ANIMAL WASTE MANAGEMENT STRATEGIES, A REVIEW

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ABSTRACT

The issue of pollution and environmental protection now command widespread interest and political attention. Increased concern over environmental destruction has led to the introduction of new anti pollution laws and regulations in many countries throughout the world. Some such regulations focus on curbing pollution caused by industrial and agricultural activities. Animals produce enormous quantities of waste per day. In areas supporting intensive livestock production, accumulation of such waste can pose a serious environmental hazard. A single animal pen of a moderate size will produce quantities of waste equal to that produced by a small town annually. Waste produced from these pens usually lead to soil, water and the atmosphere pollutions. Several nutritional advances have been reported which serve to reduce the excretion and pollutive effect of animal waste.

Keywords: Environmental pollution, Animal, Nutrition, Animal waste

INTRODUCTION

Intensive animal production systems are inefficient feed converters into. This is particularly true for nitrogen (N), phosphorus (P) and potassium (K) ratio in animal diet compare to the dietary intake. A large fraction of these elements in feed are not deposited in animal tissue, but wasted as a mixture of urine and faecal matter (Tamminga and Verstegen, 1992). Losses in animal excreta occur in form of solid, liquid and gases.

High animal stocking density often, results in high waste production per unit area, thus animal manure is becoming a burden on the environment (AFRC, 1991). This is particularly the case in areas where intensive systems are employed for animal husbandry such as in The Netherlands and Holland. Public pressure aimed at reducing environmental pollution, including that caused by the animal industry, is a growing concern. In order to avoid a forced, significant reduction in the size of the animal industry, measures will have to be taken to reduce its negative impact on the environment (Tamminga and Verstegen, 1992). A number of biological approaches may be pursued which can help reduce environmental pollution arising from animal waste.

Dietary manipulation designed to increase feed digestibility reduces the quantity of faecal matters produced by the animals. The incorporation of specific enzymes in diets has also solved some specific nutritional problems. Enzymes rich feed often reduces the level of pollutants excreted in the faecal matter (Bateman, 1998).

MAJOR POLLUTANTS

To sustain their growth, plants must assimilate a variety of nutrient, most notably nitrogen and phosphorus. These nutrients are invariably present in animal manure (Headon and Walsh, 1994). Manure thus serves as an effective fertiliser. However, if manure is applied to the soil at a rate, which exceeds plant assimilation, a build up of nutrients can occur (Tamminga *et al.,* 1992). Such nutrients, which include nitrogen, phosphorus and minerals, can cause serious pollution.

Phosphorus: Low efficiency in the utilization of dietary phosphorus is seen in pigs and other monogastric animals. This is reflected by the large quantity of phosphorus normally associated with animal waste (Cromwell, 1980). Dietary supplementation of phytase enzyme can effect the concentration of phosphorus in poultry and livestock wastes through its ability to liberate phytate phosphorus contained in the cell walls of feed grains (Edens *et al.,* 1999). However this liberation of phytate phosphorus can only be accomplished if a concomitant reduction is made in supplemented dietary inorganic phosphorus and calcium. Phytate forms acid salts with mineral cations such as calcium, magnesium, copper, Zinc, iron and potassium thereby reducing mineral solubility and availability (Erdman, 1979). When acted upon by phytase enzyme, these cations are released much like phosphorus. Consequently, increased availability of these minerals will result in increased retention of phosphorus in chicken given phytase. In contrast with nitrogen, phosphorus generally remains in association with the surface layer of soil. This limits the extent to which phosphorus pollutes the ground water (MAFF, 1996). Soil erosion or manure run-off from the soil surface, however, can result in appreciable quantities of phosphorus entering the waterways. The presence of excess nutrients in such waterways invariably leads to pollution.

Nitrogen: Excess nitrogen present in manure is in inorganic form (often as ammonium ion NH_4^+). Some may be lost to the atmosphere as ammonia (NH_3) (MAFF, 1996). Because of its positive charge, NH_4^+ tends to associate electrostatically with the soil particles. This renders much of the applied nitrogen initially immobile in the soil. However, some of the NH_4^+ in the soil, which remains unassimilated by plants, is subsequently converted to nitrate in the soil. Although a proportion is converted to nitrogen gas (N_2) by the process of denitrification, much of the nitrate will find its way into ground water supplies (Headon and Walsh, 1994).

