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

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EAAP, Heraklion, Session 11, 23.08.2010



Introduction



ZINC (Zn)

- o **Heavy metal**, pollutant toxic for plants and microorganisms
- o **Non renewable resource**
- o **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:

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



Introduction

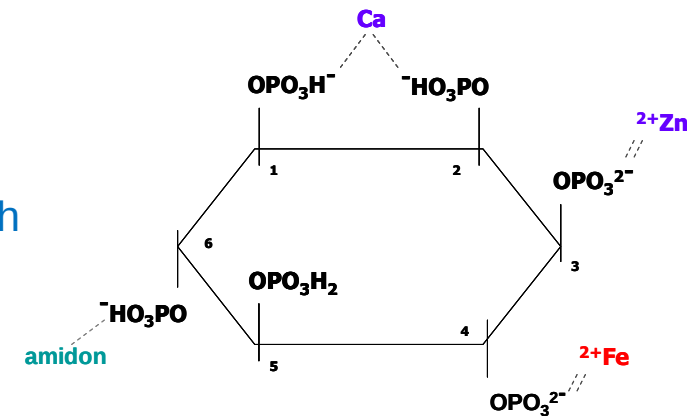


Dietary Zn bioavailability ↗

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.



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, ...)



Material and method

Two databases (broiler, weaned piglets):

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

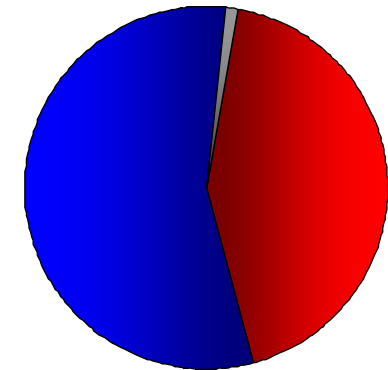


Diets: cereal-soybean meal, corn-soybean meal based

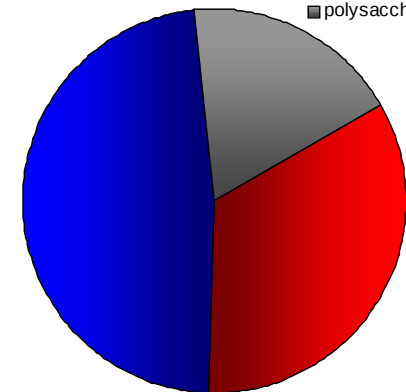
Dietary Zn content: 17 – 3195 mg/kg

Inorganic Zn: oxide, sulfate

Organic Zn sources:



■ acide aminé
■ protéine ou peptide
■ polysaccharide





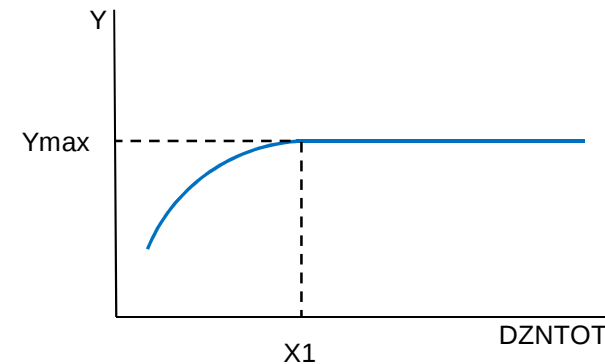
Material and method: phase 1



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 $DZNTOT_{wx} \leq X1$, $Y_{wx} = Ymax_w * (a + b * DZNTOT_{wx} + c * DZNTOT_{wx}^2) + \epsilon_{wx}$

