Dietary Phytate and Zinc Bioavailability in Monogastrics

Source: Patrick Schlegel - Agroscope Liebefeld-Posieux ALP, Posieux, Switzerland; Catherine Jondreville - INRA, Nancy Université, Vandoeuvre-les-Nancy, France

(dated 08/09/2010)

Introduction

The future animal production should aim for a sustainable intensification and for further improvements in the efficient use of limiting resources. An efficient use of zinc (Zn) in animal nutrition is encouraged in this respect, as it is one of the few heavy metals, which is simultaneously an essential trace mineral for living animals. As a transition metal, Zn presents a high affinity for complexing with ligands, such as proteins which involve this element to numerous structural and physiological functions in the metabolism. Zinc contents of feed components and their bioavailability are susceptible to vary greatly. This leads to the application of comfortable safety margins, when compared to recommended dietary Zn levels in poultry and pigs. A better understanding of Zn bioavailability will allow the feed industry to fine tune Zn supplementation levels.

Phytate – Zn antagonism

Zinc bioavailability can be defined as the maximal degree of ingested Zn, utilized for the biological, physiological and storage functions by a healthy animal. As the metabolic use of Zn is relatively high, Zn bioavailability is mainly limited by its absorption. When Zn as sulfate is supplemented below Zn requirement of rats into a purified Zn diet, its true absorption reaches levels close to 100%. Such a diet does not contain any complexing agent known to interact with Zn, suggesting that the supplemented Zn is completely soluble at absorption sites. When sodium-phytate is gradually supplemented, true Zn absorbability in adult rats is progressively reduced. This molecule contains sodium (Na) bonds which are easily dissociated in aqueous solutions. Stronger cations, such as Zn replace Na to form insoluble phytate – Zn complexes. In poultry and swine nutrition, it is difficult to avoid the presence of phytates as they are the main storage forms of P in seeds. Diets based on corn and soybean meal generally contain between 2,0 and 2,5 g phytic P / kg. Zinc content in feed components from plant origin is positively correlated to the phytic P content, with ~10 mg of Zn to 1 g phytic P. Recently, it was also found that two out of the three identified phytate molecules from wheat grains contain Zn.

Ways to improve zinc bioavailability

In order to avoid Zn-phytate antagonism, we may either “destroy” the antagonist or “avoid” any reaction between dietary Zn and the antagonism. Thus, phytase, low phytate diets and the supplementation of organic Zn sources can be considered as candidates to improve dietary Zn bioavailability.

The use of phytase

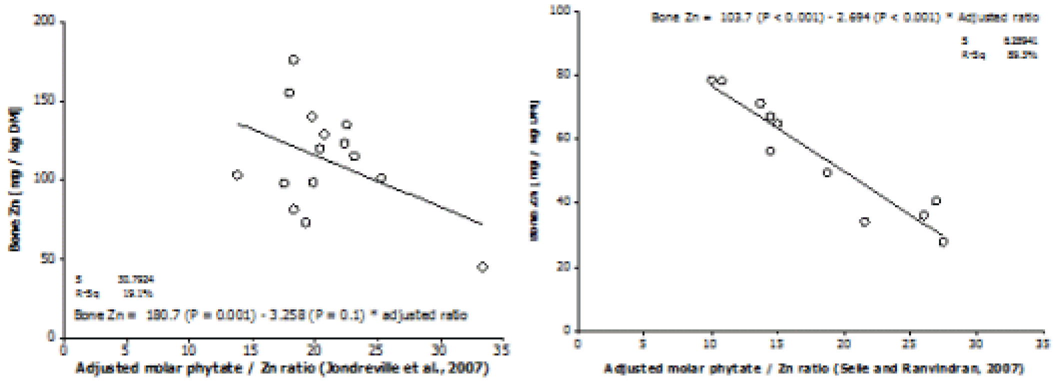
Microbial phytase hydrolyzes up to respectively 35 and 50% of the dietary phytates in poultry and pigs (Selle and Ravindran, 2007). Through this hydrolysis Zn is liberated from phytate. Jondreville et al. (2005; 2007) have estimated that 500 FTU from microbial phytase added into corn soybean meal diets permits to replace an equivalent amount of respectively 32 and 5 mg Zn / kg from $ZnSO_4$ in pigs and in broilers. Recently, it was also found that the addition of microbial phytase (500 FTU) increases Zn solubility in the piglet stomach, but not significantly in the broiler gizzard (Schlegel et al., 2010).

The use of feed components low in phytate contents

Data from our latest experiment (Schlegel et al., 2010) show that soluble Zn contents in the stomach were equal between piglets fed a diet low in phytate and in native Zn (1,3 g phytic P / kg diet; 25 mg Zn / kg diet) and a corn soybean meal diet rich in phytate and native Zn (2,3 g phytic P / kg diet; 38 mg / kg diet). Pigs fed the low phytate diet (also lower in Zn) had higher bone Zn contents (+ 44%) than pigs fed the phytate rich diet.

To review the antagonism of phytate on native Zn availability we used the molar phytate / Zn ratio adjusted with the potential of phytase to hydrolyze phytate (Selle and Ravindran, 2007) or liberate Zn (Jondreville et al., 2007). This was done using data from INRA experiments within the linear response of bone Zn. Figure 1 shows bone Zn contents from broiler and weaned piglet experiments dependent from the most suitable corrected phytate / native Zn molar ratio. The strong correlation between the adjusted phytate antagonism and bone Zn in piglets indicates, that native dietary Zn bioavailability is highly dependent from dietary phytate remaining in the diet following or not an eventual addition of microbial phytase. In broilers however, native Zn is not affected by the remaining dietary phytate.

