STØTTET AF
Mælkeafgiftsfonden

Harper Adams University

Mineral nutrition of dairy cows:

Can you ever have too much of a good thing?

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Getting mineral nutrition right

1. How much should we feed?
2. Are we feeding enough, or too much?
3. What is the effect of over or under-feeding?
4. What about mineral source?

Minerals of most interest

hydrogen 1 **H** 1.0079																	helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122											boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305											aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	ununnium 111 **Uuu** [272]	unumbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

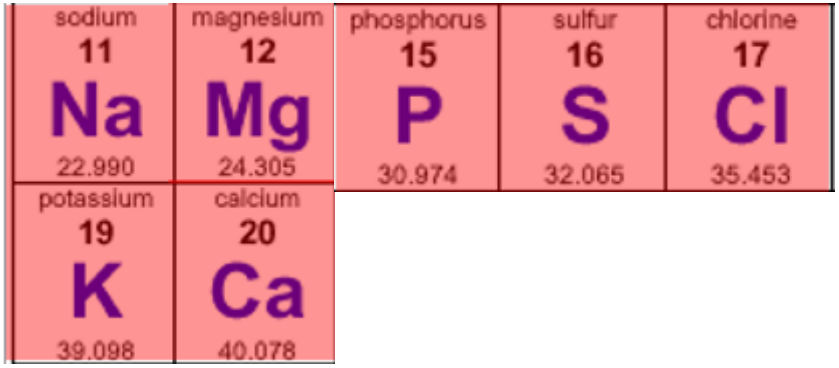
Key:

element name
atomic number
symbol
atomic weight (mean relative mass)

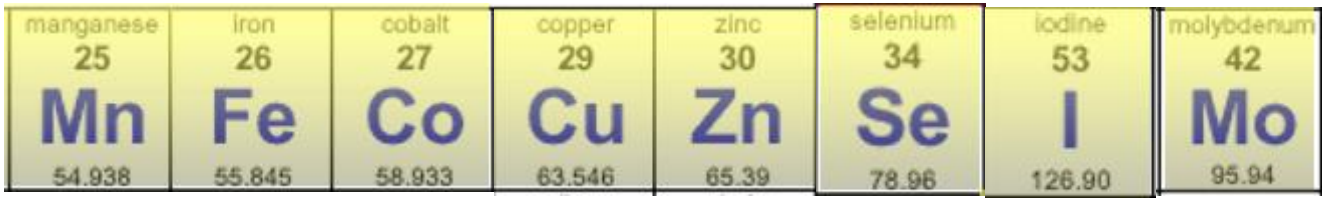
*lanthanoids	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**actinoids	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Minerals of most interest

Major minerals (g/kg)



Trace minerals (mg/kg)



How much minerals should be fed?

Requirements based on the net requirement for:

- Maintenance
- Lactation
- Growth
- Foetus

- Converted to a dietary requirement (per d or per kg DM) by an absorption co-efficient
- Coefficient is low for many minerals (e.g. 5% Cu, 20% Zn)

