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Nutrition as a tool to reduce the impact on the environment

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SUMMARY - The structure of swine production has changed dramatically compared with the fifties. Raw materials for swine feeds are often grown in other regions than where swine production takes place. However, swine manure produced is mostly spread in the neighbourhood of the facilities which may lead to accumulation of minerals in the soil, such as, phosphorus, copper and zinc. Moreover, nitrate may leach, thus increasing nitrate levels in ground and surface water. Large swine units generate bad smell, ammonia and dust, that may exceed tolerable levels. Negative aspects of swine production on the environment in some countries or states have already led to a new legislation that limits the use of animal manure or the expansion or localization of pig operations. The consequences of intensive swine production on the environment are outlined as well as possible ways of solution by means of nutrition. In this respect we focus on nitrogen, phosphorus and ammonia emission. Also, attention is paid to the Dutch experience and forthcoming legislation, and the environmental constraints on pig production in the future.

Key words: Pigs, nutrition, environment, ammonia emission.

RESUME - *"La nutrition comme instrument pour réduire l'impact sur l'environnement". La structure de la production porcine a changé spectaculairement par rapport aux années 50. Les matières premières pour l'alimentation porcine sont souvent cultivées dans des régions autres que celles où cette production porcine a lieu. Les effluents produits par les porcins, cependant, sont répandus principalement aux environs des bâtiments ce qui peut mener à l'accumulation de minéraux dans le sol, tels que le phosphore, le cuivre et le zinc. De plus, les nitrates peuvent être lessivés et élever ainsi les niveaux de nitrate dans le sol et les eaux de surface. Les grandes unités de production porcine présentent en général de mauvaises odeurs, de l'ammoniac et de la poussière, qui parfois dépassent les niveaux tolérables. Les aspects négatifs de la production porcine sur l'environnement, dans certains pays ou états, ont déjà abouti à une nouvelle législation qui limite l'utilisation des effluents animaux ou bien, l'expansion ou l'implantation d'activités liées au porc. Les conséquences de la production intensive de porcins sur l'environnement sont mises en relief ainsi que des voies possibles de solution par le biais de la nutrition. A ce propos nous nous focaliserons sur les émissions d'azote, de phosphore et d'ammoniac. De même, l'expérience des Pays-Bas sera présentée ainsi que leur prochaine législation, et les contraintes environnementales concernant la production porcine à l'avenir.*

Mots-clés : *Porcins, nutrition, environnement, émission d'ammoniac.*

Introduction

Nowadays, there is an increasing awareness of the negative impact of livestock production systems on the environment, especially in countries or regions with a dense animal population, e.g., in the Netherlands (Jongbloed and Henkens, 1996).

In the past, animals were fed on farm produced feeds and the manure produced was regarded as a scarce and valuable commodity for maintaining soil fertility. In this way, the nutrients remained within the cycle except for some losses associated with storage, transport and nutrients deposited in milk and meat. This way of production has greatly changed in most countries during the last decades. Thus, large confinement systems for livestock have been developed on holdings with limited acreage, sometimes in the neighbourhood of big cities.

Apart from its undoubtedly advances of animal production on a large scale, several drawbacks can also be noted. One of them is the impact on environmental pollution. This can be divided in those related to the soil (accumulation of nutrients), to the water (eutrophication) and to the air (global warming, bad smell, dust). The major concern in the Netherlands is that there is no acceptable balance between the input and output of N and minerals per hectare of cultivated land. Table 1 lists the contributions of phosphate (P_2O_5) from animal manure and fertilizers for some animal dense provinces and for the whole Netherlands (CBS, 1995).

Table 1. Amount of P_2O_5 in animal manure and fertilizers (kg/ha cultivated land)

Province/country	1970	1980	1987	1990	1995
Noord Brabant	110	195	245	200	204
Gelderland	115	170	200	175	162
Limburg	110	165	215	160	174
Netherlands (manure)	78	114	124	110	107
Netherlands (fertilizer)	49	42	44	38	32
Netherlands (total)	127	156	168	148	139

Considering that crops withdraw on average 50 kg P_2O_5 per hectare, it is apparent that in the Netherlands accumulation of P takes place.

