

NITROGEN LOSS FROM CATTLE FEEDLOTS AS IMPACTED BY THE
ADDITION OF CLINOPTILOLITE ZEOLITE TO THE RATION OR OPEN-LOT
SURFACE CONDITIONS

by

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PREVIEW

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**Nitrogen loss from cattle feedlots as impacted by the addition of clinoptilolite zeolite
to the ration or open-lot surface conditions**

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University of Nebraska, 2007

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Increasing media and public awareness are bringing environmental changes and concerns into the spotlight. Animal production systems use and subsequently release large amounts of nitrogen. As a result, producers will need to incorporate cost effective methods to reduce N loss from feedlots without negatively affecting cattle performance. Clinoptilolite zeolite clay is a proposed method to reduce N volatilization. Zeolite clay has a high cation exchange capacity, which may make it effective in adsorbing ammonia. The theory evaluated was that by adding zeolite clay to the diet, the zeolite clay matrix could bind the excess ammonia (NH_3) in the rumen; therefore, reducing the amount of ammonia excreted and thus lost to the environment. Two experiments were conducted in which zeolite clay was added to a finishing ration at 0 or 1.2% of the diet. Nitrogen levels for intake, retention and excretion were calculated for nitrogen mass balance. Ammonia emissions were measured the last six weeks of each trial using forced-air wind tunnels. The zeolite clay had no effect on the performance of the steers, nor did it affect NH_3 volatilization.

Surface conditions of feedlots may influence ammonia emissions. Atmospheric ammonia can contribute to ecosystem acidification, eutrophication and nitrogen deposition. A summer trial was conducted in August, 2005, to determine differences in

NH₃ flux as affected by four different treatments: moisture (DRY or WET) and/or urine. Forced-air wind tunnels were used to measure NH₃ volatilization over a two-day collection period, which was repeated weekly for three weeks. In this experiment, ammonia loss appeared to be related to soil moisture with greater loss of ammonia from dry surfaces. Ammonia loss followed a diurnal pattern, with the greatest loss prior to 9 AM, then decreasing into the afternoon and evening. No effects of urine addition were detected.

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PREVIEW

REVIEW OF LITERATURE

Environmental Impact of Nitrogen

There are approximately 10.85 million head of cattle on feed in the United States each year. The National Research Council in its Air Emissions From Animal Feeding Operations document reports that 155 g of nitrogen (N) is excreted per day per beef animal. This means that 0.304 teragrams of N (TgN) ($1 \text{ Tg} = 10^{12} \text{ g}$ or 1 million metric tonnes) are potentially excreted each year; of which, 10 to 50 % is volatilized (Howarth et al., 2002; Power et al., 1994) into the atmosphere as ammonia (NH_3).

It is important to remember that none of the natural resources, including water and air, are completely pure. Air often contains dust, pollen and other particulate matter. Natural water, which includes surface water, ground water and precipitation, contains foreign substances which occur naturally such as algae and particulate matter. Therefore, air and water can be considered to be naturally contaminated. Air and water can be “contaminated”, but not be considered polluted. The classification of “pollution” occurs when foreign substances in the air or water result in the inability of the natural resource to be used for a specific purpose (AWMFH, 1992).

In 1970 Congress passed the Clean Air Act (CAA) which is enforced by the Environmental Protection Agency (EPA). The CAA was the first major federal pollution control program in the United States. It set air quality standards to monitor major air pollutants (carbon monoxide, nitrogen oxide, sulfur dioxide, particulate matter, volatile organic compounds, and lead). Currently, NH_3 is not on the list of regulated pollutants. Through the EPA, the federal government established the National Ambient Air Quality Standards (NAAQS) (Percival et al., 2000). State governments have to decide how to

control pollutants to meet NAAQS and carry out those procedures. If the state does not prepare and implement plans to control pollutants, the EPA must prepare a federal implementation plan and incentive funding is withheld from the state. The act was amended in 1990.

