Develop the ventilation concepts that would allow a reduction in the flow of air required during the summer in maternity and grow/finish facilities

July, 2012 | **Report**

Francis Pouliot[1], Eng., M.B.A.
Valérie Dufour[1], M.Sc.
Sébastien Turcotte[1], Agr.
Michel Morin[1], Agr.
Marie-Aude Ricard[1], Jr. Eng.
Julie Ménard[2], Agr., D.M.V.
Benoît Laplante[2], M.Sc.

[1] Centre de développement du porc du Québec inc.
[2] F. Ménard inc.

F. MÉNARD INC

CDPQ Centre de développement du porc du Québec inc.

Production team

Team leader:	Francis Pouliot, Eng., M.B.A. (CDPQ)
Project leader:	Valérie Dufour, M.Sc. (CDPQ)
Collaborators:	Benoît Laplante, M.Sc. (F. Ménard) Patrick Massabie, Eng. (IFIP – Institut du Porc) Guy Maynard, Research assistant (F. Ménard) Julie Ménard, Agr., D.M.V. (F. Ménard) Sarah Provencher-Bordeleau (CDPQ) Joël Rivest, Ph. D. (CDPQ)
Authors:	Sébastien Turcotte, Agr. (CDPQ) Valérie Dufour, M.Sc. (CDPQ) Michel Morin, Agr. (CDPQ) Marie-Aude Ricard, Jr. Eng. (CDPQ) Francis Pouliot, Eng., M.B.A. (CDPQ)

Acknowledgements

A portion of project funding was provided by the sector councils of Quebec, Ontario and Manitoba, who administer the Canadian Agricultural Adaptation Program (CAAP) for Agriculture and Agri-Food Canada. It was also financed by the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec* through the *Programme d'appui financier aux associations de producteurs désignées*, by F. Ménard and the *Centre de développement du porc du Québec inc.*

Finally, the authors wish to thank the *Fédération des producteurs de porcs du Québec* who acted as applicant with MAPAQ.

Funding for this project has been provided in part through the Canadian Agricultural Adaptation Program (CAAP) on behalf of Agriculture and Agri-Food Canada. In Quebec, the portion intended for the agricultural-production sector is being managed by the Conseil pour le développement de l'agriculture du Québec (CDAQ).

Agriculture and Agri-Food Canada   Agriculture et Agroalimentaire Canada

Agriculture, Pêcheries et Alimentation Québec

F. MÉNARD INC

CDPQ Centre de développement du porc du Québec inc.

Introduction

In North America, there is a trend toward increased ventilation flow rates in swine production facilities. However, with the advent of swine buildings equipped with an air filtration system so as to avoid contamination of herds by airborne porcine reproductive and respiratory syndrome (PRRS) virus, it is vitally important that we find ways of reducing the airflow by combining different cooling methods. This is with a view to significantly reducing the implementation and operating cost for this type of building, since fewer filters are required. Reducing these costs will enable more producers to install filters, which will, in turn, lower the risk of PRRS virus contamination in a region.

In both Quebec and North America, the recommended rates of airflow to ventilate swine housing during the summer season is twice as high as that used in swine production in the parts of France where the climate resembles that of Quebec, and in the south of France, where the climate is even hotter. These flow rates are lower in all production facilities (Table 1). In North America, the highest ventilation flow rates are such that the size of the filters required for a given pressure drop is proportionally greater than in France, as is the cost of filters (initial purchase and replacement costs).

Table 1 Maximum ventilation flow rates (summer) recommended in France and Quebec, according to stage of production

	Maximum flow rate (cfm / animal)	
	France[1]	Quebec[2]
Farrowing	250	680
Gestation	150	380
Nursery	30	70
Finishing	65	170

[1] Jégou *et al.*, 2008

[2] Pouliot, 2011. Personal communication

Moreover, higher ventilation airflow rates demand a greater number of fans, resulting in an increased risk of stray air infiltration through the shutters of the stopped fans. To overcome this problem in the case of ventilated buildings under negative pressure you have to install sealed backdraft shutters, which adds additional costs.

