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Pen fouling and ammonia emission in organic fattening pigs

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Abstarct
The aim of this project was to test different designs of outside yards, which influence pen fouling and ammonia emissions in organic pig production. 238 fattening pigs (GYxNL) in total were studied in two subsequent fattening periods. Pigs were divided in 8 groups, each consisting of 15 animals. The following treatments were studied: outside yard without anything in it (NY); outside yard with a rooting trough (RY); outside yard with a rooting trough and a drinking bowl (R+DY); outside yard with a dinking bowl (DY). The fouled floor areas with urine and faeces inside and at the outside yards were scored in a scale from 0 to 4. Ammonia emissions were calculated on the base of pen fouling and according to a previous study on practical farms. Inside pen fouled floor area was on average 19.0%, which was much lower than the fouled floor area outside - 69.3%. Clear differences in calculated ammonia emissions from the floor of outside yards between treatments were found (P<0.001). Outside air temperature and air speed had significant effects on calculated ammonia emissions from the floor of the outside yards (P<0.001). It is concluded that an outside yard with a partly slatted floor, drinker in one of the corners and a rooting trough in the other could be recommended in practical organic pig farms, because of the least pen fouling and ammonia volatilization.

1. Introduction.

In recent years, there has been an increased interest in less-intensive production systems for pigs, including outdoor production and organic systems. These systems are designed for improving animal welfare and consider the physiological and behavioural needs of the animals. According to regulations (EEC-Regulation 2092/91 on organic production), the indoor lying areas must have sufficient clean straw, good ventilation and daylight and access to an open-air exercise area and roughage.
Organic livestock farming also addresses the public demand to diminish environmental pollution, but sometimes a contradiction is seen between animal welfare and environmental protection. Increased space allowances of animals and the access to outside walking area may come in conflict with environmental issues. In Dutch organic pig farms housing is supplemented by paved yards with partly slatted floors, where most of urinations and defecations are done. This is the reason why outside yards become an additional source of ammonia volatilisation, which is considered as one of the main environmental pollutants (Hartung, 1992; Nielsen et al., 1991). In previous research, we measured ammonia emissions on organic pig farms, differing mainly in design of the floor and manure system (Ivanova-Peneva et al., in press). We concluded, that ammonia emission could exceed standards considerably. Ammonia emission seemed to be influenced by manure removal system, as well as design of the buildings. From previous research of Aarnink et al. (1993), pen fouling was also found to be an important factor for ammonia emission for conventional pig production with partly slatted floors.

The aim of this project was to test different designs of outside yards, which influence pen fouling and ammonia emissions in organic pig production. Ammonia emission was estimated on the basis of records of regular fouling of the solid and slatted floor inside the building and on outside yard.

2. Material and methods

The study was done at the Experimental Station of organic pig farming in Raalte, the Netherlands. 238 fattening pigs (GYxNL) in total were studied in two subsequent fattening periods from 25 kg to approximately 110 kg live weight. Pigs entered the experiment at an age of 75 days and stayed about 104 days. Main details about the production traits of pigs are given in table 1.

Table 1. Production traits of organic fattening pigs in two production periods.

Traits	Starting date	At the beginning		At the end		ADG ($g\ d^{-1}$)	DFI ($kg\ d^{-1}$)	FCR (kg)
		Pigs (n)	LW (kg)	Pigs (n)	LW (kg)			
I period	17.09.03	117	24.8	114	109.2	819	2.22	2.71
II period	15.01.04	121	24.1	119	113.9	853	2.36	2.77

LW – live weight; ADG – average daily gain; DFI – daily food intake; FCR – feed conversion ratio

Pigs were divided in 8 groups, each consisting of 15 animals. Fatteners had 1.42 m^2 area available inside and approximately 1 m^2 area of outside yard. The lay-out of the compartment is shown in Fig.1.

