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# Strategies for mitigation of nitrogen environmental impact from swine production

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**ABSTRACT** - This work presents strategies that can be implemented in order to minimize the environmental impact of swine slurry on soil, water, and air. This reduction can be achieved through decrease in nitrogen excretion and ammonia emissions. The correct feed formulation according to animal requirements, the increase in diet digestibility and improvement in animal performance can reduce nitrogen excretion. The use of additives either in the diet or in the manure as well as some equipment rearrangements can reduce ammonia emission.

Key Words: excretion, emissions, environment, nitrogen, swine

# Estratégias para minimização do impacto ambiental do azoto em suinicultura

**RESUMO** - Neste trabalho são apresentadas estratégias que podem ser implementadas para minimizar o impacto ambiental dos efluentes da produção suína sobre o solo, a água e a atmosfera. Esta redução pode ser obtida com a excreção de azoto e a sua volatilização. A formulação mais ajustada às necessidades dos animais, o aumento da digestibilidade da dieta e a melhoria do desempenho dos animais podem reduzir a excreção de azoto. O uso de aditivos nas dietas ou nos dejectos e alterações nas instalações pode reduzir a volatilização da amónia.

Palavras-chave: ambiente, azoto, emissões, excreção, porcos

## Introduction

Aiming at sustainable swine production, the emission of pollutants from swine farming and the use of non-renewable resources must be cut down as much as possible (Dourmad & Jondreville, 2007). The environmental concern with animal production and, particularly swine farming, has been on the spotlight for the past few years (Pedersen et al., 2004). The composition and volume of waste, concentration of swine farming in certain areas and the discrepancy between the number of animals and the farming area where manure could be potentially applied are the main concerns. The waste is biodegradable, recyclable and potentially non-pollutant, but for that to happen it is necessary to manage its application in the environment. The soil, the air and the water have limited capacity to handle this waste, making it necessary to monitor the application of these effluents because of the risk of acidification and eutrofication caused by excess nitrogen and phosphorus (Portejoie et al., 2003). In order to comply with the Kyoto protocol, EU countries should reduce the emissions of greenhouse gases in 8% between 2008 and 2012, relatively to the levels observed in 1990. As result of the EU Directive 96/61/EC for prevention and integrated pollution control, each member state must prepare and implement the best techniques available for the fulfillment of the environmental regulations (European IPPC Bureau, 2003).

In the last decades the strategies to reduce the environmental impact of nitrogen and phosphorus have been investigated, where researchers and political decision makers focused on the nutritional aspects of it (Dourmad et al., 1999; Jongbloed et al., 1999).

*Reduction of nitrogen (N) excretion*

The strategies to minimize nitrogen excretion are based on improvement of nitrogen utilization by animals, and therefore reducing fecal and urinary excretion. The efficiency of protein utilization depends on the diet and on the physiologic state or growing phase of the animals. In growing swine fed a diet based on cereals and soybean, around 32% of the nitrogen is retained. Fecal excretion is around 17% of intake and represents the non-digested

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fraction of the proteins consumed and endogenous loss, particularly digestive secretions and loss of intestinal cells. Digested proteins are absorbed as aminoacids (aa) and utilized for protein synthesis, whereas compulsory losses related to protein metabolism and the renovation of skin and fur occur. The remaining aa are catabolized and excreted mostly as urea. On conventional diets, this last fraction is the most important. Average efficiency in nitrogen retention is low on female pigs (23%), intermediate in growing pigs (34%) and high on piglets (48%) (Dourmad et al., 1999).

One alternative to minimize the nitrogen excretion is to decrease the digestible protein in the small intestine to the minimal levels needed by the animal, as the aa ingested in excess will be catabolized. This nitrogen comprises around 2/3 of the total excretion. A second strategy is to formulate diets with higher digestibility, through selection of specific ingredients or through the utilization of more technological treatments and/or enzymes. The increase in animal performance, through selection, utilization of growth promoters and improvement in management, by reducing the total protein needs, can be another alternative to reduce nitrogen excretion.

*Reduction of the excretion of urinary N – feeding to meet requirements*

The aa for maintenance, growth, milk production or pregnancy differ among one another. Through proper knowledge, the "ideal protein" for feeding animals according to their requirements may be achieved, using ingredients and synthetic aa, which will reduce the total protein on the diet and the excretion of nitrogen.

