Biotransformation and losses of organic matter during co-composting of dairy sludge with cattle manure on the Reunion Island

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Abstract
The dairy sludge elimination is still not optimized in Reunion Island as it is currently dumped in landfills. The aim of this study is to investigate the co-composting of dairy sludge with cattle manure. Three heaps were formed using cattle manure mixed with dairy sludge in the following proportions: M – 1 + 0, S1 –2/3 + 1/3 and S2 - 1/2 + 1/2. The heaps were turned after 21 days. Total composting time was 142 days. During the experimentation, temperature remained high and above 55°C during 46 days for the pure manure pile M, 32 days for S1 pile and 36 days for S2 pile. During composting, M has lost 69% of its fresh mass and 64% of its initial volume while 71% and 44% respectively for S1 and 68% and 49%, respectively for S2. Heaps have lost from 44% to 49% of the initial organic matter and the windrows formed with sludge lost more nitrogen than the pure manure one (M – 52%, S1 – 69% and S2 – 66% of its initial nitrogen).

Introduction
Aerobic composting of organic by-products is a well established method for stabilising and sterilising materials before returning them to agricultural land. Composting is a useful technique to facilitate the management of livestock manure, which is one of the major problems in regions of intensive livestock production (1). Composting cattle manure has been shown to have a number of agronomic benefits, including a reduction in material mass and water content (2), pathogen suppression, weed seed kill and the production of a stabilised organic material that is easier to spread (3) (4). High temperatures (typically 40-70°C) reached during the thermophilic composting phase reduce and eliminate pathogens in the heap (5), (6). Composts are rich in organic matter (OM) and minerals and have a good ability for soil amendment and fertilization. However, the transformation of OM leads to nutrient loss and atmospheric pollution by gases (7). The aim of this study is to investigate the co-composting of dairy sludge with cattle manure because cattle manure and dairy sludge have contrasting C:N ratios and a very different consistence which can lead to particular biotransformations. Experimentation has been conducted to determine the losses and sanitizing character during the composting, and homogeneity of the compost obtained after dairy sludge addition.

Material and Methods
Composting heaps and treatments
The experiment was conducted at SICA-LAIT farm in Reunion Island (France) between October 2011 and Mars 2012. Three heaps were formed using cattle manure mixed with dairy sludge in the following proportions (on wet weight basis): the first heap (M) was only constituted by cattle manure (M – 1 + 0), the second heap (S1) was constituted by 2/3 of cattle manure and 1/3 of dairy sludge (S1 –2/3 + 1/3) and the third heap (S2) was constituted by 1/2 of cattle manure and 1/2 of dairy sludge (S2 - 1/2 + 1/2). Characteristics of the three heaps and of the applied treatments are indicated in Table 1.
The cattle manure (sugar cane trash litter, removed twice a week) was taken from the heifer farm and the dairy sludge from the wastewater treatment plant in the milk factory CILAM. Heaps were turned after 21 days. Total composting time was 142 days.

Measurements
The heaps were weighed, measured (volume) and sampled at day 0, before and after turning, and when the compost was finally removed from the platform. The heap mass was measured by an axle weights DINO ARGEO WWSD (±5kg). The heap height was measured over the compost surface, respect to a 0.5x0.5 m^2 grid, by a Laser meter DIMETIX DLS-B 30 (±1.5mm). Volume was then calculated by the interpolation of heights. Compost temperatures were measured by five iron-constantan thermocouples in each pile: three at the heap center (50 cm in depth in the heap), one at the bottom (10 cm above the

floor), and one near the top (10 cm below the top). Measurements were made each five min, averaged every 60 min, and stored on one Campbell CR10X datalogger.

Compost sampling and analytical methods

During turning, fronts were opened on each heap in the medium part: two in the heap M and S1, and only one in the heap S2. Before the end of composting, one front was opened for each heap. The number of samples taken in each open front depended on the section of the windrow. Five composite samples were taken from each front. Pending chemical analyses, samples were stored at -18°C and mixed for homogenizing and particle size reduction (<5 mm).

Dry matter was determined by oven drying at 60°C until constant weight was reached. Organic matter (OM) content was quantified by calculating weight loss of oven-dried samples on ignition in a muffle furnace at 550°C. Ash was deduced from organic matter analysis. The dried material was analyzed to assess the total C content (Dumas oxidation method). The fresh material was analyzed for total N by the Kjeldahl method and for ammoniac N by distillation. The phosphorus content was determined after dry mineralization at 550 °C with a colorimetric assay method, potassium by emission spectrometer and calcium, magnesium and trace elements were determined by atomic absorption spectrometer. Principal characteristics of the initial windrows are presented in Table 1.

