Determination of Nutrient Digestibility, Nitrogen Retention and Excretion and ^{15}N Dilution from Labelled Corn in Swine Diets

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Abstract

The objectives of the study were to follow feed-nitrogen (N) using ^{15}N-isotope in terms of digestibility, retention, and dilution in faeces and urine of growing pigs fed unlabeled and labelled corn diets. Corn containing varied concentration of ^{15}N-isotope enrichment in grain was obtained from a study conducted to identify fertilizer application techniques that could maximize efficiency of ^{15}N-isotope uptake into grain, to determine variety differences in uptake efficiency, and to identify potential differences in uptake due to application rates. A total of 12 barrows (mean initial BW = 20.0 ± 1.28 kg, 4 pigs/diet) were used in a completely randomized design, with three dietary treatments: a) Control (unlabelled corn), b) Low ^{15}N-enrichment (mean ^{15}N-isotope = 3.5%), and c) High ^{15}N-enrichment (mean ^{15}N-isotope = 4.1%). The animals were weighed at start and end of study. Pigs were kept in individual crates for 11-d, of which 5-d were for acclimation and 6-d for sample collection. All animals were fed at 70% of predicted ad libitum intake. Chromium oxide (0.2% of diet) was used as a marker to initiate and terminate faecal and urine sampling. Mean daily faecal and urine excretion per pig was 141.99 ± 81.60 g and 1302.38 ± 776.01 ml, respectively. There were no differences ($P > 0.05$) among diets in ADFI, ADG, and BW. Diets with ^{15}N label, however, resulted in greater ($P < 0.01$) amounts of ^{15}N-isotope label in feces (0.43 vs. 2.04 vs. 2.06 N atom; SEM= 0.142 for Control, Low, and High ^{15}N-enrichment diets, respectively) and urine (0.40 vs. 1.37 vs. 1.38; 0.036) than in Control diet. Both urine and faecal percent N were higher ($P < 0.02$; 0.27 vs. 0.49 vs. 0.31%; 0.064) and ($P < 0.04$; 2.63 vs. 3.25 vs. and 3.10%; 0.179) for Low ^{15}N diet than for Control and High ^{15}N diets, respectively. There were no differences ($P > 0.05$) in N digestibility (61.23 vs. 46.17 vs. 59.41%; 5.562), retention (31.89 vs. 13.73 vs. 23.10% of intake; 9.734) and balance (17.94 vs. 8.43 vs. 14.32g; 5.463) among diets. The study provides evidence that ^{15}N atom can be used to trace nitrogen flow from grain, into the animal, and back to the field.

Key Words: Digestibility, ^{15}N-Isotope Dilution, Nitrogen Balance, Nutrient Management, Swine Production, Waste Management

Introduction

Historically, agricultural systems relied on application of manure on land because of its beneficial fertilizer values, among other positive effects on soil. However, concerns regarding environmental pollution due to confined and concentrated production practices, increased waste generation, and nutrient management are on the rise (Dourmad *et al.*, 1999; Jongbloed & Lenis, 1998; Jongbloed *et al.*, 1999). Potentials for environmental degradation from agricultural enterprises have necessitated governmental regulations designed to ensure proper disposal of manure. Nutritional and managerial approaches of reducing N losses in the form of ammonia and other volatile organic compounds are essential to ensure environmental sustainability in agriculture (Colina *et al.*, 2001). To improve crop N use efficiency of animal manures, the availability of N in individual manure components must be better understood (Jensen *et al.*, 1999).

Most of the N consumed by animals is excreted as manure, an excellent source of fertilizer for crop production. The cycling of N potentially could lead to environmental degradation through volatilization, leaching, and runoffs (de Vries *et al*., 2001; Rotz, 2004). Managing animals, crops, and nutrient flow for effective and efficient use of the available nutrients remains a challenge (Klausner, 1995). Low digestibility of nitrogenous compounds, presence of dietary factors that increase endogenous N losses in faeces and urine, and consumption of amino acids in excess of biological needs, all contribute to increasing amount of N excreted. Since considerable amounts of manure N may volatilize, be immobilized or denitrified, reliable estimation is crucial for protecting the environment while sustaining crop production. Use of ^{15}N-isotope can be suitable to distinguish exogenous from endogenous fractions and elements of interest, especially in nutritional studies (Gaudichon *et al.*, 1995, 1999; Mahé *et al.*, 1994) and also useful for studying the dynamics of manure and its subsequent fate in the feed-animal-manure-soil-crop-environment continuum.