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: $-b / 2 * X1$

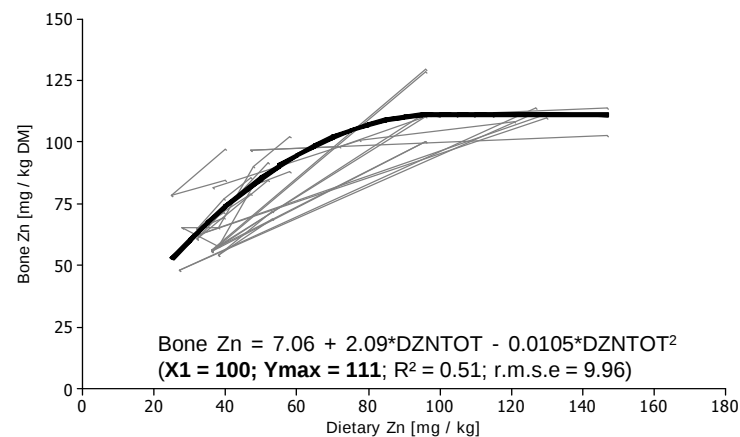
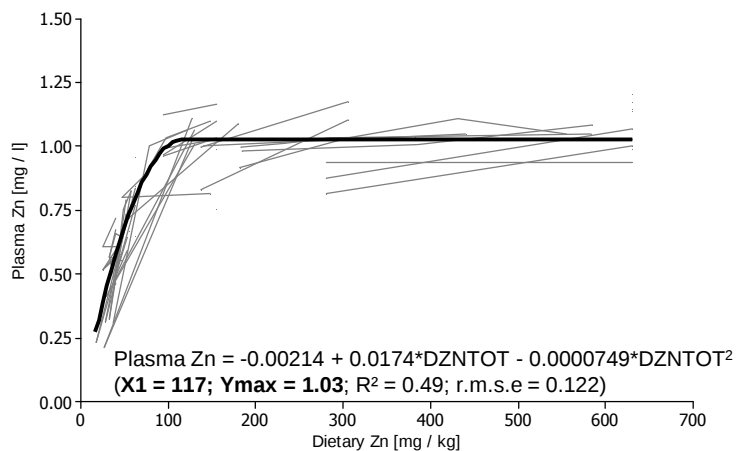
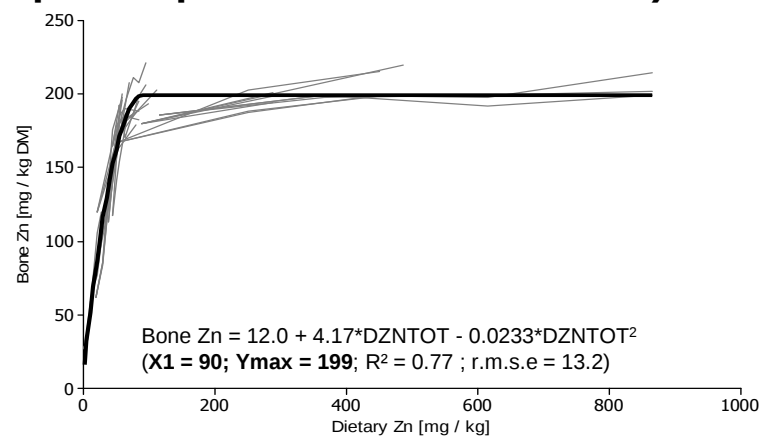
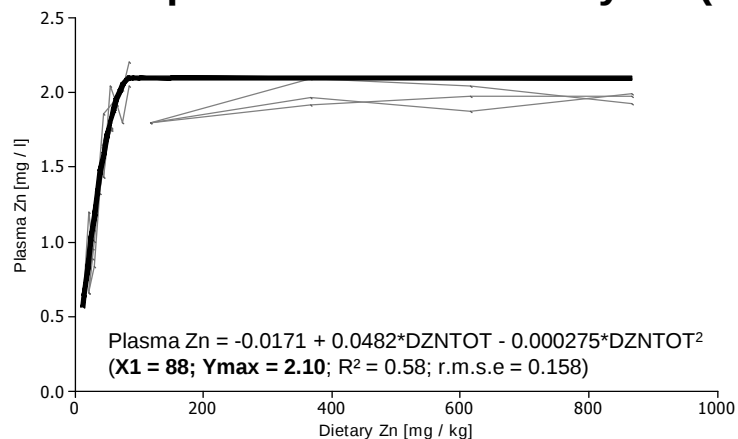
ϵ : residual error



Results: phase 1

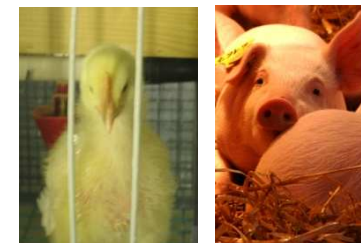


Dose-response effect of dietary Zn (example for plasma Zn and bone Zn)





Material and method: phase 2



Bioavailability of Zn sources within dose-response effect

Mathematical model: General linear model

$$Y_{wxyz} = a + a_w + b \cdot \text{DZNN}_{wx} + c \cdot \text{DZNI}_{wy} + d \cdot \text{DZNO}_{wz} + f \cdot \text{DZNN}_{wx}^2 + g \cdot \text{DZNI}_{wy}^2 + h \cdot \text{DZNO}_{wz}^2 + i \cdot \text{DZNN}_{wx} \cdot \text{DZNI}_{wy} + j \cdot \text{DZNN}_{wx} \cdot \text{DZNO}_{wz} + \epsilon_{wxyz}$$

