Dairy cow manure separation a pre-treatment to reduce manure application pollution risks: a whole-farm perspective

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Abstract

Cantabria Region (Spain) has an important dairy farm sector. Dairy cow manure is managed as a slurry, *i.e.*, a mixture of manure and varying quantities of water or other liquid. To apply slurries in agricultural fields without knowing their nutrient composition could produce environmental and agronomic problems. In order to achieve the goal to make better use of dairy cow manure as fertilizer and to reduce pollution risks, convenient and sustainable treatments are at present ready to be used. One of the most diffused, even at farm scale, is a pre-treatment by separation. For that reason, a liquid-solid separation treatment (screw press) has been studied on a 190-Friesian cows intensive commercial dairy farm. Analytical results show that a pre-treatment by separation is able to reduce significantly DM content and TN and TP concentrations. The technique used to separate slurry into a nutrient-rich fraction (solid fraction) and a liquid fraction has been a screw press. Overall, the obtained results show that a pre-treatment of dairy cow manure by separation is reliable at reducing N pollution risk deriving from manure application.

Keywords: dairy cow, manure, solid-liquid separation, screw press, DM, TN, TP

Introduction

Specialization into livestock production has led to a concentration of animal production on large farms in restricted areas, a pattern found throughout Europe (Møller et al., 2000). Animals in houses with slatted floors are producing large amounts of manure which contain a mixture of faeces, urine, waste feed and water, and manure characteristics are greatly affected by diet, species and growth stage of the animals and the amount of water added to the manure collection systems (Zhang and Westerman, 1997). Separation of slurry can be an effective technique for production of a liquid and a nutrient-rich solid fraction.

Livestock production areas may produce a surplus of plants nutrients relatives to crop requirements, thereby increasing the risk of nutrient losses to the environment: soil, water and atmosphere (Sommer and Thomsen, 1993). Due to the low concentration of plant nutrients it is expensive to transport the surplus plant nutrients from livestock farms to arable farms that have a nutrient deficit. However, transport cost can be reduced by separating the manure into a nutrient-rich solid fraction and a liquid fraction (Møller et al., 2000).

There are several techniques for separating slurry into a DM and nutrient rich fraction and a liquid fraction; for instance, mechanical screen separators, sedimentation, centrifugation, biological treatments and reverse osmosis (Burton, 1997). The separation efficiency of these mechanical separators may vary widely, due to differences in the efficiency of the separators and because the separation efficiency is affected by the variable physical-chemical composition of the animal manure (Westerman and Bicudo, 2000).

At present study, a 190-Friesian cows intensive commercial dairy farm has been monitored during a year to evaluate manure separation process vantages. Fresh slurry, solid fraction and liquid fraction have been withdrawn once per month during a year to determine samples composition and separation effects on DM content and TN and TP concentrations.

Materials and methods

The experiment was conducted at an intensive commercial dairy farm (190 dairy cows, which 110 in lactation) in Cantabria Region (Spain) during a year: until December 2006 to November 2007. Farm uses manure separation by a screw press (CRI-MAN CM 260) with a screen sizes of 0.5 mm. Representative samples were taken during separation from fresh manure (after a stirred process) and the solid and the liquid fractions once per month (n = 12). The samples of slurry, solid and liquid fractions were stored at -18ºC until laboratory analysis.

Analytical procedures

pH and EC were determined potentiometrically in the raw samples (pH meter Crison Basic 20 and conductimeter Crison GLP 31, respectively). DM was determined after drying at 105ºC for 24 hours, while ash was determined burning samples at 550ºC during 4 hours. Total nitrogen (TN) was analyzed by means of the Kjeldahl method while ammonium nitrogen (NH_4^+-N) in the slurry was analyzed by distillation (Tecator Foss Kjeltec 2300). Organic nitrogen (N org) was calculated as the difference of TN and NH_4^+-N, while carbon-nitrogen relationship (C:N) was calculated as: C:N = ((OM x DM)/1.72)/TN; where OM = 100 – ash. Total phosphorus (TP) was analyzed colorimetrically (FIAstar 5000 Analyzer) after dry ashing and solubilisation in acid and a coloring reaction with ammonium molybdate vanadate.

Statistical procedures

A simple statistical descriptive analysis was carried out to find the mean, maximum, minimum and standard deviation (sd) values of determinate parameters with SPSS 11 (2002) software. Results were analyzed statistically using an analysis of variance, where fresh slurry, liquid fraction and solid fraction were the variables.

Calculations: reduced efficiency index (E_t')

The traditional definition of separation efficiency is the total mass recovery of solids or nutrient in the solid fraction as a proportion of the total input of solids or nutrients (Svarovsky, 1985): $E_t = (U \times M_c)/(Q \times S_c)$; where E_t is the simple separation efficiency; U (kg) the quantity of the solid fraction; M_c (g kg^{-1}) the concentration of the component (DM, TN, TP) in the solid fraction; Q (kg) the amount of slurry treated and S_c (g kg^{-1}) is the concentration of the component in the slurry.

