

The role of bedding material in recycling the nutrients of horse manure

Johanna Nikama, Riikka Keskinen, Aaro Närvänen,
Jaana Uusi-Kämpä
MTT Agrifood Research Finland
Plant Production Research
Jokioinen, Finland
firstname.lastname@mtt.fi

Susanna Särkijärvi, Marianna Myllymäki, Markku
Saastamoinen
MTT Agrifood Research Finland
Animal Production Research
Ypäjä, Finland
firstname.lastname@mtt.fi

Abstract—In Finland, horses produce around 700 000–800 000 m³ of manure per year, over half of which is composed of the bedding material. The manure should be efficiently recycled in agriculture avoiding any uncontrollable loss of its nutrients into the environment. In this study, we compared the nutrient cycling properties of three bedding materials: peat, wood shavings and pelleted straw. Their composting characteristics, ability to store nutrients while subjected to rainfall and their effect on mineralization-immobilisation of N during incubation were examined.

The differences in the N and P concentrations between the fresh manures were small. The amount of total N ranged between 10 and 15 g kg⁻¹ dry weight (dw) and the concentration of total P between 2 and 3 g kg⁻¹ dw. The relative proportions of water soluble N and P were rather high (30-40% N, 50-60% P), which poses a risk of nutrient leaching. Peat manure was shown to be especially susceptible to P loss when subjected to rainfall. The C:N ratios were high in all the fresh manures, which led to net N immobilisation when mixed with soil. Composting increased the nutrient concentrations and decreased the C:N ratios. Therefore, the composted manures had a slight positive or an insignificant fertilizer effect. Manure with pelleted straw bedding had superior composting characteristics.

Keywords—horse bedding, manure, composting, nutrient cycling, fertilization

I. INTRODUCTION

The 75 000 horses in Finland are estimated to produce around 700 000–800 000 m³ manure yearly. Faeces comprise only 20 - 30% of the manure while bedding material makes up over half of the volume. The choice of bedding has thus a marked effect on the properties of the manure. For the welfare of both horses and their caretakers, stall bedding should be easily available, affordable, absorbent, dust free, hygienic and easy to apply and remove. From environmental perspective, the bedding should also have high capacity to retain nutrients during use and storage but at the same time efficiently release them once recycled into agricultural soil.

Horse manure has typically a high C:N ratio, meaning that the decomposing microbes need to absorb N to satisfy their growth requirements [1]. Due to this net immobilisation, horse

manure is not very desired fertilizer. Composting provides a way to improve the fertilizer value of manure since it reduces the overall volume and thus increases nutrient concentrations and the C:N [2].

In this study, three bedding materials, peat, wood shavings and pelleted straw were compared in relation to their nutrient content, ability to store nutrients during storage even under rainfall, compostability and ability to release N when used as a soil amendment.

II. MATERIAL AND METHODS

A. Collection of manure

Manure was collected from six Finnhorse mares rotated in six boxes, of which two of each were bedded with either peat, wood shavings or pelleted straw. Enough bedding was used to ensure adequate absorption of urine yet allowing easy maintenance. In total, the consumption of clean bedding per 2 boxes was 740 kg peat, 730 kg pelleted straw and 440 kg wood shavings during a 5-week study period (4 weeks of manure collection and 1 preceding test week). Soiled bedding and dung were removed daily by same person. A portion of the manure removed was weighed and placed into a 0.5 m³ storage box, one for each manure type. The total quantity of manure produced was not recorded. After a one-week collection period, the manure acquired into each box was mixed thoroughly and sampled for chemical analyses. Temperature sensors were installed in the middle part of each manure pile, after which the boxes were transported to a storage barn. The one-week collection period was repeated four times in January-February 2013 to obtain four replicates of each of the three types of manure.

B. Composting

Composting of the manures was conducted between January and September 2013 in 0.5 m³ containers placed under roof in outdoor temperature. The composting process was enhanced by aerating and moistening the materials. The masses in each box were turned manually in the beginning of June and July. Deionised water was added once during the latter turning. Temperatures of the manures were recorded automatically in

every four hours to follow the changes in microbial activity. Finally, the boxes were weighed to define the loss of dry mass and the material sampled for chemical analyses. Changes in the structure of the materials during composting were examined using bulk density measurement.

