Pork production in Thuringia – management effects on ammonia and greenhouse gas emissions. 1. Depiction of the state in 2015

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Summary

The formation of ammonia (NH_3) and greenhouse gases (GHG) related to pork production is scrutinized in a fictitious enterprise that comprises 1,000 fattening places, the affiliated piglet and basic breeding herds as well as the herds of purebred grandparent animals. It also provides the necessary feed production as well as the provision of mineral fertilizers, lime, energy and water. Production conditions in the model reflect the situation in Thüringen (Thuringia), Germany.

The most important NH_3 sources are animal houses and mineral fertilizer application. GHG emissions arise mainly from feed production, in particular from the release of nitrous oxide. Within animal production itself, the majority of emissions are attributed to the fattening stage. They exceed those from piglet production. Emissions from basic breeding herds are almost negligible. However, it is inadequate to restrict estimates only to the fattening stage. Our results show clearly that potential emission reduction measures have to take the entire production chain into account.

Key words: *pork production, ammonia, greenhouse gases, area under cultivation, fertilizing, energy, water*

Zusammenfassung

Schweinefleischproduktion in Thüringen – Auswirkungen von Managementmaßnahmen auf Ammoniak- und Treibhausgasemissionen. 1. Abbildung des Zustands im Jahr 2015

Die Entstehung von Ammoniak (NH_3)- und Treibhausgas (THG)-Emissionen bei der Produktion von Schweinefleisch wird am Beispiel eines fiktiven Unternehmens untersucht, das neben der Mast mit 1.000 Mastplätzen gleichzeitig eine zugehörige Ferkelproduktion einschließlich einer Basiszucht (reinrassige Großelterntierbestände) betreibt und den Futteranbau sicherstellt. Einbezogen sind darüber hinaus die Mineraldünger- und Kalkherstellung sowie die Bereitstellung von Energie und Wasser. Die Produktionsbedingungen entsprechen den Verhältnissen in Thüringen.

Die wesentlichen NH_3-Quellen sind die Ställe und die Anwendung von Mineraldüngern. Die THG-Emissionen resultieren im Wesentlichen aus der Futtererzeugung, hier insbesondere als Lachgas-Emissionen. Die der Mast zuzuordnenden Emissionen sind deutlich größer als die aus der Ferkelproduktion, die der Basiszucht zuzuordnenden Emissionen erscheinen vernachlässigbar. Die Ergebnisse verdeutlichen, dass mögliche emissionsmindernde Maßnahmen die Betrachtung der gesamten Prozesskette erfordern. Es genügt nicht, nur die letzte Stufe der Produktion, die Mast der Endprodukte, zu bewerten.

Schlüsselwörter: *Schweinefleischerzeugung, Ammoniak, Treibhausgase, Anbaufläche, Düngung, Energie, Wasser*

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1 Introduction

More than half the meat consumed in Germany is pork. German pork and pork products are much sought-after commodities. For 2016, pork production exceeded domestic demand by 20 %. The ratio of pork exports to imports is about 2.5 (VdF, 2017). An ever increasing human world population is likely to result in increased demands for pork. With limited resources, future pork production demands increased efficiency. Furthermore, progress is likely with respect to daily weight gains due to improvement of the genetic potential and its subsequent exploitation. Boar fattening is likely to replace barrow fattening to some extent. This should result in increased numbers of animals produced per place and year (Dämmgen et al., 2013).

At the same time, national and international environmental policies aim at a reduction of air and water pollution. Within the EU, Germany has committed itself to a reduction of ammonia (NH_3) emissions of 29 % as compared with 2005, after 2030 (EU, 2016). In addition, animal welfare is to be improved (BMEL, 2017a). For pork production this means more floor space per animal as well as installations to improve well-being. This will result in larger soiled areas and hence increased NH_3 emissions from animal houses unless measures are taken to reduce those emissions.

If a reduction of livestock numbers is to be avoided, these ambitious goals can only be achieved by introduction of greatly advanced techniques not only in animal husbandry itself, but also in feed production and the provision of water and energy.

The Thuringian State Institute for Agriculture (TLL) initiated a desk study to identify sources of NH_3 and greenhouse gases (GHG) in Thuringian pork production, covering the entire production chain. This paper aims to describe the situation in 2015, for which plenty of statistical information is available.

A second paper (Dämmgen et al., 2019) deals with reduction potentials by discussing a systematic analysis, and reflects the changes anticipated for 2020 and 2025.

2 Material and methods

2.1 General approach

Calculations are made for a fictitious comprehensive enterprise – the "example enterprise" – with 1,000 places for fatteners, consisting of the farm itself, including all the animals needed for pork production (i.e. fattening, piglet production, and production and maintenance of sows and boars for breeding – basic production – named the "example herd" in the following), the land for feed production and processing, fertilizer manufacture, limestone extraction, water supply and fossil fuels used to provide heating and operate farm machinery.

In order to create a consistent data set, conditions prevailing in the German Federal State of Thuringia were used (animal weights, weight gains, number of pregnancies, animal losses, crop yields, fertilizer mix, etc.). However, as statistics were still incomplete with respect to our data requirements, a board of experts was asked for advice. [1]

The general procedure to identify and treat the relevant mass flows within an example herd was described in Dämmgen et al. (2016b).

[1] Thuringian State Institute for Agriculture (TLL): Thomas Bauer, Simone Müller, Jürgen Müller, Gerd Reinhold, Hubert Schröter, Wilfried Zorn. Thuringian Ministry for Infrastructure and Agriculture: Michael Mußlick. Qnetics GmbH: Brigitte Neues.

Table 1
Animal subcategories used in fattening, piglet production and basic breeding – names, lifespans and feeding phases – on overview

Category	Subcategory	Duration of lifespan in subcategory	Feeding
Weaners	weaners	6 weeks	3 phases, 3 feeds
Fattening pigs	not differentiated	4 months	3 phases, 3 feeds
	fattening gilts	4 months	3 phases, 3 feeds
	fattening barrows	4 months	3 phases, 3 feeds
	fattening boars	4 months	3 phases, 3 feeds
Breeding sows	young sows	6 months	3 phases, 3 feeds
	breeding sows (F1 sows)		
	1st litter	21 weeks	4 phases, 2 feeds
	2nd litter	21 weeks	4 phases, 2 feeds
	3rd litter	21 weeks	4 phases, 2 feeds
	etc.		
Breeding boars	young boars	5.5 months	3 phases, 3 feeds
	boars for artificial insemination (AI)	18 months	1 phase, 1 feed
	teaser boars	12 months	1 phase, 1 feed

2.1.1 Animal subcategories and numbers

Table 1 lists the animal subcategories considered, the respective production times and feeding details. The latter reflect common practice.

