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REVIEW

Nutritional strategies for reducing nitrogen, phosphorus and trace mineral excretions of livestock and poultry

LU Lin[*], **LIAO Xiu-dong**[*], **LUO Xu-gang**

Mineral Nutrition Research Division, Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing 100193, P.R.China

Abstract

Animal agriculture contributes to environmental pollutions through the surplus nitrogen (N), phosphorus (P), and trace minerals that animals excrete. Animal nutritionists have sought alternatives to formulate more efficient diets and reduce production costs and environmental concerns. In general, element excretions may be reduced by avoiding the overfeeding of specific elements or using nutritional approaches to improve element utilizations by the animals. Several nutritional strategies are possible for minimizing N, P, and trace mineral excretions: 1) to accurately meet dietary N, P and trace mineral requirements of animals, which includes reducing the dietary crude protein contents with synthetic amino acids or feeding high rumenally undegraded protein, minimizing the adequate levels of dietary P and trace elements, adopting phase or group-feeding program, and considering the bioavailable trace mineral contents in the feed ingredients; 2) to improve the bioavailabilities of dietary N, P, and trace elements for animals by using some additives (enzymes, growth promoters, probiotics, prebiotics, vitamin D isomers, and organic acids); 3) to use highly available P sources or organic trace elements. In the future, nutrient strategies must be integrated into total production systems so that animal production systems are environmentally safe as well as economically viable.

Keywords: nutritional strategies, nitrogen, phosphorus, trace minerals, animal excretions

1. Introduction

The intensive animal production systems have given rise to many environmental concerns due to the output of waste in many countries (Powell *et al*. 2008). High element (e.g., nitrogen (N), phosphorus (P), and trace minerals) concentrations in manure, when used as fertilizer, can lead to soil concentrations that exceed crop requirements. These excess elements can leach through soils, potentially contaminating ground water supplies. Nitrate leaching has been considered a major N pollution concern on livestock and poultry farms. Manure can be a major source of methane and N oxides which contribute to the accumulation of greenhouse gas. Volatilization of ammonia causes acid rain which leads to forest dieback in some countries (Apsimon *et al*. 1987). Phosphorus entering surface waters can stimulate growth of algae and other aquatic plants (Sharpley and Smith 1994), which reduces the dissolved oxygen to levels that favor plants over animal life (Nahm 2007). Overgrowth of certain blue green algae causes concern since they produce toxins that are a potential health hazard for humans and animals (Kotak *et al*. 1993).

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LU Lin, E-mail: lulin1225@163.com; Correspondence LUO Xu-gang, Tel: +86-10-62816012, E-mail: wlysz@263.net
[*] These authors contributed equally to this study.

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In addition, repeated application of livestock and poultry manures to land may eventually result in accumulation of excessive levels of trace minerals, such as copper (Cu) and zinc (Zn), etc., and these minerals may impose a medium or long-term toxicity risk to plants and micro-organisms (Jondreville *et al*. 2003).

Over the last decades, the ways to reduce the environmental impacts of N and minerals used in livestock and poultry productions have been investigated. The nutritional approaches depend on the accurate estimation of nutritional requirements in order to achieve the supply to be closer to the requirement. The improvement of the nutrient utilizations for animals is a second option to be investigated.

The objective of this paper is to review the nutritional strategies and approaches to reduce N, P, and trace mineral excretions by livestock and poultry, and to describe the means that could be or have been already implemented in practice.

2. Reduction of nitrogen excretion

Nitrogen is required by animals in a significant amount, though most of N consumed is excreted *via* faeces and urine. The estimated excretion of N, relative to dietary intake, is 70–80% for dairy cattle (Dou *et al*. 1996; Kohn 1997; Oenema *et al*. 2001), and 65–70% for poultry or swine (Mohan *et al*. 1996; Lenis and Jongbloed 1999; Han *et al*. 2001). Nitrogen losses are mainly due to protein turnover related to muscle metabolism and amino acid catabolism (Nahm 2007). Two main nutritional strategies can be used to reduce N losses in animal production. The first is to match the dietary protein/amino acid supply as close as possible to the requirement of animals. The second is the addition of feed additives, such as enzymes, probiotics, and organic acid to the diets of animals to improve the N utilization.

2.1. Dietary formulations that closely match protein/amino acid requirements of animals

Nitrogen excretion can be reduced by accurately feeding animals according to their protein/amino acid requirements. Dietary crude protein (CP) levels in practice are usually higher than those animals actually require. It is reported that about 25% of CP in the typical corn-soybean meal diet could not be utilized by pigs, resulted from the imbalance of some amino acids, and the catabolism of these amino acids contributed to the N excretion in urine (Rademacher 2000). Based on the ideal protein concept, it is possible to reduce CP levels in animal diets and meet the amino acid requirements by supplementation with synthetic amino acids. The addition of synthetic amino acids to low-CP diets was shown to reduce N excretion in pigs and poultry without any negative effects on the growth performance of animals (Table 1). For ruminant animals, the rumen fermentation is very important in their digestive process. Rumenally degraded protein (RDP) and rumenally undegraded protein (RUP) are the most important sources of amino acids absorbed in the intestinal tract. Therefore, it is crucial to supply the appropriate quantity of protein with the proper degradation rates to provide the right amount and type of amino acids in the intestinal tract (Rotz 2004). The major nutritional strategy to reduce N excretion of ruminants is to decrease dietary CP level through the supplementation of feeds with high RUP (NRC 2001). A study with lactating dairy cows indicated that when the diets were formulated to meet the requirements of RDP and RUP, the urinary N excretion on a high CP diet (18%) was 2.3 times greater than that on a low-protein diet (12%). Rotz *et al*. (2000) also found that the use of a feed with lower RDP decreased N excretion by 39 kg per cow per year, compared with the use of soybean meal as the sole protein source. In a full lactation study with dairy cows, a reduction in dietary CP content from 17.5 to 16% led to a reduced (14%) N excretion without any negative effect on production. Most of the excreted N in manure is easily transformed into ammonia (Han *et al*. 2001). A study with dairy cattle showed that ammonia emissions from manure were reduced by 70% when the dietary CP contents decreased from 17.5 to 12.5% (Külling *et al*. 2002). A significant reduction of ammonia emissions was also observed in a similar experiment (Frank *et al*. 2002).

The element requirements of animals varies with the physiological state and growth potential. Phase feeding

Table 1 Reducing concentrations of nitrogen (N) in animal manure through reducing dietary crude protein (CP) levels and adding synthetic amino acids to diets

Experimental animals used	Reduction of dietary CP levels (%)	Reduction of N in animal manure (%, dry matter basis)	References
Growing-finishing pigs	3–4	35–45	Dourmad *et al.* (1993); Canh *et al.* (1998)
Swine	No data	25–30	Lenis (1989); Hartung and Phillips (1994)
Broilers	3–4	10–27	Blair *et al.* (1999)
Broilers	2–4	12–17	Wang *et al.* (2014); Zeng *et al.* (2015)
Layers	3.5	30–35	Blair *et al.* (1999)
Turkeys	10	16	Parks *et al.* (1996)

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