Role of Protein Intake in Containment of Ammonia Emissions in Dairy Cattle

Aparna[1*], J.S. Hundal[2], U.B. Singh[2], I. Singh[2] and A.S. Singh[2]

[1]Krishi Vigyan Kendra, Roopnagar, Punjab Agricultural University, Ludhiana, [2]Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Science University, Ludhiana-141004, India

*Corresponding author: aparnapau@gmail.com, Ph 9872805020

Journal of Livestock Science (ISSN online 2277-6214) 7: 226-230
Received on 27/5/2016; Accepted on 8/9/2016

Abstract

In ruminants excess dietary Nitrogen (N) is excreted as urea mainly through urine. Urea, the major form of urinary N is rapidly converted to ammonia after excretion. Ammonia is an important environmental pollutant that impacts the quality of human and animal life .The NRC (2001) considered ammonia emissions from concentrated animal feeding operations (CAFO) as a major air quality concern. Ammonia can cause serious environmental problems and health issues in gaseous or particulate phases. Dairy cattle contributed 13% of the total NH_3 emissions for the year 2002 while all animal operations including dairy contributed 55% of the total NH_3 emissions. Thus decreasing N excretion from dairy cows will help reduce ammonia pollution. Ruminants are only 30% efficient in converting intake N to milk or tissue N and the remaining N is lost into the surroundings. Nitrogen efficiency could be as high as 80% in pigs, assuming similar potential, increasing N efficiency in lactating cows will decrease N excretion. Great improvements in N efficiency could be achieved by reductions in feed N if milk production could be maintained. In addition to the economic and environmental impacts, feeding excess Crude Protein may affect the fertility of dairy cows thus, it is beneficial to avoid excess dietary protein in lactating dairy cow diets without compromising milk production. Decreasing dietary RDP than recommended, proper Protein:carbohydrate ratio and feed additives will have positive economic and environmental impacts if diets can be constructed to maintain milk and milk protein production in dairy cows. Milk production may be maintained when essential AA requirements are met by maximizing ruminal microbial protein outflow.

Key words: Protein intake; Dairy cattle; Containment; Ammonia emissions

Introduction

Ammonia is a colourless, pungent-smelling and corrosive gas that is produced by the decay of organic matter and from the humans and animals excreta. When released into the atmosphere, ammonia increases the level of air pollution as this may lead to photochemical air pollution, reduced visibility, polluting the surface waters, changes in biodiversity, acid rain, stratospheric ozone depletion, and global warming. Ammonia emissions from agriculture mainly occur as a result of evaporation from dissolved livestock excreta. This may occur from manure spreading on agricultural land (35%-45%), livestock housing (30%-35%), urine and dung deposition in grazed areas (10%-25%) or manure storage (5%-15%). A large proportion of ammonia emissions result from the evaporation of ammonia from nitrogenous fertilizers and from fertilized crops (Ammonia emission statistics 2015; Gay and Knowlton 2009). Aneja *et al* 2012 conducted a study to estimate the Nitrogen (NH3) emissions from India from livestock (1705 Gg/yr) and fertilizers (2697Gg/yr) and found that these emissions were second only to China. It was observed that the state of Uttar Pradesh has the highest NH3 emission (522 Gg/yr) followed by the state of Maharashtra (425 Gg/yr) both from animal and crop farming. However, ammonia emissions from livestock operations have recently received significant attention. Among these emissions, cattle have been estimated to have the largest contribution, followed by buffaloes. The other categories of livestock like pigs, poultry, horses and sheep have small contributions in the total national NH3 emission (Sharma *et al*, 2008). New air quality standards that cover ammonia emissions in the United States have been adopted in 1997. These regulations will have a significant impact on the future of animal production operations.

In livestock operations, two types of strategies i.e. pre excretion and post excretion strategies can be adopted to control this form of pollution. Pre excretion strategies include a regulation of animal protein intake and post excretion strategies involve management of manure. Hence the present review has been planned with the objective to study the role of animal protein and nitrogen intake in control of ammonia emissions by dairy cattle.

