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IMPACT OF TEMPERATURE CONTROL STRATEGIES ON ANIMAL PERFORMANCE, GAS EMISSIONS AND ENERGY REQUIREMENTS FOR GROWER-FINISHER PIGS

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ABSTRACT When grower-finisher pigs are housed within their thermoneutral zone, the feed energy required to maintain animal thermal comfort is at a minimum and their retained energy is at a maximum. Beyond the lower and upper limits of the thermoneutral zone, pig performance will decrease. A warmer building air temperature may increase ammonia emissions and building energy requirements for heating during cold weather conditions. The objectives of this study were to compare the impact of three control strategies of the temperature setpoint for grower-finisher pigs on the animal performance, ammonia emissions, and heating and ventilation energy requirements under Quebec conditions. The three control strategies were defined from the literature information and industry practices: 1) warm strategy (22.2 to 20.0ºC); 2) intermediate strategy (21.7 to 17.2ºC) and 3) cool strategy (21.1 to 14.4ºC). Two 11-wk trials occurred in 12 environmentally controlled chambers each housing three grower-finisher pigs from 30 to 115 kg. Each temperature control strategy was replicated eight times over both trials. Pig weight and feed/water disappearance were measured once a week and the room air temperature, relative humidity, ventilation rate and gas emissions were continuously monitored by electronic sensors and gas analysers. On average, combining both trials, for the warm, intermediate and cool temperature strategies, the ADG was 1.04, 1.11 and 1.06 kg/day-pig, respectively. The corresponding FE values for the three strategies were 2.61, 2.59 and 2.62 kg_{feed}/kg_{gain}. Pigs housed under the warm temperature strategy produced more heat (≈ 140 W/pig) as compared to the pigs maintained under intermediate or cool temperatures ≉ 100 W/pig). Ammonia emissions ranged between 0.1 and 0.2 g/d-kg of live weight. In Trial 1, emissions were less for pigs raised at cooler temperatures. The complete statistical analysis of the results will point toward a recommended temperature strategy for grower-finisher pigs optimising animal performance, energy requirements and environmental impacts.

Keywords: Temperature control strategy, pig performance, heating requirements.

INTRODUCTION The thermal well being of growing pig has been described in a number of ways. Verstegen et al. (1982) and Baxter (1984) referred to optimal thermal well being of a pig occurring in a zone of thermoneutrality. This zone of thermoneutrality occurs in a thermoneutral zone or temperature range where heat production is at a minimum and is independent of the ambient temperature (Bruce and Clark 1979). When ambient temperatures drop below this thermoneutral zone, heat production is increased and retained energy is diverted from productive purposes. The range of the temperature of the thermoneutral zone is dependent of the ability of the growing pigs to maintain their thermal well being by their behaviour, physiological mechanisms and physical adjustment (Gonyou et al. 2006). The range of the thermoneutral zone is the lower (LCT) and upper critical temperatures. The value of the LCT is dependent on the pig body weight, feed intake, ambient air velocity, radiant temperature of surrounding surfaces, type of flooring and group size. Thus, the LCT value decreases as the pig mass increases. By optimizing the air velocity, floor type and group size, the LCT can be minimized. The LCT value for growing pigs will impact the heating requirements of the animal space during cold weather conditions. As the LCT decreases, the heating requirements to maintain the LCT will decrease. Industry needs to maintain the ambient temperature of the growing pigs at the lower crucial temperature to minimize heating requirements.

The objective of this study was to grow pigs (30-115 kg) at three temperature regimes. The three control strategies were defined from the literature information and industry practices: 1) warm strategy (22.2 to 20.0ºC); 2) intermediate strategy (21.7 to 17.2ºC) and 3) cool strategy (21.1 to 14.4ºC) over the growing period of 11 weeks. Associated variables for each treatment were pig performance, sensible heat production, ammonia production, airspeed at pig level and incidence of pig behaviour. The results will demonstrate the decreased heating costs required when maintaining the ambient temperature for the growing pigs considering their weight and environmental conditions. A cooler building may also decrease ammonia emissions.