The main purpose of ventilation during hot periods is to maintain a certain difference (about 2°C) between the indoor and outdoor temperatures by evacuating the heat produced by the animals and other heat sources to the outside. Thus, if it is 30°C outside, the air flow must be sufficient to maintain an inside temperature of less than 32°C. Airflow delivery is increased over time so as to boost the air velocity at animal level and cool them off by convection. Unfortunately, in many ventilation systems, the air speed is increased at ceiling level, and not, as is wanted in summer, on the level of the animals to cool them off (inefficient).

Massabie (2001) demonstrated that at a temperature in the building of between 24°C and 28°C, an average air speed of 1 m/s (200 fpm) gives a 5 to 6°C reduction in the temperature experienced by the pigs. Massabie (2001) also showed that at an ambient temperature of 28°C, adding recirculation fans to obtain an average air speed of 1 m/s (200 fpm) meant it was possible to increase the average daily weight gain (ADG) by 100 g (3.5 oz.) a day. The main problem during hot weather is that hot animals thermoregulate themselves by cutting their food intake. This leads to reductions in average daily gain (ADG) in finishing, reduced milk production in farrowing and lower fertility rates in gestation.

For instance, to demonstrate the impact of air velocity and spraying pigs with water, Dong *et al.* (2001) found that at an ambient temperature of 31.5°C, adding recirculation fans to obtain a current of air of 0.5 m/s (100 fpm) at the level of sows in the farrowing area, combined with the use of a misting system to sprinkle water onto the sows' necks, significantly reduced both their body temperature by 0.5°C (39.5°C vs. 39.0°C) and their respiratory rate by 42% (79 vs. 46 breaths/min), when compared to the same air velocity without the misting system.

Project objective

The aim of this study was to develop and test ventilation concepts in maternity and finishing facilities in order to decrease the airflow required during periods of hot weather without affecting zootechnics performances and animal wellbeing. And this with the goal of reducing costs related to the implementation of air filtration systems inside farrow and farrow-to-finish swine buildings.

The project took place on two farms in the Montérégie region of the province of Quebec, a farrowing barn and a finishing barn. Monitoring in maternity began on June 1, 2011 and ended October 15, 2011. A complete batch in finishing was tested from May 26, 2011 to September 22, 2011. The trial in a finishing barn is summarized in this document following the trial in the farrowing barn.

During the summer of 2011, the outside temperature was over 30°C for 1.32% of the time during the summer, a period equivalent to 50.64 hours. The only heat wave in that summer occurred from July 20 to 23 (Humidex factor equivalent to 48°C).

Maternity

Method

The 1,000 sow capacity maternity facility consisted of two buildings connected by a corridor. It comprised a barn with four gestation rooms and another barn with ten farrowing rooms, a gestation room for gilts and a quarantine room.

Sows were moved from one section to another according to the farm's usual routine. Gestating sows were confined while those in all the farrowing rooms were fed dry feed *ad libitum*. There was ready access to fresh water throughout the farm.

All rooms were ventilated separately .The temperature set point was 18.9°C in gestation, and it varied in farrowing room, according to age of the piglets. When sows were moved to the farrowing rooms a few days before the expected date of farrowing, the set point was 18.9°C, as in the gestation rooms. During farrowing, the temperature that was called for was 22.8°C. After that, it was gradually reduced to 20°C until the piglets were weaned.

In maternity, five ventilation strategies were evaluated in gestation and four different approaches were tested in farrowing (**Table 2**). The ventilation rates used for the different strategies were based on the results of a heat assessment.

