NITROGEN AVAILABILITY OF TREATED AND RAW DAIRY MANURE

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Abstract

There is minimal information on the nitrogen (N) availability and composition of treated manures. Knowing how N availability differs with manure treatment will result in better N crediting guidelines. Raw dairy manure and anaerobically digested manure were incubated with five typical Wisconsin soils for 112 d. Net N mineralized from the different N sources were compared. Nitrogen mineralization differed by manure type and also by soil. Overall, the digested slurry and the digested separated liquid mineralized more N than the raw slurry. The digested separated solid mineralized significantly less N than the other manures. Net N mineralization as a percent of total N applied was 39, 58, 49, and 17 % for raw, digested slurry, digested separated liquid, and digested separated solids, respectively, when averaged over all soils. C:N ratio of manure was found to be the most useful predictor of manure N mineralization.

Introduction

On farm manure treatment systems are increasing in popularity among producers nationwide for various reasons, including more efficient transportation and storage along with reduced odor and lower pathogen levels in treated manure. Such treatment systems (anaerobic digestion, composting, and solid separation) alter the chemical and physical properties of manure, which have the potential to affect plant available nutrients. Little research has been conducted assessing the impacts of manure treatment on availability of N in the treated manures.

In Wisconsin, first year N application rates for dairy manure are based on 30% availability of total N if surface applied and 40% total N if incorporated within 72 hours of application (Laboski et al., 2006). No adjustments are currently made for N availability regarding the treatment type or manure composition. A few past studies have shown manures with different handling systems or at different stages of treatment mineralize N differently. For example, Kliese et al. (2005) and Shi et al. (1999) found composted manures mineralize N slower and less than raw manures. Several studies have also shown relationships between certain manure properties (such as C:N or neutral detergent fiber, NDF) and N mineralization rates (Griffin et al., 2005; Kyvsgaard, 2000). However, more research is needed to quantify the differences in N mineralization between treated and raw manures to determine if nutrient availability guidelines should be modified to consider manure treatment or manure characteristics.

The objectives of this study are to 1) determine how much N mineralization differs between raw and treated manures, 2) assess manure compositional effects on N mineralization, and 3) evaluate soil series effects on manure N mineralization.

Materials and Methods

An incubation was carried out for 112 days with various dairy manures incorporated into multiple agricultural soils to study the effects of manure treatment and soil type on N mineralization. Five common Wisconsin soils were collected from throughout the state including: Plano silt loam, Kewaunee silt loam, Fayette silt loam, Withee silt loam, and Richford sand. The soils were collected from a 0 to 0.2 m depth, sieved through a 2-mm sieve, air dried, and stored in plastic containers until needed. Soil characteristics are provided in Table 1.

Four dairy manures were collected from one farm at various treatment stages (Figure 1) and include: raw slurry, digested slurry, and digested and separated liquid and solid manures. All manures were analyzed and stored frozen until needed. Manure characteristic data can be found in Table 2.

For each soil/manure combination, manure was mixed with soil at a rate of 150 mg total N kg^{-1} soil with four replications. Deionized water was then added to each container to reach 60% water filled pore space. After thoroughly mixing the manures and soil, each 350 g container was aliquoted into seven 40 g subsamples and placed in smaller containers and packed to a bulk density of 1100 kg m^{-3}. Lids with four small ventilation holes were placed on each subsample container and incubated at 25°C for 0, 3, 7, 14, 28, 56 and 112 days. Water was periodically added to the samples to maintain 40 to 60% water filled pore space. On each sampling date, the entire subsample was removed, air dried, ground, and stored until analyzed.

Soil samples were extracted with 2 M KCl. Ammonium and nitrate were analyzed on a PowerWave™ XS microplate spectrophotometer (BioTek Instruments; Winooski, VT) using the sodium salicylate-nitroprusside method (Keeney and Nelson, 1982) and the single reagent method with vanadium (Doane and Horwáth, 2003), respectively.

Net N mineralized was calculated as the N mineralized in a treatment minus the N mineralized from the control. A generalized linear model for a completely randomized design was used to assess the affect of manure treatment and soil type on net N mineralized at 112 d ($Nmin_{net112}$) using Fisher's protected LSD for means separation at α=0.05. Relationships between $Nmin_{net112}$ and manure characteristics (including total N, neutral detergent fiber, acid detergent fiber, lignin, total C and C:N ratio) were assessed.

Results and Discussion

For all silt loam soils (Fayette, Kewaunee, Plano, and Withee) the digested slurry had greatest N mineralization over the course of the incubation, followed by digested separated liquid, raw slurry, then the digested separated solid (Figure 2). On the sand soil (Richford), the digested separated liquid had the greatest N mineralization, followed by the digested slurry, raw slurry, then the digested separated solid. The digested separated solid mineralized N rapidly in the first 7 to 14 days of the incubation, after which some of the mineralized N immobilized.

