BEEF FACTS: SUSTAINABILITY

BEEF RESEARCH

Towards Sustainability: Nitrogen and Beef Cattle Feedyards[1, 2, 3]

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Background

Greater public awareness of the potential effects of food production on the environment calls for livestock management systems that are sustainable with regard to the environment, society, and the economy. The concept of sustainable agriculture challenges producers to better understand the dynamics of agricultural systems and consider the long-term implications of management practices, particularly from an ecological perspective, and to balance production efficiency and profitability with community and consumer needs (**Figure 1**). Issues that impact beef feedyards and other concentrated animal feeding operations include global warming, air quality, ground and surface water availability and quality, and wildlife. The possibility of a more highly regulated cattle industry always looms as public concerns grow.

Environmental issues frequently arise when livestock are raised in high densities typical of beef cattle feedyards. Most issues revolve around the large quantity of manure (a mixture of urine and feces) produced in a relatively small area. Less than 20% of the nutrients consumed by livestock are converted into animal product. The rest are excreted, accumulate, and constitute an active system of physical, chemical and biological processes and transformations. A key element in this system is nitrogen (N), an element vital for all life.

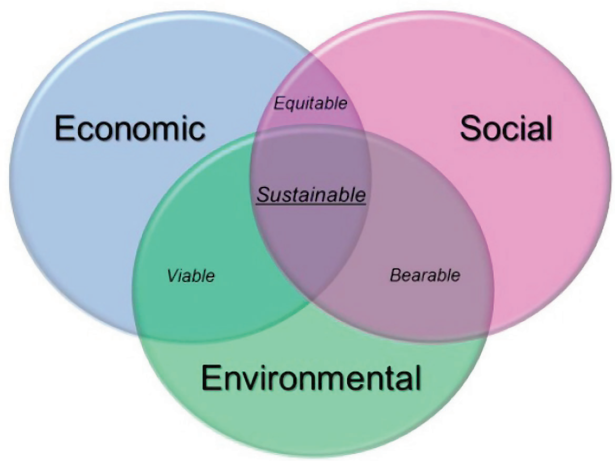

Figure 1. Sustainable agricultural systems incorporate economic, social, and environmental factors to create production systems that are long-lasting, fair, profitable, and promote good relationships with communities.

The amount of N cycling through terrestrial ecosystems has roughly doubled since the 19th century, primarily

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because of human activities. These include the production and use of fertilizers, cultivation of N-fixing crops, N released from storage in soils and plant biomass, and burning fossil fuels. Agriculture contributes from 50 to more than 90% of the increased N in global ecosystems.

Dinitrogen (N_2), an inert nonreactive gas that is unavailable for organisms, makes up 78% of the earth's atmosphere. Reactive N compounds, such as ammonia (NH_3), nitrous oxide (N_2O) and nitrate (NO_3^-), however, are available for the myriad biochemical reactions that living organisms require. Reactive N is the limiting factor in the function of many ecosystems, but is abundant in feedyards and other highly managed systems like feedyards. The benefits of reactive N (e.g., manure with increased fertilizer value) can be realized when it is kept in place. The environmental costs accrue when it escapes or leaks from feedyard systems, with potential impacts on climate change, air and water quality, and biodiversity. Cattle producers are challenged to manage N to realize its benefits and to minimize its costs.

The concept of N balance is key when considering the role of N in feedyards. A N balance is constructed by accounting for all the types of N in the feedyard system. Nitrogen inputs, predominantly as feed, are balanced against N outputs. Nitrogen outputs include N retained in cattle and excreted manure, losses of gases like NH_3 and N_2O, and soluble forms of N like NO_3^- that can move in water or through soil (**Figure 2**). Efforts to improve the sustainability of feedyard operations revolve around managing the components of the N balance so that N is used efficiently and losses are minimized.

