RABBIT REARING AND AIR QUALITY: STATE-OF-THE-ART AND KEY UNKNOWNS

Calvet S., Cambra-López M., Adell E., Torres A.G., Estellés F.*

Institute of Animal Science and Technology, Universitat Politècnica de València, Camino de Vera 14, 46022, Valencia, Spain
*Corresponding author: feresbar@upv.es

ABSTRACT

Animal production is a potential source of atmospheric pollution in regards to ammonia, greenhouse gases, and airborne particulate matter. Ammonia can cause respiratory problems to human and animals and cause environmental eutrophication and acidification. Methane and nitrous oxide are greenhouse gases with high global warming potential. High concentrations of particulate matter (PM) can cause detrimental effects on health and welfare of humans and animals and can threaten the environment, as well. These pollutants have been quantified in most livestock production systems. However, information about these emissions from rabbit farming is scarce. For this reason, emission values cannot be extrapolated from other species, and therefore research in regards to the quantification of airborne pollutant concentration and emissions from rabbit houses is still necessary. The main objective of this work was to describe recent advances on the research line developed by the "Livestock and Environment" research group of the Institute of Animal Science and Technology of the Universitat Politècnica de Valencia (Spain), regarding the quantification of airborne pollutant concentration and emissions from rabbit houses: ammonia, greenhouse gases, and particulate matter. This paper will also address research gaps and future research directions in this area. Gas concentrations and emissions were monitored in three rabbit farms in Eastern Spain during four seasons, while particulate matter concentrations and emissions were monitored in two rabbit units during autumn. Fattening rabbits and does were studied in both cases. Concentrations of ammonia and carbon dioxide remained below the thresholds recommended for animal and human health, while nitrous oxide concentrations were found to be low. Regarding emissions, significant differences were obtained among different observation periods, both for does and fattening rabbits. Ammonia and nitrous oxide emission factors for rabbit production were found to be higher than those reported for other animal categories. Airborne PM concentrations in both rabbit farms were below occupational thresholds according to human health, and below maximum exposure recommendations for livestock. Particulate matter concentrations were significantly influenced by type of human farm activity performed in the building rather than by animal activity. Average PM emission rates (g/h) were slightly higher in fattening rabbits compared to reproducing does. Emission rates expressed per animal unit were lower compared to poultry, pigs or cattle. According to our current knowledge, future research should examine the relationship among air pollutants on the farm, environmental impacts, and farm productivity. The effect of increased concentrations of air pollutants, especially NH3 and PM, on rabbit health should be further analysed. To improve the quality of national air pollutant emission inventories, representative emission factors for different regions and management systems would be required.

Key words: Ammonia, methane, nitrous oxide, particulate matter, emissions.

INTRODUCTION

Animal production is a potential source of atmospheric pollution in regards to ammonia (NH_3), greenhouse gases (GHG), and airborne particulate matter (PM). Ammonia emissions from animal production arise from the inefficient use of nitrogen by animals. In the production of fattening rabbits, approximately 60% of the nitrogen intake is excreted in urine and faeces (Calvet *et al*., 2008), and a part of the excreted nitrogen is lost as ammonia. Ammonia can cause respiratory problems to humans and animals and cause environmental eutrophication and acidification (Arogo *et al*., 2003). Methane (CH_4) and nitrous oxide (N_2O) are GHG with high global warming potential, which is 21 and 310 times the greenhouse effect of carbon dioxide (CO_2), respectively (Solomon *et al*., 2007). Methane is produced by fermentation of organic matter, whereas N_2O is closely related to the agricultural nitrogen cycle, and is produced in the nitrification-denitrification process in the management of manure and after its application to agricultural soils. The CO_2 is released from animals due to their respiration process and the decomposition of manure. The PM in livestock facilities can originate from several sources such as manure, feed, feathers, skin, and bedding material (Cambra-López *et al*., 2011). High concentrations of PM can cause detrimental effects on health and welfare of humans and animals and can threaten the environment, as well (Cambra-López *et al*., 2010). These pollutants have been quantified in most livestock production systems. However, information about these emissions from rabbit farming is scarce (Estellés *et al.*, 2009; Calvet *et al.*, 2011; Adell *et al.*, 2012). In addition, the unique biology and(or) management of rabbit production (physiology of the animals, housing systems, and manure management) may influence the emission of atmospheric pollutants. For this reason, emission values cannot be extrapolated from other species, and therefore research in regards to the quantification of airborne pollutant concentration and emissions from rabbit houses is still necessary.

