PHOSPHORUS SUPPLY TO PIGS WITHOUT PRODUCTS OF ANIMAL ORIGIN

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1. Introduction

There is an increasing awareness of the impact of livestock production systems on the environment, especially in countries or regions with a dense animal population, e.g., in the Netherlands or in the Vechta region of Germany (JONGBLOED et al., 1999b). 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, meat and eggs. This way of production has greatly changed in most countries in recent decades. Large confinement systems for livestock have been developed on limited acreage. Apart from the undoubted advantages of large-scale animal production, several drawbacks can also be noted. These have already led to legislation in some countries.

Since January 2001, the use of processed animal feedstuffs like meat meal, meat and bone meal, blood meal and feather meal in the feeds of all livestock is prohibited in all countries in the European Union, due to the risk of Bovine Spongiform Encephalopathy (BSE). This is due to the fact that consuming animal products from animals with BSE may lead to the Creutzfeldt-Jacob disease. This ban on using animal products in the diets has resulted in changes of diet formulation.

The goal of this paper is to describe the environmental concerns associated with phosphorus in intensive pig production. Nutritional means to reduce the excretion of phosphorus (P) will be presented also in the light of the ban on using animal meals in diets of pigs.

2. Environmental Concerns

Environmental concerns with regard to phosphorus can be divided in those related to the soil (accumulation of nutrients), and to the water (eutrophication). The major trust in most countries is finding an acceptable balance between the input and output of minerals per hectare of cultivated land. Some minerals such as P accumulate in the soil and contribute via leaching and run-off to eutrophication of ground and fresh water sources. Table 1 lists the contributions of phosphorus (P) from animal manure and fertilisers in the Netherlands (FONG, 1999). Considering that crops use an average of 20 to 30 kg P per hectare, it is apparent that, even at a substantial decline of the amount of P per hectare of cultivated land in The Netherlands, P accumulates in the soil. This may lead to eutrophication and may cause excessive algae blooming, sometimes resulting in massive fish mortality (ROLAND et al., 1993). Generally, the enrichment of the environment may lead to less biodiversity. This aspect is stressed more and more in several countries.

3. Phosphorus

Phosphorus is an essential element, and therefore, its supply to animals should be adequate. A too low supply may reduce bone mineralisation, reduce fertility in breeding stock and impair animal performance. Recently, the fate of phosphorus in the nutrition of pigs has been described extensively by POULSEN et al. (1999), so that it will only be briefly described in this paper.

Table 1: Amount of phosphorus in animal manure and fertilisers in (regions of) The Netherlands (kg/ha cultivated land; adapted after FONG, 1999 and CBS, 2001)

Province/Country	1970	1980	1987	1990	1998
Noord-Brabant	48.2	85.4	107.3	87.6	n.a.
Gelderland	50.4	74.5	87.6	76.7	n.a.
Limburg	48.2	72.3	94.2	70.1	n.a.
Netherlands (manure)	34.2	49.9	54.3	48.0	42.0
Netherlands (fertiliser)	21.5	18.4	19.3	16.5	15.5
Netherlands (total)	55.6	68.3	73.6	68.5	64.0

n.a. = not available

3.1 Apparent digestibility of phosphorus

The environmental impact of P has led to considerable research efforts to obtain tabulated data on the nutritive value of P in feedstuffs for pigs in several countries. For P tabulated values are provided for practice which are based on availability, absorbability or apparent digestibility in raw materials for pigs. However, one should realise that there are a lot of factors that affect mineral digestibility (JONGBLOED, 1987). The most well-known is the interaction between Ca and P (POINTILLART et al., 1987). Dietary Ca content should be standardised for assessing the P digestibility of feeds. Results on P digestibility in feedstuffs from plant origin, animal origin and feed phosphates for pigs are listed in Table 2. More figures on P digestibility of feed ingredients for pigs can be found in CVB (2001).

