



Ammonia Emission and Nitrogen Balances in Mink Houses

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(Received 22 May 2001; accepted in revised form 17 April 2002; published online 11 July 2002)

Ammonia emissions from mink houses were measured over two seasons for growing kits in a two-row open-sided building with slurry gutters (385 mm wide). In the first season, a layer of sand was placed below the cages, and in the last season a layer of chopped barley straw on sand, to serve as a collector for urine and faeces dropped outside the gutter. When the slurry was removed weekly in the houses with slurry gutter and sand layer, the ammonia emission was 0.59 g [N] per animal per 24 h at 6°C and 1.15 g [N] per animal per 24 h at 16°C. By covering the ground area below the cages with a layer of chopped barley straw, renewed weekly, the nitrogen loss increased with the time since the latest renewal of the straw. One week after renewal of straw and removal of slurry, the emission amounted to 0.70 g [N] per animal per 24 h at 6°C and 1.44 g [N] per animal per 24 h at 16°C.

Nine-week nitrogen balance measurements were carried out in three sections over the second season. When a layer of chopped barley straw on the ground area was renewed once a week, about 45% of the nitrogen in the consumed feed was collected in the slurry gutter by emptying the gutter twice a week. About 19% was collected in straw beneath the cages, about 5% was deposited in the carcass, about 20% evaporated, and the rest, about 11%, was assumed to be collected in the sand layer below the cages. © 2002 Silsoe Research Institute.

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1. Introduction

Mink production differs from most other animal production types in the annual cycle of reproduction, feed composition and manure handling. The time span for whelping is very short. In Denmark, for instance, mink are typically born in the last week of April and the first week of May. At the time for whelping, the number of animals increases rapidly by a factor of 6, and the feed consumption increases by a factor of 4.5 until the beginning of September. Consequently, the N excretion from mink and the potential for ammonia evaporation will be high during the period from June to November. Due to high ambient temperature during the summer months, the actual ammonia emission will also be high.

The mink is a strictly carnivorous animal with high protein demands. The protein content of mink feed is, therefore about twice as high (35–40% of dry matter) as that of feed for omnivorous animals, *e.g.* pigs. Another important factor is the manure-handling system, in which urine and faeces drop from the cages to the slurry

gutter or to the floor of the house, where they are stored for days or weeks, contrary to slurry systems with slats above manure channels or cellars.

It is important to restrict nitrogen loss for two reasons. Firstly, ammonia is one of the sources of global air pollution that contributes to acidification and eutrophication in the environment, and secondly, nitrogen is a valuable and important fertilizer. Both the high dietary protein content and the housing system are challenges in respect to limiting the ammonia evaporation from mink production facilities.

Knowledge about ammonia emission from mink is limited. Beek *et al.* (1991) showed that on a diurnal basis ammonia emission from male mink was 2.5 g [NH₃] per animal (2.0 [N] per animal) at 22°C, dropping to 1.6 g [NH₃] per animal (1.3 [N] per animal) at 16°C when the slurry was stored in gutters below the cages over longer periods. By emptying the gutters every 8 h, the ammonia emission was halved, compared with long-term storage.

The protein content in the feed is an important factor for the ammonia emission. Glem-Hansen (1980) showed

Notation			
A	ammonia emission, g per animal per 24 h	S	floor covering (0 for no straw below cages and 1 for straw below cages)
a, b, c, d, e, f, g, h	regression coefficients	T	temperature, °C
C_{am}	ammonia concentration, p.p.m.	t_g	time after latest emptying of the slurry gutters, days
C_a	specific air density in kg m^{-3} (1.293 kg m^{-3} at 0°C)	t_s	time for storage of straw below cages, days
M_{am}	molecule weight for ammonia (17.031)	V	ventilation rate, $\text{m}^3 \text{ h}^{-1}$
M_{air}	equivalent molecule weight for atmospheric air (28.96)	w	average body weight, g

that the N retention in carcasses increased proportionally to the N content in the feed up to a certain level, above which no further N retention took place. As a consequence, increased nitrogen content in the feed above that level resulted in an increased amount of nitrogen excreted in faeces and especially in urine, thereby causing increased evaporation and nitrogen accumulation in the sand beneath the cages.

