Derivation of TAN related ammonia emission factors in pig production

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Abstract

Hitherto, the emission factors for ammonia in pig production used in the German agricultural emission inventory were based on expert judgement. They were derived from absolute amounts of ammonia emitted, later related to absolute nitrogen excretion rates. However, the N flow model used in emission calculations presupposes proportional emission factors related to the amount of ammonium nitrogen (TAN) available.

Recently, the original performance and feeding data upon which these data were based was communicated. Hence, a recalculation of TAN related emission factors became possible. This turned out to work without problems for animal housing systems. The results were approved of by the working group responsible. For emissions from storage, the results were contradictory. Therefore a consistent set of emission factors had to be derived for all storage systems frequently used in Germany.

It became obvious that the data quality definitely needs to be improved. The necessity to measure emissions adequately is addressed.

Keywords: Emission, emission factor, ammonia, pigs

Zusammenfassung

Ableitung von TAN-bezogenen Emissionsfaktoren für Ammoniak im Stofffluss-Modell zur Abbildung der Schweineproduktion

Die Emissionsfaktoren für Ammoniak aus der Schweinehaltung für das deutsche landwirtschaftliche Emissionsinventar basierten bisher auf Expertenschätzungen von absoluten Emissionen und von dazugehörigen Stickstoff-Ausscheidungen. Das Stoffflussmodell zur Berechnung von Emissionen benötigt relative Emissionsfaktoren, die auf vorhandenen Ammonium-Stickstoff (TAN) bezogen sind.

Die nunmehr mögliche Einsicht in die verwendeten Hintergrunddaten zur Ermittlung der Stickstoff-Ausscheidungen (Leistung und Fütterung) ermöglichte eine Neuberechnung solcher TAN-bezogenen relativen Emissionsfaktoren. Für die Emissionsfaktoren für Ställe war dies unproblematisch; die Ergebnisse wurden vom zuständigen Gremium gebilligt. Dagegen erwiesen sich die für das Lager ergebenden Faktoren als widersprüchlich. Sie wurden durch einen in sich konsistenten Satz von Emissionsfaktoren für alle in Deutschland üblichen Lagerverfahren ersetzt.

Auf die Notwendigkeit geeigneter Messungen zur Verbesserung der Qualität der Emissionsfaktoren wird hingewiesen.

Schlüsselwörter: Emission, Emissionsfaktor, Ammoniak, Schweine

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1 Introduction

The German agricultural emission inventory describes emissions of nitrogen (N) species in animal husbandry with a mass flow approach (Dämmgen and Hutchings, 2008, Haenel et al., 2010a). The emission factors used for ammonia are related to the total ammoniacal nitrogen (TAN) available at the site from which emissions occur. However, the basic review of experimental data as documented in Döhler et al. (2002) produced absolute emission factors for standard sows and standard fattening pigs without a relation to the amount of N excreted.

Data had to be transformed into relative and TAN based emission factors to serve the needs of the mass flow approach.

This paper relates N and TAN excretion rates to the properties of standard sows and pigs as provided by LWK-WE (1997) in their standard values for fertilizer application ("Düngemittelverordnung"). In a second step, the absolute emission factors given in Döhler et al. (2002) are transformed into TAN related emission factors.

2 Assessment of N excretion rates for standard animals – applicability of the mass flow modules

2.1 Materials and methods

2.1.1 The basic data set

Döhler et al. (2002) agreed on absolute ammonia (NH_3) emission factors for fattening pigs for all relevant housing systems. This data set refers to pigs excreting 13 kg place^{-1} a^{-1} N.

Due to insufficient experimental data, just one emission factor was proposed for sows in any housing system. No N excretion rate was mentioned in Döhler et al. (2002).

Weaners were not dealt with at all.

Emissions from storage were described using emission factors related to total N (N_{tot}) available at the respective site as shown in Table 3 (central column).

When a first attempt was made to relate emission factors to variable excretion rates, i.e. the amounts of N or TAN available, the standard N excretion rates as published in LWK-WE (1997) were used in combination with feed digestibilities estimated by expert judgement.

2.1.2 The data set used for the assessment of standard values for fertilizer application

In 2009, the background information for animal excretion rates in LWK-WE (1997) were communicated by their authors (BLAG, 1996). This allowed for a recalculation of the N and TAN excretion rates as well as emission factors for sows and fattening pigs in a consistent way.

