Novel guidelines for trace metals supplementation in bovines

Jean-Baptiste Daniel & **Javier Martín-Tereso**
R&D Ruminants

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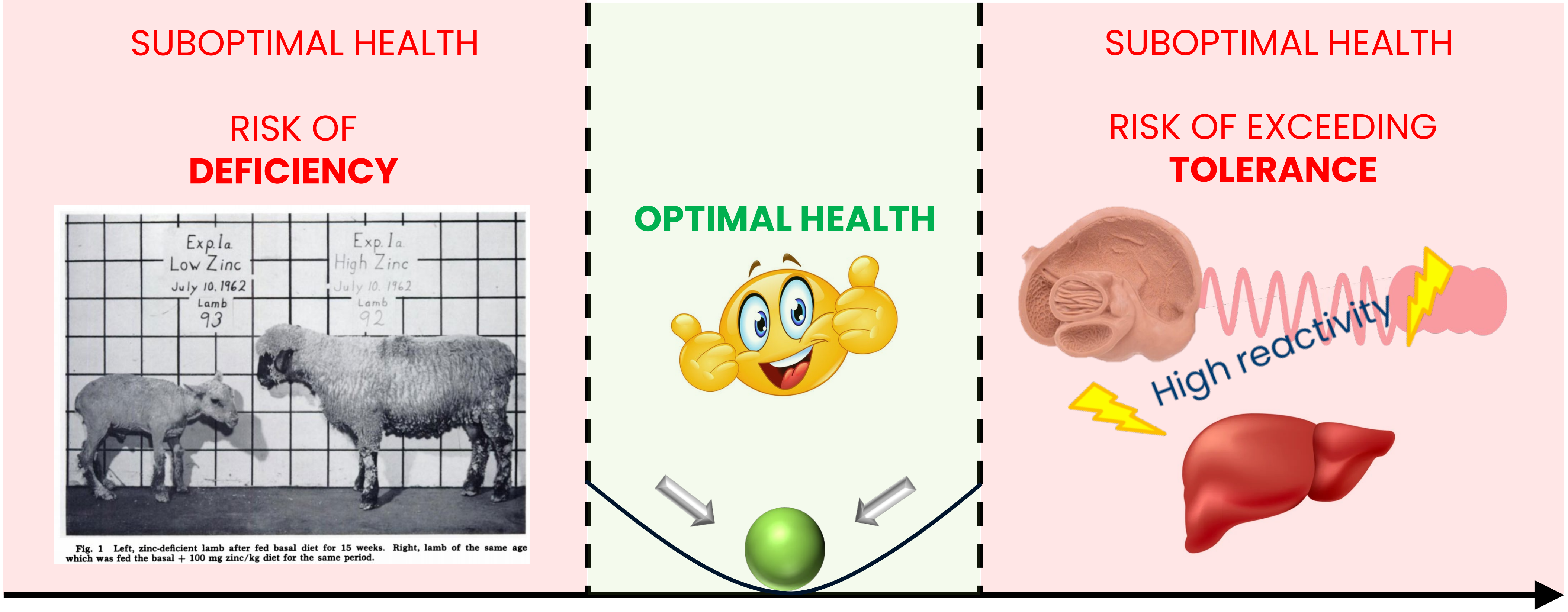
Trace metals – Essential AND dangerous to animal physiology



Gross trace metal supply above net requirement

Trace metals in bovine nutrition

30
Zn
Zinc
65.38

29
Cu
Copper
63.55

25
Mn
Manganese
54.938

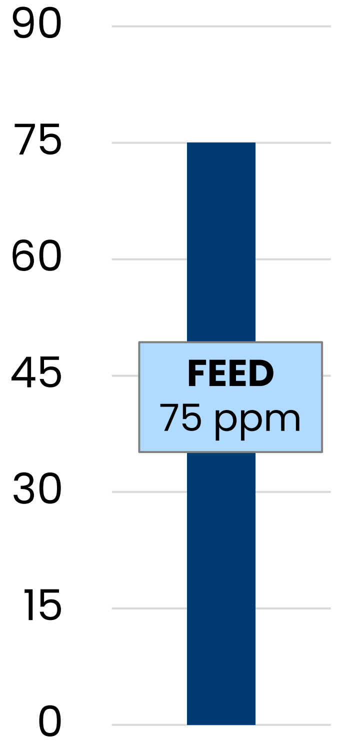
Outline

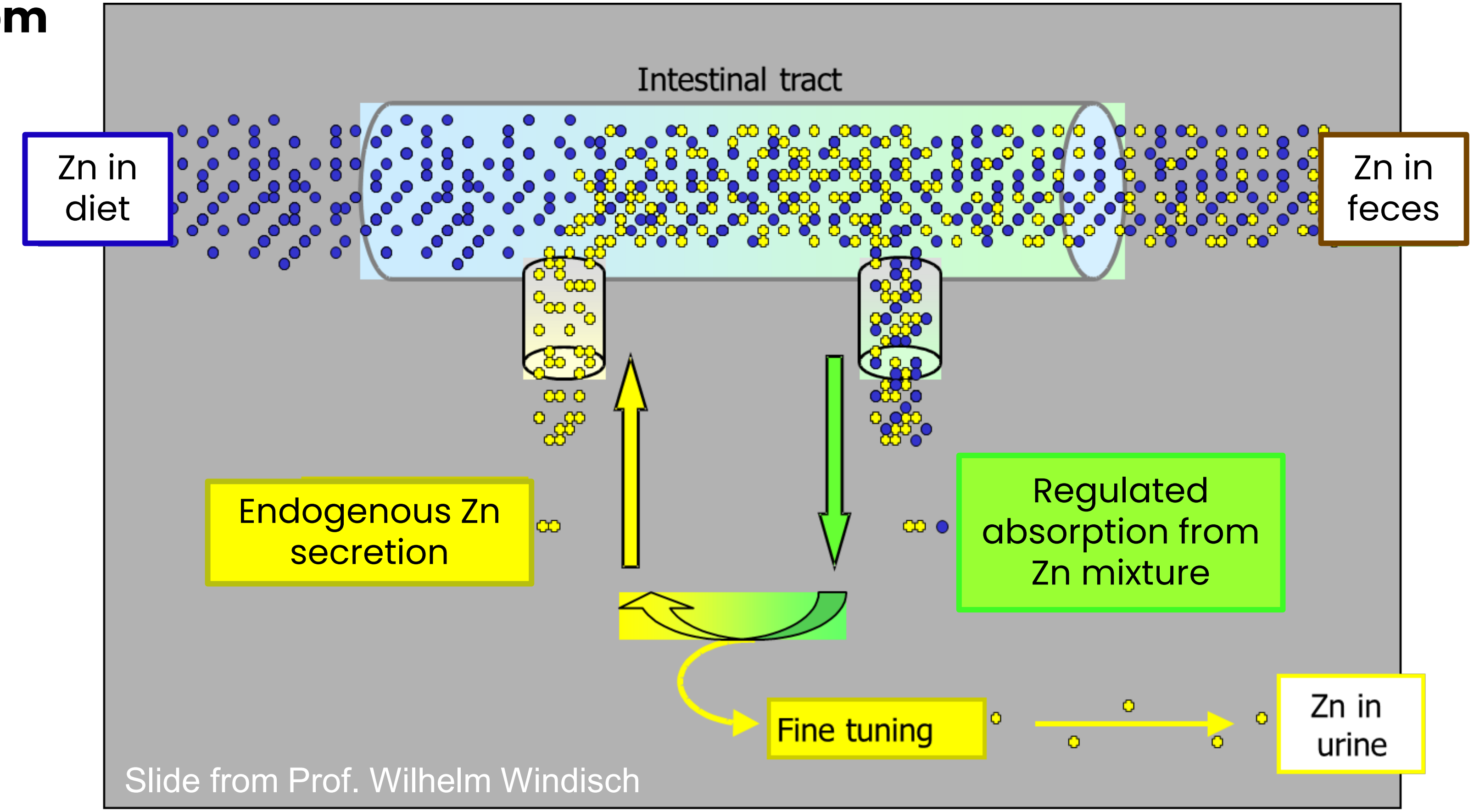
- Trace metal regulation …
- … and its limitations
- Novel guidelines for trace metals supplementation



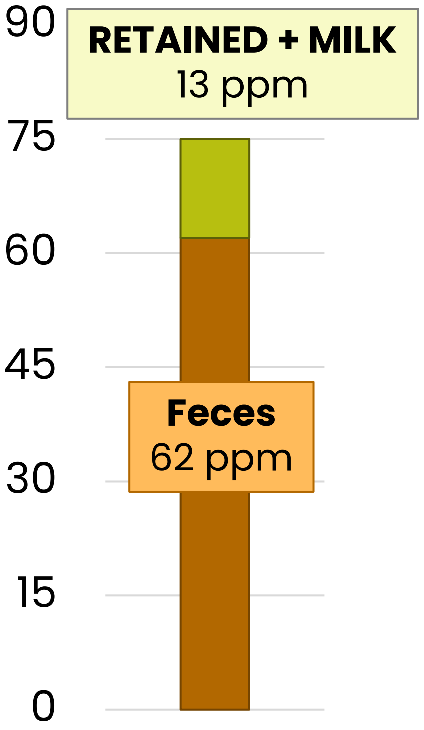
Key aspects of trace metal regulation

Zn INPUT, ppm





Zn OUTPUTS, ppm



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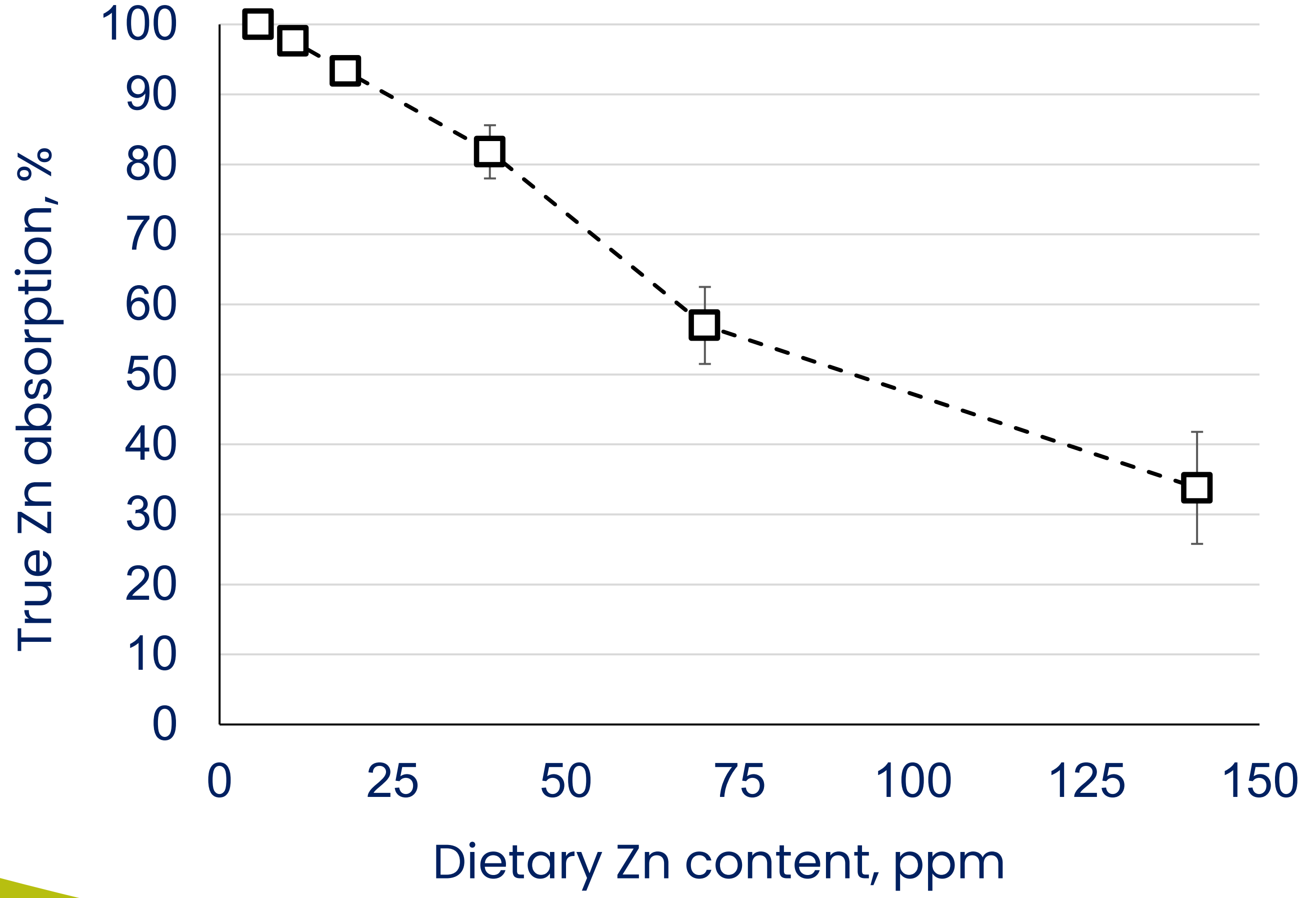
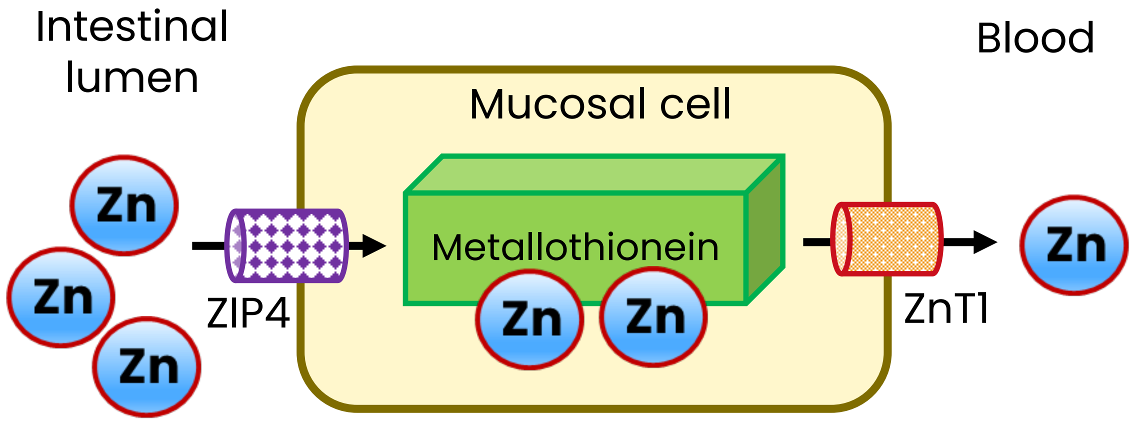
Key aspects of trace metal regulation





Absorption efficiency
decrease with higher Zn supply !

Weigand and Kirchgessner, 1978

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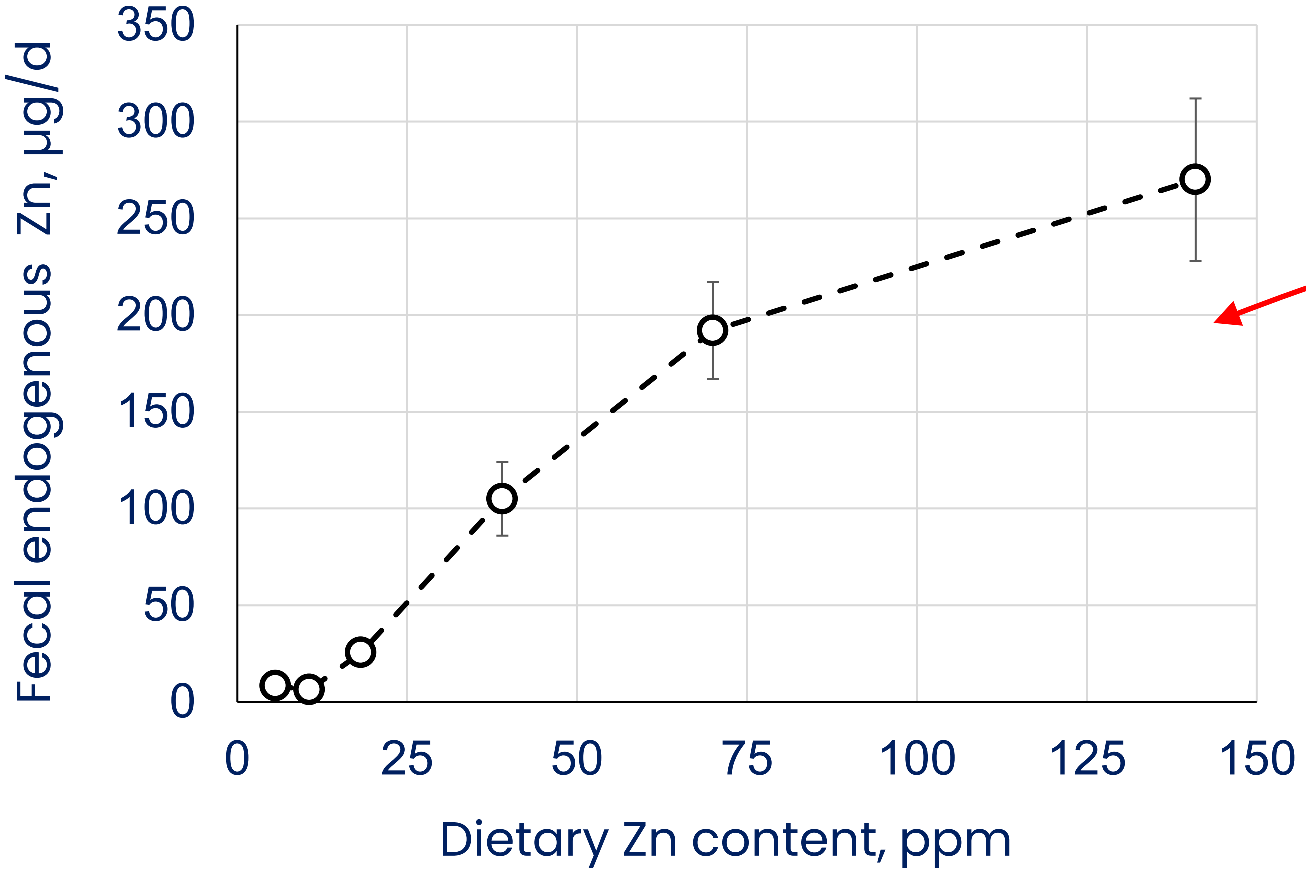
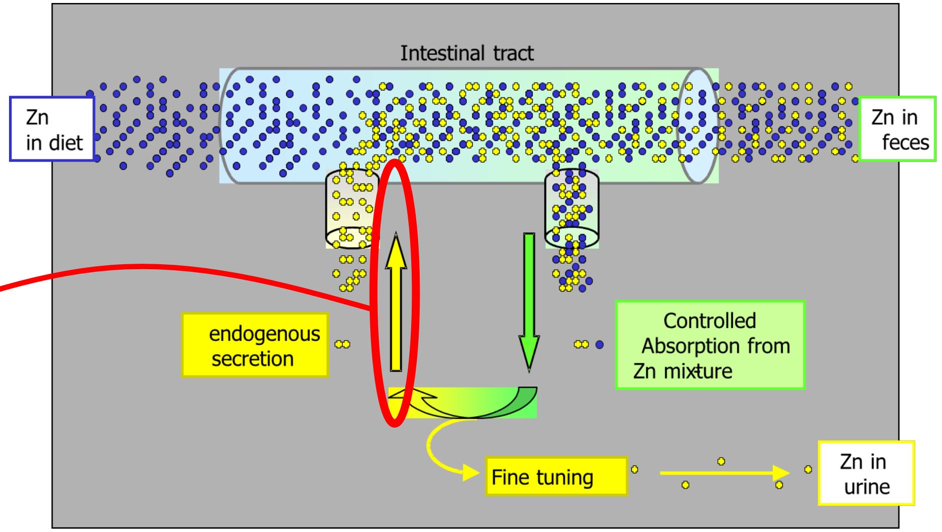
Key aspects of trace metal regulation