In 1972 the Federal Clean Water Act (CWA) was established and is monitored by the EPA. States and Native American tribes are required to adopt and maintain water quality standards as set by the EPA. The goal of the act is to restore and maintain “fishable, swimmable” lakes and streams in the United States. Section 502 of the CWA defines “feedlots” as “point sources” along with meat packing plants and fertilizer manufacturers. Point sources are defined as “a stationary location or fixed facility from which pollutants are discharged or emitted such as a pipe, ditch or ship” (Percival et al., 2000). A federal permit program called the National Pollutant Discharge Elimination System (NPDES) was created to monitor discharge from point sources such as feedlots. The rules have been in place since 1976, but were revised in 2003. According to the rules and regulations of the CWA published in the Federal Register on February 12, 2003, animal feeding operations (AFO) are categorized as large, medium or small concentrated animal feeding operations (CAFO). Many of the feedlots in the United States fall into the category of large CAFOs as they house greater than 1000 cattle for more than 45 days over a 12-month period (Federal Register, 2003). CAFOs have to apply for NPDES permits in regard to potential or accidental discharge of holding ponds and run-off from pens, controlled discharge from holding ponds for irrigation, and for land application of manure.

In 2001, the EPA began requesting comprehensive nutrient management plans (CNMP) from large CAFOs as part of the process for obtaining NPDES permits. There are six elements of a CNMP: 1) animal inputs (feed management), 2) animal outputs (storage and handling), 3) land application and nutrient management, 4) site evaluation of land proposed for application, 5) record of CNMP implementation and 6) other utilization activities such as odor control plans. It is estimated that 5 percent of confined livestock operations are potential CAFOs (USDA-ERS, 2001). In 1997, these operations produced over half of the excess on-farm N (USDA-ERS, 2001). If these potential CAFOs followed a CNMP, the amount of nutrients that could pollute the water resources should be significantly reduced.

Nitrogen the Element

Nitrogen was discovered by several different chemists in the late 18th century. It was during the 19th century that the importance of N for crop production and the process of biological nitrogen fixation were discovered.

Approximately 78% of the Earth's total atmospheric mass is made up of triple-bonded nitrogen gas (N_2 ; Galloway and Cowling, 2002). However, the N_2 gas is not biologically available to most organisms. The triple bonds have to be broken, resulting in single $-N$ atoms. For the N-atom to become available to most plants, animals, insects and microorganisms the atom must be bonded with one or more of three other essential nutrient elements. Via N-fixation the N-atom can be bound to oxygen and/or hydrogen. The N-atom can be bound to carbon through N-assimilation processes (Cowling and Galloway, 2002). In nature, N-fixation of N_2 is carried out by special microorganisms that can produce biologically active reduced forms of nitrogen. Nitrogen compounds

formed in nature can be divided into two groups: 1) nonreactive N which is dinitrogen (N_2), and 2) reactive N (Nr) which includes all biologically, photochemically and radioactively active nitrogen compounds in the Earth's atmosphere and biosphere.

Reactive-N includes inorganic reduced forms of nitrogen such as ammonia and ammonium. It also includes inorganic oxidized forms of nitrogen such as nitrogen oxide (NO_x), nitric acid (HNO_3), nitrous oxide (N_2O), and nitrate (NO_3^-). Organic Nr compounds include urea, amines, proteins and nucleic acids (Galloway et al., 2003).

Reactive Nitrogen (Nr)

Human production of food and energy is the dominant reason for N-fixation, which results in the formation of reactive N. Production of Nr results in a wide variety of beneficial and detrimental effects. Increased yields and nutritional quality of foods are needed to meet the dietary requirements and food preferences of the growing population. These food needs are met by foods produced from Nr created by human action. The application of Nr can increase the productivity of Nr-limited ecosystems. Even though the main benefit of Nr production is that it feeds the world's population, there are many detrimental effects, if left uncontrolled and mismanaged, could cause harm to humans and the ecosystem alike. Detrimental effects are due to the demand and use of Nr that is accumulating on the Earth's atmosphere, soils, forests and waters, both fresh and coastal. This can lead to eutrophication and acidification of forests, soils and fresh waterways. It can also lead to blooms of toxic algae, which can result in injury to both humans and animals. Smog, injurious atmospheric particles, acid deposition, forest decline, greenhouse effects and stratospheric ozone depletion are all caused by the release and deposition of reactive-N into the atmosphere (Galloway and Cowling, 2002).

