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Bioavailability of zinc sources in piglets and broilers: a meta-analysis

Schlegel P., Sauvant D. and Jondreville C.

EAAP, Heraklion, Session 11, 23.08.2010

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Introduction

ZINC (Zn)

- **Heavy metal**, polluant toxic for plants and microorganisms
- **Non renewable ressource**
- **Essential nutrient in pigs and poultry**

  Zn requirement is usually not met without dietary Zn supplementation

For an efficient and sustainable use of Zn in monogastric nutrition, two main strategies are recommended:

- **Dietary Zn « safety margins »** ↘
- **Dietary Zn bioavailability** ↗

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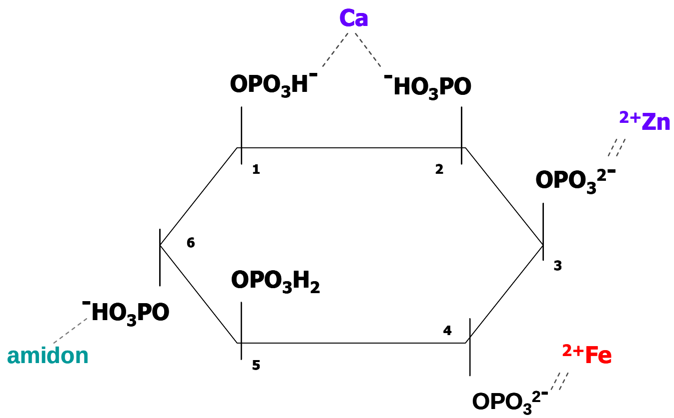
Introduction

Dietary Zn bioavailability ↗

Major limiting dietary factor: Zn antagonism from phytate

⇒ Reduce plant phytate content.

⇒ Supplement Zn supposed not to interact with phytate (organic Zn sources).



Hypothesis: Organic Zn sources are more bioavailable than inorganic Zn sources.

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Material and method

Two databases (broiler, weaned piglets):

Criteria for the choice of experiments:

o Minimum one treatment with an inorganic and one with an organic Zn source

Criteria for the choice of experimental treatment:

o Microbial phytase: 0 FTU/kg (piglets); < 500 FTU/kg (broiler)

o No other experimental factor than trace elements (amino acids, org. acids, …)

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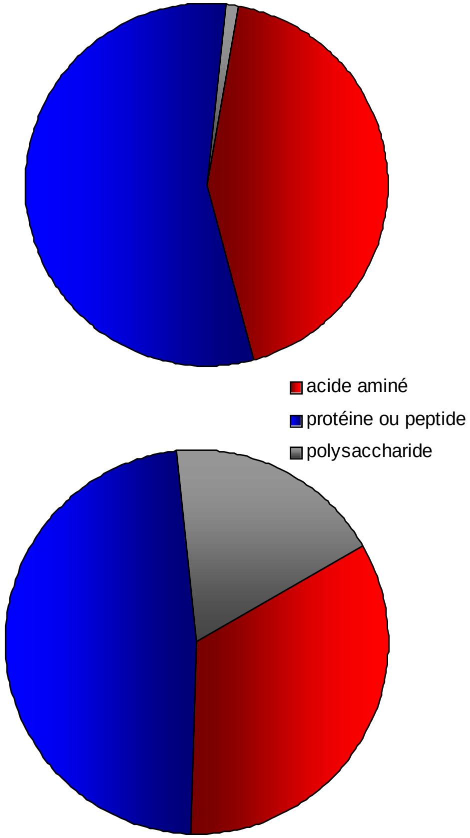
Material and method

Two databases (broiler, weaned piglets):

Organic Zn sources:



Broilers: 28 experiments, 175 treatments

Diets: synthetic, cereal-soybean meal, corn-soybean meal based

Dietary Zn content: 1 – 867 mg/kg

Inorganic Zn: oxide (8), sulfate (55), acetate (3), nitrate (1)

