Definition from an animal nutrition point of view

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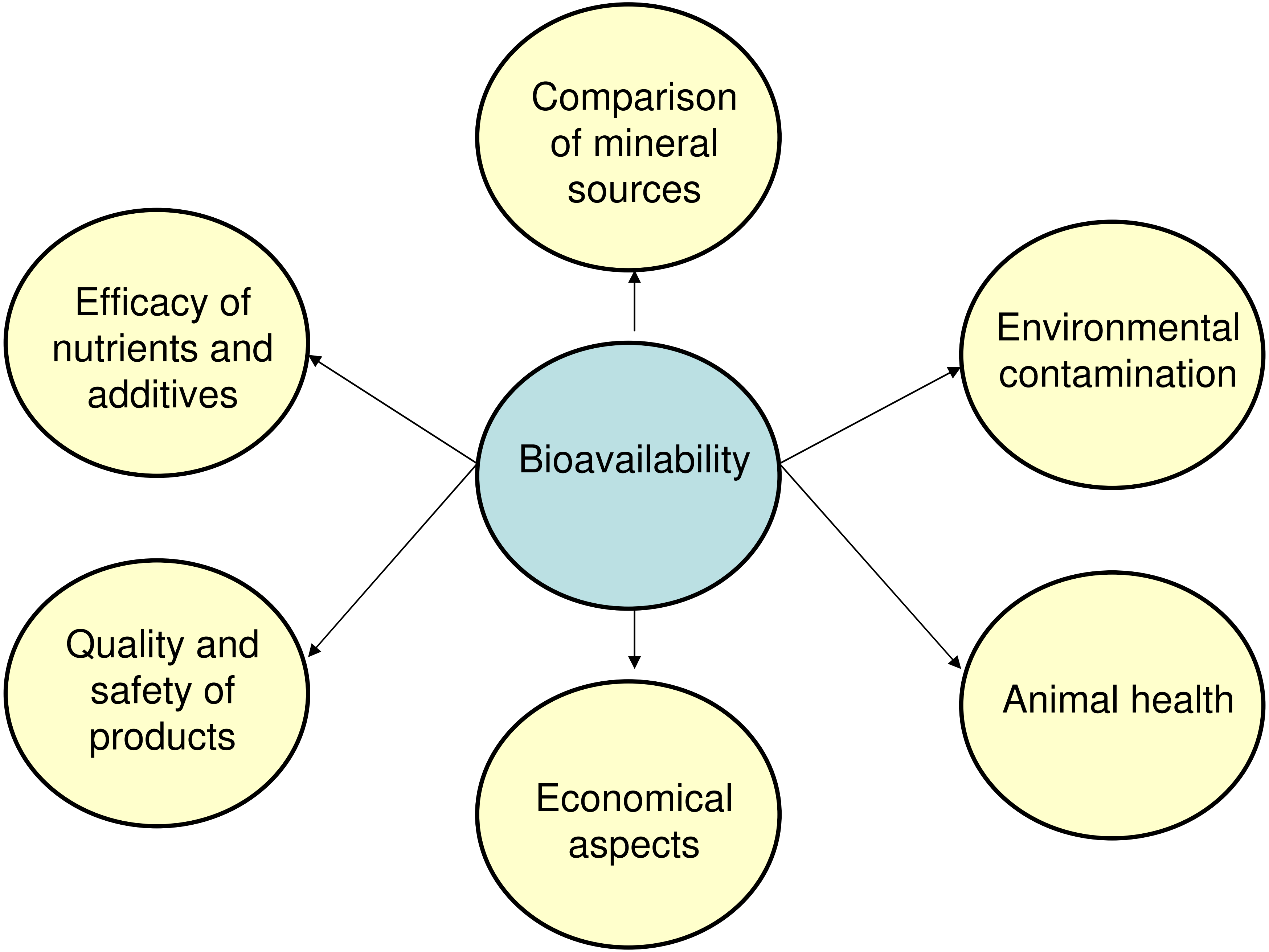
Agenda

- Potential prospects
- Definition
- Limitations
- Conclusions

Bioavailability in animal nutrition

- The term is generally used to describe properties of absorption and utilisation of nutrients including the optimal conversion from feed to performance, health and products
- The term can be also used (indirectly) for estimations of environmental contamination

Potential prospects of bioavailability in animal nutrition



Definition of bioavailability

O`Dell 1983:

“Bioavailibility in terms of minerals may be defined as the proportion of an ingested mineral that is absorbed, transported to its site of action, and converted to the physiological active species “

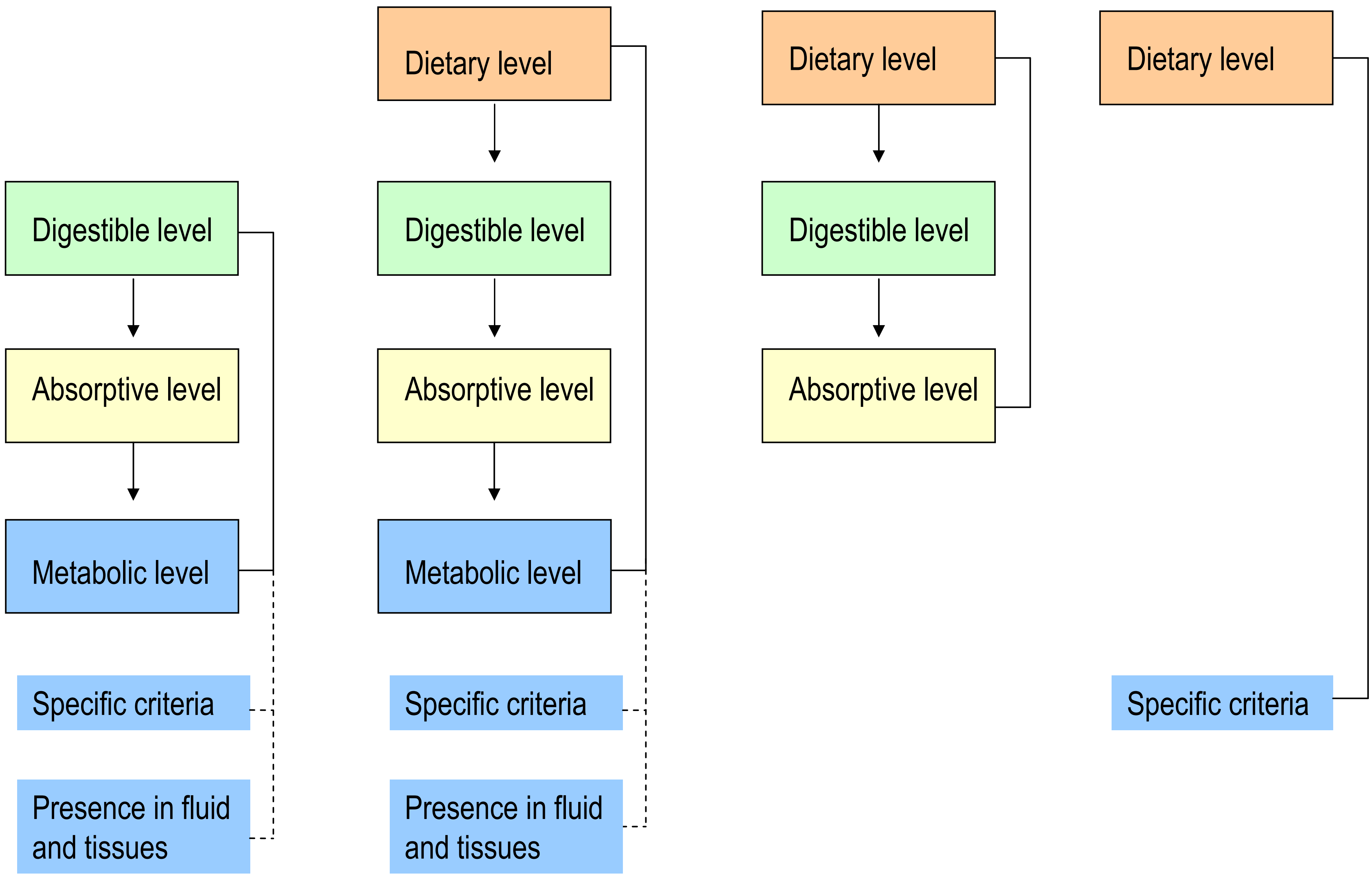
Ammermann et al. 1995:

“Degree to which an ingested mineral is absorbed in a form that can be utilized in metabolism by the normal animal“

Fuller 2004:

“Bioavailability is that proportion of a dietary nutrient that is absorbed and may then be utilized by an animal for physiological function(s) “

Evaluation of bioavailability in animal nutrition



Bioavailability in animal nutrition

- The term is generally used to describe properties of absorption and utilisation of nutrients including the optimal conversion from feed to performance, health and products
- The term is also used for estimations of environmental contamination and risk assessment
- Absorption and intermediary utilisation of minerals varies according to numerous factors

Specifics of bioavailability of trace minerals included in diets

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- Supply
  - Trace mineral contents in ingredients + mineral composition of premixes
  - But trace mineral contents in ingredients are estimated to be zero