Very little of the Nr in animal feeds is actually converted to protein as most of it is excreted. Of the excreted Nr, some of it is volatilized. Bouwman et al. (1997) reported that roughly 33% of the Nr fed to livestock in the United States and other developed countries is excreted and volatilized to the atmosphere as ammonia. However, guidelines used by the Intergovernmental Panel on Climate Change (IPCC) use 20% as the amount of excreted Nr converted to atmospheric ammonia or NO_x . The difference is due to differences in emission coefficients used to calculate the percentages. Of the remaining Nr on the surface, IPCC suggests that approximately 30% of manure-N is leached in the form of nitrate, the rest is denitrified (Howarth et al., 2002).

Using data from the Food and Agriculture Organization of the United Nations (2001), 15% of the Nr is consumed by livestock via feed. It is estimated that humans in the United States consume 5% of the reactive-N inputs to cropland via animal protein.

There are multiple linkages among the ecological and human health effects of Nr molecules as they move from one environmental system to another. This linkage is known as the Nitrogen Cascade (Galloway, 1998; Figure 1). This cascade is defined as the sequential transfer of Nr through environmental systems, which results in environmental changes as reactive-N moves through or is temporarily stored within each system.

Nitrogen Cascade

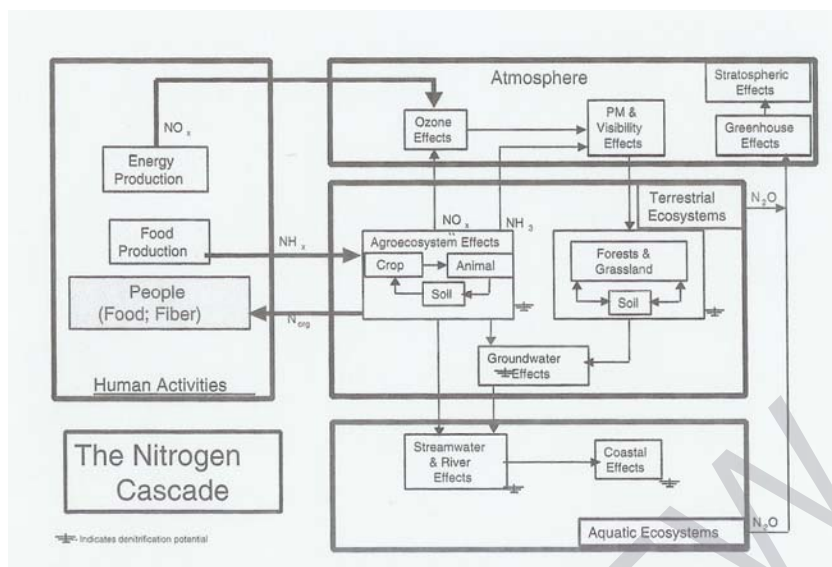


Figure 1. The Nitrogen Cascade illustrates the movement of reactive nitrogen as it cycles through various environmental reservoirs in the atmosphere, terrestrial ecosystems and aquatic ecosystems of the earth (Galloway, 1998).

Examining the cascade of effects for Nr during the production of food, atmospheric N_2 is converted to ammonia in the Haber-Bosch process to produce fertilizer. Approximately half of the Nr fertilizer applied to global agroecosystems is incorporated into crops that are harvested and used for human food or livestock feed (Smil, 1999 and 2001). The other half is lost to the atmosphere as NH_3 , NO , N_2O , or N_2 . Nitrate is lost into aquatic ecosystems.