In order to improve the methods for evaluating the possibilities for reduction of the ammonia evaporation from mink houses, a series of tests was initiated in 1999 at the Danish Institute of Agricultural Sciences (DIAS). The tests included measurements of the ammonia emission from a two-row house with slurry gutter and sand layer. In 2000, the tests were modified by placing a layer of chopped barley straw on the sand layer below the cages for collection of the faeces, urine and feed that was dropped outside the slurry gutter. Furthermore, nitrogen balance measurements were carried out with and without slurry gutters.

2. Materials and methods

2.1. Experimental layout

In seasons 1 and 2, the ammonia emission measurements were carried out in one section (section A). In the second season, in addition nitrogen balance measurements were carried out in three sections (sections A–C) of a traditional Danish open-sided two-row mink house, as shown in Fig. 1. The cage dimensions were as follows: depth 920 mm (exclusive of the nest), width 300 mm, height 460 mm, and distance from cage bottom to edge of slurry gutter of 210 mm.

Each section had 12 cages on either side, corresponding to 48 animals in 24 cages (one male and one female in each). The animals were of the type Scanbrown. The three sections can be defined as follows:

section A—system with a 385-mm wide elevated slurry gutter (area 1) and sand bottom (area 2), where the whole section is enveloped in a tent equipped with an exhaust fan, and where the sand layer was covered with a layer of chopped barley straw in the second season;

section B—system with a 385-mm elevated slurry gutter (area 1) and sand layer (area 2) and with natural ventilation, with the sand layer covered with a layer of chopped barley straw; and

section C—system without slurry gutter and with chopped barley straw beneath the cages, divided into areas 1 and 2 and with natural ventilation.

With respect to be able to measure the ammonia emission in seasons 1 and 2 (section A), the house section was enclosed in a 6.0-m long tent, equipped with a fan with a constant ventilation rate and with continuous measurement of the ammonia content of the outlet air. The ammonia concentration in the incoming air (outdoor air) was checked regularly and it was negligible. The leakage of the tent was balanced in such a way that the negative pressure in the tent was in



Fig. 1. Mink house divided in three sections A, B and C, of which section A is enclosed in a tent, with respect to measurements of ammonia emission

the range 10–20 Pa. The length of the cage section was 4.0 m, and the remaining 2.0 m was used as service area for slurry handling.

Figure 2 shows the cross-section for group A with elevated gutter in season 1. In season 2, a layer of chopped straw was used in sections A and B, to collect urine, faeces and feed dropped outside the gutter; and in section C, the original gutter was filled with sand, and chopped straw was placed over the entire area below the cages.

The experiments were carried out over 12 weeks in season 1 and 15 weeks and 2 days in season 2, as shown

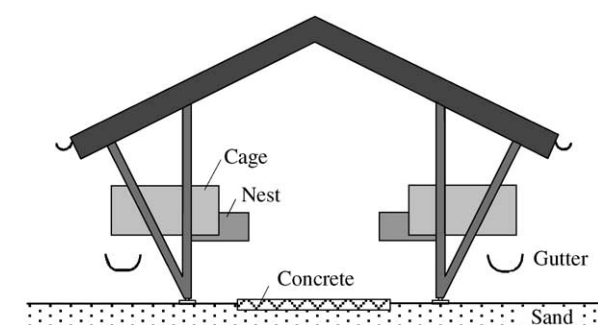
in Table 1. Table 1 also shows the time schedule for emptying the slurry gutter.

2.2. Feeding

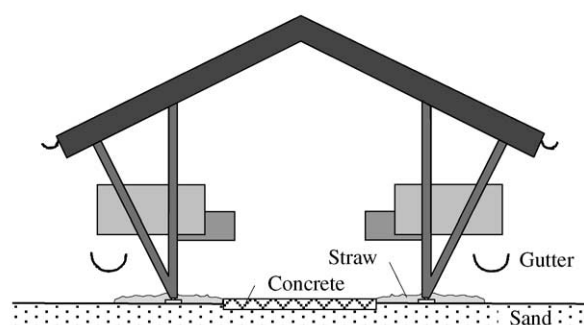
The animals were fed *ad libitum* on conventional mink feed, which was analysed weekly. The average daily feed consumption in season 1 for a weight range of 1540–1850 g (weeks 36–44) was 174 g per animal. For a dry matter content of 43.5% and a protein content of 36.2% in the dry matter, this corresponded to a nitrogen intake of 4.38 g per animal per day. The average daily feed consumption in season 2 for a weight range of 1405–1950 g (weeks 33–41) was 186 g per animal. For a dry matter content of 40.7%, and a protein content of 37.7% in the dry matter, this corresponded to a nitrogen intake of 4.55 g per animal per day. The daily N intake per mink up to a body weight of 1650 g for both seasons was about 4.8 g of N after which it then decreased to about 3.6 g of N daily per mink at 1850 g.

