Research Application Summary

The effectiveness of lignite coal and biochar in reducing nitrogen (N) losses from cattle feedlot manure

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Abstract

This study was conducted at the University of Melbourne Burnley campus aimed at investigating the effectiveness of lignite coal and biochar in reducing nitrogen losses from feedlot cattle manure. Forty (40) kg of manure was mixed with either 6kg of biochar or lignite and the other 40kg of manure were used as control. These were put in 220 drum replicated 3 times where 50g of N in form of urea were sprayed in them. The concentration of urea, NH_4^+ and NO_3^-, and emissions of N_2O and NH_3 were monitored for 21 days in each drum to assess nitrogen loss. At the end of the experiment (3 weeks), biochar and lignite reduced ammonia loss by 38% and 72% respectively as compared to the control. However biochar increased N_2O flux 10 fold as compared to that of the control.

Key words: Ammonia volatilisation, biochar, C/N ratio, green house gas, lignite, nitrification

Résumé

Cette étude a été menée sur le campus de Burnley à l'Université de Melbourne. Elle a visé à étudier l'efficacité de la lignite et du biochar dans la réduction des pertes d'azote provenant du fumier de bovins des abattoirs. Quarante (40) kg de fumier ont été mélangés avec soit 6 kg de biochar ou de lignite et les 40 autres kg de fumier ont été utilisés comme témoin. Ceux-ci ont été mis dans un tambour de 220 répliqué 3 fois où 50g d' N sous forme d'urée ont été pulvérisés sur eux. La concentration de l'urée, NH4+ et NO3-, et les émissions de N2O et NH3 ont été suivis pendant 21 jours dans chaque tambour pour évaluer la perte d'azote. A la fin de l'expérience (3 semaines), le biochar et la lignite ont réduit la perte d'ammoniac de 38% et 72% respectivement par rapport au témoin. Cependant le biochar a augmenté 10 fois le flux de N2O par rapport à celui du témoin.

Mots clés: volatilisation d'ammoniac, biochar, rapport C/N, gaz à effet de serre, lignite, nitrification

Background

Emission of nitrogen into the atmosphere has got adverse pollution effects such as formation of acid rain, soil acidification and alteration of plant biodiversity, eutrophication of water bodies, health disorders and contamination of ground water. Nitrous oxide (N_2O) is a potent greenhouse gas as a result of N emissions. Livestock is one of the important emitters of N into the atmosphere mainly from manure. Direct manure application in field result in large amount of nitrogen emission into the atmosphere. A need to keep nitrogen in manure is necessary.

Literature Summary

Low carbon to nitrogen (C/N) ratio, high temperature (Bernal *et al*., 2009, Robertson, 1995), and high pH (Sommer and Hutchings, 2001) are important factors that enhance NH_3 volatilisation from manure. There are recommendations for reducing gaseous N emission into the atmosphere and N leaching in form of NH_4^+ and NO_3^- from manure. These include addition of amendments in manure with high C/N ratio and easily decomposable C so as to induce the immobilisation of NH_4^+; high surface charge and area to adsorb NH_4^+ and lower pH (Kirchmann, 1989). The physiochemical properties of biochar and lignite coal have a potential to reduce N emissions and leaching. Lignite with low pH range of 3.5 to 6.5(Vorres, 2000) can reduce manure pH (usually more than 7.5) (Bernal *et al*., 2009). Volatilisation of NH_3 is limited at the pH below 4.5 (Hartung and Phillips, 1994). Lignite also contains humic acid which chelates nutrients (Kalaichelvi, 2006). This makes it a potential manure amendment to adsorb NH_3 and reduce the loss by emission and leaching. Biochar has high surface area, is highly porous, and carry a high surface charge which can influence nutrient transformation like the nitrogen cycle (DeLuca *et al*., 2006).

Study Description

Cattle feedlot manure was collected from Charlton Feedlot located in north central Victoria (36° 21' 29" S, 143° 24' 20" E). Fresh manure was cleared directly from the pen, and transported to the University of Melbourne Burnley campus. The initial characteristics of the material were determined. These included initial moisture content, pH, and total N and C and Cation Exchange Capacity (CEC). CEC was determined using the method of Gillman and Sumpter (1986) while total N and C were determined using the Elementar EA by vario isotope cube. Forty (40) kg of ground manure was mixed with 6kg of biochar (MB), Forty (40) kg of ground manure mixed with 6kg of lignite (ML) and loaded in 220lt drums. Another forty (40) kg of ground manure were not mixed with anything and was used as a control

(MC). All treatments were replicated three times. At this stage manure was believed to have lost up to 90% of all urea in it. To simulate urine patches in the cattle pen, 50g of N in form of urea was dissolved in milli-Q water and sprayed in each drum. This rate is equivalent to 1000kg N/ha and it was derived from N content in urine patch which ranges from 800-1300 kg N/ha (Eckard *et al*., 2010).