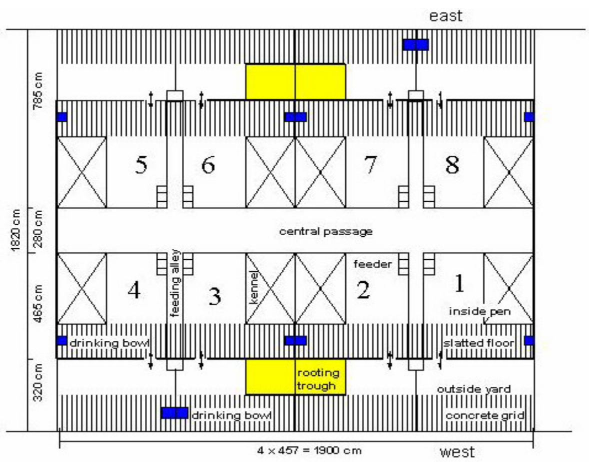

Fig. 1 Lay-out of the compartment of fatteners

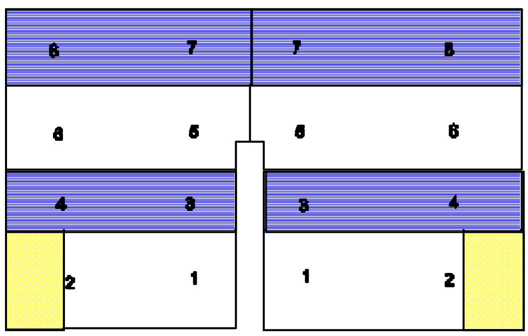

Fig 2. Determination of areas in the pen (section 1 and 2 – 6.97 m^2; section 3, 4, 5, 6, 7 and 8 – 3.66 m^2).

The research was designed as a two by two factorial design. One of the factors was presence of a rooting trough and the other was presence of a drinking bowl. The following treatments were studied:

- outside yard without anything in it (NY);
- outside yard with a rooting trough (RY);
- outside yard with a rooting trough and a drinking bowl (R+DY);
- outside yard with a dinking bowl (DY).

The four treatments were implemented in four pens at the east side of the building, and were repeated at the same time in four pens at the west side of the building (see Fig.1).
Pigs were fed limited twice daily, by automatically filled feeders and according to feeding curve with diets, contained natural substances. Diets from 25 to 50 kg live weight consisted of 11.05 MJ kg^{-1} NE, 175 g kg^{-1} CP and 9.7 g kg^{-1} Lysine; after 50 kg live weight till the end of experiment – 9.06 MJ kg^{-1} NE, 166 g kg^{-1} CP and 8.5 g kg^{-1} Lysine. Water was available *ad libitum* during the whole day. Drinkers were positioned on the wall of the building above the slatted floor inside. In four of eight pens additional drinkers on outside yard were available (Fig. 1).
The measurements were done two times per fattening period, when animals reached approximately 45 kg and 80 kg. Representative samples of urine and faeces were taken directly from pigs and were analyzed in laboratory for total-N, NH_4^+-N, urea-N, pH, dry matter, ash. Additionally urea-N was determined in urine. Samples of manure of fatteners were taken from different parts of outside yard and were analyzed for the same traits.
The inside and outside temperatures were determined every hour and recorded in the computer. The compartment was naturally ventilated. Figures about wind speed and rain were collected from a weather station in the neighborhood.
The fouled areas from inside and outside yard were visually assessed, according to dung scoring system. Each pen was divided in eight sections, as shown in Fig. 2. Each section received a score from 0 to 4, according to the area fouled with urine and faeces; in percentage (0-0%, 1-25%, 2-50%, 3-75%, 4-100%).
Ammonia emissions were calculated on the base of fouled area and according to many measurements done in a previous study on practical farms (Ivanova-Peneva et al., in press). It was found that clean areas inside emitted 1.9 g d^{-1} m^{-2}; fouled areas inside emitted 13.3 g d^{-1} m^{-2}; clean areas outside emitted 2.7 g d^{-1} m^{-2}; fouled areas outside emitted 11.4 g d^{-1} m^{-2}. Statistical analyses were done by using General Linear Model of Genstat – Release 7.1 (Genstat 5 Committee, 1993). The model included pen, period and treatment as a variable and air temperature and air speed as a covariate.

3. Results

Composition of excreting products from fatteners is presented in table 2. The results are summarised for the two periods of the study and two weight classes. There are no significant differences in components of excreting products between pens with different designs. Only in total N content of urine there are differences between R+DY outside yard and DY ($P<0.05$).
In table 3 the calculated percentage of degree of fouling in different sections in all pens of fatteners is given. The data are summarized for the two periods of the study. On average 19% of the inside area was fouled, while this was 69.3% of the outside area.
In the area inside the pen, near the kennel (section 2) almost no fouling was registered. The degree of fouling of the other parts of the solid floor inside (section 1) was low as well (average 5.1% of the area). A high percentage of fouling was seen over the slatted floor in section 3 and section 4. The fouling score was smaller (28.4%) and more constant for section 3. No equal trend for section 4, which was between the kennel and the wall (average 41.4% for all pens), was observed. Section 5, the solid floor of the outside yard, showed moderate degree of fouling for all pens

Table 2. Composition of excreting products of fattening pigs in pens with different design.