2.3. Concentration and ventilation rate

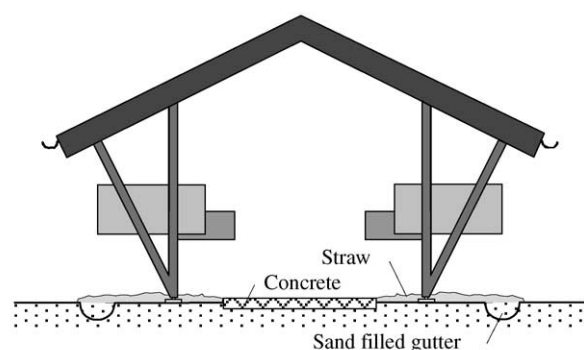
The outdoor temperature, the indoor temperature 1.5 m above floor level in the tent, the temperature of the



Season 1, section A



Season 2, sections A and B



Season 2, section C

Fig. 2. Cross-section of experimental house

Table 1
Number of gutter cleanings per week in experiments with ammonia emission in seasons 1 and 2, section A, and nitrogen balances, sections A, B and C in season 2

Week	Number of gutter cleanings per week			
	Season 1		Season 2	
	Section A (tent)*	Section A (tent)	Section B†	Section C†
33	—‡	2	2	2
34	—	2	2	2
35	—	2	2	2
36	1	2	2	2
37	1	2	2	2
38	3	2	2	2
39	3	2	2	2
40	7	2	2	2
41	1	2	2	2
42	1	2*	—	—
43	1	2*	—	—
44	1	2*	—	—
45	1	1*	—	—
46	1	2*	—	—
47	1	1*	—	—
48	—	1*	—	—

*Only ammonia emission measurements.

†Only nitrogen balance measurements.

‡Not recorded.

slurry gutter in the tent, the relative humidity in the tent and the ammonia emission were measured hourly in section A, and the results were stored by means of a data logging system.

The temperatures were measured by means of thermocouples, and the relative humidity was measured by means of a Vaisala Humitter 50U. In 1999, the analyser for measuring the ammonia concentration was a combination of a chemiluminescence nitric oxide (NO) analyser and an upstream thermal ammonia (NH₃) converter (Wathes *et al.*, 1998). Not only was NH₃ measured, but also organic components such as trimethylamine and dimethylamine were included. However, the concentration of these and other N compounds in the mink house are expected to be negligible in comparison with NH₃. In 2000, the measurements were carried out by means of an Innova Photoacoustic Single-gas Monitor, type 1312A-1 with narrow band-pass filter type 9-1 MIC, sensitive to NH₃.

The tent section A was ventilated by a negative-pressure ventilation system, with air inlet balanced to a sufficiently high negative pressure to prevent uncontrolled air exchange. The exhaust fan had a relatively stable ventilation rate in respect to different pressure drops. The calibration was carried out in a fan test rig before the start of the measurements and at the end of the experiments. The negative pressure in the house was checked once a week, ranging from 15 to 19 Pa in season 1 and from 13 to 20 Pa in season 2. The initial fan capacity for a clean fan at a pressure drop of 17 Pa was 352 m³ h⁻¹ in season 1 and 324 m³ h⁻¹ in season 2. During the measuring period, the decrease in fan capacity due to dust was 0.7% week⁻¹, and the decrease in fan capacity at increased pressure drop for the actual pressure range was 0.32% Pa⁻¹. The error in airflow measurement due to dust is estimated to be about 2%,

and the error in airflow measurement due to pressure loss is estimated to be about 1%.

In addition, weekly spot measurements on air temperature, relative humidity, ammonia and carbon dioxide concentrations were carried out for section A.