*Reduction of crude protein levels and adjustment of the aminoacid profile*

One of the most important factors that affect the use of protein on the diet is its aa balance. The closer the diet protein is from the protein to be synthesized, in terms of aa composition, the lesser will be the amount of protein to be consumed by the animal. In the most commonly used feedstuffs on pig diets, the most critical aa are lysine, methionine, threonine and tryptophan, followed by isoleucine, valine and histidine. In order for these aa not to become limiting it is necessary to formulate diets with high protein content, to combine different protein sources and/or substitute part of the protein for synthetic aa. A cereal-based diet (1/3 of wheat, 1/3 of corn, 1/3 of barley) and soybean meal, with 17% of CP, may assure the level and the aa requirements of growing pigs. However, that content of CP can be reduced to 15.3% if L-lisine is supplemented at 0.13% or to 12.2% using other synthetic aa (Mordenti & Piva, 1992). The decrease in the CP content of the diet causes a reduction in the urinary N excreted. Parisini et al. (1991) reported reductions of 25 to 28% of total nitrogen excretion and 28 to 31% of urinary N by decreasing the CP content of the diet and improving aa balance, while animal performance was maintained. Also Gatel & Grosjean (1992) and Voermans *et al.* (1994), observed reductions in the excretion of N from 15 to 30% when CP content of the diet was reduced by 1.5 to 2.5 percentage points, respectively, without any loss in performance. In a work carried out by us, reductions of 3.5 to 1.5 points in the CP content, respectively, for animals from 30 to 55 kg and from 55 to 90 kg, 19% decrease in the total excretion of nitrogen was observed, without compromising performance (Outor-Monteiro, 1996).

Diets with low protein content and optimized for aa balance are not the cheapest because the ingredients utilized for these diets are not cheap and synthetic aa are expensive. However, if the formulation takes into account the savings obtained from reduction in nitrogen loss then diets with low protein content may become competitive.

*Formulation based on ileal digestibility*

Van Leeuwen & Van Kempen (1993) showed that a reduction in the excretion of N may be obtained by formulating diets based on the apparent ileal digestibility of the aa instead of the apparent fecal digestibility. In fact, the former is a closer estimate of aa that are absorbed in the intestine, and therefore available for the animal.

*Phase-feeding*

Assuring adequate supply of protein/aa along the time, according to the growth potential of the animals or to their physiological state, is one of the approaches to increase the efficiency of nitrogen utilization and, consequently, reduce its excretion. Fulfillment of the daily energy and protein/aa requirements according to the genetic potential, production phase and productive objectives must be achieved to improve nitrogen utilization. Dourmad et al. (1989) compared the nitrogen excretion in breeding sows when using a single diet (17% CP) for pregnancy and lactation with the use of two diets, one for pregnancy (12% PB) and another for lactation (17% PB). The latter strategy resulted in reductions in nitrogen excretion of 48% and 34% for the pregnancy and for the pregnancy and lactation, respectively. Additional reductions may be achieved with dietary changes through pregnancy (Dourmad & Étienne, 2002). Nitrogen retention increases linearly in growing swine between 25 and 50 kg of body weight, leveling off shortly after that (Dourmad et al., 1989). There are, however, authors who consider it constant between 20 and 110 kg (Van Der Peet-Schwering et al., 1993). Nevertheless, when only one single diet is used along the growing period, the intake increases in order to meet the energetic needs and, consequently, the excreted N also increases (Dourmad et al., 1989; Dourmad et al., 1993). Therefore, it is more reasonable to use at least two diets, with decreasing protein levels (Dourmad et al., 1989; Latimier & Dourmad, 1993). The use of additional diets during the growing cycle may further decrease the excretion of nitrogen. Voermans *et al*. (1994) observed an additional reduction of 9% in the excretion of N in pigs in growing/finishing phase (25-105 kg) when using three diets instead of two. Another approach is the continuous change in dietary protein content according to animal's need, mixing two feeds containing different protein content. Using that principle, Voermans et al. (1994) obtained reductions of 20% in the excretion of N. The introduction of phase-feeding systems may allow a substantial reduction of nitrogen excretion. In those systems, diet composition is continuously adjusted, with a possibly daily, but usually on a weekly basis, using computer controlled feeding systems (Feddes et al., 2000; Pomar et al., 2007). Van Peet-Schwering et al. (1993) compared phase-feeding with the two-diet feeding system. Pigs received the same diet up to 45 kg, whereas those in the second system received a diet with 160 g/kg CP after that. During phase-feeding, every week two diets with 164 and 130g/kg CP were mixed at different ratios, which resulted in 15% reduction of nitrogen excretion. Bourdon et al. (1997) compared with the growing/finishing phase of a diet (17.5% CP) with a phased strategy in which, every week, the diet was adjusted with a variable mix of two diets (13.0 and 10.7% CP balanced with synthetic aa) and were able to achieve a 50% reduction in excretion. Nitrogen excretion with that strategy represents only around 50% of the ingestion, which is near the maximum that can be reached. The combination of phased feeding systems with the perfect aa balance (ideal protein concept) and the optimization of non-essential aa supply demands a good knowledge of the aa availability in the feeds (NRC, 1998; CVB, 2000; INRA-AFZ, 2004) and the variation of animal needs along the growth cycle or along the various physiological states (NRC, 1998; Van Milguen et al., 2008; Dourmad et al., 2008).