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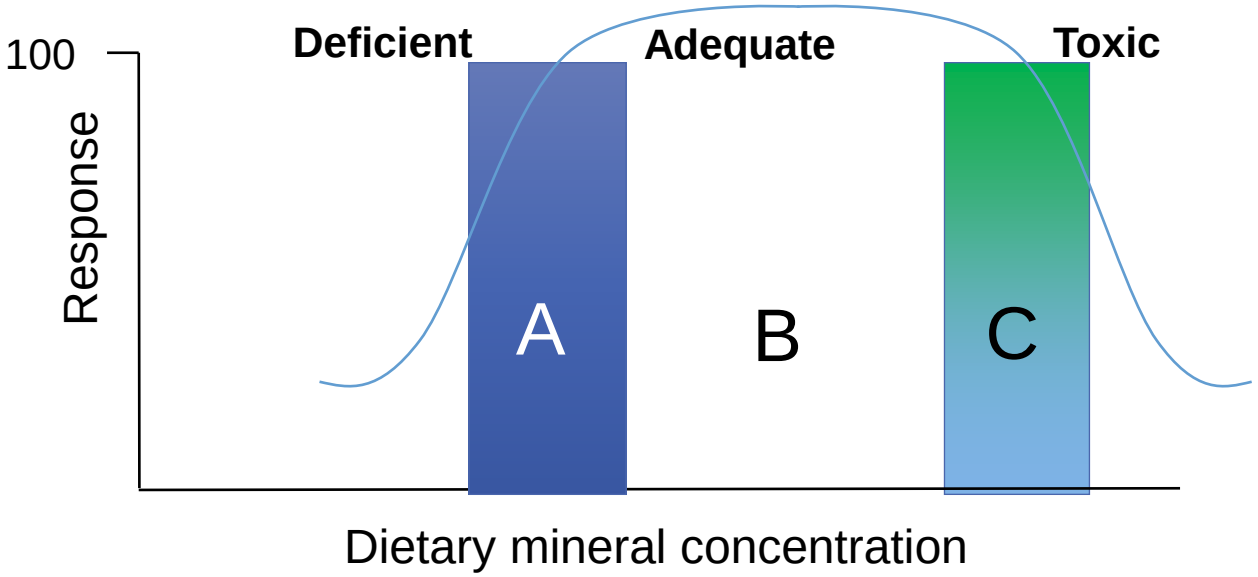
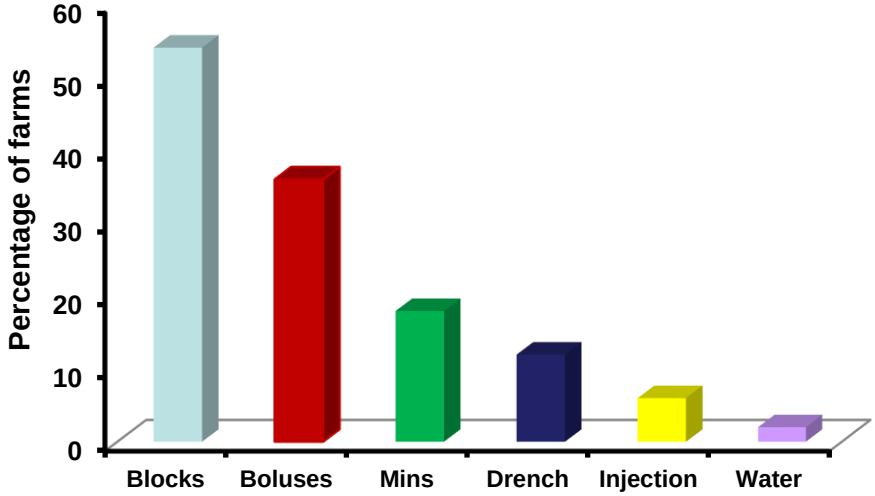


