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Pig nutrition: impact on nitrogen, phosphorus, Cu and Zn in pig manure and on emissions of ammonia, greenhouse gas and odours.

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Introduction

For a sustainable pork production, emission of pollutants from pig farms and use of non-renewable resources should be decreased as much as possible. Nitrogen and phosphorus from manure may be involved in eutrophication of freshwater or seawater. Besides, the world reserves of mineral phosphates are limited and should be preserved. In the same way, the accumulation of Cu and Zn in soils may impose a medium or long term toxicity risk on plants and micro-organisms. Ammonia emission from manure is involved in acidification and eutrophication, with recognized detrimental effects on soil status, forests and biodiversity. Pig production also contributes to the emission of greenhouse gas, especially CH₄ from enteric fermentation, and CH₄ and N₂O from manure.

Over the last decades, different ways to reduce the environmental impact pig production have been investigated. The nutritional approach has received great attention from researchers and legislative decision makers (Jongbloed et al., 1999b; Aarnink and Verstegen al. 2007). It relies on improvements in our knowledge of the physiology of pigs in order to achieve a better agreement between supply and requirement and improve nutrient availability in feedstuffs.

The aim of this paper is to give an overview of the nutritional possibilities to reduce N, P, Cu and Zn excretion by pigs, as well as emissions of ammonia and greenhouse gas, and to describe the means that could be or are already implemented in practice.

Reduction of N excretion in pig manure

The efficiency of protein utilisation by pigs depends on the dietary composition and the physiological status or the growth stage of the animals. In growing-finishing pigs fed a cereal-soybean meal diet, about 32% of N intake is retained (Dourmad et al., 1999b). Faecal N excretion which amounts to 17% of the intake corresponds to the undigested protein fraction and endogenous losses. Digested proteins are absorbed as amino acids which are used for protein synthesis. Obligatory losses of amino acids relate to protein metabolism (turnover) and renewal of skin and hair. The remaining amino acids, after protein deposition and obligatory losses, are catabolised and excreted mainly as urea. With conventional diets, this last fraction is often the most important. Average efficiency of N retention is lowest in sows (20-30%), intermediate in growing pigs (30-40%), and highest in weaners (45-55%) (Dourmad et al., 1999a).

Two complementary nutritional approaches can be used to improve the efficiency of N utilisation in pigs and, consequently, to reduce N excretion. The first approach is to ensure adequate protein/amino acid supply over time according to the growth potential of the animals or their physiological state. This requires a joint fitting of daily supply of energy and protein (amino acids), depending on genetic potential and stage of production, and on production objectives. In reproducing sows, N excretion was reduced by 20 to 25% when different diets are allocated for pregnancy and for lactation instead of a single diet for the whole period. Further improvements could be achieved with the use of multiphase feeding during pregnancy. Indeed, the protein requirement is much lower during the early pregnancy compared with later pregnancy (Dourmad et al., 2012). In fattening pigs, Latimier and Dourmad (1993) measured about 10% reduction in slurry N when different diets were applied during the growing and finishing periods, compared to feeding the same diet during both periods (Fig. 1).

The second approach is to improve the dietary amino acid balance and consequently reduce the required crude protein (CP) content of the diet. This can be obtained through a combination of different protein sources and/or the substitution of protein by inclusions of free amino acids. In fattening pigs, Dourmad et al. (1993) measured a 35% reduction of N excretion after improvements in the dietary amino acid profile) without affecting feed intake, average daily gain, feed efficiency and carcass composition.

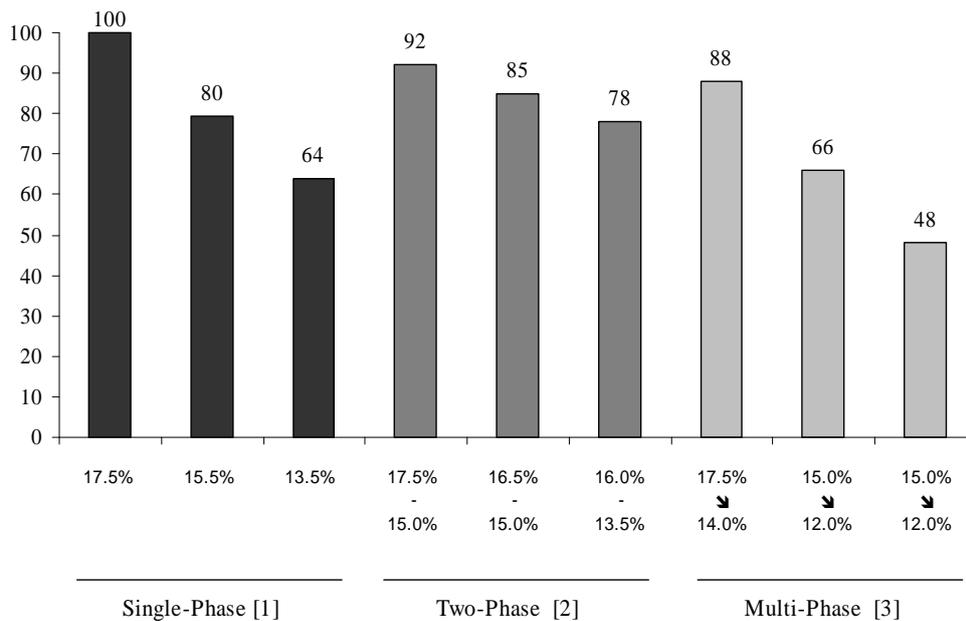


Figure 1. Effect of dietary protein content and protein feeding strategy on N excretion (100 = excretion with one-phase feeding of a 17.5% CP diet). Adapted from [1] Dourmad et al. (1993), [2] Latimier et al. (1993) and [3] Bourdon et al. (1997).