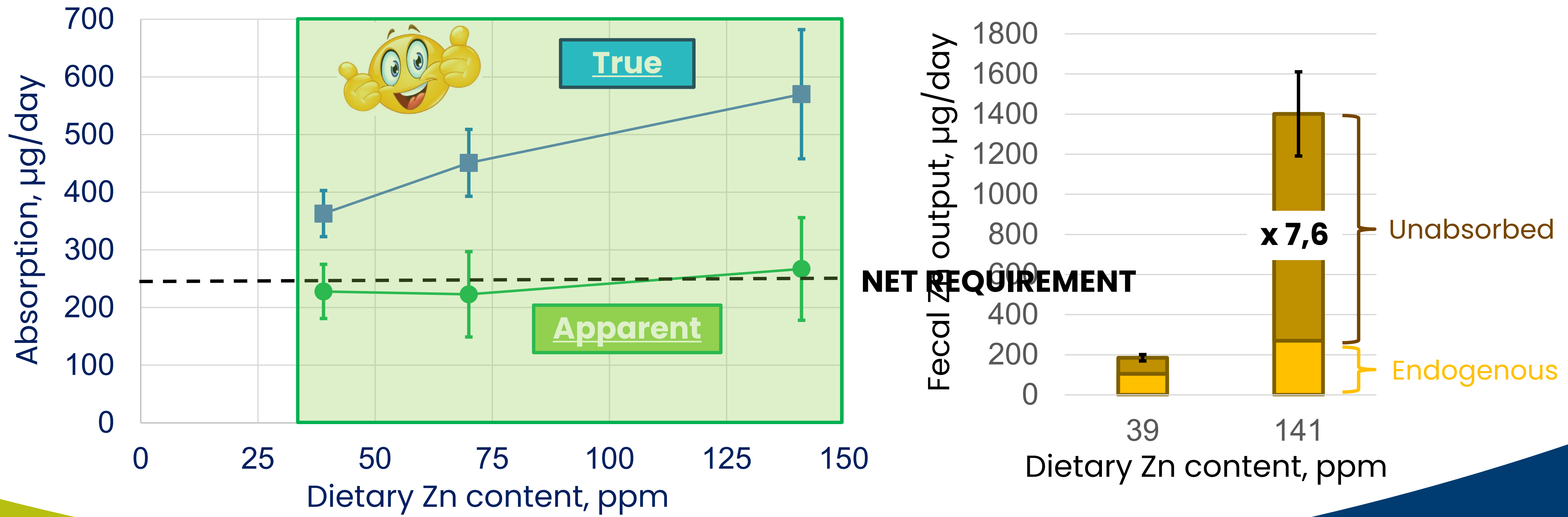




Fecal endogenous Zn losses
increase with higher Zn supply !

Key aspects of trace metal regulation

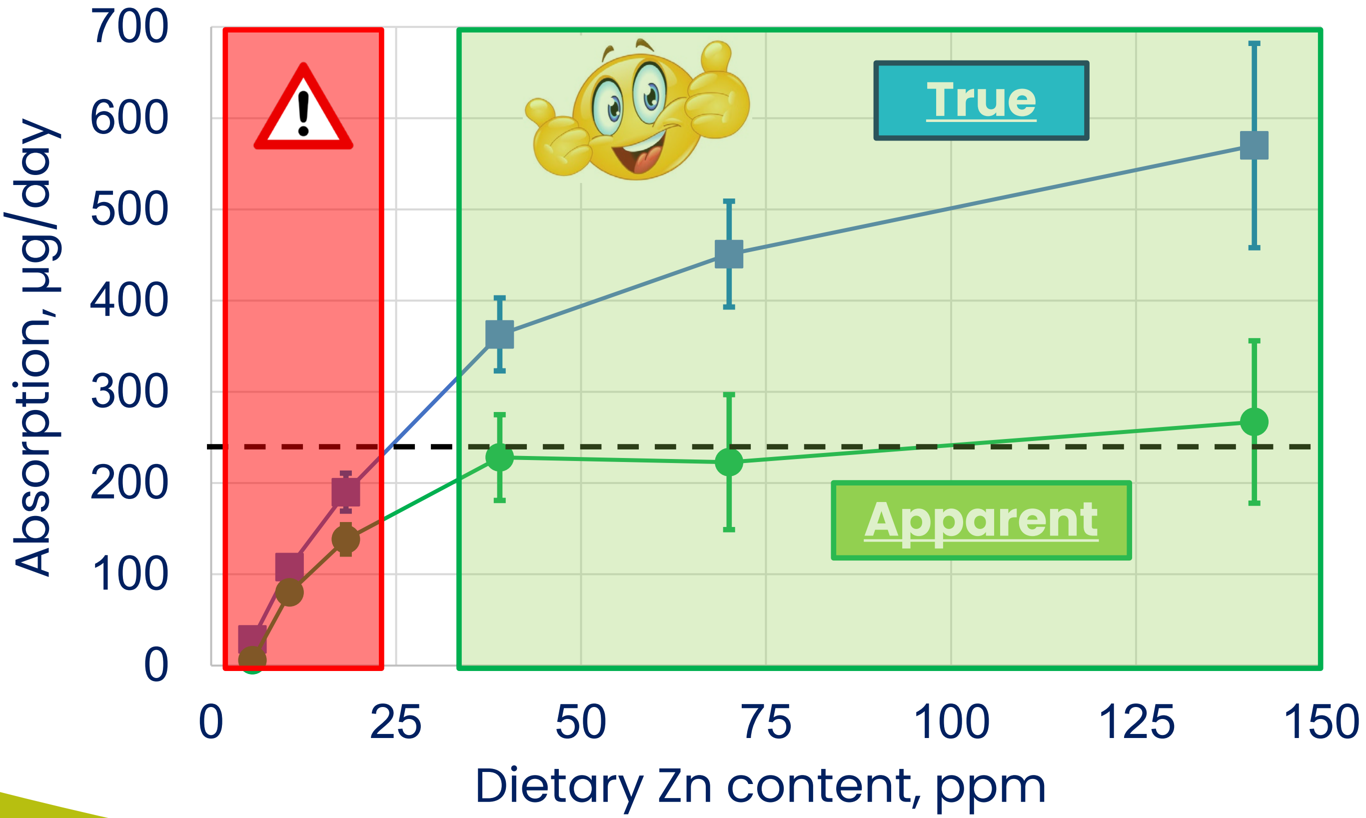
A TIGHTLY REGULATED process … where apparent absorption = net requirement

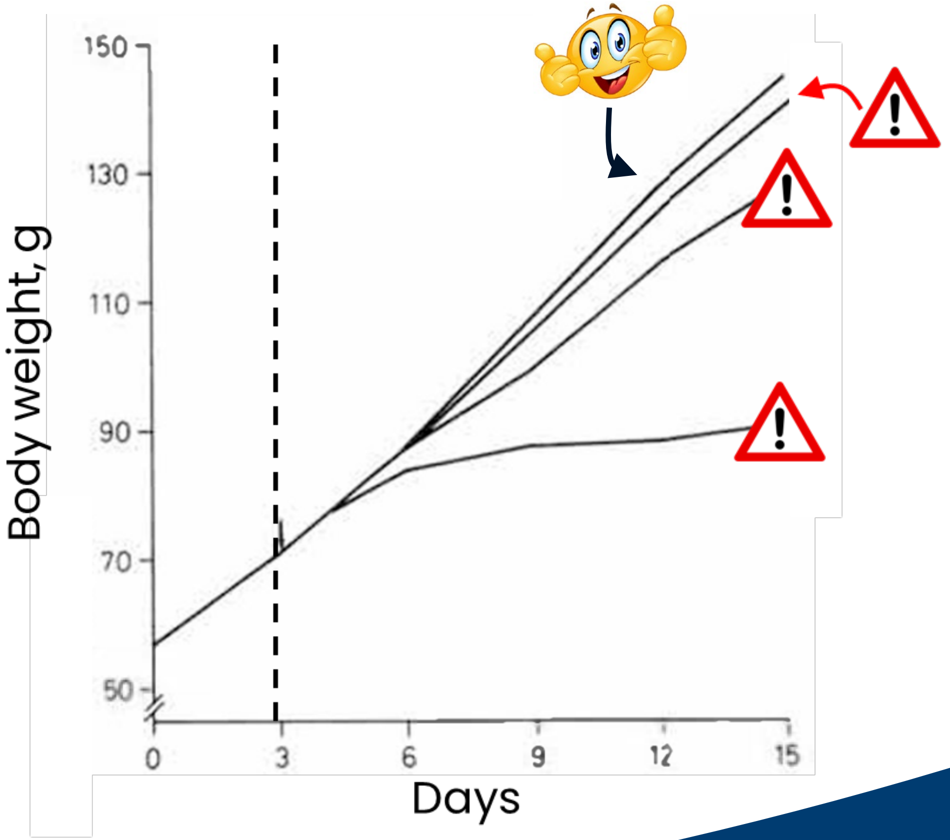


Weigand and Kirchgessner, 1978

Key aspects of trace metal regulation

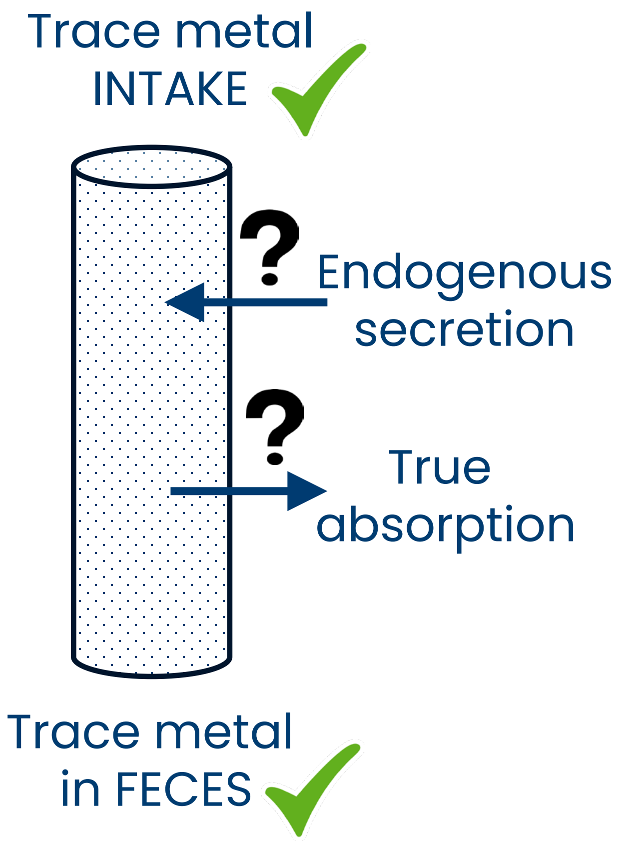
… until AVAILABLE SUPPLY IS LIMITED and <u>apparent absorption</u> < <u>net requirement</u>





Weigand and Kirchgessner, 1978

Current approach to dietary recommendations



Example with Zn in NASEM 2021

- **Faecal endogenous losses** = 5 x kg DMI ?

+

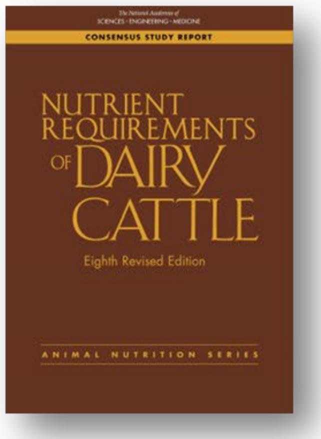
- **Gestation** = 0.017 x kg BW (last trimester)

+

- **Growth** = 24 x kg ADG

+

- **Lactation** = 4 x kg milk



All in mg/day

÷ **True absorption = 20%** ?

Feeding practices exceed reference recommendations …

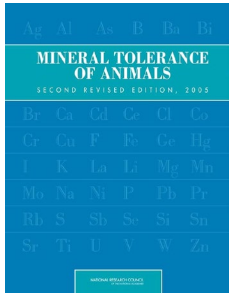
… but not maximum tolerable limit

100 eastern Canadian commercial dairies, Duplessis et al., 2021

in ppm	NASEM 2021 (32 kg MY)	Average ± SD	Centile 1	Centile 99
Copper	11	17 ± 5	10	34
Manganese	27	65 ± 18	27	123
Zinc	56	76 ± 21	33	144

39 Californian commercial dairies, Castillo et al., 2013

in ppm	NASEM 2021 (32 kg MY)	Median	Centile 10	Centile 90
Copper	11	18	10	31
Manganese	27	73	48	106
Zinc	56	74	51	103



MTL
(NRC, 2005)

40 ppm **Cu**

2000 ppm **Mn**

500 ppm **Zn**

Trace metal balance in dairy cows

- 24 weekly periods of 48h total collection of feces and urine
- 12 dairy cows

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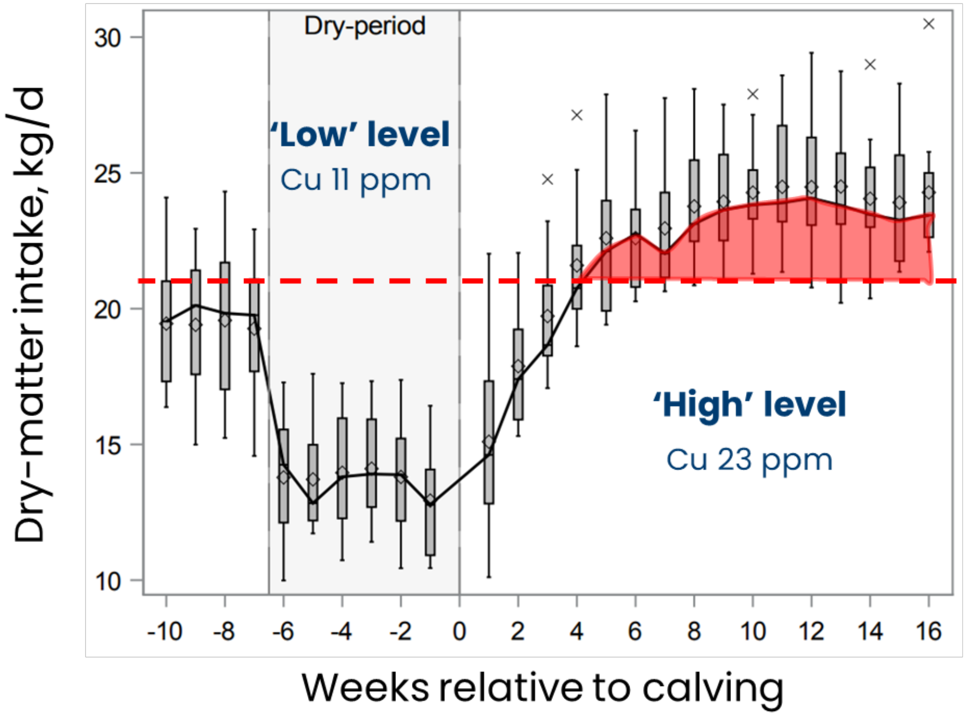
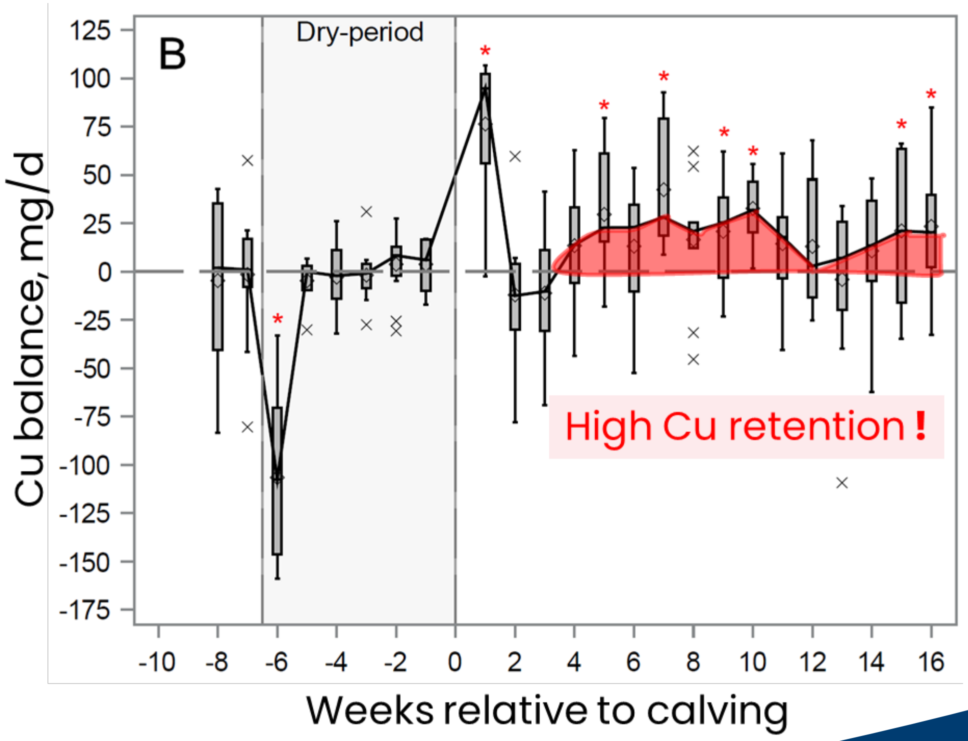
journal homepage: www.journals.elsevier.com/the-journal-of-nutrition
Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

Zinc, Copper, and Manganese Homeostasis and Potential Trace Metal Accumulation in Dairy Cows: Longitudinal Study from Late Lactation to Subsequent Mid-Lactation

Jean-Baptiste Daniel [1,*], Daniel Brugger [2], Saskia van der Drift [3], Deon van der Merwe [3,4], Nigel Kendall [5], Wilhelm Windisch [6], John Doelman [1], Javier Martín-Tereso [1]