Another aspect is the aerial pollution, like ammonia and greenhouse gases, together with noxious odors from animal husbandry. Animal husbandry in the Netherlands causes 92% of the total NH_3 emission in the Netherlands (Heij and Schneider, 1995). Ammonia and gases like SO_2, and NO_x may lead to acidification of the soil.

Generally, the enrichment of the environment may lead to less biodiversity. This aspect is stressed more and more in the Netherlands. The negative impact of livestock production on the environment has already led to legislation in some countries and states that limit the use of animal manure or the number of animals per hectare of cultivated land.

The aim of this paper is to give insight in legislation to alleviate the environmental pollution, focused on the Netherlands. Examples will be presented to reduce excretion of nitrogen (N) and phosphorus by means of nutritional measures. Also attention will be paid to nutritional means to reduce ammonia volatilization from pig operations.

Legislation in the Netherlands

Legislation 1984

In 1984 legislation was enforced in the Netherlands. Global aims of governmental policy were: (i) equilibrium fertilization; (ii) reduction of acid deposition; and (iii) protect surface and ground water quality. In the same year, pig and poultry farmers were not allowed to expand their number of animals anymore.

The following criteria were formulated for N. The concentration of NO_3^- in groundwater should not exceed 50 mg/l, whereas surface water should not contain more than 2.2 mg of N per liter (about 10 mg of NO_3^- per liter). Moreover, surface water should not contain more than 0.02 mg of NH_3 N per liter. Furthermore, NH_3 emission should be reduced by 50% in the year 2000 as compared with 1980. From 1992 onwards, all manure pits should be covered. For P, the groundwater should not exceed 0.10 mg of *ortho*-P per liter (about 0.15 mg of P_t per liter). Surface water should also contain not more than 0.15 mg of P_t per liter.

Equilibrium in fertilization for the minerals of interest means a good balance between input and output taking into account obligatory losses. The amount of animal manure that could be applied per ha of land was based on its P content (Table 2).

The allowed application was gradually reduced for all types of land, resulting in an amount of 110 kg of P_2O_5 for both arable land and land used for maize silage and 135 kg for grass land. In order to reduce leaching of NO_3^-, application of manure on the field was restricted more and more during the autumn and winter when there is no growth of crops. Application also depends on the soil type and crop. Additionally, restrictions were made with regard to the method of application. A greater use of the injection method or ploughing immediately after application was enforced to prevent ammonia emission. If the P_2O_5 production per hectare of land on a farm exceeded the amount allowed, the farmer has to pay a levy for the surplus, which has to be transported to other regions.

Table 2. Allowed application of P_2O_5 (kg/ha) from 1987 onwards in the Netherlands

	Grass land	Arable land	Maize silage
≤1990	250	125	350
≤1994	200	125	150
1995	150	110	110
≤1997	135	110	110

MINAS legislation 1998

In 1998 a new minerals accounting system (MINAS) has been introduced in the Netherlands. MINAS involves far-reaching amendments to earlier manure regulations and has become into effect on 1 January 1998. For farms with more than 2.5 Livestock Units (LU) per hectare compulsory minerals input and output registration has to take place (about 50,000 farms). Apart from phosphate also nitrogen is included in the new legislation. MINAS includes all animals to which manure legislation applies: cattle, pigs, chickens, turkeys, foxes, mink, goats, ducks and rabbits. 2.5 LU is equal to the number of animals that produce 102.5 kg of phosphate through manure each year. This might be 2.5 dairy cattle, 13.9 growing pigs, 5 breeding sows with piglets or 427 broilers. Phosphate from the herd and from input fertilizer must be totalled. The allowed quantities (per hectare) for 1998 and 1999 are 120 kg of phosphate on grassland and 100 kg on arable land. When these quantities are exceeded, a farmer must submit a minerals account based on fixed rates. Typically, this will result in the paying of a levy. The allowed quantities will be reduced in the course of time. After the year 2000 all farms with livestock will have to participate in the minerals accounting system.