The ultimate reduction of N excretion can be reached when multiphase feeding is combined with a perfect balance between essential amino acids (close to the ideal protein concept), and with an optimisation of the supply of non-essential amino acids. Such a feeding strategy has been evaluated experimentally in fattening pigs by Bourdon et al. (1997). In that study, the use of a single diet (17.5% CP) over the whole growing-finishing period was compared to a “multiphase” strategy which consisted of the mixing of two diets (13.0 and 10.7% CP, re-

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equilibrated with free amino acids) in proportions that were optimised each week. Growth performance and carcass quality were similar, and N excretion was reduced by about 50% (1.83 vs. 3.56 kg N per pig) (Fig. 1). With this feeding strategy, N excretion represented only 50% of N intake. This can be considered to be close to the maximal attainable reduction in N excretion.

It must be pointed out that the development of such feeding techniques for reducing N excretion by pigs requires good knowledge of the amino acid availability in feedstuffs, and of the changes in amino acid requirements according to growing stage or physiological state. This is now within reach with the use of modelling techniques for predicting requirements (NRC, 2012; van Milgen et al, 2008; Dourmad et al., 2008) together with a better knowledge of variations in amino acid availability in feedstuffs (NRC, 2012; CVB, 2000; INRA-AFZ, 2004). Moreover, more numerous amino acids are now available for feed use (lysine, methionine, threonine, tryptophane and valine) which allows a further reduction in dietary protein content. This can also be achieved in practice by using computerized blend feeding systems which allow adapting the diet composition on a daily or weekly basis (Feddes et al., 2000; Pomar et al., 2007).

The reduction in dietary protein content results in a lower proportion of N excreted in urine relative to faeces, which might affect the utilisation of manure N after field application (Sørensen and Fernandez, 2003). In a study of Portejoie et al. (2003) the ratio ammoniacal N:total N in fresh manure decreased from 0.79 with the 20% CP diet to 0.63 with the 12% CP diet. However, in the studies of Gerdemann et al. (1998) and Sørensen and Fernandez (2003) the plant availability of slurry N was not clearly affected by the dietary protein content.

Feeding strategies with reduced protein content are already implemented in practice in many countries. Different strategies are compared in table 1. The first two-strategies correspond to the hypothesis used for the official calculation of N excretion in France (Corpen, 2003). Compared to the one-phase feeding strategy, used as reference, the two-phase feeding strategy with limited CP contents, reduces N intake and N excretion by 10 and 15% respectively. A further reduction in dietary CP and consequently N excretion could be achieved at rather short term by incorporation of more amino-acids in free form and by using multiphase feeding for fattening pigs (Garcia-Launay, 2013, Table 1).

Table 1. Protein feeding strategy and N excretion (Corpen, 2003; Garcia-Launay et al., 2013)

	Corpen, 2003		Perspectives	
	Standard	Two-phase	Two-phase	Multiphase
Crude protein, g/kg				
Gestation	170	140	120	120
Lactation	170	165	155	155
Pre-starter	210	200	180	180
Starter	190	180	160	160
Grower	175	165	150	150
Finisher	175	150	130	110
Average	177	158	140	131
N per slaughter pig (0-115 kg)				
Intake	9.10	8.16	7.23	6.78
Retention	2.89	2.89	2.89	2.89
Excretion	6.06	5.13	4.22	3.78
% of standard	100	85	70	63

Reduction of ammonia emissions

By changing feeding practices, it is possible to influence urea concentration in the urine and the pH of slurry, which will affect ammonia release (Van de Peet-Schwering et al., 1999). When pigs are fed low CP diets, urinary urea concentration and pH decrease (Canh et al., 1998; Portejoie et al., 2004). When water is available ad libitum, feeding low CP diets also results in lower urine production due to decreased water consumption (Pfeiffer et al., 1995; Portejoie et al., 2004). The changes in slurry characteristics result in lower ammonia losses during housing, storage and following application of slurry (Canh et al., 1998; Hayes et al., 2004; Portejoie et al., 2004; Jarret et al., 2011). For instance, in the study of Portejoie et al. (2004) ammonia emissions over the whole period from excretion to field application, was decreased by 63% when dietary CP was decreased from 20 to 12% in finishing pigs (Table 2). However ammonia emission was rather similar when expressed as a % of N excreted.

Table 2. Effect of protein feeding of fattening pigs on slurry characteristics and ammonia volatilisation (Portejoie et al., 2004).

