Understanding Nitrogen Availability from Applications of Anaerobically Digested Beef-Cattle Manure in Florida Sandy Soil[1]

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The purpose of this publication is to provide research-based information to farmers and UF/IFAS Extension agents about the use of anaerobically digested solid (ADS) and liquid (ADL) obtained from anaerobic digestion of beef-cattle manure as an organic source of nitrogen (N) for supplementing crop nutrition in Florida sandy soils. This publication also provides information related to the application timing, rate of application, method of application, and initial N concentrations of ADS and ADL for supplying N to crops in sandy soils. Application of ADS and ADL for vegetable production is restricted due to potential microbial food safety issues and is a subject for research investigation (Suslow 1999).

Anaerobic Digestion

Anaerobic digestion of livestock manure is a microbe-mediated process carried out in vessels or tanks, where the livestock wastes (such as beef-cattle manure, along with bedding materials) are digested slowly in an anaerobic environment (i.e., an environment absent of oxygen). The bedding materials are generally comprised of high carbon-to-nitrogen (C:N) ratio materials such as peanut hulls, old hay, sawdust, or used horse bedding. The anaerobic digestion process breaks down the complex organic compounds into simpler compounds along with co-generation of biogas (methane plus carbon dioxide). More information on anaerobic digestion and types of anaerobic digesters can be found in the EDIS document *Anaerobic Digesters for Manure Management at Livestock Operations* (Prasad et al. 2014) available at http://edis.ifas.ufl.edu/ss615. This publication presents information on ADS and ADL obtained from a plug-flow type of digester and their N release patterns in sandy soils.

Figure 1. Beef cattle in a confined feeding operation will produce manure that can be easily collected and digested anaerobically
Credits: George Hochmuth, UF/IFAS

1. This document is SL424, one of a series of the Soil and Water Science Department, UF/IFAS Extension. Original publication date April 2015. Visit the EDIS website at http://edis.ifas.ufl.edu.

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Products of Anaerobic Digestion of Beef-Cattle Manure

The main products of anaerobic digestion of beef manure are biogas, ADL, and ADS, and the amounts can vary depending on digester type, operating temperature, and retention time.

- The biogas consists of methane (60%–70 %), carbon dioxide (30%–40 %), trace amounts of hydrogen sulfide, and gaseous forms of N.
- The ADL is comprised of low C:N compounds and water and is reported to contain greater fractions of mineral N (which is comprised of ammonium-N and nitrate-N) (Prasad 2014).
- The ADS have high fiber content with a lower C:N ratio than the original bedding material and have the potential to release mineral N upon mineralization.

These products of anaerobically digested beef-cattle manure/bedding can be land-applied as an organic soil amendment or a source of plant nutrients.

Major Plant Macro-Nutrients Present in ADS and ADL of Beef-Cattle Manure

Anaerobically digested solids and ADL from beef-cattle manure can serve as an excellent fertilizer material because they contain readily-available nitrogen (N), phosphorus (P), and potassium (K) and have the capacity for continued mineralization in the field to release mineral N for plant uptake (Prasad 2014). Organic N is the major constituent, followed by K and P (Table 1). The nitrate-N is either absent or present in minor quantities. Most of the N is present as organic-N (Table 1). Because of high pH (largely due to the high-pH well-water that is included in the digestion process) of ADL and ADS, initial ammoniacal-N is susceptible to volatilization losses to the atmosphere. However, the volatilization losses from manure also depend on soil temperature, soil moisture, and application rates (Beauchamp et al. 1981). In addition to supplying nutrients, ADS and ADL can serve as excellent soil amendments to improve soil organic matter content. Increasing soil organic matter (especially in sandy soils) will help improve the soil's nutrient- and water-retention capacities.

Nitrogen Mineralization

Anaerobically digested solid and liquid effluents from beef-cattle manure contain N mainly in organic forms (Table 1). When ADS or ADL is applied to soil, the organic N is progressively converted to ammonium (NH_4) by soil microbes through a process known as *mineralization*. Subsequently, the ammonium produced is converted to nitrate (NO_3) by nitrifying bacteria. Both ammonium and nitrate are plant-available forms of N. However, the mineralization process is highly variable and dependent on soil temperature, soil moisture, soil texture, and soil bacterial population (Katterer et al. 1998; Watts et al. 2007). Mineralization increases with increasing soil temperature, whereas it declines when the soil dries down due to reduction in soil microbial activity (Eghball 2000; Cassman and Munns 1980).

Soil texture affects mineralization by influencing soil aggregation. Soil with higher aggregate stability (such as clay) protects the organic matter from decay and hence mineralization is slowed down (Jastow 1996). The NH_4 and NO_3 produced as a result of mineralization may be taken up by plants, assimilated by soil microbes (known as immobilization), lost through leaching to deeper soil profiles and to groundwater, or lost as gas to atmosphere via denitrification or volatilization.

Considerations for Using ADS and ADL Effluents from Beef-Cattle Manure to Supply Nitrogen to Crops in Sandy Soil

Initial Nitrogen Concentration in ADS and ADL

Initial N concentration and pH of the ADS and ADL are important factors in deciding the application rates of ADS and ADL. Hence, farmers must determine the nutrient concentrations of ADS and ADL by submitting a *representative sample* to a livestock waste testing laboratory.