Farmers register how many kilograms of phosphate and nitrogen enter the farm and how many leave the farm. Main sources of input are for instance supply of animals, (compound) feed, fertilizers and animal manure from other farms. Main items of output are discharge of slaughter animals, milk, animal manure and crops. Because it is never possible to exactly balance inputs and outputs, some minerals are always lost. The regulation therefore prescribes a maximum allowable loss for phosphate and nitrogen, the so-called Standard losses or Levy free surpluses (Table 3).

Table 3. Standard losses or levy free surpluses of P (kg P_2O_5/ha) and N (kg/ha) in the Netherlands in the new MINAS legislation of 1998

Year	Grassland and arable land	ırassland	Arable land
	P	N†	N†
1998	40	300	175
2000	35	275	150
2002	30	250	125
2005	25	200	110
2008/2010	20	180	100

†Deposition and mineralization not included

Levy free surpluses per hectare for phosphate and nitrogen are rather stringent and will be lowered in increments. Levy free surplus for P for each hectare of arable land and grassland will gradually decrease from 40 kg P_2O_5 per hectare in 1998 to 20 kg in the year 2008/2010. For grassland the levy free surplus for N will decrease from 300 to 180 kg per hectare. Drawing up the minerals account farmers may deduct the levy free surplusses and the corrections from their minerals account.

In 1998 and 1999, farmers whose nitrogen and phosphate losses exceed the maximum have to pay levies of Dfl. 2.50 per kg for the first 10 kg phosphate surplus per hectare and Dfl. 10 for each successive kg. From the year 2000 these levies will be doubled. The levy for nitrogen surplus will be Dfl. 1.50 per kg per hectare. In addition, MINAS participants will have to pay destination levies at a fixed rate of Dfl. 400, though some form of discount may be possible. For the specialized pig and poultry farmer, having no or little land, the main costs due to MINAS legislation probably will be costs for discharging and sampling and analyzing the manure. The costs of selling manure to arable farms will depend on "supply and demand" of manure. The amounts of P_2O_5 and N in the manure will be very decisive for that. However, discharging manure from the farm probably will result in substantial costs. Most likely, farms with less than 2.5 LU per hectare will have to supply the Levies Office with an overview of these data at the end of the year. Arable farmers and growers may not exceed the input standards per hectare for animal manure and other fertilizers brought in from outside. If they do, they are required to submit a minerals account.

Apart from the minerals accounting system, a set of measures which has proved its effectiveness in the past will become applicable to all farms as a basic package. It contains the following measures: (i) a ban on spreading manure in autumn and winter (1 September - 1 February) for leaching-prone grassland and arable land; for non-leaching-prone grassland starting on 15 September; (ii) when spreading manure to make use of techniques that keep ammonia emission to a minimum; and (iii) to cover manure stores, built after 1987.

It is not the government's intention to charge farmers as much as possible. The levies are meant as a stimulus for change. Farmers will often find that taking the necessary measures is cheaper than paying levies for surplus losses. Nevertheless, the new legislation, especially the stringent Loss standards, concerns Dutch farmers who have doubts whether under these conditions a socio-economic strong agriculture is possible. Farmers organizations have asked for a more regional approach. At a certain level this will be allowed. If the environmental targets prevail over the possibilities of good agricultural practice, then either high investments are to be made or the number of animals has to be reduced. Possibly new solutions will come forward from research. Anyway, under the new legislation farmers will have to pay attention as much as possible to an optimal agreement between supply and requirement of minerals. Apart from the MINAS legislation 1998, discussions in the Parliament are going on to reduce the number of pigs by 20 to 25%.

Reduction of excretion of N and P by pigs by altering nutrition and feeding

The Netherlands was the first to initiate a large research programme to reduce environmental pollution by livestock production. Three main solutions were proposed. The first one was a reduction of input of minerals via the feed. The second one was a stimulation of practical solutions at farm level such as distribution and application of manure. The third solution was to upgrade manure by processing on a large scale for export purposes. In this chapter we will only deal with some general aspects of altering nutrition because details have been described elsewhere (Jongbloed and Lenis, 1992; Jongbloed and Henkens, 1996).