The main objective of this work was to describe recent advances of the research line developed by the "Livestock and Environment" research group of the Institute of Animal Science and Technology of the Universitat Politècnica de Valencia (Spain), regarding the quantification of airborne pollutant concentration and emissions from rabbit houses: NH_3, GHG and PM. This paper will also address research gaps and proposed future research directions in this important area.

MATERIALS AND METHODS

Ammonia and greenhouse gases

Gas concentrations and emissions were monitored on three rabbit farms in Eastern Spain. Ten observation periods were designed to cover the normal operations of the two main production phases (breeding and fattening rabbits), covering different seasons. Gas concentrations (NH_3, N_2O, and CO_2) were semi-continuously (2-h intervals) monitored with a photoacoustic multi-gas analyser (Innova-1412, Air Tech Instruments, Denmark), during 122 complete days in breeding houses and 65 days in fattening houses.

Gas emission rates (E, mg/h per animal) were obtained by determining ventilation rates (V, m3/h per animal) and gas concentrations in the building outlet and inlet air (C_{outlet} and C_{inlet}, mg/m3) following Equation 1. Ventilation rates were measured following the methodology described by Calvet *et al*. (2010).

$$E = \left(C_{outlet} - C_{inlet}\right) \times V \quad \text{Equation 1}$$

Particulate matter

Particulate matter concentrations and emissions were monitored on two rabbit farms in Eastern Spain during autumn: one rearing fattening rabbits and another rearing reproductive does. Both farms were mechanically ventilated and housed 2,100 fattening rabbits and 530 reproducing does in cages.

Concentrations of two PM size fractions: PM10 fraction (coarse PM) and the PM2.5 fraction (fine PM) were monitored. The PM10 and PM2.5 size fractions were simultaneously determined using a tapered element oscillating microbalance, TEOM (model 1405-D, Thermo Fisher Scientific, U.S.). The PM concentrations were recorded every minute for both fractions during 15 consecutive days per farm. At the same time as PM concentrations were measured indoors, the time and type of activity being performed by workers on each farm were recorded. This information was used to identify the main factors relating to farm activities that possibly influence PM generation. Activities included animal handling and supervision, mortality inspection, feed distribution, cleaning cages with pressurized water or burning hair, application of powdered disinfectant on the floor (calcium superphosphate), and floor sweeping on all farms, as well as the preparation of nests using cotton waste as bedding material, and powdered sulphur as disinfectant, but only for reproductive does. The emissions of PM were obtained by determining ventilation rates (m^3/h) and PM concentrations in the building outlet and inlet air as a gas emission.

The analysis of variance (Proc GLM) of the statistical program SAS (2001) was used to determine significant differences in emissions of NH3, N2O and CO2, between different types of animals (reproductive does and fattening rabbits), and also among observation periods. Regarding PM, differences between fattening rabbits and reproductive does for average daily PM concentrations (mg/m3) and emission rates (g/h) were determined with a 2-tailed t-test for 1 treatment with 2 levels (animal type) using the same software (SAS, 2001)

RESULTS AND DISCUSSION

Average gas concentrations recorded for all observation periods are summarized in Table 1. A clear seasonal trend was observed since gas concentrations inside the building were inversely related to ventilation rates (data not shown). Therefore, highest gas concentrations were found for winter measurements when low outside temperatures lead to a reduction of ventilation rates. Concentrations of NH_3 and CO_2 remained below the thresholds recommended for animal and human health (CIGR, 1992). Nitrous oxide concentrations were also found to be low.

Significant differences in gas emissions were obtained among different season periods, both for does and fattening rabbits. In addition, besides the seasonal trend, different housing systems used in this study may have affected emission values. Ammonia emission values obtained here are lower than those obtained by Hol *et al*. (2004). However, Michl and Hoy (1996) estimated a lower emission rate for fattening rabbits in Germany (1.9 mg/h per animal). Regarding CO_2 emissions, average emission values obtained in this study were slightly higher than those previously reported (Kiwull-Schöne *et al*., 2005; Estellés *et al*., 2010). Nevertheless, those studies were conducted in flux chambers, and CO_2 production by manure was therefore not considered.

