MICROBIAL PHYTASE AS A MEANS TO REDUCE THE ENVIRONMENTAL IMPACT OF ZINC IN PIG FEEDING

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Introduction

Zinc oversupplied in pig feeding concentrates in manure and may cause environmental pollution (Jondreville et al., 2003). Lowering zinc dietary supply is undoubtedly an efficient way to prevent this adverse effect on environment. However, such an approach requires an accurate knowledge of zinc dietary requirement and of the factors by which it may be altered.

The NRC (1998) recommends a zinc supply of 80 mg / kg diet to weaned piglets. However, the zinc requirements of these animals have not been recently re-assessed.

In addition, although improved zinc availability by the addition of microbial phytase to piglet diets was previously reported (e.g. Lei et al., 1993), a zinc equivalency for phytase has not yet been established.

Therefore, four experiments were conducted in our laboratory in order to update the zinc dietary requirements of weaned piglets and to evaluate the sparing effect of phytase on the need for supplementation of diets with zinc as sulphate.

Material and Methods

In each experiment a basal diet was formulated to exceed all nutrient requirements for piglets weighing between 5 and 20 kg (INRA, 1989; NRC, 1998), except zinc. All of them were made of 79 to 90% of feedstuffs of plant origin. Their zinc, phytic P and Ca concentrations were 30 to 33 mg, 2.1 to 2.9 g and 8.3 to 9.6 g / kg, respectively (Table 1).

Table 1 : Characterisation of each basal diet without zinc and phytase added

Experiment	1	2	3	4
Plant feedstuffs (%)[1]	79	83	90	82
Dry matter (DM) (g / kg)[2]	905	896	880	903
P (g / kg)[2]	7.6	7.3	5.8	6.8
Phytic P (g / kg)[3]	2.5	2.9	2.5	2.1
Ca (g / kg)[2]	9.5	9.5	8.3	9.6
Phytase activity (U / kg)[2]	116	150	139	60
Zn (mg / kg)[2]	32	33	30	30
Cu (mg / kg)[2, 5]	26	8	6	11
Phytate:Zn[4]	27	31	29	25
(Ca x Phytate):Zn[4]	7.2	8.2	6.9	6.6

[1] Maize, soybean meal, isolated soy protein and heated wheat bran.
[2] Analysed according to the procedures described by Revy et al. (2004).
[3] Calculated from INRA-AFZ (2002).
[4] Molar ratio calculated accounting for a P content in a phytate molecule of 28.18% and a molecular weight of 660, 65.4, 40.08 for phytate, Zn and Ca, respectively. (Ca x Phytate):Zn is expressed as g / kg DM.
[5] Including 20, 5 and 5 mg / kg diet added as sulphate for experiments 1, 2 and 4, respectively.

The experimental diets were obtained by adding zinc as sulphate and/or microbial phytase (Natuphos ®, BASF AG, Ludwigshafen, Germany) to the basal diet. In experiment 3, dietary copper supply also varied (Table 2). In each experiment, crossbred (Piétrain, Large White x Landrace) piglets, weaned at 28 d, were fed the basal diet without zinc nor microbial phytase added for a 7-day period. For the subsequent 19- to 21-day (experiments 1, 2 and 4) or a 30-day (experiment 3) period, animals were housed individually in stainless steel and plastic pens and fed one of the experimental diets. Six piglets were used per treatment. At the end of each experiment, the zinc status of piglets was evaluated through plasma alkaline phosphatase activity (APA), plasma zinc concentration and bone zinc concentration. The experimental and analytical procedures were detailed by Revy et al. (2004).

Table 2 : Experimental treatments

Exp.	Supplement [1]									
1	Zn	0	20	0	20					
	Phytase	0	0	1200	1200					
2	Zn	10	25	40	60	80	0	10	25	40
	Phytase	0	0	0	0	0	700	700	700	700
3	Cu	20	0	0	0					
	Zn	100	50	100	50					
	Phytase	0	0	0	850					
4	Zn	10	25	40	100	0	0	0	0	
	Phytase	0	0	0	0	150	250	500	850	

[1] Cu, mg / kg diet as $CuSO_4$; Zn, mg / kg diet as $ZnSO_4$; Microbial phytase, U / kg diet, as Natuphos ®

Statistical analysis of data was performed by means of the NLIN procedure of the SAS software (SAS Institute, Cary, NC, USA), using treatment means. The models included the experiment effect.

In accordance with the response of phosphorus availability to phytase supplementation (Kornegay, 2001), the equivalency equation of zinc added as sulphate for microbial phytase was supposed be of the following form: $a\,(1 - e^{-k\,Phyt})$, with Phyt = microbial phytase added (U / kg diet).

For plasma APA and zinc concentration the model was a linear plateau model of the following form: If $Zn + a\,(1 - e^{-k\,Phyt}) < Opt$, $Y = Max + b\,[Zn + a\,(1 - e^{-k\,Phyt}) - Opt]$; If $Zn + a\,(1 - e^{-k\,Phyt})$ ÓOpt, $Y = Max$.