*Reduction of the fecal nitrogen excretion - increase of digestibility*

The use of diets with highly digestible proteins can reduce fecal nitrogen excretion. Mordenti & Piva (1992) observed in pigs weighing between 20 and 120 kg of body weight that the increase in protein digestibility from 85% to 90% or 95% reduced nitrogen fecal excretion from 1 kg to 700 g and 400 g, respectively. But, for environmental protection, the formulation of diets with higher N digestibility is only advantageous if followed by lower N intake, otherwise the excretion will be the same, being only shifted from feces to the urine (Huisman et al., 1993).

*Reduction in the production of endogenous nitrogen*

The non-digested protein and the endogenous nitrogen that reach the large intestine do not benefit protein deposition, being excreted as microbial protein or absorbed as $NH_3$, after microbial degradation, and excreted in the urine. The nature of fiber and the fiber content in the diet are important factors that stimulate the synthesis of endogenous N in pigs. Increase in dietary NDF content from 0 to 20% resulted in great increase in the nitrogen fecal excretion (Schulze et al., 1993). Therefore, by lowering the NDF content to acceptable levels and reducing anti-nutritional factors, nitrogen loss through feces and urine can be reduced.

*Reduction of anti-nutritional factors*

The anti-nutritional factors (ANF) in feeds, such as protease inhibitors, lectins, tannins, antigenic proteins, fitates and others, may reduce the digestibility of protein and other nutrients and animal performance. The ANF hinders the enzyme action, originating compounds of difficult digestion and increasing endogenous nitrogen excretion (Gatel, 1993). On the other hand, when food with inhibitors is utilized, an increase in the protein content of the diet is necessary, which leads to a higher nitrogen excretion (Jansman et al., 1995). The thermolabile ANF may be inactivated through careful temperature and pressure treatments. Nevertheless, there are thermo stable ANFs that can only be inactivated by complex technological processes or, alternatively, by developing vegetable varieties exempt or with lower content of ANFs (Whittemore, 1993).

*Use of enzymes*

There are numerous studies about the use of the exogenous enzymes which aim to improve the utilization of feedstuff by swine. Among them we can highlight fibrolytic enzymes, such as xylanases, $\beta$-glucanases and $\alpha$-galactosidases. Indeed, monogastrics have a reduced capacity of degrading constituents in the small intestine, such as non-amilaceous polysaccharides (NAP), by which digestion and absorption of cell components is negatively affected. From 20 to 30% of the protein and aa from usual cereals in the diet of pigs are associated to fiber (Dierick & Decuypere, 1994). The fibrolytic enzymes are added to animal diets aiming to increase the degradation of "fiber" before the ileum, increasing the nutrients available for digestion and absorption in the small intestine. Thus protein from common ingredients in pig diets can be better utilized and nitrogen excretion reduced (Huisman et al., 1993). Besides the encapsulation effect, the NAP exert negative effects in the digestive process and in aa absorption (Nortey et al., 2007a). From an environmental perspective, enzymes that promote the digestive use of diets and the reduction in excretions are interesting (Sheppy, 2001). Nevertheless, not always are the results evident (Nortey et al., 2007b; Woyengo et al., 2008). Van der Meulen & Inborr (1993) used a cellulase and a xylanase in pigs weighing 30 kg, on a diet with 40% of wheat and could not find improvements in the nitrogen digestibility. The addition of phytases to the diets with the objective of degrading the phytic phosphorus, increasing the use of phosphorus and reducing the incorporation of phosphates in the diet and its excretion (Dierick & Decuypere, 1994) is another important way of reducing excretions. The referred authors have, indeed, verified an increase in the digestibility of other minerals and of protein, probably due to reduction of interference from phytic acid in its digestion and, consequently, reduction of its excretion.

