Reprints from

4th
INTERNATIONAL CIEC SYMPOSIUM
AGRICULTURAL
WASTE MANAGEMENT
AND
ENVIRONMENTAL PROTECTION

1987

11–14 May
Braunschweig
Fed. Rep. of Germany

PROCEEDINGS

Edited by
E. WELTE and I. SZABOLCS

INTERNATIONAL SCIENTIFIC CENTRE OF FERTILIZERS (CIEC)
BELGRADE · GOETTINGEN · VIENNA

FEDERAL AGRICULTURAL RESEARCH CENTRE (FAL)
BRAUNSCHWEIG-VOELKENRODE

COMPOSITION, NITRIFICATION AND FERTILIZING EFFECT OF ANAEROBICALLY FERMENTED SLURRY

H. MESSNER and A. AMBERGER

Technical University of Munich, Institute of Plant Nutrition
8050 Freising - Weihenstephan, Fed. Rep. of Germany

ABSTRACT

Under laboratory conditions, manure slurry from cattle (bulls), pig and chicken was fermented in 5 l digestors (batch system: 35°C: 5, 10, or 15 weeks).

Fermentation resulted in changes within the N or P fractions. With longer periods of fermentation, a decrease in organic N and P was observed. Decomposition of phytate P was significant only in chicken slurry.

Nitrification of slurry is primarily determined by the low C content after fermentation. In an incubation trial with ^{15}N-labelled slurry-NH_4^+ (soil: silty loam, pH 6.5; simulated top-soil temperatures during winter season) application of fermented slurry resulted in reduced biological N immobilization in the soil and consequently in a quick turnover of NH_4-N into NO_3-N.

In pot trials (I: Silty loam, pH 6.5; II: Sandy loam, pH 5.8, $P_2O_{5\,CAL}$ = 3 mg/100 g soil) fermented slurry gave partially higher yields when compared on the basis of equal amounts of NH_4-N or P_2O_5; in trial no.I these differences in yields disappeared with the subsequent crop because of a better long-term N supply from untreated slurry.

INTRODUCTION

During anaerobic fermentation of manure slurry only insignificant nutrient losses occur (Besson et al., 1982 a). By bacterial turnover a certain part of the organically bound nutrients is mineralized and an increased fertilizing effect of the fermented product can be expected (Koriath et al., 1985).

These investigations were done to elucidate changes in N and P fractions during fermentation. In an incubation trial and in pot trials the nitrification rates and fertilizing effects were compared between anaerobically fermented and untreated slurry.

MATERIAL AND METHODS

1. Material

Chicken slurry (CS), bull slurry (BS) and pig slurry (PS) used in incubation and pot trials were fermented in 5 l digestors under laboratory conditions (batch system: 0, 5, 10, 15 weeks).

2. Methods

a) Determinations in slurry
pH: in aqueous dilution with glass electrode (Orion Model 701);
total C: wet ashing (Lichterfelder method) after Schlichting and Blume (1966).

Nitrogen:

Total nitrogen: after Kjeldahl;
Ammonium N: with ion-selective electrode (Orion Model 95-12);
Hydrol.N: digestion (15 h) with 6 N HCl, filtration, Kjeldahl digestion of the filtrate;
Nonhydrol. N: Kjeldahl digestion of the residue.

Phosphorus:

Total P: wet ashing, determination after Gericke and Kurmies (1952);
H_2O-soluble P: after Murphy and Riley (1962);
HCl-soluble P: after John (1969);
Phytin-P: Extraction with 1 N HCl; separation on an anion exchange column (Dowex^R-1, Cl^--form, 1x4-200) after Harland and Oberleas (1977); determination in the eluate after Latta and Eskin (1980);

b) Determination in soils

^{15}N analysis by emission spectrometry in K_2SO_4 extract after NaOH distillation without (NH_4^+) or with addition of Devarda reagent (NO_3^-) and after Kjeldahl digestion of the soil (total N) and titration with 0.005 M H_2SO_4 (Vilsmeier and Medina, 1984);