Results and discussion

Temperature

Temperature and exposure time are usually the most important and easily verified factors in determining pathogen eradication during composting (9).Temperature in the center of heap M and S1 was risen to 72 and 70°C respectively, just after 1 day of the pile dressing; it was only 63°C after 12 days for the S2 heap (Fig. 1). Following the turning, the maximum temperature reached for the S1 and S2 heap was similar (62°C and 64°C) but the temperature of M heap reached to 74°C after 10 days. Thermophilic phase (>55°C) characterizes the sanitizing process during composting (10) (11). Several authors suggested that temperature is the main parameter in the sanitation if sustained for an appropriate period of time. Their experience showed that seed germination was reduced to 0-0,2% after they were exposed for 14 days to a peak compost temperature of 58°C and a mean temperature of 43°C; complete sanitization is obtained after 30 days when temperature is superior to 55°C (12), (13). In this experimentation, temperature remained high and above 55°C during 46 days for the pure manure pile M, 32 days for S1 pile and 36 days for S2 pile.

Mass balance and losses of nutrients

Composting helped reduce the volume and the mass of heaps. Mass losses in the three heaps were similar. The total loss of N, C, P and DM shown in Table 2 was calculated by the concentration of components and the amount of matter and compost initially and at the end of composting (after 142 days). This loss is mainly composed of water and carbon. Heaps have lost from 44% to 49% of the initial OM. Loss in the DM content was between 43 and 49% which is similar to the findings of several authors (14), (15), (16). It was almost higher for S2, with less water loss. Carbon loss presented the same pattern with more loss for S2. Added dairy sludge had more than doubled the content of N and P in the heap. In the contrary, adding dairy sludge lessened the content of K by dilution in the total mass. We found that the heaps S1 and S2 have lost more than 40% of the initial N content while M lost only 15%. That results in more N pollution by ammonia volatilization (7). Mineral and nutrient contents increased during composting: N content increased from 15 to 24 $g.kg^{-1}$ DM for M, and was stable for S1 and S2: 33 to 34, and 38 to 38 $g.kg^{-1}$ DM, respectively. Loss of P was less than 8% of initial content and that of K less than 11%, which could certify the mass balance accuracy and the quality of sample and analytical methods. Because of the low P losses, phosphorus content increased from 3,1 to 5,4 $g.kg^{-1}$ DM for M, 6.5 to 10.6 $g.kg^{-1}$ DM for S1 and 6.2 to 12.1$g.kg^{-1}$ DM for S2 after the composting (17), (15). Potassium content increased from 18,4 to 30,5 $g.kg^{-1}$ DM for M, 15,8 to 30,1 $g.kg^{-1}$ DM for S1, 14,9 to 27,4 $g.kg^{-1}$ DM for S2.

Conclusion and perspectives

As a conclusion, the dairy sludge management by composting contributes to the improvement of compost nutrient content. Composting process limited the waste environment impact by reducing the quantity of the dairy sludge landfilled and by eliminating the pathogen agent through elevated temperature in the heaps. However, the important loss of nitrogen as ammonia must be considered as an atmospheric pollution risk and a global loss of nutrient. Produced composts were sanitized and presented high nutrient levels. With the elaboration of Near Infrared Reflectance Spectroscopy models, we are currently working on the assessment of the heaps heterogeneity in terms of DM, C, N and fiber contents. This data should be of great help (i) for modeling the greenhouse gases emissions during composting (18), and (ii) for reverse modeling in the TAO model (19) (Transformation of Added Organics) to choose the optimum composting duration that ensures the best agronomic potential of the compost to be reached.

Table 1- Principal physical and chemical characteristics of the composted mixtures

Heap	M	S1	S2
Wet weight (kg)	9500	8200	8800
Cattle manure (% ww)	100	66	52
Dairy sludge (% ww)	0	34	48
Volume, (m^3)	31.1	14.4	14.0
Density (kg DM . m^{-3})	97	126	131
Density (kg WM . m^{-3})	305	566	630
Free air space, %	73	48	42
Dry matter, (%)	31..8	22.2	20.7
Organic matter (% DM)	85..7	85.3	86.6
Nitrogen content ($g.kg^{-1}$ DM)	15.2	32.8	38.5
N-NH_4 ($g.kg^{-1}$ DM)	2..4	5.6	5.1
Carbon content ($g.kg^{-1}$DM)	430	443	450
C/N	28	14	12
P ($g.kg^{-1}$ DM)	3.1	6.5	6.2

ww, wet weight; DM, dry matter

Free air space is calculating considering a DM density of 1600 kg m^{-3}

Table 2- Mass and volume losses in the composting heaps

Heap	M	S1	S2	M	S1	S2
		$kg.ton^{-1}$			% initial mass	
Mass	685	709	679			
Dry matter	147	97	102	46.1	43.4	49.2
Water	538	612	577	79.0	78.7	72.8
Carbon	69	49	51	50.4	49.7	54.2
Nitrogen	0.7	3.0	4.0	15.4	41.6	49.6
Phosphorus	0.05	0.1	0.0	5.0	7.9	0.6
		m^3 ton^{-1}			% initial volume	
Volume	2.1	1.1	1.1	63.6	60.9	66.2

