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Comparison between air inlet via channels under the building and air inlets via the ceiling for growing-finishing pigs

Jos Botermans, Knut-Håkan Jeppsson and Anne-Charlotte Olsson, Swedish Univ. Agric. Sci., Dept. of Biosystem and Technology, Box 103, 230 53 Alnarp, Sweden

Erik Damsted, Pig Research Centre, VSP, Axeltorv 3, 1609 Copenhagen, Denmark

Abstract

The aim of the studies was to compare the indoor climate between two different ventilation systems for growing-finishing pigs. In one housing system the air came into the pig house via channels under the lying area of the pigs. The air came into the compartment close to the lying area of the pigs. The first part of the exhaust air was via another channel along the manure channel (pit ventilation). The rest of the exhaust air was via two fans in the ceiling (farm 1). In the other housing system the air came into the pig house via air inlets in the ceiling. The exhaust air was via two fans in the ceiling (farm 2). Measurements were done during one summer batch and one winter batch. Air temperature was measured for 5-8 weeks with mini-loggers. Ammonia concentration, carbon dioxide concentration, air speed and differences in air pressure between in and outside the pig house, were registered at 4 occasions.
During summer time, the temperature of incoming air via the channels under the building (farm 1) was almost the same as the temperature of the air outside. So the cooling effect in the channels was very small. However, on the farm with air inlets in the ceiling (farm 2), the incoming air, during the afternoon, was about 3 ^{0}C above the temperature outside. So during the warmest period of the day, the air was heated on the ceiling. On the farm with channels under the lying area, the pigs continued to lie on the concrete lying area instead of the slatted flooring and the cleanliness of the pens was good (farm 1). During winter time, the temperature of the incoming air via the channels under the building was about 4 ^{0}C above the air temperature outside. On the farm with air inlets in the ceiling, the air temperature of the incoming air was the same as the temperature of the air outside.

Keywords: energy, climate, pig

1 Introduction

In order to get a more comfortable indoor climate and for energy saving reasons, housing systems are developed in which the incoming air is led through channels under the building. Due to a higher ventilation effectiveness and also conditioning of the air in the channel (cooling down of air during summer time) lower ventilation rates might be used. In North-western Europe good experiences of these systems have been reported (van Wagenberg & Smolders, 2002). However, not much is known how these systems work under Nordic climate conditions. An investigation has been done to study the functioning of channels under the building in a farrowing unit in Finland during winter time (Botermans & Jeppsson, 2008). No studies are reported for growing-finishing pigs under cold conditions. The aim of the present pilot study was to compare the indoor climate between a housing system for growing-finishing pigs in which the air came into the building via channels under the lying area of the pigs and a housing system in which the air came into the building via air inlets in the ceiling.

2 Materials and methods

The study was performed in two housing systems for growing-finishing pigs on two different farms. Measurements were done in one compartment in each farm during one summer period and one winter period.

The first house (farm 1) was located in Denmark and in this housing system the air came into the pig house via channels under the lying area (Figure 1). The height of the channel was 56 cm. The surface between the channel and the lying area was insulated. The air came into the compartment close to the lying area of the pigs (Figure 2). The opening from the channel into the compartment was 106 cm^2/pig. This opening could not be regulated in size. One third of the lying area was covered with a kennel lid. During summer time the fresh air came into the compartment underneath this lid. During winter time, the fresh air came into the compartment above this lid. The first part of the exhaust air was via another channel along the manure channel (pit ventilation). The rest of the exhaust air was via two fans in the roof. The growing-finishing house consisted of 5 compartments with 12 pens in each compartment. Each pen housed 18 pigs from 25 kg up to 115 kg of live weight. The pigs were tail docked and had some access to straw on the solid floor. The total pen area was 0.7 m^2 per pig, with half of the area solid flooring and half of the area slatted flooring. The manure storage was under the slatted flooring (storage for some weeks) with a straight flush system (Fog Agroteknik a/s). The planned maximum ventilation rate was 80 m^3/pig/hour and the planned minimum ventilation rate was 5 m^3/pig/hour.

Figure 1: The channel under the lying area of the pigs (farm 1).

Figure 2: The pen of the pigs on farm 1. The arrow indicates where the air entered the compartment.

