Current phosphorus evaluation systems for livestock in Germany

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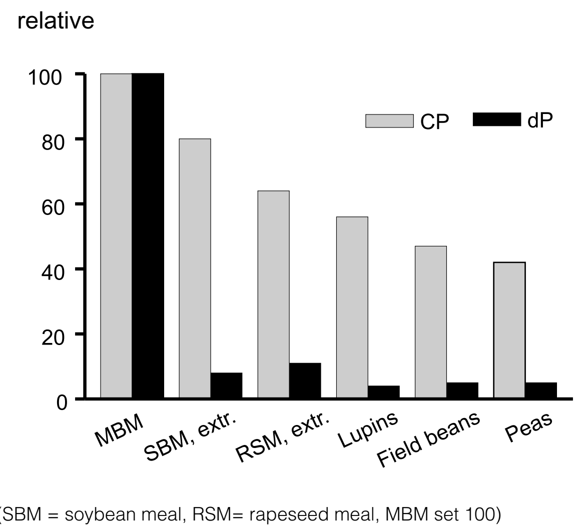
1. Introduction

Since decades, feeding strategies and feed evaluation systems for livestock have been optimised under a continuously changing framework. Phosphorus (P) was supplemented to the diets with the main goal, until about 10 years ago, of safely avoiding deficiency. As long as both the factors that determine P requirement and the availability of P from different sources were only rarely studied, this often lead to an excessive use of inorganic P salts and to relatively high concentrations of total P in the diets.

The strategy has changed in the past decade. P excretion of livestock and how it depends on feeding became an important topic for nutritionists to be studied in many countries. The high stocking density of livestock industries in some areas, often without a binding to the arable land of the farms, was one of the factors stimulating this research. The community is concerned about phosphates leached into the water, not only since extensive algae blooms negatively effect the tourism industry in the Mediterranean countries. Furthermore, on the long term we have to deal with limited resources of rock phosphates world-wide.

The ban of feedstuffs from animal origin has strengthened this problem for the pig and poultry industry. Meat and bone meal as well as fish meal are high in P concentration and this P is generally highly available. Roughly 40 % of the P requirement of a 30-kg pig was covered by bone meal when this contributed to approximately 2 % of the diet. This demonstrates that the ban of these feedstuffs is quantitatively much more important under the aspect of P supply than it is under the aspect of amino acid supply. The alternative protein sources contain significantly less total P than meat and bone meal does and, furthermore, this P is less available to pig and poultry (Figure 1).

Figure 1: Comparison of crude protein (CP) and digestible P (dP) concentration in different vegetable protein-rich ingredients and meat and bone meal (MBM)



(SBM = soybean meal, RSM= rapeseed meal, MBM set 100)

The livestock industries and scientists were challenged by these changes and have developed feeding strategies to reduce P excretion of the animals and to minimise P impact into the environment and, mostly, these strategies are successfully in use already. This paper summarises the current knowledge about the P requirement and the evaluation of different P sources for different species, including the effectiveness of microbial phytase. With regard to evaluation systems it mainly refers to the work that in the past decade has been published by the “Ausschuss für Bedarfsnormen”, the German council on nutrient requirements for livestock.

2. Phytin in plant feedstuffs

In vegetable seeds and in many by-products from the food industry such as extracted oilseed meals or bran most of the P is contained as phytic acid (myo-inositol 1,2,3,4,5,6-hexakis-dihydrogenphosphate) and the respective salts (phytate) (together: phytin) (DÜNGELHOEF and RODEHUTSCORD 1995; EECKHOUT and DE PAEPE 1994). Phytic acid is known for its chelate-forming properties and for the capacity to bind multivalent cations (PALLAUF and RIMBACH 1997). Furthermore, the formation of complexes with certain proteins and amino acids and the reduction of the activity of intestinal proteinases and α-amylase is reported from in-vitro studies (HARLAND and HARLAND 1980; SCHEUERMANN et al. 1988; SHARMA et al. 1978). Phytase, the enzyme required for phytic acid hydrolysis is to be found only with very low activity, if at all, within the intestinal tissues (POINTILLART et al. 1984; LOPEZ et al. 2000). However, phytase produced by microbes colonising the digestive tract can be very efficient in hydrolysing phytic acid, as demonstrated by the almost complete availability of vegetable P to ruminants (KODDEBUSCH and PFEFFER 1988; RODEHUTSCORD et al. 2000). Some vegetable seeds contain considerable intrinsic phytase activity, which is efficient in the digestive tract of the animal as well. While in maize or oilseed meals the intrinsic phytase activity is negligibly low, wheat, rye, and triticale may show an intrinsic phytase activity roughly ranging between 500 and 1500 U/kg (with large variation between varieties and depending on environmental conditions). This is a main reason why the availability of P for pigs and poultry is very different between grains although the contribution of phytin-P to total P is similar (see 4.2). It demonstrates the necessity for a methodologically sound and applicable system for evaluating the availability of P for both pigs and poultry.