3. Experimental outline

a) Incubation trial
150 g soil (silty loam, pH 6.5, 2 mm fine) mixed in 500 ml polyethylene bottles with 30 mg slurry-$^{15}NH_4$-N, adjusted to 60 % of the full water capacity;
Slurries: from bulls, fermented for 0 or 15 weeks.
Temperature: adapted to top soil temperatures in the winter season;
Incubation: 0, 2, 5, 12, 18, 22 weeks.

b) Pot experiments

Experiment I: N fertilizing effect - slurry incorporated before seed;
Soil: silty loam, pH 6.5, 6.3 kg per pot;
Plants: green oat, ryegrass (2 cuts);
Basic fertilizing: P, K optimal;
Fertilizer treatments:
1. control (without slurry)
2. 0.3, 0.6, 0.9 g NH_4-N as slurry
3. 0.3 - 1.2 g N as NH_4NO_3.

Experiment II: P fertilizing effect
Soil: sandy loam, pH 5.8, P_2O_{5CAL} = 3 mg/100 g, 6.3 kg per pot;
Plants: green oat, ryegrass (8 cuts);
Basic fertilizing: N, K optimal, according to demand in irregular intervals;
Fertilizer treatments:
1. control (without slurry)
2. 0.4, 0.8 g P_2O_5 as freeze-dried slurry
3. 0.4, 0.8 g P_2O_5 as dicalciumphosphate.

(To exclude a N fertilizing effect, the freeze-dried slurry was aerated for an extended period to evaporate residual free ammonia.)

RESULTS AND DISCUSSION

1. pH value, dyry matter contents (dr.m.), N and P fractions (Table 1)

While pH values of all analyzed slurries except chicken slurry increase in the course of fermentation, dry matter contents of fermented slurries are lower than untreated slurries.

Table 1: Chemical composition of anaerobically fermented slurries

Slurry/ weeks*		pH	dr.m. %	N fractions (dr.m.) Total N %	NH₄-N/ total N	Hydr.N/ total N	C/N	P fractions (dr.m.) Total P %	H₂O-P/ total P	HCl-P/ total P	Phytin P mg/100g
BS•	0	7.3	7.6	5.41	0.63	0.27	7.7	0.99	0.49	0.55	36
	5	7.9	5.1	8.17	0.68	0.24	5.3	1.30	0.31	0.73	26
	10	8.0	4.4	9.23	0.72	0.20	4.2	1.50	0.20	0.71	17
	15	8.0	4.4	9.54	0.75	0.14	3.6	1.77	0.16	0.81	14
PS•	0	6.9	6.2	4.95	0.53	0.32	9.0	2.23	0.31	0.77	19
	5	6.7	5.0	5.78	0.76	0.18	7.9	2.19	0.45	0.68	14
	10	7.3	4.8	6.22	0.71	0.18	7.4	2.29	0.55	0.71	16
	15	7.9	4.9	6.22	0.67	0.21	6.7	2.62	0.13	0.73	12
CS•	0	8.3	6.9	6.10	0.67	0.23	4.8	3.02	0.24	0.73	390
	5	8.2	3.8	10.80	0.79	0.12	2.5	4.20	0.16	0.83	98
	10	8.2	3.3	12.05	0.85	0.03	2.3	4.34	0.25	0.86	69
	15	8.2	2.5	15.80	0.86	n.b.	1.7	4.76	0.16	0.86	34

* fermentation period
• BS (bull slurry), PS (pig slurry), CS (chicken slurry)

