

¹⁵N Labeling of Dairy Feces and Urine for Nutrient Cycling Studies

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Introduction

The economic value of animal manure depends on its ability to provide nutrients to crops. The timely delivery and application of known amounts of manure to specific fields is the primary basis for proper manure management. Estimates of manure nutrient availability to crops, otherwise known as “nutrient credits”, are currently single nitrogen (N), phosphorus (P) and potassium (K) values given for the type of manure applied (solid or liquid) and method of application (incorporated or not). Nutrient credits are adjusted to account for multiple years of manure application, residual nutrient availability, etc.

Although it has been shown that proper manure management can be profitable through reduced fertilizer costs, many farmers do not credit the nutrients contained in manure. For example, in areas where manure has been land-spread, many farmers continue to apply fertilizers in sufficient quantities for attaining desired crop yield. The lack of manure nutrient crediting by farmers may be due to many factors that make manure an undependable source of plant nutrients, including differences in soil fertility levels where manure application experiments were conducted, inherent shortcomings in the “fertilizer equivalent” approach for estimating nutrient availability, etc.

The stable isotope ¹⁵N has been used extensively to evaluate the availability of fertilizer-N to crops. The use of ¹⁵N in nutrient cycling studies involving animal manure has been limited. This has been due partially to the high cost of ¹⁵N and the large quantities needed to enrich a sufficient amount of forage for feeding and labeling feces and urine. Also, the homogeneous ¹⁵N labeling of manure-N components must be assured. A disproportionate labeling of the microbial- and endogenous-N components in feces, or the undigested feed-N excreted in feces may lead to great error when determining the rate and extent of manure-¹⁵N mineralization in soils. The objective of the following experiment was to study the ¹⁵N enrichment pattern of dairy feces and urine that can be used in various short-

(e.g. manure/soil incubations, greenhouse trials) and long-term (field trials) nutrient cycling studies. Relative ¹⁵N enrichment of fecal-N fractions was also studied.

Materials and Methods

Corn (NK N1500) and alfalfa (Cenex Trailblazer) plants were enriched in ¹⁵N at the University of Wisconsin Hancock Research Station (44° 7' N, 89° 32' W) on a Plainfield sand (mixed, mesic Typic Udipsamment) during the 1997 cropping season. Ammonium sulfate, containing 12.3 atom % ¹⁵N, was applied at an equivalent rate of 75 kg N ha⁻¹. The corn plants were harvested at one-third milkline (70% moisture), chopped to three-quarter inch lengths and ensiled in PVC silos. A 20 m² area of a second-year alfalfa stand was fertilized with 10 atom % ¹⁵N at an equivalent rate of 100 kg N ha⁻¹ in each of two applications. Alfalfa was harvested three times during the season and conserved as hay.

Two ruminally-fistulated non-lactating dairy cows weighing approximately 420 kg were utilized in the feeding trial. The animals were adapted to a diet consisting of 55% alfalfa hay and 45% corn silage on a dry matter (DM) basis (atom % ¹⁵N at natural abundance) for 7 d. On the last day of the adaptation period, indwelling catheters were inserted into the bladders for urine collection. For 36-h thereafter, ¹⁵N-enriched alfalfa hay and corn silage were fed at the 55% and 45% ratio used during the adaptation period. Cows were kept in two adjoining stanchions and bedded with rubber mats. Total feces and urine were collected at 4, 8 or 12-h intervals after initial offer of ¹⁵N-enriched forage up to a total of 192-h. Feces and urine from each collection were frozen immediately. Total-N and ¹⁵N concentrations in feeds, feces and urine were determined using a Carlo Erba elemental analyzer coupled with a Europa 20/20 tracer mass. Cell wall components (NDF) of feeds and feces were determined using the detergent system as neutral detergent fiber. Total-N and ¹⁵N contained in cell walls (NDIN) of feeds and feces were determined as neutral detergent insoluble N. The NDF-soluble-N (NDSN) fraction in feed (cell wall contents) and feces

(microbial-N and endogenous-N that was secreted into the digestive tract and excreted) was obtained from the difference between total-N and NDIN.

Results and Discussion

At the end of the growing season, approximately 36% of the applied fertilizer- ^{15}N was accounted for in the three alfalfa harvests and 73% in corn silage. The ^{15}N -enriched diet consisted of approximately 55% alfalfa and 45% corn silage DM and had a total-N content of 19.42 g kg^{-1} of which 4.026 atom % was ^{15}N . The pattern of ^{15}N excretion in urine and feces was similar for both cows (Fig. 1). ^{15}N began to appear in urine between 4- to 8-h and in feces between 16- to 24-h after the initial offer of ^{15}N -enriched feed. Peak ^{15}N concentrations were attained by 30-h in urine (1.642 % ^{15}N) and by 54-h in feces (2.341 % ^{15}N). A more rapid ^{15}N excretion in urine than feces reflected rapid absorption of labeled $^{15}\text{NH}_3$ from the rumen and its conversion into urea in the liver. ^{15}N enrichment approached basal levels 132-h after feeding for both urine and feces. Peak ^{15}N concentrations attained 41% in urine and 58% in feces of the ^{15}N concentration in feed. Of the total ^{15}N fed, 97% was recovered by 192-h, 53% in urine and 44% in feces. Most (68%) of the ^{15}N fed was recovered within 96-h.

