Improved modelling of manure mineralisation through new methods for characterising the carbohydrate pools

Mohammad Feizal Daud[1,2], **David Parsons[2]**, Aduli Malau-Aduli[2] and Peter Lane[2]

[1]School of Biology and Agricultural Studies, Faculty of Applied Sciences, Universiti Teknologi Mara (UiTM), 40450 Shah Alam, Selangor, Malaysia Email mfdaud@utas.edu.au
[2]Tasmanian Institute of Agricultural Research and School of Agricultural Science, University of Tasmania, Private Bag 54, Hobart, TAS 7001, Australia Email dparsons@utas.edu.au

Abstract

Particularly in tropical low-input systems, manure plays an important role in soil fertility management, where effective use of nutrient sources is crucial to maintaining productivity. It is important to be able to understand and predict the complex mineralisation behaviour of manure in soil. In this study we developed an improved method to?characterise manure, focusing on the composition of carbohydrate pools, including soluble, fibre, and lignin.?A selection of laboratory analyses was used to determine the carbon to nitrogen ratios of carbohydrate pools for a range of temperate and tropical manures. The method was generally able to characterise the carbohydrate pools in manure samples and their carbon to nitrogen ratios; however calculating the NFC fraction by difference sometimes led to negative values and thus direct measurement of the non-fibre (soluble) carbohydrate components may be preferable. The generally greater C:N ratios for the fibre fraction compared to the lignin fraction support the hypothesis that overall C:N ratio is not a good indicator of manure quality.

Keywords

Detergent fibre method, APSIM, simulation models, organic matter

Introduction

Simulation models for nitrogen transformation of organic matter through decomposition have been around for nearly 50 years (Probert and Dimes 2004; Morvan and Nicolardot 2009). These models are very dependent on the initial parameters values, which may be unrealistic due to the estimation of stocks or rate constants (Sleutel et al. 2005).

The Agricultural Production Systems Simulation Model (APSIM) has a three pool organic matter model (Probert and Dimes 2004). APSIM SoilN which simulates nitrogen and carbon dynamics was primarily designed to be a plant residue based model, and is less successful in simulating the additional complex patterns of N release of manure (Probert and Dimes 2004). APSIM SoilN is based on three carbohydrate pools (lignin, fibre, soluble) each of which is assumed to have the same C:N ratio (Probert et al. 2005). Probert et al. (2005) argued that by assuming all pools have the same C:N ratio, the model fails to adequately represent the behaviours of N release of organic materials. Thus, they modified the APSIM SoilN model to allow specification of the C:N ratio of each carbohydrate pool. Probert et al. (2005) reported that with this modification APSIM was able to better simulate patterns of N mineralisation and immobilisation observed in the laboratory incubation studies of Delve et al. (2001). However, the analysis methods used by Probert et al. (2005) to specify each carbohydrate fraction were basic, and not well detailed in the paper. The aim of this study was to develop improved laboratory methods for characterising the composition of manure carbohydrate pools for use in simulation modelling.

Methods

Laboratory methods

Twenty four samples of manure were obtained from temperate Tasmania (12 samples) and tropical Queensland (12 samples). Samples varied in terms of climate, diet, season, livestock type, and farm.

Samples were dried in a fan forced oven at 60^{o} C until a constant weight was achieved, ground to pass through a 0.5-mm screen, and stored in air-tight containers. The basic analyses included dry matter, total ash, fat, total nitrogen, total carbon, neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL). Dry matter was determined at 105?C and total ash analysis was done using a muffle furnace at 600?C. Fat analysis was performed using soxhlet extraction equipment. Fibre and lignin analysis was performed using the sequential method described by Van Soest et al. (1991), using the ANKOM (Macedon, NY) fiber analyser with filter bags, including extraction with 72% sulphuric acid to determine ADL (Reeves and Kessel 2002). Total N and total C were analysed using a 2400 Series II CHNS/O elemental analyser (Perkin Elmer, USA).

Fractionation of carbohydrate pools

Definition of the carbohydrate pools was similar to Probert et al. (2005), with the exception being changing the name of the soluble pool to the ‘soluble and non-fibre carbohydrate pool’ (NFC). A summary of the methods used to fractionate samples is shown in Table 1. The lignin pool is composed solely of lignin, as determined by the lignin analysis. The fibre pool consists mainly of cellulose and hemicellulose, and was calculated by subtracting lignin from NDF. Neutral detergent fibre insoluble protein (NDFIP) is protein bound in the NDF fraction. It was calculated by performing an N analysis on the residue left from the NDF analysis. The non-fibre carbohydrate fraction was calculated by difference (Van Soest, 1994). The calculation involved assuming a total DM of 100%, subtracting fat, ash, crude protein (CP), NDF, and adding NDFIP.