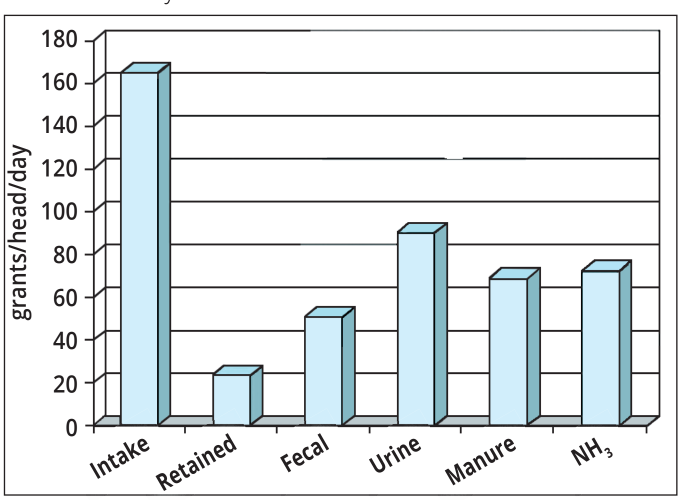

Figure 2. A typical nitrogen (N) balance at a commercial feedyard in Texas.

"Review: Nitrogen sustainability and beef-cattle feedyards" is published in *The Professional Animal Scientist*. The objectives of the review paper were to examine the critical components of the N balance, provide a comprehensive analysis of the state of the science of each component, and identify ways to minimize the negative impacts of N that detract from sustainability. The critical components addressed are cattle diet and metabolism, NH_3 and N_2O emissions, and N leaching and runoff. Processes, mitigation measures and knowledge gaps are highlighted.

N Inputs to U.S. Feedyards

About 23 million cattle are fed annually in U.S. feedyards with capacities greater than 1000 head. Most cattle are housed in open-lot, soil-surfaced feedyards. However, semi-confinement, total-confinement, and pastoral systems are still used in the United States. Cattle typically enter a feedyard weighing from 220 to 400 kg (8 to 16 months of age) and are fed for 120 to 180 days. They consume 8 to 11 kg of feed dry matter and gain 1.5 to 2.0 kg of weight daily. Beef cattle excrete 360 kg solids and 25 kg of N during a 153-day finishing period. Nitrogen balance studies show that only about 15% of the N flow through a feedyard remains in animal tissue (average of 25 g $head^{-1}$ d^{-1}). Most N (44%) is lost to the atmosphere or as runoff, whereas only 41% was removed with harvested manure.

Diets fed at feedyards vary because of cost and availability of feedstuffs. Grains are generally processed (dry-rolled or high-moisture corn in the Northern Plains, steam-flaked corn in the Southern Plains). By-products such as distillers grains and corn-gluten feed have been increasingly fed over the past decade. Finishing diets typically contain 12.5 to 13.5% crude protein (CP) and are routinely supplemented with urea to assure adequate ruminal degradable protein (RDP) in the diet. Dietary CP concentrations may exceed 15 to 18% when by-products comprise more than 20% of the diet.

Cattle have two protein requirements: 1) the RDP requirement of the ruminal microbes, and 2) the metabolizable protein (MP) absorbed in the small intestine and used by the animal. The RDP requirement varies with grain processing and other dietary characteristics. Dietary concentration and ruminal degradability of dietary protein are the primary factors affecting the quantity and route of excretion (urine vs. feces) of N by beef cattle. Excretion of urinary N increases with N intake and with increased dietary RDP.

N Losses: Ammonia

Ammonia is the primary gaseous emission of concern from feedyards. It readily combines with nitric and sulfuric acids (NO_x and SO_x) in the atmosphere to form $PM_{2.5}$ particulates, which can reduce visibility and cause respiratory issues. Fugitive NH_3 contributes to acidification and over-fertilization of terrestrial and aquatic ecosystems. Livestock account for 64 to 86% of total global anthropogenic NH_3 emissions.

Ammonia in feedyards is mostly derived from excreted urea in urine. Urea is readily converted to ammonia on the feedyard pen surface under the influence of factors such as pH, temperature, and manure water content. Per capita NH_3 emissions in feedyards range from 50 to 280 g head^{-1} d^{-1}. Ammonia losses are about two times greater in summer than in winter. Most annualized per capita NH_3 emissions range from 90 to 120 g head^{-1} d^{-1}. Ammonia emissions range from 28 to 72% of fed N. When diets contain the recommended 12.5 to 13.5% CP, NH_3 emissions are about 50% of the fed N. Nitrogen excretion increases as diet CP exceeds the needs of cattle. Ammonia emissions also increase as diet CP increases. A reasonable NH_3 emission factor for cattle feedyards would fall in the range of 30 to 40 kg head^{-1} yr^{-1}. Ammonia emissions from retention ponds or manure storage are very small, usually less than 5% of fed N.

