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Diet and Feed Management to Reduce Gaseous Emissions from Livestock Production: Principles and Practices

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Introduction

Animals emit gases to the atmosphere from feed digestion and manure decomposition. The production of gases begins in the digestive system of animals and continues after manure excretion and decomposition. Methane (CH_4) is produced by ruminants as a result of microbial breakdown of carbohydrates in the rumen. Enteric, or intestinal, CH_4 emission from feed digestion is affected by the quality and quantity of the feed consumed and physical conditions in the digestive tract. Animals usually retain less than half the nitrogen in the diet, with the remaining nitrogen excreted in the feces or urine. The feces and urine contain unretained nutrients and undigested diet components, including nitrogen and sulfur (S) compounds. The amount of ammonia (NH_3), hydrogen sulfide (H_2S), odor, and other gases emitted from manure decomposition largely depends on the nutrient levels and physical properties of manure. These gaseous emissions can be reduced through proper diet and feed management.

Five Principles in Diet and Feed Management for Reducing Gaseous Emissions

1. Formulating and delivering diet to match the nutrient requirements for the animal

Traditionally, animals were fed to meet the nutrient requirements for growth and performance with a safety margin to allow for the variability of nutrient content in feed and the differing nutrient needs of individual animals. Nowadays, animals are fed much closer to nutritional requirements with much less or no margin. Animals of different sizes, sexes, and genetics have different nutritional needs. If the diet is formulated to meet the needs of the average animal in a group, the remainder of the group may be either overfed or underfed. Similarly, if a single diet is provided to animals over a long period of time, overfeeding or underfeeding may occur during parts of the period. Overfeeding will result in excess nutrient excretion and thus will increase gaseous emissions. It can also be costly for producers because excess nutrients are not used by the animal. Excess nutrient excretion can be reduced by formulating and delivering diet to match the nutrient requirements for the animal. Although formulating and delivering a diet to exactly match the nutrient requirements for each animal is impossible, producers usually categorize animals into groups based on sex, growth/production cycle, etc., and develop diets to meet the needs of those particular groups in order to optimize production while reducing nutrient and gaseous emissions.

Additionally, animals require a specific profile (ratios) of nutrients. Diet is often formulated based on the limiting nutrients in the feedstuffs. Some nutrients are in excess in the diet formulation in order to meet the minimum requirements for other nutrients. Appropriate dietary formulation changes and supplementation may be used to minimize excess nutrients and gaseous emissions while providing essential limiting nutrients to meet animal requirements.

The process to exactly match the nutrient requirements for the animal and to use nutrient forms that are readily available for the animal for optimum production is called "precision feeding."

2. Improving feed digestibility and nutrient absorption

Not all nutrients in feed are equally available to animals. Nutrients come in a variety of forms; some are in readily available forms and some are more easily digested than others. Digestibility and nutrient availability affect nutrient absorption and retention in livestock product (e.g., meat, milk, and eggs). Improving feed digestibility will generally increase feed efficiency and productivity, reducing gaseous emissions per unit of livestock product. For cattle operations, increasing feed digestibility could increase energy intake level and result in lower percentage of digestible energy intake converted to CH_4 (Liu et al., 2017). Digestibility can be improved by lowering forage-to-concentrate ratio in diet. Forage digestibility is affected by stage of maturity, forage species, and environmental conditions.

3. Manipulating physical characteristics of manure

The physical characteristics of manure, such as pH levels, can affect the rate and type of gaseous emissions. Higher pH levels favor NH_3 emission and lower pH levels favor H_2S emission. Feed additives can be used to manipulate pH of manure and thus reduce certain gaseous emissions based on the relative importance of each air pollutant at the particular site. Nitrogen in urine is more readily released as NH_3 than nitrogen in feces. The ratio of urinary nitrogen to fecal nitrogen is another physical characteristic of manure that can be manipulated and reduced in order to reduce NH_3 emission.

4. Limiting unnecessary sulfur content in feed and water

Emissions of H_2S and volatile sulfur compounds are important sources of odor. They are generated from sulfur-containing amino acids and sulfur-containing mineral sources in diet, and sulfur content in water supplies. Limiting unnecessary sulfur content in feed and water can reduce emissions of odor, H_2S, and other sulfur compounds.

5. Minimizing feed waste

Gaseous and particle emissions may come from spoiled feeds. Improperly mixed feed or inconsistent feed deliveries can result in more waste entering the manure handling system. Feed wastes are subject to microbial decomposition and may encourage bacterial growth that increases odor and gaseous emissions from the system. Proper management during feed processing, storage, and delivery to minimize feed waste can help to avoid unnecessary feed expenses and reduce emissions.

Four Practices in Diet and Feed Management for Reducing Gaseous Emissions

1. Group and phase feeding

Group and phase feeding practices involve separating animals by age or production state (phase), and/or by sex to provide diets that more closely match the different nutritional needs of each phase and sex in order to reduce excess nutrients. More phases or groups allow for better targeting of feed nutrient requirements, but also require greater effort and expense in formulating and delivering feed rations.

In dairy cow operations, phase feeding according to milk production levels has been shown to reduce nitrogen excretion by 6 percent.

In swine production, phase feeding is always practiced while split-sex feeding is common. Gilts need more amino acids than barrows of the same weight. Using more feed phases (e.g. four to seven diets) has been shown to reduce nitrogen excretion and NH_3 emission.

In poultry production, phase feeding is frequently used but usually with fewer phases than maximum emission reduction would call for. Feeding broilers with six phases rather than four or fewer phases and adding supplemental amino acids has been shown to reduce NH_3 emission.