Piglets: 34 experiments, 159 treatments

Diets: cereal-soybean meal, corn-soybean meal based

Dietary Zn content: 17 – 3195 mg/kg

Inorganic Zn: oxide, sulfate

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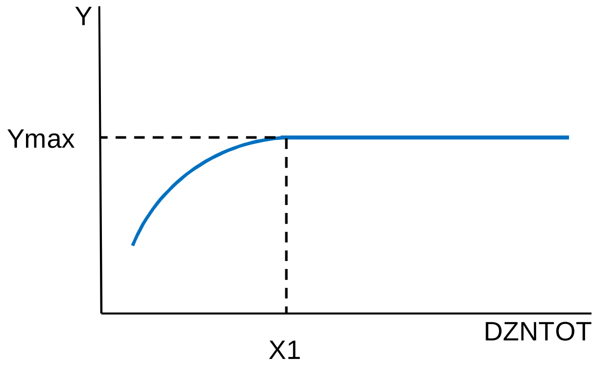
Material and method: phase 1

Dose-response effect of dietary Zn

Zn bioavailability is measured within the dose-response effect of a dependent variable.

=> Determination of X1 is necessary



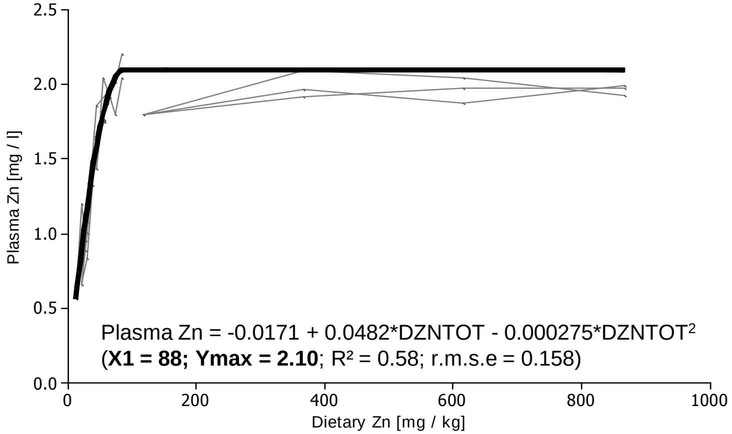
Mathematical model: Non linear model (curvilinear-plateau)

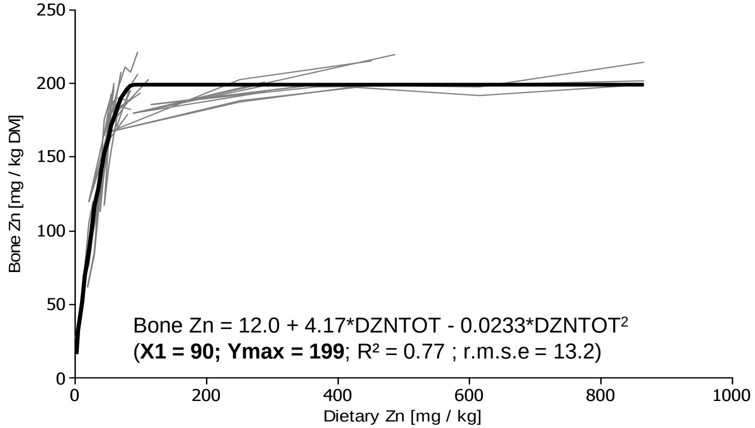
If $DZNTOT_{wx} \leq X1$, $Y_{wx} = Ymax_{w} * (a + b*DZNTOT_{wx} + c*DZNTOT_{wx}^{2}) + \varepsilon_{wx}$
If $DZNTOT_{wx} > X1$, $Y_{wx} = Ymax_{w}$