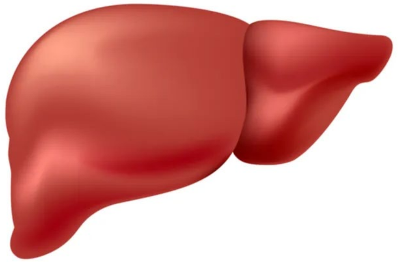
[1] Trouw Nutrition R&D, Amersfoort, the Netherlands; [2] Institute of Animal Nutrition and Dietetics, Vetsuisse-Faculty, University of Zurich, Zurich, Switzerland; [3] Royal GD, Deventer, the Netherlands; [4] Department of Physiological Sciences, College of Veterinary Medicine, Oklahoma State University, Stillwater, Oklahoma, USA; [5] School of Veterinary Medicine and Science, University of Nottingham, Loughborough, UK; [6] Animal Nutrition, TUM School of Life Sciences Weihenstephan, Technical University of Munich, Freising, Germany



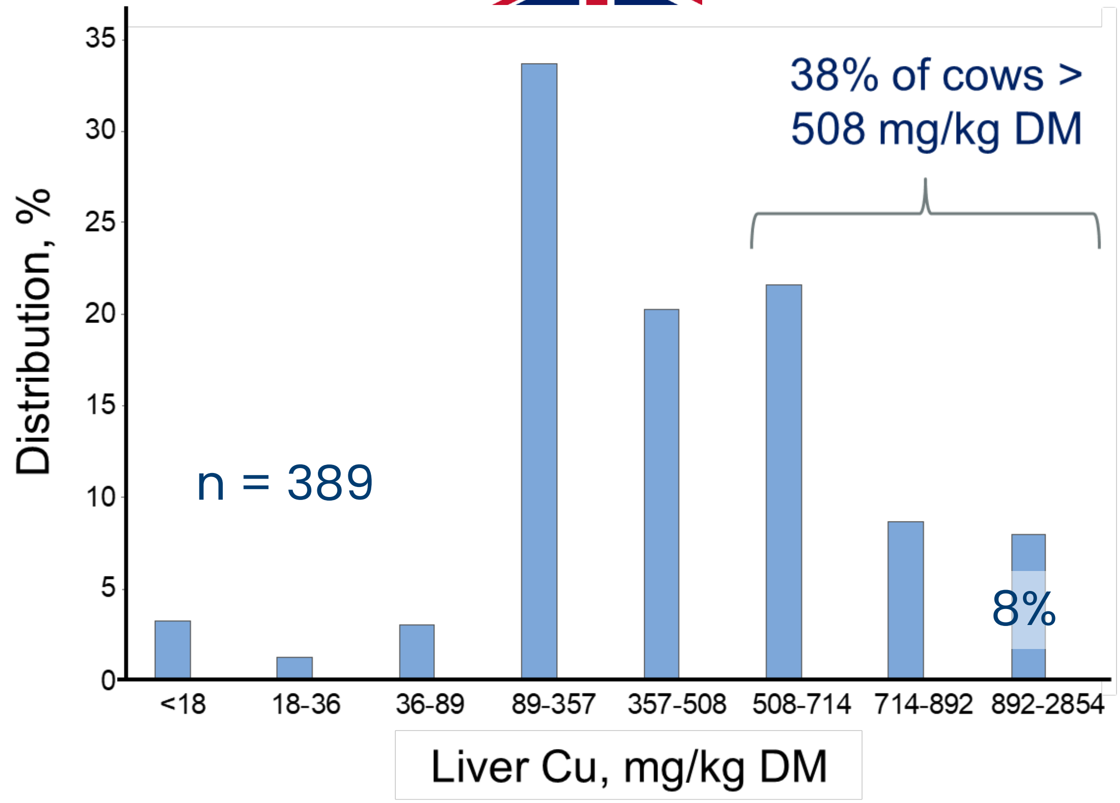


Daniel et al., 2023

High level of Cu in liver of dairy cattle



Kendall et al., 2015



Strickland et al., 2019

Adult Holstein cows (≥2 yr of age)
Michigan State, 2012 - 2015

- 31 to 44% > 500 mg/kg DM
- 5 to 12,2% > 850 mg/kg DM

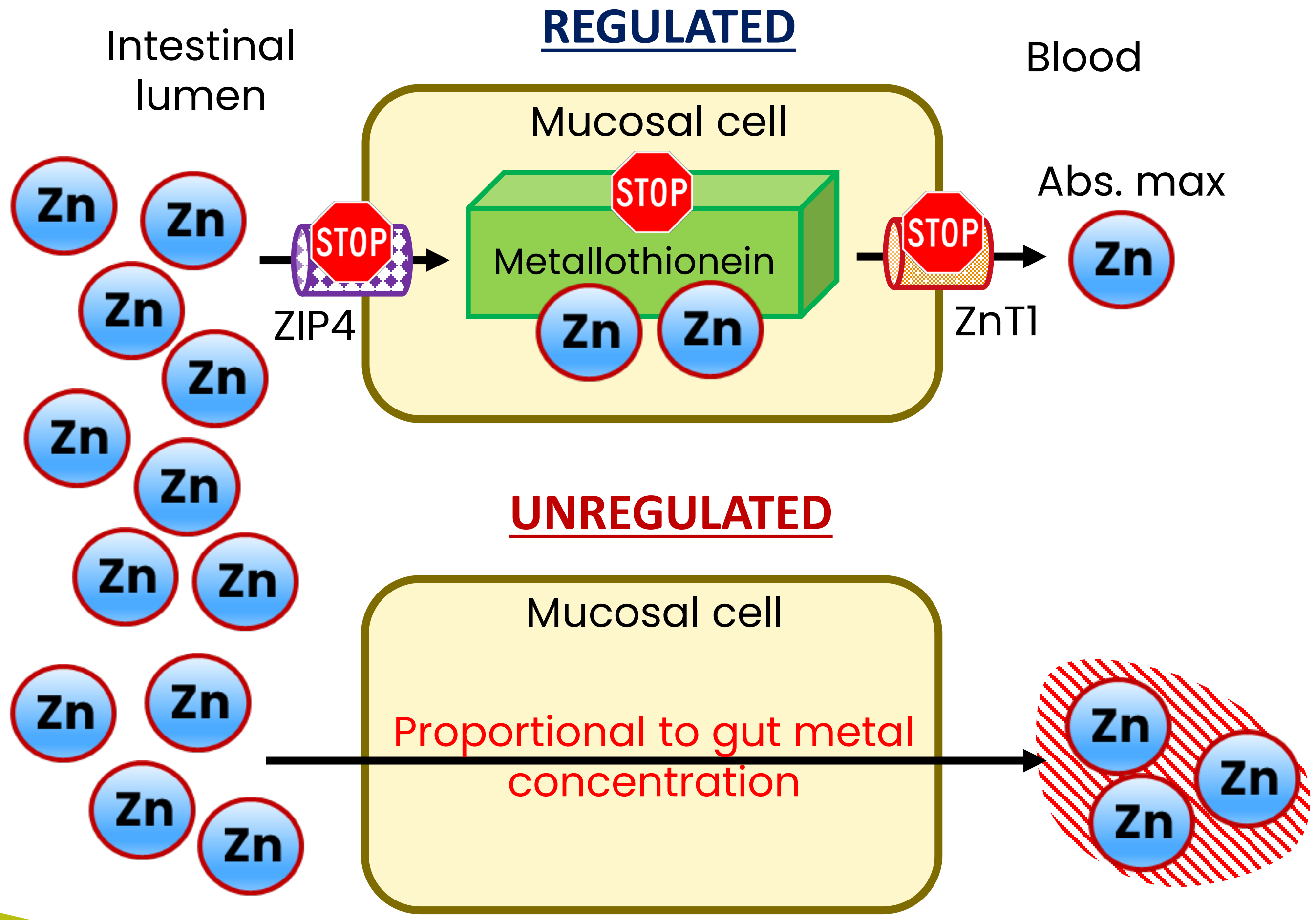
n = 562

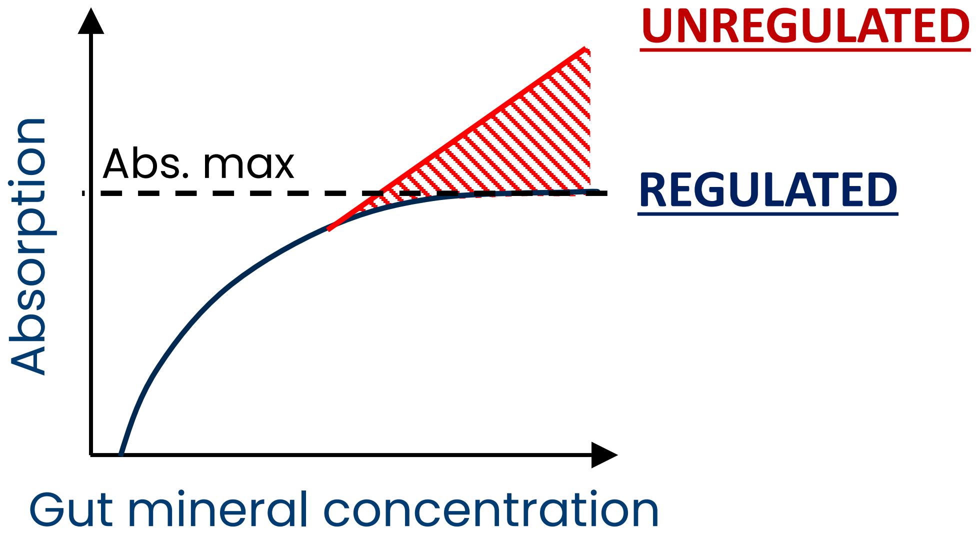
Counotte et al., 2019

Cattle ≥2 yr of age

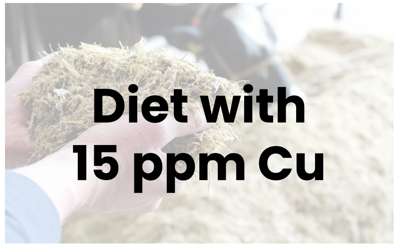
- 10% > 1066 mg/kg DM

Limitation to down-regulation upon high GIT metal content





The neglected role of voluntary dry matter intake



	Growing heifers	Medium MY (36 kg)	High MY (50 kg)
Body weight, kg	345	600	600
Dry matter intake, kg/day	7,9	19,2	25,0
• In % BW	2,3 %	3,2 %	4,2 %
Cu intake, mg/day	120	290	375
Net Cu requirements, mg/day	1,3	3,6	4,2

Cu intake (heifers → medium MY): **+ 170 mg/day**; (medium MY → high MY): **+ 85 mg/day**

Net Cu requirements (heifers → medium MY): **+ 2,3 mg/day**; (medium MY → high MY): **+ 0,6 mg/day**

Cu intake – Net Cu requirements, mg/day/kg BW	**0,34**	**0,48**	**0,62**

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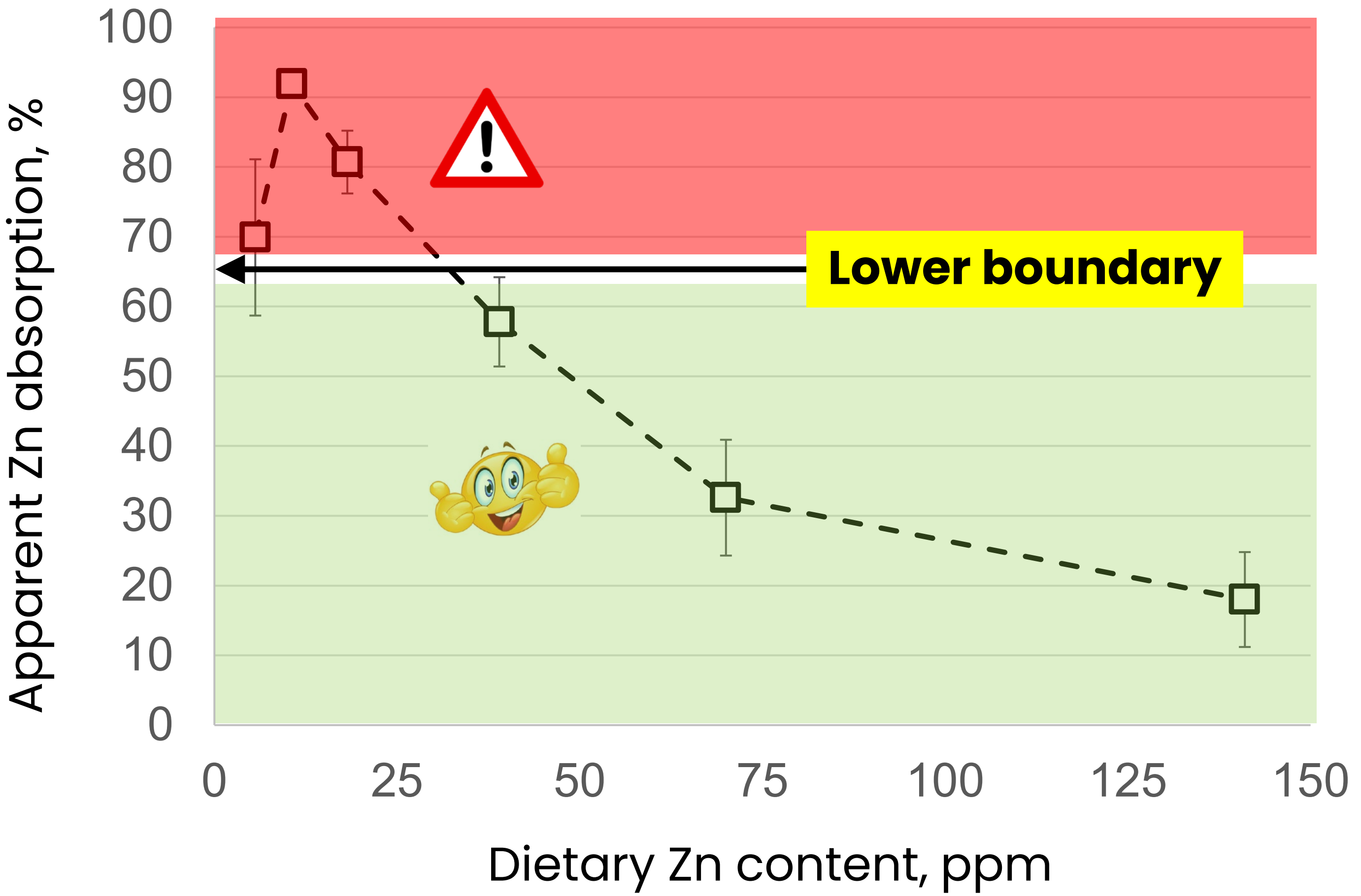
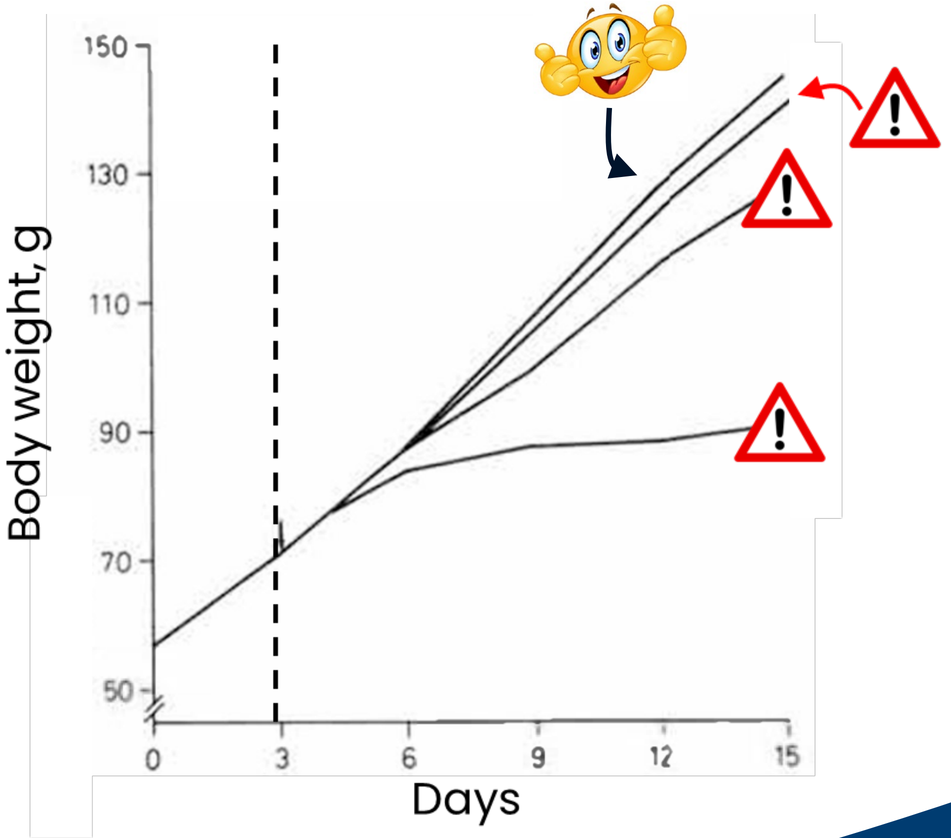
Novel guidelines for trace metals supplementation

- **Lower and Upper boundaries** of regulation
- Quantification of **probability density functions**
  - For gross native supply of trace metal
  - For animal net trace metal requirements
- Defining **confidence interval of supplementation**

