the next steps of the supply chain.

Data validity

One criticism regarding data presented in this report is that waste is not directly measured. Some data are built upon existing data from other studies, which sometimes are several years old, and other data are gained from interview with producers or a co-operation. Therefore, data from respondents are self-reported at the risk of a subjective perspective. When contacting companies or farmers and inviting them to contribute with data or estimates of their production on a voluntary basis, some stated that they did not have adequate resources to participate, or they did not want to share data, even though the data would be anonymised. Furthermore, authorities often find it negative with high waste percentages, and we cannot guarantee that the sector gives us the worst-case scenario. Thus, we cannot be sure that the data are fully valid. The present report is a snapshot and a starting point. We suggest that additional surveys and registrations/measurements are carried out in the future in a refined setup in order to get more data. This is mainly necessary for the fruit and vegetable production. In previous reports, data on waste from the primary production of fruit have been deficient or subject to great uncertainty. It is difficult to get correct estimates for this food category because large seasonal variations may occur due to influence of abiotic factors such as weather conditions.

7.2. Food Waste Definitions

There is no harmonised definitional framework for measurement and monitoring of food waste across EU-28. The lack of a common definition and quantification methods makes it difficult to compare the food waste at EU level across the member states. Exclusion of non-edible parts from the food waste definition may lead this category to be neglected even though it does contribute to removal of resources from the FSC. Innovation on how to utilise the fraction that is currently considered as inedible for humans, would be highly valuable.

7.3. Use of ADS in Tracking of Waste

One of the future challenges for the Ministry is how to track and report waste to the EU, once this task has been imposed on the member states. One rather simple option could be use of the ADS which has already been established and is up and running. The question is though whether this system already contains the correct information, or if the system – after some minor calculations or modifications – would at least be able to detect useful information. As it can be seen from section 6 in this report, the categories in the ADS are very broad, compared to the data generated in this report. It is of high priority to the Danish Ministry of Environment and Food not to impose too many administrative burdens or extra obligations on the producers and companies. Use of data from the ADS is currently not sufficient in the Danish food waste accounting, because the data categories are not sufficiently detailed to give an accurate value on food waste amounts in Denmark in the primary production and food industries. One advantage by the ADS is that it is built on NACE codes, which is a joint European classification system. This forms the basis for comparison on food waste among member states and makes it easier to track the development in the different sections of the FSC.

8. Conclusions

This report seeks to establish a basis for estimation of the magnitude of food waste in the Danish primary production and food industries. The report has been divided into the following main categories: 1) animal-based and plant-based products and subdivided into 2) primary production and food industry. Since there is no standardised way of quantifying food waste, it is complicated to compare the results of different studies. In the present study, we have not decided on a definition of food waste, but refer to the FUSIONS, FLW and SF food waste definitions.

The main findings on food waste for the primary production and food industry for animal- and plant-based products are displayed in Table 26 below. We conclude that of the annual production within each food category in both the primary production and food industry, there are rather small percentages that become food waste. The food waste percentage in the animal sector is low and very consistent from year to year. The variation in food waste for raw plant-based products, which is generally higher than for animal categories, may be due to differences in the properties of the two food categories. The main reasons for waste generation in the primary production for fruit and vegetables are attacks by pest and diseases and for animal products diseased animals, mortality during transportation and rejection at the slaughterhouse. In the food industry, entrails, bones, heads and skin are unavoidable waste along with waste from peeling, trimming and pulp generation from processing of fruits and vegetables. Table 26 also shows the usage of waste. As seen in the table, the usage of waste varies among the different food categories and is very diverse among animal- and plant-based products. The waste generated is either used for animal feed, sent to biogas production, used in the pharma industry or brought back to the field and thus back into the soil. Much of the waste from the food industry is considered as inedible, but there is a potential for utilisation of the discarded material, e.g. pulp from juice production, peels from processing of plant material and entrails from fish. Generally, producers and processors in the first steps of the FSC are very interested in minimising waste as much as possible and/or utilising waste to create increased economic value, hoping to positively affect the bottom line.