Fattening pigs are housed conventionally in pens with fully slatted, partially slatted or solid floors with bedding (see Chapter 2.3.2). Male piglets are castrated. Gilts and barrows are transferred to pens and fattened (all in all out mode; overall losses 4 %).

The herd of fatteners is maintained by weaners produced to replace 1,000 fatteners per round. These are fed and housed conventionally (flat decks; overall losses 2 %).

Calculations differentiate between animals used (slaughtered and incorporated into the fattening herd, respectively) and those which perish during production (in our calculations, these are fed to a weight of 19 kg piglet^{-1} or 75 kg fattener^{-1}; see below).

The number of sows needed to produce the required number of piglets is calculated assuming a maximum productive lifespan of eight litters. The sperm portions needed are then used to derive the number of boars for artificial insemination (AI boars) (2.4 portions per successful insemination). An appropriate number of teaser boars is deduced (3 teaser boars per 1 AI boar).

Animal numbers for basic breeding (boars and sows) consider the usual selection procedures for both genders (10 % of boars raised are used for artificial insemination; 75 % of sows raised are used in piglet production).

Pure breeding comprises the production of single breed sows and boars to produce the F1 hybrids for piglet production.

For calculation details see Dämmgen et al. (2018).

2.1.2 Feeding, housing and manure management

Animals are fed typical diets as provided by the compound feed industry (see Tables 7 to 11 and A1 to A4 in the appendix). These reflect the requirements of metabolizable energy (ME), protein and other nutrients as a function of the state of development and performance.

2.1.3 Feed production, mineral fertilizer and lime application, diesel consumption of tractors

Feed is grown according to animal requirements, using standard amounts of N, P and K fertilizers, lime and pesticides. Details of these inputs are given in section 2.3.4. The amounts of diesel fuel are used as listed for ploughing, tilling and spreading and presuppose level fields, mean tillage resistance and a distance of 2 km between farm buildings and field.

Limestone to neutralize soil acidity, for calcium ammonium nitrate and as feed limestone powders is conventionally quarried and processed. N fertilizer production is based on a modified Haber Bosch process.

All slurry or farmyard manure is applied to arable crops, as pork production does not include grassland management.

2.2 Models

For fattening pigs, weaners and sows, models describing energy requirements, feed intake and excretion rates reflect the state of the art applied to establishing the national agricultural emission inventory (Haenel et al., 2011; Rösemann et al., 2017). Modelling of all other pig subcategories follows Dämmgen et al. (2017).

Direct and indirect emissions related to crop production, mineral fertilizer and lime production as well as the provision of water (mains) and energy (natural gas, diesel fuel, electricity) follow the international rules provided in EMEP (2016) and IPCC (2006, Volumes 2, 3 and 4), using national input data wherever possible. A detailed description is provided in Dämmgen et al. (2016a).

2.3 Data

2.3.1 Data characterizing the animal herd

Tables 2 to 6 summarize the animal performance characteristics, feed intake and loss rates. All data reflect the situation in Thuringia in 2015. For fattening (Table 2), weight gains are the dominating properties, for piglet production (Table 3) the number of piglets fed affects the energy requirements. The numbers of piglets born, fed and weaned are functions of the age of the sow (number of lactation).

A side effect of the production of breeding sows is the production of male F1 animals. While the sows are fed carefully aiming at optimum body condition, boars are castrated and fattened to produce pork (as in Table 2).

In addition to boars for sperm production (artificial insemination: AI boars), mature teaser boars are used to arouse sows and improve the insemination rate. The properties of mature boars and the other subcategories involved in the production process are listed in Table 5.

2.3.2 Data characterizing manure management

A variety of housing systems has to be accounted for. We differentiate between

- fully slatted floor (fsf)
- partially slatted floor (psf)
- farmyard manure systems (FYM): solid floor with bedding
- flat decks, treated as fully slatted floors
- mix: the typical mix of systems (65 % fsf, 30 % psf, 5 % FYM) reported for Thuringian pork production (TLSt, 2011)

62 % of slurry is stored in conventional tanks without cover, 38 % undergoes anaerobic digestion producing methane in gas tight systems, which is used to generate electricity (frequency derived from Thuringian expert data).

Farmyard manure is stored in heaps.

18 % of animal places for fattening and piglet production are equipped with air scrubbers (frequency Thuringian expert information; 80 % separation efficiency for NH_3, see Dämmgen et al., 2010).

The comprehensive enterprise uses all liquid and solid manure as well as the biogas slurry as organic fertilizer. As no

Table 2
Entities characterizing the fattening stage in the example herd (fattening pigs and weaners)

	Animal category	Fattening pigs		Fattening pigs		Weaners	
	Feed	standard		N P reduced		standard	
		finished	perished	finished	perished	finished	perished
Start weight	kg animal^{-1}	30	30	30	30	8	8
Final weight	kg animal^{-1}	122	76	122	76	30	19
Daily weight gain	g animal^{-1} d^{-1}	845	845	845	845	428	428
ME requirements	MJ animal^{-1}	3,340	1,428	3,340	1,428	548	236
Feed intake FM	kg animal^{-1}	257	110	257	108	40	20
Feed intake DM	kg animal^{-1}	225	96	225	94	33	16
Excretions							
CH_4 enteric *	kg animal^{-1}	0.32	0.14	0.31	0.13	0.06	0,03
VS **	kg animal^{-1}	33.8	14.4	34.5	12.6	4.6	2,9
N ***	kg animal^{-1}	5.45	2.17	4.91	2.23	0.54	0,23
TAN ****	kg animal^{-1}	4.29	1.68	3.79	1.81	0.34	0,15
Animals fed	animal herd^{-1} a^{-1}	2,340.9	97.5	415.3	15.1	2,868.8	57.4
Manure management		mix *****	mix	mix	mix	slurry	slurry

* methane (CH_4) from enteric fermentation
** volatile solids (VS) components of the organic matter excreted
*** total nitrogen (N) excreted in urine and faeces
**** total ammonical nitrogen (TAN) excreted in urine
***** for details of mix of manure management systems see Chapter 2.3.2