Table 1: Gas concentrations and emissions (average ± SE) in rabbit houses (from Calvet *et al*., 2011).

	Farm	Observation period	Season	Gas concentrations (mg/m^3)			Gas emissions (mg/h per animal)		
				NH_3	CO_2	N_2O	NH_3	CO_2	N_2O
Reproductive does	1	1	Summer	2.50 ± 0.08	1316 ± 35	1.27 ± 0.08	55.0 ± 1.6	9956 ± 448	5.7 ± 1.0
	2	2	Winter	6.10 ± 0.08	2492 ± 37	0.76 ± 0.09	65.6 ± 1.7	16320 ± 474	0.0 ± 1.0
	2	3	Spring	4.71 ± 0.04	2258 ± 19	2.83 ± 0.04	56.8 ± 0.9	17820 ± 240	20.8 ± 0.5
	3	4	Autumn	1.05 ± 0.07	935 ± 31	0.86 ± 0.08	38.7 ± 1.4	10158 ± 403	8.1 ± 0.9
	3	5	Autumn	1.66 ± 0.07	918 ± 31	0.90 ± 0.08	63.6 ± 1.4	8333 ± 403	9.3 ± 0.9
	3	6	Autumn	0.78 ± 0.07	779 ± 31	0.70 ± 0.02	56.5 ± 1.4	4004 ± 403	0.0 ± 0.9
		Average					1253 ± 55	1.22 ± 0.02	10.3 ± 0.3
Fattening rabbits	1	7	Summer	1.33 ± 0.12	1253 ± 55	1.22 ± 0.02	10.6 ± 0.4	3880 ± 128	2.0 ± 0.2
	2	8	Winter	1.87 ± 0.21	1709 ± 91	0.97 ± 0.04	3.5 ± 0.7	1180 ± 210	0.0 ± 0.3
	2	9	Summer	3.80 ± 0.11	1825 ± 49	1.63 ± 0.02	8.9 ± 0.4	1893 ± 112	0.0 ± 0.1
	1	10	Autumn	4.71 ± 0.09	2487 ± 38	0.39 ± 0.02	12.1 ± 0.3	4354 ± 88	0.0 ± 0.1
		Average					2492 ± 37	0.76 ± 0.09	0.0 ± 0.5

The NH_3 and N_2O emission factors for rabbit production are higher than those reported for other animal categories (Table 2), except for N_2O emissions from fattening rabbits. Average concentrations of PM10 and PM2.5 in the air of fattening rabbit and reproducing doe farms are shown in Table 3.

Average PM10 concentrations were two-fold higher ($P<0.001$) for fattening rabbits compared to concentrations of reproducing does. Average PM2.5 concentrations were similar on both farms. Airborne

Table 2: Ammonia and nitrous oxide emissions corrected for animal weight in rabbit production, compared to previous studies for other species.

Animal type	Emission (g NH_3/LU per hour)	Reference	Emission (mg N_2O/LU per hour)	Reference
Cattle	2.1-3.0	Oldenburg (1989)	33	Chadwick *et al.* (1999)
Pigs	2.0-4.5		17	
Broilers	1.5-9.1		1083	
Cattle	0.26-1.79	Groot Koerkamp *et al.* (1998)	26	Amon *et al.* (2001)
Pigs	0.65-3.75		60	Osada *et al.* (1998)
Broilers	1.6-10.9		590	Wathes *et al.* (1997)
Rabbits, does	7.0	This study	1292	This study
Rabbits, fatteners	4.3		-	

Table 3: Average concentrations and emissions of PM10 and PM2.5 and standard errors for fattening rabbits and reproductive does. (from Adell *et al.*, 2012).