2. Dietary formulation changes and supplementation of synthetic amino acids

Dietary formulation changes in feed ingredients or ration formulations are sometimes used to provide essential nutrients to meet animal requirements while minimizing excess nutrients. It often involves reducing dietary protein and/or minimizes overfeeding of nitrogen, sulfur, and other nutrients. Reducing dietary protein can cause deficiency in certain amino acids that affect animal performance. Therefore, synthetic amino acid supplementation may be needed in rations with low protein content (Figure 1). The supplemental amino acids that may be considered economically feasible include lysine, methionine, threonine, and tryptophan. Synthetic amino acid supplementation is most feasible in swine and poultry diets. However, using synthetic amino acids may not be compatible with some organic certification systems.

- In beef cattle production, balancing dietary proteins can reduce nitrogen excretion. Manipulating the ratio of rumen undegradable protein to rumen degradable protein and the energy (carbohydrates) supplied in the feed can impact production levels and efficiencies. Beef cattle need less protein toward the end of the feeding period. Reducing the crude protein in beef cattle diets from 13 percent to 11.5 percent in the last 56 days of the feeding period has been shown to reduce nitrogen emission by 19 percent (Cole, 2009). Reduction of dietary protein for dairy cattle must be closely managed to avoid affecting milk productivity.
- In swine production, low protein diets with appropriate supplementation of amino acids can effectively reduce NH_3 emission without compromising animal productivity. A 3.0 to 4.5 percent reduction in dietary crude protein with supplemental amino acids has been shown to reduce pH by 0.4 units, NH_3 emission by 40 to 60 percent, and odor by 30 to 40 percent (Powers et al., 2007; Sutton, 2008). Replacing soybean meal in swine diets with corn and supplemental amino acids has been shown to reduce odor effectively.
- In poultry production, methionine and lysine are commonly added when using low protein diets. Each 1 percent reduction in dietary crude protein can result in a 10 percent reduction in NH_3 emission (Powers and Angel, 2008).

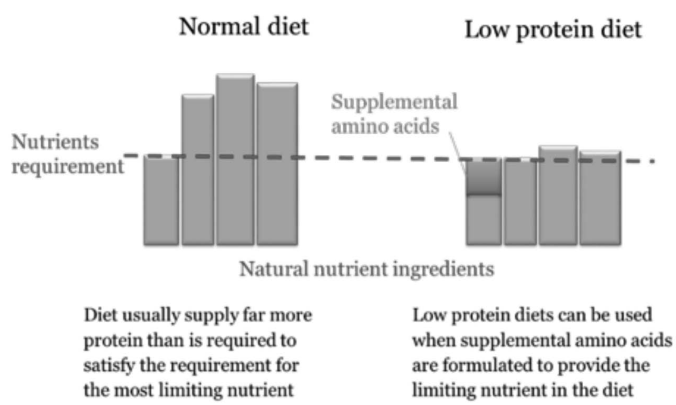

Figure 1. Lowering the dietary protein levels by using synthetic amino acids supplements.

3. Feed additives

Feed additives, such as enzymes, antibiotics, and beta-agonists, etc., have been added to animal diets to improve nutrient absorption and nutrient utilization efficiency, and to reduce production of some odor compounds (Carter et al., 2012). Adding small amounts of fiber to the diet can result in lower manure pH and lower ratio of urinary nitrogen to fecal nitrogen, and thus can reduce NH_3 emission (Aarnink and Verstegen, 2007). Fiber should be limited to 10 percent or less of the diet to avoid potential negative effects such as reduced digestibility. Addition of zeolite in feed has been shown to adsorb nitrogen and reduce NH_3 emission. When mineral additives are used to meet dietary needs, caution should be taken to limit unnecessary mineral sulfate sources in order to limit sulfur emissions.

- In cattle production, supplementing diets with fat has been shown to reduce enteric CH_4 emission.
- In swine production, soybean hulls have been used as a fiber additive, and have been shown to reduce manure pH, and reduce emissions of NH_3, H_2S, and odor (Sutton, 2008). Calcium salts (sulfate, chloride, and benzoate) are also potential additives for reducing manure pH and NH_3 emission. Addition of antibiotics in swine diets has been shown to improve feed efficiency by 5 to 15 percent and reduce odor compounds (Richert and Sutton, 2006).
- In poultry production, addition of calcium sulfate (gypsum) and replacing a portion (up to one third) of the limestone in diet have been used to reduce manure pH and NH_3 emissions, but at the expense of an increase in H_2S emission.
- For all species, adding fat/oil, water, or "wet" feed ingredients to dry feed rations can reduce particle emissions.

4. Feed processing

Pelleting feeds can reduce feed waste by up to 5 percent. Fine grinding of feed can increase nutrient utilization and reduce gaseous emissions by increasing the particle surface area, and allowing digestive enzymes to break down the feed more easily. Decreasing feed particle size from 1000 to 600 microns has been shown to increase dry matter and nitrogen digestibility by 5 to 12 percent and to lower the amount of nitrogen in manure by 20 to 24 percent (Carter et al., 2012). Smaller particles raise processing costs and may have negative health effects. The optimum particle size varies, depending on the animal species.

- In cattle production, highly processed grain in feed tends to decrease enteric fermentation and, therefore, decreases CH_4 emission. However, fine grinding has the potential to increase digestive disturbances, such as bloat, in finishing beef cattle.
- The optimum feed particle size for poultry is between 400 and 450 microns (Carter et al., 2012).

Summary

Ongoing animal nutrition research has led to a more accurate understanding about animal nutrient requirements and availability of nutrients in feed ingredients, which creates more opportunities for "precision feeding" and other diet and feed management practices. However, producers are often constrained by the types and costs of available feedstuffs. When selecting these diet and feed management practices to improve productivity and reduce gaseous emissions, careful balance or compromise should be considered to maintain the economic viability of the operation and to align with farm-specific production goals.

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MF3386 November 2017