3. Why animals excrete phosphorus

For the general understanding of the different P evaluation systems it is helpful to get an insight into the reasons for P excretion. P excretion can be allocated to one out of three following categories.

3.1 Inevitable losses

Inevitable losses of P are unaffected by the level of P intake and do occur even at a theoretical zero P intake. They reflect physiological needs of the animal and cannot be manipulated by the dietary P level. The dominating way of excretion is via faeces, caused by endogenous secretion of phosphate into the gut. The urinary excretion plays a minor role for inevitable P losses. It is generally accepted that, for non-ruminants, the inevitable P losses are a function of the body weight (BW). In ruminants, however, they depend on dry matter intake (~1 g/kg dry matter intake) and intake of digestible organic matter, respectively (RODEHUTSCORD et al. 2000; SPIEKERS et al. 1993). Recent estimates for the inevitable P losses in pigs account for 7 mg/kg BW per day (JONGBLOED and EVERTS 1992; RODEHUTSCORD et al. 1998), with a contribution of the urine to this excretion of less than 10 % (RODEHUTSCORD et al. 1998). So far, comparably solid estimates for the inevitable losses in poultry are not published. In the recent recommendations for broiler and layer, the Ausschuss für Bedarfsnormen (GFE 1999) assumes that the "maintenance requirement" for P accounts for 80 mg/kg BW per day. Regulatory excretion due to P intake exceeding the requirement is likewise included in this estimate and, therefore, it can be regarded as very safe.

3.2 Regulatory excretion

As part of homeostatic mechanisms animals adjust their P excretion to the level of P intake particularly when they are fed above the requirement. The skeleton certainly acts as a store for minerals, however it is not unlimited in depositing P. The P concentration in gained BW of pigs and poultry hardly exceeds a range of 4.5 to 5.5 g/kg. Animals that receive P above their requirement usually react both with a reduced rate of absorption and with an increased urinary phosphate excretion (FERNÁNDEZ 1995; GÜTTE et al. 1961; RODEHUTSCORD et al. 1999b; VEMMER 1982). In contrast to the inevitable losses (3.1) this component of excretion clearly depends on the level of P supply. Therefore it is conclusive that the regulatory excretion is an important matter of interest in cases where a reduction in P excretion is to be achieved by feeding.

3.3 Limited availability of phosphorus from feedstuffs

The chemical form in which it is bound in feedstuffs heavily determines the availability of P to non-ruminants. In this context, at least in pigs, a complete utilisation of digested P can be assumed at a marginal level of P supply (RODEHUTSCORD et al. 1998). Consequently, in the Netherlands and Germany, the availability of dietary P is measured as P digestibility (see 4.2) because this is a clearly defined measurement which can be conducted with pigs under standardised methodological conditions for all feedstuffs. This is very important for many European countries where a long list of feedstuffs exists that are potential ingredients for pig and poultry diets. More simple evaluation systems can be justified under conditions where only very few ingredients are used such as with the corn/soy diets widely used in the US.

A major contributor to the variation in P digestibility is the content of phytic acid in seeds and by-products (see 2.). P bound as phytic acid can be absorbed only after hydrolysis, which relies on the enzyme phytase, not provided by intestinal tissues. Feedstuffs high in phytic acid and low in intrinsic phytase activity are, therefore, low in P digestibility. Similar to intrinsic phytase, phytase produced by microbes in the digestive tract or phytase supplemented to the diet may show activity in the digestive tract. In order to minimise excretion, the consideration of the differences in P digestiblity in compounding feed is most important. Only then a precise supplementation of inorganic P salts or, alternatively, of microbial phytase is possible.