Table 1. Analyses and calculations used to specify manure carbohydrate pools.

Component	Analysis or calculation
Fat	Soxhlet analysis
Ash	Total Ash analysis
Crude Protein (CP)	(Total N)*6.25
Lignin fraction	Sulphuric acid method
Fibre fraction	(NDF)-(lignin)
NDF insoluble protein (NDFIP)	(NDF N)*6.25
Soluble and non-fibre carbohydrate fraction	100-(CP)-(NDF)-(Fat)-(Ash)+(NDFIP)

Calculation of C:N ratios of carbohydrate pools

Carbon to nitrogen ratios of the carbohydrate pools were determined by analysing the carbon and nitrogen contents of the total manure sample, the NDF residue, and the lignin residue. The method results in specified C:N ratios for each carbohydrate faction. A summary of the methods used to specify C:N ratios is contained in Table 2.

Table 2. Analyses and calculations used to specify the C:N ratios of manure carbohydrate pools.

Component	Analysis or calculation
Total C	Elemental analyzer
Total N	Elemental analyzer
Total C:N	(Total C)/(Total N)
NDF C	Elemental analyzer
NDF N	Elemental analyzer
NDF C:N	(NDF C)/(NDF N)
Lignin C	Elemental analyzer
Lignin N	Elemental analyzer
Lignin C:N	(Lignin C)/(Lignin N)
Fibre C	(NDF C)-(Lignin C)
Fibre N	(NDF N)-(Lignin N)
Fibre C:N	(Fibre C)/(Fibre N)
SNFC C	(Total C)-(NDF C)
SNFC N	(Total N)-(NDF N)
SNFC C:N	(NFC C)/(NFC N)

Results

The chemical compositions of manure samples

Selected results for the chemical compositions of manure samples from Queensland and Tasmania are presented in Figure 1. Due to a malfunction of the elemental analyser, at the time of writing complete data sets were available for 14 of the 24 manure samples. Most manure samples had high lignin, fibre, and ash fractions, with small concentrations of fat, non-fibre CP, and NFC.

Four samples had negative results for soluble CP (Figure 1). This result cannot be true, and occurred because the NDF CP was calculated to be greater than the total CP, a result which could have been obtained due to small errors in the CP or NDF analyses. Three samples (T2, T11, and T12) had negative results for non structural carbohydrates (Figure 1), a result which cannot be true. This result occurred because NSC is calculated by difference and the sum of all other components totalled more than 100%. This was likely due to the compounding of small errors in the analyses.

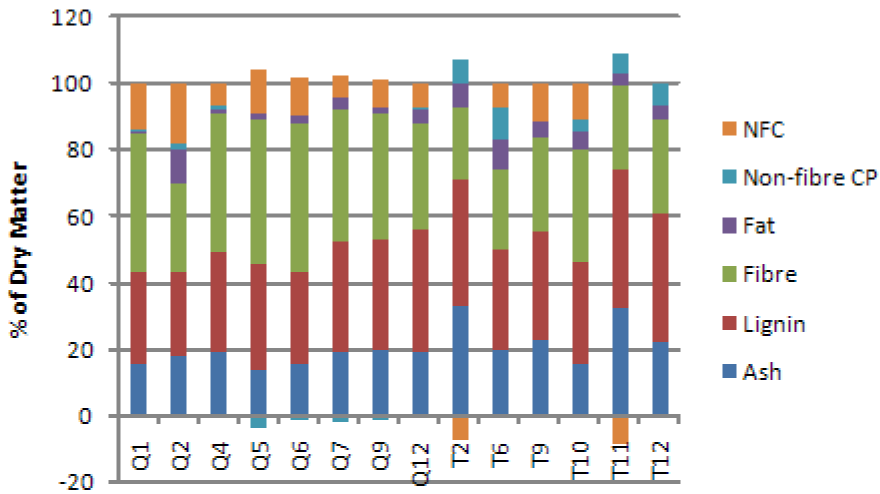

Figure 1. The chemical composition of selected manure samples from Queensland (Q) and Tasmania (T). Non-fibre CP is equal to total CP minus NDFIP.

C:N ratios were generally quite variable, as would be expected due to the diverse range of samples. For the Queensland samples the fibre C:N ratios were generally similar to the total and lignin C:N ratios; whereas for the Tasmanian samples the fibre C:N ratios were generally greater. The total C:N ratios were generally greater for Queensland samples than for Tasmanian samples. For Queensland and Tasmanian samples the fibre C:N ratios were generally greater than the total C:N ratios, and the lignin C:N ratios were generally lower. Lignin decomposes more slowly than fibre and if the C:N ratio was the major factor determining decomposition rate, then lignin would have a higher C:N ratio than fibre. However, this is not the case, highlighting that factors other than C:N ratio determine decomposition rates. This supports the hypothesis of Probert et al. (2005) that total C:N is not a good indicator of decomposition patterns; instead it is important to know the form of the nitrogen, and hence specification of the C:N ratios of the carbohydrate fractions.