The overall objectives of the project were to define linkages among components of integrated animal-cropping systems influencing nitrogen, phosphorus, and carbon balances, to evaluate quantity of nitrogen input and output geared towards improving the fertilizer value of swine manure by increasing N retention in manure. The specific objectives were to determine nutrient digestibility, nitrogen retention and excretion and

^{15}N-isotope dilution/recovery in faeces and urine of growing pigs fed labelled and unlabelled corn.

Materials and Methods

Source of ^{15}N-enriched Corn Feed

This study was part of an integrated multi-disciplinary project involving the Departments of Animal Sciences, Crop Sciences, and Agricultural Engineering at University of Illinois. A trial conducted in summer of 2002 by the Department of Crop Sciences aimed at identifying ^{15}N-isotope fertilizer application techniques that could maximize uptake efficiency into corn grain, determine variety differences in uptake efficiency, and potential uptake differences due to application rates. Enrichment of the ^{15}N-isotope in corn grain from the 13 different treatments ranged between 2.24 to 4.49 % atom (Table 1).

Table 1. Effect of ^{15}N-isotope Application Method, Application Rate, and Corn Hybrid on Percent ^{15}N-enrichment, Nitrogen, Crude Protein and Quantity in Diets for Trials on Digestibility and Labelled ^{15}N-isotope Retention with Growing Pigs

Treatment	^{15}N-enrichment, %	N, %	CP, %	Quantity, kg
Trt 1 (V6,R1 injected in soil)[a]	3.6071	1.38	8.63	3.88
Trt 2 (V12,R1R2 – injected in soil)[a]	3.5190	1.30	8.13	3.95
Trt 3 (V10 – injected in soil)[b]	4.4116	1.37	8.56	3.66
Trt 4 (V12 – injected in soil)[b]	3.9851	1.42	8.88	3.66
Trt 5 (R1 – injected in soil)[a]	3.3611	1.42	8.88	3.34
Trt 7 (foliar spray)[b]	4.4906	1.27	7.94	1.92
4g N/plant (injected in soil)[a]	3.4363	1.35	8.44	3.75
6g N/plant (injected in soil)[b]	3.9289	1.41	8.81	3.90
Hybrid 1,(33G26 – injected in soil)[b]	3.7015	1.41	8.81	3.59
Hybrid 2 (32H58 – injected in soil)[b]	3.8425	1.60	10.00	3.47

Hybrid 3 (33P66 – injected in soil)[a]	3.3944	1.42	8.88	3.64
2g N/plant (injected in soil)[c]	2.3123	1.36	8.50	4.22
Trt 6 (injected in plant)[c]	2.2433	1.28	8.00	1.04

[a]Combined together to form the Low ^{15}N diet

[b]Combined together to form the High ^{15}N diet

[c]Not used because of low concentration of ^{15}N-isotope enrichment Trt = treatment

Treatments 1-7 and 2g, 4g, 6g N/plant used Pioneer 33G26 (Hybrid 1) to determine effects of method and rate of N application

Experimental Design, Animals and Treatments

Protocols for these studies were approved by the University of Illinois at Urbana-Champaign Institutional Animal Care and Use Committee. The study was conducted as a completely randomized design in an environmentally controlled metabolism room at the Swine Research Centre.