The digestible crude protein (DCP) is widely used to evaluate protein requirements, and it corresponds to the crude protein that remains after losses in the faeces. However, a new system has been introduced which takes into account the degradability of the protein in the ration during digestion. It has been considered a more efficient system to calculate requirement levels, especially for high-yielding cows that have the requirement of proteins that escape microbial degradation in the rumen and are absorbed as amino-acids in the small intestine. Following this approach crude protein can be split into Rumen degradable Nitrogen (RDN) and Undegraded Dietary Nitrogen (UDN) or Rumen Degradable Protein (RDP) and Undegradable protein (UDP). Fish meal is for example considered as a good source of UDN.

Inorganic nitrogen sources from protein as well as other non-protein nitrogen, such as urea, are degraded by microbes in the rumen by rumen microbes and used for their protein synthesis by them. Later during the digestion process the microbes are themselves digested and the microbial protein becomes available to the animal. But microbial synthesis of protein is an energy supply dependent process. Therefore, if sufficient RDP is not available, the rate of digestion of fibrous as well as concentrate rich diets will be reduced. This leads to a reduced feed intake, lesser energy supply and lowered milk production. On the other hand, some protein nitrogen can resist microbial breakdown in the rumen and can pass directly to the cow's intestine. This feed protein fraction is called by-pass protein which is especially profitable for high-yielding cows. At a low level of production animals can meet their protein requirement entirely from microbial protein and the diet containing degradable protein is adequate. This explains why such animals can be fed with urea or poultry manure instead of bypass quality protein. It is therefore important to have the optimum balance of UDP and RDP in the diet. But in ruminants excess dietary N is excreted as urea mainly through urine (Wright et al. 1998) which is converted to ammonia after excretion (Varel *et al* 1999). Ammonia is an eminent environmental pollutant that affects the human as well as animal life (NRC 2001). Both in gaseous or particulate state Ammonia can create environmental problems and health issues. For example, gaseous NH_3 can damage foliage (Vander and Vander,1998) or when converted to ammonium (NH4+) can pollute surface waters. It can reduce air quality by catalyzing the formation of fine particles which contribute to global climate change, degrade visibility and can be fatal for human beings (Poppi *et al* 1980). Other issues generated by NH_3 are impaired lung functions and aggravating asthma and other respiratory disorders. Even it can become toxic at extremely high concentrations.

The NRC (2001) considered ammonia emissions from concentrated animal feeding operations (CAFO) as a major air quality concern. Ammonia emissions from dairy operations contribute immensely to N pollution (Aneja *et al* 2008). Dairy cattle contributed 13% of the total NH_3 emissions for the year 2002 while all animal operations including dairy contributed 55% of the total NH_3 emissions (Aneja *et al* 2008). This indicates that manipulating the level of N excretion from dairy cattle can reduce the level of ammonia pollution contributed by dairy operations.

Partition of dietary nitrogen to faeces, urine and milk nitrogen output

Nitrogen excretion in faeces and urine represent a significant proportion of total N intake, and may approach 80% of daily consumption depending on different feed sources (Bruchem *et al* 1991). Nitrogen excreted in faeces (Feed N, undigested microbial N and endogenous N) by dairy cows is in proportion to DM intake, about 7.5 g/kg DM ingested according to Peyraud *et al* (1995) or 0.6% of the diaetary DM intake (Van Soest 1994). Hence reduction in faecal N excretion does not seem to be an effective way to achieve reduction in N loss from the animal (Tamminga, 1992; Van Soest, 1994). This is due to the fact that true digestibility of dietary protein in most dairy cow rations is quite high, secondly digestibility of microbial protein is also high (Tamminga,1992). Hence Urinary N excretion is a more promising to manage N excretion in dairy cattle. Dairy cows on average secrete in milk 25 to 35 percent of the nitrogen they consume and almost all the remaining nitrogen is excreted in urine and faeces with about half of the nitrogen excreted in urine. Approximately 60 to 80 percent of the nitrogen in urine is in the form of urea which is rapidly converted to NH_3 during manure collection and storage as compared to fecal N (Varel *et al* 1999) i.e. almost all N ingested in excess of animal requirement excreted in urine (Peyraud *et aI* 1995).