Animal type		PM10 (mg/m^3)	P-value	PM2,5 (mg/m^3)	P-value
Concentrations (mg/m^3)	Fattening rabbits	0.082±0.059^a	0.001	0.012±0.016	N.S.
	Reproducing does	0.048±0.058^b		0.012±0.035	
Emissions (mg/unit/day)	Fattening rabbits	5.987±6.144	0.008	0.201±1.258	N.S.
	Reproducing does	14.853±31.468		2.831±19.540	

[a,b] Averages within a column with different superscripts differ significantly ($P<0.05$).
N.S.= Not significant differences.

PM concentrations on both rabbit farms were below occupational thresholds according to human health (HSE, 2007) and below maximum exposure recommendations for livestock (CIGR, 1994). Measured PM concentrations were below reported values for other livestock housing as reviewed by Cambra-López *et al.* (2010). Few studies have investigated and quantified PM on rabbit farms, and to our knowledge PM10 and PM2.5 concentrations have not been reported before on rabbit farms. Nevertheless, our results are in the range of reported inhalable size fractions reported in other studies (Navarotto *et al.*, 1995; Kaliste *et al*., 2002; Ribikauskas *et al*., 2010). Particulate matter concentrations were significantly influenced by type of human farm activity performed in the building rather than by animal activity. Among all activities, sweeping was found to be the activity that generated the highest concentration of PM10. Average PM emission rates (g/h) were slightly higher for fattening rabbits compared to reproducting does. Average emission rates per animal place and day showed emission rates were more than two-fold higher in reproducing does, considering that animal numbers were higher for fattening rabbits (2,100 fattening rabbits) compared to reproductive does (530 does). Emission rates expressed per animal per unit were lower compared to poultry, pigs or cattle (Takai *et al*., 1998).

CONCLUSIONS - RESEARCH GAPS

This work has revealed the concentration and emission levels of pollutants in and from livestock buildings, under a specific management system. According to current knowledge, future research should examine the relationship among air pollutants on the farm, environmental impacts, and farm productivity. The effect of increased concentrations of air pollutants, especially NH_3 and PM, on rabbit health should be further studied. Research on the combined effect that environmental conditions, such as high temperature and relative humidity, together with high NH_3 concentrations might have on rabbit production, especially on reproductive traits, is encouraged as reported by Sahuquillo *et al*. (2004). How these adverse conditions affect animal development and productivity should also be investigated. More efforts should be directed to find an optimum equilibrium between costs of achieving better environmental conditions and the detrimental effects of an impaired indoor quality. To improve the quality of national air pollutant emission inventories, representative emission factors for different regions and management systems would be required, especially if it would be of major interest to determine how different management practices (e.g., ventilation rates, feeding strategies and manure management) affect the emission of pollutants. Moreover, the characterization and quantification of air pollutants on rabbit farms is a necessary preliminary step that can contribute to design adequate reduction measures to control atmospheric pollutants (gases and PM), not only inside rabbit houses but also emissions into the atmosphere.

REFERENCES

Adell E., Calvet S., Torres A.G., Cambra-López, M. 2012. Particulate matter concentrations and emissions in rabbit farms. *World Rabbit Sci., In Press.*

Amon B., Amon Th., Boxberger J., Alt Ch. 2001. Emissions of NH_3, N_2O and CH_4 from dairy cows housed in a farmyard manure tying stall (housing, manure storage, manure spreading). *Nutr. Cycl. Agroecosys., 60, 103-113.*

Arogo J., Westerman P.W., Heber A.J. 2003. A review of ammonia emissions from confined swine feeding operations. *Trans. ASAE, 46, 805-817.*

Calvet S., Cambra-Lopez M., Blanes-Vidal V., Estelles F., Torres A.G. 2010. Ventilation rates in mechanically-ventilated commercial poultry buildings in Southern Europe: Measurement system development and uncertainty analysis. *Biosyst. Eng. 106, 423-432.*

Calvet S., Cambra-Lopez M., Estelles F., Torres A.G. 2011. Characterisation of the indoor environment and gas emissions in rabbit farms. *World Rabbit Sci., 19, 49-61.*

Calvet S., Estellés F., Hermida B., Blumetto O., Torres A. 2008. Experimental balance to estimate efficiency in the use of nitrogen in rabbit breeding. *World Rabbit Sci., 16, 205-211.*

Cambra-López M., Aarnink A.J.A., Zhao Y., Calvet S., Torres A.G. 2010. Airborne particulate matter from livestock production systems: A review of an air pollution problem. *Environ. Pollut., 58, 1-17.*

