**Manuscript title: Environmental impacts of the pork supply chain with regard to farm performance**

**SUPPORTING INFORMATION**

**Data inventory of the pork production system in Northern Germany**

The data inventory necessary for the LCA of pork production is presented in the following. The base scenario represented the average pork production in the north of Germany in the marketing year 2010/2011. The data presented was described in Reckmann *et al.* (2013) in detail. The pig production at farm level was considered as ‘landless’, as described in Nguyen *et al.* (2011). Therefore, feed and other resources were imported which reflected common practice for conventional pig farms.

*Life cycle inventory: crop and feed production*

The data needed for the life cycle inventory of feed production were provided by a feed factory in Northern Germany, reflecting the production process in 2009. The data inventory of feed is partly listed in Table S1, per 1000 kg live weight.

Six different feed compositions were used: feed for lactating and gestating sows, piglet feed and three finisher feeds. The protein content of the feed was 14 % for gestating sows, 17 % for lactating sows and 17.5 % for weaned piglets. The finishing feeds were characterized by differing protein contents of 17.2 %, 16.5 % and 15.5 %. The main components of typical conventional feed mixtures were wheat, barley, soybean meal and feed supplements (e.g. calcium carbonate and lysine), of which the wheat and barley were mainly produced in Germany. We assumed a distance between the field in which the crop was grown and the feed company to be 100 km on average. The distance between the feed factory and the pig farm was estimated at 97 km. According to statistical data, the soy was imported from Brazil (Faostat 2011). This resulted in a shipping distance of 9700 km from Brazil to Rotterdam harbour in the Netherlands. The following transport by lorry to the feed factory in Germany was 412 km.

The inventory of feed encompassed the crop cultivation, including use of fertilizers, fossil-fuels and other resources. Data of resources used and emission data due to the transformation of crop products into feed ingredients as well as the production of feed (e.g. electricity, heat and water consumption) were also supplied by the feed company. Additional data were included in databases of the software used, i.e. SimaPro 7.3.3 (Pré Consultants 2009).

*Life cycle inventory: pig production system*

We used the most recent data available for average pig production in Northern Germany, mainly from the marketing year 2010/2011 (SSB 2011). Main performance parameters are highlighted in Table S2. The pig housing encompassed all life stages of the pig, i.e. sow, weaner (8 – 30 kg) and finisher (30 – 120 kg).

The data inventory of the pig production is listed in Table S3, related to the production of 1000 kg live weight at the farm gate. The inventory started with the calculation of the amount of feed needed to raise the pigs. The housing of the animals consumed electricity for light, ventilation, feeding etc., heat for piglets and finisher pigs as well as water for animals and cleaning. Additionally, the animals needed to be transported between the different housing stages. Therefore, we assumed that piglets were transported 60 km from the piglet production to the weaning. The distance to the finisher stable was 32 km. The carcasses of lost animals also had to be disposed (40 km).

In all housing stages, pigs produced certain amounts of manure. A scheme of the manure management factors included in this study is illustrated in Fig. S2. After excretion by the animals, the manure was first stored in the pit beneath the slats for around one month. After this period, it was pumped to an external storage tank outside the stable, where the manure developed a natural crust. This natural crust regulated the emission of methane and other greenhouse gases. German regulations prescribe an outside storage duration of six months before the slurry is ready for field application. The manure can then be used to replace synthetic fertilizers for the cultivation of crops. To be applied to the field, the manure in this study first needed to be transported to the field. The average distance was 10 km. The energy needed to spread the manure was 21 MJ per tonne slurry ex-storage, relating to Dalgaard *et al.* (2001*a*). The field application of manure had a dual effect. The substitution of synthetic fertilizer was regarded as a positive effect since it avoided the production of fertilizers as well as the related resource use (e.g. 0.4 MJ per kg fertilizer N; Dalgaard *et al.* 2001) and emissions. All impacts related to the avoided fertilizer use were deducted from the system. On the other hand, the spreading of manure also produced emissions, which would be regarded as a negative effect. Since pig manure cannot be used as efficiently as synthetic fertilizer by the plants, the substitution rate of N in manure was assumed to be 75 % (Nguyen *et al.* 2011). In contrast, the substitution rate of P in the manure was 97 % (Dalgaard *et al.* 2006), whereas K in manure would substitute 100 % of synthetic K fertilizer (Sommer *et al.* 2008). N2O, nitrate and ammonia were the most harmful substances from manure of the pollutants emitted. The emission of ammonia arose out of the N in the manure, which could be easily volatised in in-house and outside storage. Phosphate was the only P substance affecting the environment. It was considered that 3 % of the P in the manure was leached as phosphate. All environmental impacts related to manure management, including in-house storage, outside storage and field application, were allocated to the pork production. The calculations related to manure characteristics were based on those described in Nguyen *et al.* (2011).

*Life cycle inventory: slaughter process*

At the end of the fattening period, pigs were transported to the slaughterhouse. The final product was pork as slaughter weight. Primary slaughterhouse data were supplied by a slaughterhouse in Northern Germany for the production in 2008. Inventory data are presented in Table S4. In Germany, pigs are slaughtered at a live weight of 120 kg, resulting in a slaughter weight of about 97 kg. The slaughtering process consumed heat, electricity, water and transportation while producing emissions to air and water. The transport distance from the farm to the slaughterhouse was estimated at 350 km (Dreier 2012). It was assumed that the non-eatable parts of the pigs as well as the manure produced in the slaughterhouse were disposed as waste.