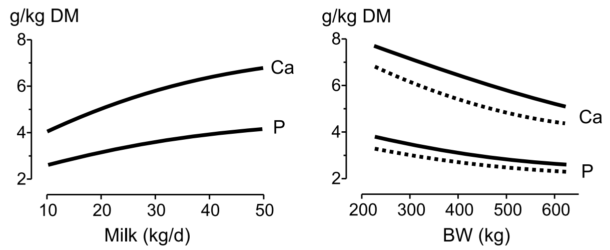
4. Current evaluation systems

4.1 Ruminants

Due to the capacity of ruminants to utilise dietary P very efficient irrespective of the P source a constant P availability is assumed and, consequently, dietary allowances are expressed as total P (GFE 1993, 1995) without the need for further differentiation. Only low-soluble inorganic salts (that are not relevant for the practice) and formaldehyde-treated oilseed meals show an incomplete availability (GONGNET et al. 1997; PARK et al. 2000). Working with a general value for the P availability of 70% includes a high safety margin that considers feedstuffs like these as well.

The quantitative P requirement of the **dairy cow** depends on both the dry matter intake and the milk yield and, as a consequence, the required P concentration in the diet increases with the attained level of milk yield (Figure 2). However, a P concentration of more than 4 g/kg DM is not necessary, even for the very high yielding dairy cow. This was shown in studies in "Haus Riswick" already about ten years ago (BRINTRUP et al. 1993) and was confirmed more recently in studies in the Netherlands and in Wisconsin with high yielding cows (VALK and SEBEK 1999; WU and SATTER 2000; WU et al. 2000). A supplementation of inorganic salts is, therefore, not necessary for most of the diets used in practice with the exception of diets that contain large proportions of maize products or beet pulp because these ingredients contain relatively low levels of P.

Figure 2: Concentration of phosphorus (P) and calcium (C) required in the diet for the dairy cattle depending on milk yield (left panel) and for beef cattle (right panel) based on BW gain of either 900 g/d (---) or 1300 g/d (—) (calculated from GFE 1993, 1995)



For the **dry cow** it is still under discussion, whether a supplementation of P may be effective in preventing milk fever in addition to minimising the Ca supply and avoiding a dietary cation excess (BREVES et al. 1999).

In the feeding of **beef cattle** the required P concentration in the diet is affected by both the BW and the BW gain. With increase in BW the concentration can be continuously reduced (Figure 2). At the beginning of the fattening period a P supplementation is usually required when diets are mainly based on maize silage. In such diets, a supplementation of Ca is always necessary.

The requirement of **sheep and goat** can be calculated based on the same concept and factors as used for cattle. For lactating animals, a concentration of 3.5 g P/kg DM is sufficient whereas the diets used in intensive lamb feeding for high BW gain should contain 4.2 g/kg DM (SPIEKERS and RODEHUTSCORD 1998).

4.2 Pigs

Similar systems based on digestible P were developed and are in use in the Netherlands and in Germany (JONGBLOED and EVERTS 1992; KIRCHGESSNER 1997). With a focus on the practical application of the system, the Arbeitskreis Futter und Fütterung of the DLG has already published a comprehensive information (DLG 1999) and only the main points are to be repeated herein.

4.2.1 Requirement for digestible P

The quantitative requirement for dP is calculated based on the factorial approach as summarised in Table 1. The factors of the *net requirement* are the inevitable losses (depending on BW), the P accretion related to growth, the P accretion in conception products and the P secretion with milk. The utilisation of digestible P for covering the net requirement is almost complete (RODEHUTSCORD et al. 1998) and a value of 95 % is applied in the system.

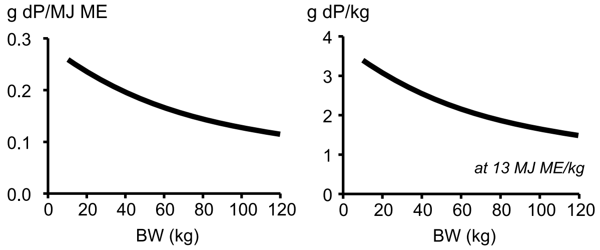
Table 1: The factors used to calculate the digestible P (dP) requirement of the pig (KIRCHGESSNER 1997)

- Inevitable losses, mg/kg BW per day	10
- P in BW gain, g/kg	
≤ 80 kg BW	5.0
> 80 kg BW	4.5
- P in conception products, g/d	
until d 84 of pregnancy	1.5
thereafter	3.0 - 5.0
- P secretion with milk, g/kg	1.6
Efficiency of utilisation of dP for covering the net requirement, %	95
Ratio total Ca : dP	2.5:1 to 3.0:1

From the data in Table 1 the quantitative dP requirement can be calculated for each production system considering the BW and the level of performance. For compounding diets, however, data for the dP concentration needed in the diet are more important. They are affected by the feed intake of the animal and the feed conversion ratio.

