Estimation of nitrogen volatilisation in the bedded-pack of dairy cow barns

Alberto Stanislao Atzori, Roberta Boe, Patrizia Carta, Antonio Fenu, Gesumino Spanu, Ana Helena Dias Francesconi, Antonello Cannas

Dipartimento di Scienze Zootecniche, Università di Sassari, Italy

Corresponding author: Alberto Stanislao Atzori. Dipartimento di Scienze Zootecniche, Facoltà di Agraria, Università degli Studi di Sassari. Via E. De Nicola 9, 07100 Sassari, Italy – Tel. **+39 079 229305 – Fax: +39** 079229302 – Email: asatzori@uniss.it

ABSTRACT - The objective of the study was to measure N volatilisation (NVOL) from bedded-pack dairy cow barns. Feed intake, milk production, bedding material used and meteorological variables were monitored in 3 dairy farms near the town of Arborea (39°46'26" N, 08°34'53" E, 7 m a.s.l.) during one month for each season from summer 2007 to spring 2008. NVOL was measured in the interval between excretion and removal of bedded-packs from barn floors. NVOL was measured using the N (nitrogen) to P (phosphorus) ratio marker method, considering P as an internal non-volatile marker in milk and manure. Nitrogen and P excretion was estimated by nutrient balance as intake minus N and P excreted in milk. NVOL coefficient and bad-pack temperature were almost constant among seasons. The annual mean NVOL in bedded-pack barns was equal to 38.8% of excreted N. Accounting also for the NVOL that occurred in the concrete floor of the feeding and walking areas of the barns, NVOL was 40.7% of N excreted.

Key words: Bed-pack, Nitrogen volatilisation, Dairy cow.

Introduction - According to the EU Nitrate Directive (91/676/EEC), the quantification of N volatilisation (NVOL) from excreted manure is very important to calculate the N from an animal source available for crop fertilisation and to establish sustainable animal stocking rates. NVOL coefficient can be greatly variable, because chemical and biological transformations of N in dairy cow farms are influenced by animal N metabolism, manure management and climate (Bussink and Oenema, 1998). Thus, specific measurements in the producing areas are needed to identify the most important factors of variability, to quantify local NVOL and to correctly apply environmental laws. Few studies have been conducted to quantify the NVOL from dairy cow wastes in Mediterranean areas. Previous experiments conducted by our group in Arborea (Sardinia, Italy) measured, in the interval from the excretion to the end of short term-storage, a mean annual NVOL of 42.5% of N excreted in dairy cow cubicle barns (Atzori *et al.*, 2008). The objective of this work was to complete that research by measuring the NVOL from manure in dairy cow bedded-pack barns.

Materials and methods – The area of study was near the town of Arborea (39°46'26" N, 08°34'53" E, 7 m a.s.l.) on the West coast of Sardinia (Italy). The study was carried out in 3 farms between summer 2007 and spring 2008. All farms raised Holstein Friesian cows and used wheat straw as bedding material in the resting area of bedded-pack barns. One series of measurements per season per farm was carried out. Starting after a complete barn cleaning, the bed pack was sampled about once a week during 4 weeks. In the same period total mixed ration intake and milk production were recorded daily. Bed-pack was sampled collecting a column of accumulated bedding from 10 points of the resting area. Bed-pack temperature and thickness were measured in each point. Total cumulative samples were weighed to measure density, then mixed, sub-sampled and immediately frozen at -20°C until N analyses were performed. Each single feed used in the ration, the wheat straw used for bedding and bed-pack samples were analysed for N content (Kpomblekou-A, 2006), P (colorimetric ascorbic acid method after muffle incineration; adapted from APHA, 1998) and dry matter (DM) at 65°C. Daily meteorological information was collected from a nearby meteorological station. Losses of N were estimated on

Table 1. Animal performances and bed-pack characteristics in the studied dairy cow farms.

