EΓME
HelAgEng

EurAgEng

AgEng 2024

Agricultural University of Athens

1-4 July 2024
Athens-Greece

ageng2024.com

PROCEEDINGS BOOK

ISBN: 978-618-82194-1-0

Reducing ambient temperature to reduce NH_3, N_2O and CH_4 emissions from a fattening piggery

Guingand Nadine [a*], Rousselière Yvonnick [a], Thomas Johan [a]

[a] Ifip institut du porc, Pacé, France

*Corresponding author: nadine.guingand@ifip.asso.fr

Abstract

In France, most buildings that house growing-finishing pigs are operated in a dynamic mode with a set-temperature of 22-24°C throughout the fattening period. In contrast, certain northern European countries use a set-temperature of 18°C with the stated aim of maintaining zootechnical performance and reducing ammonia emissions from these buildings. The aim of this experiment was to study the influence of ambient temperature on zootechnical and gaseous emissions by keeping temperatures cooler (16, 18 and 22°C) throughout the fattening period of pigs. Performance of these of pigs were compared to those kept in a conventional room with a set-temperature of 22°C. Pigs were weighted at the entry, the day of the food transition and the day before departure for the slaughterhouse. The quantity of feed distributed to pigs per treatment were weighted daily. NH_3, N_2O and CH_4 concentrations were semi-continuously measured by using a photoacoustic multi-gas monitor (Innova 1512). At the same time, the ventilation rate was continuously monitored. Data validation was achieved by applying the mass balance method for nitrogen and carbon including the calculation of inputs (piglet carcases, feed intake) and outputs (fattening pig carcases, slurry composition, gaseous emissions). Pig performance and environmental parameters (gaseous emissions and slurry volume and composition) of the reference room were validated to be representative of commercial breeding units. Afterwards, the comparison with the other rooms was done. Zootechnical performance did not differ between the rooms at the lower set-temperatures and the reference room. However, the rooms at 16, 18 and 22°C emitted 42 %, 36 % and 39 % less ammonia, respectively, than the reference room and 57 %, 53 % and 27 % less methane, respectively. In contrast, no effect on nitrous oxide emissions was observed. Reducing of ambient temperature could be one way to investigate how existing buildings can decrease their environmental impacts.

Keywords: Temperature, pig, housing, gaseous emission

1. Introduction

In most pig farms in France, buildings housing growing-finishing pigs are operated in a dynamic mode with a set-temperature of 22-24°C throughout the fattening period. The aim of this ventilation strategy is to maintain an ambient temperature that is appropriate to animal comfort and lead to optimal performance in terms of growth gain, feed conversion and carcass quality. A multitude of studies (Rinaldo and Le Dividich, 1991, Faure *et al.*, 2012, Quiniou *et al.*, 1997, Quiniou *et al.*, 2000) have been conducted to investigate the impact of ambient temperature on the performance of fattening pigs. Conversely, other countries such as Denmark and the Netherlands apply set-temperatures of around 18°C with the aim of maintaining zootechnical performance and above all, reducing ammonia emissions from the building concerned. This difference in ventilation management has been of concern to us for many years, particularly when combined with a change in the floor type, such as the introduction of partially slatted floor (Guingand *et al.*, 2010).

France's commitments at the European level to reduce ammonia emissions (-15% by 2030 compared to 2005 levels) and the desire to reduce the exposure of pigs and workers bring the need to explore new reduction pathways, adaptable to existing buildings, to the forefront of research and development priorities. Indeed, with a stock of buildings over 20 years old (Bertin and Ramonet, 2016) managed by a population of farm managers with an average age of 49 years in 2020 (Roguet, 2023), the proposed reduction solutions must be adaptable to existing building configurations without requiring costly major structural modifications. In the conventional system, widely applied in France, slurry is stored in the pit beneath the animals during the whole fattening period. The production of ammonia mainly results from the degradation of urea present in the urine by urease, an enzyme produced by microorganisms present in the feces. This process is sensitive to temperature and pH (Buscher *et al.*, 1997). Indeed, the increase of temperature influences the NH3-NH4+ dissociation coefficient promote diffusion and favors the activation of bacteria activity responsible of urea decomposition until inactivation temperature (Degré *et al.*, 2001). Thus, modifying the management of building ventilation by reducing the set temperature could represent a way to reduction ammonia concentration inside buildings and its emission to the atmosphere.

