

# AIR QUALITY

## Ammonia Emissions from Cattle-Feeding Operations Part 2 of 2: Abatement

### AIR QUALITY EDUCATION IN ANIMAL AGRICULTURE

Mitigation: Ammonia Abatement  
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This publication discusses ammonia abatement measures and when they can be implemented in livestock production.

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### Abatement Measures

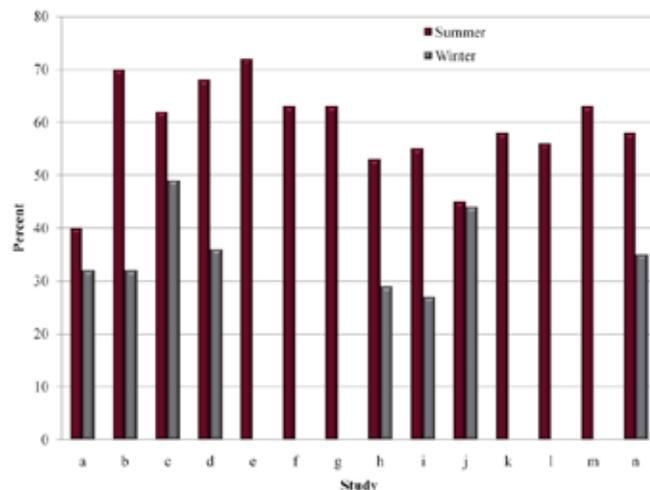
Ammonia abatement measures can be implemented at two different stages of livestock production. First-stage measures are applied in the pre-excretion stage. These include nutrition-based strategies to reduce the amount of nitrogen excreted in livestock manure. In the second or post-excretion stage, management strategies are implemented to reduce the amount of ammonia transferred to the environment from the manure by agricultural operations.

### Nutritional Ammonia Abatement Methods

One means of reducing ammonia emissions from concentrated animal feeding operations (CAFOs) is to reduce the amount of nitrogen excreted by the animals, especially the quantity excreted as urea in urine. Urinary pH also can affect ammonia emissions (Cole et al., 2008a). In some cases, it is possible to manipulate nutritional intake to reduce total nitrogen and urinary nitrogen excretion while continuing to meet the nutritional requirements and performance expectations of the animals. Based upon consistent observations among researchers over the past decade, annual ammonia losses from beef cattle feedyards tend to be approximately half of the nitrogen consumed by cattle, and summer emission rates are about twice those in winter (Todd et al., 2009).

Table 1 presents ammonia-nitrogen loss as a percentage of fed nitrogen for beef cattle feedyards in the Great Plains. Ration composition can be modified in a variety

Table 1. Ammonia-nitrogen loss as a percentage of fed nitrogen from Great Plains beef cattle feedyards. Studies: (a) Todd and Cole, unpublished data, (b) Todd and Cole, unpublished data, (c) Todd et al., 2011, (d) Todd et al., 2008, (e) van Haarlem et al., 2008, (f) McGinn et al., 2007, (g) Flesch et al., 2007, (h) Harper et al., 2007, (i) Todd et al., 2005, (j) Todd et al., 2005, (k) Cole et al., 2006, (l) Erickson and Klopfenstein, 2004, (m) Erickson et al., 2000, (n) Bierman et al., 1999.



**Reducing the amount of nitrogen excreted by livestock is one way to reduce ammonia emissions.**

of ways to effectively reduce ammonia emissions by 20-50 percent with only small effects on animal performance (Cole et al., 2005, 2006a; Todd et al., 2006). Some of the nutritional factors that can be manipulated include crude protein and/or degradable intake protein concentrations (including phase feeding), fat concentration, fiber source and concentration, cation-anion balance (CAB), as well as some growth-promoting feed additives and implants. However, the large size of many CAFOs presents economic and logistic challenges when modifying diets or feeding practices. Modifications to equipment, diets, or management practices may impose increased cost, labor, and time, for example (Figure 1).

*Crude Protein*

The concentration of protein in feed, as well as its ability to be degraded in the rumen, may affect the quantity and route of nitrogen excretion by beef cattle (Cole et al., 2005). Beef cattle consume dietary crude protein in two forms. The first is degradable intake protein (DIP), which is processed by microbes in the rumen and either absorbed from the rumen (normally as ammonia) or converted to microbial protein and nucleic acids. The second is undegradable intake protein (UIP), which escapes digestion in the rumen and passes to the intestine where it is digested and absorbed as amino acids (approximately 80 percent) or excreted (approximately 20 percent). In general,



*Figure 1. Rations can be modified in a variety of ways to effectively reduce ammonia emissions with only small effects on animal performance, but some modifications may pose economic and logistic challenges to large CAFOs.*

as nitrogen consumption increases, urinary nitrogen excretion also increases. Further, as the ratio of DIP to UIP increases, urinary nitrogen excretion also increases. Dietary changes must be made carefully and with consideration to unintended consequences. If, for example, in an attempt to lower ammonia emissions the dietary protein intake is reduced below the nutritional needs of the animal, the growth rate may be slowed, the animal will require more days on feed to reach market weight, and the cumulative ammonia emissions from a feedlot may actually increase. In addition, making changes to decrease ammonia emissions may potentially result in the increase of other undesirable emissions such as nitrous oxide.

