Effect of housing system, litter versus totally slatted floor, on mass balances of water, nitrogen, and phosphorus in growing-finishing pigs.

Effet du système d'élevage, litière contre caillebotis intégral, sur le bilan en eau, azote et phosphore, lors de l'engraissement de porcs.

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Abstract

The two objectives of this study were first to check the feasibility of continuous composting with saw dust litter, and second to compare the mass balances of both systems (pig-on-litter versus slatted floor). Two replicates of 24 pigs each were used in the experiment. The same climate was maintained in both systems (pig-on-litter versus slatted floor). The amounts of food and water consumed, and the slurry produced were weighed, and their contents in H_2O, N, and P were determined. The air flow rate and the air concentrations of H_2O, NH_3, and N_2O were also measured continuously. The composting process in the litter system volatilised almost 70% of N excreted as N_2, whereas with slatted floor most of N volatilised was lost as NH_3. It is concluded from water and nitrogen mass balances that the pig-on-litter system allows an efficient and environment friendly production of pigs.

Résumé

Les deux objectifs de cette étude étaient d'abord de vérifier la faisabilité du compostage continu avec litière sur sciure et deuxièmement de comparer les bilans matières des deux systèmes (litière versus caillebotis). Deux salles de 24 porcs chacune ont été suivies. La même ambiance dynamique a été maintenue dans les deux systèmes. Les quantités d'aliment et d'eau ingérées et le lisier produit ont été pesés, et leur contenu en H_2O, N et P a été déterminé. Le flux d'air et les concentrations en H_2O, NH_3 et N_2O ont également été mesurés en continu. Le procédé de compostage avec litière volatilise environ 70% de l'azote excrété sous forme N_2, alors que le système caillebotis volatilise l'azote sous forme d'ammoniac (NH_3). Il est donc conclu à partir du bilan en eau et en azote que le système sur litière permet une production efficace et protectrice de l'environnement.

1. Introduction

Waste management strategies are needed in almost all regions of the world that are specialized in intensive livestock production, either because of the volatile elements and the resulting air pollution, or because of the non-volatile elements that accumulate in the soils when they are not exported by the crops or lost in water. Depending on the countries, the present legislations focuse on water protection, nitrogen emissions (ammonia NH_3, nitric oxide NO_x, nitrous oxide N_2O) or phosphorus enrichment in the soils. Part of the management strategy of the organic wastes begins within the livestock building, during animal growth. They are two main breeding systems: slatted-floor or litter. The litter systems allow a dry and aerobic processing of the slurry (Chan et al, 1994), close to composting, while the slatted-floor systems allow a liquid and anaerobic conservation of the slurry. In pig production the slatted-floor systems are the most common. In those systems, efficient strategies were already proposed. They are based on the dilution of the slurry and the reduction of the emitting surfaces within the building in order to reduce the ratio of the nitrogen gas emissions to the nitrogen excreted. On the contrary, the composting process of the litter during pig production is not always successful in the temperate and cold regions of Europe. The early composting of slurry during the animal growth leads to the elimination of water and nitrogen through gas emissions while non-volatile compounds like phosphorus or heavy metals are concentrated.

Klooster & Greutink (1992) and Oliveira et al (1998) showed that the litter increases the evaporation of water. However, when the litter is not successfully managed, the water excreted accumulates in the litter, it becomes moist and the composting process stops. This is one of the major problems met during pig production on deep-litter. For this reason, our first objective was to check the continuous composting of the litter, i.e. the evaporation of almost all of the water excreted. Lesguiller et al. (1995) showed the dry matter reduction of slurry, thus reducing the costs of storage and transport. The composting process leads to the elimination of dry matter, mostly as CO_2 and H_2O, thus decreasing the C/N ratio. However, we did not find in the literature a rigorous comparison of the mass balances of both systems. Souloumiac (1995) stressed on the evidence that heat and mass emissions from livestock building depend on the 'Climate-Building-Animal' system. For this reason our second objective was to compare the mass balances in deep-litter and slatted-floor system, all three components kept identical.