Nutritional research aimed to alleviate the manure problem has focused mainly on reducing the dietary input of N and P, and on their more efficient utilization. Growing pigs use only about 30 to 35% of ingested dietary N and P (Jongbloed and Lenis, 1992). For this reason it is important to supply dietary N and P in close accordance with the animals' requirement. This requires adequate knowledge about the digestibility of amino acids (AAs) and P in the feed used, and on the requirement for these nutrients. Furthermore, it is possible to enhance the digestibility of P in feeds by using extrinsic enzymes. In addition, the excretion of N and P can be reduced further by exchanging less digestible feedstuffs by better digestible ones. Also, by improved performance (improved types of pigs) reduction of the excretion of N and P can be substantially.

Supply N and P for pigs in better agreement with their requirement

In the Netherlands, protein is evaluated by the ileal digestibility of amino acids (AAs). Therefore, protein requirements are based on the apparent ileal digestibility of lysine, methionine, cystine, threonine, and tryptophan (Lenis, 1996; CVB, 1997). Data on the ileal digestibility coefficients for some feedstuffs is provided in Table 4. For maximum growth performance of growing-finishing pigs, the requirements for ileal digestible methionine + cystine, threonine and tryptophan, are related to the ileal digestible lysine, and should be 59, 60, and 19%, respectively (Lenis, 1992). For boars and fast-growing sows, a 10% higher amino acid supply (as g/kg diet) is recommended than for castrates. The optimum ratio between essential amino acid N and total N for N utilization (% of intake) was between 0.45 and 0.55, depending on the level of daily N retention (Lenis *et al.*, 1996). For N retention, this optimum ratio is slightly lower.

Table 4. Ileal digestibility of N and some AAs (%) and fecal digestibility of P (%) in some feedstuffs (CVB, 1997)

Feedstuff	N	Lys.	Meth.	Cyst.	Thre.	Tryp.	P
Barley	73	70	80	71	66	73	39
Maize	70	56	82	70	62	48	20
Wheat	82	74	86	80	72	78	48[a]
Peas	74	83	74	63	69	67	45
Wheat middlings	69	71	76	69	63	74	30[b]
Soybeans extracted	81	86	86	76	79	83	39
Sunflower extracted	75	74	86	72	72	79	15
Meat meal fat	73	83	85	55	78	74	75

a: Wheat contains 1000 phytase units; b: wheat middlings contain 3000 phytase units

For AAs the concentration per kilogram feed decreases as the LW of the pig increases from 25 to 110 kg. Therefore, introduction of one additional feed for growing-finishing pigs (at about 70 kg LW) will help to tailor AAs in the diet better to the requirements of the animals. Therefore, introduction of a two-, three- or multi-phase feeding leads also to lower N excretion (Lenis, 1989; Kemme *et al.*, 1994). However, multiphase feeding does not always lead to optimum performance, suggesting that some amino acid shortage in the finishing period may occur (Lenis and Jongbloed, 1996).

The nutritive value of total P of a diet is evaluated by its apparent digestibility. There are relatively large differences in P digestibility among feedstuffs, both for feedstuffs of plant origin, and those from animals and feed phosphates. The large variation among and within a feedstuff is attributed to differences in phytate P content, phytase activity, and processing (Jongbloed and Kemme, 1990). Also, the requirements for phosphorus are expressed in terms of digestible P using a factorial method (Jongbloed *et al.*, 1994). As we use a model, the recommended levels can easily be adapted to the level and type of production and the physiological status of the animal. As the required concentration of digestible P per kg feed decreases as live weight (LW) of the pig increases, phase- feeding systems can be introduced to reduce P excretion.