From Table 2, it can be concluded that relatively large differences in P digestibility are observed among feedstuffs. The difference in P digestibility between conventional wheat and wheat with inactivated intrinsic phytase shows that wheat phytase has a large effect. This finding was also confirmed in experiments by FOURDIN et al. (1986) and EECKHOUT and De PAEPE (1992). The incorporation of convential wheat in the diet has, therefore, a positive effect on the digestibility of the whole diet, unless the phytase is inactivated by heat treatment. The large variation within a feedstuff is attributed to differences in phytate P content, phytase activity and processing (JONGBLOED and KEMME, 1990).

Results in Table 2 also show that the apparent digestibility of P between various types of feed phosphates and animal products differs substantially. There are large differences among mono-dicalcium phosphates, a.o. due to different in Ca/P ratios. Differences in P digestibility between various products of animal origin may be attributed to differences in origin and the fraction of bones, technological treatments and the physico-chemical structure of the products.

It can be concluded that there are reliable tabulated data for P digestibility coefficients for P in various feeds for pigs,

Table 2: P digestibility coefficients (% of intake) of some feedstuffs from plant origin, from animal origin and feed phosphates for pigs tested at ID TNO Animal Nutrition

Feedstuff	Number of trials	Mean	SD	Range	Feedstuff	Number of trials	Mean	SD	Range
Barley	5	39	4	34-44	Hominy feed	8	21	8	13-34
Maize	10	19	6	12-26	Rapeseed extr.	3	27	4	22-33
Wheat	4	48	2	46-51	Rice bran	6	14	4	9-20
Wheat inact.*	2	26	1	26-27	Soybean meal extr.	9	39	4	33-46
Peas	4	45	4	42-51	Sunflower meal extr.	10	15	4	9-20
Beans	3	37	8	29-48	Wheat middlings	3	30	5	24-35
Lupins	3	50	4	47-56	Tapioca	4	6	5	1-13
Meat+bone meal	2	81	1	80-81	$DCP \cdot 0H_2O$ (A,B)**	4	64	2	63-66
Bone precipit. A**	1	87	-	-	$DCP \cdot 2H_2O$ (A,B)**	3	69	1	69-71
Bone precipit. B**	1	61	-	-	$MDCP \cdot xH_2O$	3	80	5	76-86
Skimmilk dry	1	90	-	-	$MCP \cdot 1H_2O$	4	82	2	80-84
Fish meal	2	72	17	61-84	$MSP \cdot 1H_2O$(ref.)***	3	90	3	88-93

* intrinsic phytase inactivated by thermal treatment ** A and B are from different production processes
*** reference chemically pure monosodium phosphate

although there is still debate on the technique applied. Therefore, there still exist differences among countries concerning digestibility coefficients for P in pigs (e.g. Germany, Denmark and The Netherlands).

Digestibility figures for poultry differ in many cases from those of pigs, although in many raw materials from vegetal origin those for poultry are mostly higher than for pigs.

3.2 Requirements for phosphorus in growing pigs

Estimation of the exact requirement for phosphorus of pigs is a difficult task. Mostly two methods are used for this purpose: the empirical and the factorial approach, the latter being used more and more for P (ARC, 1981; GUÉGUEN and PEREZ, 1981; DLG, 1997; NRC, 1998; JONGBLOED et al., 1999a).

The requirement for P depends on several factors, like animal (physiological status, production level and type of production), the diet (major ingredients used, chemical composition, chemical binding form and several interactions) and feeding strategy (amount of feed supplied), environment (temperature, health status, management, housing conditions, aim of production) and the criterion used (minimal or safe P requirement, the evaluation method or response criteria (toe ash, feed conversion rate)). This means that the estimated requirements can have some variation due to differences in assumptions. For scientific and clarity reasons, we prefer the factorial approach in which an estimate is given for maintenance and production. This will be briefly outlined in the next paragraphs only for young and growing-finishing pigs; more expanded information has been presented by JONGBLOED et al. (1998, 1999a). Very recently, the P requirements for P in young pigs were re-evaluated due to results of a comparative slaughter experiment performed at ID TNO Animal Nutrition in Lelystad. Estimates of the requirements for Ca can be derived from those of P.

