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Comparison of the mass balance method with the N to P ratio marker method to estimate nitrogen volatilisation in dairy cow barns

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INTRODUCTION

Considering the phosphorus (P) in the manure as an internal non volatile marker, changes in the N to P ratio (N:P) from feed to manure can be used to estimate N gaseous emission, as suggested by Moreira and Satter (2006-JDS v.89). Validation of the N:P method in warm climates and for conventional manure storage times could allow its use for the determination of N volatilisation losses (**Nvol)** at local level, by utilising the chemical analyses and productive information routinely collected by farmers and policy agencies.

Thus, the aims of this work were i) to study the **Nvol**, from the moment of excretion to the end of manure short-term storage in buried-uncovered tanks located at the end of the feeding area, in dairy cow farms in Mediterranean climatic conditions and ii) to compare the estimates of the N:P method (N:P) with those of the well-established mass balance method (MB).

MATERIALS AND METHODS

Nvol were measured in cubicles free-stall barns of 4 farms, on the West-Coast of Sardinia, Italy (city of Arborea: lat. 39°46'26" N; long. 08°34'53" E; alt. 7 m a.s.l.), for one year between 2006 and 2007.

Nvol within each tank filling cycle was indirectly calculated as:

MB method

$$\text{Nvol} = \frac{(\text{kg of } N_{excreted} - [N_{manure}] \times \text{kg of manure in tank}) \times 100}{\text{kg of } N_{excreted}}$$

$N_{excreted}$ = N in feed– N in milk
N and P in manure = chemical analysis

N:P method

$$\text{Nvol} = = 1 - ([N{:}P_{manure}] / N{:}P_{expected}) \times 100$$

N and P in manure = chemical analysis
$N{:}P_{expected} = N_{excreted}$ adjusted for N added with bedding materials

Animal performances, manure treatments and meteorological variables were recorded and related with observed values of **Nvol**. All calculated and recorded data refer to the mean of each storage period.

Estimates of the two methods used to quantify **Nvol** were compared by:

- calculating simple Pearson correlation coefficients, and
- using the statistics of the Model Evaluation System (MES 3.0.10; Tedeschi, 2006-Agric. Syst. 89), assuming that the MB method was the reference method and the N:P method was the method to be evaluated.

RESULTS

Even if the 4 barns differed in herd size, facility type, nutrition management and milk production levels, the N and P excretions were in accordance with those reported in literature (Table 1).

Table 1. Nitrogen and phosphorus balance, animal performances, manure characteristics and Nvol of the 4 barns studied.

Variable	Farm 1	2	3	4	SEM
Cows, number	117.1^{A}	53.9^{B}	123.7^{A}	92.5^{C}	3.87
DMI, kg/d per cow	21.7^{B}	22.3^{B}	21.2^{B}	24.7^{A}	0.28
Dietary N, % of DM	2.56^{B}	2.39^{C}	2.60^{B}	2.72^{A}	0.02
Dietary P, % of DM	0.42^{A}	0.36^{C}	0.39^{B}	0.42^{A}	0.004
Milk yield, kg/d per cow	29.5^{B}	27.6^{BC}	31.3^{B}	35.8^{A}	0.56
Milk N, %	0.52^{A}	0.52^{A}	0.51^{B}	0.51^{B}	0.01
N excretion, g/d per cow	403^{B}	390^{B}	392^{B}	493^{A}	7.90
N_{milk}/N_{intake} x100 (EUN)	27.7	26.8	28.7	26.9	0.32
P excretion, g/d per cow	65.9^{A}	54.1^{B}	54.3^{B}	70.5^{A}	1.36
$N{:}P_{excreted}$	6.1^{B}	7.2^{A}	7.2^{A}	7.0^{A}	0.09
$N{:}P_{expected}$	6.0^{B}	7.13^{A}	7.17^{A}	6.21^{B}	0.09
Storage length, days	18.7^{A}	37.5^{B}	19.9^{A}	8.0^{C}	1.73
Storage length index*	0.12^{A}	0.68^{B}	0.13^{A}	0.13^{A}	0.04
Manure DM, %	8.50^{a}	9.00^{a}	7.31^{bc}	8.54^{ac}	0.20
Manure N, % of DM	3.38	3.15	3.29	3.13	0.05
Manure P, % of DM	0.98^{a}	0.85^{b}	0.85^{b}	0.92^{ab}	0.02
Manure N:P, ratio	3.45	3.84	3.97	3.47	0.10
N losses, MB method %	43.0	45.7	41.7	44.0	1.59
N losses, N:P method %	42.6	47.7	43.8	43.9	1.52

a,b ($P < 0.05$); A,B,C ($P < 0.01$). *calculated as: (days of storage/m² of tank × number of cows)/100.

The **Nvol** coefficient was positively correlated to air temperature and THI, whereas it was negatively correlated to relative humidity, EUN, and manure N content. In general, the correlations were higher when the MB method, rather than the N:P method, was used, suggesting that the former was more reliable (Table 2).

Table 2. Correlation coefficients between Nvol and weather, animal and manure variables.

Variables	Mass Balance	*P*<	N:P ratio	*P*<
Mean air temperature*, °C	0.76	0.01	0.67	0.01
Relative humidity*, %	- 0.76	0.01	- 0.69	0.01
Temperature humidity index (THI)*	0.76	0.01	0.67	0.01
Rainfall, mm/m² tank**	- 0.30	0.04	- 0.29	0.04
N excretion*, g/d per cow	0.15	0.37	0.10	0.49
N in milk/N intake (EUN), %	- 0.68	0.01	- 0.61	0.01
Manure N, % of DM	- 0.61	0.01	- 0.66	0.01

*mean of the storage periods. ** sum of storage periods.

The amount of **Nvol** was significantly affected by seasons but not by farms. **Nvol** values calculated with the two methods were not significantly different (mean of the 4 farms: 43.3% vs. 44.5%, for the MB and the N:P methods, respectively; $P > 0.1$). The N:P method slightly overestimated N losses at low N volatilisation levels and underestimated it at high volatilisation levels (Figure 1).

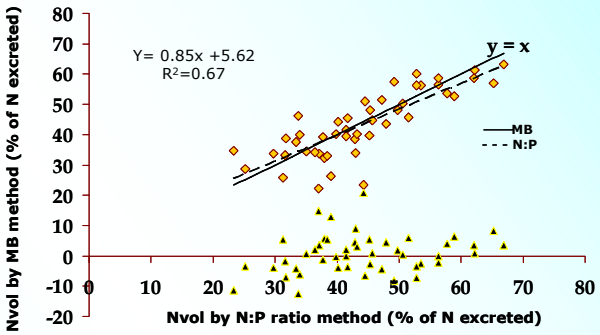

Figure 1. Comparison between N losses estimates with the N:P ratio method and the mass balance (MB) method. Triangles represent deviations in the estimates between the N:P and MB method. The continuous line represents the equivalence line.

Nvol was estimated with a mean bias equal to 0.79% of N excreted, and a root of the mean square error of prediction (RMSEP) equal to 6.42% of N excreted. Overall, the N:P method was highly accurate (Cb = 0.99) and sufficiently precise (r^2 =0.67), with high overall concordance correlation coefficient (r_c = 0.81).

CONCLUSIONS

- The two methods tested gave similar estimates of **Nvol**, even though the MB method was consistently more closely associated with meteorological variables.
- The N:P method is less laborious and can be considered sufficiently precise and accurate for applied measurements.

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