C. Nutrient concentrations and leaching

Nitrogen (N) and phosphorus (P) concentrations were analysed from both fresh and composted manure samples to assess differences in the content and solubility of nutrients. The total concentration of N was determined by the Kjeldahl method, whereas total P was analysed by ICP after dry combustion. The water soluble ammonium-N ($\text{NH}_4\text{-N}$), nitrate-N ($\text{NO}_3\text{-N}$), total N and total P were analysed from 1:60 water extracts with an autoanalyzer. In addition, the total content of carbon (C) was determined via dry combustion (Dumas method).

The ability of the bedding materials to retain nutrients during storage was studied by rain simulation. Both fresh and composted manure samples of 3 l volume were subjected to artificial rainfall with an intensity of 9 mm h⁻¹ for a period of 2 h 15 min. The percolated water was collected, weighed and analysed for total N and P concentrations with an autoanalyzer.

D. Incubation

The N mineralisation potentials of fresh and composted manures were determined by an incubation study conducted according to ISO14238. Aliquots of manure providing 100 mg of N kg⁻¹ of soil and NH_4NO_3 providing an additional 30 mg of N kg⁻¹ of soil were mixed with fine sand and let to incubate at 20 °C for 48 d. During incubation the soils were kept at a constant moisture level of 18.8% corresponding to 48% of water holding capacity. The soils were thoroughly mixed twice a week. Subsamples for N analyses were taken after 0, 7, 14, 28 and 48 d of incubation and extracted with 1 M potassium chloride (KCl) solution for soluble N. The total N content of the extracts was determined with an autoanalyzer after an oxidation treatment.

III. RESULTS

A. Composting characteristics

At the end of the one-week collection period, the temperatures of the manures stored in the 0.5 m³ boxes were around 30-40 °C in the pelleted straw and wood shavings manure and 20-30 °C in the peat manure. After transferring the boxes into outdoor winter temperatures, the manure piles started cooling and between mid March and early May the masses were frozen. During the first half of May, the temperatures began to increase peaking around 30°C in the manures containing peat, 30-50 °C in those with wood shavings and 40-60 °C in the ones containing pelleted straw. The aerating actions initiated further temperature peaks especially in the manures containing pelleted straw. During August, the temperatures of all manure piles decreased to below 20 °C.

Composting reduced the total dry mass by $48 \pm 3\%$ in the straw pellet manure, $31 \pm 1\%$ in the manure with wood shavings and $17 \pm 3\%$ in the peat manure. The bulk density was highest in the manure containing pelleted straw (106 ± 12 g dry matter l⁻¹) followed by manure with peat (89 ± 4 g dry matter l⁻¹) and that with wood shavings (72 ± 4 g dry matter l⁻¹). Composting had no significant effect on the bulk densities of the manures.

The C:N ratio was highest in the fresh manure containing wood shavings (Table 1). Composting decreased the C:N ratio in all manures but especially in the one with pelleted straw. The nitrate concentrations of fresh manures were very low, ranging between 0.003 and 0.07 g kg⁻¹ dry matter. During composting $\text{NH}_4\text{-N}$ was nitrified, which caused a decrease in the $\text{NH}_4\text{-N}:\text{NO}_3\text{-N}$ ratio. However, variation in the $\text{NO}_3\text{-N}$ concentration between replicates was substantial.

B. Nutrient storage capacity

In the clean bedding, the total nutrient concentrations were highest in pelleted straw (9.1 ± 0.4 g N kg⁻¹ dry matter (dm) and 1.4 ± 0.1 g P kg⁻¹ dm), followed by peat (8.7 ± 0.2 g N kg⁻¹ dm and 0.3 ± 0.1 g P kg⁻¹ dm). Wood shavings were clearly the poorest of the beddings in N and P (0.6 ± 0.0 g N kg⁻¹ dm and < 0.1 g P kg⁻¹ dm). In the fresh manures, the total N content was similar in the peat and pelleted straw manure but somewhat lower in the wood shavings manure (Table 2). The total P content was highest in the manure containing pelleted straw, likely due to the relatively high P content of the straw. Composting increased the nutrient concentrations of all manures due to loss of dry mass.