The current experiment used corn harvested from the above trial. Out of the 13 corn treatments, two were not used in the pig study because of low ^{15}N-isotope enrichment in the grain. Individual bags of labelled corn-treatments obtained from the Department of Crop Sciences, University of Illinois, were ground using a Thomas-Wiley Mill (Thomas Scientific, model 4, Swedesboro, NJ) grinder fitted with a 2 mm screen. Each of these treatments was stored individually in plastic bags after grinding until the time of diet preparation. The Control diet, however, was ground using the mill at Swine Research Centre. About 39 kg of ^{15}N labelled grain was used for this study. Grains that had lower ^{15}N-isotope enrichment were mixed together (18.56 kg) to make the Low ^{15}N diet while those that had higher ^{15}N-isotope enrichment were combined (20.19 kg) to make the High ^{15}N diet (Table 1). Three dietary treatments were thus formulated using labelled or unlabelled corn, with base ingredient as corn: a) Control unlabeled diet, b) Low ^{15}N labelled diet (mean ^{15}N-isotope enrichment = 3.5%), and c) High ^{15}N labelled diet (mean ^{15}N-isotope enrichment = 4.1%). The unlabelled corn diet was obtained from among Monsanto hybrids (CE18, DK65-25) that were on trial for nutrient digestibility. The labelled corn treatments used same ingredients and amounts as the Control diet (Table 2). Mixing for all diets was done at the Swine Research Centre Feed Mill, University of Illinois, and feed samples taken at the time of preparation.

Table 2. Ingredients and Calculated Composition of the Control Diet used in Digestibility and Labelled ^{15}N-isotope Dilution Trial with Growing Pigs (as Fed Basis)

Ingredients	**Basal diet, %**
Corn	97.39
Dical-PO_4	1.25
Limestone	0.91
Trace-mineral salt[a]	0.35
Illini vitamin mix[b]	0.10
Composition, %	
Crude protein	8.64
Fiber	2.53
Lysine	0.24
Lysine (true illeal digestible)	0.21
Tryptophan	0.06
Tryptophan (true illeal digestible)	0.05
Threonine	0.31
Threonine (true illeal digestible)	0.26
Methionine + Cystein	0.37
Phosphorus (available)	0.51
Calcium	0.65
ME (kcal/kg)	3.331

[a]Trace mineral premix contained: 85.7 mg Se, 100 mg I, 2.3 g Cu, 5.7 g Mn, 25.7 g Fe, 28.6 G Zn, 855 g NaCl per kg mixture.
[b]Vitamin premix contained: 3,000,000 IU Vit. A, 330,000 IU Vit D_3, 44,000 IU Vit. E, 2.2 g Vit K, 17.9 mg Vit B_{12}, 4.4 mg Riboflavin, 12.1 g D-Pantothenic acid, 16.5 g Niacin, roughage product to 1 kg.

A total of twelve barrows (*Sus scrofa*, PIC cross–Line 337 sires × C22 dams, initial mean BW = 20.01 ± 1.28 kg) were used. Pigs were formed into outcome groups of three animals on the basis of weight and randomly assigned to treatment and individual metabolism crate from within outcome group, giving four pigs per treatment. Crates consisted of solid side walls, expanded metal flooring, a feeder, and a water nipple providing water *ad libitum*. Pigs were kept in crates for 11 d, of which 5 d were for acclimation to the cages and feed and 6 d for sample collection. No additional sources of protein was included in the diets to avoid diluting the ^{15}N-isotope from corn.

All animals were fed the Control diet during the adaption after which they were switched to their respective dietary treatments. Diets were fed at 70% of predicted *ad libitum* intake rate (to minimize feed refusal/wastage) based on metabolic BW and formulas from NRC (1998), and divided into two equal rations fed at 0700 and 1500, respectively. Feed refusals were collected and weighed every morning before fresh feed was provided. All animals were weighed on the day of assignment to treatments and at the end of study. A Hobo H8 data logger (Onset Computer Corporation, Bourne, MA) was used to monitor and collect temperature and relative humidity data from the room over the study duration, with means of 26.7 ºC and 49%, respectively.