➔ Supplementation of trace minerals by using premix meeting the overall requirement + safety levels

Year of research used in estimate of trace mineral requirements (NRC, 1994, GfE, 1999/poultry; 2006/pigs)

Source	Pigs	Broilers	Layers
Fe	1968, 1981, 1973	1961, 1968, 1982	1981,1979
Mn	1956, 1975, 1982	1967, 1971, 1986	1969, 1978, 1980
Zn	1955, 1962, 1992, 2003	1975, 1993	1958, 1968, 1990
Cu	1966,1978, 1979	1970,1991, 1993	1966, 1979, 1994
Se	1977, 2002, 2003	1984, 1986	1979
I	1973, 1977, 1980, 2001	1957, 1991	1961, 1970

Dearth of research in trace mineral nutrition over the last 20 to 30 years

NRC mineral levels for pigs and those recommended by industry

Source	NRC 1998 mg/kg (88% DM)	Commercial additions mg/kg (88% DM)
Fe	80	100 - 200
Mn	20	40 - 80
Zn	50	100 - 150
Cu	5	10 - 20
Se	0.15	0.2 - 0.5
I	0.14	0.15 - 0.50

NRC mineral levels for poultry and those recommended by industry

Source	NRC 1994 mg/kg (88% DM)	Commercial additions mg/kg (88% DM)
Fe	80	100 - 220
Mn	60	80 - 120
Zn	40	40- 150
Cu	8	10 - 20 (150)
Se	0.15	0.20 - 0.30
I	0.35	1 - 2

Ranges of trace mineral levels in typical diets for poultry meat production (mg/kg (88% DM)

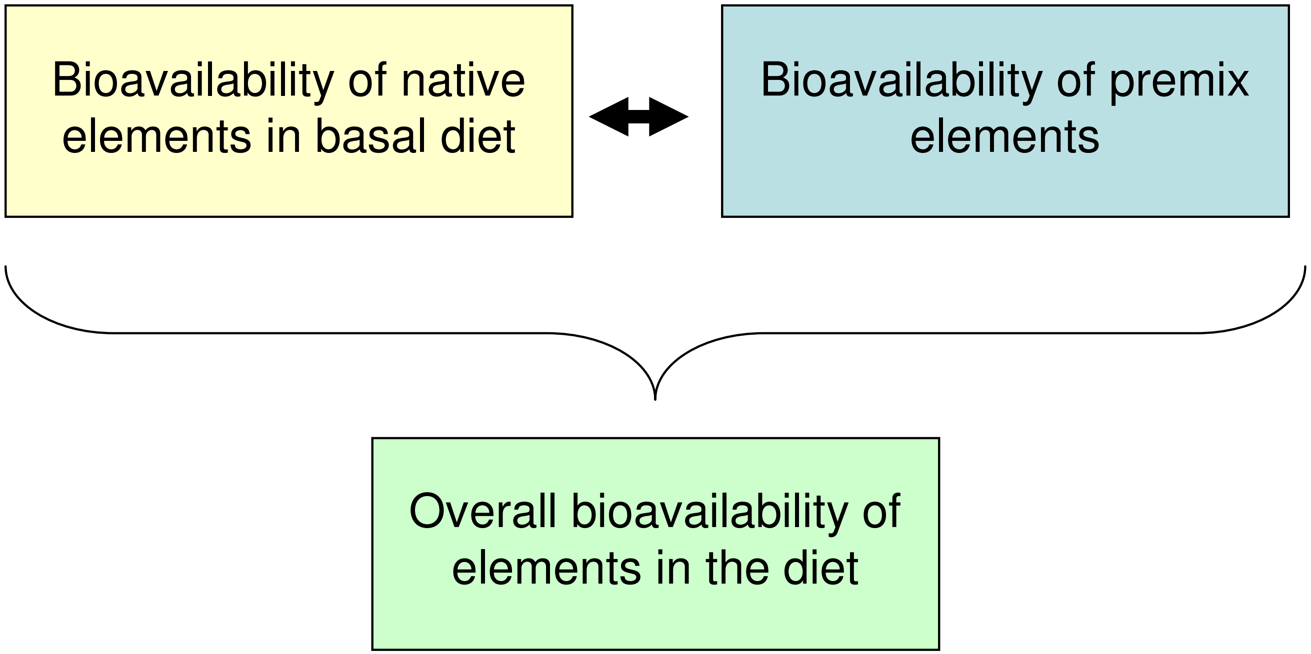
Fe	Mn	Zn	Cu	I
Contribution of native components				
45 - 180	10 - 30	18 - 30	6 - 15	0.06 - 0.5
Requirement (NRC 1994)				
80	60	40	8	0.35
Commercial additions				
20 - 120	80 - 120	40 - 150	10 - 20 (150)	1 - 2

Specifics of bioavailability of trace minerals included in diets

- Supply
  - Trace mineral contents in ingredients + mineral composition of premixes
  - But trace mineral contents in ingredients are estimated to be zero

➔ Supplementation of trace minerals using premix meeting the overall requirement + safety levels

- Consequences for characterising bioavailibility of minerals in diets



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Influencing factors of bioavailability in animal nutrition with regard to trace minerals

Dietary level → Digestive level → Absorptive level → Metabolic level

Dietary level

- Ingredients
- Feed additives
- Amount of mineral supply
- Physical properties
  - Particle size
  - condtioning processes
- Antinutritional factors
- Feeding technique
- Hygienic quality
- Amount of feed intake

Digestive level

- Maturation gastrointestinal functions
  - enzyme activity
- Solubility of the sources
- Microbiota
- Redox potential
- Health digestive disorders or disturbancy

Absorptive level

- Electronic configuration
- Chelating capacity
- Interaction among minerals and nutrients
- Homeostasis
- Cellular transport

Metabolic level

- Animal species
- Physiological state
- Previous nutrition
- Health status
- Oxidative stress
- Health status
- Response criteria
- Homeostasis

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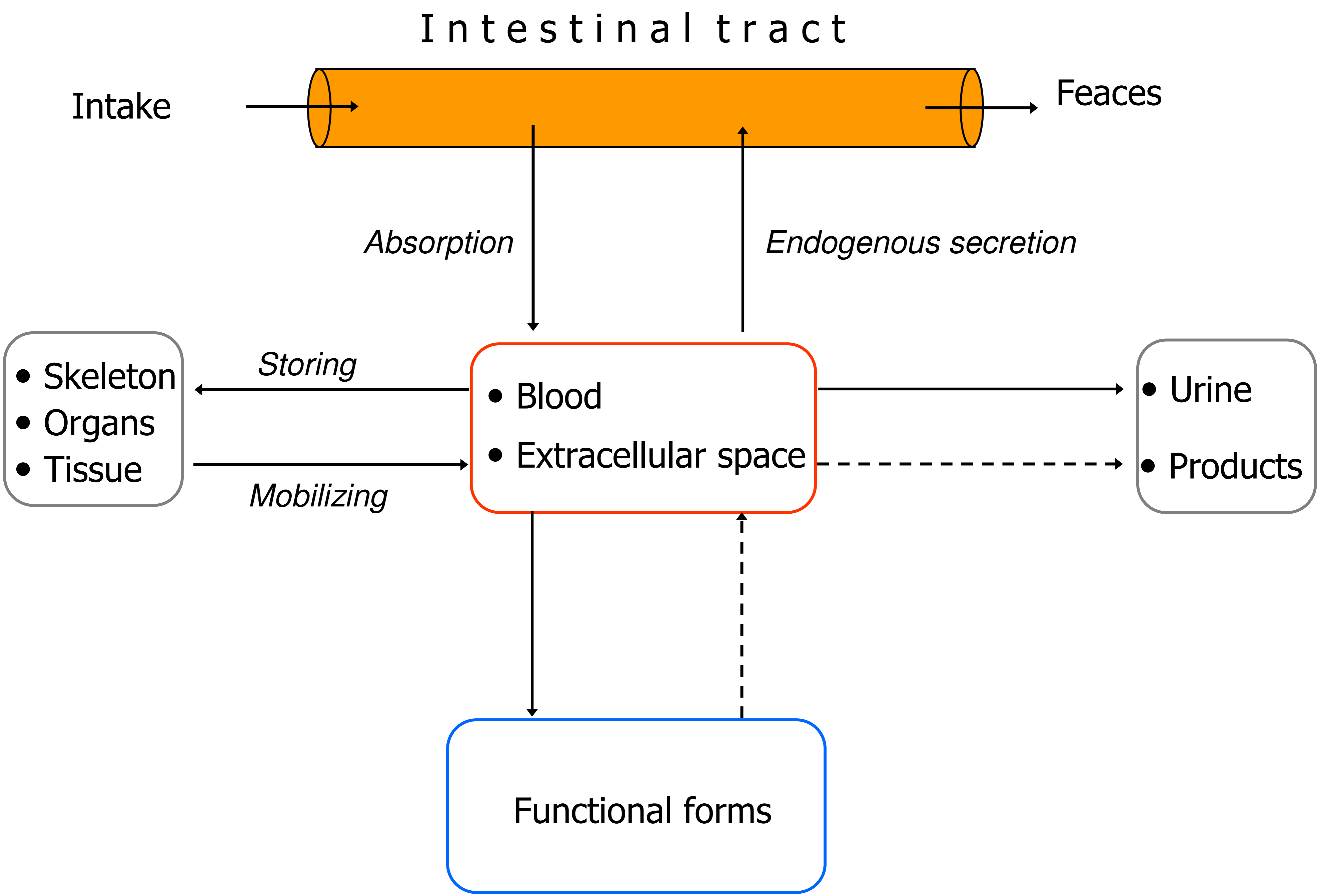
Homeostasis