3.2.1 Requirement for phosphorus for maintenance

The maintenance requirement for P is determined by the loss of endogenous P in faeces and the loss of P in urine. JONGBLOED et al. (1998) concluded that a total „maintenance requirement" for P of all categories of pigs could be adopted at the level equal to 7 mg P/kg LW per day. DLG (1997) adopted a maintenance requirement of 10 mg P/kg LW per day.

3.2.2 Requirement for phosphorus for production

Piglets and growing pigs deposit P in lean tissue, organs and bones. For estimation of the P requirement for growth, an allometric equation was used as developed by JONGBLOED et al. (1999a). The data were separated in those before the year 1985 and thereafter. The equations were based on the results of 62 and 35 data sets, respectively. It was speculated that the data which have been published after the year 1984, may represent more modern (leaner) pigs. These data sets originated from literature and own experiments, in which the amount of P had been determined of pigs in the live weight (LW) range of 5 to 110 kg (JONGBLOED et al., 1999a). Only those data have been chosen which allowed maximal bone mineralization. For both data sets a linear and a quadratic component for empty body weight (EBW; kg) proved to give the best fit (equations 1 and 2). The experiments published before 1985 resulted in equation 1, and equation 2 is for data published after 1984, in which P in g and EBW in kg.

(1) $\ln P = 1.247 + 1.284 \ln EBW - 0.042 (\ln EBW)^2$
R^2=0.994; n=62

(2) $\ln P = 1.510 + 1.071 \ln EBW - 0.0074 (\ln EBW)^2$
R^2=0.994; n=35

Pigs with a LW below 5 kg did not fit quite well in these equations. This is attributed to the amount of minerals in newborn piglets, which differs substantially from older pigs.

Unfortunately, since 1984 there were only few data sets on pigs from birth to 25 kg, which has been investigated recently (JONGBLOED et al., 2001b). In the same way as described above, an allometric function was developed for pigs from 3 to 115 kg LW. It showed that in contrast with earlier estimates, the quadratic term did not contribute significantly to the model. Therefore, this term was omitted and resulted in the following equation (equation 3).

(3) $\ln P = 1.673 + 0.999 \ln EBW$
R^2=0.992; n=40

Table 3: Calculated net requirement of P for growth (g/kg live weight gain) in growing pigs (data before 1985, after 1984 and with the newest results; JONGBLOED et al., 1999a; JONGBLOED et al., 2001b)

Live weight (kg) Period	5	10	20	30	40	50	60	70	80	90	100	110	115
Before 1985	5.38	5.54	5.47	5.32	5.17	5.03	4.90	4.78	4.67	4.57	4.48	4.39	4.35
After 1984	4.95	5.05	5.11	5.13	5.14	5.14	5.13	5.13	5.12	5.12	5.11	5.11	5.10
Newest	5.05	5.05	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04

From the above equations the total amount of P in the body can be calculated. The equations are taken to the power of e, which results for equation 3 in:

(4) P = exp (5.328 + 0.999 x ln EBW)

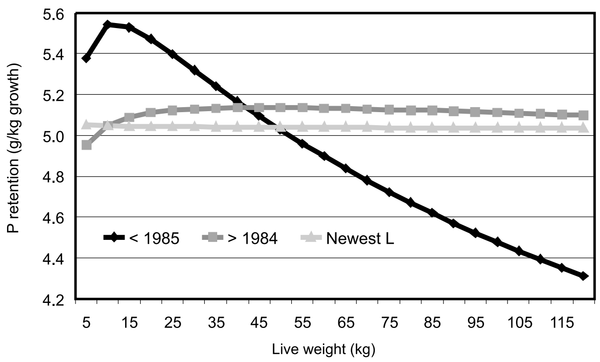
The amount of P deposited at a certain EBW is the first derivation equation 4, and results in:

(5) dP = exp (5.328 + 0.999 ln EBW) x (0.999/EBW)

To calculate the retention of P at a certain LW instead of EBW, than the result has to be multiplied by 0.95. It is assumed that no P is present as gutfill, but if required, one may correct for this. The results of the calculations are presented in Table 3.