Table 26. Summary on food waste generation in the Danish primary production and food industries for the different categories of food

Food category (sum of primary production and food industry)	Waste per year	Usage of waste
Beef	29,273 tonnes LW of dead cattle at farm 35 tonnes LW of cattle die during transportation 591 tonnes of LW cattle rejected at the slaughterhouse. In total, 29,900 tonnes LW or 11.6% of total production (= LW of cattle slaughtered in Denmark). 257,600 tonnes LW of cattle were slaughtered, of which 123,400 tonnes were edible and 134,200 not directly edible	Biogas production, fertiliser production, feed, medicine production and burnt for heat generation.
Pork	LW of pigs dead at farm, during transportation and rejected at slaughterhouse totals 93,120 tonnes or 4.4% waste of the total production (= 2.1 million tonnes LW of pigs slaughtered in Denmark) 18.4 million pigs slaughtered produced 1,770,500 tonnes which were edible and 334,000 tonnes of LW which were not suitable for human food	Pharma industry, biogas production, fur feed, pet feed
Poultry	Mortality at farm level, on average 3.4% Mortality during transportation estimated at 0.27% 0.9-1.4% discarded poultry at slaughterhouse, corresponding to between 1,386 and 2,156 tonnes 0.23% of the raw chicken meat and processed chicken meat is wasted, corresponding to 220 tonnes, assessed as being of human edible quality	No data available
Milk/dairy	At farm, 0.65% of milk production wasted due to medical treatment of cows Around 2.3-2.5% (123,579-134,325 tonnes) of milk delivered to dairies wasted due to handling, defects in quality etc.	Feeding for calves, thrown into manure
Eggs	0.5-1.8% (330-1,200 tonnes) of eggs wasted due to cracking in the primary production. In processing around 10% is egg shells, i.e. inedible waste, 3.6% is wasted from breaking and 9.4% of egg mass is wasted in the process	Mink fodder, biogas production, waste with no usage
Fish	2.8% waste of LW due to discarded entrails 130,623 tonnes wasted in the industry as heads, tails, fins, skin and shells are regarded as inedible waste	Fishmeal, oil production, mink fodder
Fruit	Between 3-15 % of fruits are wasted: Apples (861-1,435 tonnes), pears (~273 tonnes), sour cherries (223-447 tonnes), blackcurrant (104-166 tonnes) and strawberries (164-1,231 tonnes) are wasted due to e.g. diseases and poor quality at harvest due to wounding when harvesting Around 30% of juice from fruit and vegetables is pulp	Biogas production, brought back to the field, animal feed
Vegetables	3-10% is not harvested because of insufficient machinery, poor weather conditions or discarded after harvest (8-20%) due to rot and lack of quality In the industry, 8-50% is production waste from trimming and peeling, and 0.1-7% is regarded as avoidable as it is caused by quality issues and manufacturing faults	Biogas production, brought back to field
Cereals	3% weight loss due to drying after harvest and respiration in storage. 1% of cereals wasted in the cereal handling industry	Animal feed

9. Perspectives

It is important to consider the entire FSC in the prevention and reduction of food waste as the different sectors affect each other and also may help each other in the fight against food waste. As mentioned in the introduction, consumer households in the developed countries account for an estimated 40% of the total amount of food wasted in this part of the world. Likewise, food waste in the retail and in the catering sectors might be bigger than in the primary production and food industries. Hence, in the future the latter two areas of the FSC might have the highest potential for reducing food waste and, in particular, generating a significant reduction in relation to edible foods. Research-based data showing how new or improved technologies in the primary production and food industries and different uses of raw materials for processed products affect the generation of food waste, might, however, be useful as tools to further minimising the food waste. Valid data may be obtained by improving the methodology used for measuring and monitoring of food waste, and it should preferably be done in supranational collaboration.

As shown in this report, the majority of the organic food waste material from the primary production and food industries are not necessarily 'wasted', but is reused for different purposes, including animal feed or biogas production, or it is spread on the fields, i.e. contributing to the nutrient supply and potentially increasing soil fertility for future plant production. Inedible materials can be burned and used for heat production. Waste fed to animals substitutes the need for production of other animal feeds that are necessary to maintain our current livestock population. Furthermore, some of the food waste is used for other high-value products, such as fish oil or fishmeal that can be used as ingredients in food and feed production. However, higher focus on side stream products in the future might contribute to a further reduction of the food waste in the primary production and the food industries and at the same time contribute to an enhanced value creation for the involved primary producers and the food industries. The use of food waste from the primary production and food industries to extraction of components that can be used as ingredients in food and animal feed products might enhance the value of the food waste. Such components could be flavours, pigments or health-beneficial components.