Decomposition of organic matter and volatilization of biogas results in a concentration effect in the fermented substrate. Mineralization of organically bound nitrogen leads to a lower ratio of NH_4-N/total N; in chicken slurry ammonium N comes up to nearly 90 % of total N. Accordingly, a decrease in hydrolyzable N can be observed (chicken slurry). This N fraction is hardly plant available and almost completely enters the organic-N pool of the soil (Amberger et al., 1982).
Balancing the analyzed N fractions reveals significant N losses only for chicken slurry mainly due to a volatilization of ammonia (high pH value!). After Besson et al. (1982 b) these losses can add up to over 10 % depending on storage conditions.
The increase in the HCl-soluble fraction (up to 15 % more) of total P reflects a mineralization of less soluble organic-P compounds (excluding pig slurry). This is not surprising since even during normal slurry storage a more or less intensive P mineralization is observed (Gerritse, 1981). The decrease in H_2O-soluble P is caused by precipitation of hardly soluble Ca and Mg phosphates (Fordham and Schwertmann, 1978). Decomposition of phytin is observed in all slurries, but is important only in chicken slurry because of high original concentrations.

2. Nitrification of ammonia N from fermented slurry (Table 2)

With fermented slurry a smaller amount of microbially available C compounds is applied. This is the reason for the decreased biological fixation of the added slurry N and the remineralization of blocked N after a few weeks. Higher NO_3^- concentrations in the soil extract of fermented slurry are the result.
A strong microbial N fixation after straw manuring (C supply) also efficiently reduced the formation of nitrate from slurry N in the experiments of Rauhe et al. (1973) and Amberger et al. (1982).

Table 2: Nitrification of slurry-$^{15}NH_4$-N at various incubation temperatures (simulation of winter season)

Bull slurry / weeks*	weeks	Temp. °C	NH_4-N %	NO_3-N %	Residual N %	Recovery rate %
0	2	4	54.8	9.8	35.4	100.0
15	2	4	53.3	13.1	31.6	98.0
0	5	0	32.4	40.5	29.5	102.4
15	5	0	27.2	58.8	15.8	101.8
0	12	0	21.3	47.1	30.3	98.7
15	12	0	23.8	59.3	18.8	101.9
0	18	7	11.8	62.2	26.2	100.2
15	18	7	20.2	64.0	17.7	101.8
0	22	11	0.5	76.9	22.0	99.4
15	22	11	0.8	86.9	14.8	102.3

* fermentation period

The rate of immobilization of 15 % or 22 % at the end of the experiment is relatively low compared to values of other authors (Peschke and Markgraf, 1982; Flowers and Arnold, 1983).

3. Nutrient effect of anaerobically treated cattle and pig slurry in pot trials

After incorporation fermented slurry has a somewhat better N fertilizing effect on the first cut (green oat), and untreated slurry has better effects on the subsequent crops (ryegrass, 2 cuts). Altogether, fermented slurry gives slightly inferior results (Fig. 1). This might be explained by a lower microbial immobilization of easily available ammonium N in the fermented slurry (viz. incubation trial) and a higher concentration of organic residual-N in the untreated slurry. To what extent this organic N is mineralized and plant available depends largely on ecological conditions in the soil and can hardly be predicted (Amberger, 1982).
The poor growth with pig slurry was caused by the very high application rates (due to the low ammonium concentrations in fresh matter) which resulted in structural damage probably followed by considerable N losses through denitrification. The good long-term N-supplying capacity of untreated slurry however can still be recognized.
In comparison, Koriath et al. (1985) reported significantly higher yields in one-year pot trials with maize after addition of anaerobically treated slurry, on the basis of equal amounts of total slurry N.
The obviously improved P fertilizing effect of fermented slurry (removal of P is generally increased with one exception: Fig. 2) is not surprising because an influence on P forms or a possible mineralization of organically bound slurry P during fermentation has already been pointed out.
The use of freeze-dried NH_4^+-free slurry did not completely exclude an additional residual effect of organic matter. However, since the experiment was done on a uniformly high N level, the influence caused by a masked N fertilizing effect is negligible.