Feed, Faeces and Urine Sampling

Chromium oxide (0.2% of diet) was added to rations as a marker to initiate and terminate faecal and urine sampling periods. Urine collection started and ended approximately four hours after adding the marker to the feed on the morning of d 5 and 10 of trial, respectively. Urine samples were collected in a bucket containing 10 ml HCl to lower pH, thus minimize ammonia volatilization. A 100 ml of urine was sampled every morning and stored in plastic bottles at -20 ºC for N determination later. Faecal collections started and ended with the appearance of the marker in faeces. Daily faecal excretion was collected, weighed, mixed into composite, and then stored at -20 ºC in Zip lock plastic bag for each pig over the collection period. At the end of collection period, faecal samples were thawed out, homogenized, and freeze-dried in a Virtis Genesis Freeze Dryer (SP Industries, Model 25SL Gardiner, NY). Weight of freeze-dried samples was taken at the end of drying period for dry matter determination. Faecal samples were ground using a Thomas-Wiley Mill (Thomas Scientific, model 4, Swedesboro, NJ) grinder fitted with a 2 mm screen then stored in Zip Lock bags at -20 ºC for later analysis of N.

Feed, faecal, and urine samples were assayed for total N using Kjeldahl procedures and for ^{15}N-isotope enrichment using Mass Spectrometry equipped with an automated Rittenberg System (Spectrumedix, Nuclide 3-60-RMS, State College, PA) following established protocols (Bremner & Mulvaney, 1982; Mulvaney, 1993).

Statistical Analysis

Individual pig served as an experimental unit. Data were analyzed using GLM procedures of SAS (SAS Inst., Carry, NC), with models including animal and treatment. Samples for urine were analyzed as repeated measures over time, with effect of day added in the model. Least squares means were derived and compared using PDIF and STDERR options. Type III F test was used to assess the significance at $P < 0.05$ level.

Results

All pigs remained healthy throughout the study period. Calculated and analyzed crude protein content and percent ^{15}N-enrichment of the diets are presented in Table 3. The dietary treatments were very similar in calculated CP content; however, analyzed CP content showed numerical linear increase from Control to High ^{15}N diet. Analyzed values for ^{15}N-isotope in the Control diet indicated amounts similar to natural abundance (0.366 δ ^{15}N). Means for analyzed concentrations of ^{15}N-isotope in the two labelled diets closely matched formulated values (3.5 and 4.1% ^{15}N-enrichment). Feed consumption was not different among treatments; however the High ^{15}N diet had numerically lower intake compared to Control and Low ^{15}N diets. Mean daily faecal and urine production per pig was 141.99 ± 81.60 g and 1302.38 ± 776.01 ml, respectively, with no differences ($P > 0.05$) among treatments.

Both urine and faecal percent N were higher ($P < 0.02$; 0.27 vs. 0.49 vs. 0.31%; 0.064 and ($P < 0.04$; 2.63 vs. 3.26 vs. and 3.10%; 0.179) for Low ^{15}N than for Control and High ^{15}N diets, respectively. Control diet had lower ($P < 0.0001$) ^{15}N-enrichment in both faecal and urine samples as expected; however, faecal and urinary excretions from the labelled diets were not different ($P > 0.05$) in ^{15}N-isotope concentration, even though the High ^{15}N diet had numerically slightly higher values (Table 4). Mean daily variation in ^{15}N-isotope enrichment for urine is presented in Figure 1. The Control diet had lower ($P < 0.004$) ^{15}N-isotope concentration in urine than the Low and High ^{15}N diets; however, the labelled diets were not different ($P > 0.05$) from each other. Concentration of ^{15}N-isotope in urine increased faster during the first three days and much slower towards the end of study.