Variable	Units	Farm 1	Farm 2	Farm 3	Mean	SEM
Sampled intervals	n	15	15	15	-	-
Cows	n	58	58	99	72	3
CP of the diet	% of dm	14.9	15.9	15.0	15.3	0.086
P of the diet	% of dm	0.31	0.43	0.36	0.37	0.010
Diet intake	kg of dm	23.7	23.3	23.8	23.6	0.160
Milk yield	litres/d	30.4	30.3	28.4	29.7	0.279
Milk protein	%	3.41	3.31	3.26	3.33	0.011
Milk urea	mg/dl	23.6	22.6	21.0	22.4	0.350
N milk/N intake	% n intake	28.9	26.3	25.4	26.9	0.305
N excreted	g/d	400	436	423	420	0.004
N:P excreted	ratio	6.85	6.37	6.06	6.43	0.178
N:P expected	ratio	6.77	6.37	6.04	6.39	0.173
Bed pack N	% of dm	2.20	2.24	2.18	2.20	0.045
N:P in bed pack	ratio	4.24	3.45	3.87	3.85	0.092

Table 2. Seasonal and annual means of temperatures, bed pack characteristics and N volatilisation (NVOL) in the bedded-pack studied farms.

Samplings		Air temperature	Bed-pack temperature	Bed-pack density	Bed-pack DM	Bed-pack N	NVOL
Season	n	°C	°C	kg/m^3	%	%DM	% of N excreted
Summer	12	24.4	26.4 ^{A}	268.0 ^{B}	35.8 ^{A}	2.06	44.1 ^{a}
Autumn	9	17.2	26.2 ^{AB}	462.7 ^{A}	27.1 ^{B}	2.15	35.9 ^{b}
Winter	12	9.3	23.1 ^{C}	502.6 ^{A}	24.8 ^{B}	2.22	37.9 ^{ab}
Spring	12	17.7	24.4 ^{ABC}	537.3 ^{A}	23.9 ^{B}	2.38	37.2 ^{ab}
Annual mean	4	17.2	25.0	442.7	27.9	2.20	38.8
SEM		3.1	0.8	60.2	2.7	0.07	1.8

^{A,B,C}P<0.01; ^{a,b}P=0.05.

the basis of the measured N to P ratio (N:P) of the bedding and the estimated N:P of fresh excreta, as reported by Moreira and Satter (2005). Animal excretions were calculated as the difference of N and P intake minus N and P excreted in milk, considering the actual milk protein content and a concentration of P equal to 0.09% (NRC, 2001). The excreted N:P ratio was adjusted by adding the quantity of N and P derived from bedding materials to determine the expected N:P ($N:P_{expected}$) in the bed-pack if volatilisation had not occurred. NVOL was indirectly calculated for each period, from cleaning to sampling, as follows, with the assumption that wheat straw N is not volatile:

$$NVOL=1-(N:P_{bed\text{-}pack}/N:P_{expected})\times 100$$

The effects of animal and environmental variables on NVOL were studied by calculating simple Pearson correlation coefficients and analyzing the data with ANOVA in which season and barn were considered as fixed factors.

Results and conclusions – The final database included 45 measurements. One autumnal record per farm was excluded because NVOL resulted negative, probably for sampling errors. DM intake and dietary CP concentration were very similar among farms (Table 1).

In particular, CP concentration was rather low. Milk production was equal to 29.7 litres/d per head (Table 1). Farm 3 had a lower N utilization efficiency (NUE; N milk/N intake) compared to the other farms, probably due to its lower milk production. Annual N excretion was 420 g/d per cow, which corresponds to 141 kg of N/year per cow (after correcting for the dry period excretions as suggested by Smith and Frost, 2000). N and P excretion was comparable to previously reported values (Van Horn *et al.*, 1994). The measured N:P ratio (Table 1) was within the range found by Moreira and Satter (2005). The annual mean amount of wheat straw used by the 3 farms was 3.8±0.5 kg/d per cow. The annual mean of measured NVOL was 38.8% of N excreted

Table 3. Pearson correlation coefficients (P value in parenthesis) between N volatilisation (NVOL), air mean temperature and bed-pack characteristics.