Once the N atom is transferred to the air or water, it becomes part of the nitrogen cascade at different places. An important point is that once the Nr atom moves into the cascade, the source of that Nr is irrelevant. This irrelevance is due to the fact that Nr species can be rapidly converted from one Nr form to another. The critical step is the point source of the Nr in the first place (Galloway et al., 2003).

The various Nr emissions affect the air and water in different ways. Using a livestock/agricultural operation as the point source; organic-N, nitrate, nitrite and ammoniacal nitrogen are all subject to entering the nitrogen cascade at points such as the atmosphere and aquatic ecosystems. Within the cascade the different forms of nitrogen will result in different effects on the environment.

Organic Nitrogen

About 60 to 80% of the total nitrogen in fresh feces is in the organic form (AWMFH, 1992). The organic-N in the feces is usually in the form of complex molecules associated with digested food. The organic-N in the urine is in the form of urea. About 40 to 90% of the organic-N is converted to ammonia within four to five months, if applied to land. Data collected by Erickson and Klopfenstein (2001a) suggest that up to 70% of the excreted-N may be lost to volatilization from open dirt feedlots during the summer. Power et al. (1994) estimated that approximately 50% of the nitrogen deposited on a Nebraska feedlot was lost as ammonia. The remaining nitrogen on the surface is in the form of ammonium. This ion is relatively immobile in the soil as the positively charged NH_4^+ tends to attach to the negatively charged clay particles and remains in place until converted to other forms. Through mineralization, the ammonium is converted to nitrite and then to the end product nitrate.

Nitrite (NO_2^-)

Nitrite is normally a transition phase in the nitrification ($\text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^-$) and denitrification ($\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$) processes. Very little NO_2^- is found in the soil or in most natural waters. Nitrite is not useable by plants or animals and can be deadly to fish if high levels are reached in ponds.

The EPA has not recommended any special acceptable ranges on nitrites in surface water. Some states have special criteria for nitrite concentrations in finished or treated water.

Nitrate (NO_3^-)

Nitrate is the end product of the mineralization or nitrification process under aerobic conditions. Ammonium is bound in the manure pack and converted to nitrate by nitrifying bacteria that oxidize ammonium to produce nitrate. The bacteria obtain energy from readily available carbon atoms for growth during the nitrification process. Nitrate can also be converted and returned to the atmosphere as N_2 by denitrifying bacteria which are anaerobic. These anaerobic bacteria deplete the manure pack of nitrogen compounds useable by crops, making the manure or compost less valuable as a fertilizer.

Nitrate is soluble in water and is readily used by plants. In the nitrate form, nitrogen can leach through the soil as it is in an anionic form that has low sorptive capacity and does not form insoluble precipitates. The main source of agricultural nitrates in surface water is runoff from feedlots, pastures and cropland. The concentration of nitrate from these sources can vary due to rainfall, slope of land, age of manure on the ground surface and extent of crop cover.

The EPA has not set any limits for nitrates in surface water; however, there are limits set in regard to wells and drinking water. Nitrates are toxic to fish only at high levels ($> 1000 \text{ mg/L}$) for freshwater fish. The World Health Organization recommends that nitrate levels in drinking water be less than 10 mg/L . Nitrate concentrations in the United States exceed this level in more than 15% of groundwater samples from 4 of the 33 major regional aquifers (Nolan and Stoner, 2000). Nitrate in drinking water can cause

methemoglobinemia (blue-baby syndrome), which usually affects infants less than one year of age. In the human body, nitrate is converted to nitrite, which interferes with the ability of hemoglobin to take up O_2 . High levels (40 to 100 mg NO_3^- -N/L) of nitrate in water consumed by livestock can also be toxic, causing methemoglobinemia and even abortions (Di and Cameron, 2002).