Enhancement of digestibility of phosphorus and protein

The high excretion of P by pigs is mainly because about two-thirds of P in feedstuffs from plant origin is present as phytate, the salt of phytic acid (Jongbloed, 1987). Phytate P is almost indigestible for pigs, which forces feed manufacturers and farmers to add inorganic P to their feeds. In the presence of supplementary or intrinsic phytase, phytic acid can be hydrolyzed to liberate free orthophosphates and inositol for absorption (Pointillart, 1993). When 500 to 1000 units of Aspergillus niger phytase is added per kg of feed, the increase in amount of digestible P is almost 50% of the requirement for digestible P in a growing pig (Jongbloed *et al.*, 1996). More details on microbial phytase have been presented by Kemme *et al.* (1997) in the former conference. Several types of microbial phytase have been found to enhance P digestibility substantially. Phytase-supplemented feeds for growing-finishing pigs and for pregnant sows may need little or no supplementary feed phosphate. Microbial phytase is commercially available now and has been incorporated in more than 70% of pig feeds in the Netherlands.

Literature with an interesting enhancing effect of proteases on protein/AAs digestibility in pigs is rather scarce, although recently some interesting results were presented (Liu *et al.*, 1997).

Changes in feedstuff composition

The wide variety of feedstuffs available for pig diets show a considerable variation not only in P content but also in digestibility. Therefore, in order to decrease the excretion of P, feedstuffs should be chosen in which P is in a highly digestible form. Because feed phosphates are only used to supply P, one can easily choose those forms in which P is easily digestible. In the Netherlands, this has already led to a almost total shift to monocalcium phosphates at the expense of dicalcium phosphates.

Feedstuffs not only vary in N and AA content but also in AA content expressed per kg N. For economic reasons, it is impossible to formulate diets without oversupplying certain AAs, particularly when many by-products are used. Lowering the proportion of some by-products and other feedstuffs with a low ileal protein digestibility in the diet in favour of cereals and other feedstuffs with a higher protein digestibility will result in a better balance of dietary protein. Nitrogen excretion can be substantially lowered by reducing the protein level by more than 2%. In doing so, feeds need to be supplemented with lysine, methionine and, in most cases, threonine and tryptophan. It has been shown in studies on fast-growing boars and gilts that dietary protein levels can be reduced by 2% without any disadvantageous effect on growth performance, when limiting AAs are supplemented sufficiently (Lenis *et al.*, 1990). This reduction decreases N excretion by 20%. Data from other experiments in several countries show that even bigger reductions in dietary protein level are possible without affecting animal performance too much. However, special attention should be given to the accurate matching of supply and requirement of amino acids (Lenis and Jongbloed, 1996).

In addition to the changes mentioned before there is also the possibility to enhance the energy concentration in the feeds. As a result mostly raw materials are chosen that have a higher digestibility, consequently leading to a lower excretion of N and minerals via faeces.

Current status of phosphorus and nitrogen excretion by pigs in the Netherlands

Table 5 summarizes the course of P excretion by growing-finishing pigs in practice in the Netherlands. From 1973 to 1996 the total P content in feeds for growing-finishing pigs has decreased by more than 2.5 g/kg, while the feed conversion ratio has improved substantially, and the health of the pigs has not been impaired. With regard to N excretion only a slight decrease could be noted.

Table 5. Mean excretion of P and N of growing-finishing pigs from 25 to 110 kg in the Netherlands (kg/pig)

Year	In feed (g/kg)		Feed conversion ratio	Excretion	
	P	N		P	N
1973	7.4	23.8	3.37	1.62	4.74
1983	6.2	24.4	3.08	1.18	4.30
1988	6.0/5.0[a]	26.9	2.94	0.85	4.64
1992	5.5/4.9	26.9	2.86	0.77	4.46
1994	5.3/4.6	26.6	2.76	0.68	4.16
1996	5.3/4.6	26.7	2.74	0.67	4.13

a: Wheat contains 1000 phytase units

Reduction of ammonia emission from piggeries and the amount of manure

In a preceding paragraph it was shown that Dutch legislation requires that NH_3 emission from livestock production has to be lowered substantially. For growing-finishing pigs, it means that the NH_3 emission per pig place has to be reduced from 2.10 (half-slatted floor) to 1.38 kg.