Approaches to decrease NH_3 losses from cattle operations are to: 1) manipulate diet to decrease N excretion, 2) inhibit hydrolysis of excreted urinary urea to NH_3, and 3) capture ammonium (NH_4^+) in manure. Managing diets to meet, but not exceed, protein requirements of the animal offers the most promise for reducing feedyard NH_3 emissions. However, diets must be changed carefully to avoid unintended negative consequences. The effects of dietary fiber content and pen cleaning frequency on NH_3 emissions have been variable. Lab-scale studies show that applying pen surface amendments (urease inhibitors, alum, zeolites) decrease NH_3 volatilization losses. Despite their potential, each of these methods has distinct disadvantages that could limit their use on commercial feedyards. Combinations of compounds that inhibit NH_3 losses via different mechanisms may be more effective than a single compound.

N Losses: Nitrous Oxide

Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential about 300 times that of carbon dioxide (CO_2). Anthropogenic N_2O accounted for about 5% of the global warming potential from the United States in 2011. While the majority of anthropogenic N_2O originates from fertilized cropland, beef cattle manure is a significant source. The N_2O from cattle manure is produced by two microbially mediated processes: nitrification and denitrification. Nitrification is the biological oxidation of NH_3 to NO_3^- under aerobic conditions. Denitrification is the reduction of NO_3^- to N_2O and N_2, usually under low oxygen conditions. Both processes are controlled by pH, temperature, water content, redox potential and availability of substrate, all conditions that promote or inhibit specific microorganisms at the different stages of chemical transformation.

Most research on N_2O has been on soils, not manure, which offers a significant opportunity for future research. Nitrous oxide emissions are usually small and episodic, responding especially to changes in temperature and water content that create favorable conditions for production of N_2O. Wet, muddy locations in feedyards are the strongest sources for N_2O. Emissions are also highly variable in space. This creates challenges for measuring N_2O emissions. Limited studies have reported N_2O per capita emission rates that range from 0.25 to 38 g head-1 d-1 from feedyards and open-lot dairies.

Improving animal productivity can reduce the emission intensity of N_2O. Emission intensity is the N_2O emitted per unit animal product. Growth-promoting agents may reduce N_2O emission intensity by increasing growth rate and feed efficiency and shortening time on feed. However, other studies reported that growth promoters increased N_2O emissions. Managing manure water content with improved drainage or more frequent manure harvesting helps maintain drier conditions unfavorable to N_2O production.

N Losses: Reactive N Emissions to Water

Reactive N can be transported in water in both soluble and particulate-associated forms that can impair the quality of wells, groundwater, streams, and other surface waters. Nitrate is of the greatest concern, as it can negatively affect the health of both humans and livestock. Surface runoff is the dominant process transporting soluble and particulate-associated N from feedyard pens. However, feedyard runoff diversion and collection methods (settling basins and retention ponds) built in response to zero discharge limits have greatly reduced the environmental risk of feedyards to surface waters. Typical open-lot earthen-surfaced feedyard pens develop highly compacted dry and wet manure layers that limit water infiltration into the underlying soil. Studies show that these compacted layers limit the movement of NO_3^- beneath feedyards. However, it is critical to maintain the packed layers when harvesting manure.

Predicting N Emissions

Commonly used approaches to estimate NH_3 and N_2O emissions from feedyards rely on emission factors or statistical relationships. But these are relatively coarse estimates, often based on limited research and limited in applicability. Process models, in contrast, are based on the actual physical, chemical and biological processes that occur in a system and offer the best promise of more accurate emission estimates. Several have been developed and evaluated for NH_3 emissions and estimated emissions within 3 to 24% of measured emissions. Less work has focused on developing and evaluating N_2O process models, which presents a research opportunity.

Conclusions

Managing N presents one of the greatest challenges to sustainable feedyard beef production. A changing feed environment, potential regulations, consumer demands and economic pressures complicate how feedyards respond to the challenges. This complex situation requires unbiased and scientifically sound information on the potential effects of beef production on the environment and society. We cannot stress enough the importance of educating both the public and regulatory policy makers about the real and perceived impacts of beef production.

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