Table 3
Entities characterizing piglet production stage in the example herd

Sows in lactation no		1	2	3	4	5	6	7	8
Animal weights									
day 1 pp	kg animal^{-1}	*	188.8	215.3	238.0	254.1	266.4	274.1	277.1
day 14 pp	kg animal^{-1}		190.8	216.6	238.6	254.2	266.0	273.3	275.8
day 49 pp	kg animal^{-1}	157.7	191.2	216.8	238.7	254.2	266.0	273.1	275.6
day 117 pp	kg animal^{-1}	176.8	202.9	224.7	242.1	255.1	263.8	268.1	268.1
day 127 pp	kg animal^{-1}	227.2	253.9	275.6	292.1	303.7	310.1	311.5	307.9
day 128 pp	kg animal^{-1}	234.6	261.4	283.0	299.5	310.8	316.9	317.9	313.7
Piglets born	piglet litter^{-1}	13.8	14.5	14.7	14.6	14.3	13.9	13.5	12.9
Piglets fed	piglet litter^{-1}	12.2	13.0	13.3	13.2	12.9	12.4	12.0	11.5
ME requirements	MJ place^{-1} FI^{-1} **	6,464	7,239	7,533	7,665	7,709	7,660	7,551	7,436
Feed intake FM	kg place^{-1} FI^{-1}	522	583	606	617	621	617	608	599
Feed intake DM	kg place^{-1} FI^{-1}	460	514	535	544	541	544	536	528
Excretions									
CH_4 enteric	kg place^{-1} FI^{-1}	1.19	1.36	1.40	1.42	1.43	1.42	1.41	1.39
VS	kg place^{-1} FI^{-1}	92.0	102.2	106.4	108.3	109.0	108.4	106.9	105.1
N	kg place^{-1} FI^{-1}	7.21	8.49	9.05	9.44	9.68	9.81	9.86	9.84
TAN	kg place^{-1} FI^{-1}	4.97	6.00	6.46	6.80	7.02	7.17	7.25	7.28
Sows fed	animal herd^{-1} a^{-1}	23.1	20.2	17.4	14.5	11.6	8.7	5.8	2.9
Animal losses	% of sows	0 ***	0	0	0	0	0	0	0
	% of piglets born	16	13	12	12	13	14	15	15
Manure management	slurry	slurry	slurry	slurry	slurry	slurry	slurry	slurry	slurry

* For their first pregnancy, sows are inseminated at a date which corresponds to day 49 pp in subsequent lactations.
** FI: farrowing interval
*** Losses are covered by the reduction of sow numbers from lactation to lactation.

Table 4
Entities characterizing all other F1 animals in the example herd

		Young sows F1		Young boars/barrows F1	Weaners F1
		for breeding	for fattening		
Start weight	kg animal^{-1}	30	30	30	8
Final weight	kg animal^{-1}	148	110	120	30
Daily weight gain	g animal^{-1} d^{-1}	720	720	840	428
ME requirements	MJ animal^{-1} a^{-1}	5,607	3,022	3,377	548
Feed intake FM	kg animal^{-1} a^{-1}	431	232	260	40
Feed intake DM	kg animal^{-1} a^{-1}	378	203	227	33
Excretions					
CH_4 enteric	kg animal^{-1} a^{-1}	0.60	0.32	0.32	0.06
VS	kg animal^{-1} a^{-1}	72.5	37.7	34.1	4.6
N	kg animal^{-1} a^{-1}	8.21	4.35	5.40	0.54
TAN	kg animal^{-1} a^{-1}	5.91	3.14	4.23	0.34
Animals fed	animal herd^{-1} a^{-1}	55.0	13.8	68.8	139.7
Animal losses	%	3	3	1.5	1
Manure management		FYM **	FYM	mix *	FYM

* Same mix as for fattening pigs (see below)
** FYM: farmyard manure

Table 5
Entities characterizing boars for artificial insemination (AI boars) and other animals produced and needed in this context

		AI boars	Teaser boars	Young boars	Fattening sows	Weaners
Start weight	kg animal^{-1}	150	150	30	30	8
Final weight	kg animal^{-1}	308	282	150	120	30
Daily weight gain	g animal^{-1} d^{-1}	328	362	700	840	428
ME requirements	MJ animal^{-1} a^{-1}	17,293	13,063	4,948	3,317	548
Feed intake FM	kg animal^{-1} a^{-1}	1,441	1,089	391	255	40
Feed intake DM	kg animal^{-1} a^{-1}	1,254	947	341	223	33
Excretions						
CH_4 enteric	kg animal^{-1} a^{-1}	1.86	1.40	0.54	0.35	0.06
VS	kg animal^{-1} a^{-1}	210	158	63	28	4.60
N	kg animal^{-1} a^{-1}	32.8	24.5	5,8	4.3	0.54
TAN	kg animal^{-1} a^{-1}	25.0	18.6	4.2	3.1	0.34
Animals fed	animal herd^{-1} a^{-1}	0,17	0,52	1,80	1,80	3,50
Animal losses	%	2	2	2	2	2
Manure management		FYM	FYM	FYM	mix	FYM

grass is fed, the entire amount is used in crop production. Thuringian statistics suggest the following split for 2015 (in % of N handled):

slurry
- broadcast on bare soil, incorporation within 1 h 2.5 %
- broadcast on bare soil, incorporation within 4 h 1.9 %
- broadcast on short vegetation 2.6 %
- trailing hose, incorporation within 1 h 8.7 %
- trailing hose, incorporation within 4 h 6.1 %
- trailing hose, trailing shoe, short vegetation 25.2 %
- injection (immediate incorporation) 52.5 %

farmyard manure
- broadcast on bare soil, incorporation within 24 h 100 %

2.3.3 Feed properties

Animal feed compositions follow those of commercially available products, containing barley (winter), wheat, wheat bran, maize, rape seed extraction meal, soya bean extraction meal (44 and 49 % protein), soya oil, soya protein concentrate, sugar beet pulp, whey powder, Ca phosphate, salt, lime powder and amino acids (methionine, lysine HCl, threonine, tryptophan).

Table 6a
Entities characterizing pure breeding, animals except sows

		Weaners	Young sows	Young boars reproduction	Fattening sows	Fattening barrows
Start weight	kg animal^{-1}	8	30	30	30	30
Final weight	kg animal^{-1}	30	158	150	120	120
Daily weight gain	g animal^{-1} d^{-1}	428	720	700	840	840
ME requirements	MJ animal^{-1} a^{-1}	548	5,607	4,948	3,317	3,317
Feed intake FM	kg animal^{-1} a^{-1}	40	431	391	255	255
Feed intake DM	kg animal^{-1} a^{-1}	33	378	341	223	223
Excretions						
CH_4 enteric	kg animal^{-1} a^{-1}	0.06	0.60	0.54	0.35	0.35
VS	kg animal^{-1} a^{-1}	4.6	72.5	63	28	28
N	kg animal^{-1} a^{-1}	0.54	8.20	5,80	4.32	4.32
TAN	kg animal^{-1} a^{-1}	0.34	5.90	4.20	3.11	3.11
Animals fed	animal herd^{-1} a^{-1}	97,4	44,3	4,4	4,4	44,3
Animal losses	%	*	2	2	2	2
Manure management		FYM	FYM	FYM	mix	mix
* Not taken into account						