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Table S1.*Feed components and main feed ingredients of the different feed compositions used in the various stages of pig housing.*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Feed composition** | **Gestating sows** | **Lactating sows** | **Weaning pigs** | *1st phase* | **Finisher***2nd phase* | *3rd phase* |
| *Feed components* |  |  |  |  |  |  |
| Crude protein [%] | 13.8 | 16.8 | 17.5 | 17.2 | 16.5 | 15.5 |
| Lysine [%] | 0.7 | 1.0 | 1.3 | 1.2 | 1.0 | 0.9 |
| Crude fat [%] | 2.4 | 2.7 | 4.0 | 4.5 | 3.5 | 2.5 |
| Crude fibre [%] | 7.0 | 4.8 | 3.2 | 3.0 | 3.5 | 4.5 |
| Metabolisable energy [MJ] | 11.8 | 13.0 | 13.8 | 13.6 | 13.2 | 12.8 |
| *Feed ingredients* |  |  |  |  |  |  |
| Wheat [%] | 19.1 | 33.0 | 40.0 | 56.7 | 51.8 | 33.6 |
| Barley [%] | 40.0 | 35.0 | 19.6 | 10.0 | 10.0 | 20.0 |
| Rye [%] | 0 | 0 | 0 | 3.0 | 10.0 | 10.0 |
| Soybean meal [%] | 3.0 | 17.0 | 17.5 | 12.4 | 5.5 | 1.7 |
| Wheat bran [%] | 18.0 | 4.0 | 0 | 0 | 3.0 | 3.0 |

Table S2.*Main performance parameters of the average pig production in 2010/2011.*

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Parameter** | **Value** | **Unit** |
| **Piglet production** | No. of sows per farm  | 240 | pcs. |
| Replacement rateNo. of live born piglets per sow and year | 4731.8 | %pcs. |
| No. of weaned piglets per sow and yearNo. of litters per sow and year | 27.22.3 | pcs.pcs. |
| Piglet losses | 14.6 | % |
| **Weaning** | Daily weight gainPiglet losses | 4601.5 | g% |
| **Finishing** | No. of fattening pigs per farmFinal fattening weightCarcass yieldDaily weight gain | 135412079.0788 | pcs.kg%g |
| Feed conversion ratio 1:  | 2.87 | kg |
| Lean-meat content | 56.6 | % |
| Animal losses | 3.0 | % |

|  |  |  |  |
| --- | --- | --- | --- |
| **In- / Output** | **Unit** | **Amount** | **Data sources,**adapted or directly taken from |
| ***Feed***  |  |  |  |
| Wheat | kg | 1090 |  |
| Barley | kg | 440 |  |
| Rye | kg | 161 | Feed company |
| Soybean meal  | kg | 188 | and extension service |
| Others | kg | 648 |  |
| ***Energy and transports*** |  |  |  |
| Heat (oil) | kWh | 130.2 | (KTBL 2005) |
| Electricity mix | kWh | 117.6 | (KTBL 2005) & (AEL) |
| Transport |  |  |  |
| Ship | tkm | 3375 | Feed company |
| Truck 28 t | tkm | 868 | Various sources |
| Tractor and trailer | tkm | 108 | Farmers |
| Water (tap) | m³ | 353 | (EC 2003) |
| Farm traction | MJ | 206 | (Dalgaard *et al.* 2001*b*) |
| ***Emissions to air*** |  |  |  |
| Methane | kg | 26.7 | (Rigolot *et al.* 2010) & (IPCC 2006) |
| Dinitrogen monoxide | kg | 1.0 | (IPCC 2006) |
| Nitrogen dioxide | kg | -2.4 | See Nguyen *et al.* 2011 |
| Ammonia | kg | 20.7 |  |
| ***Emissions to water*** |  |  |  |
| Nitrate  | kg | 1.2 | Nutrient balance |
| Phosphate | kg | 0.5 |  |
| ***Avoided fertilizer production*** |  |  |  |
| N fertilizer | kg | 49 | (Nguyen *et al.* 2011) |
| P fertilizer | kg | 13 |  (Dalgaard *et al.* 2006) |
| K fertilizer  | kg | 12 | (Sommer *et al.* 2008) |

Table S3.*Data inventory per 1000 kg pig live weight at farm gate.*

Table S4.*Data inventory from a slaughterhouse, representing the slaughter process in the north of Germany in 2008.*

|  |  |  |
| --- | --- | --- |
|  | **Unit** | **Amount** |
| **Inputs** |  |  |
| 1 living pig | kg | 119.9 |
| Electricity mix | kWh | 26.8 |
| Water (tap) | m3 | 0.4 |
| Diesel | kg | 0.8 |
| **Outputs** |  |  |
| Pork | kg | 94.7 |
| Carbon monoxide | g | 0.3 |
| Carbon dioxide |  g | 4537 |
| Nitrogen oxides | g | 3.0 |
| Nitrogen dioxide | g | 0.08 |
| Methane | g | 0.09 |
| **Waste (-water) treatment** |  |  |
| BOD5 \* | g | 94.7 |
| COD † | g | 2462 |
| Nitrogen | g | 322 |
| Phosphorus | g | 28.4 |
| Biodegradable waste | kg | 0.4 |

\*BOD5: Biochemical oxygen demand

†COD: Chemical oxygen demand



Figure S1. *Simplified scheme of the calculation approach for manure management, including emissions and transports* (Reckmann *et al.* 2013).