Although quantitatively, nitrogen and phosphorus represent the major pollutants present in animal wastes, several other waste constituents can have adverse environmental effects. Increasing concern has been voiced by many with regard to the quantities of minerals derived from animal faeces released in the environment (AFRC, 1991).

NUTRITIONAL APPROACHES TO REDUCE POLLUTION FROM ANIMAL WASTES

A number of nutritional approaches may be pursued which can help reduce the pollutive effect of animal waste (Vandergrift, 1992). In this regards, in piggery attention has been focused on reduction of nitrogen and phosphorus in the faecal matters, while maintaining health and high performance of the pigs. Nutritional management can substantially reduce the quantity of nitrogen and phosphorus excreted by pigs (VanKlooster *et al.,* 1998).

Dietary manipulation designed to increase feed digestibility reduces the qualities of manure produced by an animal (MAFF, 1991). Inclusion of probiotics in the diet may also assist the animal to utilise dietary nutrients more efficiently (Goransson, 1997). The presence of pathogens or potential pathogens (coliform) in the gut can render digestion and absorption of nutrients less effective. This in turn results in excessive excretion of such nutrients in the faeces (Van't Klooster *et al.,* 1998).

The addition of specific enzymes to diets may also solve specific nutritional problems. Feed enzymes can reduce the levels of nitrogen and phosphorus excreted in the faeces. Phytase renders phosphorus in the form of phytic acid, which is biologically available to the animal (Cromwell, 1980). Cellulases and protease may be used to enhance digestion of fibrous and proteinacious dietary components (Tamminga and Verstegen, 1992). Glucanases and pentosanases may be employed to destroy anti-nutritive molecules such asglucans and pentosans (Headon and Walsh, 1994). Anti-nutritional factors generally have an adverse effect on digestion and on assimilation. Their removal, therefore, exerts a positive effect on these physiological processes.

Ammonia is one of the most noxious pollutants associated with animal waste (Tamminga and Verstegen, 1992). Build up of ammonia concentrations in animal pen has a detrimental effect on both animals and animal keepers alike. Excess of ammonia into the atmosphere has an obvious pollutive effect (Horn and Squire, 1997). Beal *et al.* (2001) has shown that pre-treatment of pigs diet with protease increased the *in vitro* digestion of nitrogen in weaner pigs. There are four reasons why enzymes may be added in certain diets:

1. To remove or destroy anti-nutritional factors
2. To enhance overall feed digestibility
3. To render certain nutrients biologically available
4. To reduce the pollutive effect of animal excretes

Reducing Phosphorus Excretion through Nutrition: Inclusion of microbial phytase in pig diets is one of the initial successes in the utilization of enzyme to solve specific nutritional problem. Phytase currently represents the most exciting potential application of enzyme in the animal feed industry (Nasi, 1990). Two thirds of the phosphorus in cereal grain is in form of phytic acid, (phytate). This form of phosphorus is biologically unavailable to monogastric animals, as they do not produce digestive enzyme (phytase) capable of releasing the phosphate groups from phytate (Bateman, 1998).

Jongbloed *et al.* (2000) stated that since 1990 various experiments with exogenous microbial phytase have been reported to quantify their effect on the apparent digestibility/availability of phosphorus. One of the first and most interesting experiments was the dose-response effect of microbial phytase (Natusphos®) on the apparent digestibility of phosphorus in growing pigs from 20 to 55 Kg (Beers and Jongbloed, 1992). Six doses of phytase (from 0 to 1800 FTU/Kg) were used in two types of grower's diets