2.4. Straw

Once a week chopped barley straw was placed on top of the nest boxes to serve as bedding for the animals and below the cages for collection of manure, urine and waste feed. The average amount of straw that was placed on top of the nest boxes was 3.5 kg per week per 48 animals, and the average amount placed below the cages was 8.0 kg per week per 48 animals.

2.5. Weight of the animals

In season 1, the animals were weighed at the start and the end of the experiments, and the weekly weight increase was calculated by means of a standard growth curve. In season 2, all animals were weighed weekly until test week 9, and once again in test week 14.

3. Results

3.1. Model for ammonia evaporation

Figure 3 shows the temperature and the ammonia measurement results for the first two weeks in season 2. It took approximately 3 days before the ammonia concentration was balanced. A similar trend could be seen for season 1. The figure also shows that the diurnal

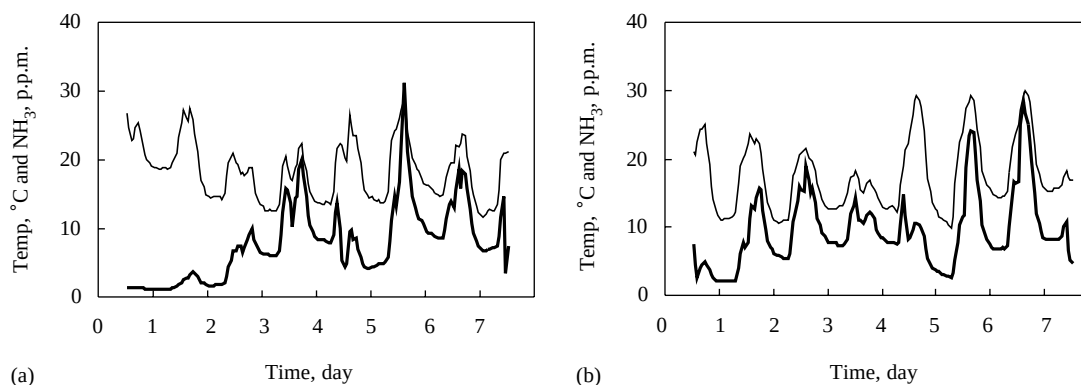


Fig. 3. Indoor temperature (—) and ammonia concentrations (—) in test weeks 1 and 2 for section A in season 2: (a) test week 1 of experiment; and (b) test week 2 of experiment

variation in ammonia concentration was high, and that it followed the ambient temperature closely.

The data analysis was carried out for 24-h periods, where slurry had been stored for from one to seven 24-h periods, according to Table 1. Altogether, 83 24-h data sets were available for season 1 and 104 24-h data sets for season 2. As it took approximately 3 days before the ammonia concentration was balanced, the ammonia emission results for the initial 3-day periods are, therefore, not included. *Figures 4* and *5* show the measured ammonia concentration for section A on a diurnal basis for seasons 1 and 2, respectively.

The ammonia concentration was higher in season 2 (*Fig. 5*) than in season 1 (*Fig. 4*), which can partly be explained by the lower ventilation flow rate in season 2 than in season 1. Taking into account the ventilation rate and the air density, the ammonia emission per mink on a diurnal basis is as follows:

$$A = C_{am}VC_a \frac{(273)}{273 + T} \frac{M_{am}}{M_{air}} \quad (1)$$

where: A is the ammonia emission in g per animal per 24 h; C_{am} is the ammonia concentration in p.p.m.; V is the ventilation rate in $\text{m}^3 \text{h}^{-1}$; C_a is the specific air density in kgm^{-3} (1.293kgm^{-3} at 0°C); T is the temperature in $^\circ\text{C}$; M_{am} is the molecular weight of

ammonia (17.031); and M_{air} is the equivalent molecular weight of atmospheric air (28.96).