The proportion of water soluble N from the total was greatest, nearly 40%, in the fresh manure with wood shavings (Table 2). The corresponding percentage for both peat and straw pellet manure was around 30%. The proportion of water soluble P from the total was high in all the manure types, around 60 % in the ones bedded with peat or wood shavings and nearly 50% in the manure containing pelleted straw. The relative proportions of water soluble N and P decreased due to composting in the wood shavings and pelleted straw containing manures, though the soluble concentrations tended to increase.

TABLE I. RATIOS OF C:N AND NH₄-N:NO₃-N IN FRESH AND COMPOSTED HORSE MANURES CONTAINING DIFFERENT BEDDING MATERIALS. THE RESULTS ARE MEANS OF FOUR REPLICATES. STANDARD ERRORS (SE) AND LEAST SIGNIFICANT DIFFERENCES (LSD) WITHIN COLUMNS ARE SHOWN IN ITALICS.

Bedding material	C:N		NH ₄ -N:NO ₃ -N	
	Fresh manure	Composted manure	Fresh manure	Composted manure
Peat	33	29	532	0.5
Wood shavings	45	32	276	55
Pelleted straw	31	14	491	15
<i>SE/LSD^a</i>	<i>3/9</i>	<i>1/3</i>	<i>92/319</i>	<i>15/53</i>

TABLE II. TOTAL AND WATER SOLUBLE (1:60) CONCENTRATIONS OF N AND P IN FRESH AND COMPOSTED HORSE MANURES CONTAINING DIFFERENT BEDDING MATERIALS. THE RESULTS ARE MEANS OF FOUR REPLICATES. STANDARD ERRORS (SE) AND LEAST SIGNIFICANT DIFFERENCES (LSD) WITHIN COLUMNS ARE SHOWN IN ITALICS.

	Total concentration (g kg ⁻¹ dry matter)		Water soluble concentration (g kg ⁻¹ dry matter)	
	N	P	N	P
Fresh manure				
Peat	14.3	2.1	3.8	1.2
Wood shavings	10.2	2.0	3.8	1.2
Pelleted straw	14.8	2.7	4.6	1.3
<i>SE/LSD</i>	<i>1.0/3.4</i>	<i>0.1/0.5</i>	<i>0.4/1.5</i>	<i>0.1/0.4</i>
Composted manure				
Peat	15.5	2.7	4.2	1.6
Wood shavings	13.8	3.3	2.1	1.7
Pelleted straw	28.8	6.3	4.7	2.2
<i>SE/LSD^b</i>	<i>0.7/2.3</i>	<i>0.2/0.8</i>	<i>0.5/1.6</i>	<i>0.2/0.5</i>

Around 5-10% of the total N content of the manures was leached within the percolated waters of the simulated rainfall. The percentages of the total N lost by leaching from the different types of manure were the following:

1) *Fresh manures*

- a) *Peat 5 ± 2%*
- b) *Wood shavings 11 ± 2%*
- c) *Pelleted straw 6 ± 2%*

2) *Composted manures*

- a) *Peat 9 ± 4 %*
- b) *Wood shavings 4 ± 1%*
- c) *Pelleted straw 6 ± 3%*

P was most readily leached by the simulated rainfall from the manure containing peat bedding. The percentages of the total P lost by leaching from the different types of manure were the following:

3) *Fresh manures*

- a) *Peat 14 ± 3%*
- b) *Wood shavings 8 ± 1%*
- c) *Pelleted straw 5 ± 1%*

4) *Composted manures*

- a) *Peat 23 ± 8 %*
- b) *Wood shavings 12 ± 1%*
- c) *Pelleted straw 7 ± 2%*

The gaseous loss of N was estimated using the total N contents of the fresh and composted manures and the mass balances calculated over the composting period. This coarse inspection showed no marked loss of gaseous N, the percentages of total N lost being 12 % in peat and wood shavings manure and 1% in manure with pelleted straw (SE 6, LSD 20).

C. Fertilizer value

The incubation study showed that additions of fresh horse manures caused decreasing nitrogen concentrations in soil (net immobilisation) relative to the soils incubated without manure amendments (Fig 1a). In the manures containing wood shavings or pelleted straw, an immobilisation – mineralisation – immobilisation cycle seemed to occur, whereas with peat the decrease in soil soluble N was steadier. In contrast, the composted manures containing pelleted straw and especially the one with wood shavings released N into the soil (Fig 1b). In the soils amended with composted peat manure, no clear trend in the soluble N concentrations of soil could be seen.