The aim of this study is to determine the influence of low ambient temperatures – under the thermoneutrality – on pig performance and on NH_3, N_2O and CH_4 emissions.

2. Material and methods

2.1. Design of the rooms

To study the influence of temperature on air quality without neglecting its influence on zootechnical performance, Ifip built a temperature-controlled unit called Climatotec at its experimental station in Romillé (35). This unit consists of two identical rooms with precise and independent ambient temperature control. The unit allows for the application of constant temperatures ranging from 15 to 30°C per room, thanks to a temperature-controlled block comprising a heater, a heat pump, and a heat dissipator/collector (Guingand et al., 2024). Each room can house twenty animals raised on fully slatted floor with effluent storage in a pre-pit for the entire fattening period. The air inlet – cold for this study – is through the attic and then through a Flud'R (Rose), while the extraction is low, under the slats. For this study, three different set-temperatures were applied: 16, 18, and 22°C. Due to the unit's configuration, the temperature comparison was conducted in two steps: the first comparing the two lowest set temperatures in the Climatotec unit (referred to as room T16 and room T18), and the second comparing the effect of maintaining a temperature at 22°C in the Climatotec unit (referred to as room T22) with a control room operated in parallel in the Ifip Pilot unit with a set temperature of 22°C (referred to as room REF22). This room, with air intake through a ceiling diffuser and low extraction, houses a total of 54 pigs raised on fully slatted floor with effluent storage in a pre-pit for the entire fattening period. The configuration and ventilation management of this room are considered representative of field conditions. The study was conducted between July 2022 and May 2023.

2.2. Pig management

The management of the pigs was identical in both type of rooms (Climatotec and control room). At the start of fattening, the animals were grouped by weight and sex to ensure an identical average weight per pen within and between rooms and a sex ratio of 1 per pen. The animals were fed ad libitum with a two-phase diet consisting of a growing feed (16% Crude Protein) provided until pigs reach approximately 65 kg and a finishing feed (14.5% Crude Protein) provided until slaughter. Water was supplied by a bowl-type drinker in each pen. The slurry produced by the pigs was stored in a pre-pit for the entire fattening period. Pigs from all rooms implicated in the study were sent to slaughter at the same time to facilitate the completion of the mass balance.

2.3. Measurements and recording

Measurements carried out in the Climatotec unit were identical to those carried out in the control room. Individual weighing of the animals was performed at the start of fattening, at each feed change, and on the day before slaughter. Feed distributed per pen was daily weighed and refusals were weighed at the time of feed change and at slaughter. Water consumption for each pen was recorded once a week. The slurry depth at various points in each pen was measured every 15 days, permitting the calculation of slurry production kinetics and volume produced per pig. A slurry sample was taken at each feed change and immediately after the animal departure for slaughterhouse. Slurry samples were taken from various points in the pen, pooled, and manually homogenized to create an average sample. Effluent analysis included pH, dry matter (DM), total nitrogen (Kjeldahl), ammoniacal nitrogen (NH_3-N), and total carbon (Ct). At the slaughterhouse, carcasses were weighed, lean meat content was measured by using Image Meater.

Regarding the environment, ventilation percentages were recorded using the ventilation control unit in each room of the Climatotec unit; recordings were made every 15 minutes throughout the pigs' presence. These percentages were then converted into ventilation rates in $m^3.h^{-1}$ using ventilation equations established per batch and per room at the pig entry; ventilation rates were measured in percentage increments to establish the relationship between percentage and ventilation rate based on the air speed in the extraction duct. Ambient temperatures were recorded every 15 minutes during the animals' presence using sensors (EasyLog MOTE-TH, Lascar, UK) positioned in the center of the room. Similarly, sensors (EasyLog Wifi-T, Lascar, UK) placed in watertight containers were installed on the slurry surface and at the bottom of the pre-pit, recording slurry temperature per room every 15 minutes.

Ammonia (NH_3), nitrous oxide (N_2O), and methane (CH_4) concentrations were measured in the ambient air using an infrared photoacoustic analyzer (Innova 1512, Lumasens Technologies A/S, Denmark) coupled with a 6-way sampler (Innova 1409, Lumasens Technologies A/S, Denmark). Measurements were taken in the ambient air every 3 minutes throughout the animals' presence. Gas emissions were then calculated by multiplying the average hourly concentrations (in mg/m^3) of each gas by the average hourly ventilation rate (in m^3/h) and expressed in kg of N or C per pig place per year.