For all soils, the digested separated solid had significantly lower net N mineralization at day 112 ($Nmin_{net112}$) than the other manures (Table 3). The digested slurry had significantly greater

$Nmin_{net112}$ than digested separated liquid and the raw slurry for three of the silt loams (Fayette, Plano, and Withee). On one silt loam soil (Kewaunee) there was no significant difference in $Nmin_{net112}$ between the raw slurry, digested slurry and digested separated liquid. The digested separated liquid had greater $Nmin_{net112}$ than the digested slurry and raw slurry in the sand (Richford). However, differences in $Nmin_{net112}$ were not always significant. For the raw slurry, there was no significant effect of soil type on $Nmin_{net112}$. For all other manure treatments there were some differences in $Nmin_{net112}$ (sometimes significant) with soil type. However, there was no consistent effect of one soil type on $Nmin_{net112}$.

$Nmin_{net112}$ as a percent of total N applied was 39% for raw slurry when averaged over all soils. This is in agreement with the current first year N availability estimates for dairy manure from Wisconsin (Laboski et al., 2006). $Nmin_{net112}$ as a percent of total N applied was 58%, 49% and 17% for digested slurry, digested separated liquid, and digested separated solid, respectively, when averaged over all soils.

$Nmin_{net112}$ was best correlated with the C:N ratio of manure ($r=-0.99$ $p<0.01$). Similar results were found by Barbarika et al. (1985). $Nmin_{net112}$ was to be significantly correlated to $C:NH_4$ ($r=-0.96$ $p<0.04$), which is consistent with findings by Griffin et al. (2005). However, $Nmin_{net112}$ was not found to be significantly correlated with $NDF:NH_4$, which contrasts with findings by Griffin et al. (2005). Ratios of NDF:N ($r=-0.97$ $p<0.03$) and ADF:N ($r=-0.95$ $p<0.05$) were also found to be significantly correlated with $Nmin_{net112}$.

Conclusion

Averaged over all the soils, N mineralization is greater in digested slurry and digested separated liquid manure and less in digested separated solid manure compared to raw manure. N availability recommendations to producers should be modified to consider these differences in N mineralization. The C:N ratio was found to be the most useful predictor of N mineralization in soil. More manure treatments are currently being evaluated to assess their N availability in comparison to raw manure.

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Table 1. Soil characterization.

Soil Series†	Taxonomic name	pH	OM
			g kg^{-1}
Plano sil	Fine-silty, mixed, superactive, mesic Typic Agriudoll	5.7	42
Kewaunee sil	Fine, mixed, active, mesic Typic Hapludalf	7.7	32
Fayette sil	Fine, silty, mixed, superactive, mesic Typic Hapludalf	7.1	27
Withee sil	Fine-loamy, mixed, superactive, frigid Aquic Glossudalf	6.7	27
Richford s	Loamy, mixed, superactive, mesic Arenic Hapludalf	6.7	19

† sil, silt loam; s, sand.

Table 2. Selected manure characteristics.

Characteristic	Units	Raw Slurry	Digested Slurry	Digested Separated Liquid	Digested Separated Solid
Dry Matter	g kg^{-1}	49.2	75.0	26.0	254
Total N	g kg^{-1}	39.6 ±0.1†	38.5 ±3.0	79.3 ±2.3	22.9 ±1.4
NH4-N	g kg^{-1}	20.6 ±1.4	20.4 ±1.1	52.5 ±2.7	5.92 ±0.06
NDF	g kg^{-1}	457 ±7	475 ±5	201 ±16	728 ±10
ADF	g kg^{-1}	320 ±13	370 ±17	214 ±11	592 ±4
Lignin	g kg^{-1}	113 ±4	167 ±11	118 ±7	261 ±3
Total C	g kg^{-1}	387 ±36	318 ±16	366 ±10	433 ±13
C:N		9.8 ±3.5	4.6 ±4.2	8.3 ±0.7	19 ±9

† mean ± standard deviation.

Table 3. Mean net N mineralization on day 112.

	——— Soil ———				
Manure	Fayette	Kewaunee	Plano	Withee	Richford
	——— mg N kg-1 soil ———				
Raw Slurry	45.9 C†	67.0 A	64.0 C	53.2 C	62.1 B
Digested Slurry	87.6 A,bc	78.4 A,cd	103.7 A,a	90.1 A,b	72.5 AB,d
Digested Separated Liquid	67.8 B,b	64.1 A,b	76.9 B,a	78.7 B,a	77.0 A,a
Digested Separated Solid	21.1 D,bc	28.5 B,ab	33.6 D,a	27.7 D,ab	16.3 C,c

† Means within a row for a given manure followed by the same lowercase letter or means with a column for a given soil followed by the same uppercase letter are not significantly different ($p<0.05$) from each other.