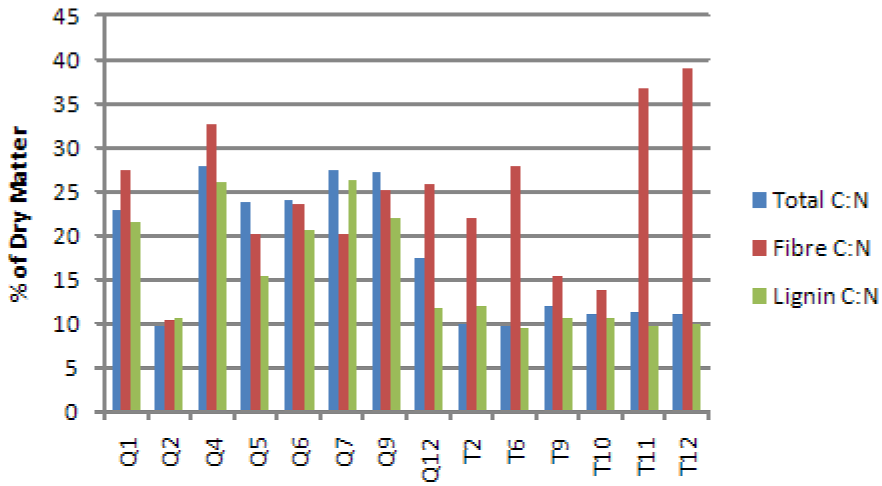

Figure 2. Total, fibre, and lignin C:N ratios of selected manure samples from Queensland (Q) and Tasmania (T).

Conclusion

The combination of laboratory methods was generally able to characterise the carbohydrate pools in manure samples and their carbon to nitrogen ratios. Calculating the NFC fraction by difference is a standard method of calculating NFC for feed analyses (CNCPS); however it is potentially a problematic method for manure. Because NFC is often only a small component of the manure it may lead to large errors. This is unlikely to make a large difference in estimating the total nutrient supply of the manure, but will likely change the dynamics of nitrogen release in relation to mineralisation and immobilisation. Future improvement of these analysis methods may include direct estimation of non-fibre carbohydrate components such as sugar and starch fractions. In addition the data support the conclusions of Probert et al. (2005) that C:N ratios of carbohydrate fractions are better indicators of manure quality than total C:N.

Acknowledgments

This experiment was performed as part of a Masters by Coursework unit at the University of Tasmania. We would like to sincerely thank Andy Measham and Angela Richardson who helped organise laboratory supplies and sample analysis. We also thank David Coates of CSIRO Sustainable Ecosystems who kindly supplied manure samples. Without the help and assistance of these people this student project would not have been able to proceed.

References

Delve RJ, Cadisch G, Tanner JC, Thorpe W, Thorne PJ and Giller KE (2001). Implications of livestock feeding management on soil fertility in the smallholder farming systems of sub-Saharan Africa. Agriculture, Ecosystems and Environment 84, 227–243.

Fox DG, Tylutki TP, Tedeschi LO, Van Amburgh ME, Chase LE, Pell AN, Overton TR and Russell JB. The Net carbohydrate and protein system for evaluating herd nutrition and nutrient excretion: Model Documentation. Department of Animal Science, Cornell University, Ithaca NY.

Reeves JB and Kessel JS (2002). Influence of ash on the fiber composition of dried dairy manures. Environmental Pollution 120, 239-244.

Morvan T and Nicolardot B (2009). Role of organic fractions on C decomposition and N mineralization of animal wastes in soil. Biol. Fertil. Soils 45, 477-486.

Probert ME and Dimes JP (2004). Modelling Release of Nutrients from Organic Resources Using APSIM. Modelling nutrient management in tropical cropping systems. ACIAR, Canberra.

Probert ME (2005). Modelling nitrogen mineralization from manures: representing quality aspects by varying C:N ratio of sub-pools. Soil Biology & Biochemistry 37, 279-287.

Sleutel S, De Neve MR, Prat Roibas MR, Hofman G (2005). The influence of model type and incubation time on the estimation of stable organic carbon in organic materials. Eur. J. Soil Sci. 56, 505–514.

Van Soest PJ, Robertson JB and Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74, 3583–3597.

Van Soest (1994). Nutrional Ecology of the Ruminant, Second Edition. Cornell University Press, Ithaca, NY.