References

ALBRECHTSEN, D. G. & BECKER, E. M. 2017. Mindre madspild fra hav til bord - en forundersøgelse, Teknologisk Institut.

ANDERSEN, S., PEDERSEN, B., OGANNISIAN, M. 1999. Slagtesvindets sammensætning. *Meddelelse nr. 429. Landsudvalget for Svin, Danske Slagterier.*

ANONYMOUS. 2015. *Danish Statistic from Milk yield recordings, milk delivered* [Online]. Available: https://www.landbrugsinfo.dk/Kvaeg/Tal-om-kvaeg/Sider/mndstat090522.aspx [Accessed 22 March 2018].

ANONYMOUS. 2018a. *Bekendtgørelse om mærkning, registrering og flytning af kvæg, svin, får eller geder* [Online]. Available: https://www.retsinformation.dk/Forms/R0710.aspx?id=191628 [Accessed March 2018].

ANONYMOUS. 2018b. *RE: Danish Dairy company.* Type to LISBETH MOGENSEN. AARHUS UNIVERSITY.

ANONYMOUS. 2018c. *RE: Danish Slaughterhouse. Confidential report.* Type to LISBETH MOGENSEN AARHUS UNIVERSITY.

ASCHEMANN-WITZEL, J., JENSEN, J. H., JENSEN, M. H. & KULIKOVSKAJA, V. 2017. Consumer behaviour towards price-reduced suboptimal foods in the supermarket and the relation to food waste in households. *Appetite,* 116**,** 246-258.

AZZURRO, P. 2016. D3.5 Recommendations and guidelines for a common European food waste policy framework. *The European Commission FP7-Coordination and Support Action (Contract No 311972).*

BELITZ, H. D., GROSCH, W. & SCHIEBERLE, P. 2009. *Food Chemistry,* Berlin, Springer.

CALDEIRA, C., CORRADO, S. SALA 2017. Food waste accounting - Methodologies, challenges and opportunities. EUR 28988 EN ; Luxembourg (Luxembourg): Publications Office of the European Union; 2017; JRC109202 ; doi:10.2760/957031.

COMMISSION REGULATION 2003. (EC) No 2295/2003 of December 2003 Introduction detailed rules for implementing Council Regulation (EEC) No 1907/90 on certain marketing standards for eggs (Consolidated version: 30/08/2004).

COUNCIL REGULATION 2004. (EC) No 1/2005 of December 2004 on the protection of animals during transport and related operations.

DAKA. 2012. Available: www.dakabio-industries.dk [Accessed March 2018].

DAKA DENMARK 2017. Guidance on the handling of animal by-products http://www.daka.dk/dk/daka/miljoe-og-sikkerhed/abp-vejledning/.

DANISH CROWN. 2012. *RE: Proportion of pigs rejected at slaughterhouse.* Type to LISBETH MOGENSEN, A. U.

DANISH REGULATION NO. 1354 2017. Bekendtgørelse om fødevarehygiejne. *Miljø - og Fødevareministeriet, 29/11/2017.*

DANMARKS STATISTIK 2016. Svinebestanden 1. januar 2016, 12.7 mio. svin i Danmark.

DANMARKS STATISTIK 2018. Slagtninger og produktion af svin efter enhed, kategorier og tid.

DANSK ERHVERVSFJERKRÆ 2017. Markedsberetning. 46 (11), 6-8.

DANSK ERHVERVSFJERKRÆ 2018. vol. 47, no. 6+7, p. 8.

DUSE, A., EMANUELSON, U., UNNERSTAD, H. E., PERSSON, Y., WALLER, K. P. & BENGTSSON, B. 2012. Milk from cows treated with antimicrobials as feed for calves, a potential risk for selection of resistant bacteria. *Poster material, SLU.*

EDELENBOS, M. 2015. Preparation and handling of fresh-cut root vegetables. *Acta Hort,* 1141**,** 77-90.