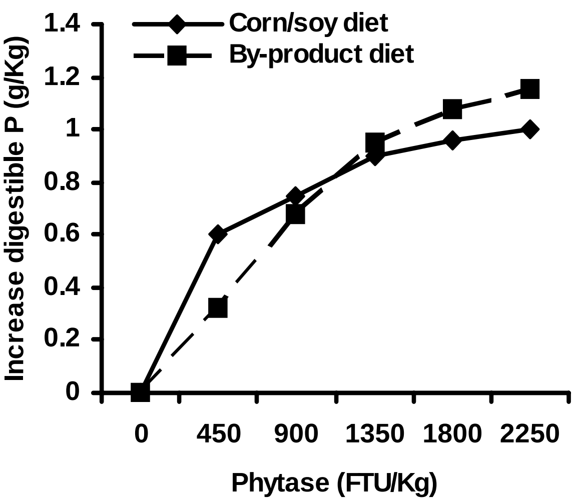

Figure 1: Improvement in digestible P by microbial phytase (Natuphos) in two diets for growing pigs (Beers and Jongbloed, 1992)

(based either on corn-soybean meal or phytate-rich by-products). The efficiency of microbial phytase appeared to be related to its dose and the type of diet (Figure 1).

From 0 – 400 FTU/Kg there was a rapid increase in microbial phytase efficacy, which flattened afterwards. In the experiment, it was shown that microbial phytase was considerably effective in enhancing phosphorus digestion and so increases the amount of digestible /available phosphorus in the feed for pigs.

Approximately 67 % of the phosphorus in plant tissue is in the form of phytate phosphorus (Myoinositol hexakisphosphate) (Cromwell *et al.,* 1993), which is only minimally available to monogastric animals since they lack the phytase enzyme that hydrolyses phytic acid to inositol and/or thophosphate (Peeler, 1972). Supplementation of phytase enzyme in corn-soybean meal diet of broiler chickens improves the availability of phytate bound phosphorus (Simons *et al*., 1992; Edens *et al.,* 1999). Phytate phosphorus content of corn is 68% of the total phosphorus, and in soybean meal phytate phosphorus represents 60 % of the total phosphorus (Edens *et al.* 1999). Simons et al (1990) demonstrated that in three-week-old broilers the availability of dietary phosphorus could be increased up to 65 % by means of supplemental dietary phytase while reducing fecal phosphorus by 50 %. Furthermore, inclusion of phytase activity in diets having wheat, triticale, rye, or their by-products resulted in better phosphorus utilization in poultry (Choct, 2001).

The efficacy of microbial phytase depends on animal related factor such as physiological status and housing condition (Kemme *et al.* 1997a). Kemme et al. (1997b) showed that the efficacy of phytase in generating digestible phosphorus decreased in the order of lactating sows, growing-finishing Pigs, sows at the end of pregnancy, piglets and sows at mid pregnancy.

A prerequisite for a good evaluation of microbial phytase efficacy is that the animal be fed below their phosphorus requirement. This is due to intestinal regulation of phosphorus absorption when animals are fed above their phosphorus requirement. It is commonly known that higher dietary calcium levels decrease apparent absorption of phosphorus. Thus a balance of calcium: phosphorus must be established for excellent performance (Jongbloed, 1993).

Reducing Nitrogen Excretion through Nutrition: To reduce the level of nitrogen in fecal matter through nutrition, two approaches are possible thus: (I) Enhancement of the deposition of nitrogen in animal products (meat, eggs, milk) and (ii) constant maintenance reduction of dietary nitrogen input while productivity is sustained (Tamminga and Verstegen, 1992). The first approach requires the intermediary metabolism to operate more efficiently, while the second approach largely depends on reducing nitrogen losses along the gastro-intestinal tract.

Both approaches will result in a reduction of Nitrogen in animal excreta by 20 %. A more efficient intermediary metabolism will reduce nitrogen excretion in urine by 10 %, whereas a reduction in losses from gastro-intestinal will reduce quantities present in both faeces and urine by 30 % (Lenis and Jongbloed, 1994). Feeding ration containing a poor balance of amino acids results in removal of excess nitrogen in the faeces. Taylor, *et al.* (1979) indicated that the dietary content of total crude protein could be reduced from 17.6 % to 14.5 % by the addition of crystalline lysine. This leads to improved balance of essential amino acids present in the diet and better protein utilisation.

Inclusion of protease in the diet may also promote more efficient utilization of dietary protein (Headon and Walsh, 1994). The endogenous proteolytic activities associated with the digestive tract are normally more than adequate to promote efficient degradation of dietary protein. For instance supplementation of feeds with exogenous microbial proteolytic activities can serve to improve protein utilization in animals subject to high protein intake.