FACILITIES AND METHODS

Animal Chambers Twelve environmentally controlled chambers were used in this experiment (IRDA, Deschambault, QC, Canada). The chambers have a width, length and height of 1.14, 2.44 and 2.44 m, respectively. All the joints in the chambers and along the manure storage area were sealed. The door hardware ensured that the doors were sealed when closed. The flooring is fully slatted with the manure being stored in a shallow pit located under the floor. The manure was removed by a vacuum pump. The ventilation system consisted of an inlet and exhaust fan mounted in the ceiling of each chamber. The capacity of the variable speed exhaust fan ranged from 14 to 75 L/s.

The inlet air was preheated by an induct heater to maintain the chamber ambient temperature. The operation of the heater and the ventilation fan was controlled by a temperature controller (EVS-22HA; Norsol Electronics, St-Hubert, QC, Canada). The minimum ventilation rate was adjusted to 14 L/s in each chamber. The setpoint temperature in the chambers varied over the growing period for each treatment (Table 1).

Table 1. Temperature control strategies.

No.	Treatment	Description
1	Warm (W)	22.2 to 20.0°C (most common in Québec)
2	Intermediate (I)	21.7 to 17.2°C (intermediate level)
3	Cool (C)	21.1 to 14.4°C (most common in Western Canada)

The setpoint temperature was progressively decreased each week such that chamber temperature setpoints reached the final temperature of each treatment when pigs were approximately 75 kg. The temperature setpoint was adjusted every Tuesday. Lighting was provided at an intensity of 70 lux at 2.3 m from the floor from 6h00 to 18h00.

Pigs Each chamber housed three male pigs at an initial mass of 30 kg up to 115 kg. Both feed and water were provided ad-libitum. The pigs were a F1 cross (YY X NN) x Duroc (Y: Yorkshire and N: Landrace) purchased from a pig breeding company. A standard industry diet was fed.

Experimental Design Pigs were raised during two trial periods. Trial 1 took place from January 8th to March 26th of 2009 while Trial 2 took place from December 8th, 2009 to February 23rd, 2010. Chambers were selected randomly for each trial so that 4 of the 12 chambers were warm (W), intermediate (I) or cool (C; Table 1).

Instrumentation and Measurements Inlet and room humidity and temperature were measured by a combined temperature and relative humidity probe (Model CS500, Campbell Scientific, Logan, UT). The temperature probe was calibrated by a mercury thermometer (± 0.4°C). The relative humidity probe was calibrated with a saturated aqueous salt solution (magnesium chloride: 32.5% RH; magnesium nitrate: 52.9% RH). The humidity ratio of the incoming air was calculated from the inlet ambient temperature and relative humidity values.

Pigs were individually weighed each Tuesday and their feed was weighed daily and at the end of the week. These data permitted for the calculation of the average daily gain and feed efficiency. Carcass quality measurements were also collected once every three to four weeks but these data will be discussed in future reports.

The exhaust air was directed through a 204-mm iris orifice damper (Model 200; Continental Fan Manufacturer Inc., Buffalo, NY). Its accuracy was rated at ± 5%. A differential pressure transducer measured the pressure across the orifice plate. The relationship between pressure and airflow was:

$$Q = A\,[P]^{0.5} \tag{1}$$

Where Q is the exhaust air flow (L/s), A is the orifice coefficient (n.u.) and P is the differential pressure (Pa).

The ventilation measurement devices were calibrated between the two Trials. Each of the 12 204-mm iris orifice dampers were installed in a 200-mm test duct located downstream from a centrifugal fan. The location of the iris orifice damper and the location of airspeed measuring device within the test duct were according to published standards (ASHRAE, 1997). The calibration of the fans ranged between 25 and 70 L/s. The airflow rates calculated from the measured duct airspeeds were correlated with the measured voltages. These regression equations predicted the airflow rates from the differential pressure transducer voltages that measured the differential pressure across the orifice dampers.