LWK-WE (1997) describes "standard excretion rates" to be used for the assessment of fertilizer amounts. Hence, the absolute emission factors related to them (Döhler et al., 2002) should provide an instrument to derive relative emission factors representative for the German situation.

2.2 General approach

The basic assumption is that emission factors relative to TAN are more appropriate to describe emissions than absolute values, as the emissions of NH_3 are considered to be proportional to the TAN pool available. This approach is recommended in both guidance documents for the assessment of agricultural emission inventories (IPCC, 2006; EMEP/EEA, 2009).

TAN is excreted almost entirely with urine. Hence it can be derived from the amount and composition of the respective animal feed once the digestibility of N in feed and the amount of N retained are known (for details see Chapter 3).

The German agricultural emission model GAS-EM (see Haenel et al., 2010a) calculates energy and feed requirements as a function of animal performance and feed properties. In a first step, these requirements are quantified and compared to those provided by BLAG (1996).

The GAS-EM modules used are PSO for sows, PWE for weaners and PFP for fattening pigs. These modules are based on data and functions provided by Flachowsky et al. (2006) and are described in detail in Haenel et al. (2010a).

2.3 Standard sow

2.3.1 Information provided by BLAG (1996)

The BLAG (1996) standard sow raises 18 piglets a^{-1} with a final weight of 25 kg animal^{-1}. A weight gain of the sow of 40 kg animal^{-1} a^{-1} is taken into account. No mean weight is provided.

The diet for the sow has a mean ME content of 13 MJ kg^{-1}. For the sucking pigs and the weaners 14 MJ kg^{-1} are given. Crude protein (XP) contents of 185 g kg^{-1}, 220 g kg^{-1} and 200 g kg^{-1} are given for the sows, sucking pigs and weaners, respectively.

The amount of feed required for the sow is 1.05 Mg place^{-1} a^{-1}, for the sucking pigs 0.05 and for the weaners 0.54 Mg place^{-1} a^{-1}.

2.3.2 ME requirements of a standard sow with piglets of 8.5 kg final weight and weaners of 25 kg as calculated with the GAS-EM module PSO

Due to lack of adequate data, PSO does not include energy requirements for mean weight gains of the sow. It relates energy requirements to the number of piglets only and considers sucking pigs to a weight of 8.5 kg animal^{-1}. Hence, the comparison with BLAG (1996) data has to consider weaners separately.

For a sow raising 18 piglets per year, ME requirements of approx. 14400 MJ place^{-1} a^{-1} are calculated in PSO.

PWE assumes a time span of 32 days between weaning and the begin of fattening (lifespan), which results in a mean weight gain of 415 g animal^{-1} d^{-1}. This is good practice according to Eurich-Menden and Schrader (2006a), pg. 538. These weaners have ME requirements of about 400 MJ animal^{-1} each, adding up to 7200 MJ per sow and year.

The total ME requirements for the standard sow including her litters is about 21600 MJ place^{-1} a^{-1}. The corresponding ME requirements used for the LWK-WE standard sow are 20400 MJ place^{-1} a^{-1}.

This agreement is taken to be satisfactory, and we assume that PSO can be used to calculate the feed requirements of a standard sow and her litters adequately.

2.3.3 Feed intake and nitrogen excretion

According to PSO, a total amount of 1.20 Mg place^{-1} a^{-1} feed has to be provided, if one uses the ME contents listed in the assumptions used for LWK-WE (1997). BLAG (1996) report 1.10 Mg place^{-1} a^{-1} for the sow alone.

With the XP contents provided by BLAG (1996), PSO calculates an N excretion of 23 kg place^{-1} a^{-1} N for a sow and 18 piglets with a final weight of 8.5 kg animal^{-1}. BLAG (1996) give a range from 21 to 27 kg place^{-1} a^{-1} N for a sow and 18 piglets of 8.0 kg animal^{-1}.

Hence we assume that PSO can also be used to provide information on N dynamics.

2.4 Standard fattening pig

2.4.1 Information provided by BLAG (1996)

BLAG (1996) describe a standard fattening pig with a weight gain of 85 kg animal^{-1} and an assumed N excretion rate of 13 kg place^{-1} a^{-1} (Döhler et al., 2002, pg. 47).

The BLAG (1996) background information on feed provides a ME content of the feed of 13 MJ kg^{-1} and an XP content of 185 g kg^{-1} XP, equivalent to 0.0296 kg kg^{-1} N.