On the basis of the ammonia concentration and the corresponding ventilation rate for each of the 187 24-h periods, the data was examined by means of Eqn (2), applicable for $2 < T < 20^\circ\text{C}$:

$$A = a + bt_g^{0.5} + cT + dT^2 + eTt_g^{0.5} + fw + gTS + hTt_s \quad (2)$$

where: t_g is the time after latest emptying of gutter in days; t_s is the time after renewal of straw below cages in days; w is the average body weight in g; S is the 0 for no straw below cages and 1 for straw below cages; and a, b, c, d, e, f, g and h are regression coefficients. The values of the regression coefficients for Eqn (2) are shown in Table 2. The standard deviation was 0.11 g of nitrogen per animal per 24 h, and the coefficient of determination R^2 for the ammonia emission was 0.75, which indicates that 3/4 of the variation in the ammonia emission from 1 day to the other could be explained by the ambient temperature, the number of days between the slurry gutter emptyings, the body weight and the floor covering in the mink house.

The results for season 1 with sand layer below cages are shown in *Fig. 6*. If the gutter were emptied twice a week, a temperature drop from 18 to 6°C would halve the evaporation. By extending the emptying intervals

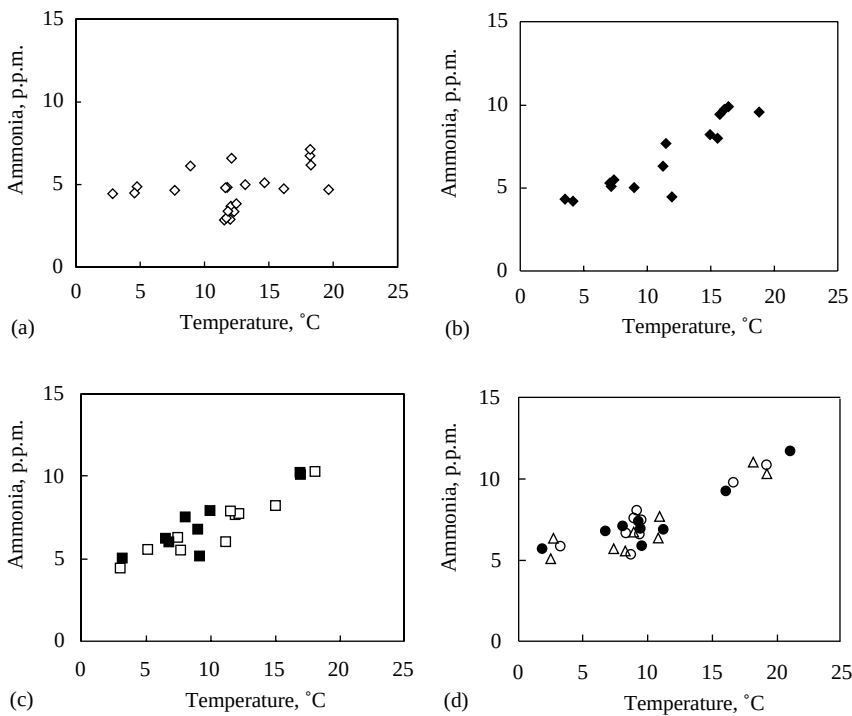


Fig. 4. Ammonia concentrations, season 1, with sand layer for different slurry storage periods: (a) $\diamond$, 1 day; (b) $\blacklozenge$, 2 days; (c) $\square$, 3 days; $\blacksquare$, 4 days; and (d) $\circ$, 5 days; $\bullet$, 6 days; and $\triangle$, 7 days