Table 6b
Entities characterizing pure breeding of sows in the example herd

		Sows in lactation number	
		1	2
Start weight	kg animal^{-1}	158	189
Final weight	kg animal^{-1}	189	215
Daily weight gain	g animal^{-1} d^{-1}	not relevant	
Piglets born	piglet sow^{-1}	13.90	14.70
ME requirements	MJ animal^{-1} Fl^{-1}	6,464	7,239
Feed intake FM	kg animal^{-1} Fl^{-1}	522	583
Feed intake DM	kg animal^{-1} Fl^{-1}	460	518
Excretions			
CH_4 enteric	kg place^{-1} Fl^{-1}	1.19	1.36
VS	kg place^{-1} Fl^{-1}	92	102
N	kg place^{-1} Fl^{-1}	7.21	8.49
TAN	kg place^{-1} Fl^{-1}	4.97	6.00
Animals fed	animal herd^{-1} a^{-1}	7.2	7.2
Animal losses	%	*	
Manure management		FYM	FYM
* Not taken into account			

Feed properties are listed in Tables 7 to 11. For details of feed composition see Appendix.

2.3.4 Data characterizing crop production

The amounts of each single crop are calculated from the ME intake figures. From these the cropped areas are derived with

Table 7
Weaners' standard feed properties

Animal subcategory		Weaner live weight kg animal^{-1}		
		8-12	12-20	20-30
Dry matter (DM) content	%	88.61	87.95	87.97
ME content	MJ kg^{-1}	14.00	13.60	13.40
Crude protein (CP)	%	17.00	17.00	17.00
Crude fibre (CF)	%	2.86	3.50	4.00
Ether extract (EE)	%	5.22	5.12	5.24
Crude ash (CA)	%	5.33	5.61	5.68
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.064	0.075	0.079
Digestibility of N	kg kg^{-1}	0.758	0.752	0.747
Digestibility of organic matter (OM)	kg kg^{-1}	0.852	0.838	0.828

Table 8a
Fatteners' standard feed properties

Animal subcategory		Fattener live weight kg animal^{-1}		
		30-60	60-90	> 90
4,674	%	87.52	87.30	87.36
ME content	MJ kg^{-1}	13.20	13.00	12.80
Crude protein (CP)	%	17.50	16.50	15.50
Crude fibre (CF)	%	3.79	3.73	4.27
Ether extract (EE)	%	3.05	1.83	1.79
Crude ash (CA)	%	5.10	4.76	4.41
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.071	0.069	0.072
Digestibility of N	kg kg^{-1}	0.866	0.861	0.829
Digestibility of organic matter (OM)	kg kg^{-1}	0.851	0.850	0.830

Table 8b
Fatteners' N P reduced feed properties

Animal subcategory		Fattener live weight kg animal^{-1}		
		30-60	60-90	> 90
Dry matter (DM) content	%	87.52	87.34	87.41
ME content	MJ kg^{-1}	13.20	13.00	12.80
Crude protein (CP)	%	17.00	15.00	14.00
Crude fibre (CF)	%	3.73	3.60	4.19
Ether extract (EE)	%	2.98	1.76	1.83
Crude ash (CA)	%	5.05	4.61	4.27
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.069	0.065	0.069
Digestibility of N	kg kg^{-1}	0.865	0.852	0.817
Digestibility of organic matter (OM)	kg kg^{-1}	0.850	0.846	0.825

Table 9
Breeding sows' and boars' standard feed properties

Animal subcategory		Breeding sow		Breeding boar
		lactating	gestating	
Dry matter (DM) content	%	87.98	88.32	86.99
ME content	MJ kg^{-1}	13.00	12.00	12.00
Crude protein (CP)	%	16.00	13.50	18.50
Crude fibre (CF)	%	4.74	7.00	5.96
Ether extract (EE)	%	5.16	4.66	1.91
Crude ash (CA)	%	5.62	4.96	5.70
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.083	0.138	0.091
Digestibility of N	kg kg^{-1}	0.826	0.762	0.824
Digestibility of organic matter (OM)	kg kg^{-1}	0.803	0.781	0.790

Table 10
Young sows' (F1) standard feed properties

Animal subcategory		Young sow (F1)		
		30-60	60-100	> 100
Dry matter (DM) content	%	87.30	87.49	87.63
ME content	MJ kg^{-1}	13.00	13.00	13.00
Crude protein (CP)	%	16.50	14.50	14.00
Crude fibre (CF)	%	4.50	5.00	5.50
Ether extract (EE)	%	4.25	5.59	6.85
Crude ash (CA)	%	5.32	4.94	4.96
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.076	0.079	0.080
Digestibility of N	kg kg^{-1}	0.835	0.802	0.785
Digestibility of organic matter (OM)	kg kg^{-1}	0.821	0.799	0.790

the fertilizer needed. The crops used in this paper and selected characteristics are compiled in Table 12.

N fertilizer application follows the recommendations by BMEL (2017b), adjusted for yields reported for Thuringia. The entire manure produced is taken into account, using a mineral

Table 11
Young boars' standard feed properties

Animal subcategory		Young boar		
		30-60	60-90	> 90
Dry matter (DM) content	%	87.34	87.23	87.27
ME content	MJ kg^{-1}	13.00	12.60	12.60
Crude protein (CP)	%	17.00	16.50	15.50
Crude fibre (CF)	%	4.50	5.00	5.00
Ether extract (EE)	%	4.09	3.00	3.21
Crude ash (CA)	%	5.34	5.17	5.11
Bacterially fermentable substrate (BFS)	kg kg^{-1}	0.076	0.081	0.080
Digestibility of N	kg kg^{-1}	0.840	0.823	0.814
Digestibility of organic matter (OM)	kg kg^{-1}	0.822	0.803	0.799

fertilizer equivalent of 0.70 kg kg^{-1} N (BMEL, 2017b). 55 % of N fertilizer is applied as calcium ammonium nitrate (CAN), 25 % as urea and 20 % as urea ammonium nitrate (UAN).

The amounts of PK fertilizers (18 % P_2O_5, 10 % K_2O) are also taken from KTBL (2014), i.e. 0.40 Mg ha^{-1} a^{-1} for all cereals, 0.36 Mg ha^{-1} a^{-1} for rape and 0.60 Mg ha^{-1} a^{-1} for sugar beet.

Lime is applied to the entire land at a rate of 1 Mg ha^{-1} a^{-1} as standard dose. Additional lime is applied with CAN. Acidifying properties of urea have to be compensated for with extra lime.

As a rule, emissions from crop production are calculated for each single gas. Table 12 gives a combined GHG emission for soya, as details are not available at present.