EDELENBOS, M., KIDMOSE, U. & BERTELSEN, M. 2010. Udredning af hvordan kvalitet og holdbarhed af frisk frugt og grønt påvirkes af alder og anvedte metoder efter høst. *Det Jodrbrugsvidenskabelige Fakultet - Aarhus Universitet.*

EINARSON, E., ANDRESEN, N. & FRANKE, U. 2013. Appendix Sweden; food waste in primary production of milk. *Kartlägging av matsvinnet i primärproduktionen (by Franke, U., Einarson, E., Andrésen, N., Svanes, E., Hartikainen, H., Mogensen, L).*

FRANKE, U., EINARSON, E., ANDRESEN, E., SVANES, E., HARTIKAINEN, H. & MOGENSEN, L. 2013. Kartlägning av matsvinnet i primärproduktionen : Kortlægning af madspild i primærproduktionen. TemaNord, Nordiska Ministerrådet.

GUSTAFSSON, J., CEDERBERG, C., SONESSON, U. & EMANUELSSON, A. 2013. The methodology of the FAO study: Global Food Losses and Food Waste-extent, causes and prevention"-FAO, 2011. SIK Institutet för livsmedel och bioteknik.

HARTIKAINEN, H., KUISMA, M., PINOLEHTO, M., RÄIKKÖNEN, R. & KAHILUOTO, H. 2014. Food waste in primary production and food processing. Abstract on results from the Finnish 'Foodspill 2' project from MTT report no. 170. 61 pp (in Finish).

HARTIKAINEN, H., MOGENSEN, L., SVANES, E. & FRANKE, U. 2018. Food waste quantification in primary production – The Nordic countries as a case study. *Waste Management,* 71**,** 502-511.

HARTIKAINEN, H., SVANES, E., FRANKE, U., MOGENSEN, L., ANDERSEN, S., BOND, R., BURMAN, C., EINARSSON, E., JOENSUU, P. E. K., OLSSON, M. E., RÄIKKÖNEN, R., SINKKO, T., STUBHAUG, E., ROSELL, A. & SUNDIN, A. 2017. Food losses and waste in primary production : Case studies on carrots, onions, peas, cereals and farmed fish. *TemaNord*.

HERSKIN, M. S., DAHL-PEDERSEN, K., DENWOOD, M., FOGSGAARD, K. K., FORKMAN, B., GAILLARD, C., HOUE, H., LUND, V. P., NIELSEN, L. R., OTTEN, N. D., THODBERG, K. & THOMSEN, P. T. 2016. Vurdering af dyrs transportegnethed.

HOLLSTEDT, S. 2011. Egg quality and its connection to production, economy and animal welfare amongst Swedish layers. *30 ECTS degree project report, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, 68 pp.*

JENSEN, J. D. & BONNICHSEN, O. 2016. Madspild, madaffald og ressourceeffektivitet i fødevarekæden: definitioner og kortlægning af mulige datakilder.

LANDBRUG & FØDEVARER 2011. Statistik 2010 - Svinekød. Juli 2011. 46 pp.

LANDBRUG & FØDEVARER 2013. Statistik 2012 - Svinekød. Juli 2013. 46 pp.

LANDBRUG & FØDEVARER 2015. Statistik 2014 - Svinekød. Juli 2015. 46 pp.

LANDBRUG & FØDEVARER 2016. Statistik 2015 - Svinekød. Juli 2016. 46 pp.

LANDBRUG & FØDEVARER 2017a. Statistik 2016 - Mejeri. Juli 2017. 46 pp.

LANDBRUG & FØDEVARER 2017b. Statistik 2016 - Okse - og kalvekød. Juli 2017. 54 pp.

LANDBRUG & FØDEVARER 2017c. Statistik 2016 - Svinekød. Juli 2017. 46 pp.

LANDBRUGSSTYRELSEN 2018. Statistik over økologiske jordbrugsbedrifter 2017 - Autorisation & Produktion.

LARSEN, E. P., DALSKOV, J., NIELSEN, E. E., KIRKEGARD, E., NIELSEN, J. W., TØRRING, P. & SCHOU, M. 2013. DTU Aqua-rapport nr. 275-2013: Dansk fiskeris udnyttelse af discardforbuddet.