When compared with earlier data on the requirement of P for growth from 5 to 115 kg, there is no decline at higher live weights. This is also shown in Figure 1. This is undoubtedly due to the leaner pigs of today compared with pigs before 1985. In fat no P is deposited. An amount of 5.05 g P/kg LW gain up to 80 kg LW is almost similar to that one of DLG (1997), but 4.5 g P/kg LW gain after 80 kg LW is according to DLG (1997) substantially lower than our figure. However, DLG (1997) assumes that only 95 % of the digestible P supplied can be utilised, so that the supply of digestible P is enhanced by 5 %.

Figure 1: Course of P retention in growing pigs in relation to live weight (data before 1985, data after 1984, and newest data after 1984)



The total requirement for digestible P of piglets and growing-finishing pigs can now be calculated. Therefore, one should know the LW of the pig (maintenance), and the daily growth at that LW. The daily requirement for digestible P mostly increases up to 80 to 90 kg LW after which there is a slight decrease. The content of digestible P in terms of g/kg diet (containing 8.79 MJ NE or 12.55 MJ ME) decreases gradually from 2.4 at 25 kg LW to 1.8 at 110 kg LW for a good type of gilt with a high feed intake capacity. It is obvious that the required amounts of digestible P are different at other growth rates.

Table 4: Requirements of pigs for Ca and digestible P (g/8.79 MJ NE)

	Ca	Digestible P
Piglets		
0 to 2 weeks post-weaning	6.0	2.4
2 weeks post weaning to 25 kg	8.7	3.1
Growing-finishing pigs		
25-35 kg	6.5	2.4
35-70 kg	6.3	2.1
>70 kg	5.5	1.8
Breeding sows		
< 70 d. pregnancy	5.0	1.5
70 - 98 d pregnancy	6.6	2.0
>98 d. pregnancy	6.7	2.1
lactating	8.0	2.8

The requirements of pigs for Ca and digestible P are summarised in Table 4.

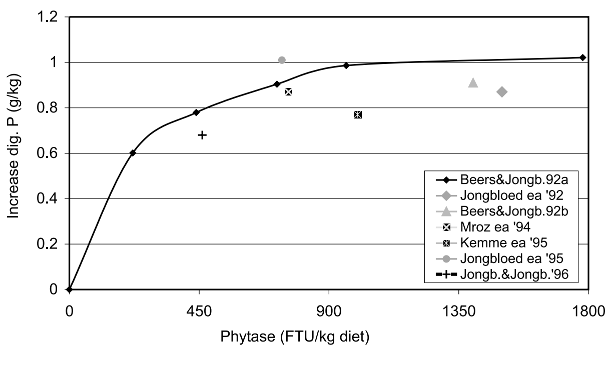
3.3 Microbial phytase

Microbial phytases can be separated into two groups, depending on the site of the phytic acid molecule where the first hydrolysis of ortho-phosphate takes place. These are the 3-phytases, like Natuphos phytase derived from *Aspergillus niger*, and the 6-phytases, like ZY Phytase II derived from *Peniophora lycii*.

3.3.1 Microbial phytase in diets for growing pigs

Several experiments with exogenous microbial phytases have been reported to quantify their effect on the apparent digestibility/availability of phosphorus. A survey of a large part of these studies has been presented by JONGBLOED et al. (2000). Most studies show an exponential dose-response curve (Figure 2).

Figure 2: Dose-response effect of 3-phytase and of several other experiments by ID TNO on the amount of digestible P generated of diets with more than 50 % maize and soybean meal



A dose of 500 U 3-phytase/kg diet was estimated to be equivalent to 0.8 g digestible P/kg diet.

The first microbial phytases had a low heat stability, but it has been improved with the newer ones. This was achieved either by formulation of the phytase (a.o. coating) or by further selection on heat stability. One should be aware that the efficacy per U may be different due to differences in physical and chemical characteristics, and the pH at which phytase activity is assessed. No negative drawbacks of using microbial phytases have been reported and are not expected because it is a protein that is digested in the gastrointestinal tract.

