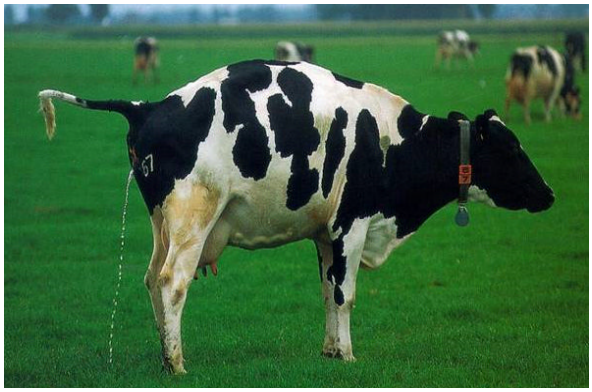
Project number: 5786
Funding source: DAFM
Date: September, 2012
Project dates: Nov 2007 - Jun 2013

Nutritional and management strategies to reduce Nitrogen excretion, Ammonia and Nitrous Oxide emissions



Key external stakeholders:

All farmers, Department of Agriculture, Food & Marine, Environmental Protection Agency.

Practical implications for stakeholders:

There is a strong relationship between urine Nitrogen (N) content and both N losses to water (nitrate leaching) and air (Nitrous Oxide emissions). As a result, the use of dietary manipulation could be an important mitigation measure for reducing both Nitrate leaching and Nitrous Oxide (N_2O) emissions. In addition, the Nitrous Oxide emission factor (amount of N_2O emitted per kg N applied) was observed to be <0.4%, which is considerably lower than the IPCC default value (2%), suggesting that soil type specific emission factors would greatly improve the assessment of sustainable farm systems. Benign Di-Nitrogen (N_2) is the main environmental loss pathway of N deposited in urine.

- **Farmers:** Optimising cow diet reduces N excretion and this directly reduces both Nitrate leaching and Nitrous Oxide emissions at little or no cost.
- **Policymakers:** Dietary manipulation results in lower reactive N loss to the environment. The measured Nitrous Oxide emission factor is considerably lower than the default value. DCD was highly effective at reducing N_2O emissions and leached N. Reduced cost application techniques could make it a viable mitigation option.
- **Scientific:** Di-Nitrogen gas (N_2) was the main environmental loss pathway observed of Nitrogen deposited in urine.

Main results:

- Nitrous Oxide emissions and Nitrate leaching were strongly related to urine N content. This suggests that dietary N manipulations can substantially reduce environmental Nitrogen losses.
- The main loss of Nitrogen from grazing animals is benign Di-Nitrogen gas emissions which accounted for close to 25% of the urine Nitrogen applied.
- The Nitrification inhibitor DCD reduced N_2O emissions and N leaching by up to 70% and 50% respectively. Increased pasture N uptake was also observed particularly in year one. However, the response to DCD was variable.
- The N_2O emission factors (EF_3 values) were below 0.4% from urine N applied in all treatments during both years, which is considerably lower than the current IPCC default value. In addition, the N_2O emission factor decreased with increasing urine N rate.

Opportunity / Benefit:

- Dietary manipulation can be used to substantially reduce Nitrogen loss to the environment from grazing cows. Nitrous Oxide emission factors for this free draining Irish soil are considerably lower than the IPCC default value.

Collaborating Institutions:

Lincoln University (New Zealand)
University College Dublin (UCD)

Contact Dr. Karl Richards Email: karl.richards@teagasc.ie.

Teagasc project team: Dr. Karl Richards
Dr. Gary Lanigan
Dr. Diana Selbie

External collaborators: Dr. Karina Pierce (UCD)
Prof. Hong Di,
Prof. Keith Cameron and
Dr. Jim Moir (Lincoln University, New Zealand)

1. Project background:

Losses of Nitrogen from agricultural production systems to the environment are of concern, particularly in the context of dairy expansion envisioned in Food Harvest 2020. Principally lost as ammonia (NH_3), Nitrous Oxide (N_2O) these emissions are deleterious to aquatic and terrestrial ecosystems and contribute directly or indirectly to climate change. Ireland, along with other countries has committed to reducing national emissions of these gases under the EU Climate and Energy Package and Gothenburg Agreement. As Irish agriculture, and in particular, animal production, contribute to large portions of national N_2O and NH_3 emissions, there is a requirement to examine strategies that reduce these emissions, of which dietary manipulation to reduce animal N excretion offers great potential. In addition to gaseous losses, Nitrogen can be lost to water via Nitrate leaching, contributing to deterioration of freshwater and estuarine ecosystems, drinking water quality and also contributing to indirect N_2O emissions. This project examined the potential of reducing urine N excretion by dietary manipulation on the fate of urinary N in the soil.

2. Questions addressed by the project:

This research addressed the following questions:

- Is there a relationship between urine N content and Nitrous Oxide emissions and Nitrate leaching?
- What proportion of the urine N applied is utilised by grass?
- What is the fate of urine N when applied to soil?
- Can Nitrification inhibitors reduce losses of Nitrogen to the environment?

3. The experimental studies:

Intact monolith lysimeters (0.5 diameter by 0.7m deep) were collected from intensively managed grassland in Teagasc, Moorepark and installed in a new facility in Johnstown Castle. Urine was collected from cows at milking a few days before the experiments started and was stored in a cold room prior to application. Urine was applied at 5 rates of Nitrogen, 0, 300, 500, 700 and 1000 kg N ha^{-1} to the lysimeters in late Autumn. Dicyandiamide (DCD), a Nitrification inhibitor was applied in solution form at 30 kg DCD ha^{-1} in two split applications following urine. Measurements of gaseous N emissions, Nitrate leaching and pasture N uptake were made for a calendar year following urine application in two consecutive experiments. The fate of urine N in soil was investigated using ^{15}N labelled urine at the 1000 kg/ha rate which enabled urine partitioning between plant uptake, Nitrate leaching and the Denitrification end products of N_2O and N_2 to be quantified.