	Dietary crude protein content		
	20%	16%	12%
Slurry composition			
Amount (kg pig ⁻¹ d ⁻¹)	5.7	5.1	3.6
DM (%)	4.4	4.6	5.9
Total N (g N/kg)	5.48	4.30	3.05
Total ammoniacal N (g N/kg)	4.32	3.13	1.92
pH	8.92	8.61	7.57
N balance (g pig ⁻¹ d ⁻¹)			
Retention	23.2	23.5	21.9
Excretion	40.7	27.6	15.0
Ammonia volatilisation	17.4	13.8	6.4
Available to plants	23.3	13.8	8.6

The electrolytic balance (EB), calculated as (Na⁺ + K⁺ - Cl⁻), is often used by nutritionists to evaluate the acidogenicity of the diet, a decrease in the EB resulting in a decrease in urinary pH. When dietary CP content is reduced, EB also decreases because of the high K content of most protein sources. This partly explains the effect of CP on urinary pH. However, as shown by Canh et al. (1998), more drastic changes in urinary pH and ammonia volatilisation can be obtained by inclusion of the Ca salts CaSO₄ or CaCl₂ instead of CaCO₃. The addition of Ca-benzoate (Canh et al., 1998) or benzoic acid (Guingand et al., 2005; Guiziou et al., 2006) was also effective in reducing slurry pH and ammonia volatilisation (by 25 to 40%), because these products are metabolized into hippuric acid which is rapidly excreted in urine. A similar effect (25% reduction in ammonia emission) was observed with adipic acid (van Kempen, 2001) which is partially excreted in urine.

Urea N excretion can also be reduced by including fibrous feedstuffs in the diet. With more fermentable non-starch polysaccharides (NSP) in the diet, some of the N excretion is shifted from urine to bacterial protein in faeces (Canh et al., 1998; Kreuzer et al., 1998, Sørensen and Fernandez, 2003; Jarret et al., 2011, 2012), while total N excretion is not affected. Moreover, slurry pH is decreased with the use of fermentable NSP due to volatile fatty acid (VFA) formation in the hindgut of the pig and in the slurry (table 1). Canh et al. (1998) measured a linear relationship between NSP intake and slurry pH or ammonia volatilisation; for each 100

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g increase in NSP intake, the slurry pH decreased by 0.12 units and the ammonia emission from slurry decreased by 5.4%. This is consistent with the recent results obtained by Jarret et al. (2012) who compared two diets differing in their fibre content (table 3)

Table 3. Effect of fibre content in fattening pigs diet on composition of excreta, N balance and ammonia emission (Jarret et al., 2012).

	Control	High-fiber	
Crude Fiber, g/kg	29.4	49.0	
N balance, g/d			
Intake	55.9	55.5	
Excretion	28.7	30.3	
% in faeces	26.3	40.0	***
pH urine	8.28	7.15	***
pH faeces	8.39	8.11	***
VFA in faeces, mg/L	62.6	260.0	***
Ammonia emission (%)	17.9	12.4	***

The utilisation of manure N after field application may also be affected by the level of NSP in the diet, because a greater proportion of N is excreted in faeces in more complex organic forms. Availability of slurry N was reduced after the inclusion of dietary fibre with low fermentability (Sørensen and Fernandez, 2003), whereas it was not affected when the dietary content of fermentable structural carbohydrates increased (Gerdemann et al., 1998; Sørensen and Fernandez, 2003), although in all cases the proportion of N excreted in urine decreased. Combined with the proportion of urinary N, the fibre content of faeces gives a good prediction of the plant short term availability of slurry N (Sørensen and Fernandez, 2003).

Effect of feeding on direct emissions of greenhouse gas

Pig nutrition may affect both emissions of N₂O and CH₄. According to IPCC (2006) emissions of N₂O are calculated from N excretion and specific emission factors that depends on manure management. This means that according to this procedure of calculation, N₂O emission will be proportional to N excretion, and all strategies that will reduce N excretion will also affect direct N₂O emissions, in the same proportion. However it should be confirmed by experimental results since, to our knowledge, this has not yet been evaluated in the literature.

CH₄ has mainly two origins in pig production: enteric fermentations and fermentations from collected and stored manure. Enteric fermentations vary according to the physiological status of the animal and the amount of digested fibre ingested (*DigFib*). *DigFib* is the difference between digested organic matter and digested protein, fat, starch and sugar, as calculated in INRA-AFZ tables (2004). The loss of energy as methane $E(CH_4)$ can be obtained by multiplying *DigFib* by 670 or 1340 J/g for growing pigs and sows, respectively (Noblet *et al.*, 2004). Methane production (CH_4 Enteric, kg) can then be calculated from $E(CH_4)$, considering methane calorific value equal to 56.65 MJ/kg (IPCC, 2006). This is illustrated in table 4 from the results of Jarret et al. (2012) who compared two diets with different fibre contents.