Table 3: Crude Protein Content and ^{15}N-isotope of the Diets used during Digestibility and Labelled ^{15}N Dilution Trial in Growing Pigs

	Dietary treatments		
Composition	**Control**	**Low ^{15}N**	**High ^{15}N**
Crude protein, %			
Calculated	8.64	8.59	8.83
Analyzed	7.78	8.28	8.58
^{15}N-isotope, % enrichment			
Calculated	0.00	3.46	4.06
Analyzed	0.37	3.40	3.86

Table 4: Analyzed Urine and Faecal Content of Nitrogen and ^{15}N-enrichment from Diets used in Nutrient Digestibility, Retention, and ^{15}N Dilution Trial with Growing Pigs

	Diets				
Measures	**Control**	**Low ^{15}N**	**High ^{15}N**	**SE**	**P-value**
Urine					
Nitrogen, %	0.27^{b}	0.49^{a}	0.31^{b}	0.06	0.02
^{15}N-isotope enrichment, %	0.39^{b}	1.37^{a}	1.38^{a}	0.04	0.0001
Faeces					
Nitrogen, %	2.63^{b}	3.25^{a}	3.09	0.18	0.04
^{15}N-isotope enrichment, %	0.43^{b}	2.04^{a}	2.06^{a}	0.14	0.0001

^{ab}Means in the same row with different superscripts differ at the indicated P value

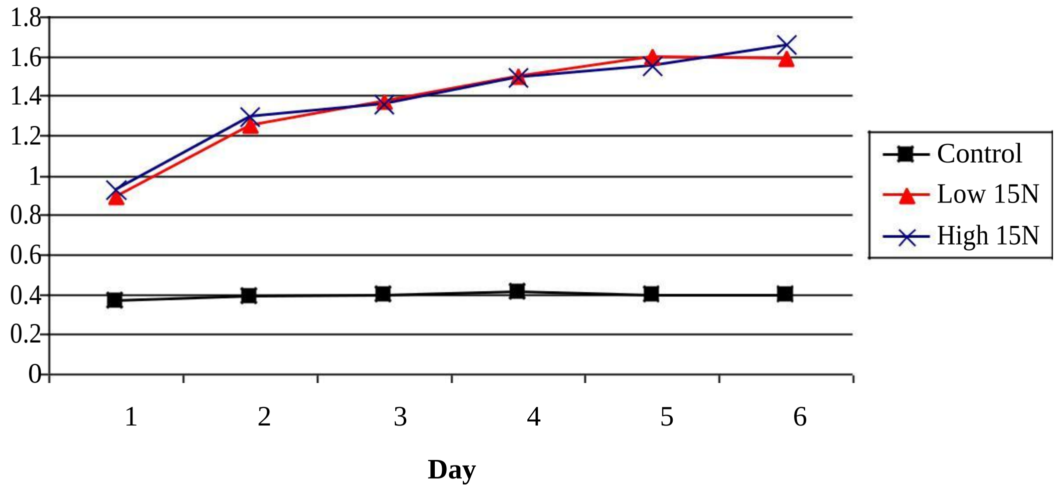

Figure 1. Mean (± SEM = 0.07, n = 12) Daily Change of 15N-isotope Enrichment in Urine from Growing Pigs Fed Corn Diets with or without 15N-isotope Label

As expected, 15N-isotope enrichment in urine from the Control diet was different ($P < 0.004$) from the Low and High 15N diets; however there was no difference ($P > 0.05$) between the labelled diets.

Animal growth performance in terms of ADFI, ADG, gain to feed ratio, and BW gain were not different ($P > 0.05$) among dietary treatments (Table 5). Amount of total N excretion was not different ($P > 0.05$) among treatments; however, Low ^{15}N diet was numerically higher (6.49 vs. 8.59 vs. 6.69 g, for Control, Low, and High ^{15}N diets, respectively). Most of the ^{15}N-isotope was recovered in faeces rather than urine in both treatments, with higher values from the Low ^{15}N diet than High ^{15}N diet (45.41 vs. 33.56%, respectively). Results for N digestibility, retention, balance, and biological efficiency were more favourable for the Control diet that the labelled diets (Table 6).