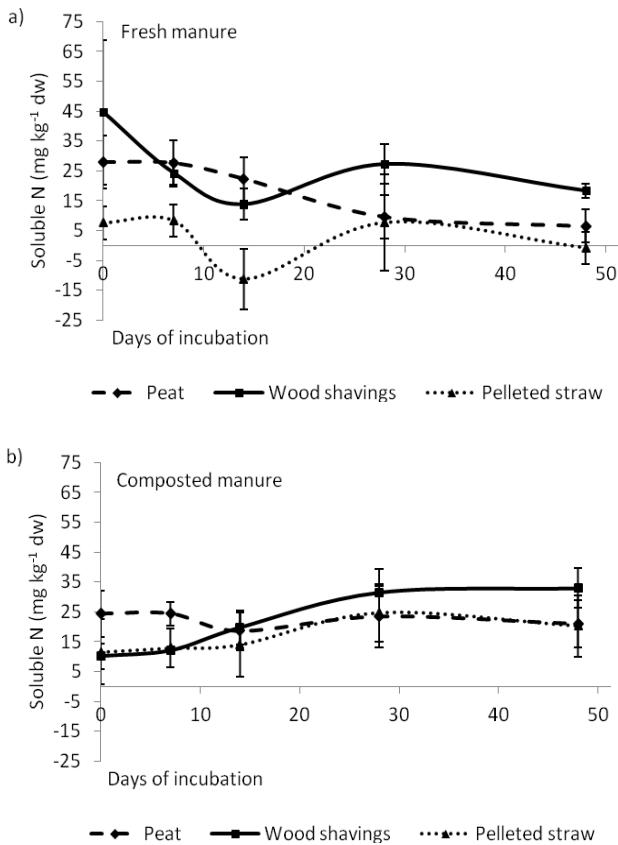


Fig 1. The effect of fresh (a) and composted (b) horse manure containing different bedding materials on the soluble N concentrations in soil. The results are means of four replications \pm standard deviation. The background N concentrations of soil incubated without manure have been subtracted from the values.

IV. DISCUSSION

The compostability of horse manure containing either peat, wood shavings or pelleted straw as the bedding material was assessed by the temperature profiles of the manures during composting, changes in the C:N and NH₄-N:NO₃-N ratios and the loss of dry mass. According to these indicators, manure containing pelleted straw composted most efficiently whereas the manure with peat decomposed only partially. The poor compostability of peat manure could be explained by the

initially high decomposition stage of the peat bedding. However, Airaksinen et al. [3] found peat manure to compost satisfactorily. Komar et al. [4] reported good composting characteristics of straw-based materials. In this study, active aeration was needed to maintain the composting process in all the manure types. In addition, it can be noted that at least when carried out in small piles, the decomposition ceases totally during the cold wintertime of Finland.

The inherently low N content of wood shavings and relatively high P content of pelleted straw were reflected in the N and P concentrations of the corresponding manures but in general, the differences in the total and water soluble N and P were small between the fresh manures studied. In the composting, dry mass was lost which led to increases in the nutrient concentrations. This phenomenon was most significant in the manure with pelleted straw, in which the N and P concentrations were doubled due to nearly 50% loss of dry mass. The proportion of water soluble N and P was rather high in all the manures, which poses a risk of nutrient leaching. Composting tended to decrease the water soluble proportion of both N and P but increased resistance against N leaching only in the composted wood shavings manure. Peat manure appeared to be more susceptible to loss of P than manures with wood shavings or pelleted straw.

In the incubation study with fresh manures, N was immobilised in soil as suggested by the high C:N ratios of the manures [1]. Composting decreased the C:N ratios but in the manures containing peat and wood shavings the ratios remained rather high. Yet no immobilisation was observed in any of the soils amended with composted manures. Though the N fertilizer value of the composted manures clearly remained low or non-existent, they could serve as soil improvement materials since the negative fertilizer effect, i.e. N immobilisation was eliminated.

In conclusion, none of the bedding materials compared was found superior to the others in relation to nutrient recycling of horse manure. Peat was shown to be more susceptible to P loss through leaching than pelleted straw or wood shavings. Composting proved to be useful since it reduced the manure volume, increased the nutrient concentrations and eliminated the N immobilisation effect of manure added to soil. Pelleted straw had the best composting characteristics.

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