The second house (farm 2) was located in Sweden and in this housing system the air came into the pig house via air inlets in the ceiling (Figure 3). The opening of these inlets were regulated by the ventilation system. The ceiling of the compartment was insulated with 20 cm insulation. However, the roof of the loft was not insulated. The roof consisted of an iron sheet with condensation sheet. The exhaust air was via two fans in the ceiling. The growing-finishing house consisted of 6 compartments with 22 pens in each. Each pen (Figure 4) housed 8 pigs from 25 kg up to 115 kg of live weight. The pigs were undocked and had access to straw on the solid floor. The total pen area was 1.0 m^2 per pig, with 75 % of the area solid flooring and 25 % of the area slatted flooring. The manure storage was under the slatted flooring (storage for two weeks) with a straight flush system (Fog Agroteknik a/s).The planned maximum ventilation rate was 100 m^3/pig/hour and the planned minimum ventilation rate was 10 m^3/pig/hour.

Figure 3: The compartment on farm 2. The arrows indicates where the air entered the compartment.

Figure 4: The pen of the pigs (farm 2).

Measurements were done during one summer batch and one winter batch. In each house, measurements were performed in one compartment. The following measurements were done:

1) Air temperature (Tinytag, Gemini Data Loggers) evaluated every 20th minute for 5-8 weeks in the following locations: outside the building, in the location where the air entered the compartment, on the lying area (1.2 m above the floor), in the feeding alley (1.5 m above the floor) and in the outgoing air. Besides measurements with loggers, the temperature was measured with a thermometer in the same locations as the gas measurements.
2) NH_3 concentrations determined using gas detection tubes (Kitagawa, 105SD) and CO_2 concentrations with an instrument (TSI, IAQ-Calc) at 10.00h during one occasion in the start of each batch (2 weeks after introduction of the pigs) and during one occasion at the end of each batch (before slaughtering out). These gases were measured in the following locations: outside the building, in the location where the air entered the compartment, on the lying area (1.2 m above the floor), in the feeding alley (1.5 m above the floor) and in the exhaust air.
3) Air speed registrations at 11.00 h during one occasion in the start of a batch (2 weeks after introduction of the pigs) and during one occasion at the end of a batch (before slaughtering out) using a hot wire anemometer (Alnor, GGA-65P). The air speed was measured at 10 cm from the air inlet and also 1 cm and 30 cm above the floor on the lying area.
4) The cleanliness in the pens was observed during one occasion in the start of each batch (2 weeks after introduction of the pigs) and during one occasion at the end of each batch (before slaughtering out).
5) The difference in air pressure between inside and outside the building at 11.00 h during one occasion in the start of a batch (2 weeks after introduction of the pigs) and during one occasion at the end of a batch (before slaughtering out).

The temperature measurements with loggers were done in the same period for both housing systems. However, the measurements of gases, temperature with thermometer, air speed and air pressure were done at different occasions.

3 Results

The measurements during summer time are presented in Table 1. When the air entered via channels under the lying area, no heating of the air occurred. However, when the air came in via the ceiling, the air was warmed up on the ceiling at one study (observation 3). Ammonia concentrations were higher in the housing system with channels under the building. Carbon dioxide concentrations did not differ very much between the two housing systems. The carbon dioxide concentrations in the air outlet of farm 1 were lower as the concentrations at 1.5 m above the floor inside on farm 1. The air speed of the incoming air was lower in the housing system with channels under the building.

Table 1: Air temperature, NH_3 and CO_2 concentrations and air speed at different locations in the two growing-finishing houses during summer time

		Air inlet via channels (farm 1)		Air inlets in the ceiling (farm 2)	
		Obs 1	Obs 2	Obs 3	Obs 4
Temperature (^{o}C)	Outside	18.5	17.0	22.0	19.5
	Air inlet	18.0	16.5	26.0	18.5
	Under kennel lid	21.0	19.0	-	-
	Lying area	22.0	19.0	27.0	21.0
	1.5 m above floor	22.0	20.5	29.0	21.5
	Air outlet manure channel	20	19	-	-
	Air outlet ceiling	-	18.5	28.0	21.5
NH_3 (ppm)	Outside	0	0	0	0
	Air inlet	0.5	0.5	0	0
	Under kennel lid	13.5	4.0	-	-
	Lying area	14.5	6.0	3.5	6.0
	1.5 m above floor	6.0	5.3	3.5	4.5
	Air outlet manure channel	21.0	13.5	-	-
	Air outlet ceiling	2.0	2.0	3.0	4.0
CO_2 (ppm)	Outside	435	440	428	425
	Air inlet	440	450	435	426
	Under kennel lid	1760	1300	-	-
	Lying area	1540	1510	1540	940
	1.5 m above floor	1235	1350	1230	920
	Air outlet manure channel	1105	1220	-	-
	Air outlet ceiling	945	900	1280	940
Air speed ($^{m}/_{s}$)	10 cm from air inlet	2.70	2.30	4.40	6.50
	1 cm from the floor lying area	0.15	0.35	0.15	0.17
	30 cm from the floor lying area	0.25	0.17	0.15	0.16