Defining lower boundaries of regulation





Data from Weigand and Kirchgessner, 1978

Estimating maximal apparent absorption for lower boundary

Cu: 75 dietary treatments

Zn: 34 dietary treatments

Mn: 32 dietary treatments

Eligibility of study

Experimentally induced changes in available supply

Reported DMI and performance

Minimum duration of 50 days

Standard set of calculations

Net requirement

Required apparent absorption efficiency

Presence/Absence of adverse effects

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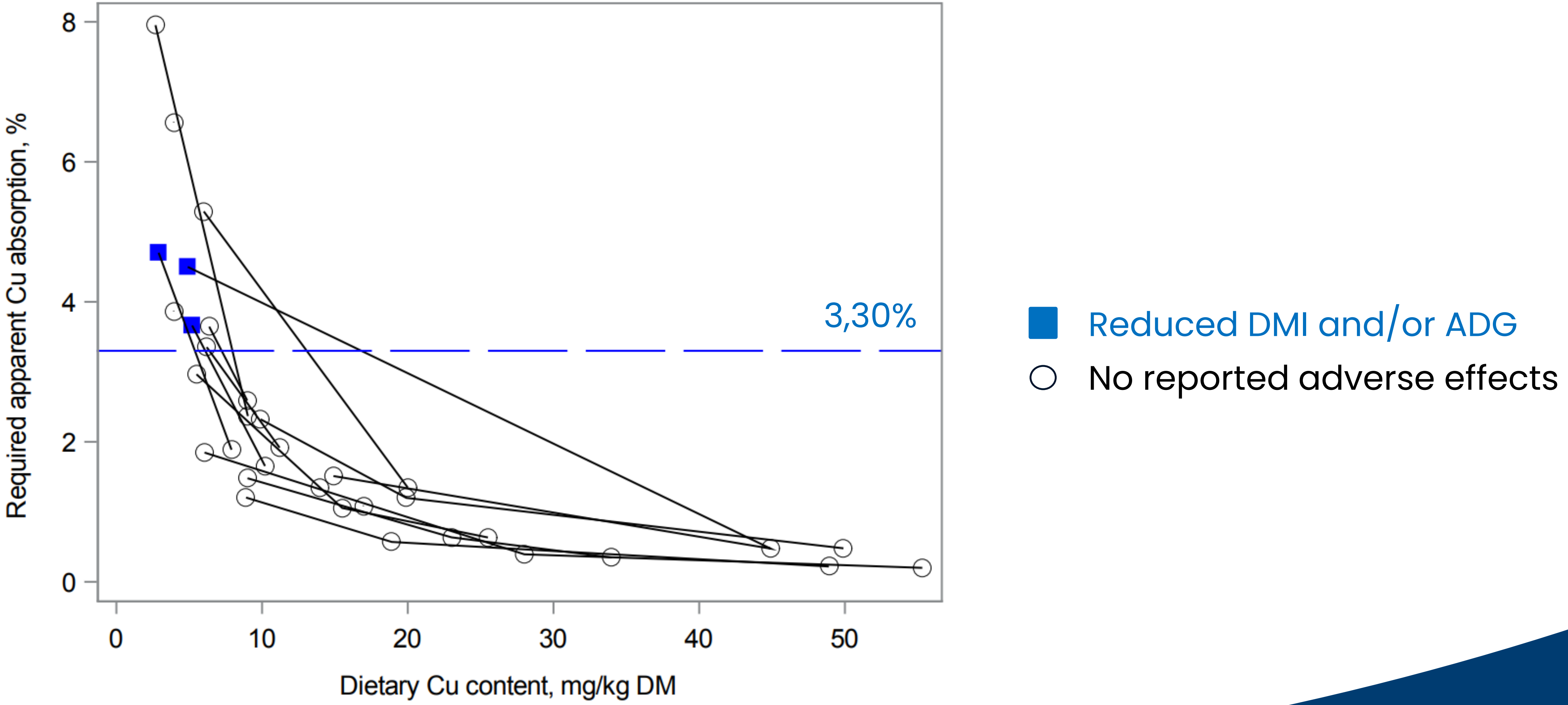
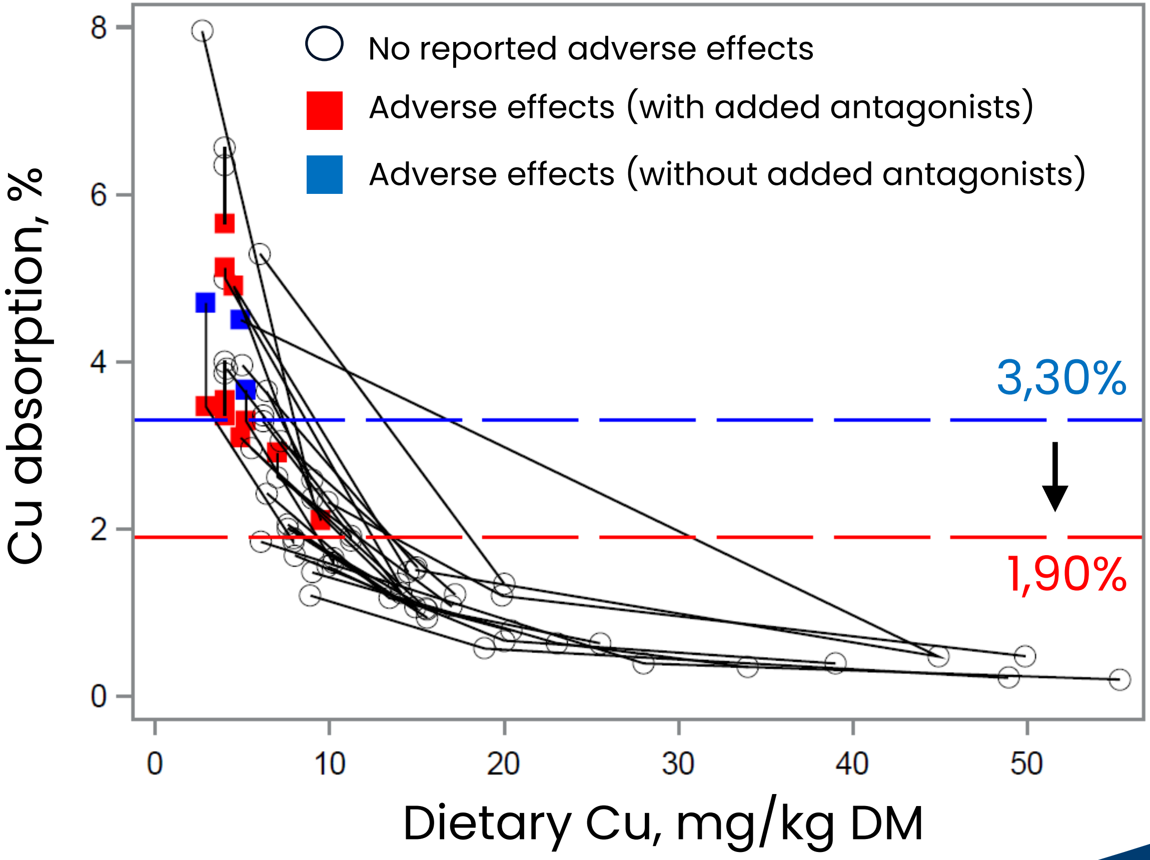
Highest Cu absorption compatible with optimal performance

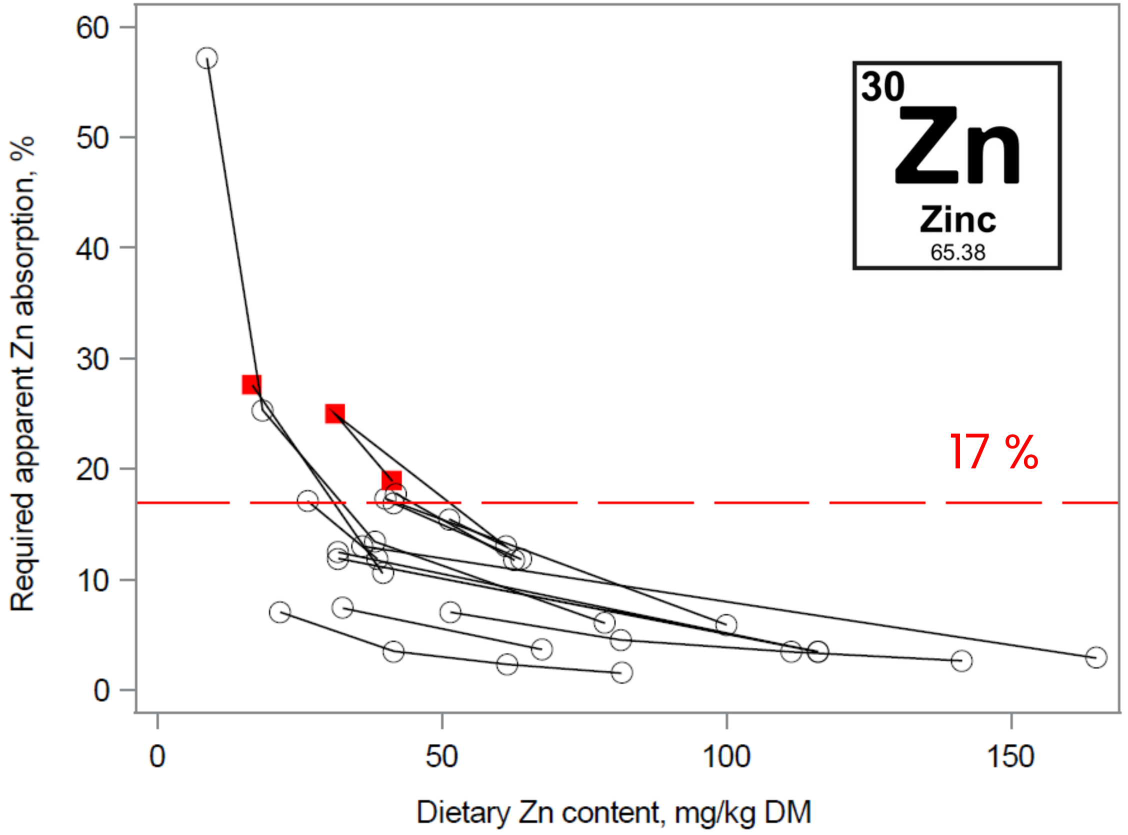


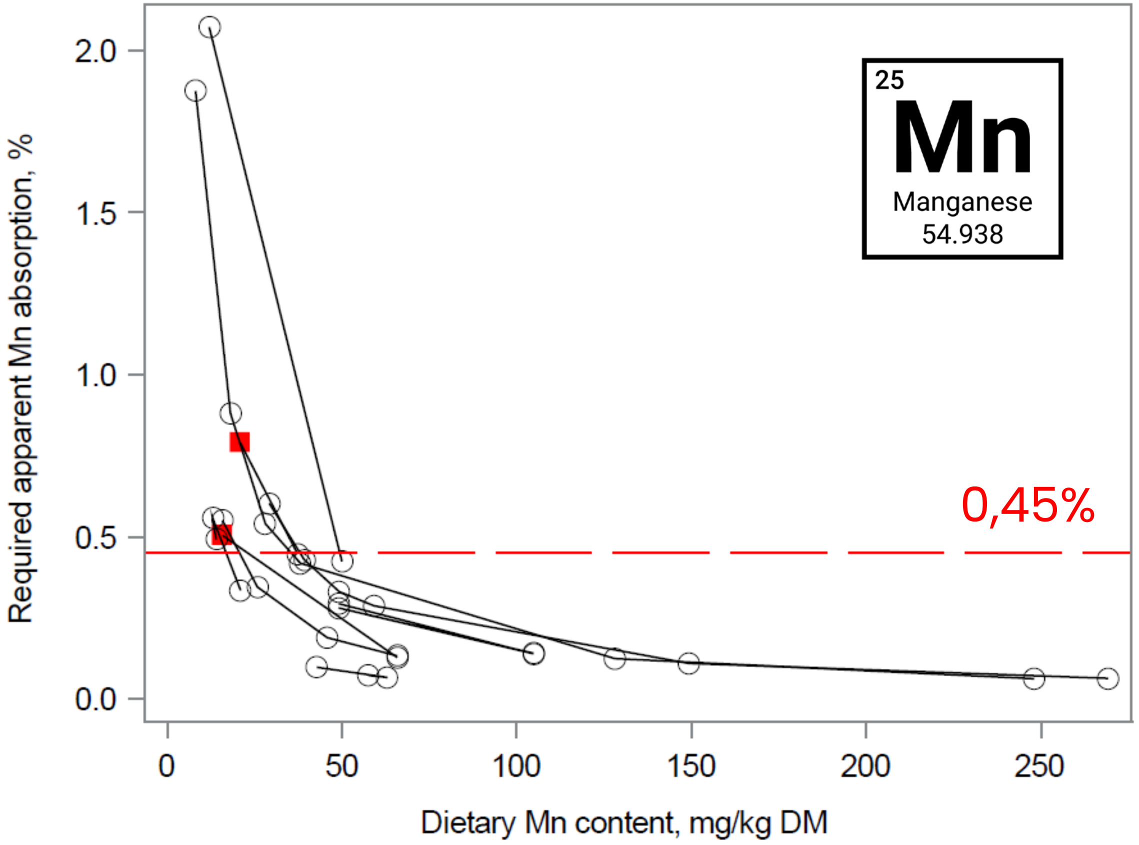
Coping with exceptions – High level of dietary Mo



Left Figure from Suttle, 1983

Highest Zn and Mn absorption compatible with optimal performance

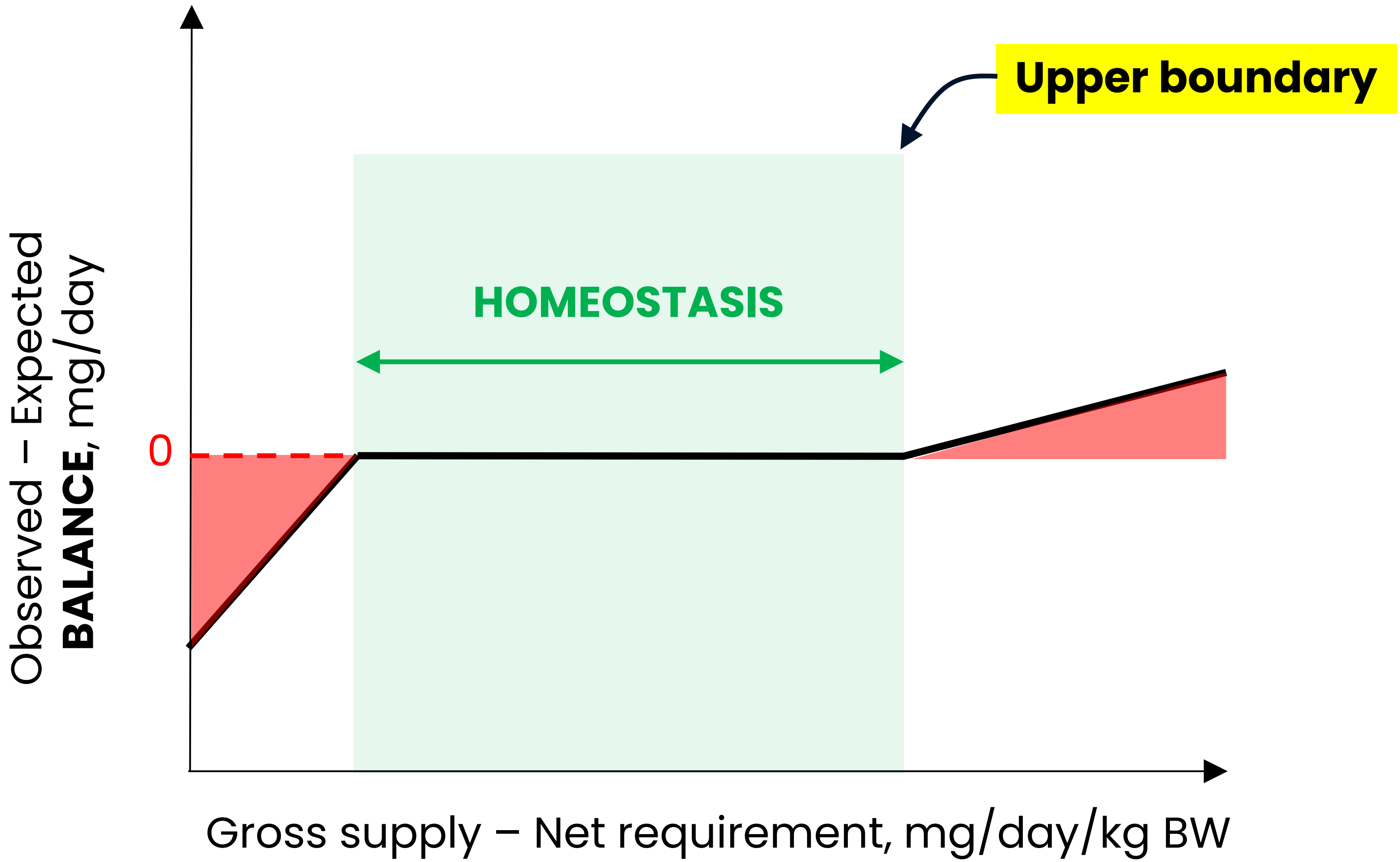




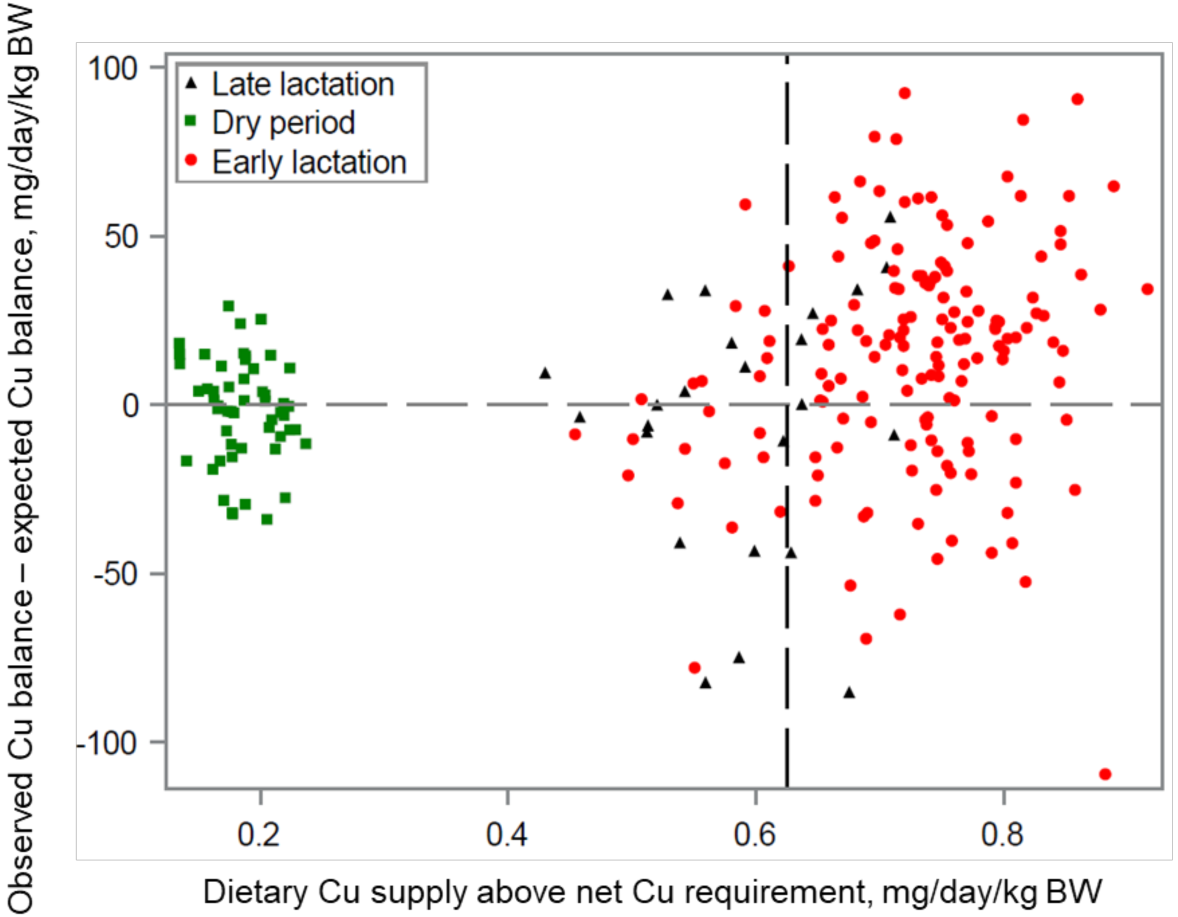
○ No reported adverse effects

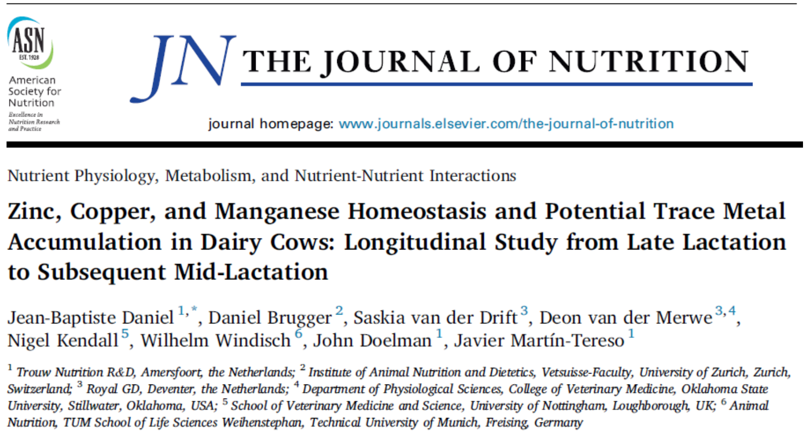
■ Adverse effects

Defining upper boundaries of regulation



The upper boundaries for Cu





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Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