2.4.2 Daily weight gain

The BLAG (1996) data set can be supplemented by deducing the daily weight gain from the weight gain per place and year (200 kg place^{-1} a^{-1}) and the weights at the beginning and the end of the fattening period (25 and 110 kg animal^{-1}), i.e. the number of animal rounds and the service times:

$$n_{\text{round}} = \frac{\Delta m_{\text{pl, a}}}{w_{\text{fin}} - w_{\text{start}}} \tag{1}$$

where

n_{round} number of animal rounds per year (in round a^{-1})
$\Delta m_{\text{pl, a}}$ annual weight gain per place (in kg place^{-1}) ($\Delta m_{\text{pl, a}}$ = 200 kg place^{-1} a^{-1})
w_{fin} final animal weight (w_{fin} = 110 kg animal^{-1})
w_{start} animal weight at the beginning of the fattening period (w_{start} = 25 kg animal^{-1})

The number of animal rounds is 2.35 round a^{-1}, the respective duration of a round is 155 d round^{-1}. With a service time of 5 d round^{-1} (Eurich-Menden and Schrader, 2006a, pg. 502), the animal lifespan can be deduced:

$$\tau_{\text{lifespan}} = \tau_{\text{round}} - \tau_{\text{service}} \tag{2}$$

where

τ_{lifespan} animal lifespan (in d round^{-1})
τ_{round} duration of animal round (τ_{round} = 155 d round^{-1})
τ_{service} service time (τ_{service} = 5 d round^{-1})

Hence, calculations are to be based on a mean daily weight gain of 567 g animal^{-1} d^{-1}. The metabolizable energy required is given by BLAG (1996) as 3400 MJ animal^{-1}, which agrees satisfactorily with the value calculated in PFP (3440 MJ animal^{-1}).

3 Assessment of N and TAN excretion rates for standard animals

The calculation of emission factors relative to TAN presupposes the assessment of the amount of N excreted and the TAN content of excreta. The latter can be obtained from the N intake and the digestibility of N in feed using the nitrogen balance:

$$m_{\text{excr}} = m_{\text{feed}} - m_{\text{g}} - m_{\text{p}} \tag{3}$$

where

m_{excr} amount of nitrogen in excreta (in kg place^{-1} a^{-1} N)
m_{feed} amount of nitrogen in feed (in kg place^{-1} a^{-1} N)
m_{g} amount of nitrogen retained in the animal (in kg place^{-1} a^{-1} N)
m_{p} amount of nitrogen in offspring produced (in kg place^{-1} a^{-1} N)

and

$$x_{\mathrm{TAN}} = \frac{m_{\mathrm{excr}} - m_{\mathrm{faeces}}}{m_{\mathrm{excr}}} = \frac{m_{\mathrm{excr}} - \left(m_{\mathrm{feed}} - m_{\mathrm{feed,\,digest}}\right)}{m_{\mathrm{excr}}} = \frac{m_{\mathrm{excr}} - m_{\mathrm{feed}} \cdot \left(1 - x_{\mathrm{digest,\,N}}\right)}{m_{\mathrm{excr}}} \tag{4}$$

where

x_{TAN}	TAN content in excreta (in kg kg^{-1})
m_{excr}	overall N excretion (in kg place^{-1} a^{-1} N)
m_{faeces}	N excreted with faeces (in kg place^{-1} a^{-1} N)
m_{feed}	N taken in with feed (in kg place^{-1} a^{-1} N)
$m_{\mathrm{feed,\,digest}}$	digestible N taken in with feed (in kg place^{-1} a^{-1} N)
$\mathrm{x}_{\mathrm{digest,\,N}}$	digestibility of XP and hence N in feed (in kg kg^{-1} N)

Undigested N is considered equal to the N excreted with faeces.

3.1 Standard sow

With the data provided by BLAG (1996) and an assumed feed composition with an ME content of 13 MJ kg^{-1} and a digestibility of 0.80 kg kg^{-1} N (for details see Haenel et al., 2010a, Table 5.12 "sows A"), PSO calculates a N excretion rate of 23 kg place^{-1} a^{-1} N. BLAG (1996) give rates from 21 to 27 kg place^{-1} a^{-1} N for different feeds. The amount of TAN is 17.7 kg place^{-1} a^{-1} N, the TAN content of excreta for a sow with piglets is 0.77 kg kg^{-1} N.