Ammoniacal-N

Ammoniacal-N refers to two compounds: ammonium ion (NH_4^+) and un-ionized ammonia (NH_3). The two forms exist in equilibrium with concentrations and fluxes dependent upon pH, temperature and moisture.

Ammonium stays in the soil until converted to other forms such as ammonia, which is lost to the environment in a gaseous form. Ammonia volatilization is considered to be the main pathway for nitrogen loss from animal production. This is a critical issue because it represents a loss of fertilizer value of the manure or compost and can adversely impact the environment (McGinn and Janzen, 1998; Harper et al., 2000).

Ammonia is the most prevalent alkaline gas in the atmosphere and it easily combines with acid species such as nitric acid (HNO_3) and sulfuric acid (H_2SO_4) to form aerosols such as ammonium nitrate (NH_4NO_3), ammonium bisulfate (NH_4HSO_4) and ammonium sulfate (NH_4SO_4). As an aerosol, NH_4^+ contributes directly to particulate matter 2.5 (PM 2.5) and once removed via wet deposition contributes to ecosystem fertilization, acidification and eutrophication. The lifetime of NH_3 in the atmosphere is short, 0.5 hours to 5 days, because of the rapid gas to particle conversion of NH_3 to NH_4^+ and deposition to natural surfaces, particularly wet surfaces and vegetation (Fowler et al., 1998; Walker et al., 2000). Forest growth and health, as well as other types of crops and

vegetation are all affected by NH_3 deposition. Conifer forests near livestock production systems may develop needle necrosis, which leads to needle loss and eventually death of the trees and forest. Deposition of nitrogen compounds such as ammonia, acid rain and ozone along with stress has been reported as key factors to the die back of many forests (Nihlgard, 1985; Pitcairn et al., 1998; Fenn et al., 2003).

Transportation of volatilized ammonia in the air depends on the competition between upward diffusion, transformation to NH_4^+ aerosols and surface deposition (Krause-Plass et al., 1993). Gaseous ammonia is removed primarily by dry deposition, but ammonia will disperse into the clouds where it affects the cloud chemistry. This change in cloud chemistry is possibly the most detrimental to the environment as it increases the atmospheric pH, which results in a change in the ozone oxidation rates. In particular it affects the SO_2 oxidation by ozone, which is important in facilitating the dispersion of SO_x in precipitation as acid rain.

Nitrogen Management

Intake to Excretion

One of the key ways to reduce excreted N is to reduce N intake by the animal. Feed intake itself is regulated and limited by the requirements of the animal's physiology and metabolism. Galyean and Gleghorn in 2001, conducted a survey of 19 nutritionists who are responsible for formulating the rations of approximately 50% of the cattle on feed in the United States. Results show the average steer was fed for 153 days and consumed approximately 8.84 kg of dry matter (DM) per day. Assuming 13.3% crude protein (2.13% N) in the ration, cattle will consume about 28.8 kg of nitrogen over the feeding period (Erickson et al., 2003).

Predicted dry matter intake can be calculated using the amount of feed or nutrients required for maintenance added to that required for growth. The amount of feed required for maintenance is a function of the net energy (NE) required for maintenance (NRC, 2000; Fox and Tylutki, 1998) as calculated using thermoneutral maintenance requirements ($\text{Mcal/SBW}^{0.75}$) and the net energy for maintenance (NE_m) concentration of the diet. The feed required for growth is a function of the energy retained as weight gain and the net energy for gain (NE_g) concentration of the diet (NRC, 2000; Fox et al., 1999).

To calculate the nutrient intake by an animal, the amount of DM consumed (Dry Matter Intake, DMI) and the nutrient values of the feedstuffs must be known. Energy density of a feed can affect the intake levels. The intake of a high energy, highly digestible diet is determined by the animals' energy demands and by metabolic factors such as pH (NRC, 1987). The high energy diet is usually comprised of high levels of concentrate and low levels of fiber. Grain sources and the processing used for the high energy diets can also affect intake. Compared with dry rolled corn and milo, high-moisture corn and milo had lower average daily gain (ADG) and DMI. Steam flaking corn, milo and wheat compared to dry rolling, decreased DMI without decreasing ADG. Steam flaking corn and milo increased metabolizable energy (ME) by 15 and 21% over that of dry rolled grains (Owens et al., 1997). Higher moisture content of high-moisture corn decreased DMI without decreasing ADG; therefore, improving feed efficiency.