For feed conversion ratio, slurry volume, water consumption, statistical analysis was limited to calculating mean and standard deviation due to an insufficient number of values per category.

3. Results and discussion

3.1. Ambiance

For the trial comparing T16 to T18, the average ambient temperatures were 16.5±1.1°C and 18.1±0.8°C respectively for T16 and T18. The cold temperature targets have thus been achieved.

For the trial comparing T22 to REF22, the average ambient temperatures were 23.2±1.9°C and 26.3±1.4°C respectively for T22 and REF22. The average temperature in room C22 was higher than the imposed set temperature of 22°C but remained significantly lower than the average temperature in room T22, with a difference of 3°C. During this period, the average outdoor temperature was 19.8 ± 6.8°C, making it more challenging to achieve the 22°C target in the Climatotec unit. With high outdoor temperatures, it becomes more difficult to lower the ambient temperature despite increasing the air exchange rate, which explains why the average temperature in room T22 was much higher than the set value of 22°C.

3.2. Pig performance

Pig performance calculated up to slaughter are presented in Table 1. The duration of pig's presence per batch varies between 81 to 85 days.

For the trial 1 – T16 vs T18 – no significant difference was observed in the weight of pigs during growing and finishing phases. Although the slaughter weight of pigs exposed to 16°C was lower than that of exposed to 18°C, the difference was not significant. During the growing phase, the ADG of pigs exposed to 16°C was lower than that of pigs exposed to 18°C with a significant difference. Nevertheless, for the whole fattening period, there was no significant difference. Concerning FCR, data were not statistically analysed due to insufficient data, but the difference between rooms was very small, around 0.1. For the lean meat content and the added value per carcass, no significant difference was observed between T16 and T18.

Table 1: Pig performance per trial

Trial	1			2		
Room	T16	T18	RSD	T22	REF22	RSD
Initial LW, kg	30.3±2.2^a	30.5±2.5^a	2.3	35.6±3.0^a	37.4±3.6^a	3.5
Final LW, kg	105.6±12.2^a	111.7±8.3^a	4.0	122.3±8.1^a	122.3±7.8^a	5.7
ADG growing p., g.d^{-1}	924±86^b	985±83^a	84	950±71^a	993±90^a	85
ADG finishing p., g.d^{-1}	990±149^a	1 020±142^a	141	1 069±112^a	981±135^b	130
Overall ADG, g.d^{-1}	956±142^a	1 002±94^a	117	1 001±77^a	987±84^a	82
FCR growing p. kg.kg^{-1}	2.35±0.05	2.18±0.02	-	2.35±0.02	2.38±0.4	-
FCR finishing p. kg.kg^{-1}	2.69±0.08	3.09±0.07	-	2.60±0.01	2.76±0.3	-
Overall FCR, kg.kg^{-1}	2.52±0.07	2.64±0.04	-	2.48±0.01	2.56±0.3	-
Lean meat content, %	60.7±2.1^a	60.7±2.0^a	2.1	60.5±1.9^a	60.8±1.9^a	1.9
Added value, €/kg	0.13±0.06^a	0.16±0.07^a	0.06	0.16±0.05^a	0.16±0.05^a	0.05

LW: Live weight; ADG: average daily gain; FCR: feed conversion ratio; TMP: muscle content rate; Growing P.: growing phase, corresponds to the period between the pig's entry and the time they reach approximatively 65kg. Finishing P.: finishing phase, corresponds to the period after the growing phase and until the departure to the slaughterhouse. (a,b) : values followed by a different letter are statistically different – $P<0.05$

For the trial 2 – T22 vs REF22 – no significant difference was observed in weight, ADG, FCR, lean meat content and added value per carcass.

According to Le Dividich *et al.*, (1987), cold temperatures do not have significant effect on the total fat mass of pig carcass but rather on its distribution, with an increase in the weight and thickness of back fat while the weight of the leaf fat decreases.

3.3. Gaseous emissions

Gaseous emissions are given in Table2.