A representative sample is created by collecting multiple subsamples from the storage barn or lagoon retention pond. The multiple samples should be combined and a subsample removed (approximately 100 grams) for the laboratory analyses. The ADS can be collected and sealed in plastic bags, whereas ADL can be collated in clean plastic bottles and capped tightly. The sample should be kept cold (refrigerated or on ice) and shipped overnight to the laboratory. The UF/IFAS Livestock Waste Testing Laboratory located at the UF/IFAS Analytical Services Laboratories in Gainesville, Florida, is among several laboratories that provide analyses of livestock waste samples. Request for specific analyses should include total Kjeldahl-N, ammonium-N, total P, total K, solid, and pH. The amount of organic N can be calculated as total Kjeldahl-N minus ammonium-N.

The anaerobic digestion process converts total N present in the manure-bedding mixture into two main forms: organic N and NH_4-N. Nitrate-N may also be present in trace amounts. The proportion of organic N to NH_4-N varies between ADS and ADL. The concentrations of NH_4-N and organic-N in ADS and ADL collected from a Florida farm are presented in Table 1.The ADL has greater amounts of NH_4-N compared to ADS. Prasad (2014) reported that on average the NH_4-N was 50% of total N in ADL and 19% in ADS. However, he also reported high initial pH of ADS and ADL (pH > 8.5). At alkaline pH (pH > 7), a significant proportion of NH_4-N exists as ammonia (NH_3), which gets lost to atmosphere via volatilization shortly after ADL application to the soil. Thus, application of a high pH ADL to soil testing high in pH should be avoided. Additionally, high temperature and high soil moisture further promote volatilization losses. So, application of ADL should be avoided immediately after rains and during hot summer days.

Rate and Time of ADS and ADL Application

The appropriate application rate of ADS and ADL to the soil is critical to prevent N losses, especially leaching loss in sandy soil. Large applications rates of ADS and ADL supply greater amounts of N compared to small application rates. However, the time taken to mineralize is greater for larger application rates compared to smaller rates. Prasad (2014) reported that large application rate of ADS, equivalent to land applications of 13 tons acre^{-1} or 93 lb organic N acre^{-1}, mineralized up to 27% within 40 days of application whereas a medium application rate, equivalent to land applications of 5 tons acre^{-1} or 31 lb organic N acre^{-1}, mineralized up to 58% within 20 days of application. Similarly, a large application rate of ADL, equivalent to land applications of 15,600 gallons acre^{-1} or 61 lb organic N acre^{-1}, mineralized up to 46% within 20 to 30 days of application whereas a medium rate, equivalent to land applications of 8000 gallons acre^{-1} or 29 lb organic N acre^{-1}, mineralized up to 81% of the initial N within 20 days of application. This finding of Prasad (2014) demonstrated the effect of application rate on the amounts of N mineralized as well as timing of release of N. The greater the application rate, the more time it takes to mineralize.

The timing of application of ADS or ADL must be synchronized to the period of maximum or linear crop growth phase in the crop growth cycle. Table 2 provides estimates of the mineral N that is released within 20 days of application from ADS and ADL (adapted from work of Prasad 2014). It should be noted (from Table 2) that smaller application rates of ADS or ADL mineralized to greater extent than large application rates within 20 days after application. Rapid release of mineral N from ADS or ADL calls for multiple applications to match N supply to crop N demand. Application of ADS and ADL should be avoided in fallow fields because mineralized N could leach down to lower depths in absence of an actively growing plant. Also application of ADS or ADL should be avoided when the crop N demand is low (such as late in the season or during dormant growth stages of small grains). These precautionary measures will reduce the chances of N losses via leaching.

Method of ADS and ADL Application

Method of application is an important factor to prevent N losses from ADS and ADL. Surface spreading and injection through center pivot irrigation systems are two of the most common land-application methods for ADS and ADL respectively. Anaerobically digested solid is typically applied through broadcast spreading and incorporated by disking, whereas ADL is frequently surface applied using center-pivot irrigation system or through traveling irrigation-gun systems. Subsurface application (or incorporation) of manure has been reported to be an effective method for reducing volatilization loss of N. However, Prasad (2014) did not find any significant difference between surface and subsurface application of ADS and ADL for N mineralization in sandy soil. This might have resulted from high pH of the ADS and ADL, leading to volatilization losses by diffusion of NH_3 in sandy soil, even if ADS and ADL were incorporated in the plough layer. The recommendation to reduce N losses from ADS or ADL and maximize plant use efficiency is to apply at appropriate rates based on crop demand and close to the period of maximum crop uptake.

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Table 1. Major nutrients and their concentrations present in ADS and ADL sampled from a plug flow digester from a Florida farm. The analyses reported here represents several sampling dates.

Effluent Type	pH	NH_4-N	Organic N	Total- P[†]	†Total-K
ADS		lb/ton			
	7.9	1	8	3	4
	7.5	1	9	3	5
	7.6	1	8	3	5
	7.8	0	10	3	6
	7.7	1	4	3	5
	7.6	1	3	1	2
	8.2	0	4	1	1
	8.7	1	5	2	3
ADL		lb/acre-inch			
	7.8	69	437	148	496
	7.8	74	450	150	508
	7.8	93	316	150	509
	7.8	90	460	146	479
	7.8	94	461	145	490
	7.9	153	209	87	335
	7.6	151	164	94	378

[†]Results are given as elemental P and K, therefore must be multiplied by 2.3 and 1.2 to be converted to P_2O_5 and K_2O, respectively. All analyses are reported on a wet basis.

Table 2. Amounts of mineral-N released from mineralization of organic N present in ADS and ADL during the first 20 days after their application.

Effluent type	Application rate (organic N lb/acre)	Amount of N mineralized (lb/acre) within 20 days after application	Percent N mineralized
ADS	93	23	25
	31	17	54
ADL	61	25	41
	29	23	78

Source: Adapted from Prasad (2014)