ISSN 1682-8356
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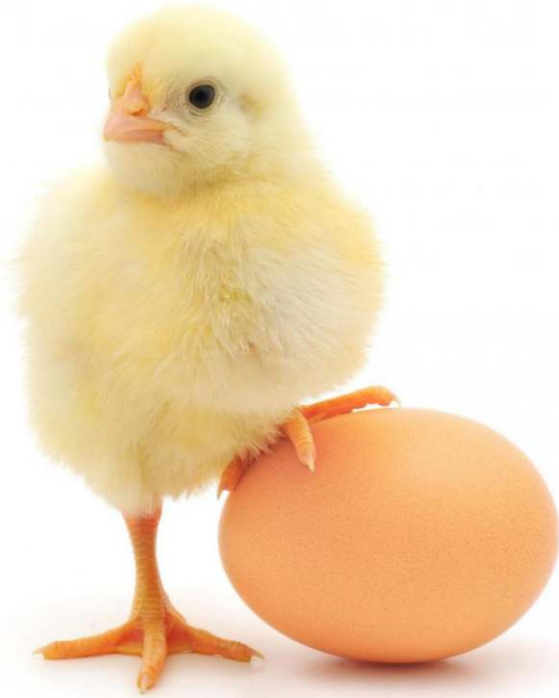

INTERNATIONAL JOURNAL OF
POULTRY SCIENCE

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International Journal of Poultry Science 5 (10): 900-904, 2006
ISSN 1682-8356

Environmental Approaches to Poultry Feed Formulation and Management

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Abstract: Increasing environmental pressures on the poultry industry challenge the status quo of ecological stewardship. Faced with this critical oversight, nutritionists, poultry and soil scientists, and pollution specialists are creatively proposing bundled strategies dealing with various practices related to dietary manipulation, poultry litter management and feed additive utilization to palliate the potential environmental impact of poultry production. Their implementation has proved beneficial to both, the poultry industry and the environment.

Key words: Environment, poultry, feedstuffs, dietary manipulations

Introduction

Printed media, radio, television, Internet and word-of-mouth are some ways in which the public receives information about how foods arrive to their tables. Consumer evolving knowledge about various foods range from newly discovered health-related properties to massive product recalls to the environmental impacts of producing them. Animal food production, be it beef, pork, fish or poultry have implicitly built within their systems a waste component -as urine and feces- that contains partially digested and undigested nutrients, excretory metabolites, water and modified fiber.

Animal Feed Operations (AFO) and Confined Animal Feed Operations (CAFO) are both agricultural enterprises where animals are kept and raised in confined conditions. They congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland. There are approximately 500,000 AFO's in the United States. The difference between AFO and CAFO is determined by many factors, chief amongst them is the number of animals kept confined, with their concomitant regulatory standards for each (in poultry, over 125,000 birds is a CAFO).

The U. S. population demands food that is safe, abundant, cheap and produced in an environmentally sound fashion. A striking fact is that 90% of U. S. poultry comes from 12 southeastern states; yet nationally, few poultry operators have adopted a nutrient management program. The potential impact of individual poultry operators on the environment varies with animal concentration, weather, terrain, soils and numerous other factors such as nutrient concentration in feeds. Therefore, the poultry industry (broilers, breeders, layers and turkeys) faces mounting scrutiny of its environmental stewardship. In response, on-farm nutrient management plans were devised, and they include, among many others, lower crude protein (CP) levels, digestible amino acids (AA) inclusions, lower available phosphorus (P) and phytase usage. Most of these practices are related to feedstuffs, but others have direct managerial applications.

Nature's cycles revolve around air, water and land, as there is nowhere else to deposit animal production outputs, thus our effort should focus on these three components of life. The three major environmental concerns with poultry production are ammonia (NH_3) vapors, phosphorus and nitrogen leaching; all of which can be reduced through conscientiously creative poultry feed formulation and management practices.

What is Ammonia (NH_3)?: It is a colorless, irritating gas with a distinctive odor found naturally in the environment as an initial by-product from the decomposition of nitrogen rich compounds found in organic materials (i.e., manure) and manufactured products, such as household cleansers. The environment has a certain capacity to convert ammonia to other compounds and the rate depends on temperature, pH, moisture and enzyme presence. When the natural ability of the environment is exceeded by discharges from human and animal activities, it concentrates in the water supply in dangerous quantities. Exposure to high levels of ammonia can cause irritation and serious burns on the skin and in the mouth, throat, lungs, and eyes. At very high levels, ammonia can even cause death (ATSDR, 2004). NH_3 buildup in poultry houses is detrimental to bird health (Reece *at al.*, 1980; Miles *et al.*, 2004).