Target: Maintaning cellular concentration gradients and substrate fluxes for achiving a physiological steady state

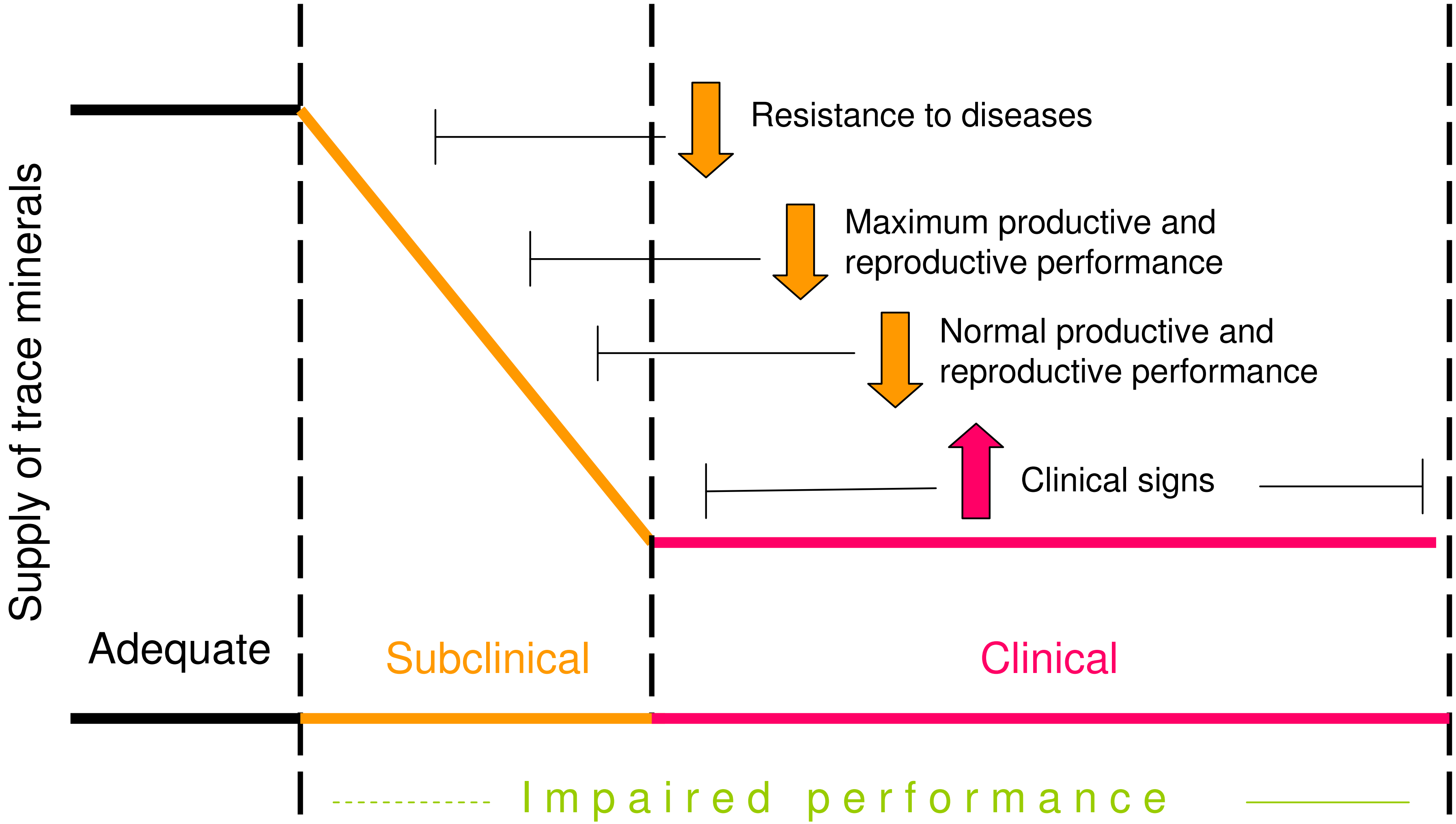
Instruments for homeostasis of trace elements



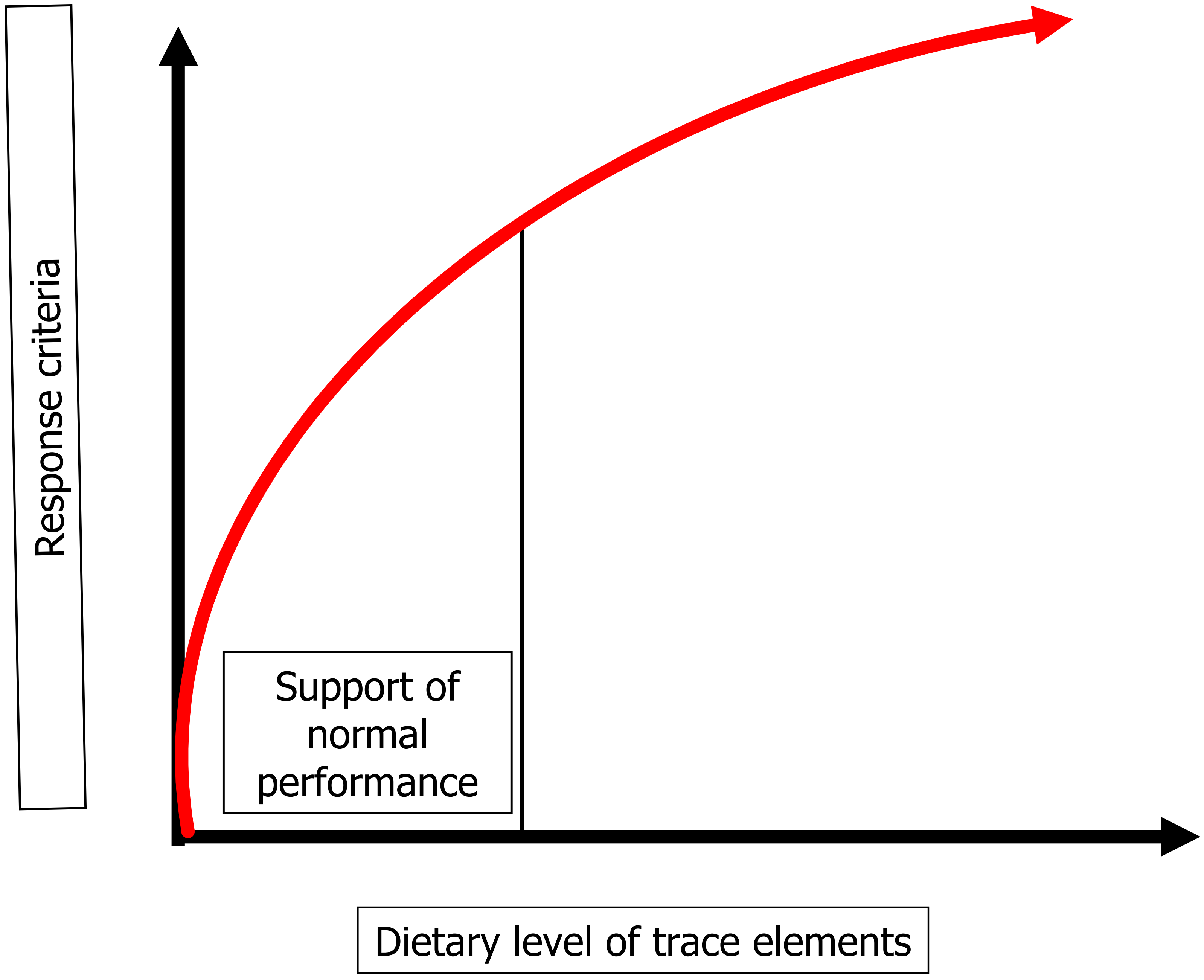
Measurement of bioavailability

- Traditionally
  - Typical or purified or semi-purified diets at deficiency levels of the tested mineral
  - Addition of the mineral source at graded levels
  - Measuring of response criteria