Type of outside yard	**Indeces**					
	Total N (g kg^{-1})	Urea-N (g kg^{-1})	NH_4-N (g kg^{-1})	pH	Dry matter (g kg^{-1})	Ash (g kg^{-1})
Urine						
NY	10.4(1.02)	5.9(0.99)	2.9(1.30)	8.2(0.31)	41.0(3.51)	13.5(1.240
RY	10.8(0.96)	6.9(0.91)	2.6(1.27)	8.1(0.26)	45.5(5.64)	16.0(1.46)
R+DY	11.8(0.87)[a]	7.8(1.22)	2.4(1.22)	8.0(0.25)	46.3(3.88)	15.6(0.91)
DY	9.4(0.69)[b]	5.3(1.12)	2.7(1.12)	8.1(0.30)	38.5(2.81)	15.1(0.69)
Faeces						
NY	9.5(0.35)		1.1(0.16)	6.3(0.06)	246.7(8.9)	30.9(1.50)
RY	9.1(0.38)		1.0(0.13)	6.2(0.11)	232.9(7.18)	29.8(1.16)
R+DY	9.1(0.26)		0.8(0.13)	6.3(0.04)	235.3(7.68)	30.2(1.44)
DY	9.6(0.28)		1.1(0.16)	6.3(0.09)	241.4(9.32)	31.3(1.27)
Manure						
NY	9.8(0.26)		1.7(0.14)	6.7(0.09)	227.4(6.14)	30.9(0.85)
RY	9.3(0.41)		1.5(0.23)	6.6(0.16)	219.7(8.51)	30.1(1.41)
R+DY	9.3(0.22)		1.9(0.26)	6.8(0.16)	213.4(6.46)	29.1(1.03)
DY	9.8(0.28)		1.9(0.27)	6.7(0.15)	220.0(6.49)	29.8(0.78)

[1]Means within a column lacking a common superscript letter differ significantly ($P<0.05$).
[2]Standard errors of differences are given in parentheses.

(from 52.6% to 67.0%), while section 6 showed a huge variation in fouling between treatments. The yards with roughage trough outside (RY and R+DY) had a low degree of fouling in this section (from 2.5% to 25.5%), because of the presence of feeding material. The other treatments had a lot more fouling (71.5%-87.5%). In section 7, half of slatted floor at the outside yard, a smaller degree of fouling was registered in the yards with drinkers (DY and R+DY), then in the other types of yards. Section 8, the area of slatted floor in all treatments without any additional equipment in it, was characterized with the highest degree of fouling (between 86.5% and 93.0%).

Table 3. Area fouled with urine and faeces in different sections of pens for fattening pigs.

Pen	**Design**	**Section 1**	**Section 2**	**Section 3**	**Section 4**	**Section 5**	**Section 6**	**Section 7**	**Section 8**
1	DY	0.5	2.5	20.0	23.0	70.0	84.5	88.5	92.5
2	RY	0.5	0.0	33.5	20.0	66.0	2.5	89.5	88.0
3	R+DY	0.0	0.0	5.5	52.5	52.5	25.5	58.5	89.0
4	NY	9.0	0.0	28.0	61.5	67.0	87.5	57.0	89.0
5	NY	3.0	0.0	32.5	19.5	62.5	71.5	87.0	86.5
6	R+DY	5.5	0.0	29.0	27.5	63.5	9.5	89.0	88.0
7	RY	10.5	0.0	40.5	73.5	65.5	15.5	76.0	91.5
8	DY	12.0	5.5	38.5	54.0	60.5	82.5	68.0	93.0
Average percentage		5.1	1.0	28.4	41.4	63.4	47.4	76.7	89.7

In table 4 ammonia emissions, calculated from pen fouling observations, are presented per m^2 per day. It is seen that calculated ammonia emissions from the floor inside were more than two times lower than emissions from the floor at the outside yards (3.49 $gm^{-2}d^{-1}$ vs 8.73 $gm^{-2}d^{-1}$). There was not a very big variation in ammonia emission between different treatments. There were no statistically significant differences inside the building, but treatment affected calculated ammonia emissions at outside yards ($P<0.001$). The R+DY pens and RY pens had lower ammonia emissions than the DY and NY pens. The lowest ammonia emissions were found on yards with a combined design of trough and drinker. Temperature had a significant effect on pen fouling and thereby on the calculated ammonia emissions, as inside as

Table 4. Ammonia emissions, calculated from pen fouling observations, in pens with different designs of outside yards.