Bonazzi & Navarotto (1992) and Lesguiller et al. (1995) showed that the litter accumulated more phosphorus than nitrogen, thus suggesting that more nitrogen is lost as gas emissions than in traditional slatted-floor systems. Moreover, Groenestein et al. (1996) measured higher emissions of NH_3, NO_x and N_2O than traditionnal slatted floor system. A rigorous comparison of housing systems should include measurements of both gas emissions and storage in the litter or the slurry, since other emissions may occur during further processing of the organic wastes (storage, spreading, etc.). Thus, we monitored the litter composition and gas emissions.

2. Materials and method

Two identical breeding cells equipped with the same feeding systems were kept in the same climatic environment (Fig. 1). Two replicates each with 24 pigs (30-100 kg live weight) randomly assigned to the two treatments were used, only differing the external climate and the initial composition of the litter. The surface allocated to the pigs was respectively 0.65 m² on slatted floor, and 1.10 m² on deep-litter. The pigs were cross-bred Piétrain x Large White. They were fed ad libitum with a commercial finishing diet (3200 kcal/kg digestible energy, 16% crude protein). The litter used in the first replicate was transfered from a commercial building. It was disposed as a 80 cm deep layer; the surface 30cm were turned once per week. Dry sawdust was added before the second replicate (512 kg sawdust + 329 kg wood shavings) in order to increase the C/N ratio. Food and water were daily weighed (Metler, 120$\pm$0.05kg). Pigs, slurry and litter were weighed at the beginning and at the end of each replicate. Food, litter and slurry were carefully sampled and analysed for dry matter, nitrogen and phosphorus. All mass measurements and chemical analysis had an accuracy higher than 5%. The outside temperature was reduced during the second replicate because most of the management problems with the litters occur during the colder periods in European countries and in order to increase the gas gradients. The mass balance was checked assuming an animal retention of 10% of the water intake, 33% of the nitrogen intake, and 49% of the phosphorus intake (Lesguiller *et al*, 1995).

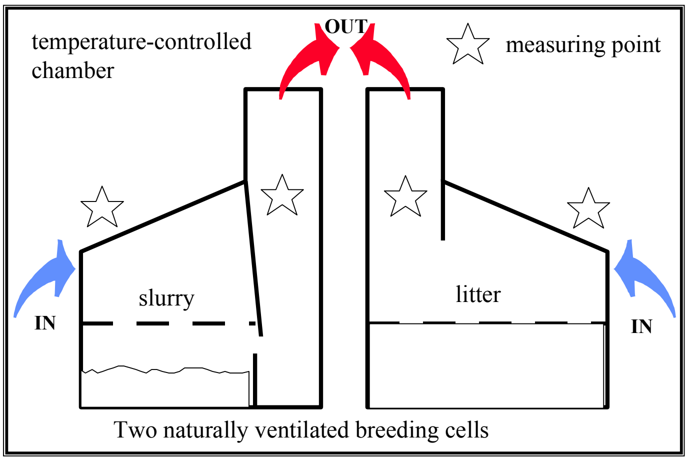

Figure 1
Experimental design.

Temperature, air humidity, and air speed of exhausted air were monitored at a one minute time step and hourly mean values were stored by a datalogger (AOIP SA120). Air speed was measured with hot-wire anemometers (TSI, 8450) where dust was regularly removed. Ammonia (NH_3) and nitrous oxide (N_2O)

concentrations were measured continuously outside and in the air extraction of the cells with a 3426 gas monitor (Bruël & Kjaer). Measurements were made during 30 minutes; only the homogeneous values in the center of the time interval were used to calculate the mean concentration; every two hours (four sampling points). NOx concentrations were checked to be negligible with Draeger tubes. Gaseous fluxes were estimated at a hourly time step. Daily means were calculated only with the observed data of the day concerned.