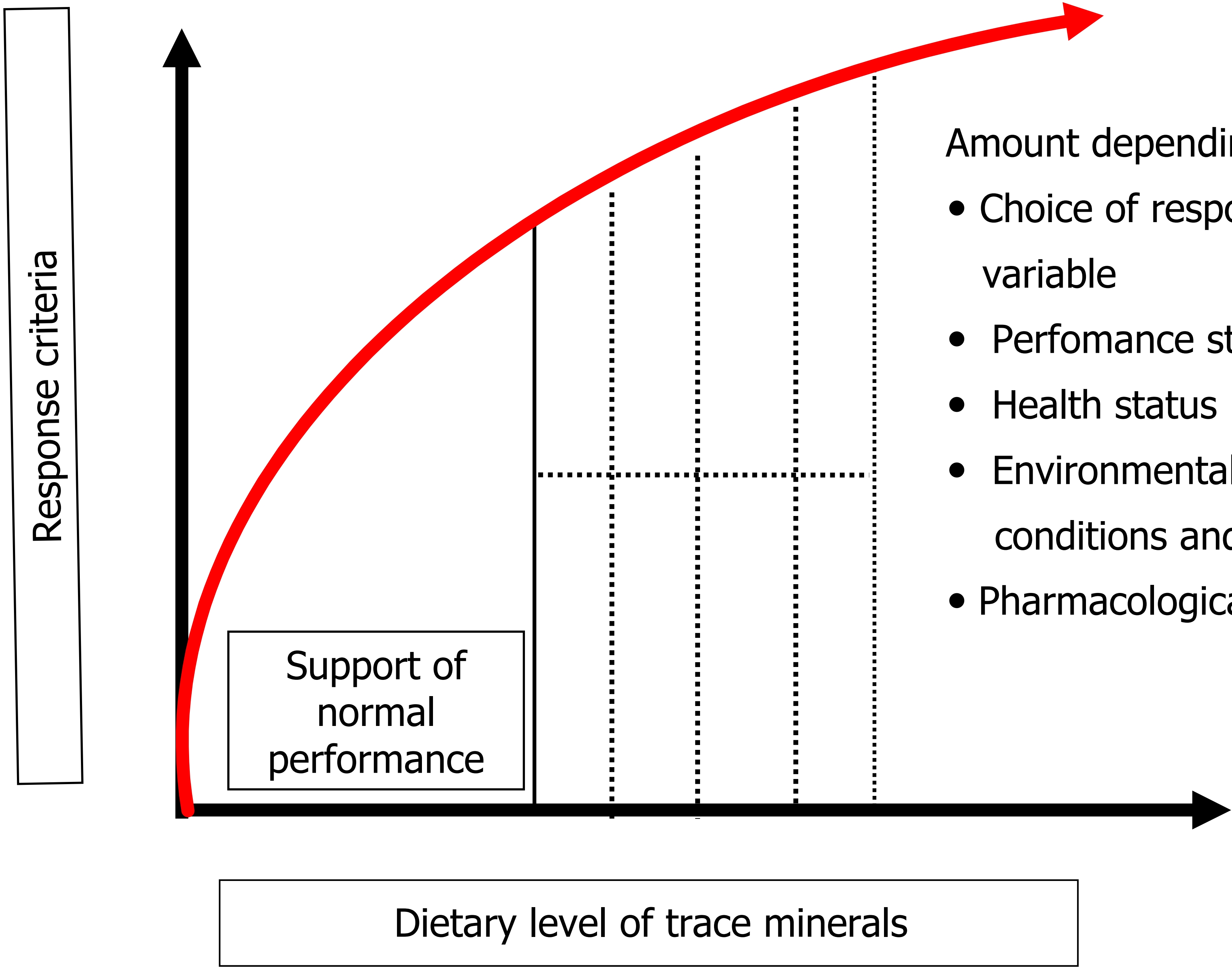
Levels of trace mineral deficiency



Determination of mineral bioavailability



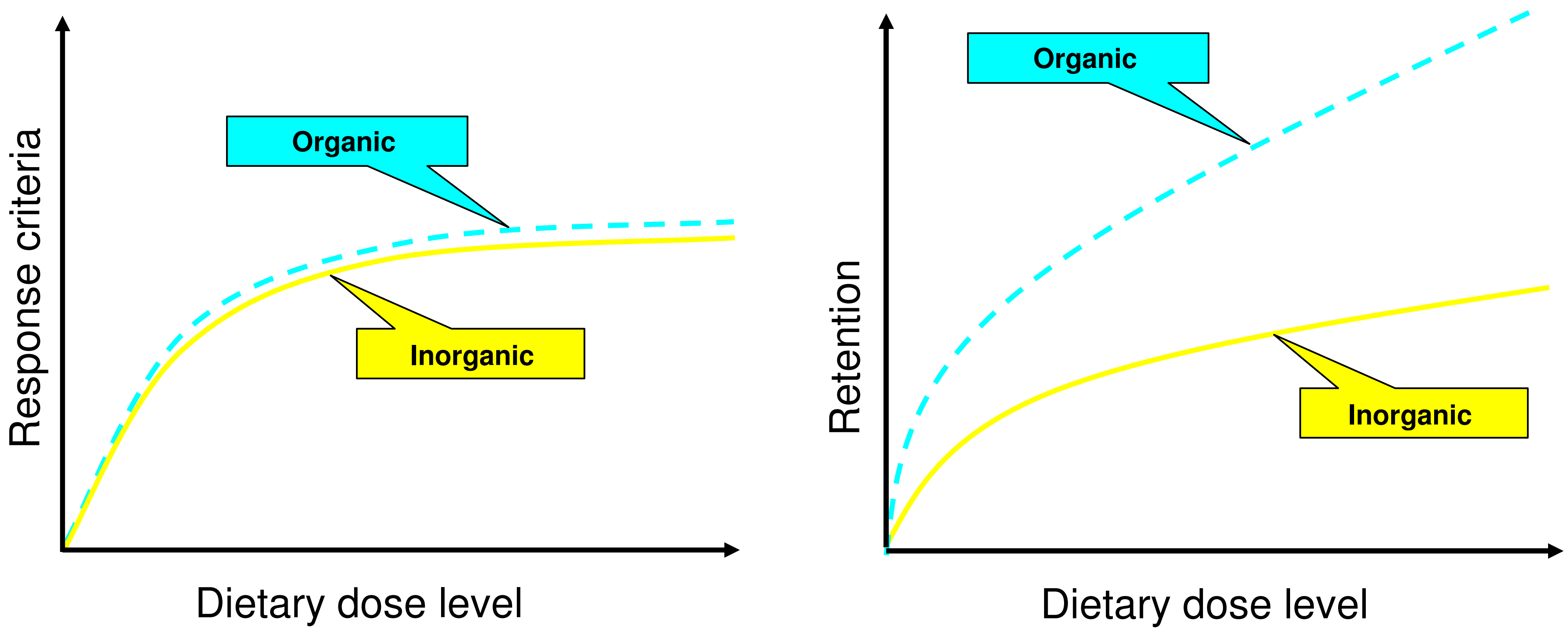
Determination of mineral bioavailability