According to IPCC(2006) Tier 2 methodology CH₄ emission from stored manure can be calculated as : CH_4 Manure (kg) = VS x B₀ x FCM, with VS = volatile solids in excreta,

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roughly considered as amount of organic matter excreted (kg), B_0 = maximum methane producing capacity (m^3/kg organic matter) and MCF = a methane conversion factor for the management system considered, expressed as a percentage of maximum potential. Volatile solids excreted depend on the digestibility of feed organic matter and is mainly affected by dietary fibre content. Volatile solid can be calculated from OM digestibility values in feed tables (INRA-AFZ, 2004). This is illustrated in table 4 from the results obtained by Jarret et al. (2012) who compared a conventional and a high fibre diet. Volatile solid excreted per pig per day was significantly increased in the high fibre diet (by 64%) whereas B_0 of excreta did not differ between treatments. This resulted in a 76% higher CH_4 emission per pig during a simulated storage of 100 d, for the high fibre diet. In the same way, when comparing diets with different types of high fibre feed ingredients (rapeseed meal, sugar beet pulp and DDGS), Jarret et al. (2011) observed only limited differences in B_0 values, but a significant increase of excreted VS, resulting in a much higher potential of CH_4 emission per pig for the high fibre diets.

Table 4. Effect of fibre content in fattening pigs diet on volatile solid of excreta (VS), composition of excreta, N balance and ammonia emission (Jarret et al., 2012).

	Control	High-fibre	
Crude Fibre, g/kg	29.4	49.0	
Digestible "fibre", g/kg feed	74.8	110	***
Enteric CH_4 , L/pig/d	3.1	4.6	***
VS, g DM/pig/d	192	315	***
B_0 , L CH_4 / kg OM	377	376	
CH_4 production, L/pig/d storage simulation (100 days, 30°C)	55	97	***
MCF, %	71%	77%	*

Composition of the diet also affects the dynamic of methane emission. Although B_0 values of excreta from pigs fed a high protein diet (471 L CH_4/kg OM) tended to be higher than from a low protein diet (449 L CH_4/kg OM) the emission during storage was accelerated for the low protein diet, in relation with a lower pH and a lower ammonia concentration (Jarret et al., 2011). In the same way, methane emission started faster from effluent from pigs fed a high fibre diet which had also lower pH and lower ammonia concentration. These results indicate that MCF values are affected by duration of storage and depend on the type of diets. For instance in Jarret et al. (2011) for 50 days of storage in mesophilic conditions MCF varied from 2% for the high protein diet to 54% for the high fibre diet (from 18% to 75% after 100 days of storage) the value for the low protein diet being intermediate.

Effect of feeding on odours

Odours are mainly associated with volatile compounds that pigs excrete with manure, or which are released during manure storage (de Lange et al., 1999). These volatile compounds are generated by the microbial conversion of feed in the large intestine of pigs or in manure pits. Based on a literature review, Le et al. (2005) suggested that CP and fermentable carbohydrate (FC) would play a major role in the production of odour nuisance from pig production.

Few studies have evaluated the direct effect of diet manipulation on odour production, mainly because it is difficult to assess odours objectively. As mentioned previously, protein nutrition affects ammonia production, but the ammonia production is not well correlated with odour strength (Le, 2006). Using olfactometry, Hayes et al. (2004) showed a significant reduction in both ammonia and odour emissions when CP content was reduced, but this was not observed in all studies. Hobbs et al. (1996) reported that the concentration of nine out of ten odorous compounds in the air was significantly reduced when low CP diets were fed to the pigs. Le (2006) also found a reduction by 80% in the odour emission, as determined by olfactometry, when dietary CP was reduced from 18 to 12%. Moreover, the results from the same author suggested an interaction between effects of CP and FC on odour production suggesting that odour production depends also on the balance between dietary CP and FC. The manipulation of gut fermentation could also be a way to alter the production of odorous compounds such as skatole (de Lange et al., 1999). Using a different methodology for assessing "pleasantness", "irritation" and "intensity" scores of odours, Moeser et al. (2003) were able to significantly discriminate between diets differing in composition. The diets that yielded manure with the worst odour were high in sulphur (rich in garlic or feather meal), whereas a purified diet mainly based on starch and casein presented the lowest score (most pleasant). This is in agreement with the >700% increase in odour emission measured by Le (2006) with diets supplemented with a sulphur-containing amino acid (methionine) at high levels.

Reduction of P in pig manure

In growing-finishing pigs fed a cereal-soybean meal diet, about 45% of P intake is absorbed, about 30% is retained, and the remaining 15% is excreted via urine (Poulsen et al., 1999). Totally, with such diets, 70% of P ingested is excreted either via the faeces or via urine. In order to reduce P losses, P supplied to pigs should be adjusted to their requirement, and strategies to improve P availability should be implemented (Poulsen, 2000; Knowlton et al., 2004). This approach relies on an accurate knowledge about feed P availability and P requirement according to the physiological status of pigs.

A first approach to improve P uptake efficiency is to use highly digestible mineral P supplements. For example, monocalcium rather than dicalcium phosphate should be used because of its much higher digestibility (INRA-AFZ, 2004). However, most strategies implemented to reduce P excretion by pigs refer to improvements in phytic P utilisation (Jongbloed et al., 1992b).