In **growing pigs**, the feed conversion ratio becomes continuously worth with increase in BW due to an increasing proportion of dietary energy retained as fat. The supply of metabolisable energy (ME) is the factor primarily driving growth and it is consequent to express the dP requirement in relation to the ME requirement as often done for amino acids already. Figure 3 shows how the dP concentration can be adjusted during the fattening period.

Figure 3: Concentration of digestible P (dP) in diets for growing pigs



It is most unlikely that pigs have any disadvantage or suffer from continuously high dP concentration in the diet. However, there is a significant potential to reduce the P excretion of the animals and to save costs for phosphates when the dP concentration is adjusted to the course shown in Figure 3. The concept of phase feeding which is successfully applied for amino acids is suitable for optimising the supply of dP to growing pigs as well (see below). Table 2 shows examples for the dP concentration in compound feed for selected growth phases and Table 3 shows examples of compound feeds for **piglets** and **sows**. During lactation the dP requirement of the sow is much higher than during pregnancy. During the first two thirds of pregnancy the requirement of the adult sow hardly exceeds the maintenance requirement. In this example it is assumed that no change in diet is made until the sows are moved to the farrowing pens. If a phase feeding during pregnancy is practised, the dP concentration in the diet for the first part of the pregnancy can be still lower than mentioned in Table 3 (1.5 g dP/kg). In a long-term feeding trial at the University of Bonn it was shown that these recommendations can safely be applied in practice (Table 4).

Table 2: Examples for the concentrations of digestible P (dP) and Ca in compound feeds for growing finishing pigs at different levels ME in the diet (g/kg)

	dP			Ca
	12.6 MJ ME/kg	13.0 MJ ME/kg	13.4 MJ ME/kg	
From 30 kg BW	2.6	2.7	2.8	7.0
From 60 kg BW	2.1	2.2	2.3	6.0
From 85 kg BW	1.6	1.7	1.7	5.0

Table 3: Recommended levels of digestible P (dP) and Ca in compound feed for sows and piglets (in g/kg, from DLG 1999)

	dP	Ca
Compound feed for pregnant sows[1] (11.8 MJ ME/kg)	2.0	6.0
Compound feed for lactating sows[2] (13.0 MJ ME/kg)	3.3	8.5
High protein supplement for lactating sows (Ratio cereals[3]:supplement = 65:35)	5.7	23.0
Piglet feed from 10 kg BW (13.4 MJ ME/kg)	3.5	8.5
Piglet feed from 20 kg BW (13.4 MJ ME/kg)	3.2	8.0

1 Also sufficient for sows in their first pregnancy
2 Equals all-in-one-feed for both pregnant and lactating sows
3 60 % wheat assumed

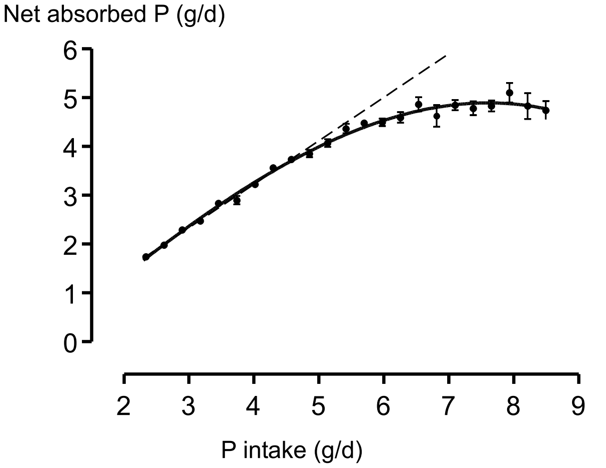
Table 4: Long-term effects of feeding different levels of digestible P (dP) to sows (Av.±SD; HOVENJÜRGEN et al. 2000b)

	% of the recommended level for dP	
	75 (*n = 206 litters*)	100 (*n = 205 litters*)
Piglets born alive	11.3±2.6	11.0±2.6
Litter weight at birth, kg	16.3±4.2	15.8±3.9
Days at weaning	26.4±2.3	26.5±2.3
Weaned piglets per litter	9.1±2.4	9.1±2.4
Birth weight, kg/piglet	1.45±0.25	1.46±0.25
Weaning weight, kg/piglet	8.0±1.4	8.1±1.4
BW gain of piglets, g/d	249±48	253±47