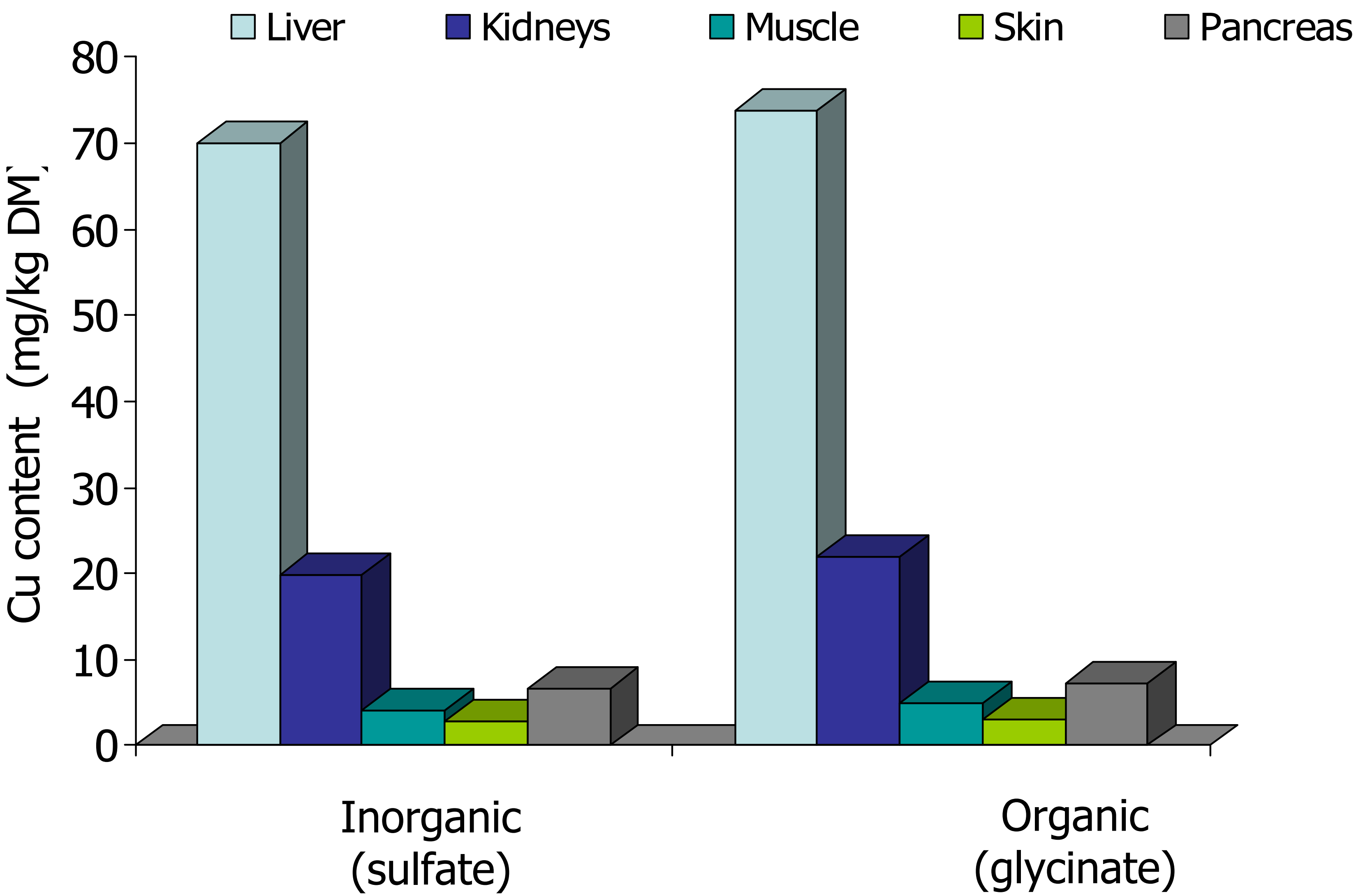
Amount depending on

- Choice of response variable
- Perfomance status
- Health status
- Environmental conditions and stress
- Pharmacological effects

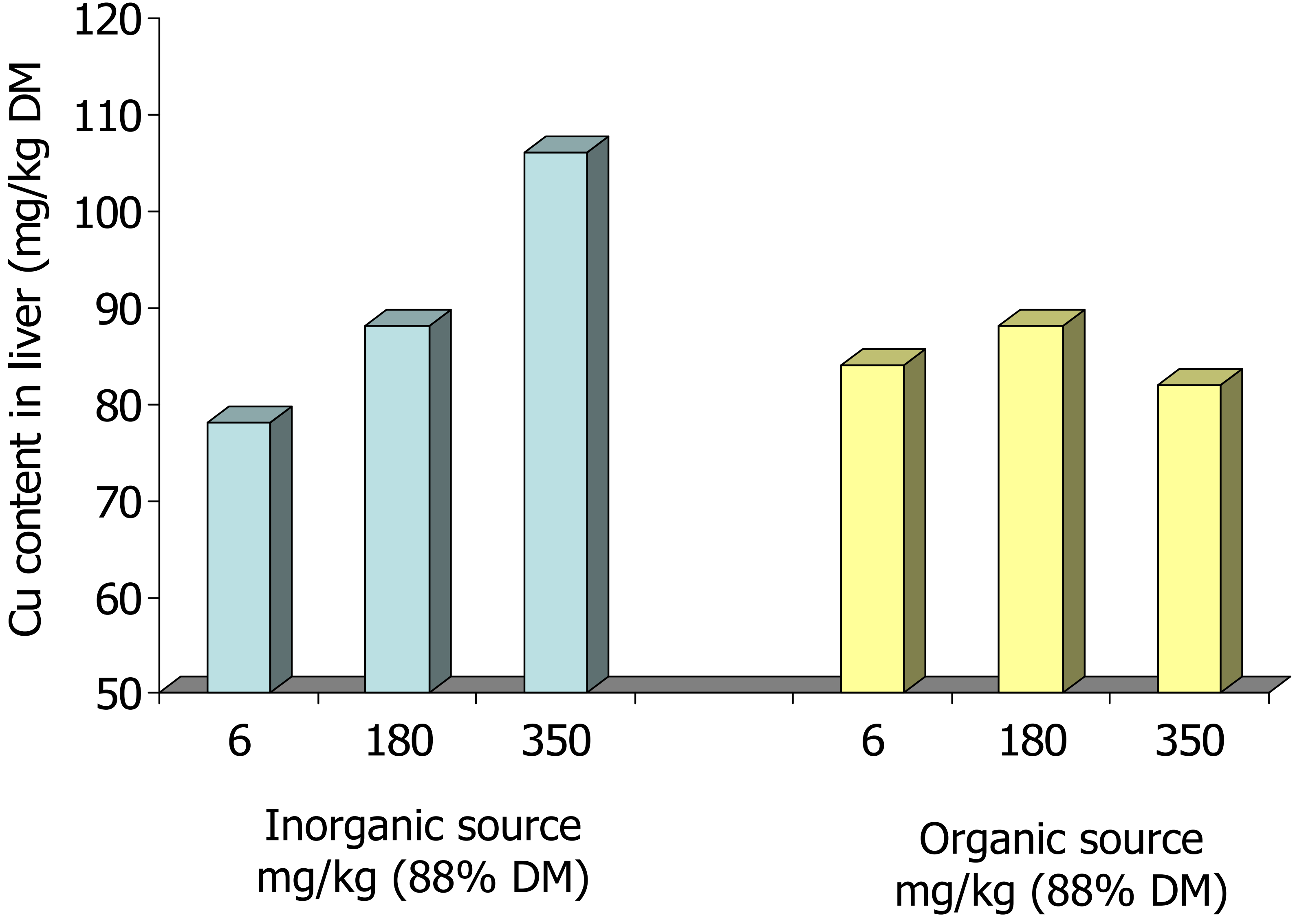
Effects of response criteria on bioavailability of inorganic and organic trace mineral sources



Effects of inorganic and organic trace elements at recommended levels on Cu content in selected organs of post-weaning piglets at 47 d of age after a 14-day-depletion period (25 to 38 d of age)



Effects of recommended and overdose levels using inorganc ($CuSO_4$) or organic copper (Cu-Lys) on copper content in liver of post-weaning piglets at the end of a 42-day-feeding period



Bioavailability used for comparisons of different mineral sources

- Bioavailability of a mineral in a particular source is determined relative to its functional availability from a standard source
- Expression of bioavailability in terms of relative biological availability

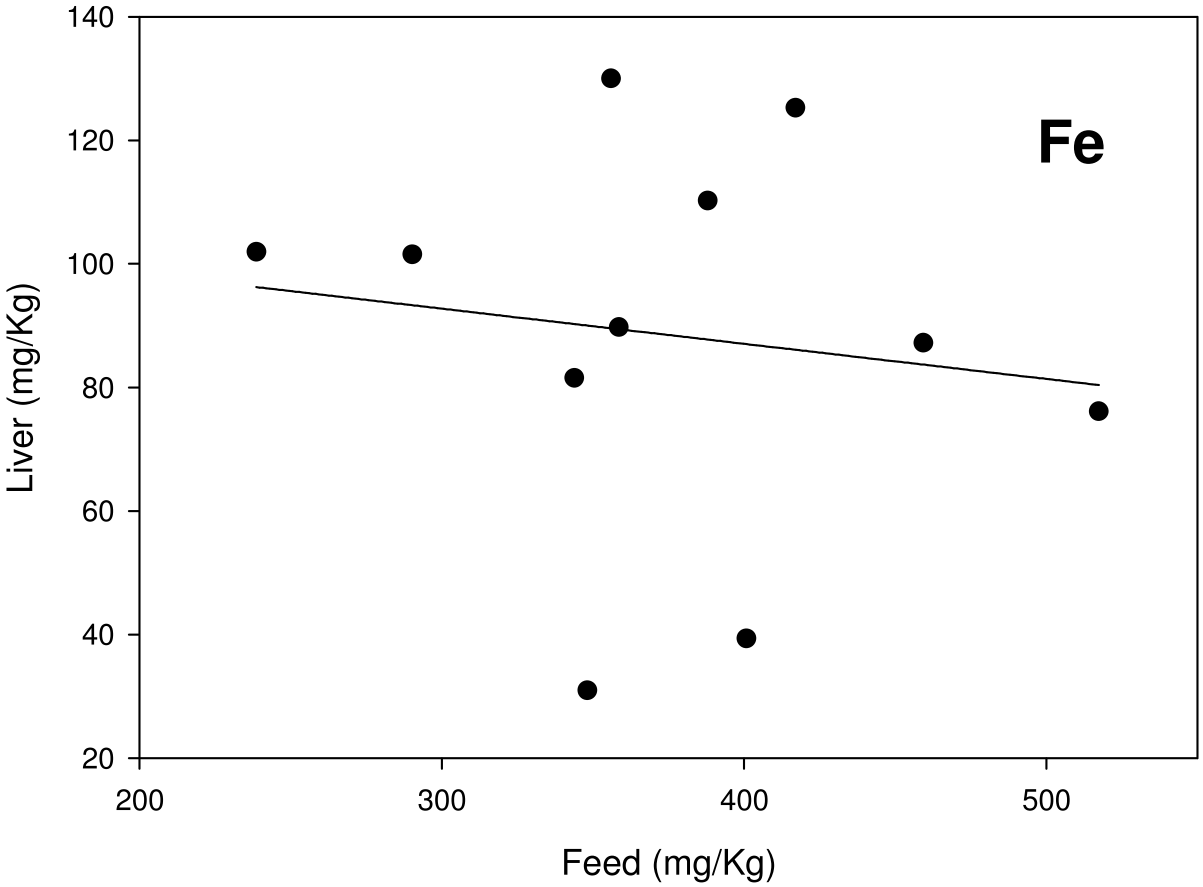
Potential parameters for characterising relative bioavailability of trace minerals (Jongbloed et al. 2002)