In many countries, microbial phytase is currently introduced in diets for pigs because of its well-documented positive effect on P digestibility. Total P supply may be decreased, resulting in a 40 to 50% reduction of P excretion (Jongbloed and Lenis, 1992a; Latimier et al., 1994,

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Table 3). However, the response of digestible P to graded levels of microbial phytase is curvilinear, and the maximum P digestibility never exceeds 60-70%, even at high levels of phytase supplementation. Based on literature reviews, equivalency equations of digestible P for microbial phytase were established (Kornegay, 2001; Johansen and Poulsen, 2003) and can be used for diet formulation.

In the same way as for protein and amino acid supply, the second approach to reduce P excretion is to ensure adequate supplies over time according to the growth potential of the animals or their physiological status. This requires a precise evaluation of pigs' P requirements, as well as P availability in feed ingredients. In practice, this can already be achieved by the use of a feeding system relying on, e.g., P apparent digestibility (CVB, 2000; INRA-AFZ, 2004) and the factorial determination of P requirements (NRC 2012, Jongbloed et al., 1999a; Jondreville and Dourmad, 2005). Finally, this allows the reduction of safety margins when formulating pig diets, resulting in a decrease in P excretion.

Feeding strategies with reduced phosphorus content are already implemented in practice in many countries. Different strategies are compared in table 5. The first two-strategies correspond to the hypothesis used for the official calculation of P excretion in France (Corpen, 2003). Compared to the one-phase feeding strategy, used as reference, the two-phase feeding strategy with limited P content reduces P intake and P excretion by 13 and 19%, respectively. A further reduction in dietary P and consequently P excretion could be achieved at rather short term by using higher level of phytase and by using multiphase feeding for fattening pigs (table 5).

Table 5. Phosphorus feeding strategy and P excretion

	Corpen, 2003		Perspectives
	Standard	Two-phase	
P, g/kg			
Gestation	6.5	5.0	4.5
Lactation	6.5	6.0	6.0
Pre-starter	7.5	6.8	6.0
Starter	6.5	5.8	5.0
Grower	5.8	4.8	4.2
Finisher	5.8	4.4	3.8
Average	6.0	4.9	4.3
P per slaughter pig (115 kg)			
Intake	1.91	1.54	1.35
Retention	0.60	0.60	0.60
Excretion	1.31	0.94	0.76
% of standard	100	72	58

Effect of nutrition on Cu and Zn in pig manure

Cu and Zn are involved in many metabolic functions, and their provision in sufficient amount in pig feeding is indispensable to ensure good performance and animal health (Revy et al., 2003, Jondreville et al., 2002). However, because they are used as growth promoters at pharmacological levels, or because large safety margins are applied, Cu and Zn are often oversupplied in pig diets. Consequently, these elements are highly concentrated in pig manure and accumulate in soil, where they may impose a medium or long-term toxicity risk to plants and micro-organisms (Jondreville et al., 2003). Moreover, when a treatment is applied to the

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slurry, Cu and Zn will follow the solid fraction where their concentration often exceeds the maximal values allowed for the utilisation of these products as organic fertilisers. The only way to decrease the concentration of trace element in manure is to restrict their incorporation in the diet.

The incorporation of 150 to 250 ppm Cu in pig diets has been employed for a long time because of its growth promoting effect (Braude, 1980). This practice is currently authorized in EU allowing diets containing a maximum of 170 ppm Cu for pigs up to 12 weeks. After 12 weeks of age, the use of Cu as a growth factor is no more allowed within EU, and the maximal level of incorporation is 25 ppm. Compared to the former allowed inclusion (175 ppm up to 16 weeks of age and 100 ppm thereafter (*former*, Table 6), this results in a drastic reduction of Cu in manure by almost 60% (*actual*, Table 6). Nevertheless, the practical supply remains higher than the usually published requirements (less than 10 ppm), and average retention efficiency is still less than 1%.

Supplementing weaned piglets diets with 1500 to 3000 ppm Zn as ZnO has also been reported to stimulate their growth (Poulsen, 1995). In fact, in 2003 the maximal allowed Zn incorporation in pig diets was reduced to 150 ppm, compared to 250 ppm before (EC, 1334/2003). These levels are much closer to the published requirement, which varies between 100 and 50 ppm depending on growing stage and authors (Revy et al., 2005). However in some EU countries supplementation with 2500 ppm Zn is still allowed as medication, resulting in an increased excretion.

As for P, the main way to reduce Cu and Zn in pig manure is to adjust the supplies to the requirement, and to improve the availability to the pigs. Zinc requirement of weaned piglets was recently evaluated to be about 90 mg/kg diet (Revy et al., 2005) which is consistent with the former recommendations and below the usual level in practice. When microbial phytase is incorporated in the diet, the Zn supply may be reduced because of increased availability. In weaned piglets, incorporation of 500 phytase units/kg diet was evaluated to be equivalent to the supply of 30 ppm of Zn as Zn sulphate (Jondreville et al., 2005).

Table 6. Estimates of Zn and Cu balance¹ according to different scenarios of supply in pig feeding. Former EU regulation, actual EU regulation and perspectives.