Regarding ammonia, the pigs in room REF22 emitted 2.87 ± 0.36 kg N_NH_3/place/year during the fattening period. These emission values are consistent with those obtained under identical conditions at the experimental station in Romillé (Guingand and Courboulay, 2019) and with those reported in the literature (Philippe *et al*., 2011; Santonia *et al*., 2017), which suggest values between 2.5 and 3.0 kg per place per year. The pigs in rooms T16, T18, and T22 emitted 1.67 ± 0.30, 1.84 ± 0.40, and 2.04 ± 0.30 kg N_NH_3/place/year, respectively, during the fattening period, which corresponds to 42%, 36%, and 29% less than the pigs in room REF22. In our study, the lower the temperature, the greater the reduction in ammonia emissions. There is limited literature on the impact of cold temperatures on ammonia emissions. According to Ocepek and Andersen (2022), the ammonia concentration in the environment increases as soon as the ambient temperature exceeds 20°C. Tabase *et al.* (2018) studied the impact of three set-point temperature levels (21, 23, and 25°C) on ammonia emission from "simulated" pigs on fully slatted floors with under-slat air entry and over-floor extraction; a system diametrically opposed to our study setup and to the majority of French farms. In this study, ammonia emission is influenced by the temperature of the incoming air rather than the set-point temperature. In Pouliot *et al.* (2011), the three ventilation scenarios studied start at temperatures between 21 and 22°C at the beginning of fattening, reaching 20°C for the control scenario, 17.2°C for the intermediate scenario, and 14.4°C for the "cold" scenario. The lack of effect of the "cold" treatment on ammonia emissions is explained by the author as a compensation between the increase in airflow rate for the "cold" scenario, raising ammonia concentrations, and the increase in temperatures for the control scenario, raising ammonia emissions. In our study, airflow rates are equivalent between the rooms in the thermoregulated unit, with the reduction in ambient temperature ensured by cooling the incoming air (Guingand *et al.*, 2024).

Table 2: Gaseous emissions per ambient temperature

Room	T16	T18	T22	REF22	RSD
N_NH_3 emission, kg/place[1]/year	1.67±0.3^b	1.84±0.40^b	2.04±0.30^b	2.84±0.36^a	0.32
N_N_2O emission, kg/place/year	0.24±0.03^a	0.22±0.02^a	0.20±0.04^a	0.23±0.02^a	0.02
C_CH_4 emission, kg/place/year	1.66±0.15^c	1.60±0.14^c	2.50±0.23^b	3.42±0.16^a	0.14

[1] the calculation per place is based on 3 rotations per finishing pig place per year - (a,b) : values followed by a different letter are statistically different – $P<0.05$

Regarding nitrous oxide, pigs in room REF22 emitted 0.23 ± 0.02 kg N_N_2O/place/year during the fattening period. This value is consistent with those reported by various authors (Philippe *et al.*, 2015; IPCC, 2019), who cite values between 0.10 and 0.25 kg N_N_2O per place per year. The emissions measured in rooms T16, T18, and T22 are very close to those measured in room REF22, ranging from 0.20 to 0.24 kg N_N_2O per place per year. In our study, temperature does not seem to affect nitrous oxide emissions. In the literature, the effect of temperature on nitrous oxide production from slurry is only documented for high temperatures (>50°C), which could inhibit the bacteria involved in the nitrification-denitrification process (Kebreab *et al.*, 2006).

Regarding methane, room REF22 emitted 3.42 ± 0.16 kg/place/year during the fattening period. This emission level is consistent with previous publications (Philippe *et al*., 2011; IPCC, 2019), which report values between 2 and 4 kg per place per year. The emissions measured in rooms T16, T18, and T22 were respectively 51%, 53%, and 27% lower compared to REF22. In relation with our study, the "cold" scenario in Pouliot *et al.* (2011) led to a reduction in methane emissions, with a 42% decrease compared to the "hot" scenario, where the setpoint temperatures were very close to those in our room REF22. In both our study and Pouliot *et al.* (2011), the cold ambient temperature reduced the activity of methanogenic bacteria in the slurry, bacteria that are particularly sensitive to the temperature of their environment (Dabert *et al.*, 2015).

Reducing the temperature to levels below thermoneutrality (T16 and T18) limits the volatilization and degradation processes, resulting in lower ammonia and methane emissions compared to room REF22. Maintaining the temperature at 22°C in room t22 throughout the day prevents the increase of temperature observed in room REF22, particularly in the afternoon, which promotes ammonia volatilization and its evacuation from the room due to the increased ventilation level.