The output from all sensors was recorded every 15 min by an acquisition system (Model CR-7, Campbell Scientific, Edmonton, AB). Water consumption was measured by a water meter (Lecomte, Québec, QC) and the signal output from the meter was scanned every 15 min.

Gas emissions Gas concentrations (CO_2, CH_4, N_2O, H_2S and NH_3) were measured at the central air inlet and at the room exhaust on an hourly basis throughout the trials. The sample air was pumped to a mobile laboratory through Teflon tubing. The concentration of methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) were measured with a gas chromatograph (Varian 3600, USA) equipped with a flame ionization detector (FID) for detection and quantification of CH_4 and an electron capture detector (ECD) for detection and quantification of CO_2 and N_2O. Ammonia (NH_3) was measured with a non-dispersive infrared (NDIR) analyzer (Ultramat 6E, Siemens, Germany) and the semi-quantitative evaluation of hydrogen sulphide (H_2S) was done with a UV fluorescence analyzer (M101E, Teledyne API, USA). Every two days, the analyzers would monitor ambient air and certified calibration gases.

Cellulose fibre filters were placed at the end of sampling Teflon™ tubes (6.4 mm OD) to prevent dust particles from damaging the gas analyzers. To prevent condensation in tubes, the conduit carrying the gas sampling tubes was ventilated by air maintained at 35°C. To maintain similar flow conditions, all tubes had the same length.

To obtain the gas emissions, the following equation was used:

$$E_{gas} = \frac{C_{gas\,exit} - C_{gas\,in}}{10^6} \, X \left(\frac{\beta_{gaz} \, X \, Q}{M_{pig}} \right) x \, 10^6 \tag{5}$$

Where E_{gas} represents the gas emission (mg_{gas}/min-kg_{pig}), $C_{gas\ exit}$ is the gas concentration at the room exhaust (ppm), $C_{gas\ in}$ is the gas concentration at the room inlet (ppm), β_{gas} is the gas mass per volume of air (kg_{gaz}/m^3_{air}), Q represents the airflow rate exhausted from the room (m^3_{air}/min) and M_{pig} is the total mass of the pigs in the room (kg).

Mass of gas by air volume:

$$\beta_{gas} = D_{gas} \; x \; \rho_{air} \tag{6}$$

Where ρ_{air} is the air density (1.2 kg_{air}/m^3_{air}); D_{gas} is the specific gravity (kg_{gas}/kg_{air}; ex.: NH_3 = 0.597 at 21 °C and 101 kPa).

The specific gravity values at 21°C and 1.013 bar were assumed for all the gas data.

Airspeed Measurement Airspeeds were measured in the pig space of each chamber. An airspeed sensor (TSI, Shoreview, MN) was attached to a suspended cord in the chamber.

The cord was operated such that the airspeed sensor was introduced from outside the chamber. In this way, the pigs were not disturbed during the airspeed measurement session. Measurements were obtained at pig height and in the centre of the chambers at mid-height. The ideal measurement in the immediate vicinity of the pig occurred while the pigs were sleeping. Otherwise, the sensor had to be kept out of reach of the pigs. Measurements were obtained during week 9, 10 and 11 during Trial 1 and during weeks 8, 9, 10 and 11 during Trial 2.

Behavioural Observations After the first trial, there appeared to be a difference in pig behaviour between treatments. The warmer pigs appeared to have increased performance, although this observation may have been anecdotal. During Trial 2, a camera system was installed. An image of the pigs in each room was recorded every 5 min every Monday (6-18h) from wks 8 to 11. The recorded images were analyzed for standing or sitting activity. An observation consisted of recording 1, 2 or 3 pigs standing or sitting in each image. The difference in the number of images of pigs standing or sitting among treatments would hopefully provide an insight in the difference in pig performance (Gonyou, 2010).