Urine and faeces, individually, emit minimal amounts of ammonia; it is the physical process of combining urine and faeces after deposition on a floor, which results in ammonia evaporation in dairy shed. There are additional factors like temperature, air velocity, pH, floor surface area, manure moisture content, and storage time which facilitate ammonia volatilization. For example, high pH and temperature favor the process (Ishler, 2004). Various routes contribute to urinary N output including ruminal and metabolic losses (Tamminga 1992). Increases in dietary protein or N intake also lead to increases in urinary loss (Van Soest 1994). Pigs have high nitrogen efficiency (80%), assuming similar potential, increasing N efficiency in lactating cows will decrease N excretion from dairy farms. Great improvements in N efficiency could be achieved by reductions in feed N but with the condition that milk production is not to be affected (Ipharraguerre and Clark 2005).

Situations leading to imbalanced feeding are (i) feeding high moisture grains as this can result in higher urinary urea excretion and an increase in urine volume too (PM 1971a, 2004); (ii) feeding NPN treated silage as it contains highly degradable protein. Excess N in the diet will occur which may not fulfill the need of un-degradable protein; (iii) Single mixed ration feeding to all animals in herd particularly when rations has higher protein levels as a safety margin. On the basis of actual of milk produced, this safety margin may result in excessive levels of N being fed and excreted.

Feeding excess N may make dairy operations less profitable due to increased feed costs in addition to the fact that it reduces efficiency of nutrient utilization (Tamminga, 1992). In addition to the economic and environmental impacts, feeding excess CP may affect the fertility of dairy cows, thus, it is beneficial to avoid excess dietary protein in lactating dairy cow diets without compromising milk production.

Ruminal microbial organisms convert degradable feed protein into peptides, AA and ammonia in the rumen and use them for microbial protein synthesis. Excess ruminal NH_3-N will be absorbed across the rumen wall, converted to urea in the liver and mostly excreted in urine. This indicates that feeding RDP to just meet microbial needs will minimize N excretion from the animal. On the other hand feeding of inadequate amounts of RDP will compromise dry matter intake (Firkins *et al* 1986) microbial protein production, and energy and protein supply to the cow (Clark *et al* 1992), while feeding RDP and UDP as per NRC re commendations will optimize the production and blood parameters (Aparna *et al* 2009 & Gupta *et al* 2010).

Increasing dietary protein primarily increases urinary N, causing an increase in N excreted through urine without changes in milk or fecal N output (Broderick 2003; Wright *et al* 1998). Decreasing dietary protein decreases N output mainly by a reduction in urinary N as output as fecal N losses are relatively constant (NRC, 2001). Jonker *et al* (2002) revealed that, feeding 6.6% more N than recommended by NRC (2001) caused a 16% increase in urinary N and 2.7% increase in fecal N loss. On average 59% of the non-ammonia N that reaches the duodenum is supplied by microbial CP and the remaining is RUP or endogenous protein (Clark *et al* 1992). Feeding RDP below requirements can compromise microbial protein production, ruminal digestion, and energy and protein availability to the cow (Clark *et al* 1992). An on farm study by Aparna and Kaushal 2009 reported underfeeding of UDP which was compromising the production, thus, it is critical to provide enough RDP to meet requirements of ruminal microbial organisms. However Klusmeyer *et al* (1990) did not observe significant difference in microbial N flow to the duodenum in 11% CP (5.7 % RDP) and 14.5% CP (8.7% RDP) diets fed cows indicating that feeding lower CP maintained microbial protein flow. Moreover, reductions in RDP may not always lead to reductions in metabolizable protein availability because reductions in microbial N flow can be offset by increases in RUP flow (Santos *et al* 1998). But considering economy an inevitable aspect, feeding RDP is less expensive than feeding RUP.