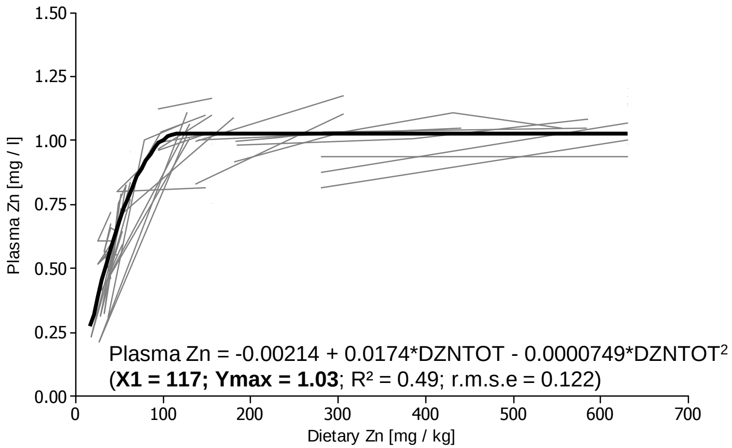
DZNTOT: Dietary Zn content
Y_{wx}: Result from a dependent variable Y observed in experiment $_{w}$ with DZNTOT $_{x}$
X1: DZNTOT value from when Y is maximized (Ymax)
b: slope
a: $1 + 4*c*b^{2}$
c: -b / 2*X1
ε: residual error

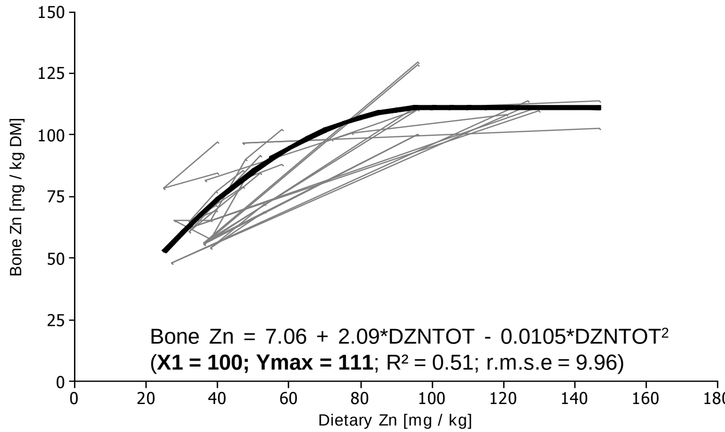
Results: phase 1

Dose-response effect of dietary Zn (example for plasma Zn and bone Zn)









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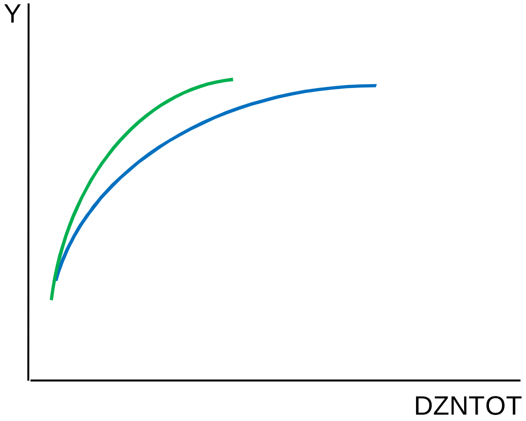
Material and method: phase 2

Bioavailability of Zn sources within dose-response effect

Mathematical model: General linear model

$$
\begin{aligned}
Y_{wxyz} = {} & a + a_w \\
& + b*DZNN_{wx} + c*DZNI_{wy} + d*DZNO_{wz} \\
& + f*DZNN^2_{wx} + g*DZNI^2_{wy} + h*DZNO^2_{wz} \\
& + i*DZNN_{wx}*DZNI_{wy} + j*DZNN_{wx}*DZNO_{wz} + \varepsilon_{wxyz}
\end{aligned}
$$