Heat Production From the Pigs The pig sensible heat production was calculated from the sum of the chamber and ventilation heat loss. The ventilation heat loss was a product of the measured ventilation rates and the change in sensible enthalpy between the inlet and exhaust air. The latent heat production from each chamber was a product of the ventilation rate and the change in latent enthalpy between the exhaust and inlet air. The latent heat was based on the relative humidity and the dry-bulb temperature measurements.

PRELIMINARY RESULTS AND DISCUSSION

Environmental Conditions Temperature data for each of the 12 chambers were obtained on a 15-min interval over the 11-wk period for both trials. A typical temperature profile over a 1-wk period is shown in Figure 1. According to this figure, the control of the treatment temperatures for each chamber was considered to be very satisfactory. The variation in temperature occurred when the chamber controller was in heating mode.

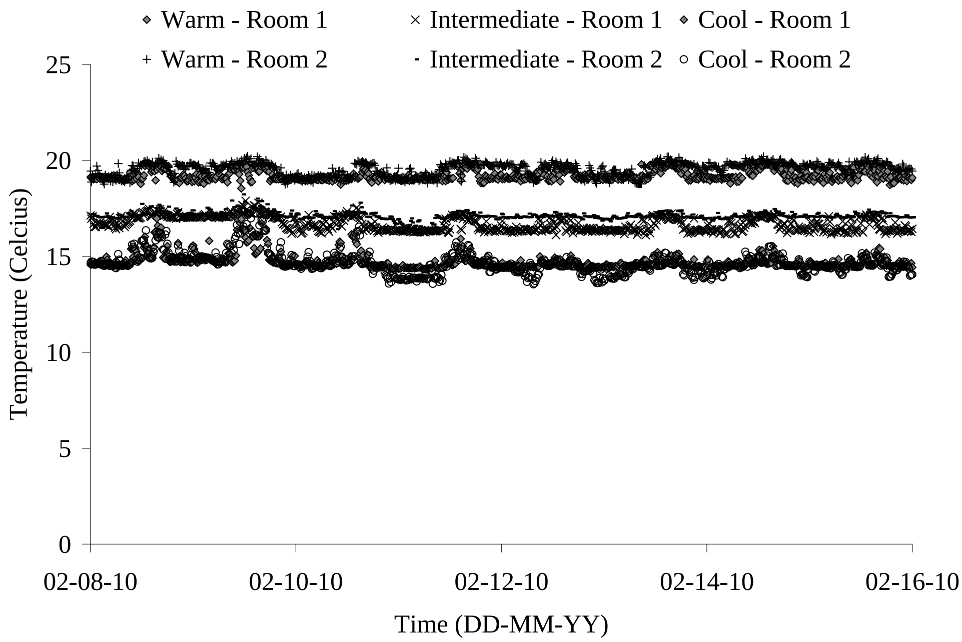

Figure 1. Temperature control during one week in 2 rooms of each treatment housing the warm, intermediate and cool treatment pigs (Trial 2 – wk 10).

Average Chamber Temperatures and Pig Performance Tables 2 and 3 indicate that as the growing cycle was progressing, the room air temperature was in fact getting colder in the I and C rooms. For the last four weeks of trial 1, the average W, I and C room temperatures were 18.4, 15.6 and 13.2ºC, respectively. For that period of trial 1, W pigs grew faster with a slightly better feed efficiency (FE; Table 2). However, in trial 2, for the last period, the best average daily gain (ADG) was observed for the I pigs but both the W and the C pigs had the lowest FE. On average, combining both trials, for the warm, intermediate and cool temperature strategies, the ADG was 1.09, 1.11 and 1.06 kg/day-pig, respectively. The corresponding FE values for the three strategies were 2.57, 2.59 and 2.62 kg_{feed}/kg_{gain}. Most of the time, the water to feed ratio of the W pigs was higher than for the other strategies (Tables 2 and 3). This confirmed that the W pigs were experiencing higher temperatures and using more water. The completion of the data statistical analysis will allow to assess if any of the differences between treatment are significant or not.