3. Results

We present in Table 1 the global inputs and outputs of the two replicates and the two treatments. The small differences between the initial and final weights of the pigs show that the differences between the animal metabolism in each group remained less than 10%. The food consumption was also similar while the water consumption was slightly less with the slatted-floor. For slatted-floor treatment of second replicate, we met some zootechnical problems: growth was slightly more heterogeneous, the pigs bite themselves. The slurry production in the slatted-floor treatment was similar in the two replicates. The weight variation of the litter during one replicate was negative in the first replicate and positive in the second replicate. The mass variations of the two treatments were different in both replicates.

	Replicate I		Replicate II	
	Slatted-Floor	Deep-Litter	Slatted-Floor	Deep-Litter
Pigs				
Initial weight (kg)	29.8±1.2	30.5±1.4	31.5±1.7	31.6±1.4
final weight (kg)	99.9±7.5	102.3±8.0	95.6±12.6	94.0±10.3
mortality	0	0	2[1]	0
Food intake				
food (kg/cell)	2276	2301	2238	2210
water (kg/cell)	5084	5357	4605	5225
Litter and slurry				
initial weight (kg)	0	7110	501[2]	5155[3]
final weight (kg)	2908	6675	3137	5842
Climate				
Inside Temp. (°C)	22.9±1.1	22.5±1.0	21.7±3.9	22.1±1.7
inside humidity (%)	63.±8.	75.±5.	63.±9.	70.±7.
Outside Temp. (°C)	13.2±1.2	12.8±1.3	8.0±0.8	7.3±0.8
outside humidity (%)	71.±10.	71.±10.	85.±10.	77±10.
Mean ventilation rate (m^3/h/pig)	25.4	32.7	20.0	27.3

Table 1
Global inputs and outputs of the two treatments and the two replicates
(90 days, each cell containing 12 pigs).

1. one animals died on day 50 and one on day 59.
2. Water was added in order to make possible the measurement of the slurry level.
3. The final litter of the first experiment rested almost three months within the cell without doing anything ; dry sawdust was added just before the second experiment in order to increase the C/N ratio.

The outside temperature was similar for the two cells and kept roughly constant during each replicate. It was 4 to 5 K colder during the second replicate than during the first. The cell temperatures were similar for the two replicates and the two treatments. The air humidity was higher in the litter treatment than in the slatted-floor treatment for both replicates. The air humidity in the litter treatment was slightly lower during the second replicate compared to the first replicate, as a consequence of the lower specific humidity of the fresh air (approximately 1 g water/kg dry air lower).

Table 2 gives the concentrations in water, nitrogen, and phosphorus for the inputs and outputs of each treatment and both replicates. The nitrogen and phosphorus concentrations of the litter increased during both replicates. The phosphorus concentration increased more than the nitrogen one. The increase in phosphorus concentration as compared to the nitrogen one was higher in the litter system for both replicates.

	H_2O (g/kg moist weight)	Nitrogen (NTK+NO_3) (g/kg moist weight)	Phosphorus (P_2O_5) (g/kg moist weight)	C/N ratio
Food[4]	135.5	26.69	12.1	14.7
slurry (exp I)	840.0	10.05	5.91	5.2
slurry (exp II)	855.0	8.03	6.10	6.8
initial litter (exp I)	659.5	4.56	5.32	32.3
initial litter (exp II)[5]	537.5	6.26	9.97	31.3
final litter (exp I)	683.0	5.99	7.80	20.5
final litter (exp II)	541.0	8.07	11.87	20.2

Table 2
Mean concentrations in water, nitrogen and phosphorus of the inputs and outputs of the two treatments and the two replicates.

[4] mean values
[5] final litter of exp I + wood shavings at 85% dry matter.