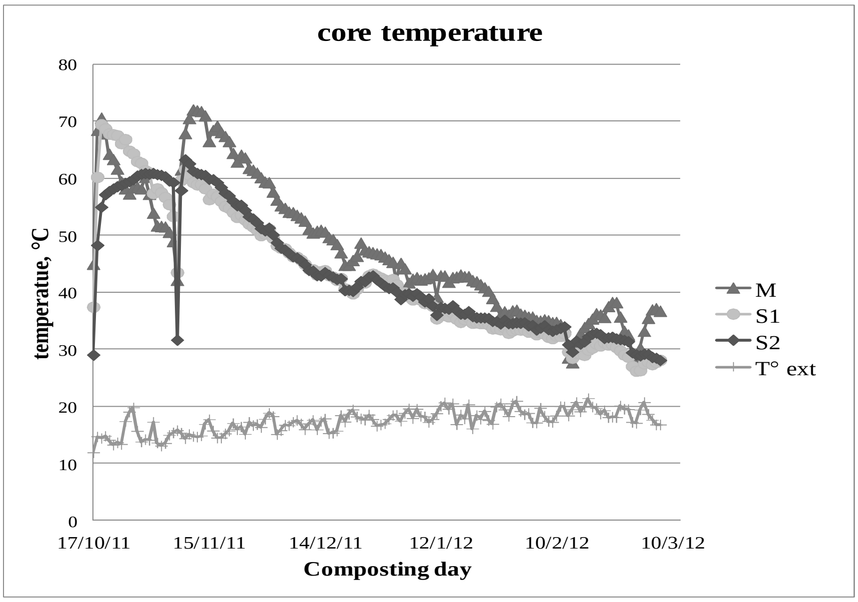

Figure 1. Temperature dynamics in the centre of the heaps during composting

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References

[1]. Mustin M, 1987. Le compost : gestion de la matière organique. François Dubusc (Ed.), p. 954 Paris, France
[2]. Andersen JK, Boldrin A, Christensen TH, Scheutz C, 2011. Mass balances and life cycle inventory of home composting of organic waste. Waste Management 31, 1934–1942
[3]. Eghball B, Gilley JE, 1999. Phosphorus and nitrogen in runoff following beef cattle manure or -compost application. Journal of Environmental Quality 28, 1201–1210
[4]. Eghball B, Lessing GW, 2000. Viability of weed seeds following manure windrow composting. Compost Science and Utilization 8, 46–53
[5]. Burge WD, Colacicco D and Cramer WN, 1981. Criteria for achieving pathogen destruction during composting. J Water Pollut Control Fed 53, 1683-1690
[6]. Yuen GY, Raabe RD, 1984. Effects of small scale aerobic composting on survival of some fungal plant pathogens. Plant Dis 68, 134-136
[7]. Paillat J-M, Robin P, Hassouna M, Leterme P, 2005. Predicting ammonia and carbon dioxide emissions from carbon & nitrogen biodegradability during animal waste composting. Atmospheric environment 39, 6833-6842
[8]. Dulphy JP, Demarquilly C, 1981. Problèmes particuliers aux ensilages. In: Prévision de la valeur nutritive des aliments des ruminants, INRA publications (Ed.), 81–104,Versailles, France
[9]. 9- Noble R, Roberts SJ, 2004. Eradication of plat pathogens and nematodes during green waste composting: a review. Plant Pathology 53, 548-568
[10]. Margesin R, Cimadom J, Schinner F, 2006. Biological activity during composting of sewage sludge at low temperatures. International Biodeterioration & Biodegradation 57, 88–92
[11]. Ligocka A, Paluszak Z, 2009. Effectiveness of different sanitization technologies on the inactivation of ascaris suum eggs in organic waste. Bulletin of the veterinary institute in Pulawy 53, 641-644
[12]. Robinson JJ, Stentiford EI, 1993. Improving the aerated static pile composting by the incorporation off moisture control. Compost Science and Utilization 1, 52-68
[13]. Fang M, Wong JWC, Li GX, Wong MH, 1998. Change in biological parameters during co-composting of sewage sludge and coal ash residues. Bioressource technology 64, 55-61
[14]. Sommer S G, Dahl P, 1999. Nutrient and carbon balance during the composting of deep litter. J. agric. Engng Res. 74, 145-153
[15]. Sommer SG, 2001. Effect of composting on nutrient loss and nitrogen availability of cattle deep litter. European Journal of Agronomy 14, 123–133
[16]. Abd-El-Kader N, Robin P, Paillat J-M, Leterme P, 2007. Turning, compacting and the addition of water as factors. Bioresource Technology 98, 2619–2628
[17]. Petersen SO, Lind A-M, Sommer SG, 1998. Nitrogen and organic matter losses during storage of cattle and pig manure, Journal of Agricultural Science Cambridge, 130 69-79.
[18]. Oudart D, Paul E, Robin P, Paillat JM, 2010 .Modeling organic matter stabilization during windrow composting of livestock effluents. Environmental technology 33, 2235-2243
[19]. Pansu M, Thuriès L, 2003. Kinetics of C and N mineralization, N immobilization and N volatilization of organic inputs in soil. Soil Biology and Biochemistry 35, 37-48