Table 2. Temperature, sensible heat and performance data for the trial 1.

Parameter	Values								
	Warm			Intermediate			Cool		
Weeks	1-3	4-7	8-11	1-3	4-7	8-11	1-3	4-7	8-11
Temperature (°C)	19.7	18.9	18.4	18.0	16.3	15.6	16.4	14.4	13.2
Sensible Heat (W)	157.3	191.6	208.4	124.3	146.5	165.8	89.7	104.4	96.5
ADG[1] (kg_{pig}/d-pig)	1.05	1.15	1.21	1.07	1.09	1.15	0.99	1.15	1.12
FI[2] (kg_{feed}/d-pig)	2.14	2.83	3.55	2.06	2.73	3.45	2.06	2.77	3.54
Water Int. (L/d-pig)	4.2	5.6	6.3	4.2	5.0	5.3	3.4	4.4	4.8
FE[3] (kg_{feed}/kg_{pig})	2.0	2.5	2.9	1.9	2.5	3.0	2.1	2.4	3.2
Water/Feed ratio	1.9	2.0	1.8	2.0	1.8	1.5	1.7	1.6	1.4

[1] Average daily gain; [2] feed intake; [3] feed efficiency.

Table 3. Temperature, sensible heat and performance data for the trial 2.

Parameters	Values								
	Warm			Intermediate			Cool		
Weeks	1-3	4-7	8-11	1-3	4-7	8-11	1-3	4-7	8-11
Temperature (°C)	20.1	19.2	18.5	18.8	17.2	15.6	18.5	15.8	14.0
Sensible Heat (W)	105	144	191	74	93	149	91	101	131
ADG[1] (kg_{pig}/d-pig)	0.90	1.10	1.07	0.96	1.21	1.14	0.92	1.09	1.06
FI[2] (kg_{feed}/d-pig)	1.83	2.70	3.25	1.94	3.03	3.60	1.94	2.77	3.24
Water Int. (L/d-pig)	3.7	5.8	6.06	3.0	4.1	5.8	3.4	4.5	5.1
FE[3] (kg_{feed}/kg_{pig})	2.0	2.4	3.0	2.0	2.5	3.2	2.1	2.5	3.0
Water/Feed ratio	2.0	2.2	1.9	1.6	1.3	1.6	1.7	1.6	1.6

[1] Average daily gain; [2] feed intake; [3] feed efficiency.

Airspeed in the Chambers The airspeed was measured at pig height and in the middle of the chamber at mid height once a week during the last 3 and 4 weeks of Trials 1 and 2, respectively. The airspeeds in the C chambers were slightly higher than those of the I and W chambers. This was due to the higher ventilation rates in the C chambers required to maintain the cooler temperatures (Table 4). All the measured airspeeds at pig height were considered satisfactory (<0.4 m/s; Bruce and Clark 1979). At chamber mid height, the airspeeds were higher since this area was more influenced by the inlet air jet.

Table 4. Mean airspeeds (m/s) at pig level for the warm, intermediate and cool treatments for the two trials.

Trial	Sampling day	Airspeed (m/s)		
		Warm	Intermediate	Cool
1	1	0.21	0.42	0.47
	2	0.25	0.28	0.31
	3	0.21	0.27	0.26
	Mean	0.22	0.33	0.35
2	1	0.20	0.32	0.38
	2	0.21	0.27	0.34
	3	0.26	0.35	0.37
	4	0.28	0.30	0.28
	Mean	0.24	0.31	0.35

Pig Behaviour Of interest was the change in pig behaviour during Trial 2, since the pigs in Trial 1 indicated that the W pigs were producing more sensible heat (Table 2). This was unexpected since the C pigs should be producing more sensible heat. Within the thermoneutral zone, the C, I and W pigs were expected to produce the same total heat production. Table 5 shows that the W pigs were consistently standing or sitting more frequently individually than the I and C pigs. The C and I pigs were standing or sitting more as a group of 2 or 3 pigs. The frequency of the W pigs standing or sitting as a group of 3 was significantly less than that for the C and I pigs. The total number of times the W pigs were standing or sitting (78 instances) over the 12 h-period was much less than that for the C (97) and I (99) pigs (Table 5).