Table 5: Body Weight, Feed Intake, Daily Gain, and Gain to Feed Ratio of Growing Pigs Fed Corn Diets with or without ^{15}N-isotope Label

	Diets				
Performance	**Control**	**Low ^{15}N**	**High ^{15}N**	**SE**	**P-value**
Initial weight, kg	20.13	20.16	19.80	0.61	0.90
Final weight, kg	20.52	20.57	20.19	0.76	0.93
ADFI, kg/d	0.74	0.74	0.67	0.03	0.30
ADG, kg/d	0.036	0.038	0.035	0.23	1.00
Gain to feed ratio, kg	0.048	0.051	0.050	0.31	1.00

Table 6: Nitrogen Balance for Growing Pigs Fed Corn Diets with Labeled ^{15}N-stable Isotope

	Dietary treatment				
Measures	**Control**	**Low ^{15}N**	**High ^{15}N**	**SE**	**P-value**
Pig wt, kg	20.52	20.57	20.19	0.76	0.93
Feed intake, g/d	763.00	751.00	662.50	310.69	0.36
Dry matter, %	89.01	93.10	93.25	-	-
Dry matter intake, g/d	679.15	699.18	617.18	-	-
Nitrogen intake, g/d	10.63	10.74	9.73	0.75	0.60
Mean daily faecal output, g	138.52	163.94	123.51	18.77	0.35
Dry matter of faeces, %	48.39	46.80	48.20	2.68	0.89
Analyzed nitrogen output in faeces, g/d	3.69	5.36	3.75	0.65	0.17
Total nitrogen output in feces, DM basis, g	10.49	14.98	10.88	1.70	0.17
Nitrogen output in faeces, DM basis, g/d	1.75	2.50	1.81	0.28	0.17
Mean daily urine output, ml	1552.63	1033.63	1320.88	377.45	0.64

Analyzed nitrogen in urine, g/100 ml	0.27	0.49	0.31	0.14	0.52
Total nitrogen in urine, g/100 ml	16.70	19.39	17.66	2.65	0.77
Nitrogen output in urine, g/d	2.78	3.23	2.94	0.44	0.17
Total nitrogen output, g/d	6.48	8.59	6.69	0.80	0.18
Nitrogen digested, g/d	53.31	49.45	47.52	3.67	0.55
Nitrogen digestibility, %	83.62	76.66	81.82	2.19	0.12
Nitrogen retention, % of intake	57.50	46.46	47.94	7.06	0.51
Nitrogen balance, %	36.61	30.06	29.85	5.31	0.61
Biological value of feed protein, %	68.53	60.28	59.20	8.40	0.70

Discussion

The drive towards sustainable agricultural enterprises is ever on the rise and there is need to initiate and work in multi-disciplinary/interdisciplinary type projects involving livestock and crop producers as well as soil and environmental scientists. In order to understand the different components of a system the various parts can be investigated in pieces while maintaining focus on the whole, thus enabling results that address the system rather than a component. Keeney (1982) defines sustainable agriculture as system that is environmentally sound, productive, profitable, and maintains the social fabric of the community. It is a development that fulfils the need of the present generation without compromising the potentials for future generations to fulfils their needs (Brundtland, 1989). Embracing an ecological and systems approach to agriculture, whereby methods that ensure production of food and fibre are coupled with environmental responsibility and stewardship, and economic, social, and community viability, is currently of paramount importance.

Swine production systems have and continue to intensify, resulting in the need to handle, store, and dispose of large volumes of waste. It has been estimated that agricultural practices account for about 90% of total atmospheric anthropogenic sources of NH_3 emissions, of which livestock accounts for 80% in Europe (Van Der Hoek, 1998). Land application of wastes and recycling nutrients has been a common and accepted practice of manure disposal; however, less credit is given to nutrients applied in manure (Nowak *et al.*, 1997). The Corn Belt States of Iowa, Illinois, Missouri, Indiana, and Ohio with their fertile, productive, and intensively cropped land has major potential competitive advantage for livestock and crop producers to maximize use of nutrients in livestock manure as fertilizer for corn and soybeans production. Such an approach would lead to sustainable, integrated, crop and livestock production system.