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 or z

a: intercept

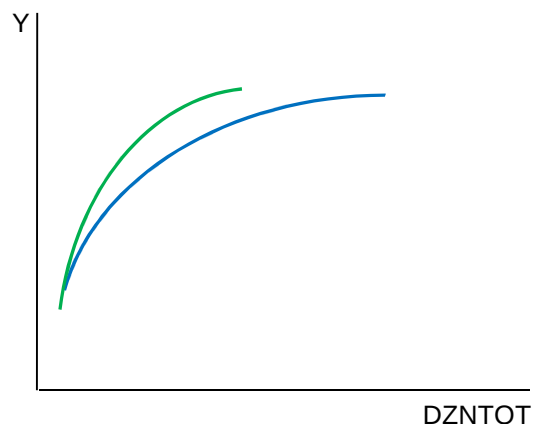
a_w : Experiment effect

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



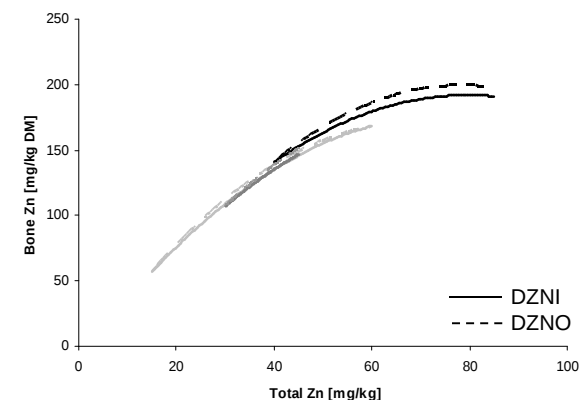
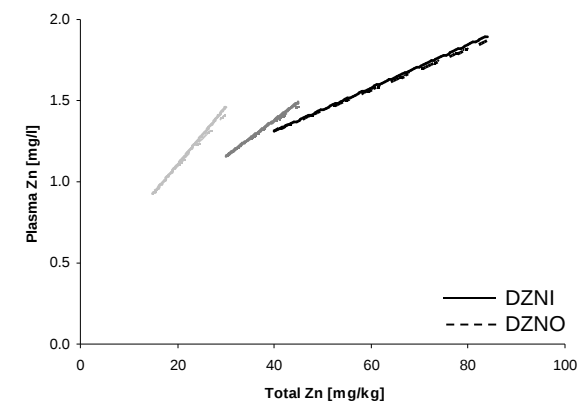
Results: phase 2



Bioavailability of Zn sources within dose-response effect

Model	Plasma Zn [mg/l]		Bone Zn [mg/kg DM]	
	Coefficient	P-value	Coefficient	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





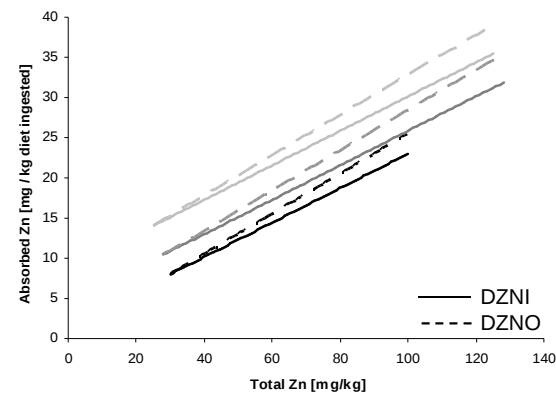
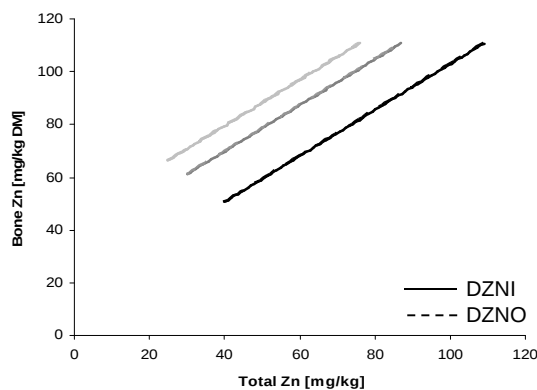
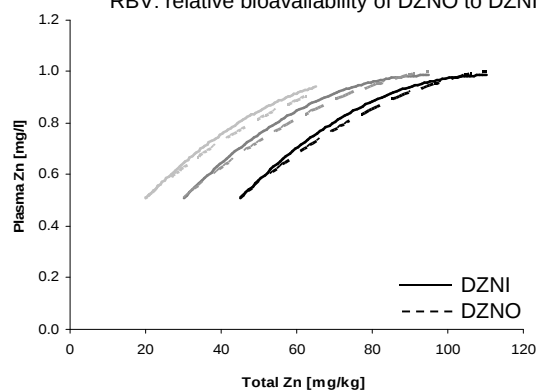
Results: phase 2



Bioavailability of Zn sources within dose-response effect

Model	Plasma Zn [mg/l]		ALP [U/l]		Liver Zn [mg/kg DM]		Bone Zn [mg/kg DM]		Absorbed Zn [mg]	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	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





Discussion / conclusions



Bioavailability of Zn sources in broilers and piglets

Bioavailability of native Zn (DZNN)

- o In broilers: highly available $\approx$ 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)

- o DZNN from plant origin is at least partially bound to phytate (*ex. Rodrigues-Filho et al., 2005*)
- o Increased dietary plant phytate reduces DZNN bioavailability, especially in piglets (*ex. Linares et al., 2007; Schlegel et al., 2010*)
- o Plant phytate does not interact with supplemental Zn (*ex. Schlegel et al., 2010*)
- o A soluble Zn source, such as ZnSO_4 is therefore highly bioavailable in broilers and in piglets (*ex. Schlegel et al., 2010*)



Thanks a lot for your attention