	Contents				Enzyme activities	Health status	Performance	Absorption
	Blood	Liver	Kidney	Bone				
Iron	-	+++	-	-	++	-	+	+++
Manganese	-	+	+++	+++	-	+++	++	+++
Zinc	++	-	-	+++	-	-	+	+
Copper	-	+++	-	-	++	-	+	+++

Relative bioavailability (Zn-content in tibia bone) of Zn-Met using different diet types in broiler chickens (Wedekind et al. 1992)

Diet type	Relative bioavailability (%) of Zinc ($ZnSO_4 \times 7\ H_2O$ = 100 %)
Purified diet	117
Semipurified diet	177
Corn-soybean meal diet	208

Effects of increasing Fe-intake on Fe-content in the liver of milk cows during lactation (Steinhöfel et al. 2012)



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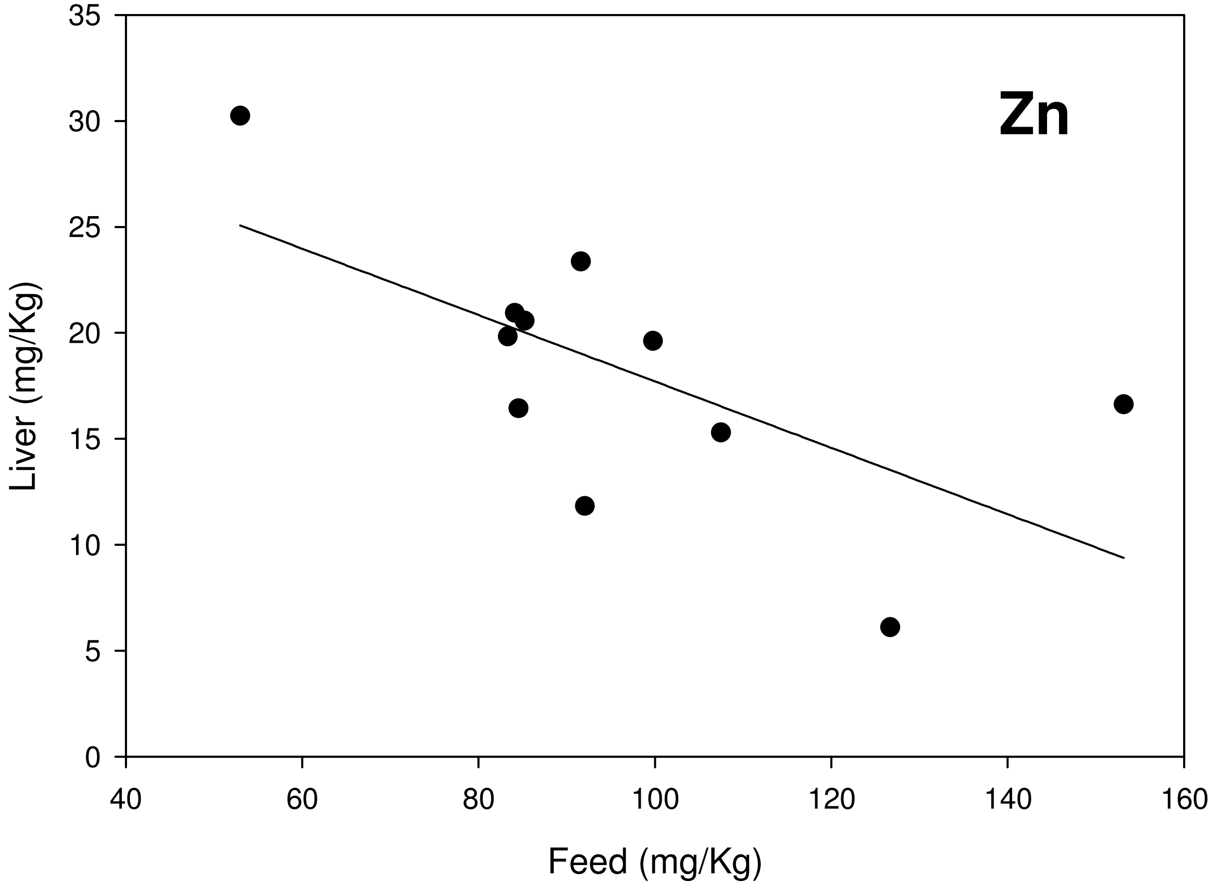
Effects of increasing Zn-intake on Zn-content in the liver of milk cows during lactation (Steinhöfel et al. 2012)



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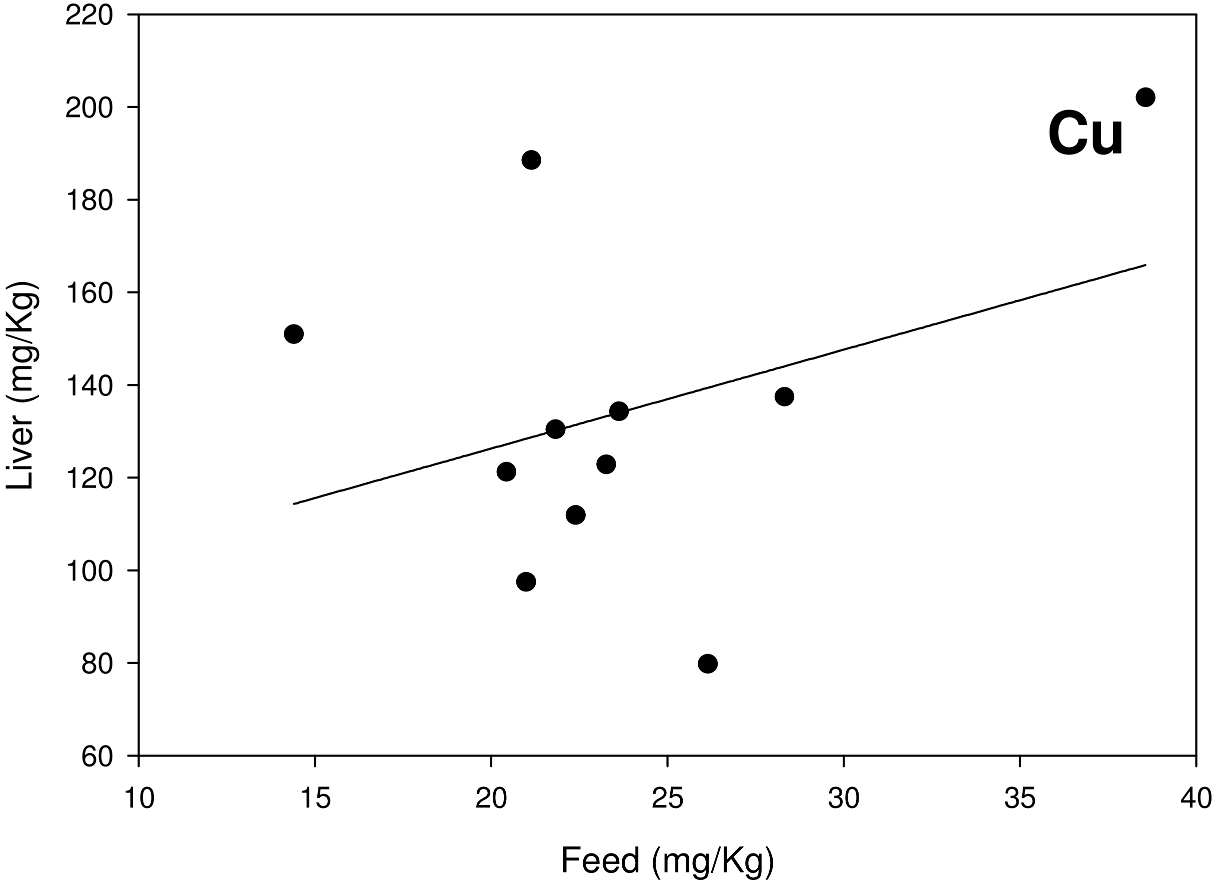
Effects of increasing Cu-intake on Cu-content in the liver of milk cows during lactation (Steinhöfel et al. 2012)