3.4. Water consumption

The average water consumption of pigs in room REF22 was 8.1 ± 2.6 l per pig per day (Table 3). This consumption level is consistent with the 7.0 ± 1.7 l per pig per day reported by Massabie *et al*. (2014) for fattening pigs. The water consumption of pigs in rooms T16, T18, and T22 was significantly lower than that of pigs in room REF22 ($P<0.05$). These results confirm those of Pouliot *et al*. (2011) obtained with the "cold" scenario (setpoint temperatures decreasing from 21.1 to 14.4°C), with average consumptions of 4.36 l per pig per day.

Table 3: Water consumption, volume and temperature of slurry in relation with ambient temperature

Room	T16	T18	T22	REF22
Water consumption, l/p/d	4.2±0.7[a]	4.8±1.2[a]	5.7±1.4[a]	8.1±2.6[b]
Slurry volume, l/p	396	406	491	540
Ambient temperature, °C	16.5±1.1	18.1±0.8	23.2±1.9	26.3±1.4
Slurry temperature – surface, °C	14.9±2.5	15.8±2.7	22.1±1.8	26.2±1.0
Slurry temperature – pit bottom, °C	14.4±2.4	15.1±2.5	21.1±1.5	23.6±1.1

Regarding the volume of effluents, the animals in REF22 produced 540 l of slurry during the fattening period, which is close to the value of 480 l per finishing pig proposed by Levasseur (2013). The pigs kept T16 and T18 produced 25% less slurry than those kept in REF22. This low effluent production is related to the lower water consumption of the animals reported previously.

The temperature of the slurry was measured at two heights: at the bottom of the pit and at the surface. For all rooms, the temperature difference between the two heights is very small. The slurry temperature at the pit bottom is always lower than the ambient temperature—measured at 1.8 m above the slatted floor in the center of the room—by 2.1°C for T16 and T22 and 3.0°C for T18. This difference is likely related to the configuration of the sensors, which are protected in a rigid plastic box, creating an insulating shield around the sensor. The lower insulation at the pit bottom also likely contributes to the reduction in slurry temperature.

4. Conclusions

In our study, the zootechnical performances (slaughter weight, ADG, FCR, lean meat content) of animals exposed to cold temperatures below thermoneutrality were not significantly affected. Regarding environmental performance, continuous exposure to cold temperatures during fattening leads to a reduction in ammonia and methane emissions, water consumption by animals, and the volume of slurry produced per pig. No effect was observed on nitrous oxide emissions.

This study was conducted in a thermoregulated unit where ambient temperatures stayed very close to the setpoint temperatures imposed. Transposing these findings to actual farming conditions will likely not achieve to the same levels of reduction at equivalent setpoint temperatures. Indeed, the differences between setpoint temperature and ambient temperature can vary considerably, particularly during warm periods. Further trials under conventional ventilation conditions, where temperatures fluctuate more than in our thermoregulated unit, will be needed to validate the effectiveness of this practice. Although the reduction in greenhouse gas emissions may be less pronounced than in this study, lowering the setpoint temperature to around 18°C could prove to be a beneficial practice for reducing the environmental impact of pig farming. However, it will require careful control of airflow to avoid high air speeds on the pigs, which could significantly compromise their health and zootechnical performance.

Acknowledgments

The authors would like to thank ADEME (APR Cortea – Temporalis – 1962C0014) and PNDAR for their financial support.

References

Bertin C., Ramonet Y., 2015. Etat des lieux des bâtiments d'élevage de porcs en Bretagne chez les naisseurs-engraisseurs en 2015. Journées Rech. Porcine, 48, 1-7.

Buscher W., Jungbluth T., Hartung E., 1997. Modeling emissions. In *Ammonia and odour control from animal production facilities*. Vinkeloord, The Netherlands, October 6-10, 15-22.

Dabert P., Beline F., Lendormi T., 2015. Projet Promethis. Optimisation de la méthanisation des lisiers porcins à basse température. Aspects microbiologiques. Rapport final. Irstea. 90 pp.

Degré A., Verhève D., Debouche C., 2001. Emissions gazeuses en élevage porcin et modes de réduction: revue bibliographique. Biotechnol. Agron. Soc. Environ. 5 ,3, 135-143.

Faure J., Lefaucheur L., Kouba M., Lebret B., 2012. Croissance du porc à une température d'élevage basse: effets sur les performances et la composition corporelle. Journées Rech. Porcine 44, 281-282.