Manure sampling from the drum for urea and mineral N (NH_4^+ and NO_3^-) analysis were done every 24 hours for the first week and every 48 hours for the second week. The sample was shaken in a 250ml vial with 2M KCl mixed with 10% phenylmecuric acetate (PMA) solution for one hour. The mixture was then filtered with Whatman 42 and the filtrate analysed by segmented flow analyser for urea and mineral N.

Two PVC pipes were connected to each of the 220lt drums, the inlet and outlet. The outlet pipe was connected with a tube to a 1lt side arm flask filled with 400ml of 10% H_2SO_4 for trapping a NH_3. Another tube connected the side arm flask to a vacuum pump so as to create a continuous air flow through the drums and pull out the air to the acid trap. The air flow to each drum was recorded with a flow meter. At each sampling time only 100ml of the acid trap was taken and put in a 100ml vial and refrigerated. The rest of the acid was discarded. The side arm flask was then rinsed with milli Q water and new 400ml 10% H_2SO_4 put and connected to the drum and vacuum pump for next sampling. The acid samples were collected every 24 hours for the first week and every 48 hours for the second week and 72 hours in the third week. The samples were then analysed using the Auto-Analyser to check the ammonium content. Ammonia emission from manure was determined by the concentration of ammonium (ìg/ml) in acid samples as read from AA.

A closed chamber technique was used to measure N_2O. A continuous flow tube for measuring NH_3 was detached from the outlet pipe on the drum and then both inlet and outlet pipes were sealed with a rubber stoppers. A fan was hung in the middle of a drum so as to mix the air in the drum before gas sample collection. A gas sample was collected using a needle inserted on a syringe through a rubber stopper fitted on the side of the drum. Three gas samples were collected at 0, 30, and 60 minutes to determine the gas flux curve. Twenty (20) ml of collected gas was kept under pressure in a pre-evacuated 12ml exetainer. Gas concentration was measured by gas chromatography (GC) whereby N_2O was measured by electron capture detector (ECD), CH_4 by flame ionisation detector (FID) and CO_2 by thermal conductivity detector (TCD). Nitrous oxide samples taken at 0, 30, and 60 minutes interval were used to calculate the emission rate per hour which was then converted in g/ha/day to get the flux rate.

Statistical analysis was run by SAS (version 9.2) using the general linear model (GLM) to determine the effect of treatment on the concentration of mineral N and urea in manure sample. The mean separation was done by least significant difference (LSD) procedure.

For gases, statistical analysis was done on the mean emission rate per day to determine the effect of the treatment on these emissions. A general linear model was used and means separation was done by LSD procedure.

Research Application

In this study both biochar and lignite proved to be effective in reducing the emission of NH_3 as compared to the control by 72%. This indicates that the addition of the amendments in manure with low pH can reduce NH_3 emission (Hartung and Phillips, 1994, Steiner, 2010). Furthermore amendments wit high CEC like lignite and biochar can explain this reduction and thus be used in cattle manure to reduce N loss and indirect green house gas like N_2O. High CEC increases the retention of NH_4^+