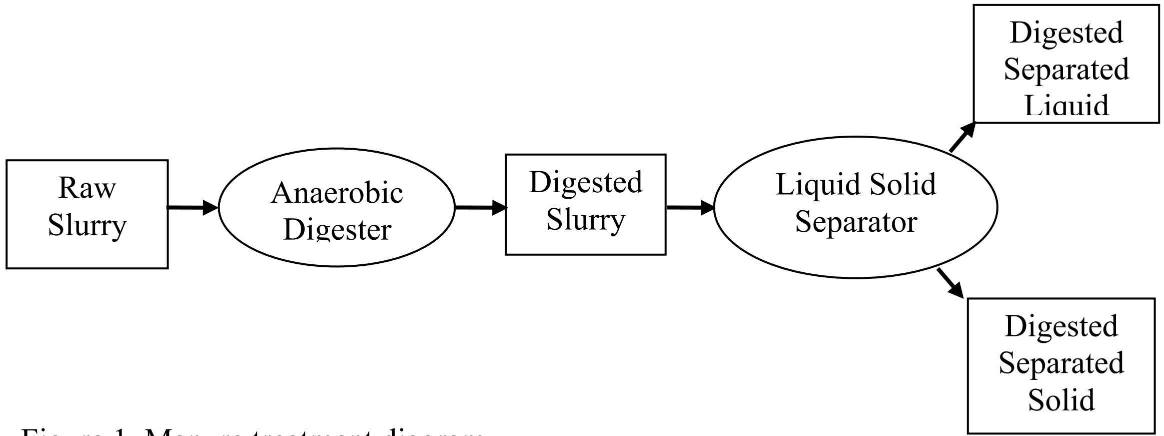

Figure 1. Manure treatment diagram.

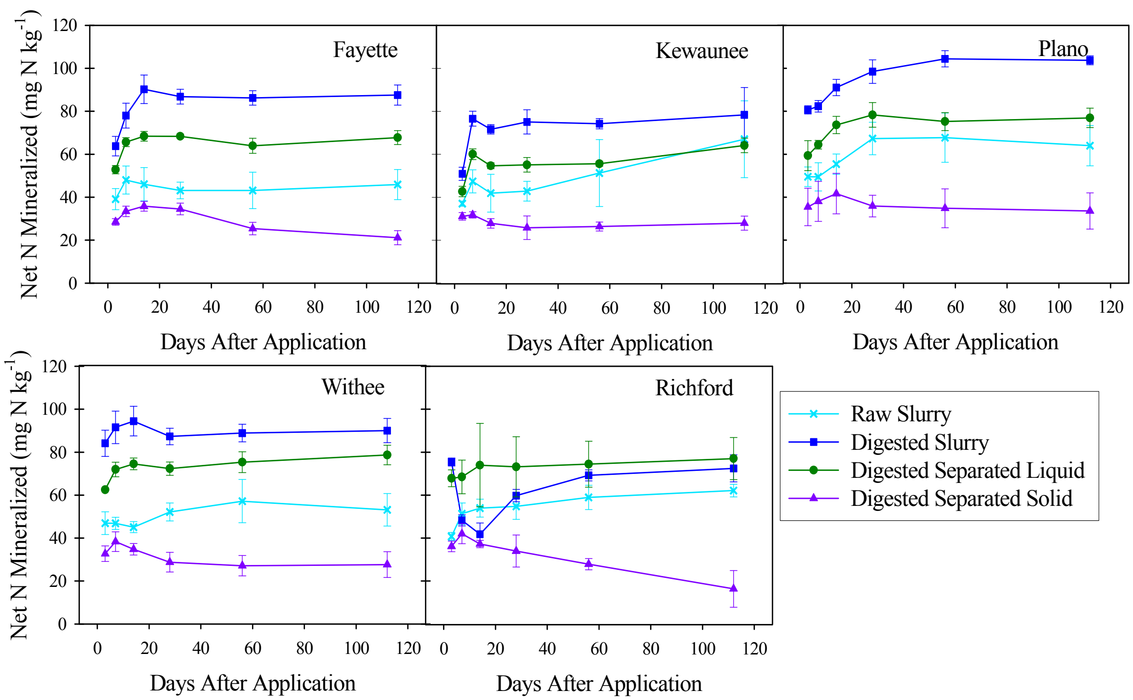

Figure 2. Net N mineralized throughout the incubation for each soil.

PROCEEDINGS OF THE

THIRTY-EIGHTH
NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 24

November 12-13, 2008
Holiday Inn Airport
Des Moines, IA

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Published by:

International Plant Nutrition Institute
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Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net

Cover photo provided by Peggy Greb, USDA-ARS.