The measurements during winter time are presented in Table 2. When the air entered via channels under the lying area, heating of the air occurred. Ammonia concentrations were low in both housing system. The concentrations of ammonia in the outlet via the manure channel (Farm 1) were high. Carbon dioxide concentrations in the air outled did not differ very much between the two housing systems. However, during the first study the carbon dioxide concentrations in the housing system with air inlets via the ceiling (observation 7) were higher as compared to the housing system with channels under the building. The air speed of the incoming air was lower in the housing system with channels under the lying area of the pigs as compared to air inlets via the ceiling.

Table 2: Air temperature, NH_3 and CO_2 concentrations and air speed at different locations in the two growing-finishing houses during winter time

		Air inlet via channels (farm 1)		Air inlets in the ceiling (farm 2)	
		Obs 5	Obs 6	Obs 7	Obs 8
Temperature (^{o}C)	Outside	-1.0	7.0	5.0	7.5
	Air inlet	10.0	10.0	5.0	10.5
	Under kennel lid	21.0	16.0	-	-
	Lying area	21.5	16.0	18.0	17.0
	1.5 m above floor	20.0	17.0	19.0	17.5
	Air outlet manure channel	14.0	17.0	-	-
	Air outlet ceiling	18.0	16.0	20.0	17.0
NH_3 (ppm)	Outside	0	0	0	0
	Air inlet	0	0	0	0
	Under kennel lid	2.0	3.0	-	-
	Lying area	2.5	3.0	3.0	7.0
	1.5 m above floor	4.0	3.0	4.0	8.0
	Air outlet manure channel	14.0	15.0	-	-
	Air outlet ceiling	4.5	4.0	3.5	9.5
CO_2 (ppm)	Outside	430	460	425	400
	Air inlet	440	450	425	410
	Under kennel lid	2150	2200	-	-
	Lying area	1890	1700	2420	1420
	1.5 m above floor	1940	1700	2390	1480
	Air outlet manure channel	1830	1930	-	-
	Air outlet ceiling	1945	1430	2370	1490
Air speed ($^{m}/_{s}$)	10 cm from air inlet	0.68	1.60	6.66	3.85
	1 cm from the floor lying area	0.16	0.20	0.15	0.15
	30 cm from the floor lying area	0.18	0.20	0.15	0.30

The measurements which were done simultaneously with data loggers are presented as figures. The air was heated with 4 ^{0}C in the channel under the lying area during a cold winter day (Figure 5). On the farm with air inlets via the ceiling no warming up of the air occurred. During a warm summer day, no cooling of the air occurred in the channels under the lying area (Figure 6). However, the air was not warmed up in the channel as it did on the ceiling on farm 2. On the farm with air inlets via the ceiling (farm 2), the air was warmed up with 2 ^{0}C on a warm afternoon (Figure 7).