3.2 Standard fattening pig

In addition to the data given by BLAG (1996), it is further assumed that the share of digestible XP is 0.83 kg kg^{-1} N (see Haenel et al., 2010a, Table 5.30 "fatteners B"). This can be used to calculate the amount of N excreted with faeces and subsequently the TAN content of excreta (see equation (4)).

The calculated amount of TAN excreted m_{TAN} is 10.1 kg place^{-1} a^{-1} N, the TAN content of excreta x_{TAN} then is 0.76 kg kg^{-1}.

This value is high compared to other European TAN contents discussed within the EAGER group[A], (ranging from 0.63 to 0.75) but almost identical with the Swiss value of 0.75 that is obtained in a similar manner (Reidy et al., 2008).

[A] EAGER - European Agricultural Gaseous Emissions Inventory Researchers Network. http://www.eager.ch/index.htm

4 Conversion of absolute emission factors for housing to emission factors relative to TAN available

4.1 Calculation procedure

The emission factor relative to TAN can be obtained from absolute emissions for a housing type i as follows:

$$EF_{\mathrm{house,\,TAN,\,i}} = \frac{E_{\mathrm{NH3\text{-}N,\,i}}}{m_{\mathrm{excr}} \cdot x_{\mathrm{TAN}}} \tag{5}$$

where

$EF_{\mathrm{house,\,TAN,\,i}}$	ammonia emission factor relative to TAN for the animal house (in kg kg^{-1} N)
$E_{\mathrm{NH3\text{-}N,\,i}}$	absolute emission rate of ammonia N for housing type i (in kg place^{-1} a^{-1} N)
m_{excr}	amount of N excreted in the house (in kg place^{-1} a^{-1} N)
x_{TAN}	TAN content of excreta (in kg kg^{-1} N)

4.2 Standard sow

Due to lack of experimental data, Döhler et al. (2002), pg. 56, list just one absolute emission factor for all housing systems. This is applied to both slurry and FYM based systems. The data and the results are compiled in Table 1.

Table 1:
Derivation of relative emission factors for housing of a standard sow

		kg place^{-1} a^{-1} N	
TAN input into house		17.7	
		absolute emission rates	relative emission factor
		$E_{\mathrm{NH3,\,i}}$	$EF_{\mathrm{house,\,TAN,\,i}}$
German housing type		kg place^{-1} a^{-1} N	kg kg^{-1} N
alle Typen, flüssig	all types, slurry	6	0.34
alle Typen, fest	all types, FYM	6	0.34

4.3 Standard fattening pig

Döhler et al. (2002), pg 55, provide estimated absolute emission factors for six common housing types. Reflecting current German practice, this list was completed with one more type (litter based, FYM, closed insulated housing). The emissions from the FYM system are considered to be equivalent to both deep litter systems (4 kg place^{-1} a^{-1} N).

The resulting data set and the relative emission factors are shown in Table 2.

The value for slurry based houses with fully and partly slatted floors agrees well with the assumption made by EAGER of 0.312 kg kg^{-1} N (Reidy et al., 2008).

Table 2:

Derivation of relative emission factors for housing of fattening pigs (nBR refers to the description and evaluation for animal housing systems in Germany [Nationaler Bewertungsrahmen Tierhaltungsverfahren], Eurich-Menden and Schrader, 2006b)

TAN input into house		10.1	
German housing type		absolute emission rates kg place^{-1} a^{-1} N $E_{NH3\text{-}N, i}$	relative emission factor kg kg^{-1} N $EF_{house,TAN, i}$
wärmegedämmter Stall, Vollspaltenboden, einstreulos, nBR: MS 0002	fully slatted floor, slurry, closed insulated housing, nBR: MS 0002	3	0.3
wärmegedämmter Stall, Teilspaltenboden, einstreulos, nBR: MS 0003	partially slatted floor, slurry, closed insulated housing, nBR: MS 0003	3	0.3
wärmegedämmter Stall, Zweiflächenbucht eingestreut, plan befestigt, nBR: MS 0007 (hier ohne Auslauf)	litter based, FYM, closed insulated housing, nBR: MS 0007 (yet without exercise yard)	4	0.4
wärmegedämmter Stall Tiefstreu, nicht im nBR	deep litter, FYM, closed insu-lated housing, not listed in nBR	4	0.4
Außenklimastall, getrennte Klimabereiche, einstreulos, nBR: MS 0004	kennel housing, slurry based, free ventilated housing, nBR: MS 0004	2	0.2
Außenklimastall, getrennte Klimabereiche, eingestreut, nicht im nBR	kennel housing FYM, free ventilated housing, not listed in nBR	2	0.2
Außenklima, Tiefstreustall, nBR: MS 0006	deep litter, FYM, free venti-lated housing, nBR: MS 0006	3.5[1)]	0.35

[1)] Original information provided in Döhler et al. (2002), pg. 55, was 4 kg place^{-1} a^{-1} with the tendency to 3 kg place^{-1} a^{-1}. KTBL working group „Emission factors for animal husbandry" agreed to use the arithmetic mean.