Table 2 Description of experimental strategies

Strategy	Acronym	Room	Description
Gestation			
Low-flow	LF	1	178 m^3 air/h/sow* (105 cfm/sow) and 6 recirculation fans
Drip cooler	DC	2	178 m^3 air/h/sow, 6 recirculation fans and drip system†
Control	C	3	246 m^3 air/h/sow (145 cfm/sow)
Misting system	MS	4	178 m^3 air/h/sow, 9 recirculation fans and high pressure misters
Recirculation	R	5‡	246 m^3 air/h/sow and 6 recirculation fans
Farrowing			
Control	C	1	637 m^3 air/h/crate (375 cfm/crate)
Low-flow	LF	2	357 m^3 air/h/crate and 2 recirculation fans (210 cfm/crate)
Drip cooler and low flow	DCLF	3	357 m^3 air/h/crate, 2 recirculation fans and a drip cooler system†
Control	C	4	756 m^3 air/h/crate (445 cfm/crate)
Drip cooler	DC	5	493 m^3 air/h/crate (290 cfm/crate) and 1 recirculation fan and a drip system†
Low-flow	LF	6	357 m^3 air/h/crate, 2 recirculation fans
Low-flow	LF	7	357 m^3 air/h/crate and 2 recirculation fans
Control	C	8	560 m^3 air/h/crate (330 cfm/crate)
Low-flow	LF	9	357 m^3 air/h/crate, 2 recirculation fans
Drip cooler and low flow	DCLF	10	357 m^3 air/h/crate, 2 recirculation fans and a drip system†

* According to the average inventory
† at the nape of sow's neck
‡ gilt pool

The 760 mm diameter variable speed recirculation fans were set up in the gestation area, on three rows of stalls, two per row, at intervals 14 m (46 ft.) apart, and oriented towards the head of the sows (Figure 1). These recirculation fans came on automatically whenever the surrounding temperature reached 23.9°C and gradually increased speed until the temperature reached 26.7°C. In the farrowing area, two on/off type recirculation fans, 609 mm in diameter, directed towards the sows' heads were installed on the outside wall. These last-mentioned fans came on whenever the room temperature was over 26.7°C.

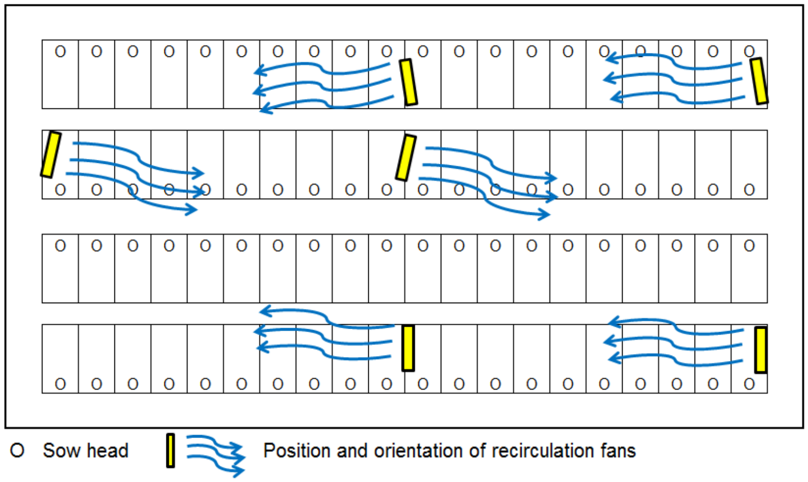

Figure 1 Position of recirculation fans in gestation area

The drip cooler system (DC strategy) was homemade: it consisted of black plastic tubing, 19 mm in diameter, mounted on top of the stalls and a nozzle for a low-pressure system above each sow (nape of the neck). The misting system (M strategy), was also homemade and comprised a misting hoop with six nozzles for a high pressure system, installed right on the recirculation fans (**Figure** 2). The operating settings for these two systems are presented in **Table 3**.

Figure 2 Misting system installed on a recirculation fan

Table 3 Operating settings for the misting and drip systems

	Misting	Drip Gestation	Drip Farrowing
Temperature at start up № 1	29.4°C	28.9°C	28.9°C
Run time № 1	1 minute	45 seconds	45 seconds
Downtime № 1	3 minutes	15 minutes	20 minutes
Temperature at start up № 2	32.2°C	32.2°C	32.2°C
Run time № 2	1 minute	45 seconds	45 seconds
Downtime № 2	1 minute	10 minutes	15 minutes

Ambient air temperature and relative humidity were measured continuously as was the electricity consumed by the exhaust and the recirculation fans. Water consumption (of both sows and cooling system) in each room was also measured. Random measurements were taken of dust concentration, CO_2 and NH_3.