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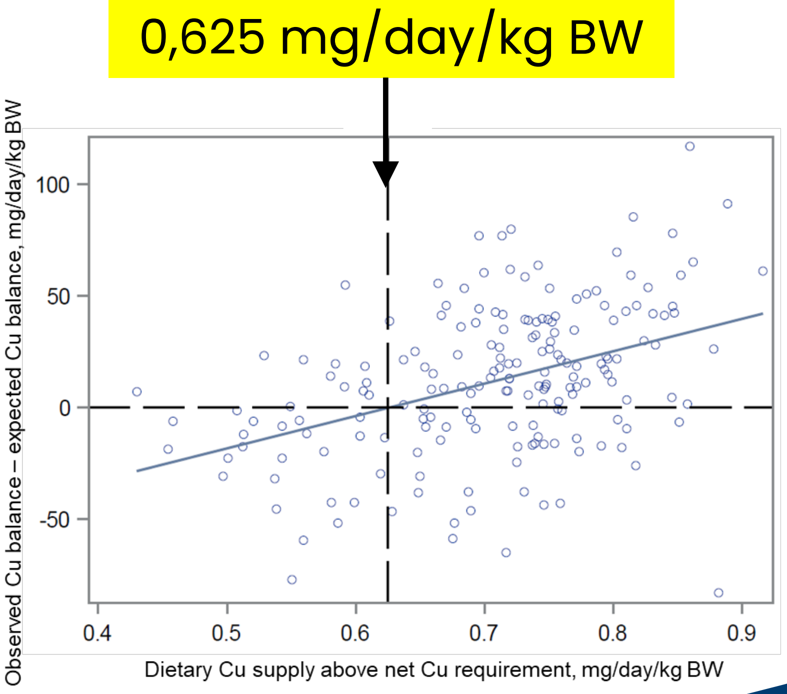

Daniel et al., 2023

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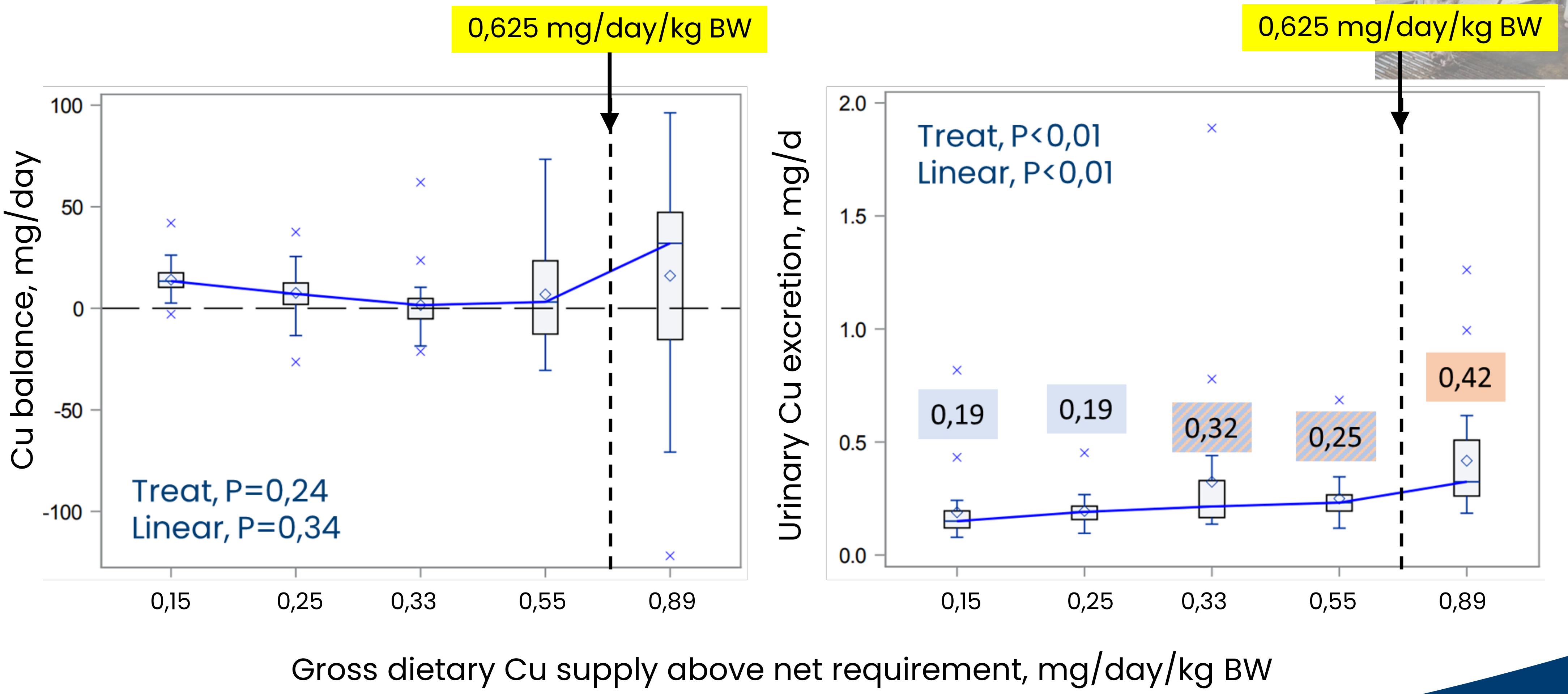
Substantiation of upper limit of adequacy for Cu supply



Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

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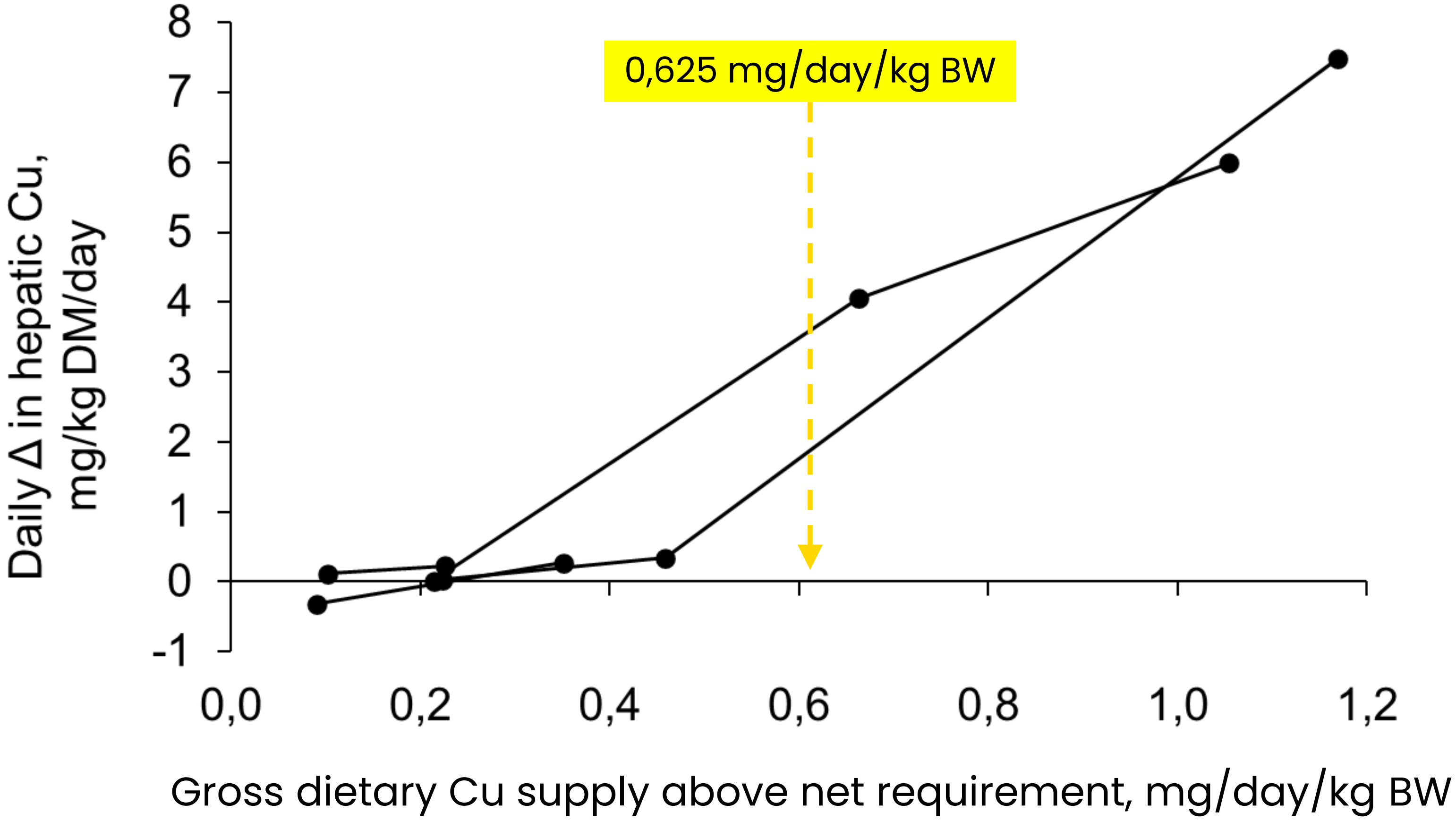

Publications used

Ward and Spears, 1997 (n=2)

Engle et al., 2000 (n=3)

Engle and Spears, 2000 (n=3)

Balemi et al., 2010 (n=2)

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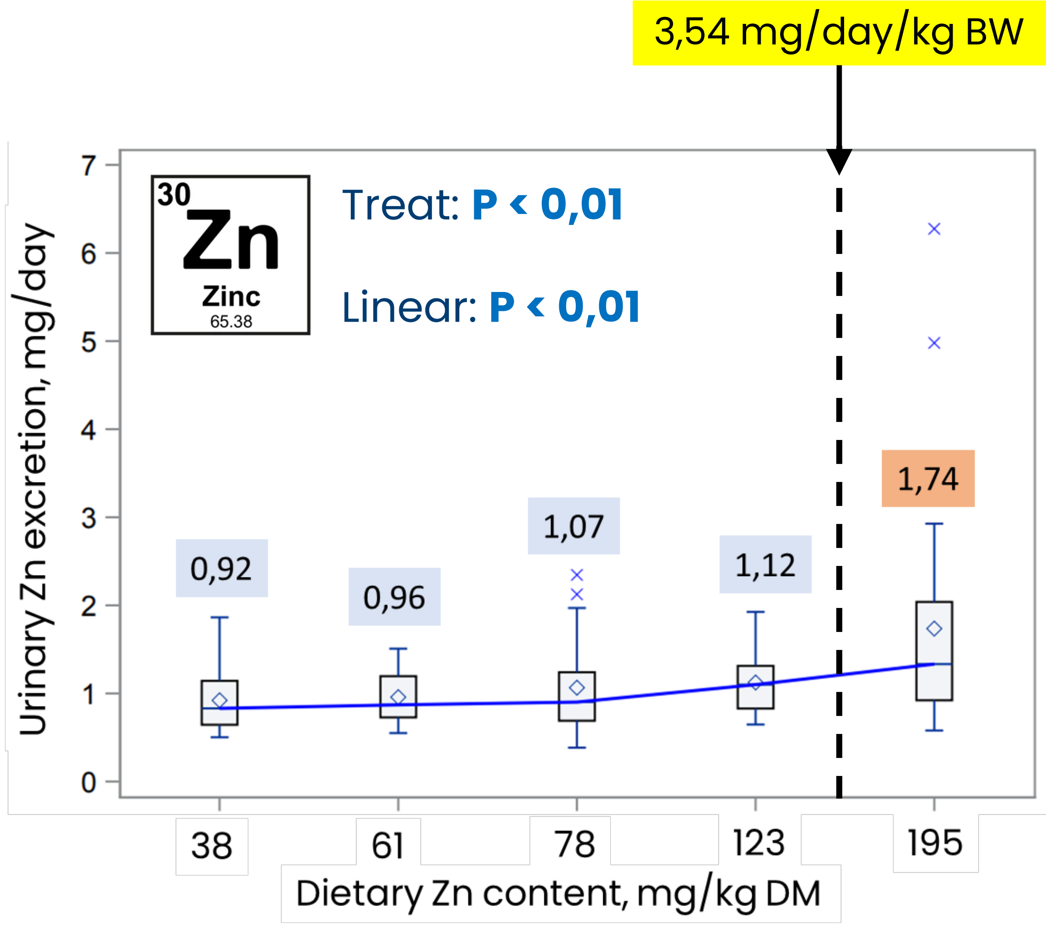
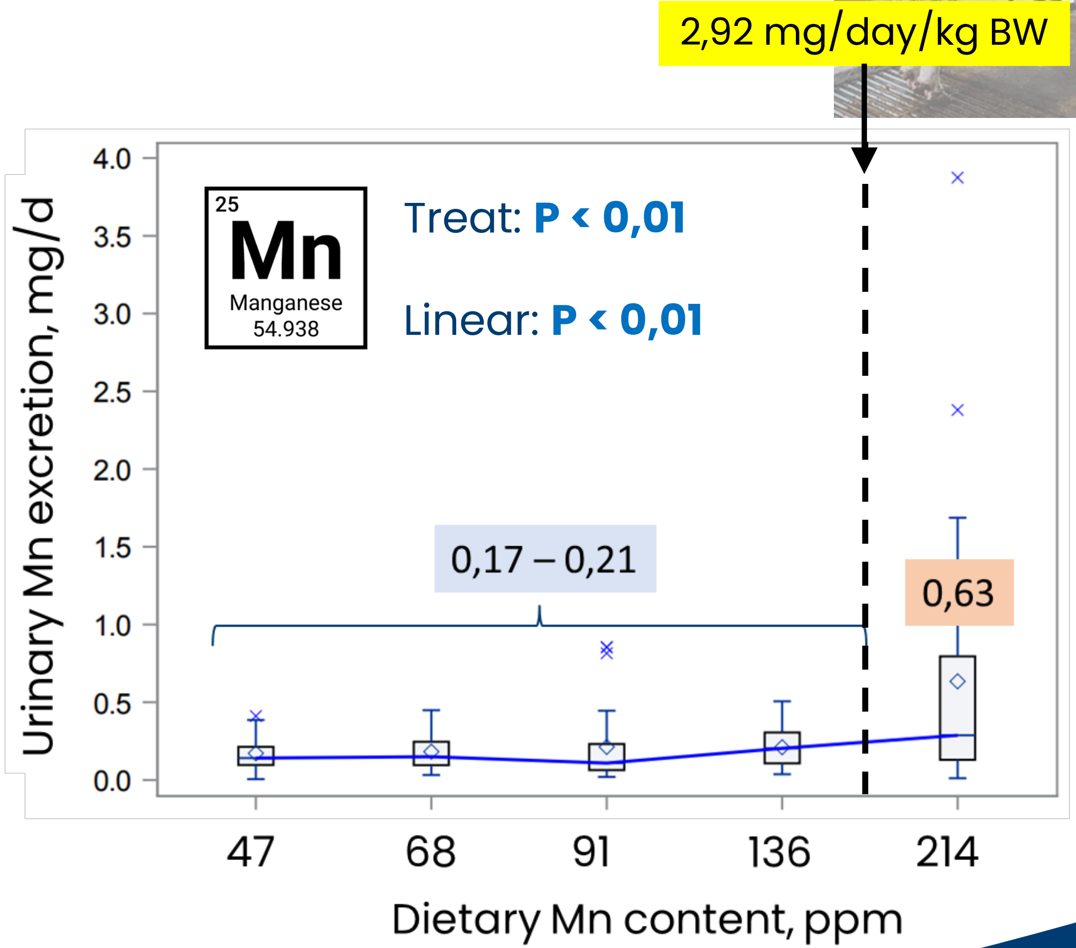
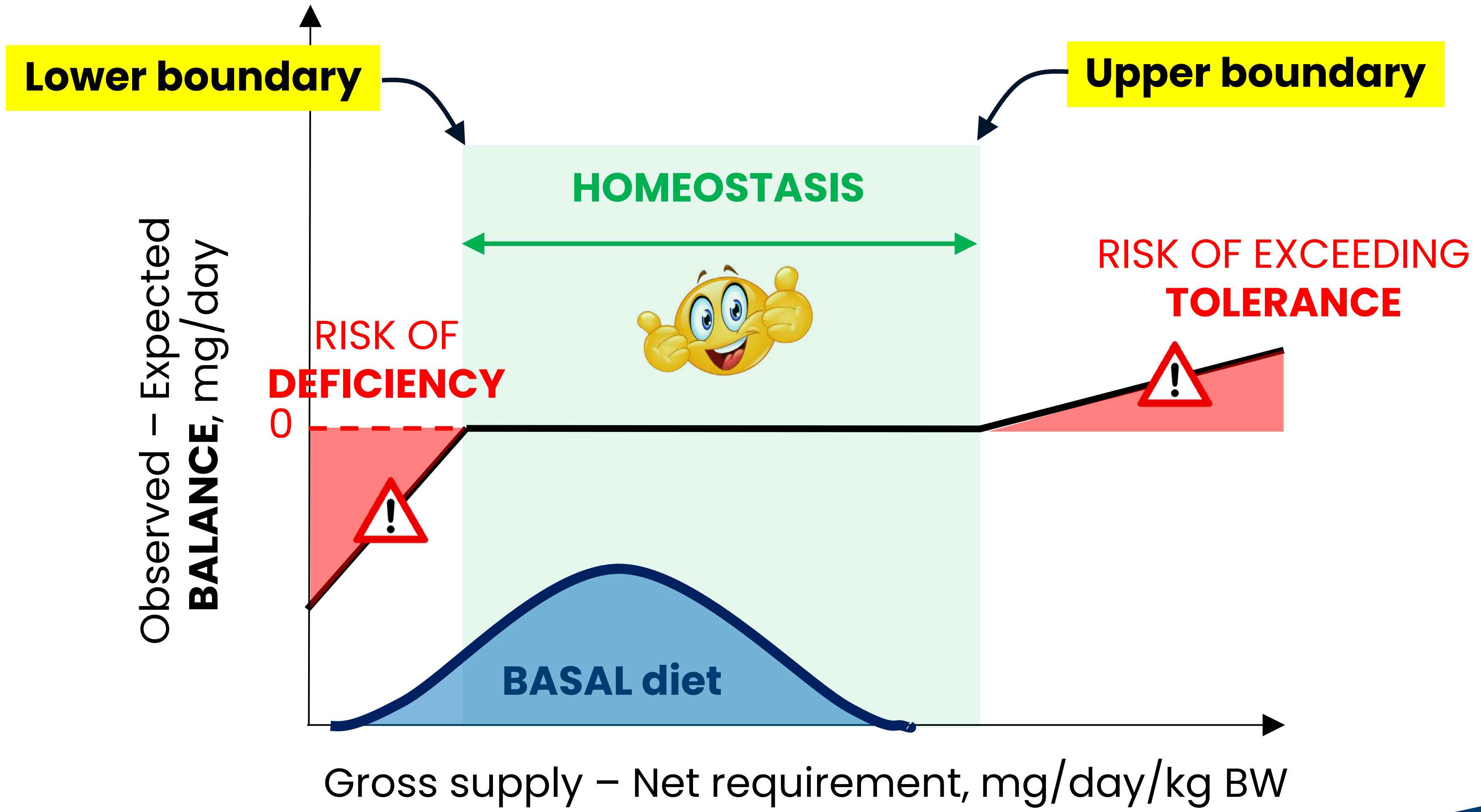
Upper boundaries for Zn and Mn