FOCUS ONAIR – Non-Dietary and Dietary Manipulations to Reduce Ammonia

Aluminum compounds: Aluminum sulfate [Alum; $Al_2(SO_4)^3$] amendment of poultry litters has been suggested as a best management practice to help reduce the potential environmental effects of poultry production. Past research has shown that Alum treatments reduced NH_3 emissions from litters, decreased the loss in runoff of P and trace metals from litter-amended soils, improved poultry health, and reduced the costs of poultry production. Sims and Luka-McCafferty (2002) found in a 16-month, on-farm evaluation that Alum decreased litter pH and water solubility of P, As, Cu, and Zn. Alum-treated houses also had higher litter total N, NH_4-N, and total S concentrations and thus a greater overall fertilizer value than litters from the control houses. Higher litter NH_4-N values suggest that Alum reduced NH_3 losses from litters.

Zeolite clays: Compositionally, zeolites are similar to clay minerals. More specifically, both are alumino-silicates. They differ, however, in their crystalline structure. Zeolites have a rigid, 3-dimensional crystalline structure consisting of a network of interconnected tunnels and cages, with an ability to exchange cations. In monogastrics, zeolite clinoptilolite was very effective in trapping the NH_3 lost during the composting process of pig slurry and chopped straw (Bernal *et al.*, 1993). Kithome *et al.* (1999) composted poultry manure for 49 to 56 days and treated it with various amendments that included two natural zeolites, clay, coir (mesocarp of coconut fruit), $CaCl_2$, $CaSO_4$, $MgCl_2$, $MgSO_4$, and $Al_2(SO_4)^3$; and concluded that zeolite and coir amendments were the most suitable for reducing NH_3 losses during composting of poultry manure. A full list of additives to reduce ammonia emissions has been comprehensively reviewed elsewhere (McCrory and Hobbs, 2001).

Lower crude protein levels: Liang *et al.* (2005) monitored NH_3 emission rates (ER) coming from air exhausts using portable monitoring units at ten commercial layer houses in the U.S. for a full year under dietary manipulations consisting of two levels of CP: standard CP level as control and essential AA supplemented 1%lower CP level in two poultry houses per dietary treatment. They concluded that manure handling practices and diet manipulation all demonstrated effects of various degrees on NH_3 emissions rates. Specifically, NH_3 ER during 12-month monitoring period averaged 0.90 and 0.81 g/d/hen for standard and lower CP levels respectively, thus providing evidence to the indirect beneficial effects of dietary manipulations on the environment. In finishing pig diets, Hayes *et al.* (2004) found that NH_3 ER per animal for 130, 160, 190 and 220 g kg^{-1} crude protein diets were 3.11, 3.89, 5.89 and 8.27 g d^{-1} $animal^{-1}$, respectively, further supporting this practice as a low cost alternative, in relation to end-of-pipe treatments, for the abatement of odor and ammonia emissions from monogastrics.

Fermentable fibers: Adding fiber to poultry diets as dried distillers grains (DDG), rice hulls, oat and wheat has been found by various researchers to reduce urinary and fecal nitrogen, and ammoniac excretions. Younes *et al.* (1995) found that as a percentage of total excreted nitrogen, fecal nitrogen was 20% in an oat fiber diet and 27-29% in the gum arabic and oligosaccharide dietary treatments, compared with only 10% in fiber-free controls. These results indicate that under specific dietary conditions, the addition of oligosaccharides to the diet induces a 20 to 30% decrease in blood urea, and renal nitrogen excretion relative to the control. Also, complex sugars such as fructooligosaccharides in fibrous diets can be effectively used to reduce odors in monogastric manure (Bunce *et al.*, 1995).

On-farm EcoCal® implementation: EcoCal® is a downloadable software tool developed in the UK that allows individuals, enterprises and households to measure the environmental impact of their lifestyles based on current multi-source pollution data set from various animal and human-related activities. This web-tool is ideally suited for businesses that want to stress their environmental policy to customers and clients, to gain ISO14001 certification and as an educational approach to staff and related parties. This software is free in Europe only.