*Increase in the animal performance*

The increase in performance through genetic improvement and the use of growth promoting agents is another way of reducing excretion.

*Growth promoters*

Growth promoters (antibiotics, chemotherapics, pST, among others) stimulate weight gain and improve the conversion index, through metabolic effects, disease control and increase of nutrient availability. But its use is not possible due to current legislation in the EU and in other countries. Mordenti & Piva (1992) examined the results from 75 studies with different promoters and verified that in 68% of the cases there was a positive effect over the nitrogen retention, with gains of up to 40%. If the conversion index (CI) decreases, there is a reduction in pollution from nitrogen. For each 0.2% reduction in the CI the nitrogen excretion decreases around 6% (Dourmad et al., 1989). Mordenti & Piva (1992) foresaw the suppression of growth promoters in EU would cause an increase in the consumption of feeds (2.8 Mt) and water (6.8 million $m^3$) and an increase both in the waste volume (7 million $m^3$) and in the nitrogen and phosphorus excretion (150 Kt). Thus, the use of growth promoters should be seriously debated over scientific evidence, before its ruling out.

*Genotypes and gender*

The administration of the same diet to pigs with different capacities of protein deposition (PDmax), a common practice, results in the excretion of different amounts of nitrogen (Van der Peet-Schwering et al., 1993). Whittemore (1993) estimated the protein retention capacity values of 115, 130 and 145 g/day, respectively, to castrated males, females and whole males of a non-improved breed, while, to the same kind of animals belonging to a selection nucleus indicated values of 220, 240 and 260 g/day. Animals from commercially operated farms present intermediate values. Such fact highlights, once again, the need for tailoring the diet and feeding levels to animal requirements.

*Reducing ammonia volatilization*

Ammonia emissions are one of the components of the environmental impact of nitrogen and it takes place, according to Voermans et al. (1994), inside the housing systems and during waste storage (36%), during spread of manure in the fields (52%) and during grazing (12%). Rom (1993) considers agriculture to be responsible for 93% of total ammonia emission, 74% resulting from animal production. Swine production is responsible for part of this ammonia, estimated in 29% in The Netherlands and 62,5% in Denmark. This emission originates from two processes: decomposition of organic nitrogen from feces and hydrolysis of urea. Since urea represents the largest part of the eliminated nitrogen, and hydrolysis is much faster than fecal nitrogen mineralization, urea is the main source of ammonia emission, whose formation is mediated by the enzyme urease. Once the urine is exposed to urease, which is produced by microorganisms from feces or bedding, hydrolysis begins, a process that occurs both in aerobiosis and anaerobiosis and is dependent on temperature and manure pH (Andersson, 1994). Dietary changes can influence the urea concentration in urine and manure pH, thus affecting ammonia emission (Van de Peet-Schwering et al., 1999). Feeding diets with lower levels of CP to swine decrease the urine pH and urea concentration in urine decrease (Cahn et al., 1998; Portejoie et al., 2004), as well as urine volume (Portejoie et al., 2004). These changes in slurry lead to lower ammonia emissions (Cahn et al., 1998; Hayes et al., 2004; Portejoie et al., 2004), which may achieve reductions of 63%, from elimination to application on soils, when CP diminishes from 20 to 12% in diets of growing swine (Portejoie et al., 2004).