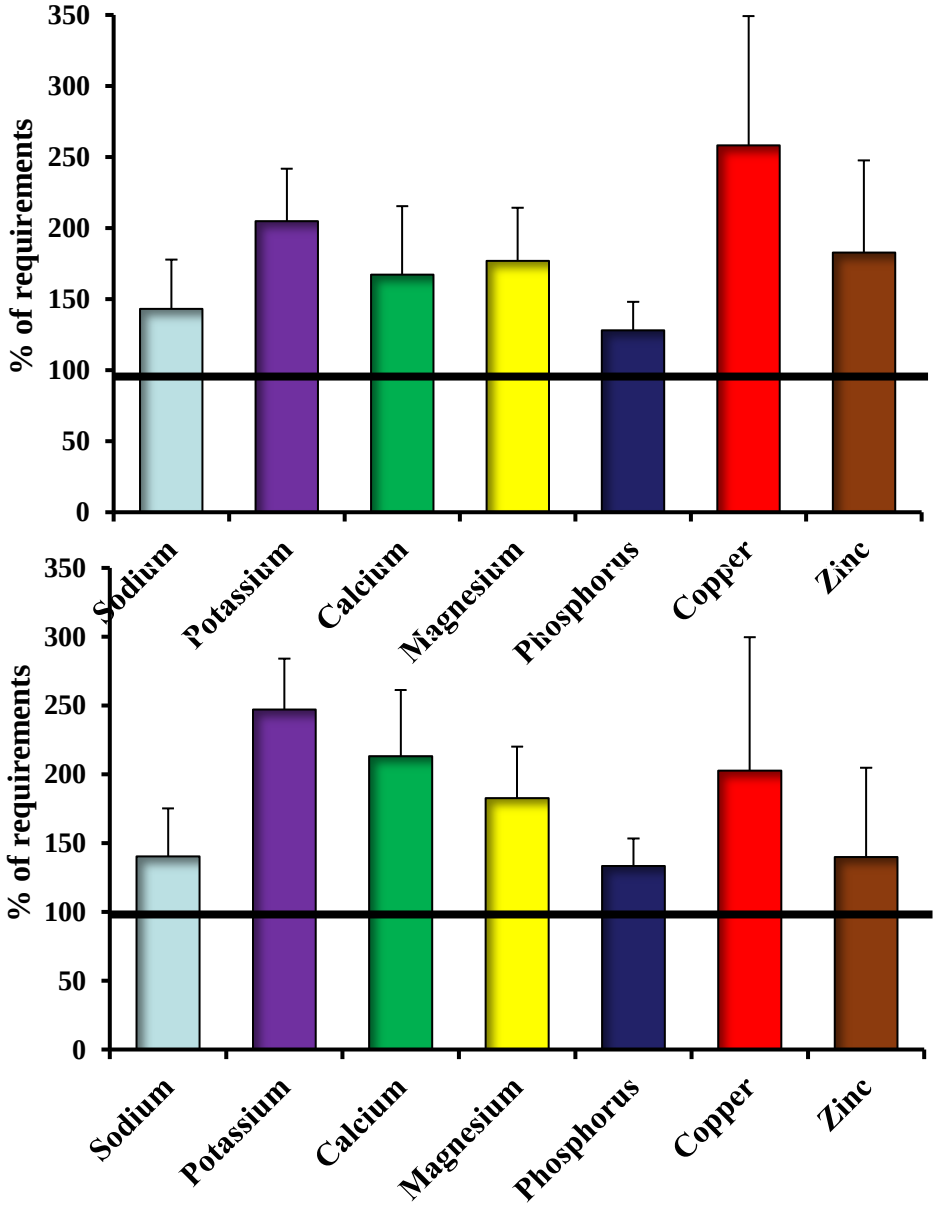
Suttle, 2010

Are we feeding enough, or too much?

- Basal point = NRC (2001/2021); AFRC (1991), ARC (1980), CSIRO (2007)
- 50 herds sampled
- Average herd size = 245 cows and yield of 7982 kg/cow
- Samples taken of TMR for lows and highs, dry, parlour concentrates, forages and water
- Details collected on supplementary mineral sources and levels.



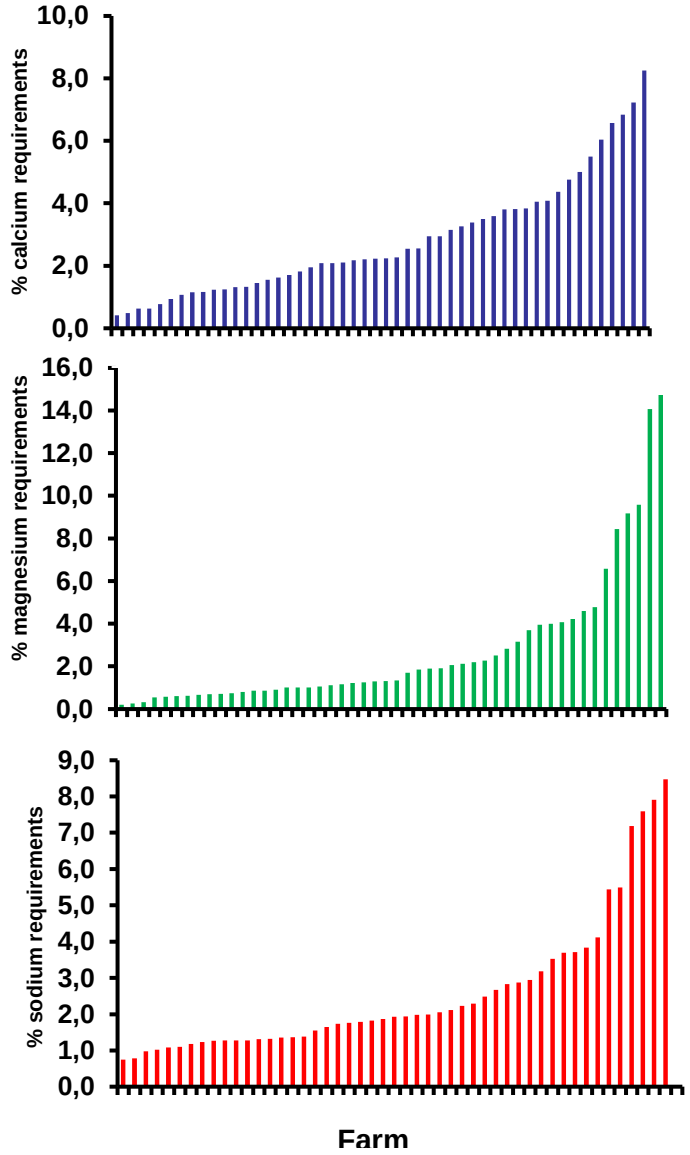
Typical winter mineral feeding levels



Sinclair & Atkins (2015)

Supply of minerals through water

- Mineral content of water varied considerably
- Up to 8% of Ca reqmnts could be through the water
- Up to 15% of Mg could be through the water
- Up to 9% of sodium could be supplied through water