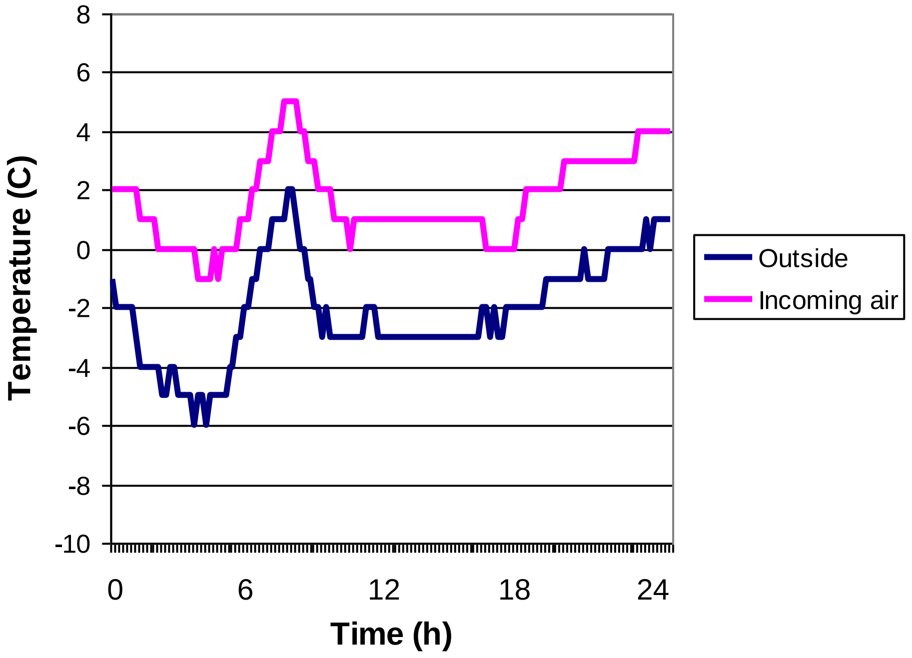

Figure 5: The temperature of the air outside and before coming into the compartment via the channel under the lying area (Farm 1) during a cold day.

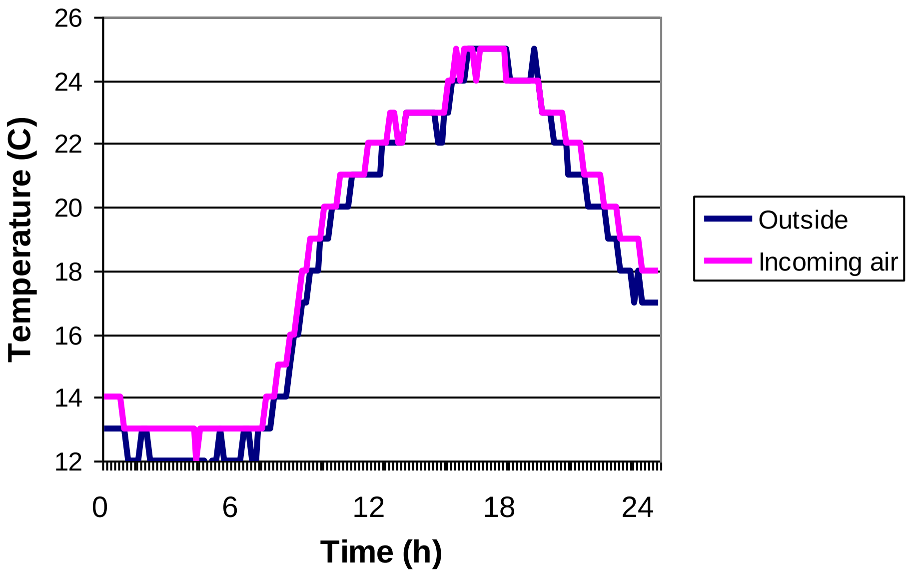

Figure 6: The temperature of the air outside and before coming into the compartment via the channel under the lying area (Farm 1) during a warm day.

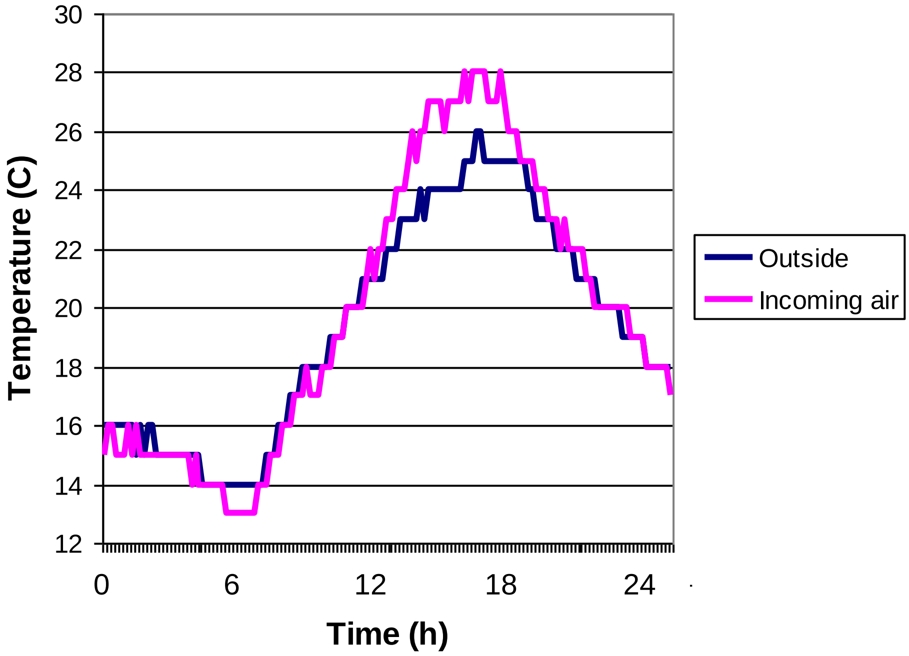

Figure 7: The temperature of the air outside and before coming into the compartment via the air inlet in the ceiling (Farm 2) during a warm day.