2.3.5 Allocation of emissions from by-products

Several feed constituents are by-products of commodities sold otherwise. The emissions are then allocated according to the share of GE content of the respective product, and expressed as a fraction of the area used to grow the crop, with consequences on fertilizer use and then on emissions (calculations based on Beyer et al., 2004, Kool et al., 2012, and BioGrace, 2012). For details see Table 13.

2.3.6 Water and electricity

Water is required as drinking water, process water and water in plant production. Electricity has to be provided to pump this amount. In mills, no water is taken into account. Processing sugar beet is a source of water.

Energy requirements in the animal house

On the farm, electricity is needed for heating, lighting, cleansing and a variety of motors (e.g. for feed transport and removal of slurry or manure). KTBL (2014) recommends electricity consumption data as in Table 14 for planning purposes.

Drinking water

For all subcategories except breeding sows and boars, the amounts of drinking water are related to feed intake (fresh matter, FM). A factor of 3 l (kg FM)$^{-1}$ water is used. For breeding boars this ratio is of 3.5 l (kg FM)$^{-1}$ water (KTBL, 2014).

Table 12
Yields, N fertilizer, lime and water required in plant production

	Yields (Thuringia) *	N requirements according to BMEL (2017b) (yield in brackets)	Lime ****	Diesel fuel ****	Water ****	GHG emissions
	Mg ha^{-1} FM ***	kg ha^{-1} N (Mg ha^{-1})	Mg ha^{-1}	l ha^{-1}	l ha^{-1}	kg kg^{-1} CO_2-eq
Wheat (winter wheat)	7.23	230 (8.0)	1.0	83.62	1,200	
Barley (winter barley)	7.00	180 (7.0)	1.0	83.62	1,200	
Maize	9.42	200 (9.0)	1.0	83.53	600	
Rape	3.87	200 (4.0)	1.0	84.61	900	
Soya **	3.17	0 (2.8)		58.77	300	0.3653
Sugar beet	66.24	170 (65)	1.0	92.50	900	

* Crop yields except soy taken from StatBA (2016) for the Federal State of Thuringia
** Soya yields taken from Sojaförderring (2013), fuel and GHG emissions for soya from BioGrace (2012). Data set incomplete, no single gas emissions available, however overall GHG emissions.
*** Mg (Megagramme). 1 Mg = 10^3 kg
**** The amounts of lime, diesel fuel and water are taken or derived from KTBL (2014). Energy content of diesel fuel is 35.73 MJ l^{-1}.

Table 13
Areas describing feed constituents that are by-products, and the respective allocation factors

Feed constituent	Crop	Area per unit of yield	Allocation factor	
		ha (Mg FM)$^{-1}$	ha ha^{-1}	
Wheat bran	wheat (winter)	0.609	0.269	
Soya bean meal 44 % CP	soya	0.458	0.656	
Soya bean meal 49 % CP	soya	0.357	0.656	
Soya oil	soya	1.880	0.344	
Soya protein concentrate	soya		0.300	*
Rape seed meal	rape	0.470	0.398	
Sugar beet pulp	sugar beet	0.339	0.242	

* Incomplete preliminary information (Sojaförderring, 2013)

Table 14
Electricity requirements in the example farm

	Unit	Weaners	Fatteners	Breeding sows
Lighting	kWh place^{-1} a^{-1}	2.0	4.0	23.0
Ventilation	kWh place^{-1} a^{-1}	7.0	20.0	60.0
Feeding	kWh place^{-1} a^{-1}	0.3	1.0	1.5
Removal of slurry/manure	kWh place^{-1} a^{-1}	0.4	0.1	0.2
Cleansing	kWh place^{-1} a^{-1}	0.6	0.3	7.0
Heating	kWh place^{-1} a^{-1}	60.0	45.0	24.0
Total	kWh place^{-1} a^{-1}	70.3	70.4	340.0

For breeding sows, KTBL (2014) recommends 3 l (kg FM)$^{-1}$ water during gestation and 6.5 l (kg FM)$^{-1}$ water during lactation.

Process water
KTBL (2014) data are used to estimate the amounts of process water:

- fatteners 140 l place^{-1} a^{-1}
- breeding sows 500 l place^{-1} a^{-1}
- weaners 68 l place^{-1} a^{-1}

Due to lack of information, the value for fatteners is also used for young sows and boars as well as breeding boars.

Water requirements in plant production
The application of pesticides is the only process where water is needed in crop production. For the respective volumes see Table 12. For soya production in Germany a single treatment using 300 l ha^{-1} is assumed (Gehring, 2014). In this survey, irrigation is not taken into account.

3 Results

3.1 *Carcasses produced*

One entity characterising pork production efficiency is the emission per unit of carcass mass [2]. Overall carcass production amounts to 301 Mg herd^{-1} a^{-1}, dominated by far by the fattening stage. However, selected young sows have to be taken into account, as have the barrows produced in this stage. In addition, the carcasses of breeding sows taken out of production will be used for pork production. Due to their boar taint, the use of carcasses of AI and teaser boars is restricted (even after castration). For details see Table 15.

3.2 *Allocated ammonia and greenhouse gas emissions*

A detailed description of the NH_3 and GHG emissions differentiating between the relevant gases and the four

[2] A uniform carcass dressing percentage of 79 % is used for all animal subcategories.

Table 15
Carcass weights produced in the various production stages

	Fattening sows	Fattening barrows	Young sows	Breeding sows	Young boars	AI and teaser boars
	Mg herd^{-1} a^{-1}					
Fattening	132.7	132.7				
Piglet production		6.5	1.2	20.5		
Basic production	0.2				0.1	0.0
Pure breeding	0.7	4.2	0.4	1.2		0.4

production stages is provided in Tables 16 to 19. The unit "herd" stands for the respective animal category within the entire example herd. The numbers illustrate where potential reduction might be most efficient. GHG emissions are given in carbon dioxide equivalents (CO_2-eq), reflecting the respective global warming potentials (GWP) of CO_2, CH_4 and N_2O ($GWP_{CO_2} = 1$ kg kg^{-1}, $GWP_{CH_4} = 25$ kg kg^{-1}, $GWP_{N_2O} = 298$ kg kg^{-1}).

General comments: While the numbers presented in Tables 16 to 19 imply a high "accuracy" it has to be kept in mind that the uncertainty of each value is considerable (see Chapter 4.1).

CO_2 emissions from the digestive tract originate from feedlime. CO_2 from respiration is not considered an emission, as it equals the amount of CO_2 fixed during photosynthesis.