Ammonia emissions also have direct economic implications in animal mortality and/or morbidity, or indirect implications, through increased intake as a result of low temperatures in the housing facilities (high ventilation), which compromise the conversion indexes (Robertson, 1993). Busse (1993) found in piglets and pigs a direct correlation between high levels of $CO_2$, $NH_3$ and moisture and respiratory diseases. Levels of ammonia between 7 and

10 ppm is enough to affect both man and animal health (Dutkiewicz et al., 1994).

*Additives to reduce ammonia emission*

Prevention of ammonia emission relies on the use of additives in the diet or in the slurry, as well as structural changes in facilities and equipments. Ventilation air filtering and enhancement of storage conditions, as well as improvements in slurry application technology, are other potential areas to be addressed. Urea is the source of around 85% of the ammonia emissions in swine housing, being the cessation or reduction of its hydrolysis a valid option (Voermans et al., 1994).

*pH regulator acids*

Reduction of pH below 7 is an effective way of reducing ammonia emission (Krieger et al., 1993). The amount needed to decrease ammonia emissions depends on solubility, reaction of the chemical utilized, as well as buffer capacity and pH of the slurry. As ammonia is alkaline, its volatilization results in the acidification of the slurry. Thus, in a non-buffered system, volatilization is self-restricted. In a system where ammonia emissions derive from urea, the carbonate produced after urea hydrolysis provides the required alkalinity, thus maintaining the reaction. Therefore, the carbonate must be neutralized in order to prevent volatilization. During decomposition of the organic forms of nitrogen, ammonia is formed through deamination of aa, comprising the main source of alkalinity. The use of acids in reducing ammonia emissions from slurry has a high potential, reductions of up to 100% can be achieved when phosphoric or nitric acid are utilized. Adding benzoic acid (Guiziou et al., 2006) is also effective in reducing the pH of the slurry and ammonia emissions. The addition of 1% of benzoic acid to the diet reduced the emissions of ammonia by 40%. Van Kempen (2001) also obtained 25% of reduction in the emissions by using adipic acid. The disadvantages of using some acids are related to their high corrosive power, the risk of handling and the strong reaction with organic matter, making them impracticable to be used inside the facilities (Andersson, 1994).

*Ca and Mg soluble salts*

Soluble salts of calcium and magnesium have been added to the slurry in order to reduce both the odor and emission of ammonia, being effective when carbonate is an important source of alkalinity. Liao et al. (1993), when investigating the action of magnesium sulfate ($MgSO_4$) as a precipitating agent in the removal of phosphates and ammonia, observed that its efficiency was small and strongly dependent on pH. However, if it is applied along with a polymer, it can be effective, lowering the level of phosphates and suspended solids. Andersson (1994), after the addition of $CaCl_2$ to fresh poultry manure applied to the soil, achieved reductions of 70% in ammonia emission in the first three days following the application, but after two weeks the reduction was less than 40%. The addition of calcium benzoate (Canh et al., 1998) as a substitute for the dietary calcium carbonate reduced ammonia emissions by 54%.

The advantages of using salts relates basically to their non-hazardousness. Chlorides have the disadvantage of enhancing the level of chlorine in the slurry and, in soils where they are applied. Disadvantages of using theses salts relate to their temporary action, and their use is therefore restricted to animal facilities (Andersson, 1994).

*Urease activity inhibitors*

Voermans et al. (1994) stated that preventing urea from turning into ammonia is difficult, as the enzyme urease is always present. Inhibitors of urease activity were developed with the objective of reducing ammonia losses after application of urea-based fertilizers to soils and their effect has been tested in animal waste (Varel, 1997). Andersson (1994) says that only one of the groups of urease inhibitors, the phosphoramides, is effective in reducing ammonia emissions, with reductions of over 70% in a period of 4 to 10 days after applying urea to the soil. Studies on the effect of theses compounds in facilities are scarce and according to Kemme et al. (1993) they have addressed mainly their role in swine performance. The downside of urease inhibitors is their temporary effect, which limits their use (Andersson, 1994).

*Ammonia fixing agents*

Using agents that bind to ammonia and neutralize it may be an effective way of reducing emission, thus avoiding its effects (Leek & Barry, 1993).