In addition to the positive effect on the digestibility of P, microbial phytase also increases the digestibility of calcium, sodium, potassium and some trace minerals (JONGBLOED et al., 2000). The effect of microbial phytase on Ca digestibility was calculated as the ratio between the increase in amount of digestible Ca to the amount of digestible P. From our own experiments and those of the literature we found a ratio between 0.55 and 0.84. The higher Ca digestibility means that supplementation of Ca in diets with microbial phytase can be slightly reduced. By using 500 U 3-phytase/kg of feed between 0.4 and 0.7 g digestible Ca/kg is generated.

Formation of complexes of phytic acid with proteins has been shown in several in vitro studies, and depends a.o. on the type of protein, the pH, and the level of calcium and magnesium. In vivo experiments show that the (ileal) digestibility of protein and amino acids is enhanced by microbial phytase by 1 to 3 percentage-units (MROZ et al., 1994; KEMME et al., 1999).

Performance of pigs fed microbial phytase is equal or better as compared with a non-supplemented diet or with a positive control diet (JONGBLOED et al., 2000). The improvement in FCR can be attributed to increased digestibility of protein/amino acids and a slight increase in energy digestibility. The magnitude of the effect also depends on the dietary phytate content.

3.3.2 Microbial phytase in diets for breeding sows

Recently, we performed two studies on breeding sows, one with lactating (JONGBLOED et al., 2001a) and one with pregnant sows (KEMME et al., in preparation), with a 6-phytase preparation (Ronozyme P) to study the efficacy of phytase. For the lactating sows, five treatments were imposed: 1) a negative control diet, 2), 3) and 4) were as 1) but with 750, 1,000 and 10,000 U phytase/kg diet, respectively, and 5) as 1) with 1.5 g of digestible P added/kg diet from monocalcium phosphate. The P content in diets on treatments 1 to 4 and 5 was 5.0 and 6.8 g/kg, respectively. The ratio between Ca and digestible P was kept constant (2.9:1). Six sows per treatment were used, which received the diets from 2 weeks before farrowing till weaning at 4 weeks. Grab samples of the faeces of the sows were taken at days 15 and 21 post-farrowing. Digestibility coefficients of dry matter and the minerals under investigation were calculated using Cr as an indigestible marker. Summarised results of this study are presented in Table 5 (JONGBLOED et al., 2001a).

The phytase was very effective in improving the digestibility of various minerals, especially for P. An amount of 750 and 1,000 U phytase/kg diet generated 0.77 and 0.83 g of digestible P/kg diet, respectively. At 10,000 U phytase/kg diet, there was still an increase of generation of digestible P, which amounted to 1.17 g/kg of diet.

Table 5: Effect of 6-phytase on the averaged digestibility (%) of dry matter (DM) and several minerals in lactating sows

Treatment	Neg. contr.	750 U	1,000 U	10,000 U	Pos. contr.
Digestibility DM (%)	78.2[a1]	78.8[ab]	79.0[b]	78.4[ab]	78.3[ab]
Digestibility of P (%)	21.4[a]	36.8[b]	38.1[b]	44.9[c]	34.9[b]
Digestibility of Ca (%)	19.5[a]	29.4[b]	28.8[b]	29.0[b]	24.6[ab]
Digestibility of Mg (%)	16.7[a]	15.9[a]	19.4[b]	20.8[b]	21.8[b]
Digestibility of Cu (%)	1.4[a]	2.0[a]	7.6[bc]	9.6[c]	5.5[ab]

[1] abc within a column, values with different superscripts are significantly different at P<0.05