4. Main results:

Increasing urine Nitrogen loading rate resulted in an increase in the cumulative Nitrous Oxide (N_2O) emissions, N leaching and pasture uptake. The relationships between urine N rate and N_2O emissions and N leaching were curvilinear, with the increase in N recovered in each fraction diminishing at the higher N rates. The exception was with pasture N uptake, where the relationship with urine N rate was curvilinear with an exponential increase at the higher N rates. The main driver for these responses was thought to be the increase in the supply of N in the soil with increasing urine N loading rate, which was able to be Denitrified, leached or taken up by the pasture. Application of the Nitrification inhibitor DCD reduced N_2O emissions and N leaching, and increased pasture N uptake, particularly in year one. However, the response to DCD was variable, and no consistent interaction between DCD and urine N rate was found. It is likely that at least some of the DCD was removed from the soil via leaching, which explained the reason for the variable response in N_2O emissions, N leaching and N uptake between urine N rates, and between years. As a percentage of the N applied, the mass recovery of N in N_2O emissions, N leaching and N uptake did not change significantly. The 'missing' N was recovered in soil immobilisation and N_2 emissions, using the ^{15}N isotopic balance method at the 1000 kg N ha^{-1} urine rate. The use of mass balance and ^{15}N balance methods highlighted the significance of mineralisation-immobilisation turnover processes in a urine patch and their contribution to N loss pathways. This study showed that the largest loss of Nitrogen was removal via environmentally benign N_2 which has major implications for N balance studies in pastoral soils.

Contact Dr. Karl Richards Email: karl.richards@teagasc.ie.

5. Opportunity/Benefit:

Nitrogen loss to the environment can be reduced through reducing N excretion via dietary manipulation and the use of DCD. Nitrogen losses from urine patches are dominated by environmentally benign N_2 emissions.

6. Dissemination:

The results of the project have been presented at national and international conferences. There are two scientific papers under review in high impact international journals. The outputs from the project have been sent to relevant national policymakers.

Main publications:

D.R. Selbie, G.J. Lanigan, H.J. Di, J.L. Moir, K.C. Cameron, K.G. Richards (2010) Importance of urinary N content on Nitrous Oxide emissions from grassland soil lysimeters. Ecotrons & Lysimeters conference, 29-31 March, 2010, Nancy, France.

D.R. Selbie, K.G. Richards, G.J. Lanigan, H.J. Di, J.L. Moir, K.C. Cameron, M.I. Khalil (2010). Manipulating N excretion – effect on N_2O emissions from grassland soil. A Climate for Change conference, 24-25 June 2010, Dublin, Ireland.

D.R. Selbie, G.J. Lanigan, H.J. Di, J.L. Moir, K.C. Cameron, K.G. Richards (2011). Improving Nitrogen efficiency using a Nitrification inhibitor on urine-affected soil – a grassland lysimeter study. Agricultural Research Forum, 14-15 March, 2011, Tullamore, Ireland.

D.R. Selbie, K.C. Cameron, H.J. Di, J.L. Moir, S. Whelan, K. Pierce, G.J. Lanigan, K.G. Richards (2011) Improving Nitrogen efficiency from urine applied to grassland lysimeters in Ireland. Nitrogen and Global Change conference, 11-14 April, 2011, Edinburgh, Scotland.

D.R. Selbie, K.C. Cameron, H.J. Di, J.L. Moir, G.J. Lanigan, K.G. Richards (2012). The effect of urinary Nitrogen content and DCD Nitrification inhibitor on Nitrogen emissions from grassland lysimeters in Ireland. Joint SSA and NZSSS Conference, 2-7 December 2012, Hobart, Australia.

D.R. Selbie, K.C. Cameron, H.J. Di, J.L. Moir, G.J. Lanigan, R.J. Laughlin, K.G. Richards (2012). The fate of urine Nitrogen with use of a Nitrification inhibitor. 17th International Nitrogen Workshop, 26-29 June, Wexford, Ireland.

D.R. Selbie, K.C. Cameron, H.J. Di, J.L. Moir, S. Whelan, K. Pierce, G.J. Lanigan, K.G. Richards (2013). Improving Nitrogen efficiency from urine applied to grassland lysimeters in Ireland. Greenhouse Gases and Animal Agriculture Conference, 23-26 June 2013, Dublin, Ireland.

Selbie, D.R., Cameron, K.C., Di, H.J., Moir J.L., Lanigan G., Richards K.G. (In review) The effect of urinary Nitrogen loading rate and DCD Nitrification inhibitor on Nitrous Oxide emissions from an Irish grassland soil, *J. Agricultural Sciences*.

Popular publications:

Richards, K.G., Selbie, D., Cahalan, E., Dennis, S., Ernfors, M., Minet, E., Lanigan, Gary, Lalor, S., Murphy, J.B., Watson, C., Laughlin, R., McGeough, K., Mueller, C., Rooney, D., Cameron, K., Di, H., Khalil, I. and Hennessy, D. (2011). Reducing N loss using inhibitors. *Tresearch 6* (2) p. 12-13 (Summer 2011)

7. Compiled by: Dr. Karl Richards

Contact Dr. Karl Richards Email: karl.richards@teagasc.ie.