MANAGEMENT STRATEGIES TO REDUCE NITROGEN LOSSES FROM SOLID CATTLE MANURE

Shah G. M*., Shah G. A., Lantinga E. A.
Biological Farming Systems Group, Department of Plant Sciences, Wageningen University and Research Centre, Droevendaalsesteeg 1, building 107, 6708 PB Wageningen, the Netherlands
Phone: + 31 (0)317481192 Fax: +31 (0) 317481203 E-mail*: ghulamM.shah@wur.nl

1 INTRODUCTION

Application of livestock manure to land is important for plant nutrition but may cause agro-environmental problems if utilization is inefficient due to poor management. In the Netherlands, cattle are the main source (~ 60%) of livestock manure. Most of this manure is collected as slurry in cubicle barns, but the proportion of solid manure is increasing due to growing interest of farmers in switching back to straw-based housing systems for the reasons of animal health and welfare. After excretion in barns, cattle solid manure is either directly applied to the field or stored for an extended period of time prior to land spreading due to restricted periods of application. It is well known that up to 50% of the initial N_{total} can be lost during storage of solid cattle manure (Eghball et al., 1997). On the other hand, Huijsmans and Mosquera (2007) concluded that in the Netherlands NH_3 emission after spreading of solid cattle manure to land can be up to 100% of the total ammoniacal N content. Contribution of these N losses from solid manure to the environment has become a major social and political concern in the Netherlands. The aim of this study was to develop and evaluate some effective measures in reducing N losses from solid manure management in order to provide some practical guidelines to minimize N losses.

2 MATERIALS AND METHODS

2.1 Mass and nutrient losses during storage

Fresh beef solid cattle manure was collected from the sloping floor barn of the organic experimental and training farm Droevendaal at Wageningen, the Netherlands, where straw was used as bedding material at a daily rate of 4-5 kg per livestock unit (500 kg live weight). After chopping once with mechanical manure spreader, 12.5 Mg of fresh manure (not older than 1 week) for each treatment was put on a clean concrete floor in order to make conical heaps of about 1.5 meter (m) height with base diameter of 4 m. Manure was stored under three different conditions including (i) stockpiled heap, (ii) composted heap with infrequent turning and (iii) sheeted heap under impermeable plastic cover. The first two heaps were made in a roofed building to prevent leaching losses during rainfall. Temperature of the heaps was monitored regularly throughout the storage period using hand held probe. Air temperature and rainfall data were collected from the weather station located at < 1 kilometre from the study site. The experiment was conducted for 130 days from mid January till the end of the May 2009.

During heap establishment and at the end of the storage period, three manure composite samples (2 kg fresh weight) from each heap were collected to estimate changes in mass and nutrient concentrations for the different storage treatments. Subsamples were analysed for dry matter (DM), organic matter (OM), total-C, total-N, ammonium-N (NH_4-N), nitrate-N (NO_3-N), raw ash and pH. After storage, DM mass losses were estimated by assuming no loss of raw ash from the heaps during the storage period. Total C and N losses during storage were estimated by comparing their contents relative to the raw ash fraction before and after storage.

2.2 Ammonia emission after manure spreading

Relative effect of irrigation in reducing NH_3 emission from manure was estimated in early September (2009) using passive flux samplers (Kirchner et al., 1999). For this, fresh (directly from the barn) and composted (from the above storage experiment) solid cattle manures were manually spread at an application rate of 400 kg N ha^{-1} on cut grassland in circular plots with diameter of 3 m. Immediately after manure spreading, 5 mm of irrigation was applied to half of the manured plots. One control plot (without manure) out of two was also irrigated. Five passive flux samplers were installed vertically 20 cm above the soil surface in the middle of each plot. After 4 days of exposure, quantities of NH_3-N (µg) entrapped in the samplers were measured in laboratory and subsequently concentrations of NH_3 (µg/m^3) in the air were calculated according to the protocol proposed by Hofschreuder and

Heeres (2002). Data were statistically analyzed using ANOVA in SPSS. Significant differences between the treatments were distinguished by the LSD test at 5% probability level.

3 RESULTS AND DISCUSSION

3.1 Mass and nutrient losses during storage

Visual observations revealed that all the heaps had decreased in size noticeably after the storage period due to moisture and DM losses. About 55% and 48% of the initial DM was lost from composted and stockpiled heaps, respectively. In contrast, only 14% of DM was lost from the covered heap (Table 1). The higher DM losses were associated with aerobic decomposition enhanced by diffusion of air into the heaps through (i) straw (in stockpiled heap) and (ii) straw as well as turning (composted heap). Our results are in line with Larney et al. (2006) who reported DM mass losses of 58% from composted and 47% from stockpiled beef cattle manure from feed lots.

TABLE 1 **Chemical composition of solid cattle manure before and after storage.**

	DM (%)	Raw ash	Total-C	Total-N	NH_4-N	Organic-N	DM_{loss} (%)	C/N	pH($CaCl_2$)
		g/kg of DM							
Before Storage									
	18.7	176	409	28.8	6.4 (22)	22.4		13	7.4
After storage									
(i) Stockpiled	20.8	340	316	38.2	1.0 (3)	37.5	48	8	7.7
(ii) Composted	21.5	390	304	34.3	5.1 (15)	29.3	55	8	8.1
(iii) Covered	18	205	397	30.1	9.5 (32)	20.6	14	12	7

* Values in the parenthesis represent percentage ammoniacal fraction of the total-N.