In the experiment with gestating sows, twenty-four crossbred gestating sows were used. Four treatments were imposed: 1) the negative control, a low-P by-product-based diet without feed phosphate and phytase, 2) and 3) as 1) but with 750 and 1,000 U phytase/kg of diet, and 4) the positive control diet being treatment 1 with 1.0 g of digestible P added/kg of diet from monocalcium phosphate. The P content in diets on treatments 1 to 3 and 4 was 3.9 and 5.2 g/kg, respectively. The ratio between Ca and digestible P was kept constant (3.3:1) with a minimum of 5.0 g Ca/kg. The feed allowance was according to Dutch recommendations for gestating sows. Six sows per treatment were used, which received the diets from day 49 to day 100 of gestation. Sampling of the faeces of the sows was done by rectal stimulation, and carried out at days 70-71 and 98-99 of pregnancy. Digestibility coefficients of organic matter and the minerals under investigation were calculated using Cr as an indigestible marker. The efficacy of the phytase was larger at 100 days of pregnancy than at 70 days of pregnancy. This is due to the higher P requirement at 100 days of pregnancy. Therefore, only the results at 100 days of pregnancy are presented (Table 6).

Table 6: Effect of 6-phytase on the digestibility (%) of organic matter (OM) and several minerals in gestating sows at day 100 of pregnancy

Treatment	Neg. contr.	750 U/kg	1000 U/kg	Pos. contr.
Digestibility OM (%)	80.0[a]	80.7[a]	79.4[a]	80.2[a]
Digestibility of P (%)	21.7[a]	32.5[c]	32.0[c]	26.7[b]
Digestibility of Ca (%)	28.1[a]	34.2[a]	29.3[a]	27.5[a]
Digestibility of Mg (%)	25.5[a]	28.3[a]	26.4[a]	23.8[a]
Digestibility of Na (%)	80.7[a]	87.6[a]	87.5[a]	84.9[a]
Digestibility of Zn (%)	-2.5[a]	3.8[b]	-1.9[a]	-0.4[a]

[1] abc within a column, values with different superscripts are significantly different at P<0.05

Phosphorus digestibility at day 100 of pregnancy of the diets fed in treatments 1 to 4 was 22, 33, 32, and 27 percentage units, respectively. When 750 and 1,000 U phytase/kg of diet was used it generated 0.42 and 0.40 g of digestible P/kg of diet, respectively. Digestibility of P was increased by 10.8 percentage units at day 100 of pregnancy as compared to the basal diet. The amount of digestible phosphorus generated by the 6-phytase at 750 U/kg was 0.42 g/kg diet at day 100 of pregnancy. Adding phytase to diets of gestating sows improved P digestibility, which is in agreement with other reports (e.g. KEMME et al., 1997).

4. Effect of ban using meat meal in pig diets

Since the first outbreak of BSE in the United Kingdom in 1989, several measures have been taken in the member states of the EU. Table 7 provides an overview of the measures in The Netherlands.

Table 7: Historical overview of measures to prevent further infection of cattle with BSE in The Netherlands

Year	Month	Measure
1989	January	Ban on using meat meal in diets for ruminants
1990	September	Ban on import of meat meal from Great Britain
1993	January	Ban on producing diets for ruminants on the same production line where diets are formulated with more than 6 % meat meal
1994	August	European ban on using meat meal from all mammals in diets for ruminants
1997	June	Legal obligation to sterilise raw materials for meat meal during minimal 20 minutes at a temperature of 133 °C and 3 bar with a maximum particle size of 50 mm
1997	August	Separation of some tissues from ruminants which have to be treated as “Specific Risk Material”
1999	March	Ban on producing diets for ruminants with animal proteins
2001	January	Total ban in EU on producing diets with animal proteins for livestock

Table 8: Effect of the ban on meat meals on chemical composition (g/kg) and nutritive value in diets for pigs from weaning to 25 kg, and from 25 to 45 kg

Feed ingredients	Diet from weaning to 25 kg		Diet from 25 to 45 kg	
	Before ban	After ban	Before ban	After ban
Enhanced price (Euro/100 kg)	-	+ 0.20	-	+ 0.25
Crude protein	185.0	178.5	177.0	177.0
Crude fat	54.7	55.4	52.9	50.2
Crude fibre	47.7	48.1	45.3	41.0
Calcium	7.2	7.2	7.2	7.2
P total	5.6	5.5	4.6	4.6
Digestible P	3.5	3.5	2.7	2.7
P from feed phosphate	0.45	0.74	0.11	0.43
Phytase added (U/kg)	500	500	500	500
Ileally dig. lysine	9.9	9.9	9.0	9.0
Ileally dig. meth. + cys.	6.0	6.0	5.3	5.3
Net energy (MJ/kg)	9.58	9.58	9.49	9.49

Although Spongiform Encephalopathy has not been observed in pigs and poultry, it is not allowed to incorporate meat meal in their diets. It is obvious that such a ban may have a large impact on animal production. It may have an effect on the price of the feed, using other raw materials for diet formulation, or affect environmental aspects.