Variables	NVOL	Mean air temperature	Bed-pack temperature	Bed-pack density	Bed-pack DM
Mean air temp.	0.19 *(0.210)*				
Bed-pack temp.	0.32 *(0.031)*	0.44 *(0.003)*			
Bed-pack density	-0.19 *(0.225)*	-0.50 *(<0.001)*	-0.13 *(0.413)*		
Bed-pack DM	0.39 *(0.008)*	0.57 *(<0.001)*	0.34 *(0.022)*	-0.48 *(<0.001)*	
Bed-pack N	-0.33 *(0.029)*	- 0.17 *(0.268)*	-0.37 *(0.013)*	0.36 *(0.016)*	-0.57 *(<0.001)*

(Table 2). In contrast to what found in the same area for cubicles barns (Atzori *et al.*, 2008), mean air temperature was not associated with NVOL. Seasonal means of NVOL had limited variations during the year. Volatilisation was associated mainly to bed-pack temperature, DM and N content (Tables 2 and 3). However, seasonal influences on the bed-pack can be highlighted by the correlation between air temperature and bed-pack DM, density and temperature (Table 3). These variables can also affect the microbial population which directly influence manure characteristics and NVOL (Yamulki, 2006). NVOL was not affected by week of sampling within sampling cycle. The mean annual NVOL coefficient of 38.8% of N excreted obtained in this experiment was measured in the area covered with the bed-pack. However, to take into account the concrete floor in the feeding and walking areas of the barns, a NVOL of 42.5% of N excreted was considered (Atzori *et al.*, 2008) for those areas. Cows' N excretion was considered proportional to the time spent by them in each area (Van Horn *et al.*, 1994), assuming that the cows spent the same daily time in the bedded-pack and concrete floor areas (12 hours of resting and rumination and 12 hours of feeding and walking, as suggested by Grant and Albright, 2001). Thus, the annual NVOL in lactating dairy cow bedded-pack barns of Arborea was equal to 40.7% of N excreted, which is a higher value than the 28% NVOL suggested by Italian regulations.

The research was supported by a grant of the Sardinian Regional Government (Assessorato alla Difesa dell'Ambiente, Regione Autonoma della Sardegna, Italy).

REFERENCES - APHA, 1998. American Public Health Association, Standard Methods for the Examination of Water and Wastewater, 20th ed. American Public Health Association, Washington, DC, USA. **Atzori**, A.S., Spanu, G., Fenu**, A., Cannas A., 2008. Meteorological variables can be used to predict N volatilization** from dairy cow manure during housing and short term storage. EAAP Annual Meeting Vilnius, Lithuania, 32. **Bussink,** D.W., Oenema, O., 1998. Ammonia volatilization from dairy farming systems in temperate areas. Nutr. Cycling Agroecosyst. 51:19-33. **Grant,** R. J., Albright, J.L., 2001. Effect of animal grouping on feeding behavior and intake of dairy cattle. J. Dairy Sci. 84:156-163. **Kpomblekou-A,** K., 2006. Relative proportion of inorganic and total nitrogen in broiler litter as determined by various methods. J. Sci. Food. Agric. 86:2354-2362. **Moreira,** V.R., Satter, L.D., 2005. Estimating nitrogen loss from dairy farms. Contributed Papers of the 3rd International Nitrogen Conference, Nanjing, China, Science Press, pp. 56-60. **NRC**, 2001. Nutrient requirements of dairy cattle. 7th revised edition. National Academy of Science, Washington, D.C, USA. **Smith,** K.A., Frost, J.P., 2000. Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 1: cattle and sheep. Bioresource Technol. 71:173-181. **Van Horn,** H., Wilkie, A.C., Powers, W.J., Nordsted, R.A., 1994. Components of dairy manure management systems. J. Dairy Sci. 77: 2008-2030. **Yamulki**, S., 2006. Effect of straw addition on nitrous oxide and methane emissions from stored farmyard manures. **Agric. Ecosyst. Environ. 112:140-145.**