On eight occasions during the trial, the rectal temperature and respiration rate of ten sows per room were measured twice or three times during the day when the outside temperature was over 28°C.

Results and Discussion

Ambiance Conditions

Temperature and humidity

In gestation, decreasing the ventilation rate had the effect of increasing the frequency of a warmer T_{in} (inside temperature) when T_{out} (outside temperature) was between 16 and 26°C, than in strategy C. However, the temperature difference between the T_{in} of the different strategies and the control room was almost always (> 97.9%) less than 2°C, and this, for all the T_{out}. Moreover, the hotter it got, the more the ΔT (delta temperature) with the outside (T_{in} minus T_{out}) were small or even negative, meaning that it was colder in the rooms than outside. This can be explained by the thermal inertia of the building and the soil. Therefore, despite the significant reduction in air flow, there was no significant increase in temperature in the rooms.

The cooling system of the DC strategy had no influence on the $T_{in,}$ because when the system started to operate, it did not lower the T_{in}. However, the aim of the drip cooling system was to wet the animals in order to cool them down and not to lower the T_{in}. The airflow had no effect on the rate of relative humidity, since the humidity in the low-flow strategies (LF, DC and M) was within a ± 5% range of the control room value more than 95% of the time. On the other hand, when the water cooling systems (DC and M) started to operate, the humidity in these rooms was 10% or more higher than in the control room for from 2 to 17% of the time.

In farrowing, in all the strategies, the T_{in} was never more than 2°C higher than the T_{out} whenever the T_{ext} exceeded 32°C. In addition, the temperatures of the LF, C and DC strategies were similar, the drip cooling system did not lower the T_{in} of the rooms while it was operating, which is normal. Air flow reduction (LF and DCLF) had a slight effect of increasing T_{in} when the T_{out} was between 22 and 28°C, but this was not an issue.

Air Velocity

In the gestation section, in those strategies using air recirculation, the average air velocity at 0.40 m above the ground was about four times higher (0.42 *vs.* 0.09 m/s) but it varied a great deal, depending on the distance from the recirculation fans. In farrowing, the air velocity measured at the piglet level was twice as high when there was air recirculation (0.12 *vs.* 0.06 m/s), but it remained low despite the presence of ceiling fans. This level of air velocity was not problematic for piglets, but the cooling effect was relatively low as far as the sows were concerned. There are a great many obstacles in this section that deflect and slow the air, and so, are not conducive to the cooling of the sows. In addition, other solutions must be found to increase airflow by means of recirculation inside the crates, while not adversely affecting the comfort of the piglets.

Gas and dust

The concentration of CO_2 varied between 800 and 950 ppm in the various low-flow strategies in (LF, DC, M and R) and NH_3, was between 4 and 7.5 ppm. These values are below acceptable limits and were not problematic. Dust concentration in the LF, DC and R strategies was also below the average for swine farms (130,000 particles per liter of air) by 25,000 to 37,000 particles/l of air.

Energy and water consumption

The control room in gestation is the room with the lowest energy consumption, an average of 0.39 kWh/sow/d, and R is the strategy that consumed the most energy (0.89 kWh/sow/d). Both these strategies had the same airflow, but there were four more recirculation fans used in strategy R. Strategies DC and M consumed about 0.50 kWh/sow/d and the LF strategy (at 0.67 kWh/sow/d) is higher than the M/F and DC strategies, and this even when the airflow per pregnant sow is the same for all three strategies.

Contrary to expectations, drinking water consumption in the control room in gestation (15.2 l/sow/d) was lower than that of the strategies with air recirculation (from 21.9 to 24.4 l/sow/d), most likely because this room (control) held sows awaiting mating and water consumption by these sows would be less than that of pregnant sows or those whose pregnancy is more advanced. The amount of water used by cooling systems during the summer were 0.5 and 0.3 l/sow/d for the drip cooling and misting systems respectively, which is extremely small compared to the sows' consumption. Total water consumption is similar for the LF, R and M strategies (21.9 to 23.7 l/sow/d) and slightly higher for the DC strategy (24.9 l/sow/d).