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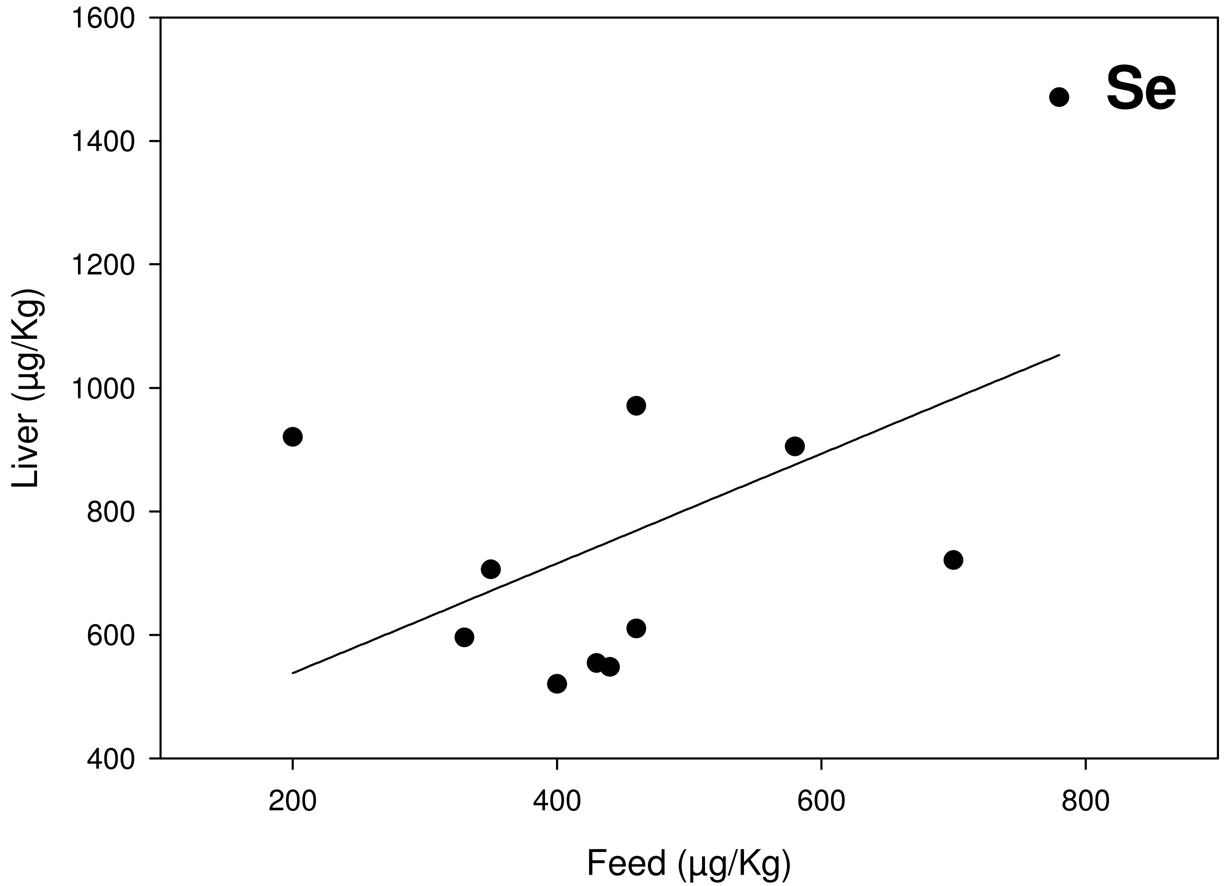
Effects of increasing Se-intake on Se-content in the liver of milk cows during lactation (Steinhöfel et al. 2012)



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Relative bioavailability of zinc and copper sources for pigs (NRC 1998, Revy et al. 2003)

Source	Relative bioavailability with respect to $ZnSO_4$ x 7 H_2O or $CuSO_4$ x 5 H_2O
ZnO (source 1 to 3)	55 - 87
$ZnSO_4$ x H_2O (source 1 to 3)	41 - 97
Zn-Met	77 - 120
Zn-Lys	79 - 110
Zn-Amino acids	100
CuO	0 - 10
$CuCO_3$ x $Cu(OH)_2$	60 - 100
Cu-Met	100 - 105
Cu-Gly	90 - 115

Possible reasons for inconsistent results evaluating relative bioavailability of trace minerals in diets for pigs and poultry

Source

- Chemical properties
  - Mineral concentration
  - Ligands
  - Stoechiometry
  - Chemical structure crystalline / amorphous
  - Solubility
- Physical properties
  - Particle size distribution
  - Water absorption

Technique for measuring bioavailability

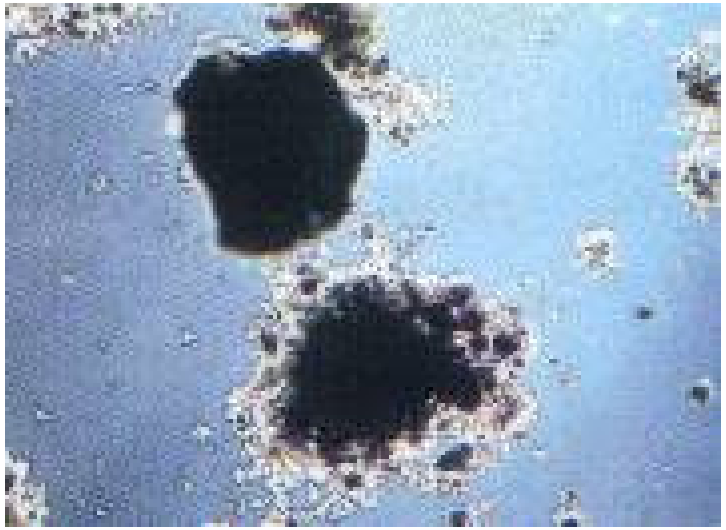
- Experimental design
  - Depletion, repletion
  - Control (negative, positive)
  - Supplementation rate
- Response criteria used
- Diet composition
  - Purified or conventional ingredients
- Feed additives
  - Phytases, probiotics, organic acids
- Palatibility

Animal and housing factors

- Physiological status
  - Breed
  - Age
  - Health
  - Performance
  - Stress
  - Mineral status
- Climatic conditions
- Hygienic conditions

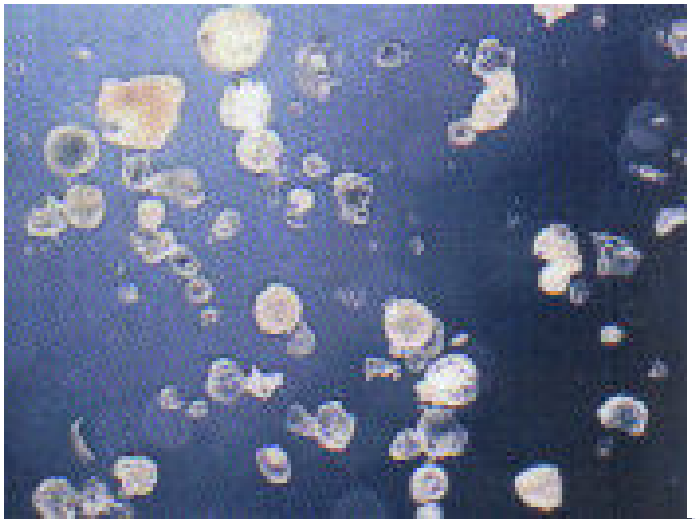
Microscopial structure of different organically bound trace minerals (modifiefd from Oguey 2007)