Table 5. Mean incidence of pigs standing or sitting (144 observations/day) in the warm (W), intermediate (I) and cool (C) treatments for Trial 2.

Number of pig in activity	Number of incidence of pig standing or sitting														
	Rep 1			Rep 2			Rep 3			Rep 4			Mean		
	W	I	C	W	I	C	W	I	C	W	I	C	W	I	C
1 pig	35	29	26	35	30	32	36	26	25	32	25	28	34	28	28
2 pig	31	42	45	36	39	43	30	35	46	28	36	35	31	38	42
3 pig	13	32	29	16	30	22	11	29	24	13	35	42	13	32	29
Total	79	103	99	86	99	96	77	90	95	72	96	105	78	97	99

Sensible Heat Production The mean hourly sensible heat production over the 11-wk period is represented in Figure 2. The heat production increases when the chamber lights are on (6 - 18h) due to increased activity. The higher heat production of the W pigs was unexpected. The chamber was calibrated at the end of each trial by placing a known heat source in the chambers once the pigs were marketed. Also during trial 2, the treatments were again randomized. The difference between the day heat production values and night values was approximately 10 W. The heat production of the W pigs ranged between 100 and 180W/pig.

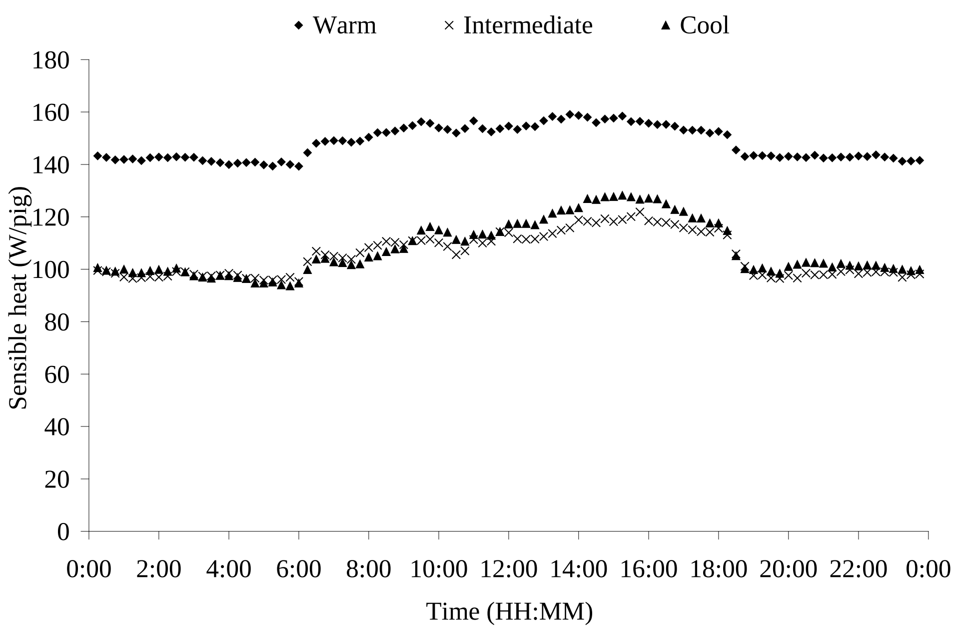

Figure 2. Sensible heat production of pigs in warm, intermediate and cool treatments over a 24-h period (77-day period).