Table 16
Emissions from the fattening of pigs (including weaners for fattening) in detail

	NH_3	N_2O	CH_4	CO_2	GHG	Total GHG
	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	Mg herd^{-1} a^{-1} CO_2-eq	Mg herd^{-1} a^{-1} CO_2-eq
Digestive tract			1,082	2,837		29.9
Manure management						
animal house	4,373					
storage	242	15	3,517			92.4
application	1,248					
overall management	5,863					
Plant production						
N mineral fertilizer	526	146				43.5
lime and calcium ammonium nitrate				15,461		15.5
plant residues		139				41.5
diesel for plant production		8	8	21,820		24.5
Mineral fertilizer production						
N fertilizers	423				21.3	21.3
P fertilizers, phosphate in feed					7.3	7.3
Lime production				128	0.0	0.1
Provision of electricity						
animal house, climate and lighting					27.1	27.1
compound feed production					2.1	2.1
lime quarry					1.5	1.5
provision of water					1.1	1.1
Provision of diesel fuel					3.0	3.0
Provision of natural gas					0.0	0.0
Indirect emissions						
from agriculture		76				
from mineral fertilizer production		5				
Total	6,812	390	4,608	40,247	63.4	334.4

Table 17
Detailed emissions from piglet production (F1 animals)

	NH_3	N_2O	CH_4	CO_2	GHG	Total GHG
	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	Mg herd^{-1} a^{-1} CO_2-eq	Mg herd^{-1} a^{-1} CO_2-eq
Digestive tract			408	18		10.2
Manure management						
animal house	767					
storage	67	6	394			11.7
application	186					
overall management	1,020					
Plant production						
N mineral fertilizer	130	114				34.0
lime and calcium ammonium nitrate				4,006		4.0
plant residues		31				9.3
diesel for plant production		1	0	1,568		1.8
Mineral fertilizer production						
N fertilizers	163				1.0	1.0
P fertilizers, phosphate in feed					0.4	0.4
Lime production		0	0	26		0.0
Provision of electricity						
animal house, climate and lighting					39.7	39.7
compound feed production					0.8	0.8
lime quarry					0.3	0.3
provision of water					0.3	0.3
Provision of diesel fuel					0.7	0.7
Provision of natural gas					2.6	2.6
Indirect emissions						0.0
from agriculture		13				3.9
from mineral fertilizer production		0				0.1
Total	1,312	166	802	5,618	45.9	120.9

A comparison of Tables 16 to 19 reveals that about 81 % of the NH_3 emissions and 66 % of the GHG emissions arise from fattening, 14 % and 27 % from piglet production, respectively. This reflects the difference in manure management. In contrast, the contributions of basic breeding to overall NH_3 and GHG emissions are almost negligible.

NH_3 emissions are dominated by emissions from animal houses (64 %); the largest proportion of GHG emissions arises from crop production (all steps, 58 %).

Emissions have to be related to the amounts of pork produced. They amount to 20 g (kg carcass)$^{-1}$ NH_3 and 1.63 kg (kg carcass)$^{-1}$ CO_2-eq GHG. (For details see Chapter 4.2.)

3.3 Area and water requirements

The areas needed for crop production amount to 138 ha herd^{-1} a^{-1}, 29 ha herd^{-1} a^{-1}, 0 ha herd^{-1} a^{-1} and 9 ha herd^{-1} a^{-1} for fattening, piglet production, basic breeding and pure breeding, respectively, totalling to 177 ha herd^{-1} a^{-1} or 0.59 ha (Mg carcass)$^{-1}$.

Water consumption is governed by drinking water (3,504 m^3 herd^{-1} a^{-1}), most of which is used for fatteners (2,524 m^3 herd^{-1} a^{-1}). Volumes of water used for cleaning and in crop production add up to 1,022 m^3 herd^{-1} a^{-1}. The entire production chain requires 4,523 m^3 herd^{-1} a^{-1} or 15.2 l (kg carcass)$^{-1}$.

3.4 Nitrogen balance

All relevant fluxes of N species are compiled in Figure 1. It is obvious that the amounts in the compartment aimed at, i.e. protein in meat, are similar to the unwanted emissions of N species: more than half the amount of N fixed in the NH_3 synthesis (13.8 Mg herd^{-1} a^{-1}) is lost in emissions (8.8 Mg herd^{-1} a^{-1}).

Provisionally, our calculations assume that 5 % of N from fertilizers and manures is lost with surface run off or leached to ground waters reflecting IPCC (2006, Agriculture, definition of $Frac_{LEACH-(H)}$) and the results of lysimeter studies (see below). This results in an N deficit Δm_N of about 0.5 Mg herd^{-1} a^{-1} or 2.8 kg ha^{-1} a^{-1} N. This (minor) deficit may be explained with the error propagation resulting from the uncertainties in the overall calculation procedures. However, this is an estimate; losses of N to surface and ground waters are likely, though smaller than the IPCC "rule of thumb". Thuringia

Table 18
Detailed emissions from the basic breeding

	NH_3	N_2O	CH_4	CO_2	GHG	Total GHG
	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	Mg herd^{-1} a^{-1} CO_2-eq	Mg herd^{-1} a^{-1} CO_2-eq
Digestive tract			2	0		0.1
Manure management						
animal house	10					
storage	4	0	2			0.2
application	2					
overall management	16					
Plant production						
N mineral fertilizer	1	0				0.1
lime and calcium ammonium nitrate				41		0.0
plant residues		0				0.1
diesel for plant production		0	0	49		0.1
Mineral fertilizer production						
N fertilizers	1				0.1	0.1
P fertilizers, phosphate in feed					0.0	0.0
Lime production		0	0	31		0.0
Provision of electricity						
animal house, climate and lighting					0.2	0.2
compound feed production					0.0	0.0
lime quarry					0.0	0.0
provision of water					0.0	0.0
Provision of diesel fuel					0.0	0.0
Provision of natural gas					0.0	0.0
Indirect emissions						0.0
from agriculture		0				0.1
from mineral fertilizer production		0				0.0
Total	19	1	4	121	0.2	0.9