	Cu			Zn			
	Former	Actual.	Persp.	Former	Actual	“Actual” ³	Persp.
Concentration (ppm)							
Prestarter	175	170	10	250	150	2500	70
starter 2	175	170	10	250	150	150	50
fattening pigs	120	25	10	250	150	150	30
sows	100	25	10	250	150	150	70
Balance (0-110 kg BW)							
intake (g/pig)	40.4	13.0	3.1	78.3	47.0	63.4	12.2
excreted (g/pig)	40.3	12.9	3.0	75.8	44.5	61.0	9.7
Slurry (mg/kg DM)	1060	348	80	1995	1171	1604	255
Delay, years	50	167	1040	99	175	125	1160

¹calculated according to Jondreville et al. (2003), expressed per slaughter pig, including intake and excretion by sows.

²delay to reach 50 mg Cu or 150 mg Zn/kg soil DM

³in case of use of 2500 ppm of zing in pre-starter diet as allowed in some EU countries

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With the present EU regulation, Cu and Zn contents in manure DM (about 350 and 1250 mg/kg DM, respectively) are below the maximal concentration allowed in sewage sludge in France (1000 and 3000 mg/kg DM, respectively), but they exceed the concentration allowed for organic fertilizers (300 and 600 mg/kg DM, respectively). Assuming that 170 kg N/ha are spread each year it will take 160-170 years for the soil to reach 50 mg Cu or 150 mg Zn /kg soil DM (table 6). This is much longer than with the previous regulation (50 to 100 years).

But although the situation has been drastically improved by these new regulations, Cu and Zn inputs to soil with a manure application rate of 170 kg N/ha still exceed the export by crops. In the future, further reductions in Cu and Zn excretion should be possible (*Perspective*, table 6), resulting in a better agreement between spreading and export by plants. However, this will require a better understanding of the factors that affect Cu and Zn availability and a more precise evaluation of the requirements.

Conclusion

Improving the efficiency of nutrient utilisation by livestock is an efficient way to reduce the excretion in slurry. In a whole-farm perspective this is an efficient way to reduce the import of nutrients, especially N, P and trace elements, from outside the farm. Moreover, gaseous emissions from livestock housing and during storage and spreading of manure are also affected whenever livestock nutrition is changed, due to changes in chemical composition of the effluents.

References

- Aarnink, A.J.A., Verstegen, M.W.A.. 2007. Nutrition, key factor to reduce environmental load from pig production. *Livestock Science*, 109, 194–203
- Bourdon, D., Dourmad, J.Y., Henry, Y., 1997. Reduction of nitrogen output in growing pigs by multiphase feeding with decreased protein level. 48th Annual Meeting of the E.A.A.P., 25th – 28th August 1997, Vienna.
- Braude, R., 1980. Twenty five years of widespread use of copper as an additive to diets of growing pigs. In: P. L'Hermite and J. Dehandtschutter, Editors, *Copper in Animal Wastes and Sewage Sludge* (1980), pp. 3–15
- Canh, T.T., Aarnink, A.J.A., Mroz, Z., Jongbloed, A.W., Schrama, J.W., Verstegen, M.W.A., 1998. Influence of electrolyte balance and acidifying calcium salts in the diet of growing-finishing pigs on urinary pH, slurry pH and ammonia volatilisation from slurry. *Livest. Prod. Sci.* 56, 1-13.
- CVB, 2000. *Veevoedertabel*. Centraal Veevoederbureau, Lelystad, The Netherlands.
- de Lange, K., Nyachoti, M., Birkett, S., 1999. Manipulation of diets to minimize the contribution to environmental pollution. *Adv. Pork Prod.* 19, 173-186.
- Dourmad, J. Y., Etienne, M., Valancogne, A., Dubois, S., Van Milgen, J., Noblet, J. 2008. InraPorc: a model and decision support tool for the nutrition of sows. *Anim. Feed Sci. Technol.* 143, 372-386.
- Dourmad, J.Y., Guingand, N., Latimier, P., Sève, B., 1999a. Nitrogen and phosphorus consumption, utilisation and losses in pig production: France. *Livest. Prod. Sci.* 58, 199-211.