Poultry litter treatment (PLT): Is a non-offensively dry, white, slightly acidic granular product whose active ingredient is $NaHSO_4$. The Product Data Sheet claims, among many things, that PLT binds ammonia in the treated area of poultry houses, reduces urease production, and reduces ammonia released from the litter.

Why is Phosphorus leaching an environmental concern?: Phosphorus is an essential nutrient needed by plants and animals, but it can be a potential pollution hazard. The primary chemical form of P attaches itself to soil particles, which can be carried by erosion and leaching into lakes and streams (Schmidt and Jacobson, 1994). P is a limiting nutrient for aquatic plant growth in most surface waters, whose introduction initiates a dramatic increase in plant growth. When these plants die they are decomposed by aerobic bacteria, which deplete oxygen levels in the water and can cause fish mortality (Eutrophication).

FOCUS ON WATER – Dietary manipulations to reduce phosphorus (P) and arsenic (As): Due to concerns over P losses from agricultural activities decreasing surface water quality, recent efforts have been directed towards decreasing P in animal feeds; therefore, P excreted in manure can be effectively reduced.

Reduce dietary phosphorus levels: Maguire *et al.* (2005) reviewed the literature on dietary manipulations to reduce P excretion and reports that feeding P closer to animal requirement could decrease total P in manure by up to 33% in poultry. Combining this practice with other feeding strategies, such as using phytase and high available P corn, could decrease total P in poultry and swine by approximately 40%. Decreasing total P applications to agricultural land by reducing total P in manure will help control buildup of soil test P in the long term. Moreover, Smith *et al.* (2004) reports that changing from normal corn to high available P corn in broiler diets decreased water-soluble P by 35% and total P by 18%. These findings provide evidence to the fact that dietary strategies not only change the total P concentration in the manures produced, but also the forms of P that are present, particularly of water-soluble P in manures, as this has been linked to the potential for soluble P losses in runoffs immediately after land applications.

Phytase usage: Phytase is a natural enzyme used to improve the nutritional quality of phytic acid rich feed components, (i.e., soybeans), by hydrolyzing the bonds that hold tight inorganic phosphorus in plants. Supplementation of graded levels of phytase coupled with low or normal phosphorus diets resulted in moderately enhanced production parameters, but with reduced fecal P output (Broz *et al.*, 1994; Denbow *at al.*, 1995; Perney *at al.*, 1993). Some studies suggest that poultry production can do without P additions; as Shirley and Edwards (2003) demonstrated that broilers consuming a total P-deficient corn-soybean meal diet can achieve maximum performance when phytase is supplemented to 12,000 U/kg diet, thus implying that current phytase supplementation levels in the poultry industry may need further evaluation. Regardless of procedural polemics, it is clear that phytase supplementation is a viable strategy to reduce P outputs into the environment.

Replace organoarsenical feed additives: Arsenic (As) is a notoriously potent poisonous metalloid that has many allotropic forms and it is used as a component of various alloys, pesticides, herbicides and insecticides. Poultry feedstuffs, mainly broilers, can contain trace amounts of As in the form of organoarsenical feed additives such as Roxarsone (3-nitro-4-hydroxy-phenylarsonic acid) for its growth-promoting and disease-controlling properties, especially to combat coccidiosis. Poultry litter, a combination of poultry manure and bedding material, can contain arsenic at concentrations of 10-50 mg/kg (Garbarino *et al.*, 2003). Ingestion of As, both from water supplies and living tissues, has been scientifically linked as a cause of skin, liver, lung, kidney, breast and bladder cancer (Chen *et al.*, 1992; Jackson and Grainge, 1975; Schrauzer *et al.*, 1978). Non-toxic, natural alternatives are now available to combat coccidiosis.

Why is Nitrogen leaching an environmental concern?: Nitrogen is an essential nutrient needed by all living plants and animals. However, nitrogen can also be a pollutant in certain chemical forms and locations in the environment (Schmidt and Jacobson, 1994). For example, nitrate nitrogen in soil is utilized as an essential nutrient for plant growth, but because it is soluble in water, it can be carried into lakes, streams and ground water supplies. When animals and humans consume nitrate-contaminated water, it may cause health problems after bacteria in the body convert it to nitrite. Nitrogen is also commonly found in the form of ammonium, which is another form of nitrogen used for plant growth. However, ammonium can easily be converted into ammonia, which is released into the atmosphere and can contribute to acidification of soil and water supplies.