No direct comparison was possible with the additional experimental data compiled in Eurich-Menden et al. (2005). Only one team (Kaiser and Van den Weghe, 1999) reported emission rates combined with N excretion rates for a ventilated house and a daily weight gain of about 840 g animal^{-1} d^{-1}, i.e. well above the standard pig. The mean emission factor here is in the order of 0.05 kg kg^{-1} N (related to TAN). It differs considerably. Webb et al. (2010) propose to use an emission rate of about 2.6 kg place^{-1} a^{-1} N, indicating that the experimental basis of this estimate is poor.

5 Conversion of absolute emission factors for storage to emission factors relative to TAN available

5.1 Rationale

Döhler et al. (2002), pg. 62, provide NH_3 emission factors for storage related to the amount of N available before storage for each common storage type and assumed to be **valid for all pig subcategories**. These can be converted to emission factors based on amounts of TAN available using equation (6):

$$EF_{\text{NH3-N, storage, TAN}} = \frac{m_{\text{house, N}} \cdot EF_{\text{NH3-N, storage, N}}}{m_{\text{house, TAN}}} \quad (6)$$

where

$EF_{\text{NH3-N, storage, TAN}}$ ammonia emission factor **relative to TAN** for storage (in kg kg^{-1} N)

$m_{\text{house, N}}$ amount of N transferred from the house to storage (in kg place^{-1} a^{-1} N)

$EF_{\text{NH3-N, storage, N}}$ ammonia emission factor **relative to N** for storage (in kg kg^{-1} N)

$m_{\text{house, TAN}}$ amount of TAN released from the house (in kg place^{-1} a^{-1} N)

In principle, the amounts of $m_{\text{N, house}}$ and $m_{\text{TAN, house}}$ vary with the animal subcategory and the type of the animal house. However, with the data situation for sows being insufficient, this procedure relates to fattening pigs only.

5.2 TAN inputs into storage

For **slurry based systems** both with fully slatted and partly slatted floors, the amounts of $m_{\text{N, house}}$ left calculated with PFP are 10.3 kg place^{-1} a^{-1} N, and of $m_{\text{TAN, house}}$ 6.7 kg place^{-1} a^{-1} TAN. Kennel houses are not considered.

For **straw based systems**, the deep litter system serves as reference. Here, $m_{N,\ house}$ amounts to 10.9 kg place^{-1} a^{-1} N. Due to immobilisation of TAN in straw (40 % of the TAN are assumed to be immobilized in the straw mattress), $m_{TAN,\ house}$ comes to 2.6 kg place^{-1} a^{-1} TAN.

In straw based systems (except deep litter), leachate ("Jauche") is formed. The amount of TAN to be found in leachate is calculated in PFP to be 2.3 kg place^{-1} a^{-1} N. In deep litter systems the formation of leachate is negligible.

5.3 Emission factors for storage systems

Döhler et al. (2002), pg. 62, give an estimate of emission factors for two liquid (tank and lagoon) and one FYM storage system (heap). However, no experimental basis was available at the time.

Using the information provided by Döhler et al. (2002), relative emission factors are calculated for these systems (Table 3). In comparison with factors used in other inventories in Northwest Europe, these factors were regarded inadequate and thus rejected.

Hence, for **slurry** and open tanks, the value agreed upon in Reidy et al. (2008) is used in the German inventories: $EF_{NH3\text{-}N,\ storage,\ TAN}$ = 0.15 kg kg^{-1} N. The emission factor for open lagoons is provisionally fixed at 0.25 kg kg^{-1} N.

It should be kept in mind that the emission factor for open tanks is a reference value that may be reduced by covering the slurry surface.

In addition to these factors, storage inside the house underneath a slatted floor was added and an emission factor provided by expert judgment (see explanation in Table 3).