4.2.2 Determination of P digestibility

In order to make the digestibility of P a meaningful measure for P availability, methodological restrictions need to be obeyed when conducting the digestibility studies with pigs, particularly regarding the P supply. For P, the intestinal absorption and the endogenous secretion of phosphate play an important role in maintaining homeostasis, which is completely different from, for example, amino acids. While under marginal P supply the digestibility of P is almost constant irrespective of intake, the digestibility becomes increasingly lower with an increase in intake above a certain threshold level (Figure 4). These regulative mechanisms need to be avoided if the capacity of a feedstuffs needs to be described and methodological guidelines were published in 1994 in order to make results from different experiments comparable (KIRCHGESSNER 1994). One important restriction formulated in this guideline is that the dP level in the experimental diets must not exceed 2 g/kg (for a pig weighing 30 kg). Most ingredients, therefore, must be tested after being blended into a low-P basal diet of known digestibility (DÜNGELHOEF et al. 1994).

Figure 4: Effect of increasing intake of P from Monosodiumphosphate on the amount of net absorbed P in pigs (RODEHUTSCORD et al. 1999b)



The Arbeitskreis Futter und Fütterung of the DLG has published a table which summarises the data on P digestibility for ingredients from the literature (Table 5). Only such values were considered that were determined at a sufficiently low level of P supply and for some ingredients, estimates were made. Not considered in this table is meat and bone meal, which showed a P digestibility in the range of 80 to 85 % (RODEHUTSCORD et al. 1997).

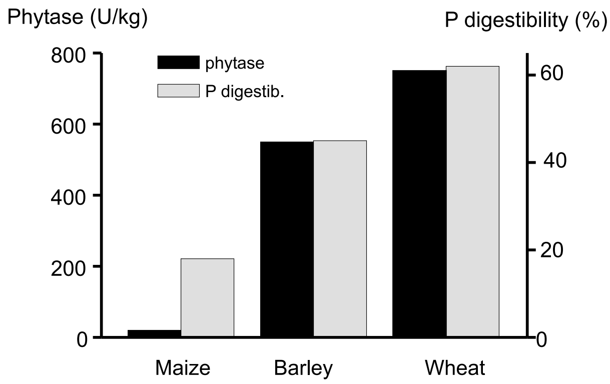
4.2.3 The role of intrinsic phytase activity

Vegetable ingredients considerably differ in P digestibility although the proportion of P bound as phytate is similar as outlined already in chapter 2. The main reason for this is the intrinsic phytase activity which can be found in some seeds and which is effective within the digestive tract (Figure 5). While intrinsic phytase can hardly be found in maize and oilseed meals which underwent heat treatment, it shows considerable activity in wheat, rye, and triticale (with great variation between varieties and depending on environmental conditions). If intrinsic phytase activity is completely destroyed, P digestibility is as low as 20 % even in wheat. In wheat-based diets it is therefore an important aspect whether the intrinsic phytase activity is stable during storage and handling (drying) or not. Temperatures above 70 °C which are easily achieved during pelleting and conditioning are sufficient to largely destroy intrinsic phytase.

Table 5: Grouping of ingredients for pig diets in classes of P digestibility (from DLG 1999)

P digestibility (%)	Ingredient
10	Solvent extracted linseed meal, beet pulp, dried molassed or ensiled, beet, hay, straw, tapioca
15	Maize (seed)
20	Solvent extracted cottonseed meal, maize gluten feed
25	Oat, potato residues, wheat gluten feed
30	Solvent extracted peanut meal, bran, solvent extracted coconut meal, solvent extracted palm kernel meal, solvent extracted rapeseed meal
35	Field beans, brewer's grains, soybeans, solvent extracted soybean meal, solvent extracted sunflower meal
40	Rapeseed
45	Peas, Barley
50	Yeast (dried), Corn-Cob-Mix, dried grass meal, green forage, potatoes and potato products, lupines, dried alfalfa meal, rye, silages, triticale
65	Wheat
70	Di-calciumphosphate, potato protein
80	Whey products, mono-di-calciumphosphate
85	Fish meal
90	Milk (fresh and dried), mono-calciumphosphate
95	Mono-sodiumphosphate, Ortho-phosphoric acid

Figure 5: Intrinsic phytase activity and P digestibility in selected ingredients for pig diets (from DÜNGELHOEF et al. 1994; RODEHUTSCORD et al. 1996)