For bone zinc concentration the model, which involved two linear splines with no plateau (Wedekind et al., 1994), was as follows: If $Zn + a\,(1 - e^{-k\,Phyt}) < Opt$, $Y = Max + b\,[Zn + a\,(1 - e^{-k\,Phyt}) - Opt]$; If $Zn + a\,(1 - e^{-k\,Phyt})$ ÓOpt, $Y = Max + c\,[Zn + a\,(1 - e^{-k\,Phyt}) - Opt]$, with Zn = dietary zinc (mg / kg diet), Phyt = microbial phytase added (U / kg diet) and Y = response criteria.

Results

The parameters of the models are presented in Table 3 and the response of plasma zinc to dietary zinc at different levels of phytase is presented in Figure 1.

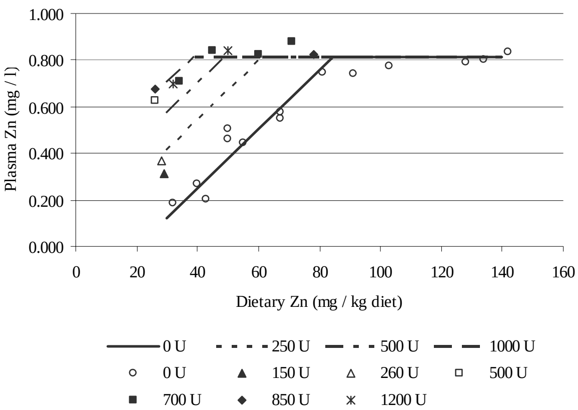
Without phytase added, the requirements were fulfilled when the supply of total zinc was 84, 75 and 87 mg / kg diet, accounting for plasma zinc, plasma APA and bone zinc as indicator of zinc status, respectively. All indicators taken into account, the supply of zinc needed to meet the requirements was reduced down to 61, 49 and 42 mg / kg diet when the diets were supplemented with 250, 500 and 750 U of phytase, respectively. Two-hundred and fifty, 500 and 750 U of phytase were thus equivalent to 21, 33 and 40 mg of zinc as sulphate, respectively.

Table 3 : Prediction of indicators of zinc status according to dietary zinc (mg / kg diet) for different amounts of phytase added (U / kg diet) [1]

Phytase added	Breakpoint [2]	b	c	Max
		Plasma zinc (mg / l)		
0	84	0.0127		0.815
250	62	0.0127		0.815
500	49	0.0127		0.815
750	43	0.0127		0.815
		Plasma APA (U / l)		
0	75	4.52		237
250	58	4.52		237
500	47	4.52		237
750	41	4.52		237
		Bone zinc (mg / kg ash)		
0	87	2.57	0.635	226
250	65	2.57	0.635	226
500	51	2.57	0.635	226
750	44	2.57	0.635	226

[1] For plasma zinc and alkaline phosphatase activity (APA) calculated as follows: If Zn < breakpoint, Y = Max + b * (Zn - breakpoint), if Zn Ó breakpoint, Y = Max;
for bone zinc, calculated as follows: If Zn < breakpoint, Y = Max + b * (Zn - breakpoint), if Zn Óbreakpoint, Y = Max + c * (Zn - breakpoint).
[2] Breakpoint = Opt - a $(1 - e^{-k\ Phyt})$, with Opt = 84, 75 and 87; a = 49.8, 44.6 and 54.5 and k = 0.00247, 0.00191 and 0.00215 for plasma zinc, plasma APA and bone zinc, respectively.
Zn = dietary zinc (mg / kg diet) and Phyt = microbial phytase added (U / kg diet)

Figure 1 : Prediction of plasma zinc according to dietary zinc (mg / kg diet) for different amounts of phytase added (U / kg diet) [1]



[1] Parameters of the equations are presented in Table 3.

Discussion

The zinc requirements estimated from plasma and bone zinc are slightly higher than the 80 mg of zinc / kg diet recommended by the NRC (1998) for piglets between 10 and 20 kg. However, in accordance with the current results, Höhler and Pallauf (1994) also reported that a corn-soybean meal diet supplemented with zinc as sulphate to contain 80 mg of zinc / kg did not maximise plasma zinc concentration in weaned piglets.

The current zinc equivalencies for phytase are consistent with the 30 mg of zinc as sulphate for 1350 U of microbial phytase that can be derived from the plasma zinc data published by Lei et al. (1993). The equivalency values for the highest amounts of phytase added exceed the total zinc contained in the basal diet. This suggests that dietary zinc released by phytase is better absorbed than zinc added as sulphate in the basal diet and/or that microbial phytase prevents endogenous zinc to be complexed by phytates (Oberleas and Harland, 1996).

The body zinc retention by pigs being very low, zinc ingested is almost totally excreted (Jondreville et al., 2003). Thus, zinc excreted may be reduced by almost 30% by replacing 30 mg of zinc as sulphate by 500 U of phytase in a piglet diet formulated to contain 100 mg of zinc / kg.

Conclusion

From a practical point of view, the current results allow to update the requirements of zinc by weaned piglets. In addition, they indicate that microbial phytase provides an important means to reduce not only phosphorus but also zinc excretion by pigs.

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