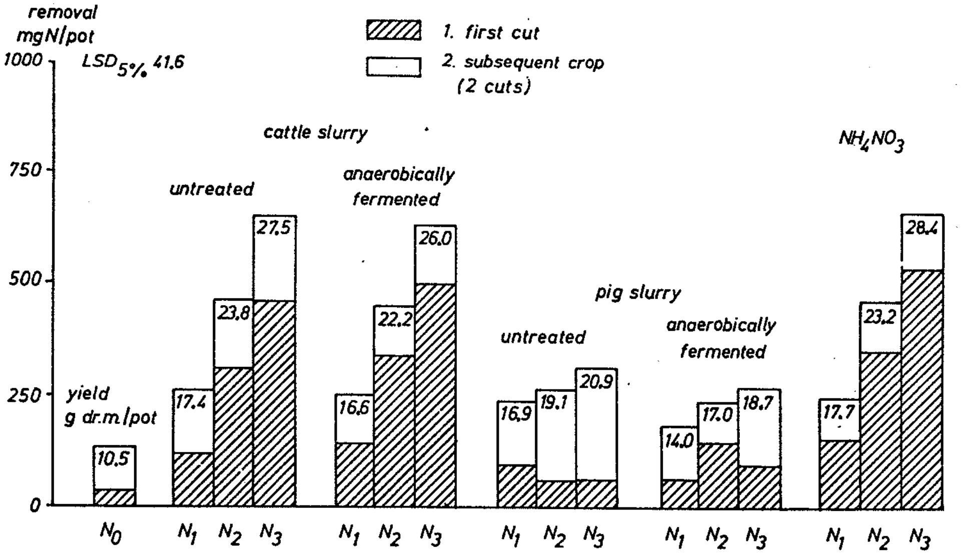

Fig.1: Effect of N from untreated and anaerobically fermented cattle and pig slurry

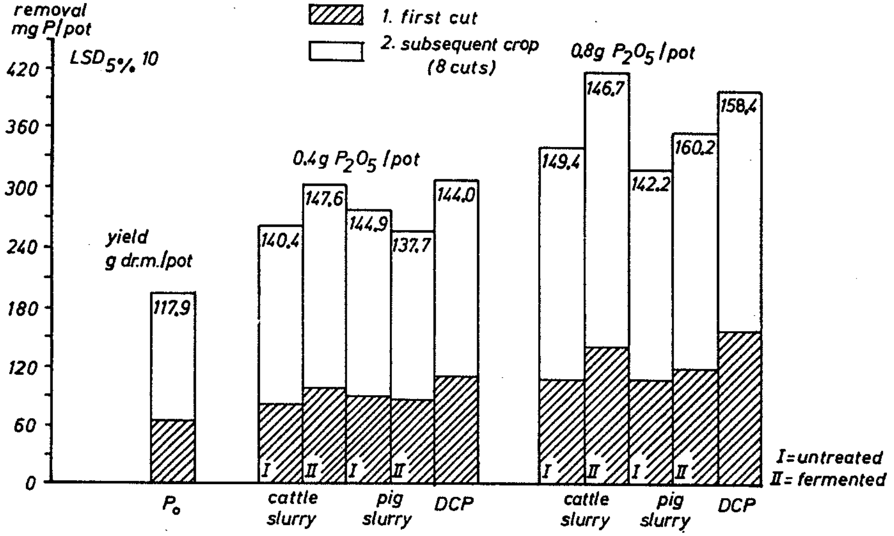

Fig.2: Effect of P from untreated and anaerobically fermented cattle and pig slurry

CONCLUSION

Anaerobic fermentation leads to mineralization of organic N and P compounds in slurry. As a consequence fermented slurry shows a long-term N-supplying capacity inferior to the untreated one. The low C/N ratio due to fermentation exerts an influence on nitrification. The reduced biological fixation of slurry N might favor possible leaching and translocation of nitrate into deeper soil layers. Anaerobically fermented slurry, therefore, must be applied in controlled amounts adapted to the N demand of the plants.