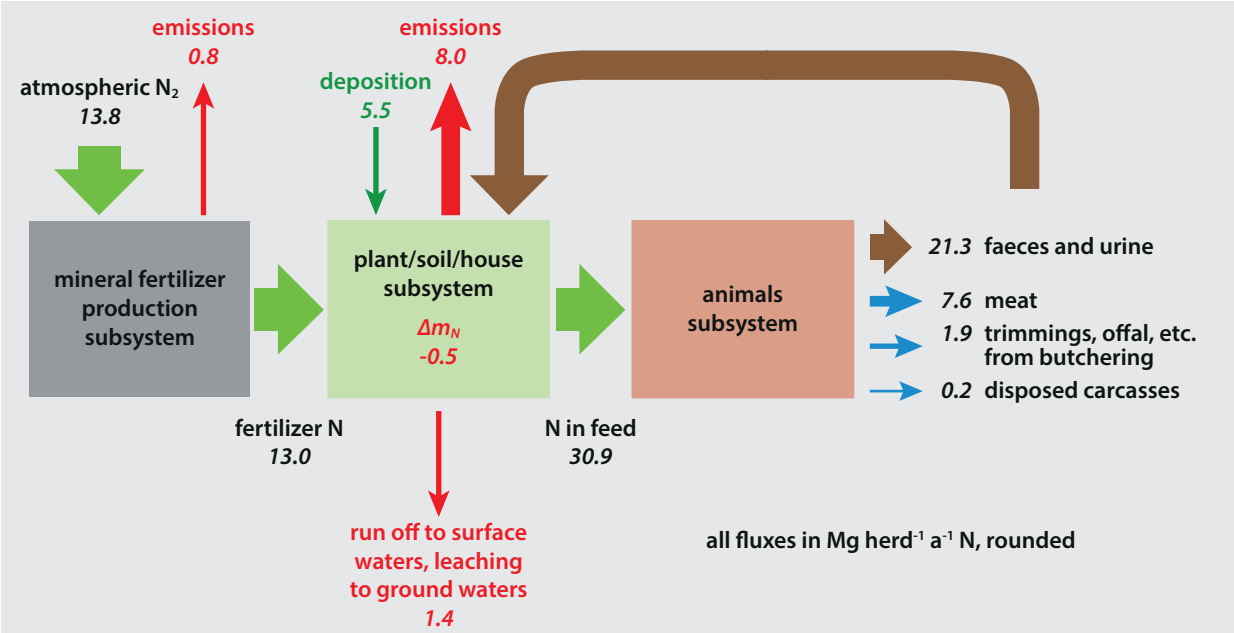

Figure 1
N fluxes in the pork production of the example enterprise (rounded values)

Table 19
Detailed emissions from the pure breeding

	NH_3	N_2O	CH_4	CO_2	GHG	Total GHG
	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	kg herd^{-1} a^{-1}	Mg herd^{-1} a^{-1} CO_2-eq	Mg herd^{-1} a^{-1} CO_2-eq
Digestive tract			98	2		2.4
Manure management						
animal house	250					
storage	59	9	152			6.6
application	57					
overall management	366					
Plant production						
N mineral fertilizer	38	13				3.8
lime and calcium ammonium nitrate				1,139		1.1
plant residues		14				4.0
diesel for plant production		1	0	1,411		1.6
Mineral fertilizer production						
N fertilizers	29				1.6	1.6
P fertilizers, phosphate in feed					0.1	0.1
Lime production		0	0	51		0.1
Provision of electricity						
animal house, climate and lighting					9.8	9.8
compound feed production					0.1	0.1
lime quarry					0.1	0.1
provision of water					0.0	0.0
Provision of diesel fuel					0.2	0.2
Provision of natural gas					1.0	1.0
Indirect emissions						0.0
from agriculture		7.				2.0
from mineral fertilizer production		0.				0.1
Total	434	43	250	2,603	12.9	34.7

clearly has nitrate polluted drinking water (TLUG, 2015), and leaching of agricultural N is considered the reason.

In the main agricultural production areas in the Thüringer Becken, evapotranspiration almost equals precipitation (Roth et al., 2005). Long-term lysimeter experiments with arable crops showed losses with leaching of 2 kg ha^{-1} a^{-1} N, equivalent to 0.35 Mg herd^{-1} a^{-1} N.

4 Discussion

4.1 Uncertainties

Uncertainties of the input data and the calculation procedures have to be addressed and reported in the national emission inventory. In this paper, input data are exact by definition. Uncertainties stem from the emission factors used. These vary between 40 % (most emission factors for NH_3 and GHG) and 400 % (indirectly emitted N_2O). Rösemann et al. (2017) report that the German inventory's uncertainties for GHG are 38.1 % (mainly due to uncertainties of N_2O emissions), and about 18.5 % for NH_3.

4.2 Comparability and comparative data

4.2.1 Ammonia

NH_3 emissions originate almost entirely from agricultural production. Beyond the farm gate no emissions occur at the slaughter house or during transport. In the example enterprise, NH_3 emissions related to carcass weight amount to 28 g (kg carcass)$^{-1}$.

Reckmann (2013) reports 20.7 g (kg carcass)$^{-1}$ NH_3. However, the calculation procedures are not communicated in detail. We assume that carcasses other than those of fattening pigs are not included. It seems that a natural crust was assumed for slurry storage. A mineral fertilizer equivalent different from ours was used (0.75 kg kg^{-1}).

Nguyen et al. (2011) report the acidification potential resulting from NH_3 emissions. This can be back calculated to an NH_3 emission of 30 g (kg carcass)$^{-1}$ which exceeds our results. Their model outline is very similar to the one described in this paper.

British investigations (BPEX, 2014) relate acidification to pork which results in carcass related NH_3 emissions of 77 and 69 g (kg carcass)$^{-1}$ in 2008 and 2012, respectively.

McAuliffe et al. (2017) provide a wide range of acidification equivalents. Values related to carcass weights are between 20 and 26 g (kg carcass)$^{-1}$ NH_3.

Thuringian pork production makes use of exhaust scrubbers and biogas production which (in combination with a considerable share of low emission incorporation conditions) has a beneficial effect on emissions.

4.2.2 Greenhouse gases

The GHG emissions listed in this paper reflect the entire production chain until slaughtering. They add up to 1.63 kg CO_2-eq GHG per kg of carcass. If only carcasses of fattening pigs are considered, this value increases to 1.83 kg CO_2-eq GHG. If, in addition, biogas plants are not taken into account, this value increases to 2.1 kg CO_2-eq GHG. If only standard feed is used, emissions increase by further 0.2 kg CO_2-eq GHG.

Reckmann (2013) calculated 3.2 kg (kg carcass)$^{-1}$ CO_2-eq, including road transport and slaughterhouse (in contrast to our calculations). The latter amount to 0.2 kg (kg carcass)$^{-1}$ CO_2-eq. Reckmann (2013) estimated GHG emissions per kg of carcass up to slaughtering of 3.0 kg CO_2-eq, still exceeding the value reported here by far. However, Reckmann (2013) presupposes daily weight gains of only 788 g animal^{-1} d^{-1} which is considerably less than the one listed in Table 2 (which results in higher emissions per unit of pork produced).

Danish investigations (Nguyen et al., 2011) are in line with our findings reporting 2.0 to 2.4 kg (kg carcass)$^{-1}$ CO_2-eq at farm level (depending on systems and modelling procedures).

A Swedish study relating GHG emissions from pork production to bone free meat can be re-calculated to carcass weights, resulting in about 2.6 kg (kg carcass)$^{-1}$ CO_2-eq. (Sonesson et al., 2009).