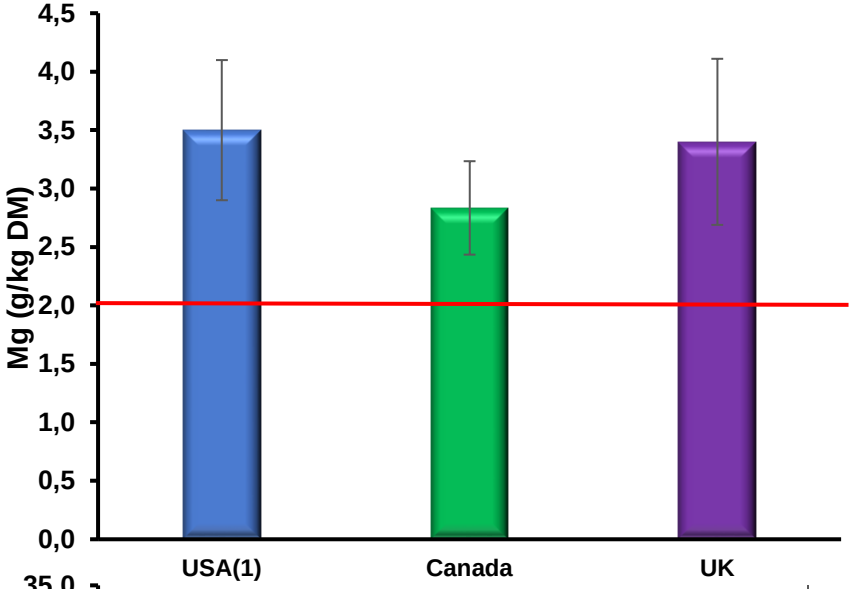
Mean and range for macro minerals

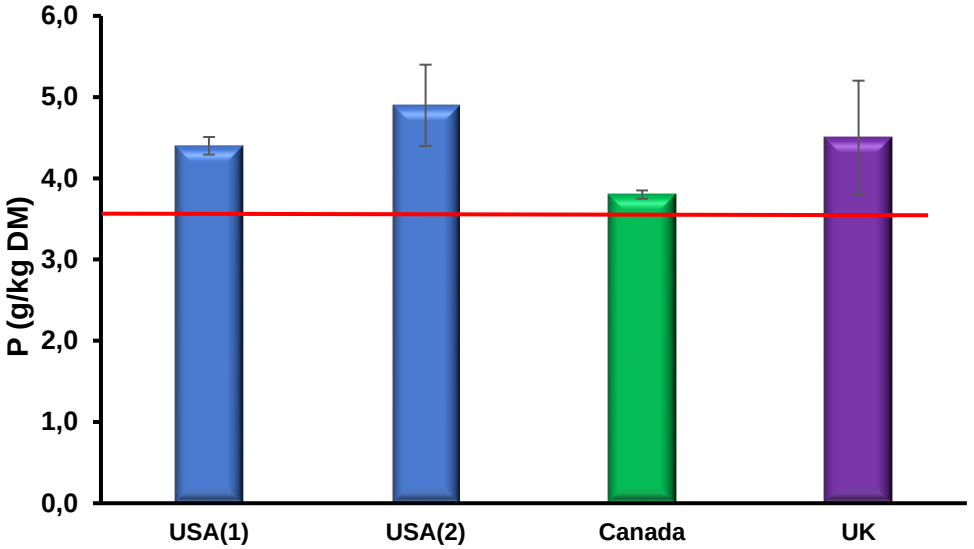
DM basis	NRC (2001)	Mean	S.D.	Max	Min
Ca, g/kg	6.2-6.7	9.5	2.91	19.7	5.1
P, g/kg	3.2-3.8	4.2	0.71	5.8	2.6
Mg, g/kg	1.8-2.1	3.1	0.68	5.0	1.8
Na, g/kg	2.2-2.3	3.2	0.82	5.0	0.7
K, g/kg	10.0-10.7	22.6	4.24	33.8	14.6