Ammonia Emissions Figure 3 shows the ammonia emissions over the 11-wk period in Trial 1. Of interest is the lower ammonia emission from the C chambers. The emission rates for the W, I and C chambers ranged between 0.1 and 0.2 g/d-kg of pig mass. However, during Trial 2, the NH_3 emissions were similar and there were no apparent differences between the treatments.

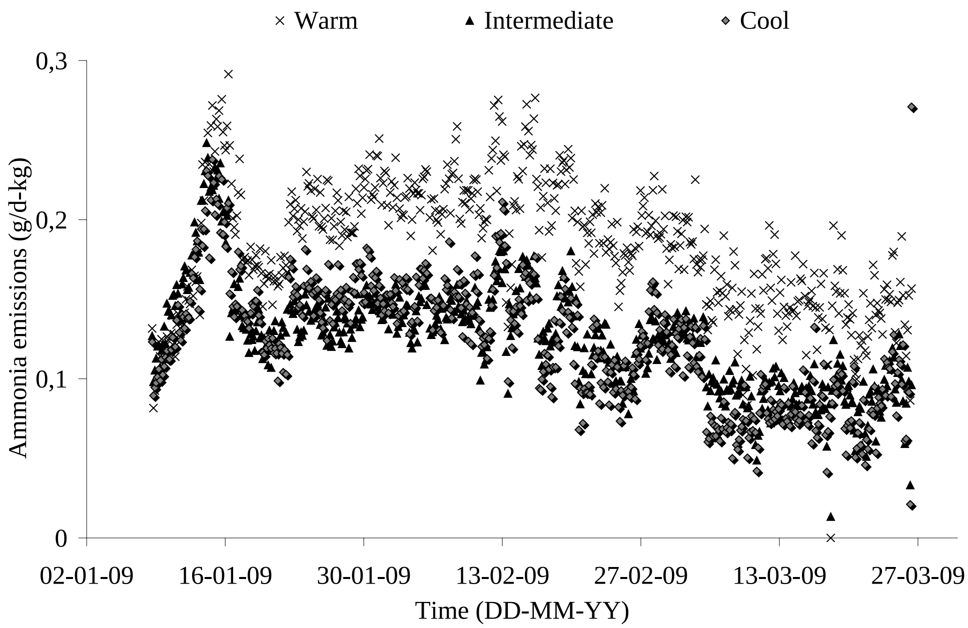

Figure 3. Ammonia production over a 77-day period (Trial 1).

Future Work Considering that trial 2 was completed only on February 23rd 2010 the complete data analysis process is not finished. An appropriate statistical analysis will be performed on the data set to evaluate if the temperature treatments provided statistical differences. The overall analysis of the study results considering the average environmental conditions, the animal performance, the gas emissions and the heating energy requirements will lead to optimised temperature control strategies for grower-finisher pigs raised in climate similar to the one in Québec.

SUMMARY

Three control strategies of the setpoint temperature in swine buildings have been studied over the last two winters. Based on the data analysis completed to date, the following statements can be made:

1) On average, combining both trials, for the warm, intermediate and cool temperature strategies, the ADG was 1.04, 1.11 and 1.06 kg/day-pig, respectively. The corresponding FE values for the three strategies were 2.61, 2.59 and 2.62 kg_{feed}/kg_{gain}.
2) Pigs housed under the warm temperature strategy produced more heat (140 W/pig) as compared to the pigs housed under intermediate or cool temperatures (100 W/pig).
3) Ammonia emissions ranged between 0.1 and 0.2 g/d-kg of liveweight. In Trial 1, emissions were less for pigs raised at cooler temperatures.
4) Warm temperature pigs stand or sit individually more frequently (7.9%) than the intermediate/cool temperature pigs (6.5%). Also, warm temperature pigs stand or sit more frequently as a group of three (3.0%) than the intermediate/cool temperature pigs (6.9%).

The complete data analysis of the results will point toward a recommended temperature strategy for grower-finisher pigs optimising animal performance, energy requirements and environmental impacts.

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