Gressley and Armentano (2007) fed lactating dairy cows either a high RDP (10.1%) or a low RDP (7.4%) diet with RUP either 6.0 or 6.1% of DM, respectively and fixed DMI at 90% of *ad libitum* intake. Even though the low-RDP diet was predicted to be 28% below requirements, it did not affect milk yield. However, Klusmeyer (1990) found that milk production was decreased when dietary CP was reduced from 14.5 to 11% of DM. So, Probably RUP compensated in former case. Because Kalscheur *et al* (2006) used decreasing CP (17.1 to 12.3), RDP (11.0 to 6.8) and RUP (6.1 to 5.5) %of DM, respectively, in diets of mid lactation dairy cows and observed that 6.8% RDP diet decreased N excretion but also declined milk and milk protein yield. However, both RDP and RUP contents of the diet were reduced, so it was not clear which component was deficient.

Increase in milk production with raised CP content of rations increased milk production due to higher passage of non-NH_3 non-microbial N that supplied essential AA for milk production. Thus it is important to understand minimum RDP required to maximize microbial protein flow out of rumen and maintain milk production.

Pre excretion strategies also include the use of acid-producing phosphorus sources or calcium chloride and calcium sulfate to feed. The use of feed additives such as yucca plant extracts and the reduction of dietary protein may also reduce ammonia emissions (Gay and Knowlton, 2009, Hristov *et al*, 2011). Addition of fermentable carbohydrates, such as bran or pulp, into diets, resulted in a 14 percent reduction of ammonia emission for each increase in carbohydrate. The reduction may be due to a pH effect, to the shift from urinary to fecal nitrogen excretion, or both (Hristov *et al*, 2011).

Conclusion

Manure composition (affected primarily by the diet fed) and manure collection and storage are the main factors affecting NH3 emissions from an animal operation. Pre excretion strategy of reducing crude protein concentration in cattle diets is perhaps the most feasible method for mitigating these losses. Availability of relatively inexpensive, high-protein feeds can lead to a significant overfeeding of protein to feedlot and dairy cattle, thus contributing to even greater N concentration in manure and farm NH3 emission. The NRC (2001) recommends 9.5 to 10.5% dietary RDP for lactating dairy cows and these recommendations are generally followed. However, it may be concluded that decreasing dietary RDP than recommended, proper protein carbohydrate ratio and use of feed additives will have positive economic and environmental impacts if diets can be constructed to maintain milk and milk protein production in dairy cows. Milk production may be maintained when essential AA requirements are met by maximizing ruminal microbial protein outflow.

References

1) Agriculture - Ammonia Emission Statistics, 2015. Available online http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultureammonia_ emission _statistics

2) Aneja VP, Blunden J, James K, Schlesinger WH, Knighton R, Gilliam W, Jennings G, Niyogi D, Cole S, 2008. Ammonia assessment from agriculture: US status and needs. Journal of Environmental Quality 37(2): 515-520.

3) Aneja VP, Schlesinger WH, Erisman JW, Sailesh N, Behera D, Sharma M, Battye W 2012. Reactive nitrogen emissions from crop and livestock farming in India. Atmospheric Environment 47: 92-103.

4) Aparna, Kaushal JR, Hundal J 2009. Effect of altering level of dry matter and RDP on production performance of dairy cattle. Indian Journal of Animal Nutrition 26 (2):125-129.

5) Aparna and Kaushal JR 2009 Evaluation of feeding practices in crossbred cattle by progressive dairy farmers of Punjab- an on farm study. Indian Journal of Animal sciences. 79 (7) :710-715

6) Broderick GA, 2003. Effects of varying dietary protein and energy levels on the production of lactating dairy cows. Journal of Dairy Science, 86:1370-1381.

7) Bruchem JB, Bosh MW, Oosting SI, 1991. Nitrogen efficiency of grassland-based dairy farming -New perspectives using an integrated approach. In: G.E. Groen, J.V. Bruchem (Editors). Utilisation of Local Feed Resources by Dairy Cattle. EAAP Publications No 84, Wageningen Press, Wageningen (The Netherlands), pp. 99-101.

8) Clark JH, Klusmeyer TH, Cameron MR, 1992. Microbial protein synthesis and flows of nitrogen fractions to the duodenum of dairy cows. Journal of Dairy Science, 75:2304-2323.

9) Firkins JL, Berger LL, Merchen NR, Fahey GC, Nelson DR, 1986. Effects of feed Intake and protein degradability on ruminal characteristics and site of digestion in steers. Journal of Dairy Science, 69(8): 2111-2123.