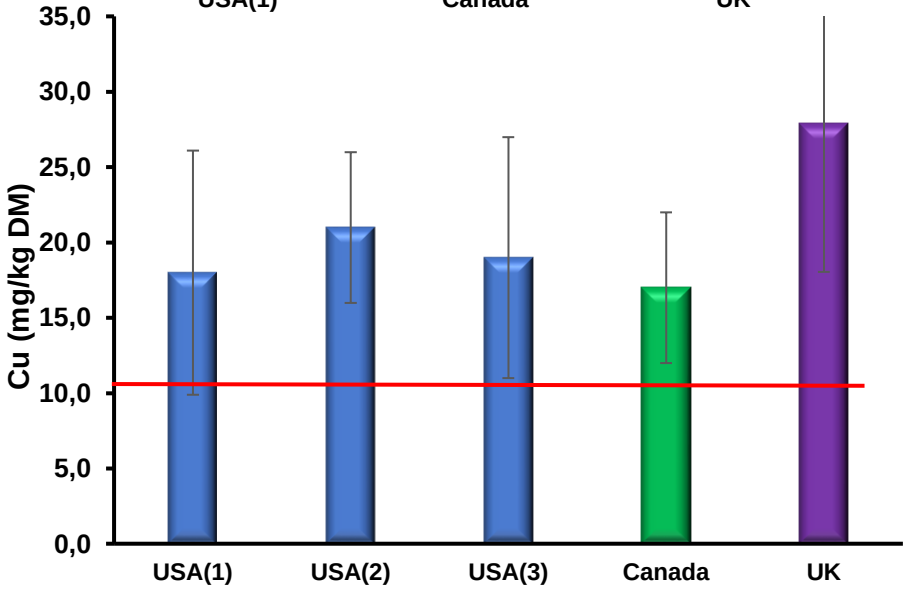
Mean and range for trace minerals

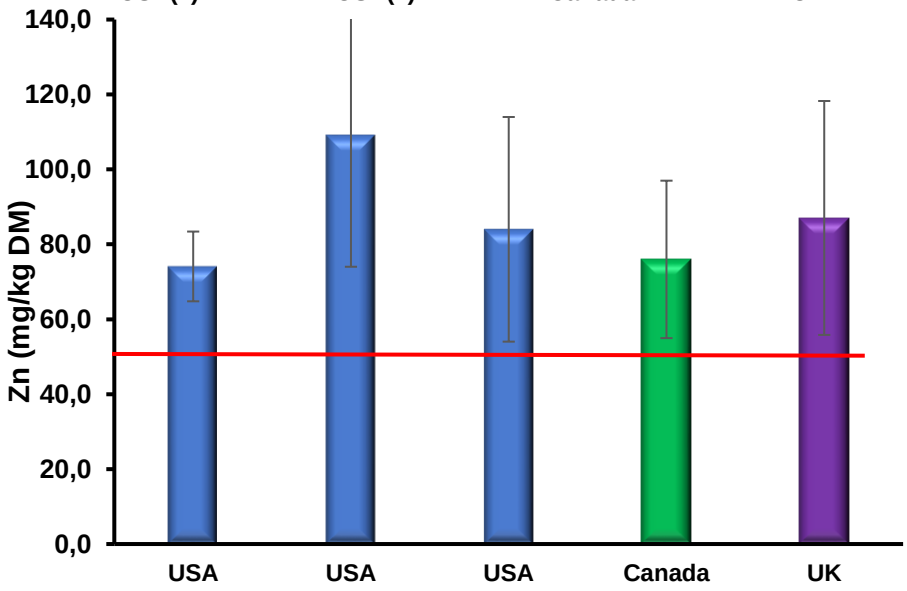
DM basis	NRC (2001)	Mean	S.D.	Max	Min
Cu, mg/kg	11	24.2	8.35	44.3	12.9
Zn, mg/kg	43-55	78	28.5	169	31
Fe, mg/kg	12-18	315	99.6	591	111
Mn, mg/kg	13-14	100	31.1	193	41.2
Mo, mg/kg	--	1.2	0.84	5.2	0.3
Co, mg/kg	0.11	0.59	0.35	1.99	0.11

International feeding levels (Mg, P, Cu and Zn)