Cambra-López M., Hermosilla T., Lai H.T.L., Aarnink A.J.A., Ogink N.W.M. 2011. Particulate Matter Emitted From Poultry and Pig Houses: Source Identification and Quantification. *Trans. ASABE, 54, 629-642.*

Chadwick D.R., Sneath R.W., Phillips V.R., Pain B.F. 1999. A UK inventory of nitrous oxide emissions from farmed livestock. *Atmos. Environ., 33, 3345-3354.*

CIGR. 1992. Climatization of animal houses. Second Report of the Working Group on Climatization of Animal Houses, Centre for Climatization of Animal Houses., pp. 1-147. Ghent, Belgium.

CIGR. 1994. Aerial environment in animal housing. Concentrations in and emissions from farm buildings. Working Group Report Series No 94.1 , pp. 83-112. Cemargref, Groupement de Rennes, France.

Estellés F., Calvet S., Blumetto O., Rodríguez-Latorre A.R., Torres A.G. 2009. Technical Note: A flux chamber for measuring gas emissions from rabbits. *World Rabbit Sci., 17, 169-179.*

Estellés F., Rodríguez-Latorre A.R., Calvet S., Villagrá A., Torres A.G. 2010. Daily carbon dioxide emission and activity of rabbits during the fattening period. *Biosysts Eng., 106, 338-343.*

Groot Koerkamp, P.W.G.G., Metz J.H.M., Uenk G.H., Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P., Hartung J., Seedorf J., Schroder M., Linkert K.H., Pedersen S., Takai H., Johnsen J.O., Wathes C.M. 1998. Concentrations and emissions of ammonia in livestock buildings in Northern Europe. *J. Agr. Eng.Res., 70, 79-95.*

HSE. 2007. List of approved workplace exposure limits. *Health & Safety Executive, United Kingdom. http://www.hse.gov.uk.*

Kaliste E., Linnainmaa M., Meklin T., Nevalainen A. 2002. Airborne contaminants in conventional laboratory rabbit rooms. *Lab. Anim., 36, 43-50.*

Kiwull-Schöne H., Kalhoff H., Manz F., Kiwull P. 2005. Food mineral composition and acid-base balance in rabbits. *Eur. J. Nutr., 44, 499-508.*

Navarotto P., Crimella C., Luzi F., Guarino M., Heinzl E., Dragoni I., Papa A., Massola A. 1995. Air-quality in the environment of intensively reared fattening rabbits. *Farm Build. Progr. 117, 28-32.*

Oldenburg J. 1989. Geruchs- und Ammoniak Emissionen aus der Tierhaltung. *KTBL Schrift-333.*

Osada T., Rom H. B., Dahl P. 1998. Continuous measurement of nitrous oxide and methane emission in pig units by infrared photoacoustic detection. *Trans. ASAE 41, 1109-1114.*

Ribikauskas V., Ribikauskiene D., Skurdeniene I. 2010. Effect of housing system (wire cage versus group-housing) and in-house air quality parameters on the behaviour of fattening rabbits. *World Rabbit Sci., 18, 243-250.*

Sahuquillo J., Villagrá A., Blanes V., Torres C., Torres A.G. 2004. Effects of ammonia concentration on reproductive performance in rabbits. *In Proc. AgEng 2004, 2004, Leuven, Belgium, 698-699.*

SAS, 2001. SAS/STAT User's Guide. *SAS Inst. Inc*., Cary, NC, USA.

Takai H., Pedersen S., Johnsen J.O., Metz J.H.M., Koerkamp P.W.G.G., Uenk G.H., Phillips V.R., Holden M.R., Sneath R.W., Short J.L., White R.P., Hartung J., Seedorf J., Schroder M., Linkert K.H., Wathes C.M. 1998. Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *J. Agr. Eng. Res., 70, 59-77.*

Wathes C.M., Holden M.R., Sneath R.W., White R.P., Phillips V.R. 1997. Concentrations and emission rates of aerial ammonia, nitrous oxide, methane, carbon dioxide, dust and endotoxin in UK broiler and layer houses. *Brit. Poultry Sci., 38, 14-28.*