The intake of low energy diets, often comprised of large amounts of fiber in the form of hay or silage is usually controlled by physiological factors such as rumen fill and passage rate. Small increases of 5% dry matter or less in the concentration of bulky roughage and changing from less fibrous to more fibrous sources of roughage typically

will increase dry matter intake (Galyean and Defoor, 2003; Kreikemeier et al., 1990; Gill et al., 1981). This increase in DMI could be due to energy dilution effects of the added fiber. Rumen pH is less acidic for high fiber diets. This change in pH is thought to be due to increased chewing and/or rumination, which increases salivation and buffering capabilities. Altered ruminal and/or intestinal digesta kinetics and altered site and extent of digestion may reduce rumen acidity and thus potentially increase DMI.

Body composition of the growing steer, especially the percent of body fat, seems to affect feed intake (NRC, 1987). As steers begin to finish, thus increasing body fat, there is thought to be a feedback mechanism controlling feed intake. It is suggested that DMI decreases 2.7% for each 1% increase in body fat within the range of 21.3 to 31.5% body fat (Fox et al., 1988). This allows the amount of feed consumed or actually the decrease of feed consumed near the end of the finishing period to be a useful tool in predicting when cattle are ready to be harvested.

The age of the animal when placed on feed also affects intake. Older animals such as yearlings will consume more feed per unit of body weight than younger animals such as calves due to body composition differences. A 10% increase in predicted DMI was suggested for cattle started on feed as yearlings compared to calves (NRC, 1987; Fox et al., 1988). This is due to a positive relationship between initial weight on feed and dry matter intake. An animal's frame size may also affect DMI. It was suggested that intake predictions be increased by 8% for Holsteins and 4% for Holstein-British breed crosses (Fox et al., 1988), compared with British breeds of cattle.

When addressing the issue of intake, diet composition and the environment the amount of protein, and thus nitrogen, consumed is of great importance. In the 1996 Beef

NRC, the metabolizable protein (MP) system was introduced. The MP system takes into account where in the digestive system protein degradation occurs and to what extent it proceeds. It also separates out the protein requirements of both the animal and the rumen microorganisms. Metabolizable protein is comprised of true protein (amino acids), supplied as microbial protein absorbed by the small intestine and undegradable intake protein (UIP) from the feedstuff. The UIP is the fraction of the feedstuff protein which escapes rumen degradation and is digested and absorbed in the small intestine. Degradable intake protein (DIP) is the portion of the total protein that is degraded in the rumen and provides the ruminal microbes with nitrogen. Approximately 70 to 85% of the DIP is broken down by enzymes secreted by the microorganisms in the rumen (Bondi, 1987). The true digestibility of protein ranges from 80 to 100% (Orskov, 1992). Proteins are degraded into peptides, which are further converted to fatty acids, carbon dioxide and ammonia. With the presence of carbohydrates or other energy sources the microbes can use ammonia to synthesize new proteins. Generally, only a small amount of ammonia is used by the microbes due to limited energy sources (Sniffen and Robinson, 1987; Orskov, 1992). The excess NH_3 is adsorbed and transformed into urea ($\text{CO}(\text{NH}_2)_2$) which is then recycled back to the rumen or excreted in the urine. The UIP and newly synthesized microbial protein are transported to the small intestine where digestion into amino acids occurs. The amino acids are then absorbed by the jejunum and ileum of the small intestine (Merchen, 1988). Undigested amino acids, endogenous nitrogen, dead microorganisms and feed nitrogen are excreted via the feces. Although nitrogen retention increases as average daily gain increases (Erickson et al., 2003), large amounts of protein consumed generally lead to large amounts of nitrogen being excreted.