After storage, approximately 16% of the initial C_{total} from covered, 60% from the stockpiled and 67% from the composted manure were lost during the storage period (Fig. 1). This could be attributed to greater decomposition of C during stockpiling and composting as reflected in their temperature dynamics. Temperature of the stockpiled and composted heaps increased up to 50-60 °C after establishment, declined thereafter and stabilized at the end of the storage period. In covered heaps, highest temperature (25 °C) was observed immediately after establishment. Afterwards, it declined gradually to ambient level. The lower temperature in the covered heap could be attributed to the anaerobic fermentation of organic material where less energy is released than during aerobic degradation, which restricts microbial activity and thus the decomposition of OM (Hansen et al., 2006). Therefore, loss of C during storage is reduced by covering the heap with impermeable plastic sheet.

N losses were significantly ($P<0.05$) affected by the handling techniques and were lowest from the covered heap (~10 %). On the other hand, 35% and 46% of the total-N was lost from stockpiled and composted heaps, respectively (Fig. 1). At the end of the storage period, NH_4-N concentration was lower in composted and especially in stockpiled compared to sheet covered manure, probably due to immobilization as well as combination of higher NH_3 and denitrification losses during storage. Therefore, the percentage ammoniacal-N calculated as $\{(NH_4\text{-N} + NO_3\text{-N})/\text{total-N} *100\}$, was significantly higher for the covered heap as compared to both stockpiled and composted heaps where proportion of organic-N was relatively higher (Table 1). Covering the manure heaps blocks air circulation, inhibits OM degradation, and lowers internal heat production as well as the pH, which ultimately reduces the NH_3 emission. Further, the formation of nitrate/nitrite is prevented through anaerobic conditions and thus also the possibility of denitrification losses (Kirchmann, 1985). C/N ratio was decreased in stockpiled and composted manure and could be attributed to higher C losses compared to N as depicted in Fig. 1.

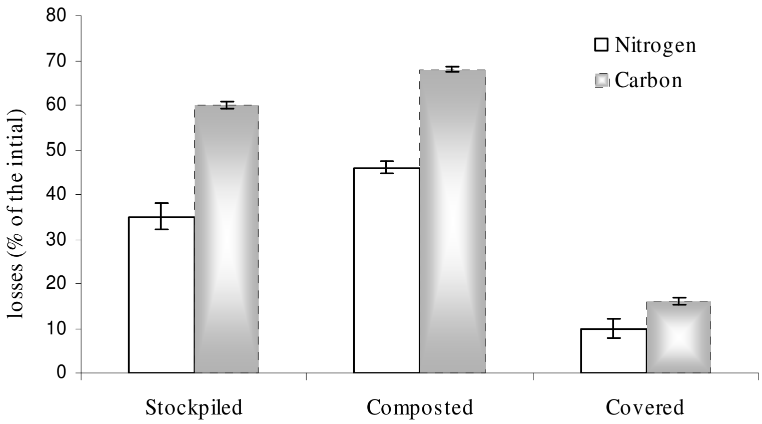

FIGURE1 **C and N losses from solid cattle manure subjected to different storage conditions.**

3.2 Ammonia emission after manure spreading

Land spreading of the manures significantly ($P<0.05$) increased the NH_3 concentration of the air compared to the control plots. Without irrigation, NH_3 emission levels from fresh and composted solid cattle manure were not significantly different (Fig. 2). This could be linked with application of almost equal amounts of inorganic-N in both manure types as calculated from their analysis reports (38 g and 42 g in fresh and composted manure, respectively).

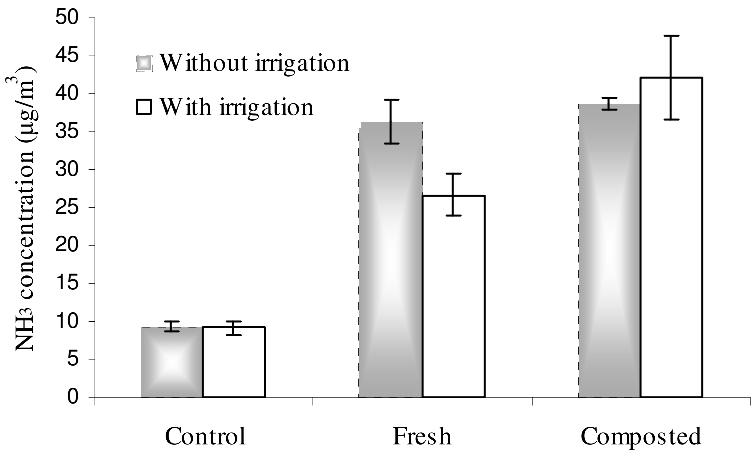

FIGURE2 **Ammonia concentration of the air following land spreading of solid cattle manures.**

In case of fresh manure, 5 mm irrigation immediately after land spreading significantly reduced NH_3 emission by 30% compared to unirrigated manured plot (Fig. 2). The irrigation water dissolves the manure ammoniacal N and enhances its infiltration (i) into the inner side of the manure clumps where it might be safeguarded from exposure to external high temperature and wind, and (ii) into the soil where it can be protected against volatilization by adsorption onto the soil colloids. Nevertheless, this level of irrigation did not reduce NH_3 emission from composted solid cattle manure, in all probability due to its higher DM content (21.5%) compared to fresh solid cattle manure (18.7 %).

4 CONCLUSIONS

C and N losses during solid cattle manure storage can be reduced remarkably by covering the heaps with impermeable plastic sheet. In addition, covering the manure during storage increased ammoniacal-N content that may subsequently improve manure-N utilization after field application. Five millimetres of irrigation/rainfall immediately after fresh manure spreading significantly reduced NH_3 emission. However, to develop effective integrated strategies during storage and after application, investigation of NH_3 emission and promising abatement techniques (i.e. irrigation) following spreading is also needed in case of sheet covered manure. The field trials were started in spring 2010 for these detailed enquiries.

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