DZNN: native Zn source
DZNI: supplemented inorganic Zn
DZNO: supplemented organic Zn
x, y, z : concentration de DZNN, DZNI, DZNO
Y_{wxyz}: Result from a dependent variable Y observed in experiment $_w$, with Zn level $_{x, y \text{ or } z}$
a: intercept
a_w: Experiment effect
b, c, d: linear coefficients
f, g, h: quadratic coefficients
i, j: coefficients for interactions
ε: residual error



Removal of experimental treatments for phase 2:

- o When DZNTOT > X1 (Phase 1)
- o When combined supplementation of DZNI and DZNO
- o When DZNO and DZNI were not iso-dosed

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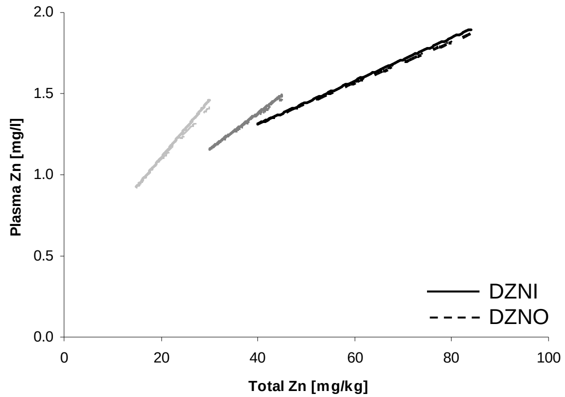
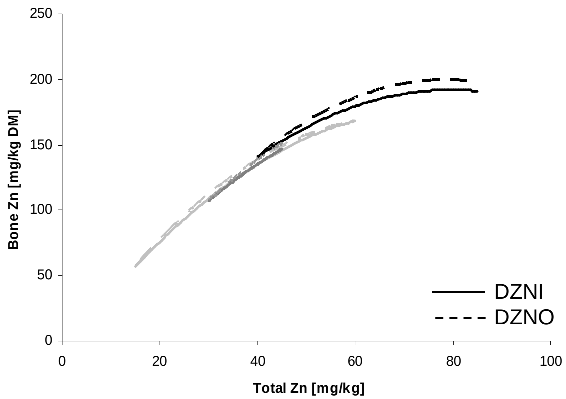
Results: phase 2

Bioavailability of Zn sources within dose-response effect

Model	Plasma Zn [mg/l] *Coefficient*	Plasma Zn [mg/l] *P-value*	Bone Zn [mg/kg DM] *Coefficient*	Bone Zn [mg/kg DM] *P-value*
Intercept	0.692	***	6.44	n.s.
DZNN	0.0155	**	3.35	***
DZNI	0.0493	***	4.78	***
DZNO	0.0446	***	5.00	***
$DZNI^2$			-0.0333	***
$DZNO^2$			-0.0401	***
DZNN x DZNI	-0.000945	***	-0.0544	***
DZNN x DZNO	-0.000773	**	-0.0481	***
N° data	36		66	
R^2	0.91		0.91	
r.m.s.e.	0.161		12.3	
DZNI vs DZNO	n.s.		n.s.	
$DZNI^2$ vs $DZNO^2$	-		n.s.	
DZNN x DZNI vs DZNN x DZNO	n.s.		n.s.	
RBV average	93		113	

