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Improving the product stability and fertilizer value of cattle slurry solid fraction through co-composting or co-ensiling

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ABSTRACT

Separating dairy cattle slurry in a liquid and solid fraction (SF) is gaining more interest, since it enables a more targeted use of both fractions. However, the valorization of the SF is limited on P-rich soils, due to its high P content, and the export or use as bedding material requires sanitation. Therefore, we investigated the influence of composting or ensiling the SF, whether or not mixed with bulking agents, on the product quality in terms of fertilizer value, sanitation and stability. Ensiling can be considered as a controlled storage method for conserving C and nutrients. Soil amendment with co-ensiled SF resulted in a higher N mineralization and crop growth compared to amendment of co-composted SF. Co-composting SF with structure-rich feedstock materials optimized the composting process and sanitation when compared with composting pure SF and did not increase the risk for extreme-heat-resistant spores of thermophilic aerobic spore-forming bacteria (X-TAS). Further, the composts contained more P per unit of fresh weight than the silages, beneficial for the export of the composted SF. The oxygen uptake rate was found to be less powerful to determine the stability of fresh, composted and ensiled SF.

1. Introduction

Inappropriate application of cattle slurry can cause severe environmental problems (e.g. input of harmful trace metals, inorganic salts and pathogens, nutrient leaching and emissions of toxic gases), especially in regions where the amount of cattle manure exceeds the loading capacity of soils available for manure application (Gomez-Brandon et al., 2008; Hutchison et al., 2005). Separating liquid and solid fractions of cattle slurry is gaining more interest, since it enables a more targeted use of both fractions: the liquid fraction is less rich in P compared to the solid fraction (SF) (Ford and Fleming, 2002), hence rebalancing the N/P ratio enables applications of this liquid phase which better suit crop requirements. According to Schröder et al. (2009) N/P ratio equals 7.6, 8.0 and 5.9 for slurry, liquid fraction and SF, respectively. Furthermore, due to the increased N/P ratio of the liquid fraction, higher doses could be applied per hectare. The direct use of the SF as a fertilizer is then limited, particularly given the restrictions in P fertilizer application in soils (e.g. Manure Decree in Flanders, Anonymous, 2015) due to the EU Nitrates and Water Framework Directive. On the other hand, the use of SF (directly or after treatment) can be a cheap and valuable means to maintain soil organic carbon levels (Vanden Nest et al., 2016). The latter is a major challenge since the soil organic carbon content of many croplands in temperate regions is declining. Besides the potential use as soil improver, the SF could be exported and used as a crop fertilizer abroad or could be used as bedding material in stables. In both cases sanitation is a key requirement. The implementation in Flanders of the EU regulation (EC 1069/2009 of the European Parliament and of the Council of 21 October 2009) requires heating the material at least 1 h above 70 °C as well as a bacteriological analysis before export. Use of SF as bedding material is currently not allowed in Flanders. In contrast, in the Netherlands, where the EU regulation is interpreted differently, use of SF as bedding material is allowed on the farm where the cattle slurry is produced. Dutch dairy companies discourage the use of compost and composted organic materials as bedding material, since the transfer of spores of thermophilic aerobic spore-forming bacteria with an

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exceptionally high heat resistance (X-TAS) from these types of bedding to raw milk is assumed to pose a risk for the quality of the milk and milk products, in particular for the shelf-life of sterilized milk products (Driehuis et al., 2014).

Processing the SF before use may alleviate this problem. Two promising ways of treating SF are (1) composting and (2) ensiling, both of which are studied in this paper. Controlled composting of solid manure has several advantages, such as the potential destruction of weed seeds and pathogens, homogenization and reduction in mass and moisture content which makes the manure easier to store, transport and spread, and manure stabilization which prevents negative impacts on plant growth (Bernal et al., 2009). A potential disadvantage is the high risk for N losses during composting (Eghball et al., 1997), not only posing an environmental problem but also reducing the amount of available N for plant growth, i.e. the nutrient use efficiency of the SF. Composting animal manure with a high moisture content and limited free air space is problematic (Viaene et al., 2016a). Brito et al. (2008) reported that the efficiency of the composting process and OM stability were improved by increasing the DM content of SF. Thereto, C-rich bulking agents can be added in order to compost cattle (Aguerre et al., 2012; Michel et al., 2004) or pig (Nolan et al., 2011) slurry, and SF after separating digestate (Bustamante et al., 2012). Hence, we investigated the potential of co-composting SF with bulking agents. Thereby, the use of on-farm available byproducts as bulking agents, such as grass clippings, straw, and straw-rich cattle manure, is supposed to be straightforward, cheap and efficient. Using additives in the composting process could be another option to reduce gaseous losses and improve the agronomic value of the end product. Clinoptilolite, the most common natural zeolite in the world, has a high cation exchange capacity especially for NH_4^+-N (Hedstrom, 2001). Adding clinoptilolite (6.25% on fresh weight basis) to dairy slurry reduced ammonia gas with 50% by adsorption of NH_4^+-N (Lefcourt and Meisinger, 2001). Furthermore, Shah (2013) demonstrated that clinoptilolite reduced N loss during and after storage of cattle manure in the stable.