Cellulase help in the breakdown of cell wall structure and make nutrients in vegetable materials much more available to the animal, they also break down xylan in cereal grains and reduce viscosity of the digester. The increase in the transit time in the gut leads to increase efficiency of utilization. The enzyme activation may also help promote more efficient digestion of poorly digestible proteins, such as those found in intimate association with some other dietary factors (Bateman 1998).

In monogastric animals, protein digestibility is low for some legume seeds, due to the presence of anti-nutritional factors (ANF) like lectins and protease inhibitors (Tamminga and Verstegen 1994). Low protein digestion can be overcome by technological treatment of the diet in an optimal combination of temperature, moisture and time. Short treatment at high temperature is more effective in reducing the antinutritional factor content of the dietary ingredient. Reduction in the activity of proteinous ANF and further breakdown of non-starchy polysaccharides can be accomplished using enzymes, during germination and grinding to finer particle size.

Beal *et al*. (1998) in a factorial analysis demonstrated the difference in the *in vitro* nitrogen digestibility between raw soybean and different full fat soybean meals both with and without enzyme treatment at different p^H (Table 1). Surprisingly, they observed that raw soybean appeared to be more digestible in pigs than processed soybean meal. However, the pre-treatment of soybean with exogenous enzymes increases protein digestibility. This is because large molecular weight proteins are partially hydrolyzed before the commencement of digestion. The difference in nitrogen digestibility between the raw and processed soybean meal could be due to a number of factors. Heat denaturation preventing digestive enzymes to act on amino acid residues, differences in solubility due to the pH of the stomach and loss of available protein due to heat induced interactions with other substances.

Nitrogen excretion can also be reduced substantially by supplying dietary amino acids in accordance with the animal's requirement and by incorporating free amino acids in the feeds and lowering crude protein content.

Multi phase feeding, in which diets can be automatically adjusted by means of a computer controlled feeding system may reduce excretion of nitrogen and phosphorus by 10 and 15 to 22%, respectively. Bourdon and others achieved nitrogen and phosphorus reduction applying multi phase feeding to castrated male pigs weighing between 25 and 100kg with decreased dietary protein levels, and supplementary addition of limiting amino acids (VanKlooseter *et al.,* 1998). From the experiments they concluded that the amount of nitrogen excreted was reduced by 50 %, with multi phase feeding accounting for 0.10 %. Van-der Peet-schwering *et al.* (1996) using multiphase feeding for growing and castrated male pigs between 25 and 110Kg live weight. Reported that multi phase feeding reduced ammonia emission by 45%, compared to the single control diet. Further more, multi phase feeding lead to 22 % reduction in phosphorus excretion by growing pigs (Beers and Jongbloed 1992). Results of Kemme *et al.* (1997a, b) indicated that multi phase feeding does not always lead to optimum performance and slaughter quality of pigs.

Requirements of nitrogen and phosphorus for breeding sows are much lower during pregnancy than during lactation. The use of separate diets for pregnancy and lactation compared with one diet for both reduced the excretion of nitrogen and phosphorus by 20 % (VanKlooseter *et al.,* 1998).

Growth promoters, because of improved feed conversion ratios have an estimated 7 and 3% reduction on nitrogen and phosphorus excretion per weaned piglet and growing pig respectively, according to Jongbloed et al (1992). Both nitrogen and phosphorus excretion can be further reduced with recombinant porcine somatotropin (rPST) (Bateman 1998); unfortunately, the use of growth promoters in feed is banned.

The source and level of fermentable carbohydrates in the diet influence ammonia volatilisation of pig slurry (Coppoolse *et al.* 1990). In an experiment, using three different treatments, Aarnink and Lenis (1998) fed soluble maize starch in treatment 1 and replaced it with coconut expeller and soybean hulls in treatment II and III respectively, ammonia volatilisation was decreased under laboratory conditions by 0.35%, 0.51% and 0.36% respectively. In a second experiment, the same authors examined the effect of electrolyte balance (Na + K – Cl), Ca-level and Ca-salt on ammonia emission from slurry. When CaSO4, Ca – benzoate or CaCl2, replaced CaCO3 respectively, the ammonia emission of slurry under laboratory conditions was reduced by 30%, 54% and 33% respectively.