The gas emissions of water, ammonia and nitrous oxide are given in Table 3. The emission of the three gases were similar for the slatted-floor system between the two replicates. They were also similar for the nitrogen gas and the water for the litter system. The water emission as well as the ammonia and nitrous oxide emissions were quite different between the two treatments and for both replicates.

gas emissions (per pig in 90 days)	H_2O (water vapor in kg)	NH_3 (ammonia, in g N)	N_2O (nitrous oxide, in g N)
slatted-floor (exp I)	282	575	58
slatted-floor (exp II)	281	425	33
deep-litter (exp I)	483	267	308
deep-litter (exp II)	473	275	233

Table 3
Total gas emissions of the two treatments and the two replicates (mass/fattening pig for the 90 days period).

4. Conclusion

4.1. We showed experimentally that continuous composting is possible in deep-litter systems during the growing-finishing phase of pigs and with a cool climate. Such composting reduces the nitrogen content of the waste and limits both ammonia and nitous oxide emissions. As concluded by Chan et al (1994), the achievement of this objective in any farm requires an adaptation of the building and the management practices to the climate, the animal density, and the heat production of the chosen litter.

4.2. A rigourous comparison of the deep-litter system and the slatted-floor system, with the same building, animals and external climate showed that the final mass of organic wastes in deep-litter systems is much less than the mass excreted. This is due mostly to the evaporation of the water excreted but also to the loss of volatile elements (C, H, O, and N). The non-volatile elements (e.g. phosphorus) are concentrated by the composting process.

4.3. The comparison of the nitrogen gas emissions confirmed that ammonia emission is less than in slatted floor system with accumulated slurry. We confirmed that the deep-litter systems produces more nitrous oxide (N_2O) than slatted-floor systems (Groenestein & Faassen, 1996). When used in an environmental impact assessment, e.g. in Life-Cycle-Analysis, this information should be completed by the gas emissions at other production stages and by the impacts of the systems on water and soils. The comparison of the nitrogen gas emissions to the nitrogen mass balance suggested that the major part of the nitrogen can be lossed as dinitrogen (N_2) in deep-litter systems correctly managed.

5. Acknowledgements

This study was financialy supported by the regional Comitee Bretagne Eau Pure (Conseil Régional de Bretagne, Agence de l'Eau Loire-Bretagne, Conseil Général du Morbihan). We also acknowledge Pierre Perrin for his technical support, M. Le His and Guyomarc'h S.A. who provided the litter and the food.

6. References

Bonazzi G, Navarotto PL, (1992) Wood shaving litter for growing-finishing pigs. In: *Workshop on Deep-Litter System for Pig Farming.*, edited by J. A. M. Voermans. Research Institute for Pig Husbandry. Rosmalen. The Netherlands, 57-76.

Chan D.K.O., Chaw D., Lo C.Y.Y. (1994) Management of the sawdust litter in the « pig-on-litter » system of pig waste treatment. *Resources, Conservation and Recycling*, 11, 51-72.

Groenestein C.M., Faassen van H.G. (1996) Volatilization of ammonia, nitrous oxide and nitric oxide in deep-litter systems for fattening pigs. *Journal of Agricultural Engineering Research*, 65, 269-274.

Klooster van't C E, Greutink G J (1992) Water evaporation in deep litter pig houses. In: *Workshop on Deep-Litter System for Pig Farming.*, edited by J. A. M. Voermans. Research Institute for Pig Husbandry. Rosmalen. The Netherlands, 124-134.

Lesguillier F., Gouin R., Guiziou F., Orain B. (1995) Contribution au dossier environnemental par l'évaluation des rejets. Bilans des éléments azoté et minéraux des litières. *Journées de la recherche porcine en France*, 27, 343-350.

Oliveira P.A., Robin P., Kermarrec C., Souloumiac D., Dourmad J.Y. (1998) Comparaison de l'évaporation d'eau en élevage de porcs sur litière de sciure ou sur caillebotis intégral. *Journées de la recherche porcine en France*, 30, 355-361.

Souloumiac D (1995) Etude des microclimats realisables dans des enceintes energetiquement autonomes soumises a des flux de chaleur d'origine metabolique. *Thèse I.N.A. Paris-Grignon*, janvier 1995, 170p.