Daniel and Martín-Tereso, unpublished

Quantifying the risk of inadequate trace metal supply



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Simulating the probability density function of supply

Grass forages	
Cu	12,0 ± 7,0
Zn	26,5 ± 12,8
Mn	38,1 ± 20,8

Corn silage	
Cu	8,1 ± 4,4
Zn	30,8 ± 21,5
Mn	57,3 ± 40,0

Concentrate	
Cu	8,9 ± 1,0
Zn	48,7 ± 5,7
Mn	48,8 ± 7,8

Adams et al., 1974
Feedipedia

Remaining %DM
Random
(0% to 100% CS)

47 ± 13 % DM
Daniel et al., 2016

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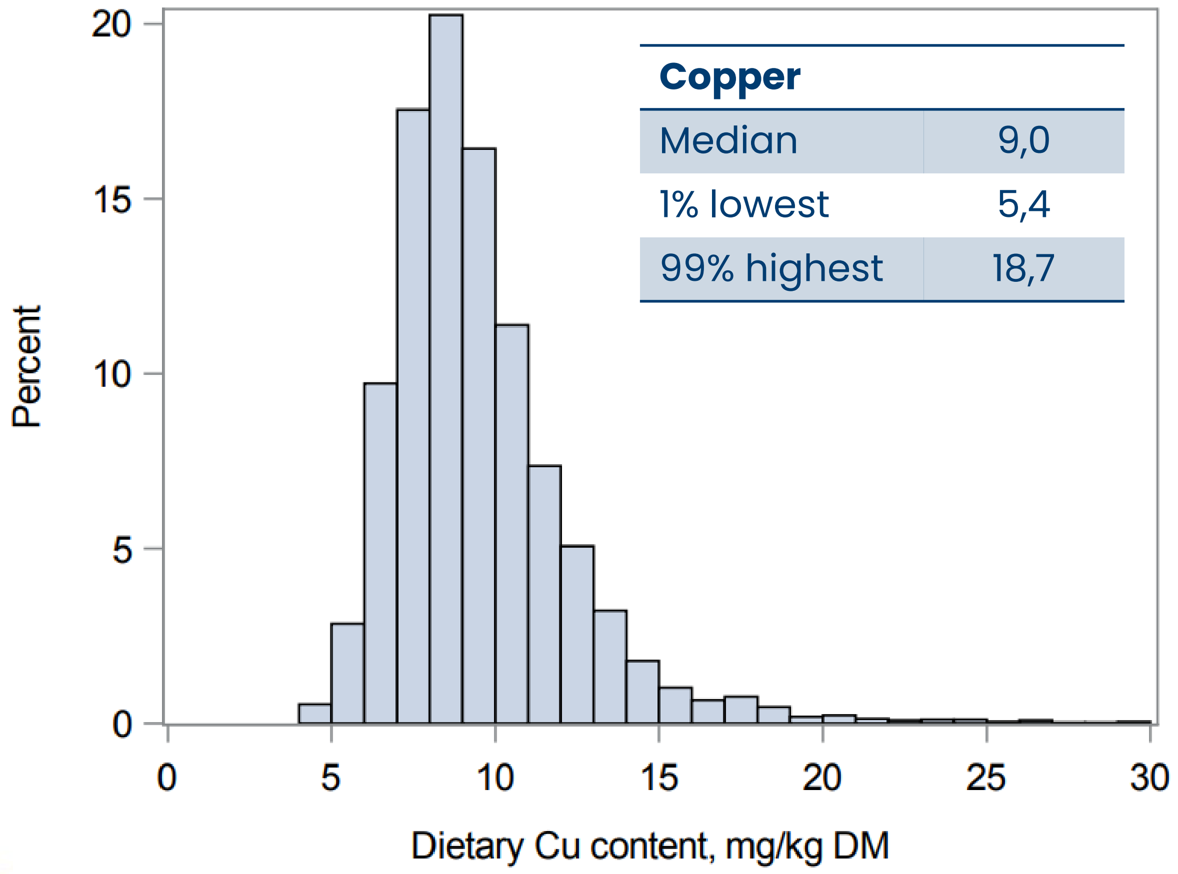
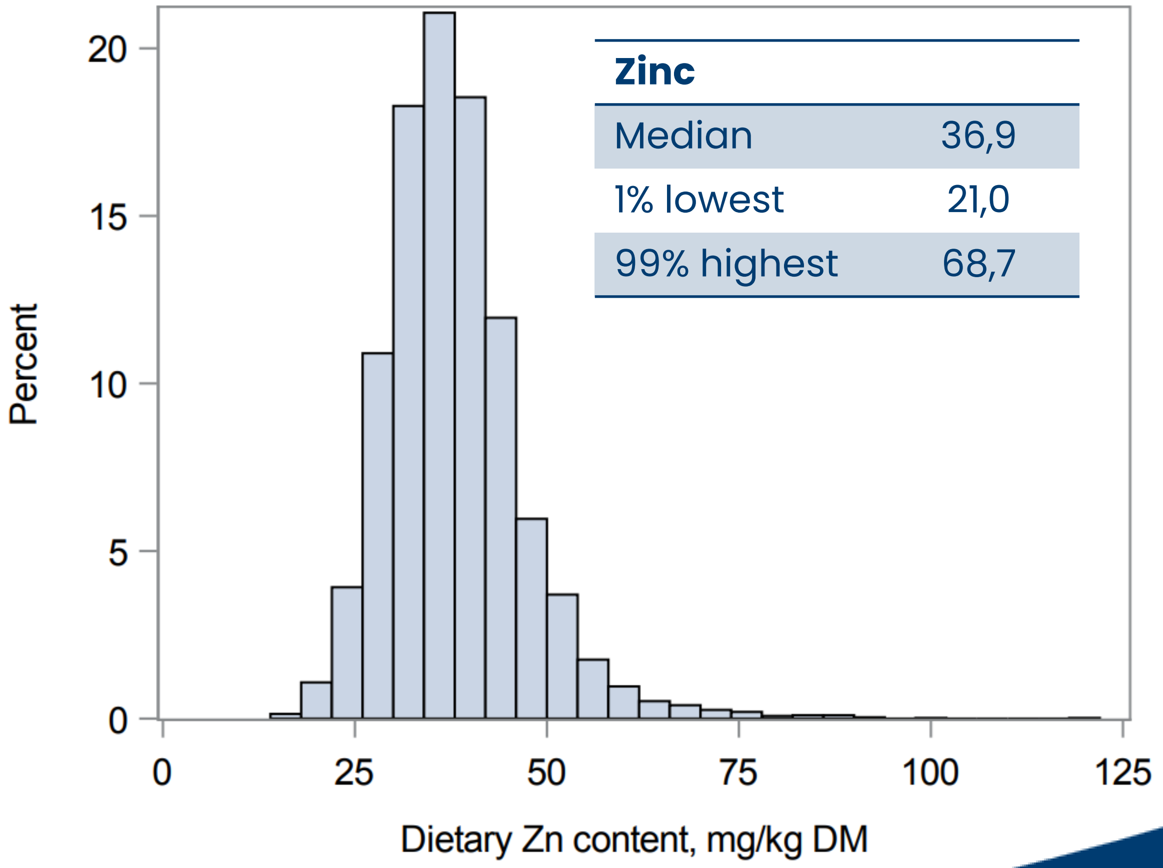
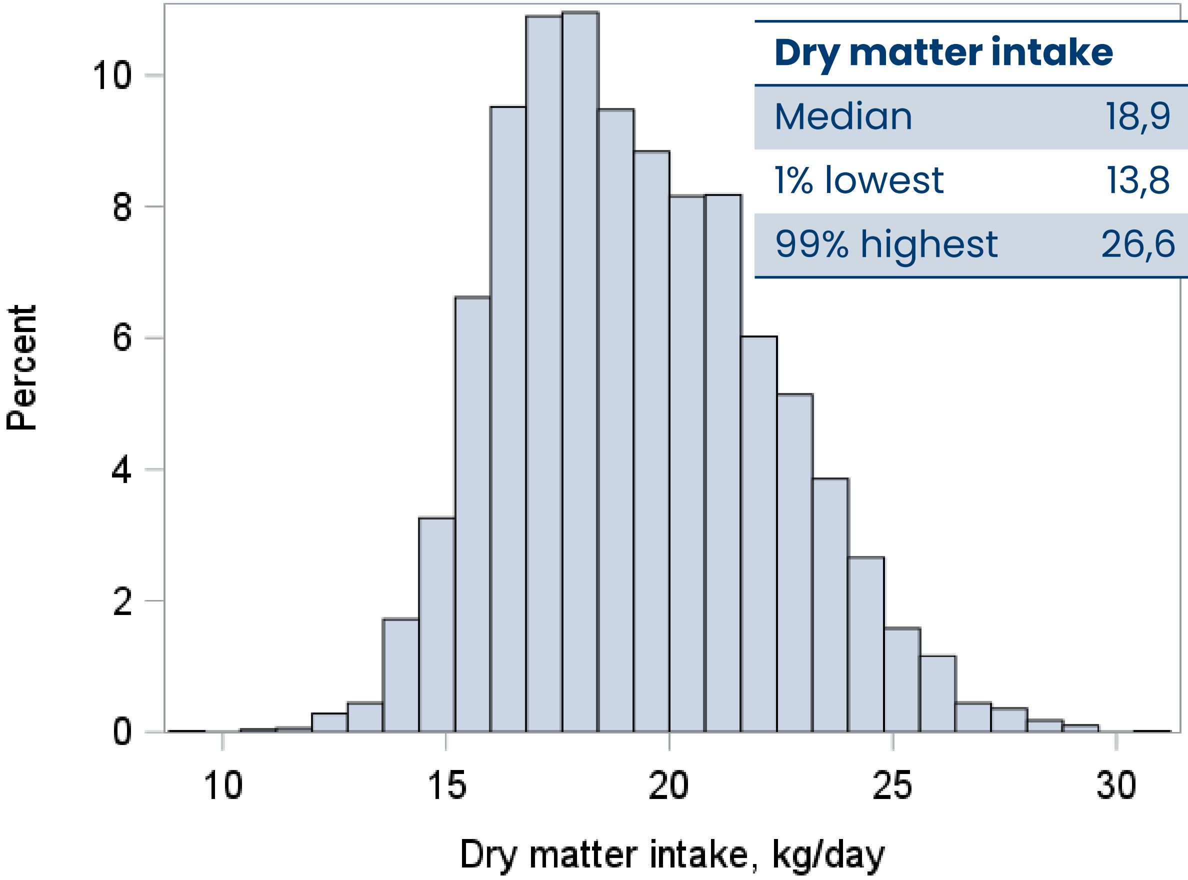
Modeling native dietary concentration

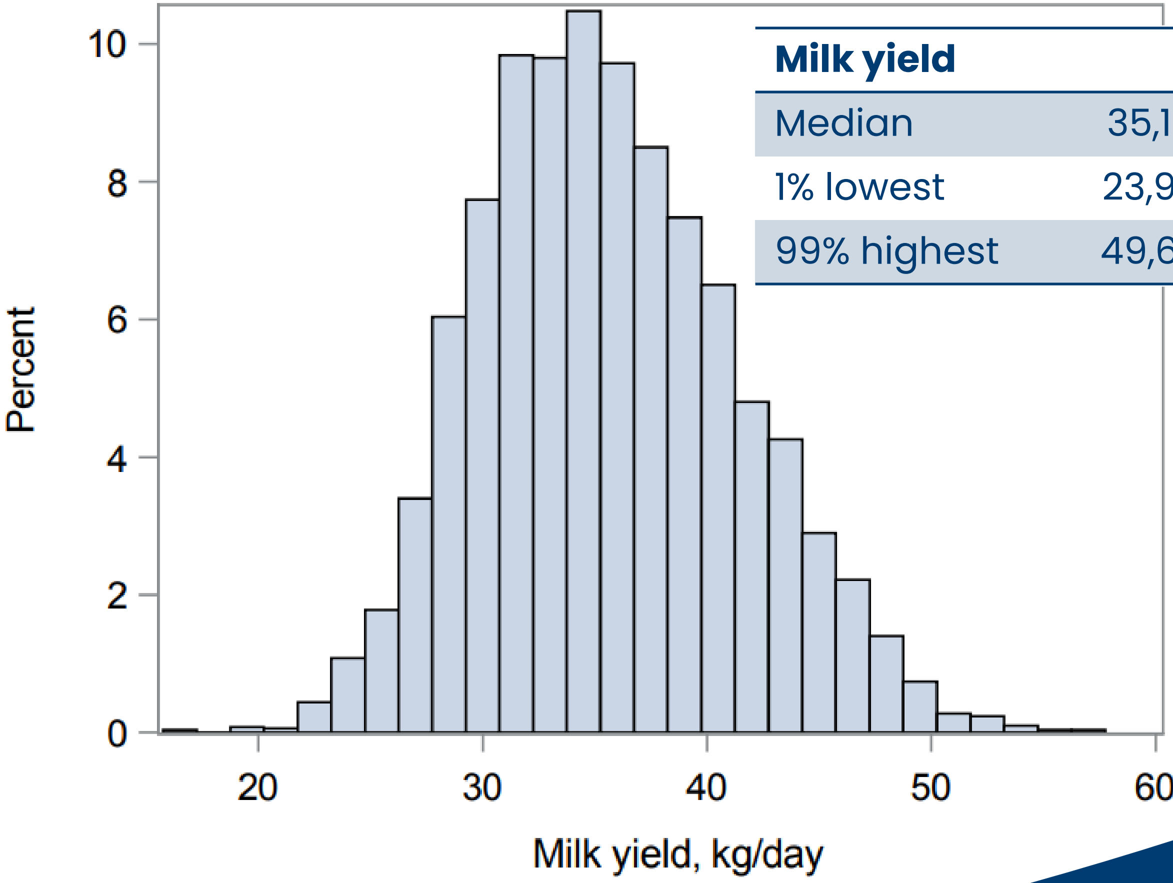




Modeling animal diversity



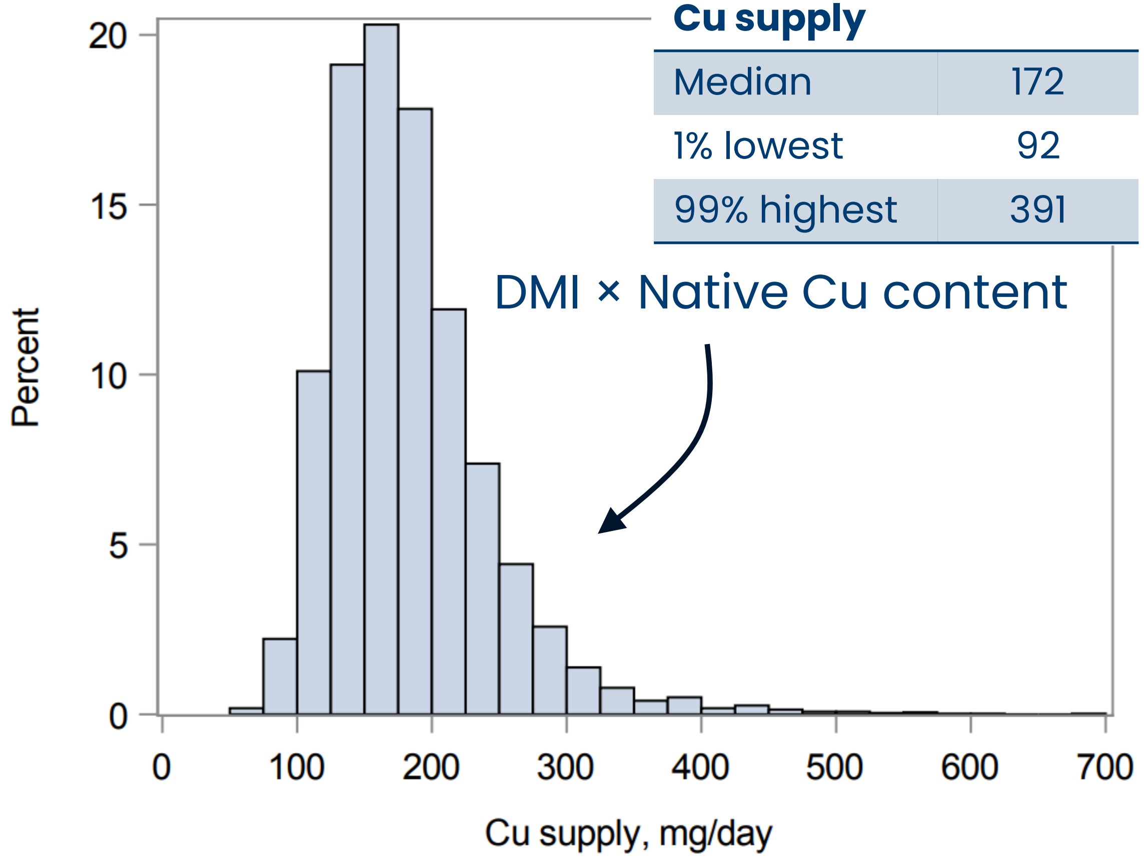
Dry matter intake	
Median	18,9
1% lowest	13,8
99% highest	26,6