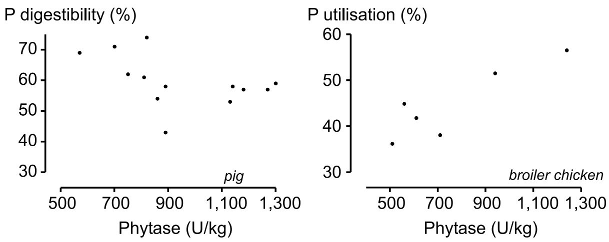
4.2.4 Inorganic P sources

Experiments conducted with inorganic P sources showed remarkable differences in the digestibility between sources as well, particularly between dicalcium-phosphates (DELLAERT et al. 1990; EECKHOUT and DE PAEPE 1997; RODEHUTSCORD et al. 1994). The extent of digestibility trials with inorganic salts differing in origin and quality is still insufficient. The ban of P from animal origin strengthens the need for a more sophisticated evaluation of new products. In-vitro estimates based on solubility are not yet fully satisfying.

4.2.5 Effects on P digestibility

Among the ingredients tested, wheat is the one that has been studied most with respect to the variation in P digestibility **between batches** and varieties, respectively. In the studies conducted at the University of Bonn in recent years, digestibility of P from wheat ranged from 43 to 74 %, without any correlation to intrinsic phytase activity (Figure 6). Other factors like phytate solubility and the contribution of different inositol phosphates likewise contribute to this variation, which needs further investigation. Crop fertilisation with N and P obviously is not relevant for P digestibility (BARRIER-GUILLOT et al. 1996; HOVENJÜRGEN et al. 2000a).

Figure 6: Relation between intrinsic phytase activity in wheat and P digestibility in pigs (left panel) and P utilisation in broiler chicken (right panel) (data from HOVENJÜRGEN et al. 2000a; OLOFFS et al. 2000; RODEHUTSCORD et al. 1996)



As compared to the coefficient of variation (cv) in the digestibility of organic matter the cv for P digestibility was high in all our experiments and ranged between 5 and 26 %. This was the reason for HOVENJÜRGEN (2000) to study a potential genetic effect on the digestibility of P in an extensive digestibility program. He showed significant differences between pig breeds and crossbreeds up to 6 percentage units (Table 6). An effect of sire, however, was not detectable and consequently an approach to consider P digestibility in selection programs appears not promising.

Table 6: Digestibility of P in different breeds and crossbreeds of pigs (least-square means ±SE, HOVENJÜRGEN, 2000)[1)]

Breed				
DEx DL	DL	DUxPi	Pi	PixDL
41.1±1.0	38.7±0.6	34.8±1.2	35.3±0.5	37.8±0.8

[1)] The effect of breed was statistically significant (P<0.001)

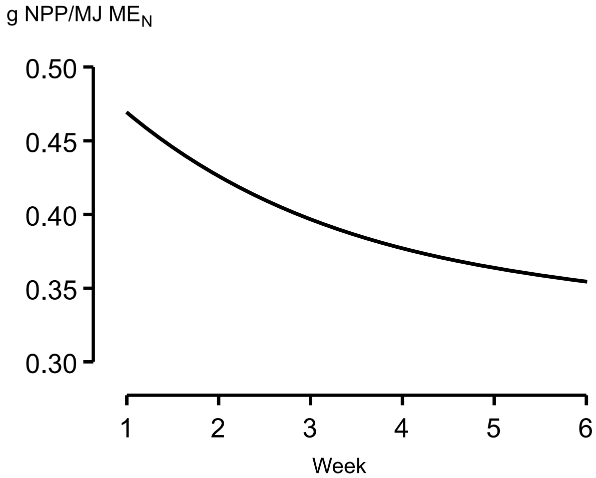
The effect of body weight on P digestibility is controversially discussed in the literature. Often a difference in BW was combined with a change in the level of P supply. As shown in Figure 3, less dP is needed in the diet with increasing BW and, therefore, the dietary P concentration needs continuous adjustment to growth if pigs are to be fed at a suboptimal P level. Considering this aspect, a comparison between pigs weighing 15 and 40 kg did not show any clear difference in the digestibility of P from MCP or vegetable P. Similarly, the efficiency of supplementary phytase was unaffected by BW (RODEHUTSCORD et al. 1999a). Therefore, digestibility values measured so far should be generally applicable in feed compounding for pigs irrespective of the pig's BW.