EFFECT ON THE PERFORMANCE OF THE ANIMAL

There have been numerous reports on the effects of microbial phytase and phosphorus utilization. In addition to the general established improvements in phosphorus digestibility, significantly higher live weight gain and better-feed conversion efficiency have often been reported (Beers and Jongbloed, 1992; Cromwell, 1980; Dungelhoef and Rodehutscord, 1995 and Kemme *et al.,* 1997a). This could be explained by interference of phytic acid with the digestion of other essential minerals and protein. Phytate complexes in acid and alkaline media have been described (Dierick and Decuypere (1994). *In vitro* studies have shown that phytate-protein complexes involving amino groups of lysine, histidine and arginine are formed, which are insoluble and biologically unavailable in

Table 1: In vitro N digestibility (%) in different full fat soybean meals pre-treated with proteases P2, P3, or P4 with pepsin digestion at p^H 2

Protease 20,000 units g/N	% N digestibility				
	RSB	SPC	MIC	TSD	AUT
Control	78.5	80.3	74.7	67.8[1]	70.1[1]
P2	85.8[a1]	84.0[a1]	79.1[a1]	73.5[a]	81.1[a2]
P3	88.9[a]	84.9[a1]	82.7[1]	74.4[a]	78.1
P4	85.8[a1]	87.8[a1]	77.8[a]	74.8[a]	82.3[a]

Values in the same column with the same letter are not significantly different P<0.05. Values in the same row with the same number are not significantly different P< 0.05 (Source: Beal et al., 1998)

Table 2: Relative performance of pigs using positive control diets as 100(n=11) and effect of phytase when added to the positive control diet (n=6)

	Negative control	Positive control	Phytase effect	Positive control	Phytase effect
Growth rate	100	115.0 ± 6.5	116.7 ±10.6	100	106.6 ± 5.5
Feed intake	100	105.4 ± 5.2	107.6 ± 7.8	100	103.0 ± 3.2
FCR	100	93.0 ± 4.9	93.2 ± 5.0	100	95.7 ± 4.9

Source: Jongbloed et al. (1999)

Table 3: Mean magnitude of effects of addition of enzymes to poultry and pig diets

Enzyme	Poultry		Pigs	
	LWG	FCR	LWG	FCR
Protease	1.05	0.97	Small	Small
Amylase	1.12	0.93	1.04	0.96
Pentosanase	1.17	0.93	1.05	0.95
β-glucanase	1.18	0.91	1.01	0.98
Cellulase/Hemicellulase	1.07	0.94	1.03	0.91
Blends	-	-	1.09	0.93

Results and treatment /control ratio (Source: Dierick and Decuypere, 1994)

normal physiological conditions (Nasi, 1990). In addition, these protein complexes are less liable to be attacked by proteolytic enzymes than the free proteins (Jongbloed and Mroz, 1999; Dierick and Decuypere, 1994). Increased protein deposition and amino acid digestion in the small and large intestine of pigs by phytase may help to explain increased performance in pigs (Edens *et al.* 2000, Schoner *et al.* 1993 and Jongbloed 1999). Jongbloed *et al.* (1999) presented results on the effect of microbial phytase on performance of pigs compared. Data in table 2 shows that the performance of both the positive control and the phytase groups were superior to the negative control group. The positive control group and the phytase-supplemented group were almost identical. Performance of the pigs receiving the positive control group with supplementary phytase was slightly better than those without phytase. The relative ratios compared with the positive control diet for growth rate, feed intake and feed conversion ratio were 106.0 ± 5.6, 103.0 ± 3.2 and 95.7 ± 4.9 respectively. This may imply that either the phosphorus requirement was not yet met, which is unlikely, or there is another positive effect of microbial phytase on performance.