Guingand N., Quiniou N., Courboulay V., 2010. Comparison of ammonia and greenhouse gas emission from fattening pigs kept either on partially slatted floor in cold conditions or on fully slatted floor in thermoneutral conditions. In *International Symposium on Air Quality and Manure Management for Agriculture*. 13-16 September. Dallas, Texas. ASABE Publication Number: 711P0510cd.

Guingand N., Courboulay V., 2019. Effet du fractionnement des apports d'eau dans la technique du lisier flottant pour réduire les émissions d'ammoniac et d'odeurs en engraissement. Journées Rech. Porcine, 51, 181-186.

Guingand N., Rousselière Y., Thomas J., Colin A., 2024. Conception d'un module thermorégulé pour l'étude de l'influence des températures sur les performances zootechniques et environnementales de porcs à l'engraissement. Journées Rech. Porcine 56, 419-420.

IPCC, 2019. Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Chapter 10. Emissions from livestock and manure management. 209 pp.

Kebreab E., Clark K., Wagner-Riddle C., France J., 2006. Methane and nitrous oxide emissions from Canadian animal agriculture: a review. Canadian J. Anim. Sci. 86,2, 135-158. doi: 10.4141/a05-010.

Le Dividich J., Noblet J., Bikawa T., 1987. Effect of environmental temperature and dietary energy concentration on the performance and carcass characteristics of growing-finishing swine fed to equal rate of gain. Livest. Prod. Sci. 17, 235-246.

Levasseur P., 2013. Production et capacités de stockage des lisiers de porc. TechPorc 10, 12-14.

Masssabie P., Roy H., Boulesstreau-Boulay A.H., Dubois A., 2014. La consommation d'eau en élevage de porcs – Des leviers pour réduire la consommation d'eau en élevage de porcs. Editions Ifip. 16 pp

Ocepek M., Andersen I.L., 2022. The effects of pen size and design, bedding, rooting material and ambient factors on pen and pig cleanliness and air quality in fattening pig houses. Animals, 12,12, 1580. https://doi.org/10.3390/ani12121580.

Philippe F.X., Cabaraux J.F., Nicks B., 2011. Ammonia emission from pig houses: influencing factors and mitigations techniques. Agriculture, Ecosystems and Environment 141, 245-260.

Philippe F.X., Laitat M., Wavreille J., Nicks B., Cabaraux J.F., 2015. Effects of high-fibre diet on ammonia and greenhouse gas emissions from gestating sows and fattening pigs. Atmos. Env. 109, 197-204.

Pouliot F., Dufour V., Belzile M., Feddes J., Lemay S., Morin M., Godbout S., 2011. Impacts de différentes stratégies de contrôle de la température ambiante en engraissement sur les performances zootechnique, les émissions gazeuses et la consommation d'énergie. Journées Rech. Porcine, 53, 193-197.

Quiniou N., Noblet J., Le Dividich J., Dubois S., Labroue F., 1997. Influence de l'abaissement de la température ambiante et du poids vif sur le comportement alimentaire des porcs en croissance élevés en groupe. Journées Rech. Porcine 29, 135-140.

Quiniou N., Renaudeau D., Collin A., Noblet J., 2000. Effets de l'exposition au chaud sur les caractéristiques de la prise alimentaire du porc à différents stades physiologiques. Inra Prod.Anim. 13,4,233-245.

Rinaldo D., Le Dividich J., 1991. Influence de la température ambiante sur les performances de croissance du porc. Inrae Productions Animales 4, 1, 57-65.

Roguet C., 2023. Evolution, diversité et typologie des exploitations porcines en France : enseignement du recensement agricole de 2020, comparaison aux recensements de 2010 et 2000. Journées Rech. Porcine, 55, 1-6.

Santonia G.G., Georgitzikis K., Scalet B.M., Montobbio P., Roudier S., Delgado L., 2017. Best Available Techique (BAT) Reference Document for the Intensive Rearing of Poultry or Pigs. EUR 28674 EN. doi: 10.2760/020485

Tabase R.K., Millet S., Brusselman E., Ampe B., Sonck B., Demeyer P.., 2018. Effect of ventilation settings on ammonia emission in an experimental pig house equipped with artificial pigs. Biosystems Engineering 176, 125-139 https://doi.org/10.1016/j.biosystemseng.2018.10.010.