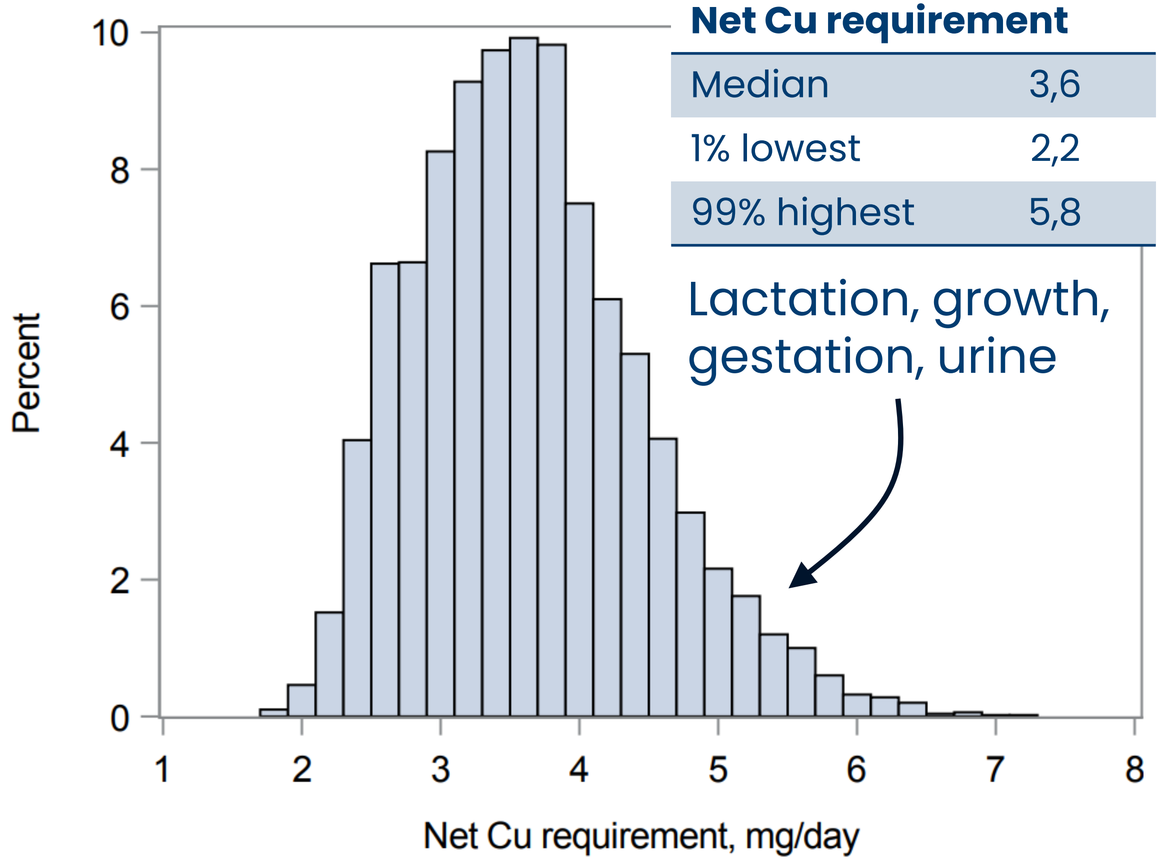
Milk yield	
Median	35,1
1% lowest	23,9
99% highest	49,6

30% primiparous and 70% multiparous ; Mean (±SD) from meta-analysis of Husnain and Santos, 2019

Modeling trace metal supply and requirement



Cu supply	
Median	172
1% lowest	92
99% highest	391



Net Cu requirement	
Median	3,6
1% lowest	2,2
99% highest	5,8

Apparent absorption efficiency for <u>LOWER boundary</u>

Gross supply above net requirement for <u>UPPER boundary</u>

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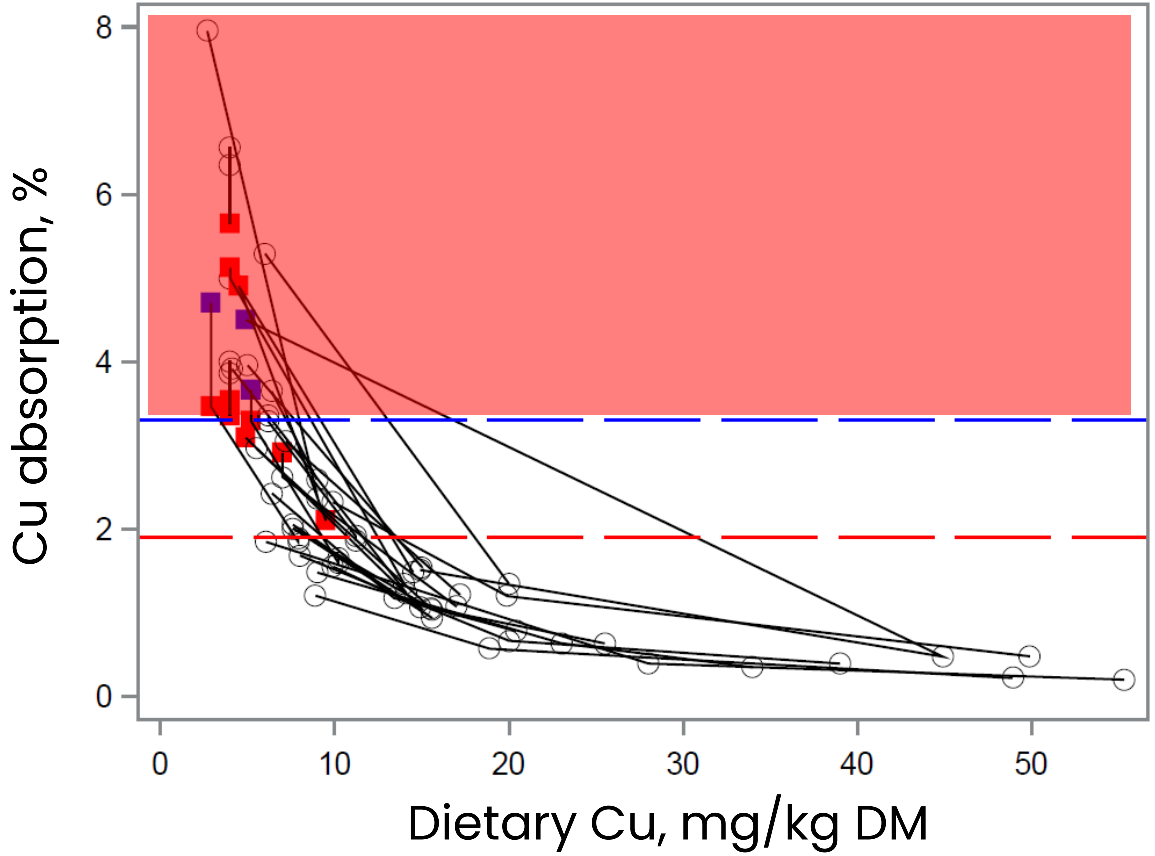
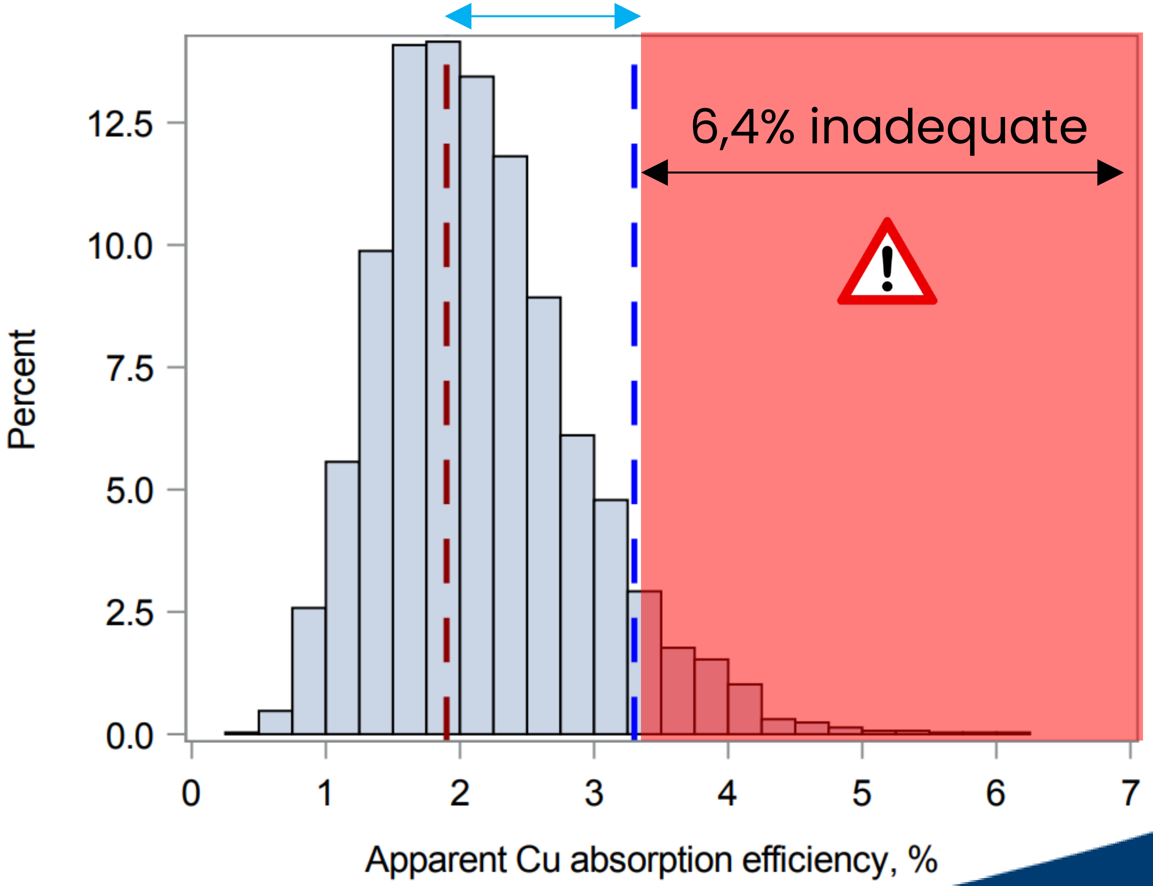
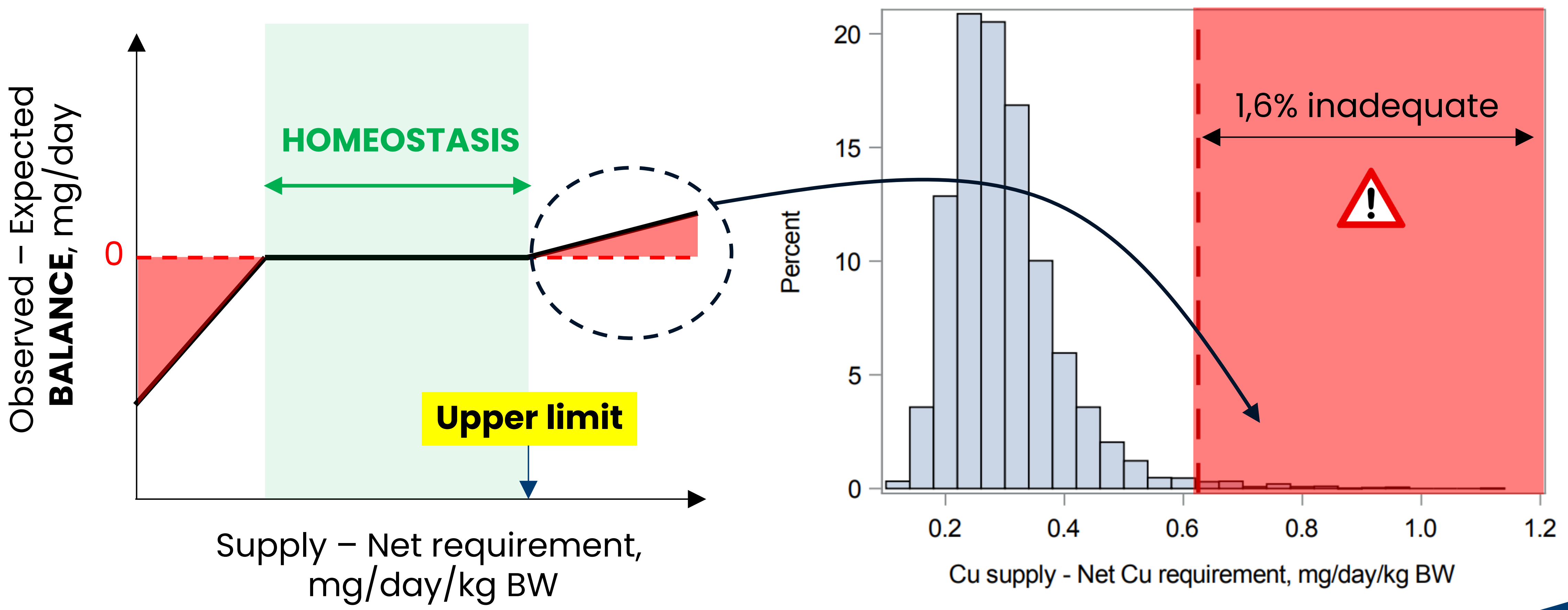
Probability that supply is below LOWER boundary



Adequate unless high antagonists



Probability that supply is above UPPER boundary



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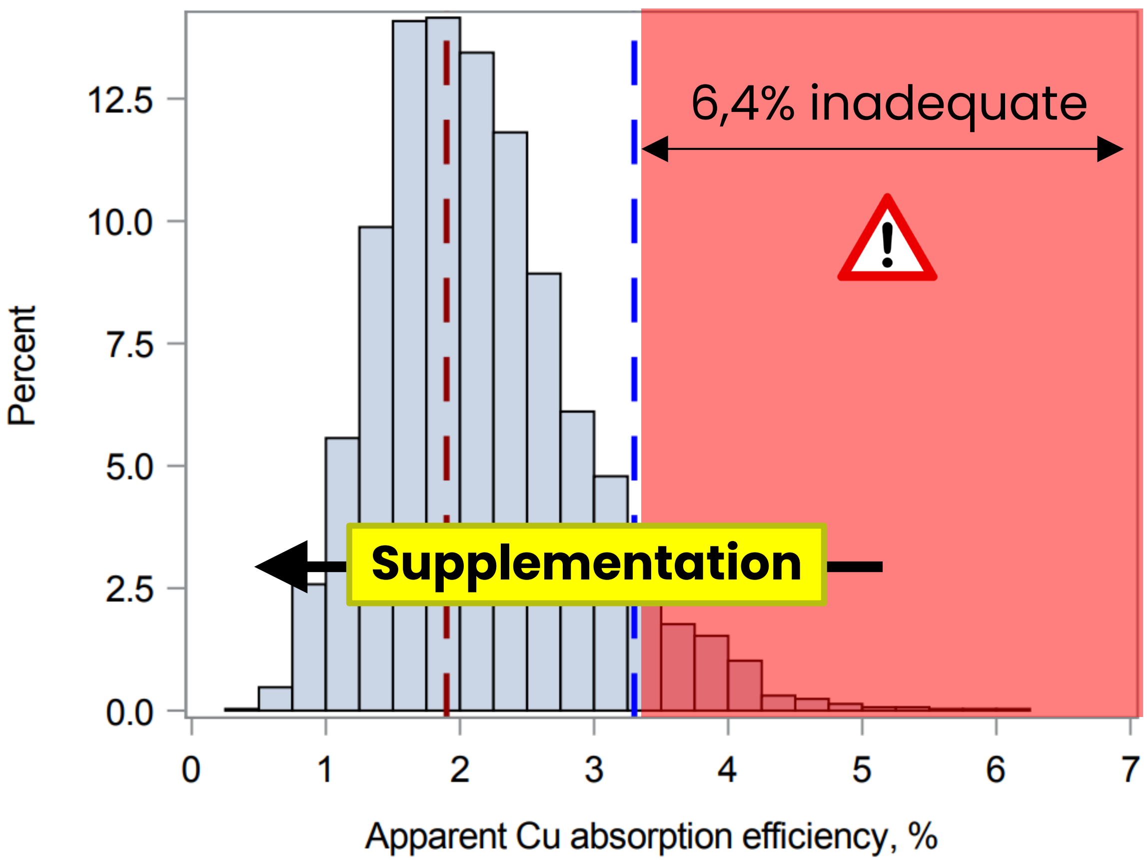
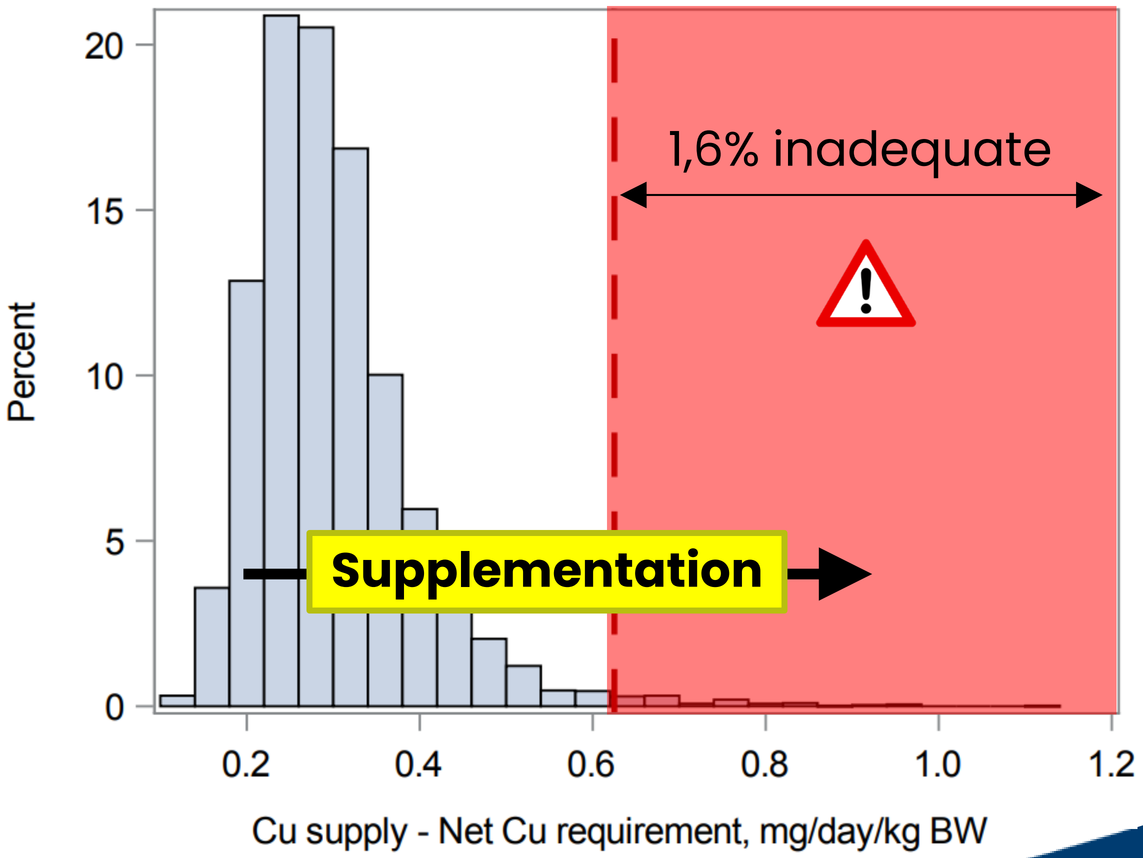
Impact of supplemental feeding strategy