LARSEN, J. N. 2017. 'Production and sales of eggs in Denmark up to first half-year 2017' [In Danish]. *Dansk Erhvervsfjerkræ,* 46**,** 28-29.

LIPINSKI, B. & ROBERTSON, K. 2017. Measuring food loss and waste. *BioCycle.* JG Press, Inc;J.G. Press Inc.

LUNDQVIST, J., C. DE FRAITURE AND D. MOLDEN 2008. Saving water: From field to fork – Curbing losses and wastage in the food chain.

MALENA, M., VOSLÁŘOVÁ, E., KOZAK, A., BĚLOBRÁDEK, P., BEDÁŇOVÁ, I., STEINHAUSER, L. & VEČEREK, V. 2007. Comparison of mortality rates in different categories of pigs and cattle during transport for slaughter. *Acta Veterinaria Brno,* 76**,** 109-116.

MILJØSTYRELSEN 1998. Organiske restprodukter i industrien. Del 1. Miljøprojekt nr. 397.

MOGENSEN, L., HERMANSEN, J. & KNUDSEN, M. T. 2013. Madspild i fødevaresektoren - fra primærproduktion til detailled. *DCA-rapport nr. 017.*

MOGENSEN, L., NGUYEN, T. L. T., MADSEN, N. T., PONTOPPIDAN, O., PREDA, T. & HERMANSEN, J. E. 2016. Environmental impact of beef sourced from different production systems-focus on the slaughtering stage: input and output. *Journal of cleaner production,* 133**,** 284-293.

PEDERSEN, L. J., BERG, P., JØRGENSEN, G. & ANDERSEN, I. L. 2011. Neonatal piglet traits of importance for survival in crates and indoor pens. *Journal of Animal Science,* 89**,** 1207-1218.

PONTOPPIDAN, O. & MADSEN, N. T. 2014. LCA-slagteridataopgørelse for kvægproduktions typer for KF/Landbrug og Fødevarer. Teknologisk Institut DMRI.

RAUNDAL, P., NIELSEN, J. & FLAGSTAD, P. 2018a. *Kalvedødelighed i Danmark* [Online]. Available: https://www.landbrugsinfo.dk/kvaeg/tal-om-kvaeg/sider/kalvedoedelighed-i-danmark.aspx [Accessed 26 March 2018].

RAUNDAL, P., NIELSEN, J. & FLAGSTAD, P. 2018b. *Opgørelse vedr. kodødelighed mv.* [Online]. Available: https://www.landbrugsinfo.dk/kvaeg/tal-om-kvaeg/sider/kododmain.aspx [Accessed 26 March 2018].

REDLINGSHOFER, B., COUDURIER, B. & GEORGET, M. 2017. Quantifying food loss during primary production and processing in France. *Journal of Cleaner Production,* 164**,** 703-714.

SEGES 2015. *Håndbog i Kvæghold. 215 pp.*

SEGES 2017. Landsgennemsnit for produktivitet i svineproduktionen 2016. Notat nr. 1716.

SEGES 2018. Ydelseskontrollens månedsstatistik alle besætninger. Af Lauritsen & Flagsted.

STATISTIKBANKEN 2018a. Høstresultat efter enhed, område, afgrøde og tid.

STATISTIKBANKEN 2018b. Danske fartøjers landing af fisk efter landingsplads, fangstområde,