The British study (BPEX, 2014) illustrates the changes of emissions with time. Carcass related GHG emissions amounted to 4.3 kg (kg carcass)$^{-1}$ CO_2-eq in 2008 [3], and were reduced to 3.2 kg (kg carcass)$^{-1}$ CO_2-eq in 2012 - a reduction by 26 % in just four years. 2.9 g (kg carcass)$^{-1}$ CO_2-eq are predicted for 2020.

A detailed study was published by McAuliffe et al. (2017) indicating the differences resulting from different modelling procedures (emissions related to live weight, slaughter weight, or carcass weight; farm gate or slaughterhouse gate). Results related to carcass weight and farm gate range between 2.5 and 3.5 kg (kg carcass)$^{-1}$ CO_2-eq.

By and large the product related GHG emissions quantified for the example herd are low in comparison with literature data. This is attributed to the fact that a considerable share of slurry is digested in biogas plants.

4.2.3 Nitrogen balance

Comparable N balances could not be found in the national or international literature. Experimental balances in Central Germany more than a decade ago determined higher surplus amounts (Eckert et al., 2004; 40 to 50 kg ha^{-1} N, depending on amounts leached). Jarvis et al. (2011) describe typical pork production in Europe with results similar to those described here.

[3] Using a carcass cutting yield of 0.7 kg kg-1.

Acknowledgement

Thanks are due to the Thuringian State Institute for Agriculture (TLL) for provision of data and financial support for UD and WB.

Appendix: Feed composition

Table A1
Weaners' standard feed composition in % FM (for properties see Table 7)

Animal subcategory	Weaner	Weaner	Weaner
		live weight kg animal^{-1}	
	8-12	12-20	20-30
Barley, heat treated	10.00	10.00	
Barley, winter	10.00	17.38	28.16
Maize	13.91	6.10	1.71
Whey powder	5.00		
Rapeseed meal			
Soya bean meal toasted 49 % CP	7.53	14.90	14.68
Soya bean meal toasted 44 % CP			
Soya bean oil	3.33	3.26	3.39
Sugar beet pulp, pressed			
Wheat	40.00	40.00	40.00
Wheat bran		3.00	7.00
Soya protein concentrate	5.00		
Soybean hulls			
Ca phosphate	0.81	0.73	0.55
Lime	0.95	1.32	1.39
Salt	0.51	0.59	0.57
Methionine	0.28	0.21	0.18
Lysine HCl	0.77	0.64	0.57
Threonine	0.31	0.29	0.25
Tryptophan	0.11	0.08	0.06
Premix weaners	1.00	1.00	1.00
Premix sows			
Premix fatteners			
Formic acid	0 .50	0.50	0.50

Table A2
Fatteners' standard and N P reduced feed compositions in % FM (for properties see Table 8a)

Animal subcategory	Fattener					
	standard			N P reduced		
	live weight kg animal^{-1}					
	30-60	60-90	> 90	30-60	60-90	> 90
Barley, heat treated						
Barley, winter	20.00	20.00	20.00	20.00	20.00	20.00
Maize						
Whey powder						
Rapeseed meal			8.00		0.94	8.00
Soya bean meal toasted 49 % CP						
Soya bean meal toasted 44 % CP	17.95	14.87	6.08	16.20	9.06	0.88
Soya bean oil	1.35	0.08		1.27		
Sugar beet pulp, pressed						
Wheat	57.73	62.53	63.15	59.43	67.18	66.80
Wheat bran			0.77			2.06
Soya protein concentrate						
Soybean hulls						
Ca phosphate	0.57	0.36		0.59	0.41	
Lime	0.93	0.90	0.85	0.93	0.90	0.87
Salt	0.32	0.32	0.27	0.32	0.32	0.27
Methionine	0.07	0.02		0.08	0.04	0.01
Lysine HCl	0.46	0.30	0.29	0.52	0.47	0.46
Threonine	0.09	0.10	0.09	0.11	0.17	0.15
Tryptophan	0.03	0.01		0.04	0.03	0.01
Premix weaners						
Premix sows						
Premix fatteners	0.50	0.50	0.50	0.50	0.50	0.50
Formic acid						

Table A3
Breeding sow's and boar's standard feed composition in % FM (for properties see Table 9)

Animal subcategory	Breeding sow		Breeding boar
	lactating	gestating	
Barley, heat treated			
Barley, winter	20.00	20.00	44.07
Maize			
Whey powder			
Rapeseed meal	8.00	12.00	10.00
Soya bean meal toasted 49 % CP			
Soya bean meal toasted 44 % CP	10.18	0.58	14.94
Soya bean oil	3.89	2.45	
Sugar beet pulp, pressed		12.20	
Wheat	45.45	42.10	23.10
Wheat bran	9.38	9.26	5.45
Soya protein concentrate			
Soybean hulls			
Ca phosphate	0.28		
Lime	1.35	0.80	1.15
Salt	0.58		0.54
Methionine	0.01		0.02
Lysine HCl	0.30	0.10	0.19
Threonine	0.08		0.04
Tryptophan	0.01		
Premix weaners			
Premix sows	0.50	0.50	0.50
Premix fatteners			
Formic acid			

Table A4
Young sows' and boars' standard feed compositions in % FM (for properties see Tables 10 and 11)

Animal subcategory	Young sows (F1)			Young boars		
	live weight in kg animal^{-1}					
	30-60	60-100	> 180	30-60	60-90	> 90
Barley, heat treated						
Barley, winter	20.00	20.00	20.00	20.00	20.00	20.00
Maize						
Whey powder						
Rapeseed meal	4.23	10.00	8.00	8.00	10.00	10.00
Soya bean meal toasted 49 % CP						
Soya bean meal toasted 44 % CP	12.35	2.76	0.96	10.74	6.61	3.66
Soya bean oil	1.41	2.49	4.09	2.33	1.10	1.28
Sugar beet pulp, pressed						
Wheat	58.75	58.94	51.02	53.02	51.54	53.02
Wheat bran		3.46	13.33	2.60	7.66	9.00
Soya protein concentrate						
Soybean hulls						
Ca phosphate	0.51	0.08		0.31		
Lime	1.18	1.06	1.37	1.21	1.19	1.20
Salt	0.45	0.45	0.44	0.45	0.45	0.45
Methionine	0.25			0.18	0.19	0.18
Lysine HCl	0.28	0.23	0.24	0.45	0.53	0.51
Threonine	0.08	0.03	0.05	0.16	0.19	0.17
Tryptophan				0.03	0.04	0.04
Premix weaners						
Premix sows	0.50	0.50	0.50	0.50	0.50	0.50
Premix fatteners						
Formic acid						

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