- Dourmad, J.Y., van Milgen, J., Brossard, L., Noblet, J. 2012. Contribution of modeling to the optimization of nutrient supplies to reproductive sows. IPVS 10-13 June. Proceedings, Jeju, Korea, 51-62
- Dourmad, J.Y., Henry, Y., Bourdon, D., Quiniou, N., Guillou, D., 1993. Effect of growth potential and dietary protein input on growth performance, carcass characteristics and nitrogen output in growing-finishing pigs. In: Verstegen, M.W.A., den Hartog L.A., van Kempen, G.J.M., Metz, J.H.M. (Eds), Nitrogen flow in pig production and environmental consequences. EAAP Publication n°69, 206-211. Pudoc Scientific Publishers, Wageningen (NLD).
- Dourmad, J.Y., Sève B., Latimier P., Boisen S., Fernandez J., Van de Peet-Schwering C., Jongbloed A.W. 1999b. Nitrogen consumption, utilisation and losses in pig production in France, The Netherlands and Denmark. *Livest. Prod. Sci.* 58, 199-211
- Feddes, J.J.R., Ouellette, C.A., Leonard, J.J., 2000. A system for providing protein for pigs in intermediately sized grower/finisher barns. *Can. Agric. Eng.* 42, 209-213.
- Garcia-Launay, F., van der Werf, H., Nguyen T.T.H., Le Tutour, L., Dourmad, J.Y., 2013. L'incorporation d'acides aminés dans les aliments permet de réduire les impacts environnementaux de la production porcine. *Journée Rech. Porcine*, 45, 123-128.
- Gerdmann, M.M., Machmüller, A., Frossard, E., Kreuzer, M., 1999. Effect of different pig feeding strategies on the nitrogen fertilizing value of slurry for *Lolium multiflorum*. *J. Plant. Nutr. Soil Sci.* 162, 401-408.
- Guiziou, F., Dourmad, J.Y., Saint-Cast, P., Picard, S., Daumer, M.L., 2006. Reducing ammonia volatilisation from pig slurry through the reduction of dietary crude protein and the incorporation on benzoic acid. In: Petersen, S.O. (Ed), 12th Ramiran International Conference. Technology for recycling of manure and organic residues in a whole farm perspective, Vol I., 71-74.
- Guingand, N., Demerson, L., Broz, J., 2005. L'incidence de l'incorporation d'acide benzoïque dans l'alimentation des porcs charcutiers sur les performances zootechniques et l'émission d'ammoniac. *Journées Rech. Porcine*, 37, 1-6.
- Hayes, E.T., Leek, A.B.G., Curran, T.P., Dodd, V.A., Carton, O.T., Beattie, V.E., O'Doherty, J.V., 2004. The influence of diet crude protein level on odour and ammonia emissions from finishing pig houses. *Bioresource Technology* 91, 309-315.
- Hobbs, P.J., Pain, B.F., Kay, R.M., Lee, P.A., 1996. Reduction of odorous compounds in fresh pig slurry by dietary control of crude protein. *J. Sci. Food Agric.* 71, 508-514.
- INRA-AFZ, 2004. Tables of composition and nutritional value of feed materials. In: D. Sauvant, J.M. Pérez and G. Tran (ed), 304 pp, Institut National de la Recherche Agronomique, Association Française de Zootechnie, Paris, France, 304 pp.
- IPCC, 2006. The international panel on climate change, Guidelines for National Greenhouse Gas Inventories: reference manual.
- Jarret, G. ; Martinez, J. ; Dourmad, J.Y., 2011. Effect of biofuel co-products in pig diets on the excretory patterns of N and C and on the subsequent ammonia and methane emissions from pig effluent. *Animal*, 5 (4), 622-631.
- Jarret, G. ; Cerisuelo, A. ; Peu, P. ; Martinez, J. ; Dourmad, J.Y., 2012. Impact of pig diets with different fibre contents on the composition of excreta and their gaseous emissions and anaerobic digestion. *Agriculture Ecosystems and Environment*. 45 (34), 6204-6209.
- Johansen, K., Poulsen, H.D., 2003. Substitution of inorganic phosphorus in pig diets by microbial phytase supplementation – a review. *Pig News and Information* 24, 77N -82N.