To evaluate the effect of the ban on using meat meals for diets in pigs, diet composition was compared just before (October 2000) and after the ban and using prices of August 2001. It is evident that for each feed compounder diets can differ due to differences in starting points. Calculations have been done for a diet from weaning to 25 kg (weaner diet) and a starter diet for pigs from 25 to 45 kg live weight. The main items are presented in Tables 8 and 9.

Table 9. Effect of the ban on meat meals on feed formulation (g/kg) in The Netherlands for pigs from weaning to 25 kg, and from 25 to 45 kg

Feed ingredients	Diet from weaning to 25 kg		Diet from 25 to 45 kg	
	Before ban	After ban	Before ban	After ban
Barley	250.0	359.8	150.0	200.0
Maize	97.5	50.0	35.8	18.1
Wheat	200.0	200.0	200.0	200.0
Other cereals	0.0	0.0	10.0	53.3
Wheat middlings	18.2	4.9	75.0	72.8
Soybean meal extr.	125.0	125.0	159.0	159.0
Sunflower seed meal extr.	75.0	75.0	20.0	0.0
Tapioca meal	38.7	0.0	181.3	78.1
Potato protein	2.9	0.0	0.0	0.0
Cane molasses	15.0	15.0	25.0	25.0
Meat meal	20.0	0.0	25.2	0.0
Fish meal	0.0	2.8	0.0	0.0
Whey powder	45.9	47.4	0.0	0.0
Animal fat	30.0	30.0	25.0	25.0
Soybean oil	3.8	9.6	0.0	0.0
Peas	50.0	50.0	30.0	100.0
Other	8.0	8.0	40.0	40.0
Premix	9.0	9.0	9.0	9.0
L-lysine	3.3	3.8	2.2	1.9
DL-methionine	1.1	1.2	0.9	0.9
L-threonine	0.8	1.1	0.4	0.4
L-tryptophan	0.2	0.2	0.1	0.1
Limestone	0.0	0.0	8.7	12.0
Monocalcium phosphate	2.0	3.3	0.5	1.9
Salt	3.7	3.9	2.0	2.5

Tables 8 and 9 show that, in The Netherlands, there are minor changes in feed formulation and diet composition. In the weaner diet the protein from meat meal was mainly replaced by fishmeal, while slightly more whey powder and free amino acids were incorporated. Another possibility could be using potato protein as a protein source for this type of diet, which may occur when the use of fishmeal in the diets is too difficult, like currently in most German feed mills. In the starter diet, more peas were used but no extra soybean meal extracted, while less tapioca is used. No higher incorporation of free amino acids was visible in the starter diet.

After the ban, more monocalcium phosphate was incorporated in both diets but no extra microbial phytase to compensate for the meat meal. This is probably due to the fact that microbial phytase was already used at a rather high incorporation level in the diets. If this was not the case, then undoubtedly more microbial phytase would have been incorporated. The price of the diets was between 0.20 and 0.25 EUR/100 kg feed higher compared with the situation before the ban. Because the incorporated amount of animal products in poultry diets ranged between 4 and 6 %, the prices of the poultry diets are between 0.40 and 0.50 EUR/100 kg feed higher compared with the situation before the ban.

5. Excretion of P by pigs in The Netherlands

The environmental impact of better knowledge on digestibility of P in raw materials and on the requirement of P for pigs together with the use of microbial phytase is substantial. An amount of 500 U 3-phytase or 750 U 6-phytase/kg of diet generates approximately 0.8 g digestible P/kg, which is equivalent to 1.0 g P from monocalcium phosphate or to 1.23 g P from dicalcium phosphate anhydrate. This is approximately one half of the requirement for digestible P of a finishing pig.