In closed chamber laboratory (Cole et al., 2005) and artificial pen surface (Todd et al., 2006) experiments, decreasing the crude protein concentration of beef cattle finishing diets based upon steam-flaked corn from 13-11.5 percent decreased ammonia emissions by 30-44 percent. Ammonia fluxes from an artificial feedyard surface were reduced by 30 percent in summer, 52 percent in autumn, 29 percent in spring, and 0 percent in winter (Todd et al., 2006). The research team concluded that despite requirements to maintain cattle performance, reducing crude protein in beef cattle diets may be the most practical and cost-effective way to reduce ammonia emissions from feedyards. Another study by Todd et al. (2009) determined that feeding high concentrations (> 20 percent) of wet distiller's grains, which are becoming increasingly available as a ration component, increased crude protein intake in beef cattle and resulted in increased ammonia emissions.

## *Phase Feeding*

As beef cattle mature, they require less dietary protein. Phase feeding involves adjusting nutrient intake over time to match the changing needs of the animal. If protein is not progressively diminished through the feeding period in balance with the animals' nutritional requirements, potentially more nitrogen is excreted and more ammonia may be emitted from the facility (Cole et al., 2006a; Vasconcelso et al., 2009). Studies on cattle fed high-concentrate, steam-flaked corn-based diets have suggested that a moderate reduction (~1.5 percent) in dietary crude protein (CP) in the final 28 to 56 days of the feeding period may decrease ammonia emissions by as much as 25 percent, with little adverse effect on animal performance (Cole et al., 2006a). Based on seven cooperative studies to determine the effect of crude protein on ammonia emissions and animal performance (Cole, 2006b), a reduction of dietary crude protein from 13 percent, which is optimal for growth, to 11.5 percent resulted in a 3.5 percent decrease in average daily gain and an approximate 30 percent reduction in ammonia emissions. Therefore, in certain economic conditions, it may be practical to accomplish a significant reduction in ammonia emissions with a minimal effect on animal performance.

## *Distiller's Grains*

Distiller's grains have recently been introduced into beef cattle rations and may affect CAFO ammonia emissions. Research by Cole et al. (2008b) reported that a 10 percent increase in distiller's grains in rations based upon steam-flaked corn increased manure production by approximately 10 percent. In rations based upon dry-rolled corn, the same increase in distiller's grains resulted in a 0-7 percent increase in manure production. In both cases, the concentration of nitrogen in the manure was not affected. The combination of increased manure volume and steady nitrogen concentrations may result in potentially greater ammonia emissions. In a comparison of ammonia emissions at two feedyards, Todd et al. (2009) found that one feedyard feeding distiller's grains averaged 149 g NH<sub>3</sub>-N head<sup>-1</sup> d<sup>-1</sup> over nine months, compared with 82 g NH<sub>3</sub>-N head<sup>-1</sup> d<sup>-1</sup> at another feedyard feeding lower protein, steam-flaked corn-based diets.

## *Fiber*

Manipulation of dietary fiber also may affect ammonia emissions from feedyards. In a study by Erickson et al. (2000), dietary fiber in the form of corn bran was increased in cattle finishing diets. During the winter-spring study period, nitrogen volatilization rates were decreased, but animal performance was adversely affected.

**As beef cattle mature, they require less dietary protein. Phase feeding involves adjusting nutrient intake over time to match the animal's changing needs.**

In another study by Bierman et al. (1999), beef cattle were fed different diets containing wet corn gluten feed (WCGF), corn silage, and alfalfa hay. The researchers concluded that dietary fiber and carbohydrate source affected the way feed was digested and excreted by cattle, resulting in changes to the amount of nitrogen excreted. Nitrogen excretion was highest for cattle fed a ration based on WCGF, but these cattle also had the highest performance.

Farran et al. (2006) manipulated alfalfa hay and WCGF in beef cattle diets and made similar observations. Increasing alfalfa hay or WCGF intake resulted in an increase in nitrogen intake, nitrogen excretion, nitrogen volatilization, and cattle performance. They further concluded that recovery of nitrogen in the manure and finished compost was also increased, especially in the case of WCGF, as a result of increased organic matter content in the manure.