Between 60 to 70% of the total-N excreted in feces was NDSN and 30 to 40% as NDIN (Fig. 2). A comparison of the ^{15}N concentrations in total-N and NDIN (Fig. 3) indicates that ^{15}N labeling of NDIN and NDSN fecal components was uniform.

The various ^{15}N enrichment levels of urine and feces offer possibilities for differential ^{15}N use in short- and long-term nutrient cycling studies involving animal excreta. For example, highly enriched material, such as urine captured between 24- and 72-h and feces captured between 32- and 84-h after feeding (Fig. 1) could be used for long-term field trials aimed at determining crop uptake of manure-N in the first, second and third year after initial manure application. Manure of lower ^{15}N enrichment could be used for shorter term studies, such as manure/soil incubations and

greenhouse trials. The minimum atom % ^{15}N abundance of urine or feces required for a particular nutrient cycling study would depend on the expected ^{15}N content of soil extracts, crops, etc. after manure application and the detection limit of the mass spectrophotometer.

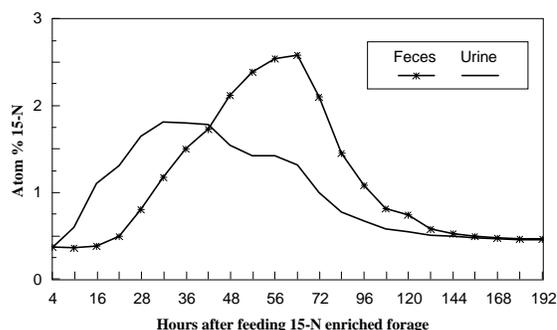


Figure 1. Pattern of ^{15}N excretion in dairy feces and urine.

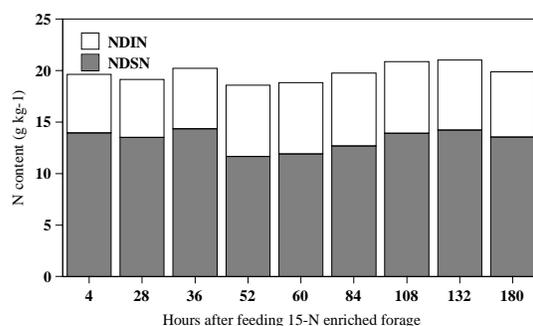


Figure 2. Neutral detergent soluble (NDSN) and insoluble (NDIN) nitrogen in dairy feces

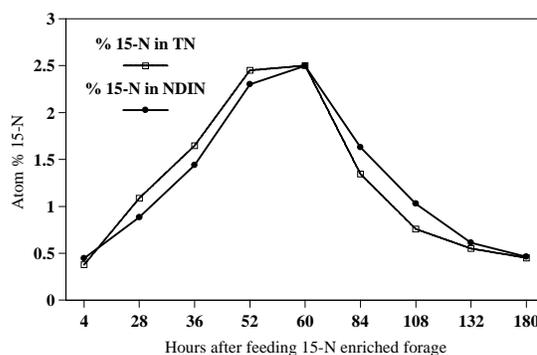


Figure 3. Atom % ^{15}N in total nitrogen (TN) and neutral detergent insoluble nitrogen (NDIN) of dairy feces.

Conclusion

The use of the stable isotope ^{15}N allows for direct measurement of nutrient flow in various aspects of the feed/animal/manure/soil-crop/environment continuum. This study determined the relative efficiency with which fertilizer-N was used to produce forages (alfalfa hay and corn silage), the conversion of forage-N into urine- and fecal-N, and the relative uniformity with which forage-N was incorporated into fecal-N components. The described enrichment pattern of feces and urine and the distribution of fecal ^{15}N between NDSN and NDIN relative to feeding time is useful in determining which components of dairy

manure would be most appropriate for short- or long-term nutrient cycling studies in the manure-soil/crop-environment continuum. Uniform labeling of the rapidly decomposable fecal-N pool (microbial- and endogenous-N) and the less decomposable pool (undigested feed-N) must be obtained in order to accurately determine the rate and extent of fecal-N mineralization in soils. The relative effectiveness of using ^{15}N -labeled urine and feces in nutrient cycling studies will depend on its ability to more accurately measure N mineralization in soils than the classical, indirect measurements (e.g. fertilizer equivalent) currently in use.