Ammonia emissions ($gm^{-2}d^{-1}$)	Type of outside yard				Mean	S.E.D.	Effect of treat-ment	Effect of covariate	
	NY	RY	R+DY	DY				Tempe-rature	Air speed
Inside	3.00	3.04	3.82	4.11	3.49	0.437	n.s.	P<0.001	n.s.
Outside	9.70	8.07	7.87	9.27	8.73	0.270	P<0.001	P<0.001	P<0.01

well as outside (P<0.001). Air speed also significantly affected pen fouling and thereby ammonia emissions, but only on outside yards (P<0.01).

4. Discussion

In the study of Aarnink et al. (1993), the most important inside emissions factors were emitting area, air movement and temperature, pH and ammonium content of the slurry. In our study with naturally ventilated building the same factors are valid - temperature and air speed were significantly affecting pen fouling and thereby ammonia emissions on outside yards. Air speed was not influencing ammonia emissions inside, because pens were situated in a closed compartment and almost no movement of the air inside the building was present. However the straw bedding, bigger area available per pig and differences in equipment of outside yards could change the importance of some factors at the expense of others. As pigs in all the treatments received one and the same diet and the same amount of feed, almost no differences were found in ammonium concentration of excreting products. However differences were found in the pattern of fouling of pens, inside as well as outside.

Animal friendly systems must have at least separated two functional areas (Amon et al., 2004). In this study each pen had an inside area available for feeding and lying, provided with straw bedding and an outside yard for activity and excretions. Moreover, a kennel inside the pen, keeping the naturally produced warmth of pigs, was provided. Since pigs are known as clean animals, which separate their dunging area from resting place (Stolba and Wood-Gush, 1984, Aarnink et al., 1996) and like to lie in a warmer area and excrete in cooler places (Hacker et al., 1994), they did not pollute inside area near the kennel and over the solid floor. It is confirmed by records of fouling, that nil percentage is registered around the place of sleeping and may be very few excretions were done on the free space outside the kennel.

Much more fouling was registered of the slatted floor inside the pen, than of the solid floor, but the degree of fouling was different for both parts. Section 3 was less polluted than section 4 (28.4% vs 41.4% for all pens), probably because the opening to the outside yard was situated at section 3 and as Randall et al. (1983) suggested, pigs are not excreting at places with a high level of activity.

As Wechsler and Bachmann (1998) found, pigs have preferred areas for eliminative behaviour. In this study slatted floor on outside yard was a preferred place for excretions, as can be seen from the highest fouling score (section 7 and 8). In all treatments outside yards received a much higher fouling score - 69.3%, than the inside area - 19.0%. This conclusion is in agreement with calculated ammonia emissions, which were more than twice higher from outside yards (3.49 $gm^{-2}d^{-1}$ vs 8.73 $gm^{-2}d^{-1}$) and in the same direction as the conclusion of Aarnink et al. (1993), that ammonia emissions increases linearly with the fouled area.

Fouling and calculated ammonia emissions in this study were clearly influenced by the equipment available on outside yards. The differences between treatments (NY, RY, R+DY and DY) are seen in different sections, for fouling score as well as for ammonia emission (*P*<0.001). In R+DY yard there was a perfect isolated place over the slatted floor near the roughage trough, in the opposite side of the crowded drinker. It was preferred by a lot of pigs in these pens and that's why pen fouling, and respectively, ammonia emissions were lowest there (7.87 g $m^{-2}d^{-1}$). Second in fouling and calculated ammonia emission was RY (8.07 g $m^{-2}d^{-1}$), which also provided a relatively isolated place for excretion.

5. Conclusion

The design of outside yard with partly slatted floor, drinker in one of the corners and rooting trough in the other could be recommended in practical organic pig farms, because of the lowest pen fouling and calculated ammonia volatilization.

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