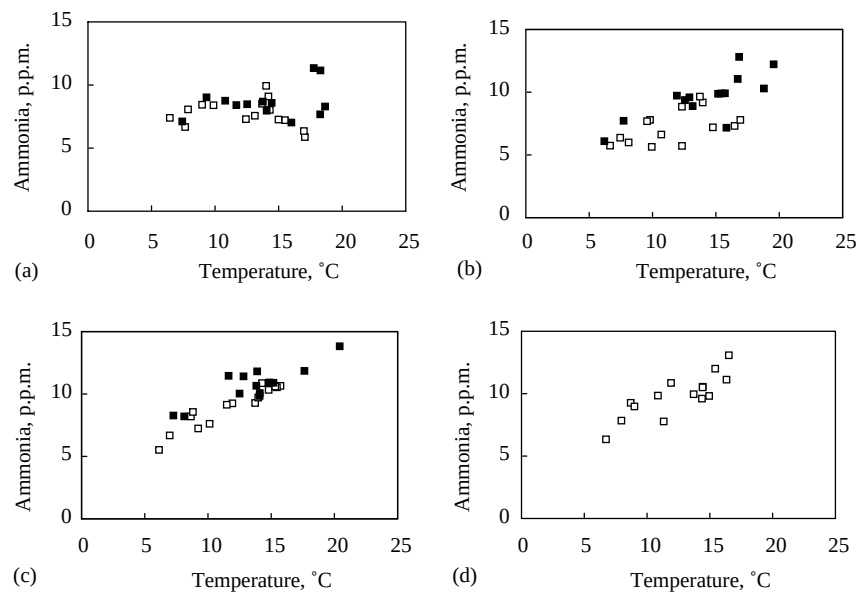


Fig. 5. Season 2, with a layer of chopped straw below the cages, removed once a week: 1–4-day-old straw, □ and 5–7-day-old straw, ■. Storage time for slurry removed 2 times a week: (a) 1 day; (b) 2 days; (c) 3 days and (d) 4 days

Table 2
Regression coefficients and levels of significance for daily ammonia emissions per mink [Eqn (1)] without straw as manure collector (season 1)

Variable	Regression coefficient		Level of significance
	Symbol	Value	
Constant	<i>a</i>	−0.134750	NS*
Storage time, slurry gutter, $t_g^{0.5}$	<i>b</i>	−0.044270	NS*
Ambient temperature, <i>T</i>	<i>c</i>	−0.026750	0.05
Ambient temperature, T^2	<i>d</i>	+0.000989	0.05
Temp. and storage time, $T t_g^{0.5}$	<i>e</i>	+0.022907	0.001
Temp. and body weight, <i>w</i>	<i>f</i>	+0.000335	0.01
Bottom covering, <i>S</i>	<i>g</i>	+0.004357	NS*
Storage time for straw, t_s	<i>h</i>	+0.002048	0.001

*NS=non-significant at probability, *p* > 0.05.

from 1 day to 1 week, the evaporation at 15°C increased by nearly 100%. The increase in per cent will be lower at lower temperatures (below 8–10°C) and higher at higher temperatures.

For an average body weight of 1800 g per animal and with uncovered sand layer below the cages in season 1,

the ammonia emission would be about 0.44 g [N] per animal per 24 h at 6°C and 0.62 g [N] per animal per 24 h at 16°C, if the slurry was removed daily. If the slurry was removed weekly, the ammonia emission would increase to 0.59 g [N] per animal per 24 h at 6°C and 1.15 g [N] per animal per 24 h at 16°C. By covering the ground below the cages with a layer of chopped barley straw and, renewing it once a week, the nitrogen loss will increase to 0.70 g [N] per animal per 24 h at 6°C and 1.44 g [N] per animal per 24 h at 16°C.

3.2. Nitrogen balances

The main results for the nitrogen balance measurements are shown in Table 3 and the nitrogen balance expressed in per cent of dietary nitrogen is shown in Table 4.

The above-mentioned 20% evaporated as nitrogen via ammonia in section A is what can be expected from gutters that are cleaned twice a week (Table 4).

As shown in Table 4, 11% of the nitrogen in the feed could not be explained by the accomplished analyses. It is expected that most of the remaining 11% of nitrogen will be accumulated in the sand below the cages.

Some of the feed will simply drop from the cage bottom during the eating process. In the present investigation, no distinctions between the consumed and the lost feed are made. As the spilt food is part of

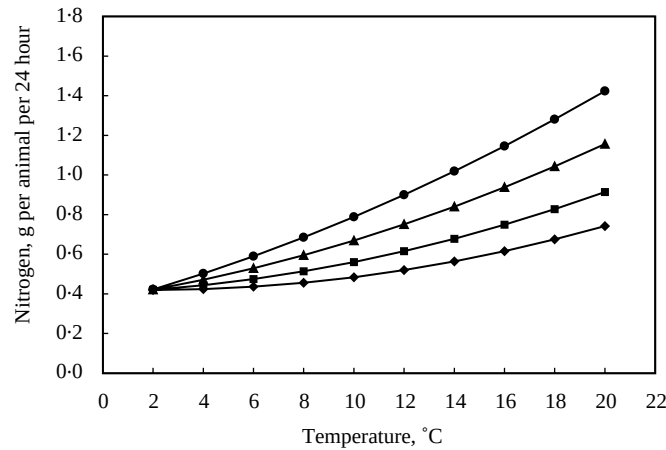


Fig. 6. Nitrogen losses via ammonia emission. Body weight 1800 g and sand layer below cages. Storage time in gutter: —◆—, 1 day; —■—, 2 days; —▲—, 4 days; —●—, 7 days