4.3 Poultry

The current P evaluation for poultry in Germany is not as sophisticated as for pigs. A solid measurement of P availability has not been done so far and a suitable method still needs to be described (GFE 1999). Comparisons between pigs and broiler or layers, however, indicate that values determined in pigs cannot be simply applied to poultry (KORNEGAY et al. 1996; OLOFFS et al. 1998; OLOFFS et al. 2000). At present, phytate P is assumed completely unavailable to poultry and the evaluation systems consider non-phytate P (NPP) as the only fraction contributing to available P supply. The availability of NPP is assumed to be 70 %. One weak point in this system certainly is that intrinsic phytase is efficient to hydrolyse phytate in the bird's digestive tract and that a considerable proportion of phytate P can be utilised in the presence of intrinsic phytase.

As factors for the net requirement the following values are in use (GFE 1999): maintenance requirement 80 mg/kg BW per day, P accretion with growth 5.5 g/kg BW gain and P concentration in the egg 1.7 g/kg. For **broiler chicken** consequently the quantitative requirement for NPP increases until reaching the final weight. As the feed/gain ratio increases as well, the NPP concentration in the diet can be reduced by approximately 25 % during a 6-week growth period (Figure 7). Very similar to the situation in pigs, this allows for a reduction in the excretion of P by phase feeding.

Figure 7: Concentration of non-phytate P (NPP) required in diets for the growing broiler chicken depending on age (adjusted from GfE 1999)



The recommendation for **laying hens** is 0.28 g NPP per MJ ME_N, with negligible effects of BW and laying performance on this ratio.

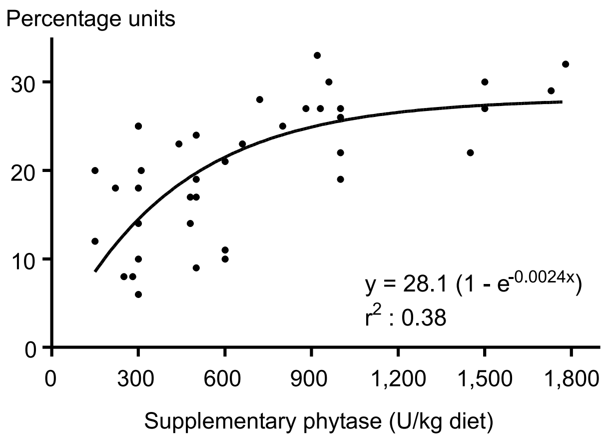
The requirement of other species like **turkeys** and **ducks** is currently under investigation. As compared to the P concentrations in current compound feeds for these species the potential to reduce the dietary P concentrations appears great. The high stocking density in the turkey and duck industries demands rapid clarification.

At present the P evaluation for poultry is a simple differentiation based on analytical data without any measurements with the birds. On the long term this is unsatisfactory. As mentioned above, phytate P can be utilised to a considerable proportion in the presence of phytase, as shown for wheat as an example in Figure 6. Furthermore it is doubtful whether the availability of NPP is constant 70 % irrespective of the ingredient. A standardised method for the determination of available P, perhaps based on P utilisation, is, therefore, needed (GFE 1999) and different institutions currently work on such a method. In this context it needs to be tested whether the utilisation determined in growing chicken can be applied to layers that are fed a much higher Ca level.

5. Microbial phytase

Since phytase can be produced with large-scale fermentation processes it is an efficient tool to improve the availability of P in phytate containing diets with low intrinsic phytase activity. This has been shown in a very high number of studies with pigs and poultry and Figure 8 shows, as an example, results for pigs form a literature survey.

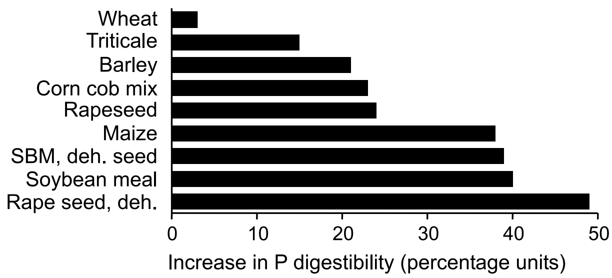
Figure 8: Increase in digestibility of P from low-phytase diets caused by supplementary aspergillus niger phytase (DÜNGELHOEF and RODEHUTSCORD 1995)



The range up to a supplementation of 500 U/kg is the one where the highest efficiency of phytase is achieved and, correspondingly, this is the level recommended for supplementation of phytase to diets in practice. A more detailed recommendation has to consider the composition of the diet. As lower the phytate concentration and as higher the intrinsic phytase activity is, as lower is the need to supply further phytase, at least with a dosage of 500 U/kg. Figure 9 demonstrates this on the basis of data obtained for ingredients. Figure 9 also shows that the digestibility of P in ingredients even with supplementary phytase is not equal. Thus, ideally the efficiency of supplementary phytase is determined for individual ingredients in dose-response-studies. As long as this work is done, the compromise for practical application is to work with a common P digestibility of 65 % for all relevant plant ingredients with 500 U supplementary phytase.