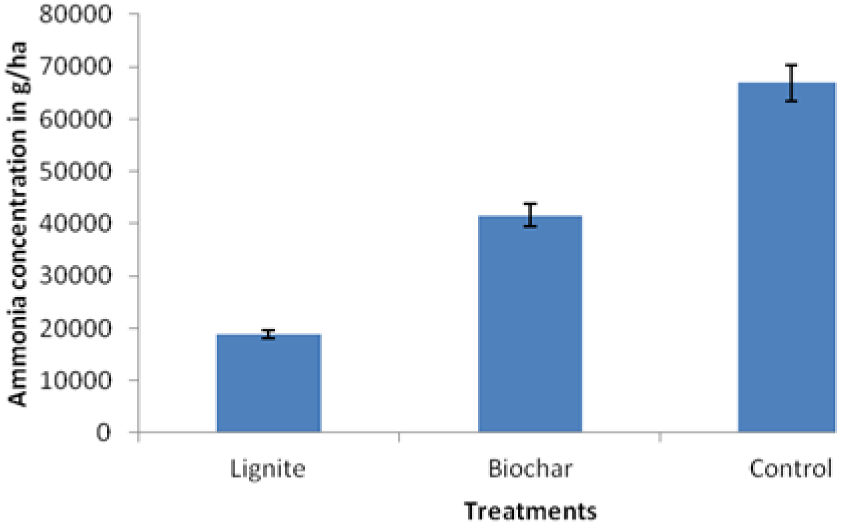

Figure 1. Cumulative NH_3 emission for each treatment over 21 days. Error bars represent standard error of the mean (n=3).

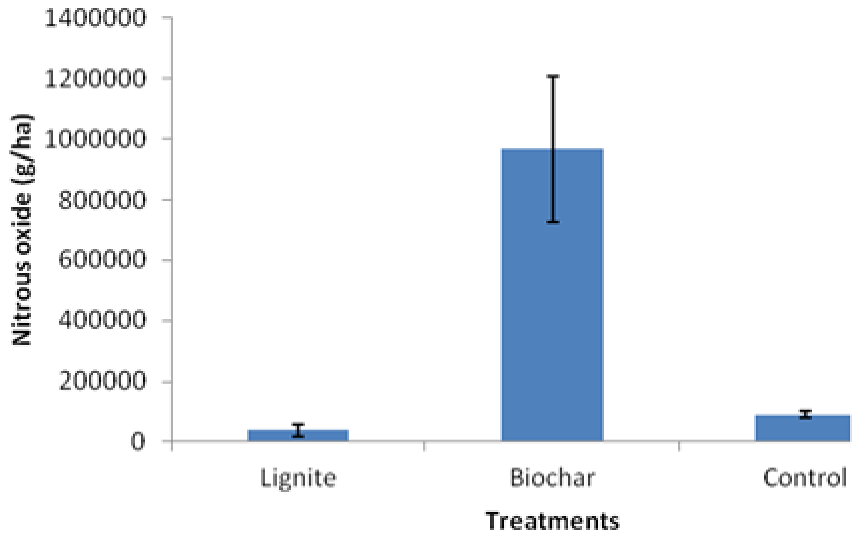

Figure 2. Cumulative nitrous oxide emission over 21 days. Error bars represent standard error of the mean (n=3).

in manure colloids thus reducing NH_3 emission (Taghizadeh Toosi, 2011).

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References

Bernal, M.P., Alburquerque, J.A. & Moral, R. 2009. Composting of animal manures and chemical criteria for compost maturity assessment. A review. *Bioresource Technology* 100:5444-5453.

Deluca, T.H., Mackenzie, M.D., Gundale, M.J. and Holben, W.E. 2006. Wildfire-produced charcoal directly influences nitrogen cycling in forest ecosystems. *Soil Science Society America Journal* 70:448-453.

Eckard, R.J., Grainger, C. and De Klein, C.A.M. 2010. Options for the abatement of methane and nitrous oxide from ruminant production: A review. *Livestock Science* 130:47-56.

Hartung, J. and Phillips, V.R. 1994. Control of Gaseous Emissions from Livestock Buildings and Manure Stores. *Journal of Agricultural Engineering Research* 57:173-189.

Kalaichelvi, K. 2006. Exploiting the natural resource-lignite humic acid in agriculture-A review. *Agricultural Reviews* 27:276.

Kirchmann, H. 1989. Ammonia volatilisation during aerobic and anaerobic manure decomposition. *Plant and Soil* 115: 35.

Robertson, F.A. 1995. Mineralisation of C and N in organic materials as affected by duration of composting. *Australian Journal of Soil Research* 33:511.

Sommer, S.G. and Hutchings, N.J. 2001. Ammonia emission from field applied manure and its reduction - invited paper. *European Journal of Agronomy* 15:1-15.

Steiner, C. 2010. Reducing nitrogen losses during poultry litter composting using biochar. *Journal of environmental quality* 39:1236.

Taghizadeh Toosi, A. 2011. A wood based low-temperature biochar captures NH 3-N generated from ruminant urine-N, retaining its bioavailability. *Plant and Soil* 1.

Vorres, K.S. 2000. Lignite and Brown Coal. Kirk-Othmer Encyclopedia of Chemical Technology. John Wiley & Sons, Inc.