*Yucca schidigera*: One of the most known additives for fixing ammonia is derived from the cactus *Yucca schidigera*, and it is able to bind to ammonia in a nonvolatile and nontoxic way (Lyons, 1993). *Yucca* extract may be used in animal waste (Headon & Walsh, 1993) or in the diet with similar efficiency (Leek & Barry, 1993). Once added to the waste, a reduction around 22% may be obtained (Kemme et al., 1993). Gipp et al. (1988) have failed to verify any change in the performance of animals fed with different Yucca extracts. Amon et al. (1995) observed a decrease of 26% in ammonia concentration and emissions from growing piglets, but neither odor nor growing were improved. Panetta et al. (2004) found similar values, but Ndegwa et al. (2008) describe Yucca extracts as having a limited ammonia-binding capacity.

*Zeolite:* Zeolites are cristaline tectosilicates (Street, 1994) characterized by a high capacity of cationic and water exchange, some of them presenting selectivity for ammonium ions (Jung et al., 2004; Sarioglu, 2005). The ammonia absorbing capacity of clinoptilolite, a type of zeolite, is around 18 mg of ammoniacal nitrogen/g, which justifies its use in several different areas of agriculture. Airoldi et al. (1993) reported that the addition of zeolites to the diet aims to improve the conversion index, decrease the incidence of digestive problems and level of ammonia emissions and the odor from slurry. These authors have evaluated the capacity of clinoptilolite to control odor, when spread over the slurry, when used as bedding or when incorporated into the diet. In these two studies, one with fattening animals and another in laboratory, a compound of 55% of phillipsite, 15% of chabazite and 30% of other clay minerals (bentonite, illite) was used. In the field study, the incorporation of 5% did not alter ammonia emission. The slurry from the treated group presented more solids (+1,5%) and an increase in N (+22%) and there was no change in weight gain, food efficiency or production cost. In the laboratory study a significant reduction of ammonia occurred only with an incorporation of 10%, where reductions of 33% and 21% relative to control (0% of zeolite) and to treatment with 5% of zeolite were observed. Nevertheless, the incorporation of 10% of zeolite increased the costs and limited nutrient intake. Zeolites yet may be used to avoid the inhibitory effect of ammonia on the anaerobic digestion of slurry (Milán et al., 2001; Montalvo et al., 2006) and as cover element for manure storage pits, in this case lowering emissions to as much as 70% (Portejoie et al., 2003).

*Turf*: turf has been evaluated on its effect in controlling odor (Kurola et al., 2010) and on $NH_3$ loss from slurry (Portejoie et al., 2003). Turf is more effective in adsorbing ammonia than in adsorbing ammonium ion, in opposition to clinoptilolite. The ammonia adsorbing capacity is around 23 mg of ammoniacal nitrogen/g and it increases as pH decreases (Andersson, 1994). Using turf is effective in the control of odors and of $NH_3$ emissions from composting piles, but as coverage for slurry it does not always perform well (Patni et al., 1992). The advantages of turf are related to its benefits in reducing ammonia emissions, to the fact that it is neither toxic nor dangerous and to its optimal performance as soil conditioning. The disadvantages of such additive relate to cost and to the difficulty of its incorporation into the slurry.

*Other types of additives*: There are other additives that may be used for reducing ammonia emissions, such as formaldehyde, lime, phosphoric acid and magnesium oxide, probiotics, among others. Given the distinct nature of such additives, their action will take diverse effects.

Formaldehyde will form a stable organic complex along with ammonia and its anti-microbial properties may inhibit urease. Utilization of lime can reduce ammonia emissions through increasing the pH above 10, which inhibits urease. It is, however, difficult to maintain such a high pH value and, because volatilization is increased at lower pH (8-9) there is little room for the application of this method. Addition of phosphoric acid and magnesium oxide to the slurry allows for ammonia removal through its precipitation as $MgNH_4PO_4$, a salt with low solubility. Its applicability is restricted by the high costs associated with it (Andersson, 1994).

The addition of microorganisms to the diet of swine aims at producing an effect of substitution of the less interesting or pathogenic microorganisms, by more desirable ones, which can optimize intestinal pH, nutrient digestion and absorption. Terada et al. (1994) added a bacterial preparation to the diet of fattening pigs which reduced the levels of ammonia, sulphidric acid, p-cresol, skatole in the excretion and reduce its pH as well as the odor of the waste. There was also a slight improvement in the average daily gain and conversion index. Kovács-Zomborszky et al. (1994) obtained a 16.1% improvement in the digestibility of essential aa, when used a probiotic, which may contribute to a reduction in dietary protein level and, consequently, in the excretion of N and ammonia emission.