In The Netherlands, the contents of several minerals in the diets are monitored frequently. Thus, the excretion of P by pigs can be estimated. In Table 10, a survey is presented for growing-finishing pigs from 1973 to 2000. In that period, in the live weight range of 25 to 110 kg average growth rate improved from 625 to 768 g/day. Despite the better performance (growth rate and feed conversion ratio), P content in pig diets decreased more than 2.0 g/kg. Data in Table 10 show that the excretion of P in growing-finishing pigs has decreased from 1.62 to 0.62 kg, so 1.0 kg! This lower P excretion has, apart from increased nutritional knowledge, undoubtedly been stimulated by legislation based on P, and by the use of microbial phytase. Microbial phytase is used in more than 80 % of the pig feeds in The Netherlands now. In the next years, higher incorporation levels of microbial phytase in pig diets will further decrease P excretion by pigs.

Table 10: Mean excretion of P of a growing-finishing pig from 25 to 110 kg in The Netherlands

Year	P feed (g/kg)	Feed conversion	Excretion (kg/pig)
1973	7.4	3.37	1.62
1983	6.2	3.08	1.18
1988	6.0/5.0	2.96	0.88
1992	5.5/4.9	2.87	0.80
1996	5.3/4.6	2.74	0.67
2000	5.3/4.7	2.60	0.62

6. Discussion and conclusions

Soil fertility and quality of the surface and groundwater determine to a large extent the amount of manure that can be applied per hectare. As nowadays on most intensive pig farms the input of P by means of manure and inorganic fertilisers often exceeds the output in meat, new legislation has been enforced, that limit the use of animal manure per hectare of land. However, animal manure is still a valuable commodity to maintain or improve soil fertility.

Nutrition management can substantially contribute to reduction in P excretion, especially in pigs. Adequate knowledge is required on the availability/digestibility of P in the feeds used and on the requirement of P at any stage and type of production. In pigs, the digestibility of P can be enhanced by using microbial phytase, resulting in a lowered P excretion of 20 to 30 %.

Despite the ban on using meat meal, it is very well possible to formulate adequate diets for pigs, although the price is 1 to 2 % higher at a replacement of 2 to 3 % of meat meal in the diets. The diets presented contain more feed phosphate, fishmeal and free amino acids. In many cases more microbial phytase can be incorporated than the levels used sofar. Currently in The Netherlands, it is considered to further increase the incorporation levels of microbial phytase in the diets.

On one hand one may think that the problem of further infection with BSE is solved by combustion of meat meal, on the other hand there are several drawbacks of this solution that should also be considered. One can argue if combustion of meat meal is sustainable, because actually more P and protein sources are imported. A recent study in The Netherlands on the ban of meat meal in all poultry diets (POS, 2001) showed that almost 10 % more fossil energy was required for cultivation, production and transport of soybean meal and monocalcium phosphate. Maybe, the combusted meat meal can be used as a fertiliser to be exchanged for commonly used phosphate fertilisers. Furthermore, a protein source with a high biological value is destroyed.

7. Summary

In intensive animal production areas, the amount of manure produced is a major problem. The amount of phosphorus present in the manure mostly exceeds the amount of minerals that can be taken up by the crop, thus leading to accumulation, leaching and run-off. Phosphorus in manure is of major concern and its environmental impact is outlined. To minimise the environmental load, the supply of phosphorus should be close to the animal's requirement. The digestibility of phosphorus in several raw materials for pigs is discussed. A recent experiment has been carried out to assess the amount of phosphorus in the body of young pigs. Based on these results, the requirements of phosphorus for pigs have been re-evaluated and the results are presented. The impact of microbial phytase in diets for pigs is discussed in the framework of reducing the excretion and improving the bioavailability of phosphorus. Special attention is paid to recent experiments with microbial phytase on breeding sows. Furthermore, the impact of the ban on using animal products in diets for pigs is discussed with special reference to diet formulation and environment. Finally, the impact on phosphorus excretion by pigs is presented.

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