Several researchers have demonstrated improved performance of broiler chickens given feeds supplemented with a phytase product. Improved growth performance, assessed by increased body weight, feed intake and better feed conversion efficiency, has been reported in chickens (Edens *et al.,* 2000; Schoner *et al.,* 1991; and Schoner *et al.,* 1993) and turkeys (Qian *et al*, 1996). They further demonstrated improved performance of broilers given supplemental dietary phytase, which was correlated with improved bone growth and mineralisation. This response was attributed to increase retention of certain minerals and nutrients in addition to phytase-liberated phytate phosphorus (Swick and Ivey, 1990). The responses of pigs to supplementation of diets with proteolytic enzymes have been studied (Partridge, 2001; Chot, 2001; Dierick and Decuypere, 1994). In piglets did proteolytic enzymes improve live weight gain (LWG) and feed conversion ratio (Chot, 2001).

The underlying rationale for enzyme supplementation is the fact that the proteolytic and amylolytic digestive system is not fully developed until 4 – 6 weeks of age (Dierick and Decuypere, 1994).

In addition, nutritional stress associated with abrupt changes in the diet of the piglet may justify the use of supplemental enzymes at such times. However, as recovery and adaptation of endogenous enzyme production is very rapid, benefits of enzyme addition will be short-lived and of the order of two weeks (Headon and Walsh, 1994). α - Amylase addition to a barley diet for young pigs improved live weight gain and feed conversion ratio by about 4 %. In grower and finishing and growing pigs, amylase supplementation to cereals did not affect pig performance (Dierick and Decuypere, 1994). Choct (2001) reported significant increase in the live weight gain and feed conversion efficiency of chickens fed barley diets. Since it is established that the starch in barley is totally digestible by the amylase secreted by chickens, improvements with amylase supplementation were probably due to the added enzymes used; i.e. the crude enzyme used contained β - glucanase activity.

The effects of added enzymes are greater in poultry than in pigs and more apparently in young than in older animals (Dierick and Decuypere, 1994). However, it is difficult to draw definite conclusions. Table 3 shows the mean effects of simple addition of enzymes to poultry and pigs diets.

EFFECT ON THE ENVIRONMENT

In the absence of microbial phytase, only approximately 16 % of phosphorus in corn and approximately 36 % of phosphorus in soybean meal is digested by pigs (Jongbloed *et al.,* 2000). Because of the large amount of undigested dietary phosphorus, a substantial amount of phosphorus is removed via the faces. Based on the estimates of Cromwell *et al.* (1993), a dose of microbial phytase equal to 1000FTU/g converted approximately one third of the unavailable phosphorus to an available form. About 500FTU/Kg of diet generates approximately 0.8 g digestible Phosphorus per kilogram of diet, which is equivalent to 1.0 g phosphorus from monocalcium phosphate or 1.23 g phosphorus from dicalcium phosphate, which is often used in the United States.

A significant reduction in poultry manure phosphorus can be achieved via the use of microbial phytase in feed. This can reduce the nitrogen: phosphorus ratio in poultry wastes. Blander and Flegal (1997) studied the effect of feed supplemented with allzyme phytase in layer diets and reported a 16 % reduction in fecal phosphorus from laying hens fed inorganic phosphorus at 80 % of NRC requirements and a 25 % reduction in fecal phosphorus from laying hens fed 60 % of NRC requirements. A 35 % decrease in fecal phosphorus from laying hens given microbial phytase product at 250 FTU/Kg diet was reported by Coppoolse *et al.* (1990). Similarly, Blanda and Flegal (1996) reported decreased phosphorus excretion in turkeys given allzyme phytase. The fecal reductions from laying hens and market turkeys given allzyme phytase supplemented feeds were similar to the phosphorus reduction found in pigs given another phytase feed supplement, (Simons and Versteegh, 1992) and broilers (Yi *et al.,* 1996).

Conclusion: Many of the environmental impact of pig farming are known and ultimately controllable. The use of enzymes in pig production is an well-accepted practice today. Generally, most of the enzymes effectively depolymerise the soluble NSP into smaller polymers, though some products with affinity for both soluble and insoluble NSP are also used. It is wise to test economic policy and regulatory changes against the environmental consequences and ensure proper planning and implementation of control measures. That said, it is clear that whilst the potential for damage on the environment is great, nutritional manipulation to enhance efficient utilisation of Phosphorus and nitrogen by monogastric animals will reduce the damage done to the environment by these animals by at least 30 %.

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