BATFarm Workshop - Rennes, 19-20 March 2013

- Jondreville C., Revy P.S., Jaffrezic A., Dourmad J.Y., 2002. Le cuivre dans l'alimentation du porc : oligoélément essentiel, facteur de croissance et risque potentiel pour l'homme et l'environnement. *INRA Prod. Anim.* 15, 247-265.
- Jondreville, C., Dourmad, J.Y., 2005. Le phosphore dans la nutrition des porcs. *Inra Prod. Anim.* 18, 183-192.
- Jondreville, C., Hayler, R., Feuerstein, D., 2005. Replacement of zinc sulphate by microbial phytase for piglets fed a maize-soybean meal diet. *Anim. Sci.*, 81, 77-83.
- Jondreville, C., Revy, P.S., Dourmad, J.Y., 2003. Dietary means to better control the environmental impact of copper and zinc by pigs from weaning to slaughter. *Livest. Prod. Sci.* 84, 147-156.
- Jongbloed A.W., Everts H., Kemme P.A., Mroz, Z., 1999a. Quantification of absorbability and requirements of macroelements. In: I. Kyriazakis (eds), *Quantitative biology of the pig*, CAB International, Wallingford, UK, 275-298.
- Jongbloed, A.W., Lenis, N.P., 1992a. Alteration of nutrition as a means to reduce environmental pollution by pigs. *Livest. Prod. Sci.* 31, 75-94.
- Jongbloed, A.W., Mroz, Z., Kemme, P.A., 1992b. The effect of supplementary *Aspergillus Niger* phytase in diets for pigs on concentration and apparent digestibility of dry matter, total phosphorus, and phytic acid in different sections of the alimentary tract. *J. Anim. Sci.* 70, 1159-1168.
- Jongbloed, A.W., Poulsen, H.D., Dourmad, J.Y., van der Peet-Schwering C.M.C., 1999b. Environmental and legislative aspects of pig production in The Netherlands, France and Denmark. *Livest. Prod. Sci.* 58, 243-249.
- Knowlton, K.F., Radcliffe, J.S., Novak, C.L., Emmerson, D.A., 2004. Animal management to reduce phosphorus losses to the environment. *J. Anim. Sci.* 82, E173-E195.
- Kornegay, E. T., 2001. Digestion of phosphorus and other nutrients: the role of phytases and factors influencing their activity. In *Enzymes in Farm Animal Nutrition*, pp 237-271. M. R. Bedford and G. G. Partridge (Ed), CAB International, Wallingford, UK.
- Kreuzer, M., Machmüller, A., Gerdemann, M.M., Hanneken, H., Wittmann, M., 1998. Reduction of gaseous nitrogen loss from pig manure using feeds rich in easily-fermentable non-starch polysaccharides. *Anim. Feed Sci. Tech.* 73, 1-19.
- Latimier, P., Dourmad, J.Y., 1993. Effect of three protein feeding strategies, for growing-finishing pigs, on growth performance and nitrogen output in the slurry and in the air. In: *Nitrogen flow in pig production and environmental consequences*. Pudoc Scientific Publishers, Wageningen, The Netherlands, pp. 242-245.
- Latimier, P., Pointillard, A., Corlouër, A., Lacroix, C., 1994. Influence de l'incorporation de phytase microbienne dans les aliments, sur les performances, la résistance osseuse et les rejets phosphorés chez le porc charcutier. *J. Rech. Porcine Fr.*, 26, 107-116.
- Le, P.H., 2006. Odor from pig production: its relation to the diet. Ph.D. thesis, Wageningen University, The Netherlands.
- Le, P.H., Aarnink, A.J.A., Ogink, N.W.M., Becker P.M., Verstegen, M.W.A., 2005. Odor from animal production facilities: its relation to the diet. *Nut. Res. Rev.* 18, 3-30.
- Moeser, A.J., See, M.T., van Heugten, E., Morrow, W.E.M., van Kempen, T.A.T.G., 2003. Diet and evaluators affect perception of swine waste odor: An educational demonstration. *J. Anim. Sci.* 81, 3211-3215.

BATFarm Workshop - Rennes, 19-20 March 2013

- Noblet J, Seve B and Jondreville C 2004. Nutritional value for pigs. In Tables of composition and nutritional value of feed materials: pigs, poultry, cattle, sheep, goats, rabbits, horses, fish (ed. D Sauvant, JM Perez and G Tran), pp. 25–35. INRA Editions, Versailles, France.
- NRC, 2012. Nutrient Requirements of Swine. Eleventh Revised Edition. National Academy Press, Washington, DC.
- Pomar, C., Pomar, J., Babot, D., Dubeau, F., 2007. Effet d'une alimentation multiphase quotidienne sur les performances zootechniques, la composition corporelle et les rejets d'azote et de phosphore du porc charcutier. *J. Rech. Porcine Fr.* 39, 23-30.
- Portejoie, S., Dourmad, J.Y., Martinez, J., Lebreton, Y., 2004. Effect of lowering crude protein on nitrogen excretion, manure composition and ammonia emission from fattening pigs. *Livest. Prod. Sci.* 91, 45-55.
- Poulsen, H.D. 2000. Phosphorus utilization and excretion in pig production. *J. Environ. Qual.* 29:24–27.
- Poulsen, H. D., Jongbloed, A.W., Latimier, P., Fernandez, J.A., 1999. Phosphorus consumption, utilisation and losses in pig production in France, The Netherlands and Denmark. *Livest. Prod. Sci.* 58, 251-259.
- Poulsen, H.D., 1995. Zinc oxide for weanling piglets. *Acta. Agric. Scand.* 59, 159-167.
- Revy P.S., Jondreville C., Dourmad J.Y., Nys Y., 2003. Le zinc dans l'alimentation du porc: oligoélément essentiel et risque potentiel pour l'environnement. *INRA Prod. Anim.* 16, 3-18.
- Revy, P.S., Jondreville, C., Dourmad, J.Y., Nys, Y., 2005. Assessment of dietary zinc requirement of weaned piglets fed diets with or without microbial phytase. *J. Anim. Phy. Anim. Nutr.* 90, 50-59.
- Sørensen, P., Fernandez, J.A., 2003. Dietary effects on the composition of pig slurry and on the plant utilisation of pig slurry nitrogen. *J. Agri. Sci.* 140, 343-355.
- van de Peet-Schwering C.M.C., Aarnink A.J.A., Rom H.B., Dourmad J.Y. 1999. Ammonia emissions from pig houses in the Netherlands, Denmark and France. *Livest. Prod. Sci.* 58, 265-269.
- van Kempen, T.A.T.G., 2001. Dietary adipic acid reduces ammonia emission from swine excreta. *J. Anim. Sci.* 79, 2412-2417.
- van Milgen, J., Valancogne, A., Dubois, S., Dourmad, J.Y., Sève B., Noblet, J., 2008. InraPorc: a model and decision support tool for the nutrition of growing pigs. *Anim. Feed Sci. Technol.* 143, 387-405.