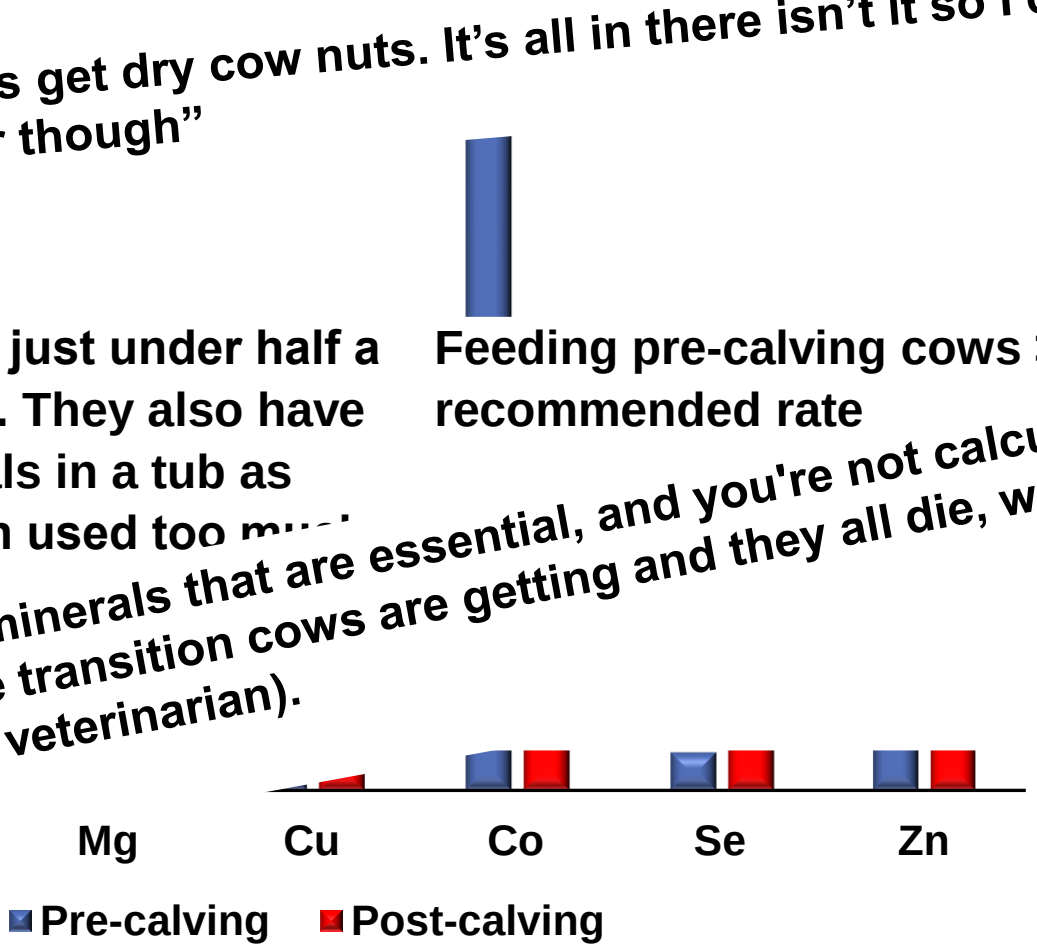


Dairy farmer, vet and nutritionist attitudes

F3: ‘The pre-calvers get dry cow nuts. It’s all in there isn’t it so I don’t have to worry. Bloody dear though”

F14: “Yes, they get just under half a kilo per head a day. They also have some ad lib minerals in a tub as well…It hasn't been used too much really. You can ov… so…

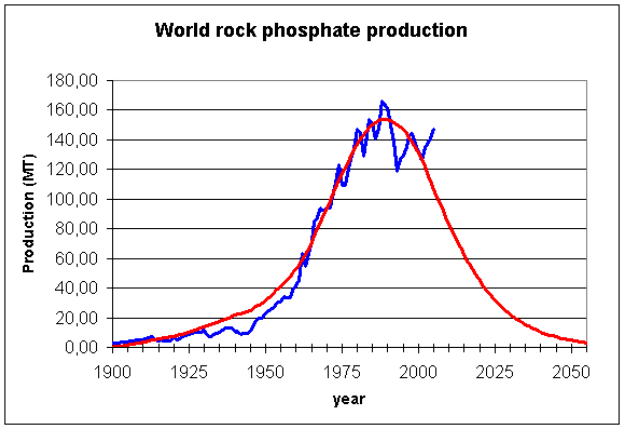
If you're selling feed minerals that are essential, and you're not calculating how much magnesium the transition cows are getting and they all die, who gets sued?’ (A13- mixed practice veterinarian).



Redfern, Sinclair & Robinson (2022)

Phosphorus

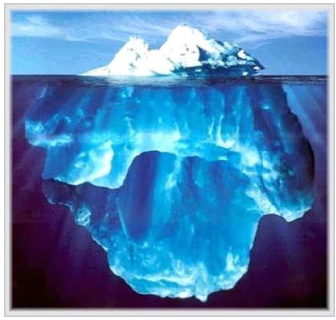
- Traditionally fed at high levels to benefit intake, milk production and reproduction
- Issues relating to cost and environmental impact
- Long term (4 yr) studies do not justify high levels of P



	4.4 g/kg DM	3.6 g/kg DM	s.e.m.
Yield, kg (year 4)	9002	8976	394.0
Fat, g/kg	39.9	40.7	1.26
Protein, g/kg	32.7	33.2	0.56
Depth of rib, mm	12.0	11.4	0.36
Faecal P output, g/d	75.0	41.2	1.31
CI, d (av. 4 lactn)	383	392	ns

Ferris et al., (2010a,b)