The feedlot steer will retain small amounts of the nutrients they consume.

Bierman et al. (1999) reported that feedlot cattle retained only 10% of the nitrogen they consumed. Retention of N is based on protein and energy retention equations from the 1996 Beef NRC. The complex set of equations take into account DMI, days on feed, hot carcass weight and other pieces of data to calculate the amount of nitrogen retained as product, in this case, meat.

The conversion of dietary N to animal protein (meat, milk, eggs, etc.) is often inefficient with 50 to 80% of the consumed nitrogen being excreted (Tamminga, 1992; Arogo et al., 2001). More than 50 to 60% of the excreted N is found in the urine with over 70% of the urine-N in the form of urea-N (Bristow et al., 1992; Tamminga, 1992; Aarnink et al., 1995). Urea-N in the urine can range from 50 to 90% of the nitrogen contained in the urine (Bussink and Oenema, 1998). Other major components in the urine are hippuric acid (1.9 to 7.7%), allantoin (2.2 to 22.2%), uric acid (0.6 to 1.9%), creatine (0 to 6.3%), creatinine (0 to 8.1%) and other minor components (Bussink and Oenema, 1998).

Urinary nitrogen is derived from various sources with excess nitrogen being removed from the rumen, which is the major source (Merchen, 1988). Turnover of ingested dietary protein into microbial nucleic acids and the conversion of amino acids into body proteins and milk protein are also associated with nitrogen loss found excreted via the urine. Additionally, nitrogen is accumulated and excreted from maintenance and metabolic processes.

Fecal nitrogen originates from the feed, endogenous sources (enzymes, mucus, and epithelial cells) and microbial sources. Undigested feed nitrogen and endogenous

nitrogen are mainly excreted as true protein or amino acids. From 15 to 20% of the microbial nitrogen will be present in nucleic acids (Tamminga, 1992). Tamminga (1992) reported that approximately half of the fecal-N comes from feed and microbial proteins and the remaining 50% from metabolic losses.

Fresh feces and urine contain little ammonia. After excretion, feces and urine mix, activating enzymes. There are large numbers of microbes in the feces releasing microbial enzymes. The enzymes, predominantly urease, degrade the N-containing compounds producing ammonia by a combination of hydrolysis, mineralization and volatilization. These processes are quite complex, but have been simplified in equations 1 to 3 (Koerkamp et al., 1998).



NH_3 in the atmosphere

Ammonia formed from manure is generated partly from urea via enzymatic conversion, which is a rapid process. Organic-N in the feces is converted to NH_3 through mineralization which occurs slowly. Undigested proteins and unabsorbed sugars in the feces are readily available for decomposition, while plant structural carbohydrates, such as hemicellulose are slowly available (DEH, 2006). The total amount of fecal-N and organic matter is affected by the degree of hindgut fermentation (Giger-Reverdin et al., 1991; Larson, 1992). Ulyatt et al. (1975) reported that hindgut fermentation increases fecal-N and decreases urinary-N excretion.

Nitrogen Mass Balance

To fully understand the relationship of nitrogen intake to nitrogen loss, a nutrient/nitrogen mass balance calculation is of great value. Mass balance based prediction models can be used to identify farms that could be an environmental risk and help identify what is causing that risk potential. The environmental risk that farms may pose can be predicted according to their management practices. Using mass balance techniques and nutrient management plans, the environmental impact by a farm can be quantified, evaluated and modified to improve the farms environmental impact and management. Mass balance calculations take into account the dry matter, organic matter, nitrogen and phosphorus levels of feed and excreta including manure, slurry and holding ponds. The amount of nutrient excreted is directly proportional to the amount of nutrient consumed. Therefore, it is important for a producer to know the levels of nutrients they are feeding, and for this review nitrogen will be the focus.