Table 3
Nitrogen balances in season 2 (average for 24 males and 24 females in the house)

Week	Date	Body weight, g	Temp, °C	Relative humidity, %	NH ₃ , p.p.m.	Feed cons., g day ⁻¹	Dry matter, g day ⁻¹	Total N on feed, g day ⁻¹	Nitrogen balance,* g day ⁻¹					
									Bed-ding	Slurry	Straw/manure	Depos-ited	Evapo-rated	Rest
Section A														
33-35	14.8-4.9	1503	17.4	76	9.6	197.5	78.2	4.68	0.20	2.26	0.69	0.37	0.91	0.65
36-38	4.9-25.9	1759	14.8	80	9.6	180.1	74.2	4.35	0.13	1.90	0.92	0.30	0.95	0.42
39-41	25.9-16.10	1917	13.4	85	9.3	179.0	73.7	4.47	0.12	1.98	1.11	0.14	0.85	0.50
Average		1726	15.2	80	9.5	185.5	75.3	4.50	0.15	2.05	0.91	0.27	0.90	0.52
Section B														
33-35	14.8-4.9	1545	14.4			208.9	82.7	4.95	0.18	2.26	0.89	0.32		1.67
36-38	4.9-25.9	1735	12.3			200.8	82.7	4.88	0.14	2.23	1.16	0.22		1.41
39-41	25.9-16.10	1893	11.0			194.7	80.1	4.88	0.13	2.01	1.47	0.14		1.39
Average		1724	12.5			201.5	81.9	4.90	0.15	2.16	1.17	0.23		1.49
Section C														
33-35	14.8-4.9	1502	14.4			196.8	77.9	4.64	0.18	1.53	0.94	0.31		2.04
36-38	4.9-25.9	1707	12.3			187.3	77.2	4.55	0.17	1.32	0.96	0.24		2.20
39-41	25.9-16.10	1861	11.0			184.0	75.7	4.60	0.15	1.56	1.62	0.16		1.38
Average		1690	12.5			189.4	76.9	4.59	0.17	1.47	1.17	0.24		1.88

*According to Moeller et al. (2001), the average nitrogen deposition in carcass is set to 2.93% of the carcass mass.

the faeces and urine collected in the gutter and in the straw below the cages, it is included in those fractions. In accordance with Poulsen and Kristensen (1997), the loss is about 8%. If the evaporated nitrogen is expressed

in per cent of the feed adjusted for 8% losses, the evaporation will increase from 20 to 22%. The nitrogen content in the bedding to be added to the nitrogen in seed will only count for approximately

Table 4
Nitrogen balance as percentage distributions for season 2

Period	Nitrogen balance, percentage distribution					
	Feed	Slurry	Straw/manure	Deposited	Evaporated	Rest
Section A						
1	100	48.2	10.5	8.0	19.5	13.8
2	100	43.6	18.2	6.8	21.8	9.6
3	100	44.4	22.2	3.1	19.0	11.3
Average	100	45.4	17.0	6.0	20.1	11.5
Section B						
1	100	45.6	14.3	6.5	(19.5)*	14.1 [†]
2	100	45.6	21.0	4.5	(21.8)*	7.1 [†]
3	100	41.3	27.5	2.8	(19.0)*	9.4 [†]
Average	100	44.2	20.9	4.6	(20.1)*	10.2 [†]
Section C						
1	100	32.9	16.3	6.7		44.1
2	100	29.0	17.3	5.3		48.4
3	100	34.0	32.0	3.5		30.5
Average	100	32.0	21.9	5.1		41.0

*Evaporation assumed to be equal to section A.
[†]Adjusted by evaporation figures from section A.

4% of the nitrogen in the feed, and so, an error in the nitrogen content and the amount of straw is negligible.