10) Gay SW, Knowlton KF, 2009 Ammonia Emissions and Animal Agriculture, Available online https://pubs.ext.vt.edu/442/442-110/442-110_pdf.pdf

11) Gressley TF, Armentano LE, 2007. Effects of low rumen-degradable protein or abomasal fructan infusion on diet digestibility and urinary nitrogen excretion in lactating dairy cows. Journal of Dairy Science, 90(3): 1340-1353.

12) Gupta A, Kaushal JR and Hundal J 2010. Effect of dry matter and rumen degradable protein on blood profile of dairy cattle. Indian Veterinary Journal, 88: 98-99

13) Hristov AN, Hanigan M, Cole A, Todd R, McAllister TA, Ndegwa PM, Rotz A 2011. Review: Ammonia emissions from dairy farms and beef feedlots. Canadian Journal of Animal Science 91:1-35.

14) http:// www.extension.iastate.edu/Publications/PM1971a.pdf 2004 Practices to Reduce Ammonia Emissions from Livestock Operations

15) Ipharraguerre IR, Clark JH, 2005. Impacts of the source and amount of crude protein on the intestinal supply of nitrogen fractions and performance of dairy cows. Journal of Dairy Science 88(E. Suppl.): E22-E37.

16) Ishler V, 2004. Nitrogen, Ammonia Emissions and the Dairy Cow. DAS 4-87 available online http://extension.psu.edu/animals/dairy/nutrition/nutrition-and-feeding/diet-formulation-and-evaluation/nitrogen-ammonia-emissions-and-the-dairy-cow-1

17) Jonker JS, Kohn RA, High J, 2002. Dairy herd management practices that impact nitrogen utilization efficiency. Journal of Dairy Science, 85(5):1218-1226.

18) Kalscheur KF, Baldwin RL, Glenn BP, Kohn RA, 2006. Milk production of dairy cows fed differing concentrations of rumen-degraded protein. Journal of Dairy Science, 89: 249-259.

19) Klusmeyer TH, McCarthy RD, Clark JH, Nelson DR, 1990. Effects of source and amount of protein on ruminal fermentation and passage of nutrients to the small intestine of lactating cows. Journal of Dairy Science, 73(12):3526-3537.

20) National Research Council (NRC), 2001. Nutrient Requirements of Dairy Cattle, 7th rev. ed. In Natl. Acad. Sci., Washington, DC.

21) Peyraud IL, Verite R, Delaby L, 1995. Nitrogen excretion by dairy cows: effect of the diet and of the level of production. Forages, 142: 131-144.

22) Poppi DP, Norton BW, Minson DJ, Hendricksen RE, 1980. The validity of the critical size theory for particles leaving the rumen. The Journal of Agricultural Science 94: 275-280.

23) Santos FA, Santos JE, Theurer CB, Huber JT, 1998. Effects of rumen undegradable protein on dairy cow performance- A 12-year literature review. Journal of Dairy Science, 81: 3182–3213.

24) Sharma C, Tiwari MK and Pathak H. 2008 Estimates of emission and deposition of reactive nitrogenous species for India. Current Science, 94:11, 1439-1446.

25) Tamminga S, 1992. Nutrition management of dairy cows as a contribution to pollution control Journal of Dairy Science, 75, 345-357.

26) Van Der Meer HG, Van Der Pullen HI, 1995. Reduction of nutrient emissions from ruminant livestock farms. In: G.E. Polloll (Editor). Grassland into 21st Century: Challenges and Opportunities. Occasional Publication, Brit. Grassl. Soc. No 29, Harrogate (UK), pp. 118-134.

27) Van Soest PI, 1994. Nutritional Ecology of the Ruminant. 2nd Edition. Corflell University Press, Ithaca.

28) Varel VH, Nienaber JA, Freetly HC, 1999. Conservation of nitrogen in cattle feedlot waste with urease inhibitors. Journal of Animal Science, 77: 1162–1168.

29) Wright TC, Moscardini S, Luimes P, Mcbride HBW, 1998. Effects of rumen-undegradable protein and feed intake on nitrogen balance and milk protein production in dairy cows. Journal of Dairy Science, 81:784-793.