REFERENCES

AMBERGER, A., VILSMEIER, K. and GUTSER, R. (1982): Stickstofffraktionen verschiedener Güllen und deren Wirkung im Pflanzenversuch. Z. Pflanzenernähr. Bodenkde. 145: 325-336.

AMBERGER, A., GUTSER, R. and VILSMEIER, K. (1982): N-Wirkung von Rindergülle unter Zusatz von Dicyandiamid bzw. Stroh in Gefäß- und Lysimeterversuchen. Z. Pflanzenernähr. Bodenkde. 145: 337-346.

BESSON, J.M., LEHMANN, V., ROULET, M. and LISCHER, P. (1982 a): Inhaltsstoffe der belüfteten Gülle sowie Einfluß der Methangärung auf die Güllezusammensetzung in Praxisbetrieben. Mitt. schweiz. Landw. 7: 149-161.

BESSON, J.M., LEHMANN, V., ROULET, M. and WELLINGER, A. (1982 b): Influence de la méthanisation sur la composition des lisiers. Revue suisse Agric. 14: 143-151.

FLOWERS, T.H. and ARNOLD, P.W. (1983): Immobilization and mineralization of nitrogen in soils incubated with pig slurry or ammonium sulphate. Soil Biol. Biochem. 15: 3, 329-335.

FORDHAM, A.W. and SCHWERTMANN, U. (1978): Instability of phosphate during storage and shaking of gülle. Z. Pflanzenernähr. Bodenkde. 141: 443-451.

GERICKE, S. and KURMIES, B. (1952): Die kolorimetrische Phosphorsäurebestimmung mit der Ammonium-Vanadat-Methode und ihre Anwendung in der Pflanzenanalyse. Z. Pflanzenernähr., Düng., Bodenkde. 59: 235

GERRITSE, R.G. (1981): Mobility of phosphorus from pig slurry in soils. in: HUCKER, T.W.G., CATROUX, G.(eds.): Phosphorus in sewage sludge and animal waste slurries. Reidel, Dordrecht, 347-366.

HARLAND, B.F. and OBERLEAS, D. (1977): A modified method for phytate analysis using an ion-exchange procedure: application to textured vegetable proteins. Cereal Chem., 54: 4, 827-832.

JOHN, M.K. (1970): Soil Sci. 109: 214.

KORIATH, H., HERRMANN, V., VOLLMER, G.R. and FRANZ, J. (1985): Nährstoffdynamik während der anaeroben Fermentation von Gülle und Wirkung auf den Ertrag und Inhaltsstoffe von Mais im Gefäßversuch. Arch. Acker-Pflanzenb. Bodenkde., 12: 741-747.

LATTA, M. and ESKIN, M. (1980): A simple and rapid colorimetric method for phytate determination. J. Agric. Food Chem. 28: 6.

MURPHY, J. and RILEY, J.P. (1962): Anal. Chem. Acta 27: 31.

PESCHKE, H. and MARKGRAF, G. (1983): Vergleichende Untersuchungen zurStickstoffverwertung der Pflanze mit Ammoniumnitrat und Gülle als ^{15}N-Tracer. Arch. Acker- Pflanzenb. Bodenkde. 26: 5, 309-313.

RAUHE, K., FICHTNER, F., FICHTNER, E., KNAPPE, E. and DRAUSCHKE, W. (1973): Untersuchungen zum Verbleib ^{15}N-markierter organischer und mineralischer Düngerformen in ausgewählten Stickstofffraktionen des Bodens. Arch. Acker- Pflanzenb. Bodenkde. 17: 11/12, 895-905.

SCHLICHTING, E. and BLUME, H.P. (1966): Bodenkundliches Praktikum, Paul Parey Verlag, Hamburg und Berlin.

VILSMEIER, K. and MEDINA, R. (1984): Eine Memory-freie Methode zur Hypobromitoxidation von $^{15}NH_4^+$ für die Emissionsspektrometrie. Z. Anal. Chem., 318: 597-598.