3.3. Nitrogen accumulation in the sand bottom of the house

The animals were removed after 15 weeks and 2 days, after which the slurry gutter was emptied, and the straw on the ground was removed. When no gutters were used in section C, the original submerged gutter was filled with sand. Analyses of the sand in the 385-mm wide gutter showed that the concentration of nitrogen was about 2300 p.p.m. at a depth of 50 mm and about 2000 p.p.m. at a depth of 150 mm, corresponding to an accumulation of 1.25 kg of N throughout the production period, or 5% of the nitrogen supplied in the feed for the same period. The amount of stored nitrogen in the sand bottom outside the sand-filled gutter was not measured.

4. Discussion

Breeding of mink differs from breeding of most other domestic animals in that it involves a doubled nitrogen concentration in the feed, elevated cages and natural ventilation—often in open-sided houses. Therefore, the potential for ammonia emission is high.

The nitrogen emission via ammonia was 1.15 g [N] per animal per 24 h at 16°C, because the slurry was stored over one week in a house with slurry gutters and sand bottom. The ammonia emission rate was of the same order as that measured for male mink by Beek *et al.* (1991).

By covering the sand layer beside the gutter with a layer of chopped barley straw and renewing it once a week, the nitrogen emission will increase to about 1.44 g [N] per animal per 24 h. The theory of placing a layer of straw below the cages was to collect the urine and faeces in the straw and to reduce the penetration of nitrogen and other components into the sand bottom. The negative effect of the straw resulting in increased ammonia evaporation is probably due to a higher emission potential from the straw than from the sand bottom.

In houses for broilers with about the same body weight, the evaporation of nitrogen via ammonia was 0.21–0.48 g per animal per 24 h in UK, Germany, The Netherlands and Denmark (Groot Koerkamp *et al.*, 1998). It will thus be seen that the ammonia emission from mink houses is at least twice as high as for broilers. For Denmark with a production of about 10 million mink furs per year and the predominant use of sand layer below cages without slurry gutters, it counts for about 10% of the total ammonia emission from animal buildings.

The effect of using a slurry gutter to collect the main part of the faeces and urine dropped from the cages was examined by simultaneous measurements with and without gutters. With a layer of chopped straw below the cages, 64% of the nitrogen in the feed was collected and distributed as 45% in the slurry gutter and 19% in the chopped straw. With straw in the entire area below the cages, 54% was collected and distributed as 32% in the gutter area and 22% in the other area. These results shows that for collection of manure and urine, slurry gutters are more effective than straw.

Determination of the nitrogen accumulation in the sand layer was not a part of this investigation, but some spot measurements were made of the nitrogen content in a sand-filled and submerged 385-mm wide slurry gutter. Analyses of the slurry gutter showed that about 5% of the nitrogen from feed consumed over the whole season from April to December was stored here. Further measurements, made 4 months after the house was emptied of animals, showed that ammonia was still emitted from the sand layer into the atmosphere.

In the present experiments, elevated slurry gutters were used. It is likely that the gutter temperature for submerged slurry gutters would be slightly lower. However, it is assumed that the difference in temperature and thereby the emission is marginal.

5. Conclusion

The nitrogen loss in the form of ammonia is 0.44 g [N] per animal per 24 h at 6°C and 0.62 g [N] per animal per 24 h at 16°C, when the slurry is emptied diurnally, increasing to 0.59 g [N] per animal per 24 h at 6°C and 1.15 g [N] animal per 24 h at 16°C, when the slurry is stored for 1 week.

With a layer of chopped barley straw below the cages, the ammonia emission increases with the number of days since the latest renewal of the straw. After 1 week the emission amounts to 0.70 g [N] per animal per 24 h at 6°C and 1.44 g [N] per animal per 24 h at 16°C.

If slurry is stored for 1 week, the ammonia emission is nearly twice as high as that with diurnal removal. By emptying the gutters once a week, the ammonia

emission is nearly twice as high at 16°C as at 6°C. The reduction is smallest at low temperatures.

By emptying the slurry gutter twice a week, 45% of the nitrogen in the feed is collected in the gutter for the period from mid-September until the beginning of December. Nitrogen collected in straw covering the floor below the cages will account for 19%, about 5% will be retained in the carcass, and 20% will be evaporated. Without slurry gutters, 32% of the nitrogen is accumulated in the straw covering the gutter area, and 22% is accumulated in the straw covering the other area.

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