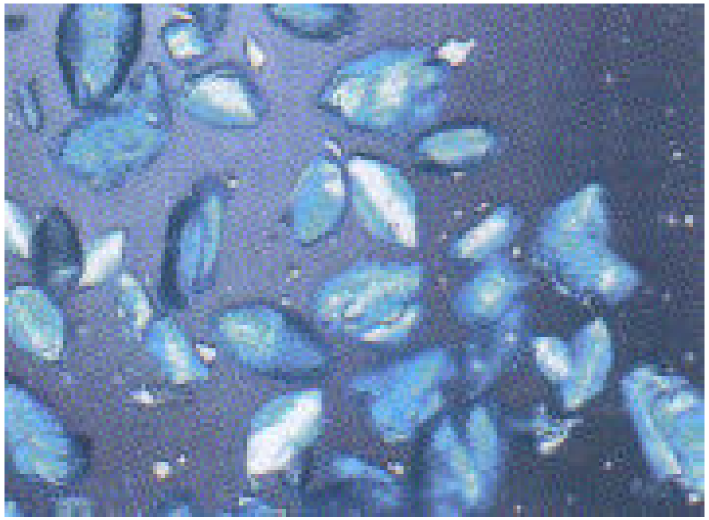
Zinc



Copper

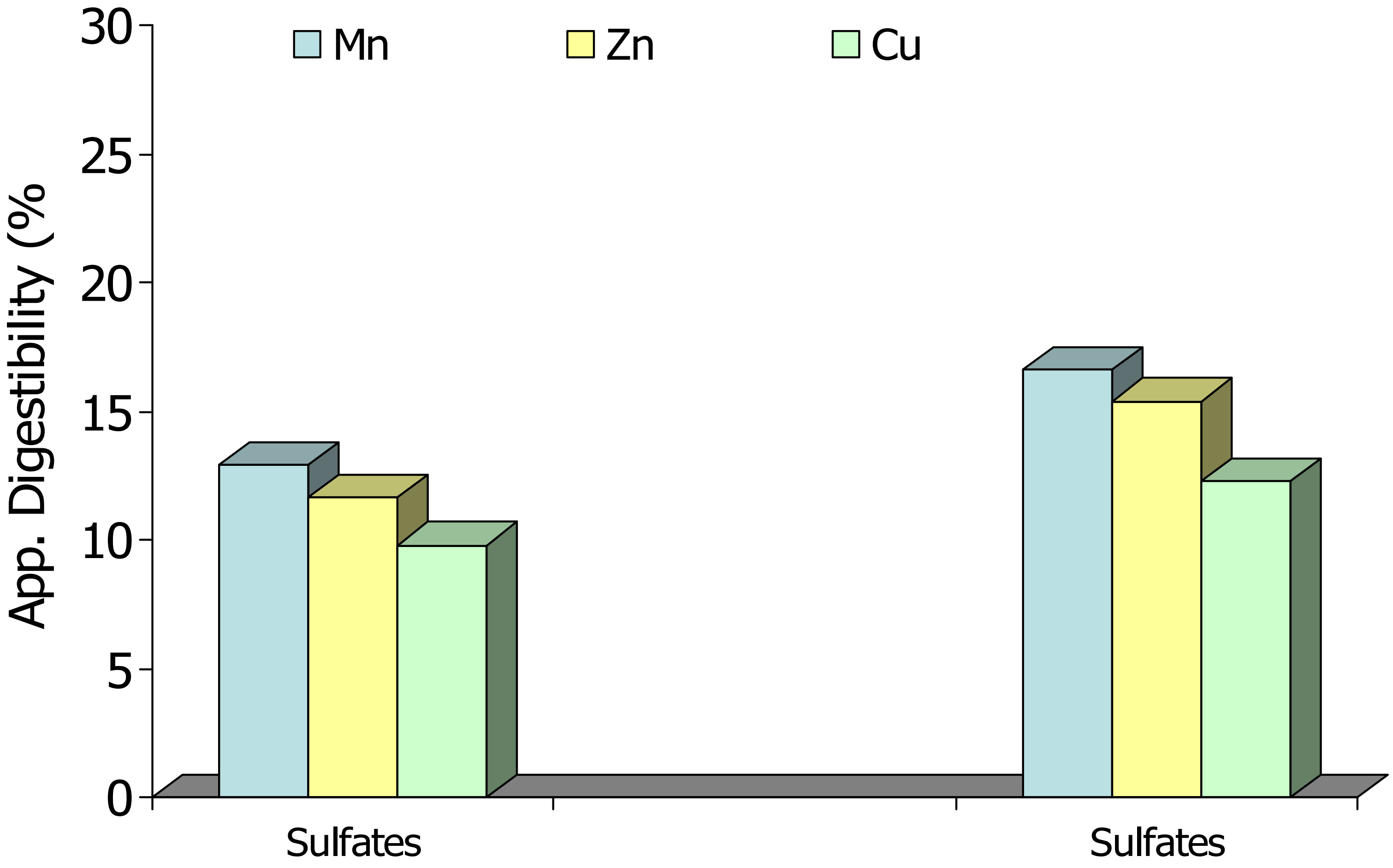
Zinc





Copper

Effects of reduced premix addition by using inorganic trace minerals (Mn, Zn, Cu) on app. digestibility in broilers over a 35-day-feeding period



Normal inorganic premix using sulfates (ppm):
Mn 100, Zn 90, Cu 15

Premix using in amounts of 10% (Mn), 11.1% (Zn) and 67% (Cu) of the normal premix

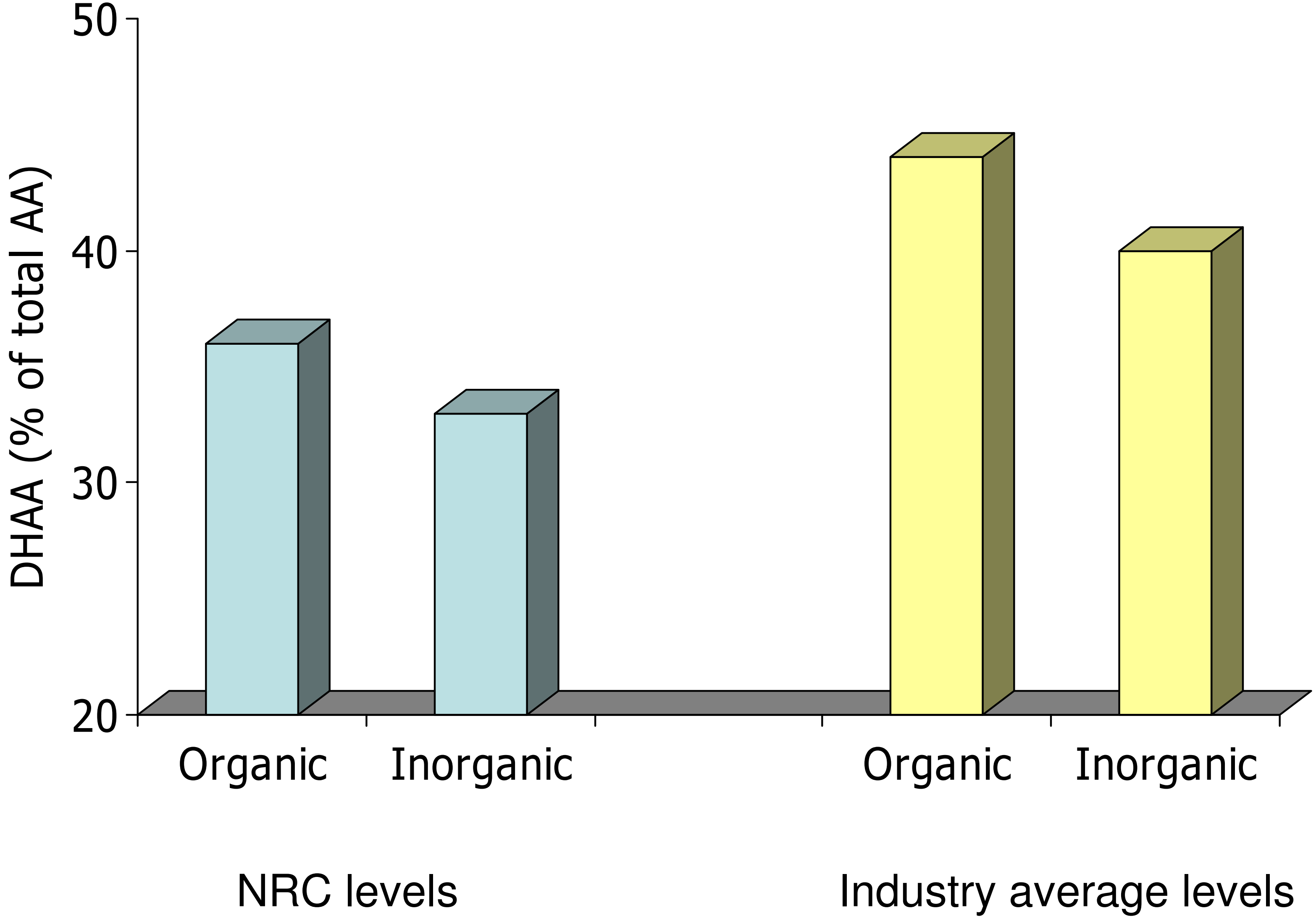
Native contents (calculated)

Mn: 41ppm

Zn: 79 ppm

Cu: 8.5 ppm

Ratio of oxidized (dehydroascorbic acid) to reduced ascorbic acid (active antioxidant) in sows when fed inorganic and organic trace mineral sources at different levels (Peters and Mahan, 2004)



Interactions among minerals

Element	Typical antagonism
Fe	Ca, Cd, Cu, lignine, Ni, P, Pb, protein, phytate, Zn, sugar
Mn	Ca, Fe, Mg, P, phytate
Zn	arginine, Ca, Cd, Cu, Fe, Mg, Se, glucosinolates, P, phytate, S, Ni
Cu	Ag, Ca, Cd, Fe, Hg, Mo, P, Pb, phytate, S, Zn, Se
Se	As, Ca, Cd, Ag, Mg, Zn, Pb, Hg, Fe, S, Cu, J,
J	As, Ca, Co, F, glucosinolates, NO_3
Co	Fe, J

Upper limits for animal health and avoiding interactions among minerals (values in mg/kg DM)

Element	Recommendation	Upper limits (88% TM)	Upper limits for	
		EU 1334/2003	Animal health	Interactions
Fe	50 - 120	750	500 - 1000	350
Mn	15 - 40	150	600	550
Zn	50 - 100	150 - 250	300 - 1000	100
Cu	4 - 15	15 - 35	20 - 100	50
Se	0.15 - 0.25	0.5	0.2 - 2	2
J	0.15 - 0.60	4 - 10	25	20
Co	0.20	2	10	10
Mo	0.10	-	3 - 5	2

Conclusions

- Bioavailability of trace minerals in animal nutrition varies according to numerous factors at dietary, digestive, absorptive and intermediary level
- Bioavailability varies according to the level of determination and the choice of response variables
- The validity of bioavailability at present is only warranted when using standardized measurement conditions (minimizing homeostases, standard source and dietary effects, ……) and a specific response criteria
- Bioavailability of native ingredients or typical basal diets of trace elements is scare and incomplete

Thank you for your friendly attention!