The simple separation efficiency gives no indication as to whether nutrients or DM have been transferred to the solid fraction. It is shown that the simple index is fairly reliable when calculating DM separation, but not when calculating TN or TP separation (Møller et al., 2000). For this reason, it is useful to consider the separation effect by including the increase in concentration of nutrients in the solid fraction (Møller et al., 2000). The most widely used of these is the reduced efficiency index: $E_t' = (E_t - R_f)/(1 - R_f)$; where R_f is the solid fraction to total slurry ratio and E_t is the simple separation efficiency. This equation satisfies the basic requirement for an efficiency definition in that it becomes 0 when no separation takes place ($E_t - R_f$) and 1 when separation is complete (Svarovsky, 1985).

Results and discussion

Composition of slurry and the two separation fractions

Table 1 shows the manure physical-chemical characteristics, while the chemical characteristics of the solid and liquid fractions after separation in the screw press are given in Table 2. The animal manure used in this study had composition typical of dairy cow manure sampled in Spain (Martinez-Suller, 2006; Salcedo, 2006).

Table 1. Dairy cow manure chemical composition before separation

		pH	EC	DM	ash	TN	TAN	N org	C:N	TP
			mS cm^{-1}	*g l^{-1}*	*g l^{-1}*	*g l^{-1}*	*g l^{-1}*	*g l^{-1}*	*%*	*g l^{-1}*
Fresh slurry	*n*	12	12	12	12	12	12	12	12	12
	mean	6.91	16.13	71.77	27.69	3.06	1.37	1.92	9.73	0.60
	sd	0.25	3.57	28.85	6.20	1.09	0.38	0.89	1.49	0.29
	min	6.66	8.35	15.60	19.21	0.60	0.70	0.75	6.32	0.12
	max	7.38	19.95	120.60	41.26	5.21	2.25	3.88	12.21	1.00

The DM content of the solid fractions was 2.62 times higher than the DM content of the manure, according with Møller et al. (2002) and showing that the mechanical screw press separator transfers DM from the liquid to the solid fraction. The concentrations of TN and TP in the DM-rich fraction were 1.41 and 2.25 times higher than the concentration in the slurry, respectively. Techniques for separating physical fractions of the slurry will merely transfer the organic N to the solid fraction, but the dissolved ammonium-N will not be transferred to the solid fraction using a screw press separator (Møller et al., 2000).

Table 2. Solid and liquid fractions composition after separation of the manure

		pH	EC *mS cm^{-1}*	ash *g l^{-1}*	DM *g l^{-1}*	TN *g l^{-1}*	TP *g l^{-1}*
Liquid Fraction	*n*	12	12	12	12	12	12
	mean	7.59	17.71	42.93	24.95	2.12	0.18
	sd	0.17	2.85	8.85	7.27	0.39	0.12
	min	7.33	11.67	32.42	15.10	1.23	0.02
	max	7.85	20.50	64.04	41.10	2.61	0.38
Solid fraction	*n*	*12*	*12*	*12*	*12*	*12*	*12*
	mean	7.83	1.50	24.29	187.7	4.32	1.35
	sd	0.28	0.93	10.91	74.66	1.64	0.54
	min	7.62	0.58	13.41	90.00	3.73	0.23
	max	8.15	2.44	35.23	312.0	6.90	2.20
	sem	0.06	0.86	3.00	11.34	0.25	0.08
	Sig	ns	***	**	***	***	***

em: standard error of the mean

Separation efficiency

Table 3 shows reduced separation efficiency index (%) for DM, TN and TP. The average index were 18, 3 and 14%, respectively for DM, TN and TP. These values are in the range showed by Møller et al. (2000): 16-33, 1-2 and 8-23%, respectively for DM, TN and TP index. Fig 1 compares the simple separation efficiency index with the reduced separation index.

Conclusion

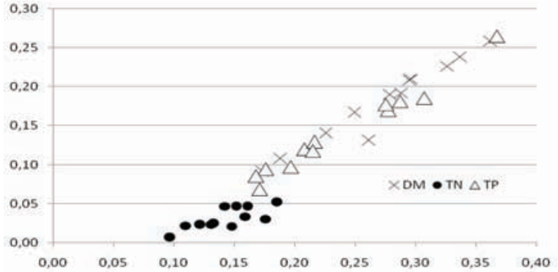
Simple mechanical screen separator can separate DM and TP content into the solid fraction on dairy cow manure, while TN separation efficiency is slightly lower.

Table 3. DM, TN and TP reduced separation efficiencies

	U/Q	Reduced separation efficiency (%)		
	%	*DM*	*TN*	*TP*
n	12	12	12	12
mean	11.50	0.18	0.03	0.14
sd	0.02	0.05	0.01	0.06
min	0.09	0.09	0.01	0.07
max	0.15	0.26	0.05	0.26

U/Q: solid fraction to total manure ratio (%)

Fig 1. Simple separation efficiency index (E_t) and reduced separation efficiency (E_t') relationship



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