Ammonia emission from pig manure mainly originates from urea in the urine. Nitrogen in the faeces comprises undigested dietary N and endogenous N, mainly as amino acids, and microbial N, partly present in nucleic acids. Due to the urease activity of faecal microbes, urea is rapidly converted into ammonia which easily volatilizes into the air. Factors influencing the rate of ammonia emission are concentrations of urea and ammonia/ammonium in the manure, temperature and air velocity, pH, emitting surface, and dry matter content (Aarnink *et al.*, 1993; van Vuuren and Jongbloed, 1994).

It is possible to reduce ammonia emission substantially by nutrition management aimed at reducing the nitrogen and urea content in urine and slurry, lowering the pH of urine and slurry, and reducing total nitrogen excretion by improvement of the utilization of dietary protein. The latter reduces the amount of urea and N excretion. If with increased utilization of dietary protein the volume of the urine produced does not change, the concentration of mineral N in manure declines. This will result in a diminished emission of ammonia (Oldenburg and Heinrichs, 1996). However, to predict the amount of urine produced, quantitative insight is required with regard to factors that determine the water requirement. Besides, as a surplus of slurry on a farm often has to be transported over a long distance more attention should be paid to increasing DM content of slurry.

In order to reduce ammonia emission many measures have been developed by changing the ratio between urinary N and faecal N (bacterially fermentable carbohydrates), reducing urea degradation (separation of urine and faeces, urease inhibitors), binding the ammonia (Yucca extract, clay minerals), lowering the slurry pH (acidification), and reducing the emitting surface (flushing, sloped floors, slurry removal; van der Peet-Schwering *et al.* (1996)), airtight storage, soil injection). Some measures are still speculative and need further research.

Concerning bacterially fermentable carbohydrates, several authors investigated possibilities to reduce the ratio between urinary N and faecal N by including these carbohydrates in the diet. Nitrogen incorporated in bacterial protein in faeces is less easily degraded to ammonia than urea-N excreted in urine. Microbial fermentation of OM in the hindgut can increase the excretion of N in faeces, while it reduces the N excretion in the urine. Recently Bakker *et al.* (1996) showed that inclusion of raw potato starch (PS), which is highly fermentable, in diets for growing pigs increased the amounts (g/d) of DM disappearing from the hindgut, while less N disappeared from the hindgut (Table 6). With the diet PS there was even a net N appearance in the hindgut. The N excretion with urine was lower with more PS in the diets, while the N retention was not different.

Table 6. Nitrogen balance (relative values) and ammonia emission using fermentable carbohydrates

	Treatments†		
	1	2	3
Intake	100	100	100
Feces	15	29	36
Urine	49	32	32
Retained	36	37	32
NH_3 emission	100	-	87

†Treatment 1: basal diet 35%, corn starch 65%; Treatment 2: basal diet 35%, corn starch 32.5%, raw potato starch 32.5%; Treatment 3: basal diet 35%, raw potato starch 65%

According to Canh *et al.* (1997), a lower slurry pH related to a higher VFA content and a lower dietary base excess may also affect ammonia emission. Recently, Mroz *et al.* (1996) measured the effect of dietary cation anion difference (DCAD) and acidifying salts on urinary pH, nutrient retention and indoors ammonia emission by growing pigs (Table 7). They added acidifying Ca-salts to dietary Ca levels of 7 and 10 g/kg. Urinary pH was reduced by 1.6 to 1.8 units, thereby diminishing ammonia emission by 26 to 53%. Besides, reducing DCAD from 320 to 100 meq/kg DM lowered urinary pH by 0.48 units, and ammonia emission by 11%.