Gilbertson et al. (1971) estimated that 50 to 60% of the nitrogen was removed from an open, dirt feedlot in the manure and soil at cleaning. Bierman et al. (1999) reported that manure-N removed from feedlot pens was highest for steers on a wet corn gluten feed (WCGF) diet. Expressed as a percentage of total nitrogen excreted, 18.7, 12.4 and 8.9% of excreted nitrogen was removed in the manure for WCGF, 7.5% roughage and all-concentrate diets. From 10 to 16% of excreted-N remained on the pen surface after cleaning.

Of the excreted N, a small portion is lost in the runoff as nitrate. Gilbertson et al. (1971) estimated that 10% of the excreted nitrogen was removed in the runoff. In the Great Plains, which has a dry climate, 3 to 6% of the excreted-N was lost in the runoff

(Eghball and Power, 1994). In a comprehensive feedlot experiment, Bierman et al. (1999) found that 5 to 19% of the excreted nitrogen was lost in the runoff with 10 to 16% remaining on the pen surface after cleaning.

A major portion of excreted-N is transformed into NH_3 which may volatilize and move into the atmosphere. Volatile loss of nitrogen begins approximately two hours after excretion and continues through all manure handling processes until the manure with its nutrients are incorporated into the soil (Elzing and Monteny, 1997). Gilbertson et al. (1971) estimated that 30 to 40% of the excreted-N is lost into the atmosphere. Klopfenstein and Erickson (2002) reported that nitrogen loss varied with the time of year. From 60 to 70% of excreted-N was lost during the summer and a 40% loss was observed from November to May. Bierman et al. (1999) calculated that 57 to 67% of nitrogen was lost, presumably via volatilization of ammonia. Phase feeding of steers reduced volatilization losses by 32% (Klopfenstein and Erickson, 2002).

Methods to Reduce Nitrogen Loss

There are management methods that reduce the amount of excreted nitrogen lost to the environment. The importance of nitrogen management varies according to the nature of the waste, concerns of the farmer, distance from neighbors, conditions of the surrounding environment and current legislation. Controlling ammonia can be grouped into two primary management strategies: 1) pre-excretion strategies such as altering diets and 2) post-excretion strategies such as altering pH by applying pen or floor surface additives.

Pre-excretion Strategies:

The concentration and ruminal degradability of crude protein in feedlot cattle diets may affect the partitioning and amount of urinary and fecal excretion of nitrogen. This may affect ammonia emissions from the feedyards. It has been reported that as nitrogen intake increases, excretion of urinary urea-N increases (Gueye et al., 2003b; McBride et al., 2003). Research has also shown that as the dietary ratio of degradable intake protein to ruminally undegradable intake protein increases, urinary-N excretion increases (Cecava & Hancock, 1994; Gueye et al., 2003b; McBride et al., 2003).

A study by Cole et al. (2005) was conducted using 54 steers in a 3 x 3 factorial with three CP concentrations (11.5, 13, and 14.5 % of DM) and three supplemental sources (100% urea, 50:50 urea:cottonseed meal, and 100% cottonseed meal). Ammonia emissions increased 60 to 200% when the protein concentration of the diet increased from 11.5 to 13%. The ammonia was measured in a polyethylene chamber. The increased ammonia was due primarily to increased urinary-N excretion. In the same study, as days on feed increased, ammonia, measured by in vitro methods, also increased. The ammonia losses were highly correlated to urinary-N ($r^2 = 0.69$), urinary urea-N excretion ($r^2 = 0.58$), serum urea-N concentration ($r^2 = 0.52$) and intake of degradable protein ($r^2 = 0.23$).

Different levels of urea supplementation (0, 50 and 100 % of all diet protein equivalent) were compared to determine their effects on nitrogen excretion partitioning. Fecal-N excretion was greater for the 0% urea diet than for the 50 and 100% urea diets. Urinary-N and urinary urea-N excretion increased with increasing dietary urea concentration (Cole et al., 2005). Chemical composition of feces and urine were affected