For **solid systems**, the application of the conversion equation for solid systems leads to inconsistent results: calculated NH_3 emissions from farmyard manure exceed the amount of TAN available. This is a consequence of the fact that immobilisation was not considered in the original expert judgement. Hence, keeping in mind that the N based emission factor is an assumption without experimental background, the relative emission factor for cattle of 0.60 kg kg^{-1} N of the TAN remaining after immobilisation (Kirchmann and Witter, 1989; Dämmgen et al., 2010a) is used as a temporary measure. As shown in Reidy et al. (2009), the application of this value results in emissions comparable to those obtained without direct consideration of immobilisation in Northwest European countries.

Leachate is traditionally stored separately in pits with solid covers. Thus, the calculated emission factor considers an 80 % reduction of the factor given in UNECE (1999), pg. 106. If the N based factor is related to TAN using a mean TAN content of 0.9 kg kg^{-1} N, a value of 0.03 kg kg^{-1} N results.

Eurich-Menden et al. (2005) and Webb et al. (2010) do not report any measurements for pig excreta storage systems.

Table 3:
Derivation of relative emission factors for slurry and FYM storage

		excreta released from house		EF relative to N transferred from house[1)]	EF relative to TAN transferred from house	
		$m_{house,\ N}$	$m_{house,\ TAN}$	$EF_{NH3\text{-}N,\ storage,\ N}$	$EF_{NH3\text{-}N,\ storage,\ TAN}$	
					calculated[2)]	proposed
		kg place^{-1} a^{-1} N	kg place^{-1} a^{-1} TAN	%	kg kg^{-1} NH_3-N	kg kg^{-1} NH_3-N
Slurry storage						
Gülle-Rund-/Hochbehälter	open circular tank	10.3	6.7	15	0.23	0.15[3)]
Lagune offen	open lagoon	10.3	6.7	25	0.38	0.25[4)]
Güllekeller unter Spaltenboden	underneath slatted floor					0.105[5)]
Farm yard manure storage						
Misthaufen	heap	10.9	2.6	25	1.05	0.60[6)]
Leachate						
Behälter mit fester Abdeckung	pit with solid cover	2.7	2.3	20	0.022	0.03[7)]

[1)] estimated emission factor according to Döhler et al. (2002)
[2)] calculated by relating the amount emitted to TAN released from house
[3)] Reidy et al. (2008)
[4)] same proportion as the N related emission factors
[5)] estimated using a reduction of 30 % in comparison to emissions from open circular tanks due to restricted aeration similar to the formation of a natural crust (Döhler et al., 2002, pg. 63)
[6)] no experimental basis; to be on the safe side, twice of the Swiss emission factor is used (Eidgenössische Forschungsanstalt, 1997), see also Kirchmann and Witter (1989)
[7)] the emission factor for leachate as given in Döhler et al. (2002) is used with a TAN content of 0.9 kg kg^{-1} N and a reduction efficiency due to solid cover of 80 % (UNECE, 1999, pg. 105)

6 Emission factors for application of slurry and farmyard manures

At present, the German inventory uses emission factors related to the amount of TAN present before spreading in accordance with Döhler et al. (2002). Hence, a recalculation is unnecessary.

The emission factors applied to the reference spreading techniques in Europe (broadcast spreading) scatter considerably (Reidy et al., 2008, 2009). However, consensus (or lack of data) results in little divergence with the valuation of emission reduction techniques used for pig slurry (Webb et al, 2009).

7 Emission factors for weaners and boars (mature males)

The emission factors derived for fattening pigs are also used to describe weaners, those for sows are also used for boars (mature males).

8 Conclusions

The German data base for the derivation of emission factors for pig production is extremely insufficient (to say the least). Hence, the results of the calculations reported here form a data set which is just consistent. The few comparison data indicate that the order of magnitude is likely to be correct or does not contradict the data used in Northwest Europe (Reidy et al., 2008, 2009, Webb et al., 2010).

At present, an international group between Denmark, Germany and The Netherlands establishes a set of joint measurement protocols that are likely to overcome the situation where many experimental studies were performed that are of no value for the derivation of emission factors (see description of the data base in Döhler et al., 2002, and Eurich-Menden et al., 2005).

Dämmgen et al. (2010b) try to establish a data set describing the digestibility of N and hence improved TAN contents.

Until more reliable data are available, the data set described in this paper will have to serve as a temporary solution for the assessment of nitrogen flows and emissions in the German agricultural emission inventory.

9 Official approval

The contents of this paper dealing with emissions from housing systems were checked and approved of by "KTBL Working Group on Emission Factors in Animal Husbandry".

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