tid, fiskeart og enhed.
STATISTIKBANKEN 2018c. Produktion af frugt og grønt efter område, tid, afgrøde og enhed.
STATISTIKBANKEN 2018d. Høstresultat efter område, afgrøde og enhed.
STATISTIKBANKEN 2018e. Anvendelsen af korn efter afgrøde, periode, oprindelse og typ.
STENMARCK, A. S., JENSEN, C., QUESTED, T., MOATES, G., BUKSTI, M., CSEH, B., JUUL, S., PARRY, A., POLITANO, A. & REDLINGSHOFER, B. 2016. *Estimates of European food waste levels*, IVL Swedish Environmental Research Institute.
STRID, I., RÖÖS, E. & TIDÅKER, P. 2014. Förluster av svenskt nötkött inom primärproduktion och slakt.
SØGAARD, L. S. 2016. Mange yverbehandlinger er uden effekt (SEGES).
SØRENSEN, J. T. 2008. Danske mælkeproducenter bruger masser af sødmælk til kalve. *Kvaeg*.
THE DANISH AGRIFISH AGENCY 2017. Yearbook of Fishery Statistics 2016.
THE_DANISH_POULTRY_COUNCIL 2016. Årsberetning 2016 [Annual report 2016]. 1-128.
THORUP, F. 2010. Fødselsvægt. Videncenter for Svineproduktion.
TOFT, R., NISSEN, E. L. & SØRENSEN, A. 2017. Waste Statistics 2015. The Danish Environmental Protection Agency.
VIDENCENTER FOR SVINEPRODUKTION 2011. Svineproducenter i verdensklasse.
VINTHER, J. & JENSEN, T. B. 2018. Udvikling i sodødelighed - tal fra DAKA 2017. Notat nr. 1915. *Seges Svineproduktion*.
ZANONI, S. & ZAVANELLA, L. 2012. Chilled or frozen? Decision strategies for sustainable food supply chains. *International Journal of Production Economics,* 140**,** 731-736.

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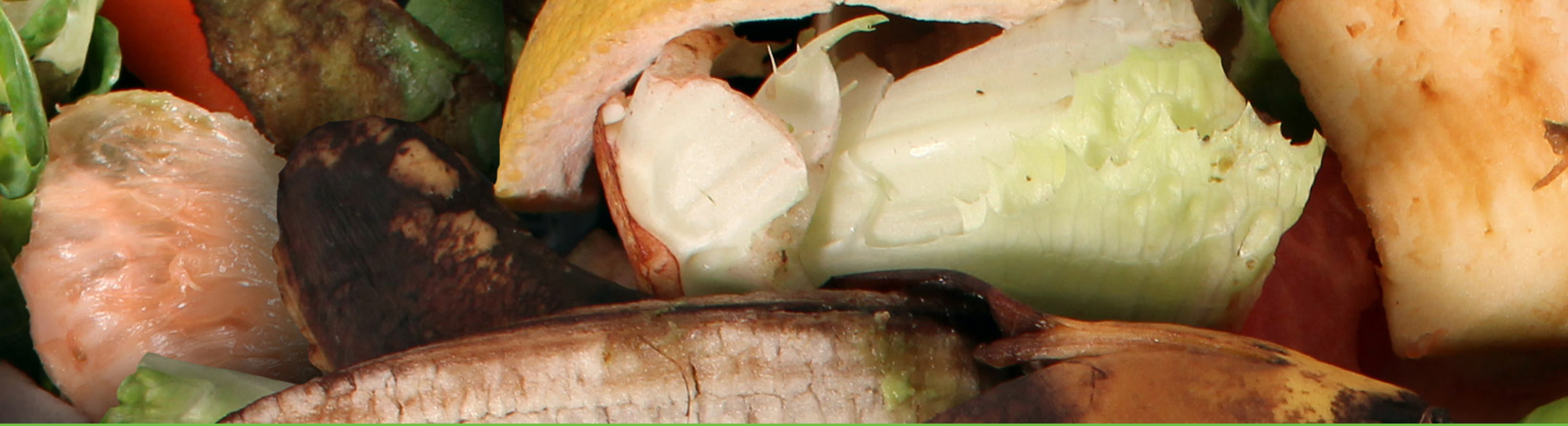
The centre coordinates knowledge exchange and advice with regard to the departments that are heavily involved in food and agricultural science. They are:

Department of Animal Science
Department of Food Science
Department of Agroecology
Department of Engineering
Department of Molecular Biology and Genetics

DCA can also involve other units at AU that carry out research in the relevant areas.



SUMMARY

This report seeks to establish a basis for estimating the magnitude of food waste generated in the Danish primary production and food industries. The food categories investigated are meat and meat products (including fish), milk and dairy products, eggs and poultry, cereals and bakery products and fruit and vegetables, including potatoes. Food waste has been investigated based on existing literature and interviews with key persons from the Danish primary production and food industries. In the report, the amount of waste, reasons for waste generation and waste treatments/end destinations of the waste have been revealed. The report concludes that a rather small percentages of the annual production within each food category, in both the primary production and food industry become food waste. Furthermore, we conclude that waste is typically higher for plant-based products than for animal-based products.