*Biological immobilization of nitrogen to reduce ammonia emissions*

The urea excretion may be reduced by the inclusion of fiber in the diet. Higher levels of NAP in the diet result in a shift in nitrogen excretion from urine to feces, as microbial protein (Cahn et al., 1998; Kreuzer et al., 1998; Sørensen & Fernandez, 2003), but total excretion is not affected. The inclusion of NAP in the diet also allows the reduction of waste pH as a result of production of volatile fatty acids in the large intestine and in the waste. Cahn et al. (1998) obtained, for every 100g of increase in the ingestion of NAP a reduction of 0.12 units in the pH of the waste and a reduction of 5.4% in ammonia emissions.

The microbial synthesis on the waste is limited by the lack of appropriate substrate. The addition of a substrate with a high ratio of C:N, the microorganisms will use the inorganic forms of N in the waste. This N becomes biologically immobilized by the incorporation in the microbial tissue, being an effective method for reduction of emissions. There are no adverse environmental effects and the immobilized N can be remineralized after the application of the waste in the fields. Some of the disadvantages of this method relate to a non-immobilization in anaerobic conditions, which makes the method applicable to solid waste in aerobic and semi-aerobic conditions, such as it is in the “deep-litter” systems, but less applicable in slurries (Andersson, 1994).

*In situ composting for “deep-litter” systems*

The in situ composting is an animal housing system over sawdust, straw, scrap wood or forest waste bedding in deep-litter (40-80 cm) (van Schaijk, 1993). The oxidation of the organic matter yields $CO_2$, $H_2O$ and heat. Such heat increases the temperature in the bedding up to 30-40ºC, which allows the evaporation of the waste water and the stabilization of the microbial activity. Nitrogen, carbon and water are also used in the microbial biomass synthesis. Urea turns into ammonium, which is used in processes of nitrification and denitrification. At low temperatures the fermentative processes are limited, heating of the material is suboptimal, and evaporation of water is limited, which soaks the bedding, demanding the continuous addition of new material, although with poor results (Kay & Thomas, 1993). Kay (1992) compared, for pigs weighing 25 and 85 kg, a classic slurry producing system, with 3 variants of composting system (without additive and with two different additives) and found no differences between treatments in intake, growth and conversion index. The odor was less in the composting system, although it is more perceived at the turning of the beddings. Lüke et al. (1994) compared this system with the semi-slatted floor and verified reduction in the ammonia emission and odor. Böhmer & Hoy (1993) observed, comparing this system to a fattening in slatted floor, better animal well-being. Schaijk (1993) tried a system using an additive that turns the carbon in the sawdust more accessible, since it can be a hindering factor of microbial activity, which allowed an increase in temperature in the bedding. A reduction of 80-90% in the waste volume produced yearly (less than 200kg of compost/ pig installed), 70% reduction in ammonia emissions, the disappearance of intense odors and improvement in the well-being of the animals were reported. Philippe et al. (2007) observed larger emissions in the “deep-litter” system relatively to slatted floor, with values around 20% higher for greenhouse effect gases in fattening pigs. Also, during the breeding phase, the same group reported higher emissions in the “deep-litter” system compared to plastic slatted floor (Cabaraux et al., 2009). The use of such system in female pigs fed fiber rich diets produced ambiguous results (Philippe et al., 2009).

## Final Considerations

The evolution of the world population and its food demand will require, in the future, a substantial increase in the production of food. Ideally, mankind should be able to respond to such demand without increasing the cultivated area, as to not further endanger any ecosystems. The conversion of vegetable goods into animal protein will never be done with total efficiency, that is, without generating different kinds of effluents. Nevertheless, based on existing knowledge, and on further knowledge yet to be obtained, there is the possibility of achieving productive improvements and the lessening of the environmental impact. Thus, animal science in particular carries the duty of increasing the efficacy of both animal and of the production systems, so that, now and in the future, the production of food in general, and particularly pork, can be a sustainable process.

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