Replacement values are introduced in order to calculate how much inorganic P can be saved by 500 U of phytase. With the more sophisticated evaluation based on digestible P this replacement is no longer fully satisfying because

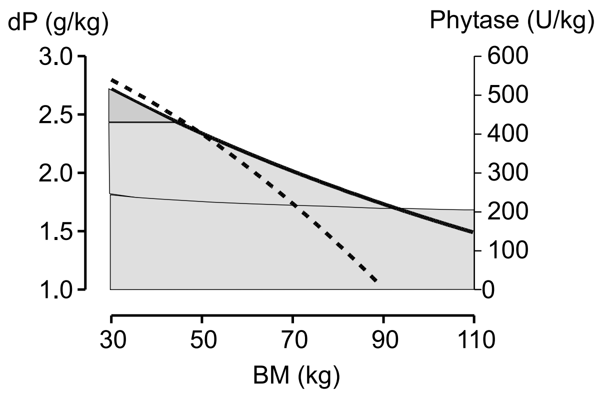
Figure 9: Increase in digestibility of P from different ingredients for pig diets caused by supplementary aspergillus niger phytase



inorganic P sources differ in digestibility (see 4.2.4). It is consequent to express a replacement value for future use on the basis of dP. On the basis of a literature survey (DÜNGELHOEF and RODEHUTSCORD 1995) a replacement value of 0.16 g dP per 100 U was calculated which is valid up to a supplementation of 500 U/kg. This value is calculated based on the 3-phytase from aspergillus niger. Newly developed phytases need to be tested for their replacement value in pigs on the basis of standardised methods that are established.

A replacement value based on dP is useful in compounding diets also because under many conditions a supplementation of less than 500 U can be used in order to meet the animals dP requirement. In Figure 10 this is demonstrated based on the example of a barley/wheat/soy-diet for growing fattening pigs. The graph again shows the required dP concentrations depending on the pig's BW. From about 90 kg onwards, the dP needs of the pigs are completely fulfilled by dP from barley, wheat and soy alone without any phytase and without any inorganic P supplementation. Up to this BW, a deficit in the dP supply exists which becomes increasingly lower with increasing BW. Correspondingly, the supplementation of phytase can be reduced from about 500 U/kg at the beginning to 100 U/kg at 80 kg BW. Even with 500 U/kg an additional use of inorganic P is necessary in this example up to 45 kg BW.

Figure 10: Calculation of the necessary phytase supplementation in a barley/wheat/soy diet for pigs



The two lines show the recommended dP level in the diet (——) and the phytase supplementation required to attain the respective dP level in such a diet (- - - -). The areas under the curve show the contribution of phytase to the supply of digestible P (middle area) and the amount of inorganic P which is still needed (upper area).

It is questionable at present whether the flexible use of phytase shown in Figure 10 can be fully applied under practical conditions in the feed mill and on the farm, respectively. The figure, however, shows the potential which is given by phase feeding. Microbial phytase can be a component of this concept, if the replacement is expressed on the basis of dP and if the evaluation of phytase efficiency is adjusted to the general P evaluation.

6. Summary and conclusions

In recent years, revisions were made of the P evaluation systems for ruminants, pigs and poultry in Germany. For ruminants, a constant availability of dietary P of 70 % is assumed irrespective of the P source. In most diets for dairy cattle, beef cattle, sheep and goat under intensive European feeding conditions a supplementation of inorganic P is not necessary. In pigs and poultry, a large variation in P availability exists depending on the P source. Ingredients high in phytic acid are low in P availability if they do not contain intrinsic phytase activity. This is considered in the current digestible P systems for pigs in the Netherlands and Germany. The evaluation based on non-phytate P basically considers this as well. Further basic research, however, is needed to evaluate and to compare the availability of different P sources to poultry in animal trials. During the fattening period of pigs and poultry, the P supply can be continuously reduced and a potential to save inorganic P and microbial phytase is given. In face of the current ban of ingredients from animal origin and in face of the limitations in the world-wide rock phosphate resources this should be standard in formulating diets for pigs and poultry.

7. Literature

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