Focus on land - dietary manipulations to reduce mineral excretion, mainly nitrogen (N): Only 45% of the N consumed by poultry is retained as animal protein, with the remaining 55% of the N intake excreted in the manure. Substantial quantities of these mineral losses are recycled as landmass organic fertilizers are applied, but excess amounts tend to accumulate in the environment after repetition and time.

Reduce crude protein levels: Feeding more efficient diets, especially by decreasing protein levels, can reduce excess N. Decreasing protein in broiler and layer diets, while maintaining the same performance is possible, provided that the diets are rebalanced to account for lysine, methionine, threonine, various secondary AA and in the case of layers, tryptophan as well. A one-percent point reduction in dietary crude protein decreases nitrogen excretion by 10%. Therefore, with commercially available supplemental amino acids, a 10 to 15% reduction in nitrogen output from poultry production is a viable option (Blair *et al.,* 1999; Deschepper and De Groote, 1995; Van Cauwenberghe and Burnham, 2001).

Reconsider mineral and vitamins: Selenium, an essential trace element, also performs as a detoxifier as part of selenoproteins in living organisms that would otherwise end up in fecal matter, whilst ultimately circulating in the environment (Combs and Combs, 1984). Additionally, dietary reductions of Zinc (Zn) and

Copper (Cu) by 20% with a concomitant replacement of Vitamins A, C and E, could reduce mineral excretions without compromising antioxidant status.

Conclusions: Nowadays, with what is known about mineral losses, nutrient management plans are moving from N to P basis and are, more often than not, embracing cost-effective options. Practical, feasible and general multi-source contributions to reduce environmental damage can include, but are not limited to, the following:

Replace synthetic feed additives by all-natural options: This transition is becoming more frequent in the industry, as a move into natural options can be appreciated in end-product pricing. Also, more international firms are providing these nature-based feed additives at reasonable prices.

Reduce fecal and diet moisture to reduce mineral solubility: Feed moisture, water management, pen location and feed spilling in the house are pivotal points to consider in nutrient management plans, especially of P (Maguire *et al.*, 2006).

Dust reductions: Dust concentrations in poultry houses have been reported to vary from 0.02 to 81.33 mg/m^3 for inhalable dust and from 0.01 to 6.5 mg/m^3 for respirable dust. Sources of dust in broiler houses include feed, down feathers, excrement, microorganisms, and crystalline urine. There are a number of factors that affect dust levels in poultry houses, including animal activity, animal density and moisture conditions that can be managed to reduce dust (Ritz, 2006).

Implement and compare ecosustainability-based formulation vs. least cost-based formulation: By simply treating past dietary formulations as controls and new ecosustainable-based diets as treatments, poultry nutritionists can statistically determine the predictable outcomes of these strategic implementations. A comparative data set will be able to provide insight into the beneficial claims behind these proposed practices.

Fine tuned and comprehensive environmental management systems: The U.S. Department of Agriculture (USDA) and the Environmental Protection Agency proposed a nutrient management implementation policy, addressing P as well as N, which each state must enact by 2008 (EPA, 1977). There are three approaches that address P: Agronomic soil test P recommendations, environmental soil test P thresholds, and a P index to rank fields according to their vulnerability to potential P loss. Of the three P-based approaches, the P indexing approach has been most widely adopted with 47 states using this approach to target P management (Weld, 2003). The development of the indexing approach, which ranks site vulnerability to P loss by accounting for source (soil test P, fertilizer, and manure management) and transport factors (erosion, runoff, leaching, and connectivity to a stream channel) and incorporates modifications made among states that reflect local conditions and policy was studied by Sharpley *et al.* (2003).

Alternate use of manure: Forestland application of poultry manure offers an alternative to the conventional practice of pastureland application. Friend *et al.* (2006) put forward the proposal of applying poultry litter at moderate rates of approximately 5 Mg ha^{-1} to young stands of loblolly pine (*Pinus taeda* L.) growing in areas of high poultry production as an alternative disposal option with minimal impacts to water quality and potential increases in tree growth.
A change in paradigm is required to improve our environmental stewardship. Our aims are to present applicable environmental approaches to the manufacture of poultry feedstuffs, offer ecofriendly management practices, and demonstrate that these strategies are also applicable to other monogastrics with some modifications.

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