Ensiling is a widespread technique for storing many field crops (e.g. grass and maize), thereby producing fodder or feedstock for anaerobic digesters. This technique can be applied for manure as well (Viaene et al., 2016a). According to Thomsen and Olesen (2000), anaerobic storage is superior to composting when considering the manure as a N resource, since anaerobically stored manure contains more mineral N than composted manure. Viaene et al. (2016a) concluded that semi-anaerobic storage of cattle farmyard manure resulted in lower pile temperatures and a less stabilized end product with higher mineral N concentrations compared to composting. Thus, ensiling could be an alternative management option for the SF, however, given the high moisture content of the SF, it is presumable that, comparable to composting SF, bulking agents should be added.

The effect of adding bulking agents or clinoptilolite to the SF of cattle slurry in an aerated on-farm windrow composting has received little attention, and to the best of our knowledge (co-)ensiling SF of cattle slurry has not been investigated previously. Therefore, the **first aim** of this study was to test the following hypotheses:

1. Ensiling is a controlled storage method resulting in a non-stabilized end product that further decomposes after soil addition. Ensiling the SF could optimize the fertilizer value of the SF in terms of conservation of C and nutrients.
2. Composting generally results in a more stable and sanitized product. The addition of bulking agents, such as straw-rich cattle manure or a mixture of straw and fresh grass clippings, will enhance the composting process and thereby optimize the agronomic value of the end product in terms of sanitation and stability, both important criteria for export.
3. Composting as well as co-composting of the SF does not increase the concentration of X-TAS spores, important for use as bedding material.
4. Adding clinoptilolite to the SF reduces N losses during composting and thus reduces the negative environmental impact. This conservation of N from the initial SF is also in favor of the fertilizer value of the end product.

More specifically, the difference in process, fertilizer value (in terms of conservation of nutrients and effect on N uptake in perennial ryegrass) and product stability among the treatments were compared. The product stability is an important factor to assess the fertilizer value, as application of unstable products can immobilize N from the soil, resulting in a negative effect on crop growth (Bernal et al., 2009). Stability is strongly related to the rate of microbial activity in the compost (Gomez-Brandon et al., 2008), however, there are many indicators to determine this and it cannot be established by one single parameter (Bernal et al., 1998, 2009). For animal manure-based composts, stability evaluated by e.g. a decrease in pile temperature to ambient air temperature (Brito et al., 2012), a decrease in organic matter (OM) content and C/N ratio to approximately 20:1 (Larney and Hao, 2007), a lower oxygen uptake rate (OUR) (Bernal et al., 2009; Grigatti et al., 2011), an NH_4^+-N concentration lower than 400 mg kg^{-1} dry matter (DM) and the conversion of NH_4^+-N to NO_3^--N resulting in a NO_3^--N/NH_4^+-N ratio > 1 (Zucconi and de Bertoldi, 1987). The biochemical composition (relative amounts of cellulose, hemicellulose and lignin) of the end products are also determining the stability of the OM (Lashermes et al., 2012; Veeken et al., 2007). However, few studies have used cell wall components as a successful stability parameter for manure-containing composts and silages. Therefore, the **second aim** of this study was to compare different stability indicators for composted and ensiled SF.

2. Materials and methods

2.1. Treatments and process monitoring

The experiments ran for two months (mid-April to mid-June 2014) and were conducted in an open-air composting facility with a concrete pad at the Institute of Agricultural and Fisheries Research (ILVO), Merelbeke, Belgium. Shortly before the start, fresh dairy cattle slurry (animal feed: 60% maize silage, 15% grass silage and 15% beet pulp) was separated with a mobile screw press (type XXXL, Maverko, The Netherlands) and was covered during storage (10 days) until the start of the experiment. At the start of the experiment, a windrow with a volume of approximately 24 m^3 (8 m length × 3 m width × 1 m height) was set up for each of the five treatments:

- composting pure SF (24 m^3) (*SF_C*)
- composting SF (24 m^3) with 2% clinoptilolite (Orffa, Bornem, Belgium) on dry weight (*SF + Clin_C*)
- co-composting SF (12 m^3) with straw-rich cattle farmyard manure (CFM) (12 m^3) (*SF + CFM_C*)
- co-composting SF (16 m^3) with straw (4 m^3) and fresh grass clippings (4 m^3) (*SF + S + G_C*)
- co-ensiling SF (16 m^3) with straw (4 m^3) and fresh grass clippings (4 m^3) (*SF + S + G_E*)

The CFM, straw and fresh grass clippings consisted, respectively, of 83%, 95% and 89% OM on dry matter (DM); 32%, 86%

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