In farrowing, the total water consumption, including water for cooling, was similar in all four strategies (25.6 to 26.7 l/sow/d). No other analysis was possible; the daily temperature and humidity data cannot be compared, since at any given time, the sows in each room are not at the same stage (days peripartum, i.e. the number of days before, during, or after delivery) and temperature set points are not the same.

Respiration rate and rectal temperature

The sows' physiological stage greatly influences their baseline respiratory rate and rectal temperature and since those sows that were in the different strategies were not at the same stage on the hot days, no clear tendency can be found.

Finally, during the dog days of summer, the pregnant sows in strategies M, MS and LF had to be sprayed in turn using a garden hose, as they were in respiratory distress. For example, the respiration rate of sows in room M went from 60 to 42 breaths per 30 seconds after spraying down. This indicates that watering sows in heat stress is a very effective means of cooling them down rapidly. However, the respiration rate of sows in the DC strategy was fairly stable and the lowest of all the strategies. The combination "drip cooler and current of air" has proven very effective. The rectal temperature of sows in the different strategies followed the same tendencies as the respiratory rate.

Investment costs in maternity

For gestation, the costs of equipment for the LF, DC, M/F and R strategies were $15.04, $17.04, $20.89 and $6.80 per stalls respectively. However, the "head-to-head" configuration of the stalls (rather than "back-to-back") enabled us to limit the number of recirculation fans needed in the room with the R strategy.

In farrowing, installing the low-flow strategy took the lowest level of investment, or $24.40 per crate. Of the three strategies, the drip cooler system proved the most expensive, at $45.57 per crate. The small farrowing rooms increase the cost per crate considerably, because, compared to its capacity, the equipment is underutilized. The costs of air filtration drop by almost half with a reduced flow rate, resulting in annual savings of $13 to $19/place (per sow space) per year in filtration costs and additional savings connected to the reduced air flow (a reduction in the number of backdraft shutters, to which could be added the filter installation costs and building adaptation costs). These savings are greater than the installation and energy costs in the low-flow strategies in gestation and farrowing, as well as the costs of both the drip cooler and "recirculation" strategies in gestation. This suggests that, in the case of installing a filtration system, the addition of certain systems designed to reduce the ventilation rate, could be funded from savings in the capital costs and the filtration system operating costs.

Finishing barn

Method

The experimentation was conducted between May 26 and September 22, 2011 in a finishing facility with 990 places, including three rooms of 24 pens (Rooms 1, 2 and 3) and a room of 27 pens (Room 4), with each pen holding ten pigs.

Eight hundred and eighty eight grower pigs, 440 barrows and 440 females, were weighed and assigned to each pen in such a way as to have a similar average total weight per pen and per room. There were ten pigs per pen, five females and five barrows, and 22 pens per room. The animals were finished from 25 to 125 kg. The floor area per pig was 0.7 m^2. Water and feed were available *ad libitum.*

The rooms of the facility were ventilated separately. The temperature set point at pig entry was 20°C and gradually decreased by 0.6°C per week until it reached 17°C. Four ventilation strategies were tested (Table 4). Ventilation rates used for the different strategies are based on the results of a heat assessment.

Table 4 Description of the four strategies

Strategy	**Acronym**	**Room**	**Description**
Control	C	1	Airflow of 136 m^3/h/pig (80 cfm/pig)
Median Airflow	MA	2	Airflow of 102 m^3/h/pig (60 cfm/pig) and 6 recirculation fans
Misting system	MS	3	Flow of 76.5 m^3/h/pig (45 cfm/pig), 6 recirculation fans with misting system
Sprinkler System	SS	4	Flow of 76.5 m^3/h/pig (45 cfm/pig), 6 recirculation fans and a sprinkler system

For the MA, MS and SS strategies, six 760 mm (30 in) diameter recirculation fans were fixed to the ceiling, two for each row of pens, and spaced eight meters apart. The recirculation fans started to operate whenever the temperature exceeded the temperature set point by 4.4°C.