However, adequate management and realistic application rates ought to be identified to ensure minimal adverse impacts on animal productivity and environmental quality. Increased degradation of drinking water and eutrophication of coastal and inland water mashes are consequences of steadily increasing NO_3 levels in surface, ground, and coastal waters, much of which is being blamed on livestock operations (Jongbloed & Lenis, 1998). Ingestion of NO_3 in drinking water above the established limit of 10 mg/L by US Environmental Protection Agency has been cited as cause of methemoglobinemia in infants (Johnson *et al.*, 1987).

Nutrients released from manure are highly variable as shown through the use of fertilizer equivalent approach, ranging from 12 to 63% of dairy manure N and from 12 to 89% of dairy manure P being taken up during the first growing season after application, with availability in subsequent years being even more difficult to predict (Motavalli *et al.*, 1989; Klausner *et al.*, 1994). Most current estimates for manure N contribution to crop N use these indirect measures with a number of assumptions. Manure N is organically bound, varies widely in composition and nutrient content, and must be mineralized for nutrients to become plant-available; as opposed to fertilizer N which has guaranteed nutrient content, is more soluble and readily available for crop uptake (Jansson & Persson, 1982).

The stable isotope, ^{15}N, has been used extensively in studies to elucidate dynamics of nutrient flow, especially fertilizer N to crops (Hauck & Bremner, 1976; Menzel & Smith, 1984; Beline *et al.*, 2001). A number of studies have used the technique in following the fate of manure N in agroecosystem (Chantigny *et al.*, 2004; Thomsen, 2004; Muñoz *et al.*, 2003). Other studies have reported ^{15}N-isotope manure labeling for poultry (Kirchmann, 1990; Uenosono *et al.*, 2002), dairy (Powell & Wu, 1999; Muñoz *et al.*, 2004; Powell *et al.*, 2004), and sheep (Sørensen & Jensen 1998); with some studies focusing on amino acid flow and endogenous N sources in pigs and rats (de Lange *et al*., 1992; Lien *et al.*, 1997; Hodgkinson *et al.*, 2003). However, its use in nutrient cycling has been limited, partly due to the high cost of ^{15}N, large quantities required to enrich sufficient feed, as well as the need for lengthy feeding period for homogeneous labelling of manure. Faecal N is composed of N undigested residues in feed, gut microbial products and microorganisms, and N from digestive tract (Mason & Fredriksen, 1979). The use of ^{15}N-isotope was essential because it enabled direct tracking of N in the soil-crop-animal-manure continuum, providing more reliable, accurate, and direct measure. Sommer and Husted (1995) report that of the total N excreted by pigs, urine comprises 55-60%, 70% of which is urea-N.

Nitrogen has been determined to be the most limiting crop nutrient, especially for cereals, and greater amounts of manure than fertilizer N are applied to crops because of its lower N availability. However, repeated application can cause N accumulation in soils with potential long term environmental hazards (Meisinger, 1984; Muñoz *et al.*, 2003). Optimal use of manure to ensures adequate supply of nutrients to crops while avoiding pollution problems, require accurate and reliable estimates of nutrient availability to crops during the growing season. Even though fertilizer N is readily soluble in soils and becomes immediately available for crop uptake, it can be highly susceptible to leaching losses and may cause long term serious consequences (Bouldin *et al.*, 1984; Comfort *et al*., 1987). Sutton *et al*. (1978) observed greater downward movement of NO_3^- in plots that received fertilizer rather than manure applications. As well, He *et al*. (1994) report that manure N is more efficiently and readily available to crops than recycling the same through straw and green manure.

Conclusion

Feeding ^{15}N labelled corn diets does not affect performance; however, because the diets were deficient in CP and were fed at restricted amounts, performance of all animals was markedly impacted negatively over the duration of the study, thus very small gains in weight. The difference in ^{15}N concentrations of the labelled diets was not large enough to cause significant differences in faecal and urinary dilution. The labelled diets, however, showed higher amounts of the ^{15}N than the control. Digestibility, retention, and balance of N were better for the Control diet suggesting that a more comparable result ought to use feed sources of similar origin and nutrient content.

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