The cleanliness in the pens on farm 1 (air via channels) was good. During summer time, 11 and 10 pens out of the 12 pens were clean at the first respectively second study. During winter time all 12 pens were clean at both studies. The cleanliness on farm 2 (air via ceiling) was somewhat poorer. During summer time, 15 and 17 pens out of 22 pens were clean at the first respectively second study. During winter time, 22 and 18 pens out of 22 pens were clean at the first respectively second study

4 Discussion

It is difficult to draw any far going conclusions from the present study since the studies were not done parallel. The measurements were done on two different farms in two different countries. Legislation for total area per pig, size of the lying area, etcetera are totally different between Sweden and Denmark, where pigs in Sweden have more space available. Even group size in Sweden is smaller than in Denmark, since large group sizes would result in pen fouling due to the large compulsory solid lying area per pig in Sweden. Different types of feed were used on the farms with probably different amounts of crude protein, MJ net energy, etcetera per kg feed. This might have influenced the emissions of ammonia. Even performance of the pigs might have been different between the two farms, affecting the production of heat and carbon dioxide. So the present study only can give some indications how the ventilation systems worked. By comparing these two systems with each other some differences can be discussed, but no far reaching conclusions can be made.

One reason for taking the air into the building via channels under the lying area was to reduce the ventilation rate. By taking in the air closer to the lying area of the pigs and by taking out the air via channels along the manure channel, higher ventilation effectiveness should be achieved which would allow lower ventilation rates. It is also claimed that conditioning of the incoming air in the channel (cooling the air during summer time) would allow lower ventilation rates. In the present studies, the concentrations of carbon dioxide in the air outlet were not higher on the farm with channels under the building than on the farm with air inlets via the ceiling. This shows that ventilation rate on the farm with channels under the building might not at all been lower as on the farm with air inlets via the ceiling. The lower concentrations of carbon dioxide in the air outlet as compared to the concentrations on 1.5 m above the floor

on farm 1 showed that the air did not come inside the compartment in an even way. This means that the air inlet from the channel into the compartment should have been made smaller 106 cm^2/pig. In this way the difference in air pressure would have been higher between the channel and the compartment, resulting into a more even distribution of the air coming into the compartment along the entire length of the compartment.
The warming up of the air in the channel under the building during winter time was 11 degrees (Table 2) when the pigs were small and ventilation rates were low. The warming up of the air also leads to a more stable temperature with less variation within a day.
We had expected some cooling of the air in the channel and also a more even air temperature of the incoming air with a lower air temperature in the afternoon. However, the cooling effect of the air in the channels was very small in the present studies, probably due to the high ventilation rates.
Pen cleanliness on the farm with channels under the building was good. Of course, it is always easier to have a clean lying area if this area is smaller. The size of the lying area was only half of the size of the lying area on the farm with air inlets in the ceiling. Because of this large difference in size of the lying area it is difficult to draw any conclusions. However, during the studies it was noticed that the pigs were lying in the lying area where the fresh air came into the compartment. During warm periods, the pigs might feel comfortable when fresh air enters the compartment close to the lying area. On the other hand, the risk for draught on the lying area might be larger when the air enters into the compartment close to the lying area. Therefore it might be important to develop a regulation mechanism which can steer the direction of the air automatically (under or above the kennel lid) and also the size of the opening depending on the ventilation rate.

5 Conclusions

From the present measurements it can be concluded that it is possible to take in air via channels under the building under Nordic conditions. During a cold winter day, the air was pre-heated with 4 ^{0}C before entering the compartment. The cooling effect of the air in the channel was negligible during summer time. However, there was at least no extra warming up of the air as it was during summertime on the farm with air inlets in the ceiling. The cleanliness of the pens was good with channels under the building. The regulation how the air came into the compartment (under or above the kennel lid) should be improved from manual to automatically regulation. The opening between channel and the compartment should also be reduced somewhat in order to get a more even distribution of the incoming air.
Taking out the first part of the exhaust air via a channel along the manure channel worked well. The high concentrations of ammonia in the air outlet via the manure channel indicates that this way of removing air from the compartment improves the indoor air quality but at the same time might increase ammonia emissions from the pig house when no air cleaning system is installed (e.g. scrubber or biofilter).

6 Acknowledgements

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7 References

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