For the MS strategy, a hoop with six nozzles for a high pressure misting system was attached to each fan (Figure 2). The sprinkler system for the SS strategy makes use of the system of sprinklers used to soak the organic material on the surfaces before washing the rooms. The system was slightly modified, i.e. the downspouts with the nozzle at the bottom were lengthened by 0.3 m in order to reduce the surface spray and avoid water drifting into the feeder.

Table 5 Adjustment of the misting and sprinkler system

	Misting	Sprinkler
Temperature at start up	29.4°C	28.4°C
Run time	1 min	1 min
Downtime	3 min	15 minutes
Temperature at start up 2	32.2°C	32.2°C
Run time 2	1 min	1 min
Downtime 2	1 min	10 minutes

Ambiance Conditions

Temperature and humidity

Above 14°C, the temperature difference between that of the rooms of the different strategies and that of the control room was always less than 4°C. The MA strategy had virtually no ΔT (delta temperature) greater than 2°C.

Distribution and air velocity

In the strategies with air recirculation, the velocity of the air at the height of the pigs (0.4 m above ground level; 0.39 to 0.49 m/s) was 4 to 5 times greater than that in the control room (0.09 m/s) and 8 to 9 times greater at the level of the temperature sensors (1.6 m; 1.70 to 1.87 vs. 0.19 m/s).

Gas and dust concentrations

Reducing the ventilation rate meant that the dust concentration was increased from 6 to 26% compared to the control room, but this remained well below the acceptable limit. And even with the lowest airflow rate (76.5 m^3/h/pig), concentrations of ammonia (NH_3) and carbon dioxide (CO_2) remained at very satisfactory levels.

Animal performances and slaughter data

When compared with the control approach, average daily gain (ADG) and average daily feed intake (DFI) were numerically higher in the three strategies with a reduced ventilation rate, but using recirculation fans. The addition of a water cooling system (MS and SS) increased ADG by 75% compared to the strategy with only recirculation fans (45 vs. 26 g). Drinking water consumption was also reduced in the three experimental strategies, from 1.9 to 2.8 l/d per pig. DFI and water consumption in this instance are indicators demonstrating that the pigs were less hot.

Energy and water consumption

The sprinkler system used three times more water than the misting system. Their respective water consumption quantities were 9,400 and 3,000 liters per room. Despite the use of water to cool the animals, water use overall was less than in the control room.

Costs in finishing barn

Of the three treatments, median airflow (MA) needs the lowest investment, or $11.20/pen, followed by the sprinkler system with $13.56/pen. Misting at $20.01/pen requires the highest investment. All three treatments resulted in increased electricity consumption for the summer period compared to the control approach, with a 45% increase for the median airflow, and 55% for the misting and sprinkler systems. For the rest of the year, the equipment (recirculation fan, misting system, sprinkler system) might be little used or not at all.

Given the additional electricity costs, the annual expenses related to the three strategies range from $2.76/place for the median airflow (MA) to $4.69/place for the misting system (MS) if the equipment is paid off over 5 years. This cost will be less if amortized over 10 years.

However, other factors could lead to lowered costs. Among other things, increasing ADG may increase the average slaughter weight (or increase the number of batches produced) and returns. There is also the reduction in water consumption, which should translate into a decrease in the slurry produced and reduce the cost of spreading it. For new buildings, the saving during construction on the number of wall fans brings a return on the investment in the three systems to reduce the airflow. It would be important therefore, to take this possibility into consideration in any projected new building construction. As for the air filtration costs, they are reduced by half with the reduction in airflow and additional savings from reduced airflow are also possible (e.g. backdraft shutters, installation of air filters). These savings are greater than the installation and energy costs of the three strategies. In short, in the case of installing a filtration system, the addition of a system to reduce the ventilation rate should pay for itself in savings in the capital costs and the operating costs of the filtration system.

Conclusion

The increase in air velocity at the level of the animals, obtainment of a temperature difference less than 4°C, compared to the control room and maintenance of animal performance (zootechnics) confirm that it is possible to optimize and to reduce ventilation flows by adding recirculation fans and, if desired, a cooling system using water. However, in maternity, more work has to be done to increase the cooling effect on sows, using both air (velocity) and water, without necessarily affecting the piglets.