Table 7. Effect of dietary cation-anion difference (DCAD) and Ca source on urinary pH and ammonia emission

	DCAB (meq/kg DM)		Ca source		Benzoate	Cl_2
	320	100	CO_3	SO_4		
pH urine	7.34	6.75	7.05	5.44	5.25	5.39
NH_3 emission from manure (%)	100	81	100	79	56	78

Concerning urease inhibitors, several dietary additives are claimed to increase nitrogen utilization, reduce urea degradation and reduce ammonia volatilization (Easter *et al.,* 1993). Certain extracts of the Yucca plant are sometimes regarded as urease inhibitors, but their mode of action relies on binding or converting ammonia (Kemme *et al.,* 1993). Headon and Walsh (1994) reported promising effects of inclusion of these extracts in the diet of pigs in the USA, like a 50-70% reduction in ammonia concentration in the stable after 9 weeks. On the other hand, Kemme *et al.* (1993) reported small and inconsistent reductions in ammonia emission after a two-week adaptation period at similar and higher dosages of Yucca extract. They concluded that for the Dutch practice inclusion in the diet will not provide a relevant contribution to ammonia reduction.

Results of inclusion of other materials, such as clinoptilolite and clay minerals on animal performance seem quite variable (maybe partly due to a lower dietary energy content), whereas their effect on ammonia emission is unclear (Easter *et al.,* 1993; Krieger *et al.,* 1993). We performed an experiment on growing pigs with a Spanish sepiolite from Tolsa by inclusion of 2% of the product in the diet and studied the effect on ammonia emission. A reduction of ammonia emission was measured by 6 to 7%, and approached significance (Canh *et al.,* 1996). It was calculated that almost all binding capacity of this material was used for binding the ammonia.

It may be speculated that by reducing the ammonia emission also the amount of noxious odors will be reduced.

Implications for practice

In the Netherlands, it has been shown that despite early warnings of researchers that the mineral balance on a farm was disturbed, 15 years passed before it became politically interesting. Therefore, a lot of precious time was lost and expansion of large operations took place. Because measurements increased in general production costs as well, farmers wanted to delay implementation of legislation. This was partly correct because we did not have adequate knowledge and technologies available. However, society does not want to wait for that and farmers are forced to invest substantially in environment by means of alteration of housing and feed and feeding strategies. If environmental constraints can be anticipated at an early stage money may be saved on the long term. In the Netherlands, an intensive research programme, in which government and business participate, can result in faster solutions. To prevent problems on the long term the production of minerals per amount of animal product should be as least as possible in animal dense areas. The surplus has to be transported to other areas. Basically, the aim of governmental policy should be to achieve an equilibrium in fertilization, which means a good balance between input and output taking into account obligatory losses. Manure legislation can help to achieve this. However, farmers need time to adopt drastic measures and a socio-economic strong agriculture should still be possible. Besides, a regional approach can be recommended.

Nutrition management can substantially contribute to reduction in N and P excretion by pigs. Adequate knowledge is required on the digestibility of AAs and P in the feed used and on the requirement of these nutrients at any stage and type of production. Even more sophisticated evaluation systems than ileally digestible amino acids may be introduced (true digestible) in the future. Supplementary microbial phytase can enhance the digestibility of P by 20% or more so that feeds for growing-finishing pigs and for pregnant sows may need little or no supplementary feed phosphate. Phosphorus excretion can be lowered by 20 to 30% by using microbial phytase. The use of enzymes for hydrolysing non-starch polysaccharides seems interesting. A powerful tool to decrease the excretion of N and P is to aim at improvements in feed conversion ratio of pigs. This also contributes to a lower excretion of minerals per kg lean meat, which probably can be considered as an even better criterion in judging excretion of pigs, because goal of pig production is to supply lean meat for the market. The incorporation of more free AAs in the feeds and lowering crude protein content in the feed by 2% units can lower N excretion of growing pigs by 20%. However, special attention should be given to the accurate matching of supply and requirement of amino acids. It is possible to reduce ammonia emission substantially by nutrition management using several measures. Some are still speculative and need further research.

Current knowledge concerning the possible reduction of the manure surplus has to be integrated into future feed strategies. A further integration of the nutrition research with other disciplines is necessary. In this respect, both the genetical potential of the animals and hygienic conditions should be evaluated. An approach more at system level should be emphasized.

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