Figure 1 Response of bone Zn content on the dietary adjusted molar phytate / Zn ratio in broilers (left) and piglets (right) fed cereal based diets unsupplemented with Zn.



The supplementation of highly bioavailable zinc sources

Organic Zn sources are generally considered as more bioavailable than inorganic sources, such as oxides or sulfates. It is suggested that Zn from organic sources is protected by the ligand from reacting with feed antagonists, such as phytate to form insoluble complexes. Zinc from organic sources is absorbed by the intestinal cells as an ion, or it is also suggested that Zn is absorbed intact thanks to a second absorption pathway related to the ligand.

When having again a look on rats fed purified Zn diet containing added Na-phytate, the supplementation of Zn glycinate numerically improved apparent and true Zn absorption (respectively +30% and +17%) and significantly improved Zn retention (+ 30%) when compared to supplemented ZnSO4 (Schlegel and Windisch, 2006). Expressed as percent of ingested Zn, all Zn fluxes, except urinary Zn, were significantly improved with rats fed Zn glycinate. This data suggests that the amino acid protects Zn, at least partially, from complexing with added Na-phytate in the digestive tract. However, When the same Zn sources (ZnSO4 and Zn glycinate) are supplemented into three corn soybean meal basal diets varying in their native Zn (25, 38 and 38 mg / kg), phytic P (1,3, 2,3 and 2,3 g / kg) and phytase activity (27, 201 and 688 FTU / kg), the Zn status (plasma Zn and bone Zn) from broilers and piglets is improved, but irrespective of Zn source nor basal diet. There was no interaction between basal diet and supplemented Zn suggesting that there is no antagonistic effect from plant phytate on supplemented Zn in either specie. The relative bioavailability of organic Zn sources was recently assessed in broilers and weaned piglets using a meta-analysis technique. No significant difference between organic and inorganic sources was calculated within the dietary Zn range presenting a dose-response (Table 1).

All this data suggests that the potential of organic Zn sources compared to inorganic Zn sources cannot be expressed in broiler and piglet diets, because there is no antagonism between supplemented Zn and dietary plant phytates.

Table 1 Relative bioavailability of organic Zn sources in broilers and weaned piglets.

Parameter	Broiler		Piglet	
	RBV [1]	P-value [2]	RBV [1]	P-value [2]
Plasma Zn	93	> 0.05	85	> 0.05
Plasma AP activity	-	-	98	> 0.05
Liver Zn	-	-	97	> 0.05
Bone Zn	113	> 0.05	100	> 0.05
Absorbed Zn	-	-	117	> 0.05

[1] RBV: Relative bioavailability. Relative difference of response slope between organic and inorganic source.
[2] Difference of the linear effects between inorganic and organic Zn sources.

Differences between broilers and piglets

Zn absorbability is dependent from pH conditions in the digestive tract. Based on our combined broiler and piglet experiment (Schlegel et al., 2010), Zn solubility (Znsol) is dependent from gizzard / stomach pH with following regression: Znsol [%] = 225.9 - 75.53 * pH + 6.571 * pH2; R2 = 0.62 ; P < 0.001 ; n = 81). Zn solubility was not dependent from intestinal pH. Bone Zn was dependent from Znsol in gizzard / stomach: Bone Zn [mg / kg DM] = - 12.60 + 9.199 * Znsol - 0.1027 * Znsol2; R2 = 0.67; P < 0.001 ; n = 81). We can expect that Zn-phytates complexes dissociate as soon as pH is decreased down to 4. Thus the low pH in gizzard (~3,5) allows zinc-phytates complex to dissociate, even in the absence of phytase, whereas, in piglet's stomach, where the pH is higher (~4,5), phytates must be hydrolyzed by phytase before Zn can be released. This phenomenon would explain why microbial phytase (500 FTU / kg diet) is eight times less efficient in improving Zn bioavailability in broilers compared to piglets. This phenomenon would result in a physiologically higher Zn bioavailability in chickens than in piglets, explaining the lower dietary Zn requirements of chickens than piglets. In the end, the potential to improve native Zn bioavailability in pigs is large, whereas in poultry, it is rather limited.

Conclusions

Ways to improve dietary Zn bioavailability in broilers are lower than in piglets, as the birds are able, at least partially, to separate Zn from phytates in the gizzard. In piglets, reduced dietary phytate or the addition of microbial phytase are highly efficient to improve Zn bioavailability. As plant phytates are bound with strong cations such as native Zn or Mn, data suggest that the bioavailability of supplemented Zn is not negatively affected by plant phytate. A soluble Zn source, such as ZnSO4 is therefore highly bioavailable in broilers and piglets.

All literature sources are available on request to the author.

For further information on this research, feel free to contact:

Patrick Schlegel, Ph.D.
Agroscope Liebefeld-Posieux Research Station (ALP)
Tioleyre 4
P.O. Box 64
1725 Posieux
Switzerland
Tel: +41 (0)26 407 72 75
Fax: +41 (0)26 407 73 00
E-mail: **patrick.schlegel@alp.admin.ch**