### *Cation-Anion Balance*

Ammonia emissions are inhibited in low-pH environments, and lowering dietary cation-anion balance (DCAB) can potentially lower the pH of cattle urine. Thus, notwithstanding other factors, lowering the pH of cattle urine may potentially reduce CAFO ammonia emissions. However, Erickson and Klopfenstein (2010) noted no effect of DCAB on nitrogen volatilization losses. Lowering urine pH may have little effect on ammonia emissions because the pen surface of feedyard pens may have significant buffering properties that strongly resist pH changes, tending to maintain a pH of approximately 8 or higher (Cole et al., 2009). Furthermore, cattle performance may be reduced by low-DCAB diets (Cole and Greene, 2004).

### **Post-Excretion Ammonia Abatement Methods**

Post-excretion ammonia abatement strategies, such as improving manure management, can reduce the rate of nitrogen volatilization and ammonia emissions. Animal health considerations in post-excretion methods are not as great a concern when compared to nutritional methods. However, some manure management strategies, such as pen scraping, can be beneficial for animal health. Manure contains nitrogen and phosphorus, both of which contribute to the value of manure as a fertilizer. Nitrogen volatilization can reduce the nitrogen:phosphorus ratio to below most plant requirements, thereby reducing the fertilizer value of the manure and requiring a greater land application area to avoid excessive phosphorus applications. Reducing ammonia emission rates from manure will enhance the fertilizer value of manure and lower ammonia emissions. Besides manure management, manipulating other factors such as the pH and moisture content of soil and/or manure also can affect ammonia emissions (Cole et al., 2008a).

### *Urease Inhibitors, Zeolites, Fats, and Other Pen Surface Amendments*

Based upon laboratory studies, a number of compounds can potentially be applied to feedlot pen surfaces to reduce ammonia emissions from feedyard surfaces (Varel, 1997; Varel et al., 1999; Shi et al., 2001; Parker et al., 2005; Cole et al., 2007). Substances such as zeolites (a microporous, aluminosilicate mineral), fats, and urease inhibitors such as N-(n-butyl) thiophosphoric triamide, cyclohexylphosphoric triamide, and phenyl phosphorodiamidate may change manure properties such as pH, ammonia adsorption potential, or hydrolysis potential, which in turn affects ammonia emission rates.

Urease inhibitors work by slowing down or blocking the hydrolysis of urea (found in urine) by the enzyme urease (found in feces). However, urease inhibitors must continually be applied to manure because they rapidly degrade (Powers, 2002; Parker et al., 2005). Application of some compounds such as fats may be accomplished indirectly via dietary supplementation. Zeolites and urease inhibitors have been shown to decrease ammonia emissions when applied as a surface amendment, but not when used as a dietary amendment (Varel, 1997; Varel et al., 1999; Shi et al., 2001; Parker et al., 2005; Cole et al., 2007). Both dietary and surface amendments of fat appeared to

decrease ammonia emissions (Cole et al., 2007). The dietary fat effect is likely because a proportion of fed fat is voided onto the feedyard surface after being excreted in undigested form by feedyard cattle. No significant effects on animal performance were observed.

## *Lowering pH*

One of the most important factors involved in ammonia emissions from surfaces is the pH of the emitting medium. In general, ammonia volatilization rates increase with pH. Therefore, lowering the pH of soil or manure can reduce ammonia emissions. With acidic conditions, given a constant temperature, more nitrogen will remain in the form of ammonium ( $\text{NH}_4^+$ ), thereby decreasing the amount of ammonia available to volatilize. A significant reduction in ammonia emissions has been observed with acidifying amendments such as aluminum sulfate (alum), ferrous sulfate, phosphoric acid, or calcium salts.

Maintaining the low pH can be challenging, however, because manure may have a strong buffering capacity, which results in the pH eventually returning to a more basic level and a resumption of ammonia emission. Strong acids are more cost-effective than weak acids or acidifying salts, but they are more hazardous and, therefore, are not suitable for use in agricultural environments (Ndegwa et al., 2008).

## *Manure Harvesting, Storage, and Application*

Frequent pen cleaning may help to capture nitrogen in the manure by decreasing loss to the atmosphere. Research in Nebraska (Erickson and Klopfenstein, 2010) revealed that cleaning pens once per month, as opposed to once after every 166-day feeding period, reduced apparent ammonia nitrogen losses by 24 percent. The effectiveness of the monthly cleaning strategy varied seasonally, being less in winter. This may be due to the accumulation of nitrogen that occurs in the pen surface manure pack during the winter, apparently the result of decreased ammonia losses during the colder months (Cole et al., 2009). In addition, the amount of nitrogen collected in the manure was 50 percent greater from pens cleaned monthly.

Covering manure to reduce its exposure to elements such as sun, wind, and rain is very effective at reducing ammonia emissions from storage areas. When manure is land-applied, immediate incorporation or injection into the soil has been shown to significantly reduce ammonia losses when compared to broadcasting alone (Ndegwa et al., 2008).

**Post-excretion ammonia abatement strategies can reduce the rate of nitrogen volatilization and ammonia emissions.**

**Frequent pen cleaning may help capture nitrogen in the manure by decreasing loss to the atmosphere.**

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