RISK OF **DEFICIENCY**

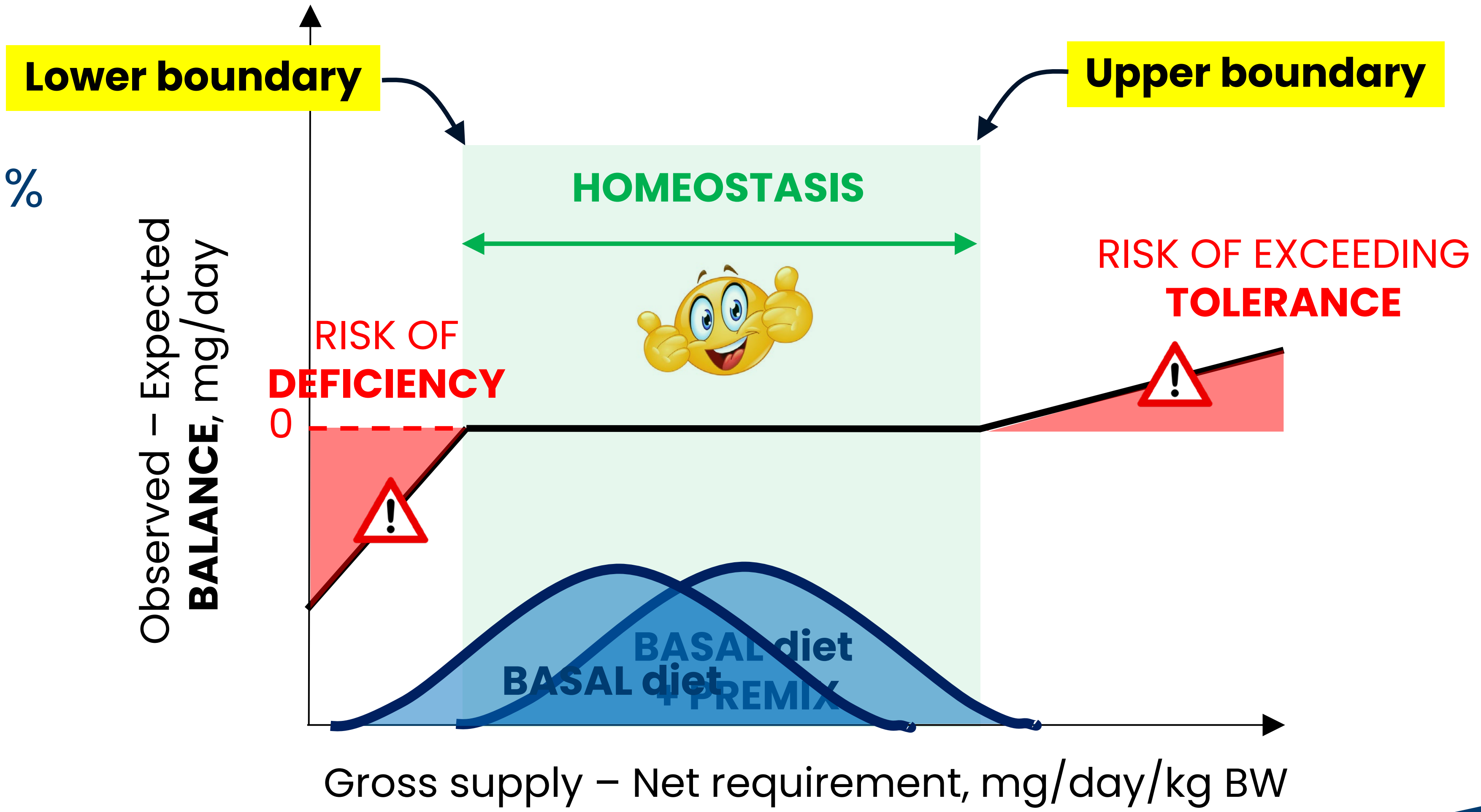


RISK OF EXCEEDING **TOLERANCE**



Defining confidence interval of supplementation

Less than 1%
BELOW



Less than 5%
ABOVE

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Optimal ranges of supplemental Cu (in ppm)

29
Cu
Copper
63.55

Boundaries of adequacy, ppm

	LOWER limit	UPPER limit
Growing heifers (4 to 20 mo.)	2	8
Prepartum heifers (0 to -3 mo. prior to 1^{st} calving)	5	22
Lactating cows	2	4
Dry-cows (0 to -3 mo. prior to 2^{nd} (or >) calving)	3	17

Less than 1% < lower limit AND less than 5% > UPPER limit

Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

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Optimal ranges of supplemental Cu (in ppm)

29
Cu
Copper
63.55

Boundaries of adequacy, ppm

	LOWER limit	UPPER limit
Growing heifers (4 to 20 mo.)	2 (8*)	8
Prepartum heifers (0 to -3 mo. prior to 1st calving)	5 (13*)	22
Lactating cows	2 (8*)	4
Dry-cows (0 to -3 mo. prior to 2nd (or >) calving)	3 (10*)	17

Less than 1% < lower limit AND less than 5% > UPPER limit

*Assuming high antagonists across **ALL** diets

Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

Optimal ranges of supplemental Zn (in ppm)

Boundaries of adequacy, ppm

	LOWER limit	UPPER limit
Growing heifers (4 to 20 mo.)	11	82
Prepartum heifers (0 to -3 mo. prior to 1st calving)	3	156
Lactating cows	41	57
Dry-cows (0 to -3 mo. prior to 2nd (or >) calving)	0	128

Less than 1% < lower limit AND less than 5% > UPPER limit

Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

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Optimal ranges of supplemental Mn (in ppm)

25
Mn
Manganese
54.938

Boundaries of adequacy, ppm

	LOWER limit	UPPER limit
Growing heifers (4 to 20 mo.)	15	34
Prepartum heifers (0 to -3 mo. prior to 1st calving)	1	95
Lactating cows	0	18
Dry-cows (0 to -3 mo. prior to 2nd (or >) calving)	0	76

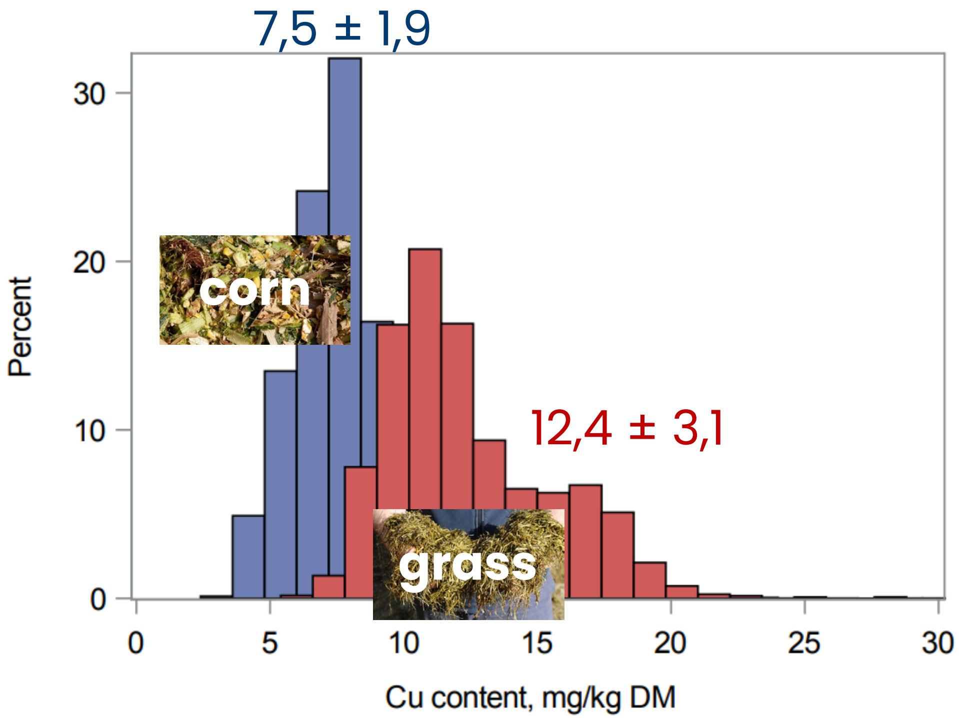
Less than 1% < lower limit AND less than 5% > UPPER limit

Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

Evaluation with local practical dataset

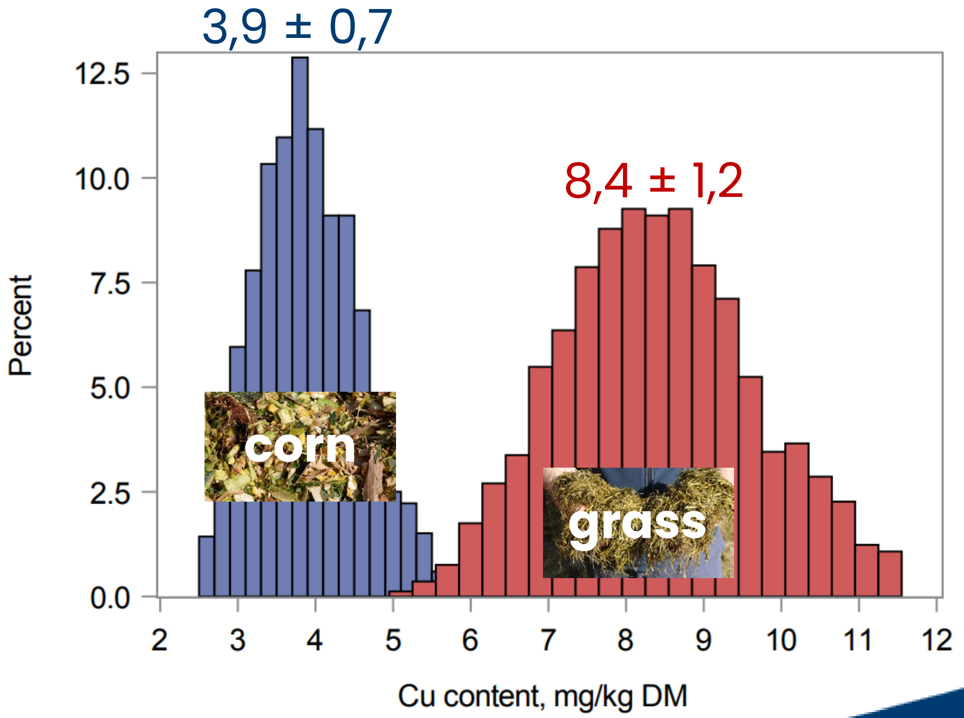
Québec, Canada

Diet composition (% DM)	
Corn silage	37,1 ± 11,9
Grass silage	32,9 ± 14,0
Concentrate	31,8 ± 10,4



Noord-Brabant, the Netherlands

Diet composition (% DM)	
Grass silage	33,4 ± 7,0
Corn silage	29,8 ± 6,2
Concentrate	29,5 ± 8,8



Left: XRF analysis, TN Canada ; **Right**: Eurofins analysis, Kempenshof

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Optimal ranges of supplemental Cu, Zn, and Mn (in ppm)

Boundaries of adequacy, ppm

29
Cu
Copper
63.55

	Lower limit	Upper limit
Literature data	2 (8*)	4
Québec (1248 farms)	0 (5*)	4
Kempenshof (individual cow data)	2 (9*)	7

30
Zn
Zinc
65.38

	Lower limit	Upper limit
Literature data	41	57
Québec (1248 farms)	30	57
Kempenshof (individual cow data)	34	46

25
Mn
Manganese
54.938

	Lower limit	Upper limit
Literature data	0	18
Québec (1248 farms)	0	19
Kempenshof (individual cow data)	0	16

Less than 1% < lower limit AND less than 5% > UPPER limit

Lactation

3 ppm Cu

43 ppm Zn

10 ppm Mn

Daniel and Martín-Tereso, Trouw Nutrition R&D, unpublished

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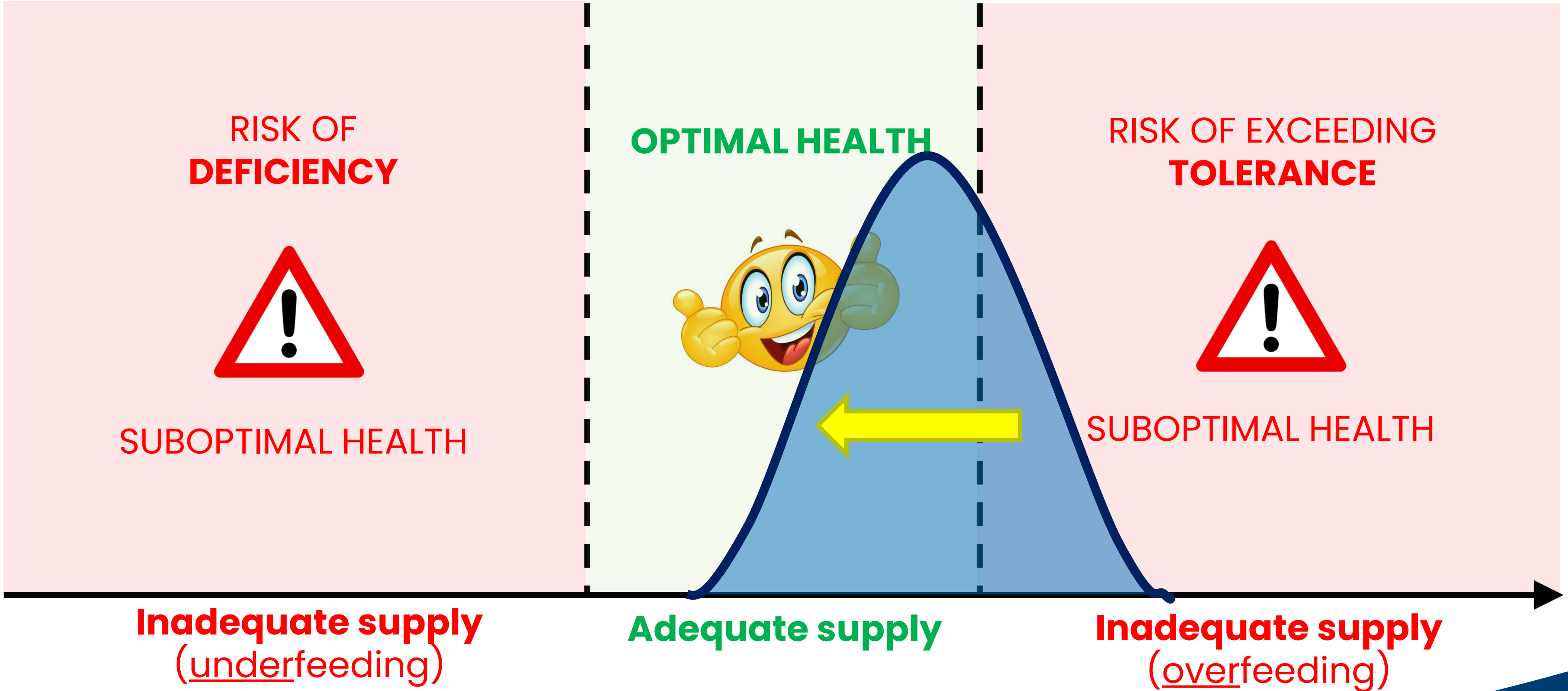
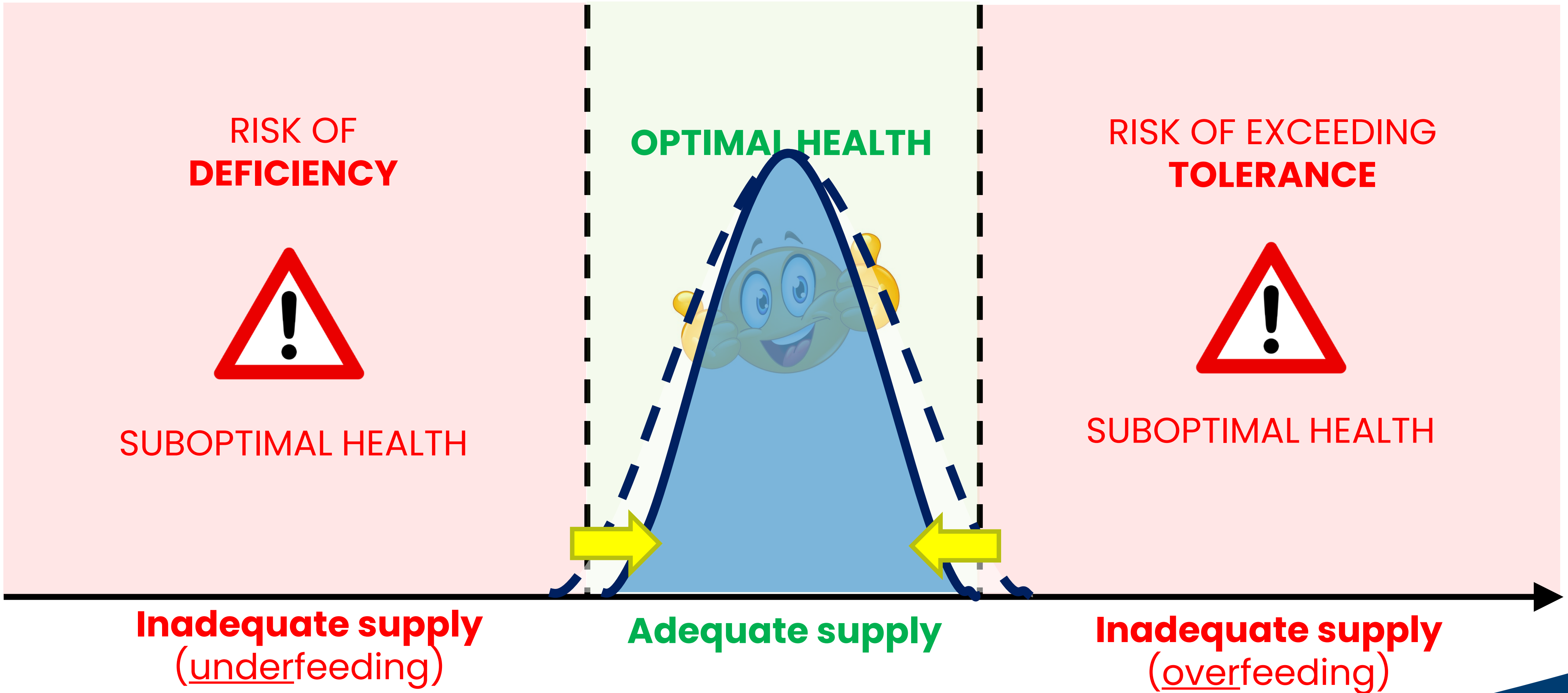
Trace mineral supply and animal health



Trace mineral quality and animal health



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Take home messages

- **Unregulated retention of trace metals** in bovines is a **biological anomaly** induced by supplementation practices and the high DMI of dairy cattle.
- Supplementation guidelines should consider:
    - **Opportunity** of **UP regulation** competence
    - **Risk** of exceeding **DOWN regulation** competence
- These novel guidelines confirm the value of supplementation BUT expose the potential risk of excess supplementation

Adequate trace metal nutrition requires
an accurate definition of supplemental **dose**,
and a **form** of supplementation that support homeostasis

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