RBV: relative bioavailability of DZNO to DZNI





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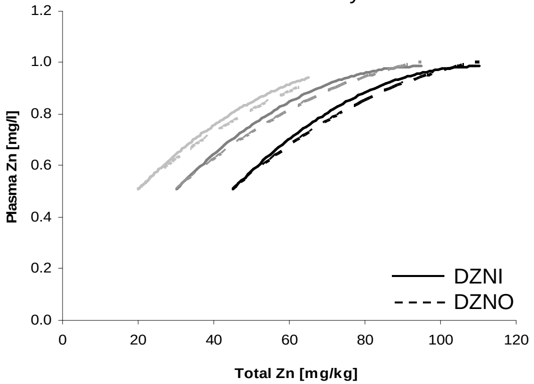
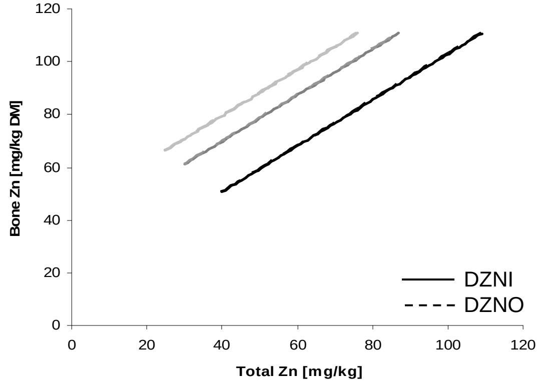
Results: phase 2

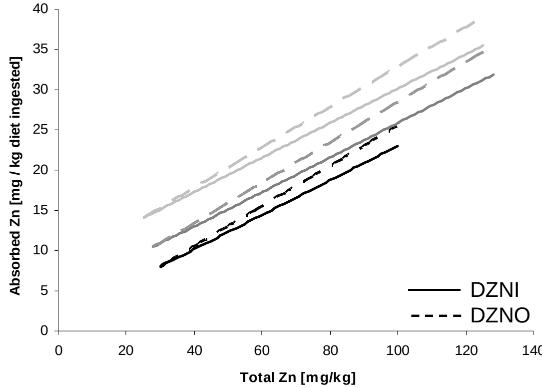
Bioavailability of Zn sources within dose-response effect

Model	Plasma Zn [mg/l] Coeff.	Plasma Zn P-value	ALP [U/l] Coeff.	ALP P-value	Liver Zn [mg/kg DM] Coeff.	Liver Zn P-value	Bone Zn [mg/kg DM] Coeff.	Bone Zn P-value	Absorbed Zn [mg] Coeff.	Absorbed Zn P-value
Intercept	0.508	***	61.3	***	251	***	92.7	***	44.4	*
DZNN					-4.757	***	-1.051	*	-1.211	+
DZNI	0.0147	***	4.751	***	0.757	***	0.871	***	0.214	***
DZNO	0.0125	***	6.601	***	0.736	**	0.874	***	0.250	***
$DZNI^2$	-0.000113	***	-0.0786	+						
$DZNO^2$	-0.000075	*	-0.0835	*						
N° data	46		23		23		28		28	
R^2	0.93		0.91		0.92		0.96		0.90	
r.m.s.e.	0.0943		20.98		23.833		7.42		2.982	
DZNI vs DZNO	n.s.		n.s.		n.s.		n.s.		n.s.	
$DZNI^2$ vs $DZNO^2$	+		n.s.		-		-		-	
RBV	85		98		97		100		117	

RBV: relative bioavailability of DZNO to DZNI







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Discussion / conclusions

Bioavailability of Zn sources in broilers and piglets

Bioavailability of native Zn (DZNN)
o In broilers: highly available ≈ supplemented Zn.
o In piglets: availability was reduced with increasing contents, most probably due to Zn antagonism from diet components such as phytate

Bioavailability of supplemented Zn sources (DZNI vs. DZNO)
o In broilers: similar bioavailability
o In piglets: similar bioavailability

Possible reason (could not be tested in the present dataset)

oDZNN from plant origin is at least partially bound to phytate *(ex. Rodrigues-Filho et al., 2005)*
oIncreased dietary plant phytate reduces DZNN bioavailability, especially in piglets *(ex. Linares et al., 2007; Schlegel et al., 2010)*

oPlant phytate does not interact with supplemental Zn *(ex. Schlegel et al., 2010)*
oA soluble Zn source, such as $ZnSO_4$ is therefore highly bioavailable in broilers and in piglets *(ex. Schlegel et al., 2010)*

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Thanks a lot for your attention

Schlegel P., Sauvant D. and Jondreville C.; patrick.schlegel@alp.admin.ch