Copper: an iceberg indicator

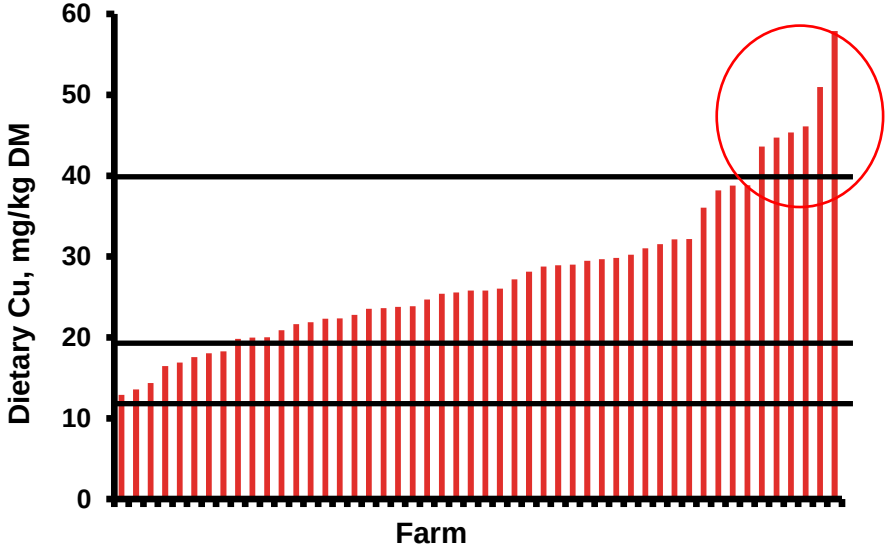


- Copper is the most common trace element deficiency in ruminants in UK
- Co-factor in 300 proteins
- Signs of deficiency include:
  - Pigmentation; Reproduction
  - Growth; Immune function;
  - Cardiac failure; Bones and joints
- Excess copper stored in liver
- 20 to 30 cases of toxicity per annum
  - Intravascular haemolysis
  - Anaemia/jaundice
  - Blood in urine
  - Dull/letharigic

Copper feeding levels

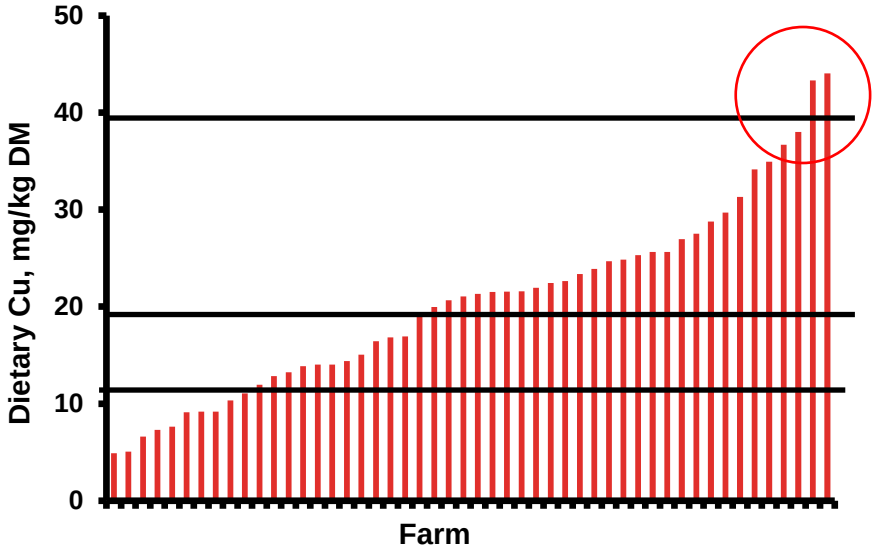
In early lactation:

- 6 out of 50 herds feeding above 40 mg/kg DM
- 40 above 20 mg/kg DM

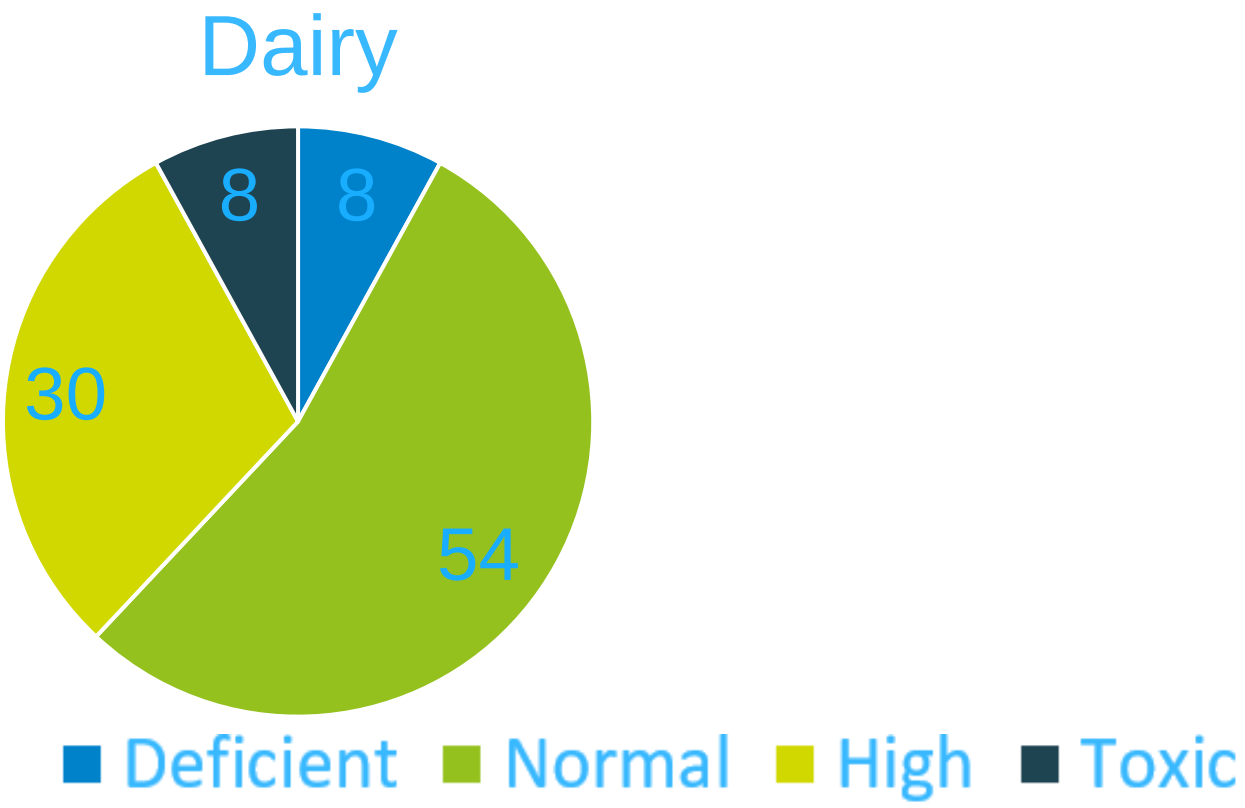


In late lactation:

- 2 out of 50 herds feeding above 40 mg/kg DM
- 27 above 20 mg/kg DM



Copper levels in 510 cull cow livers



Kendall et al., (2015)

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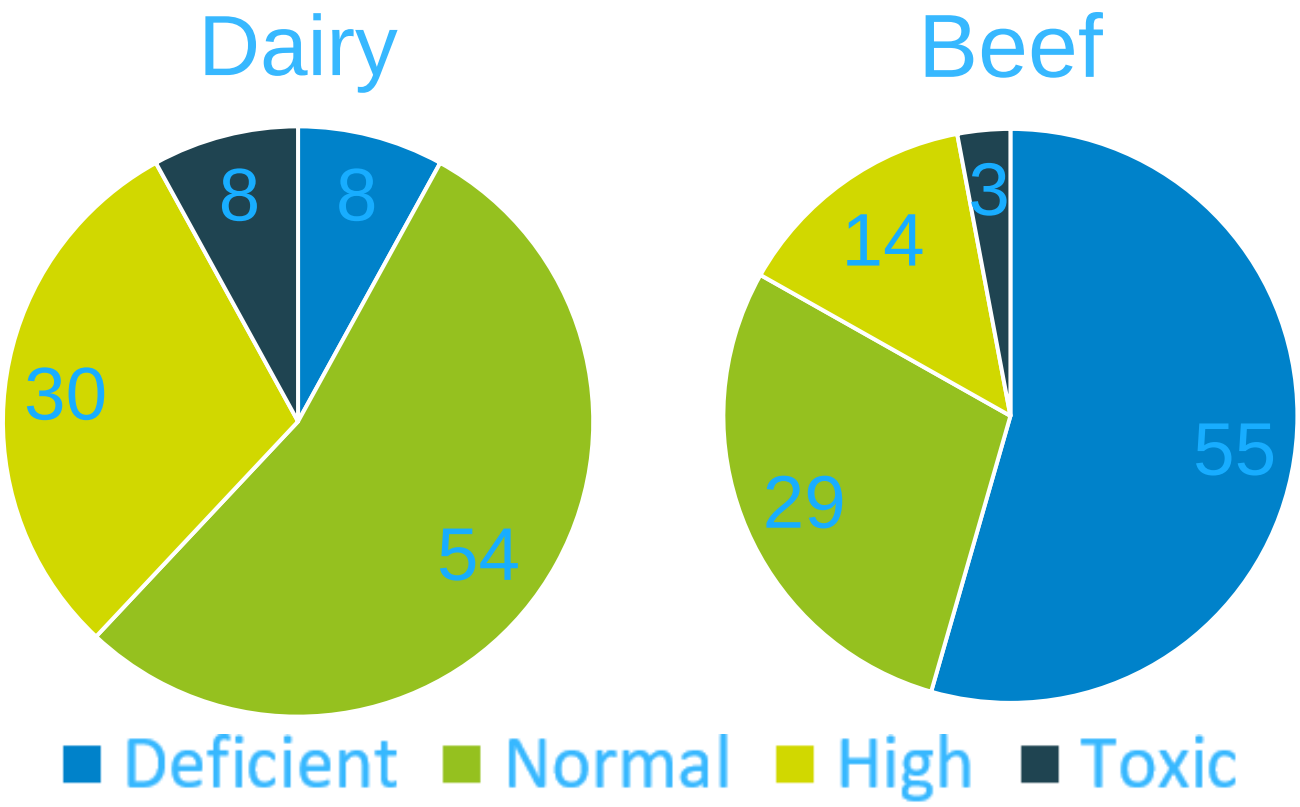


Kendall et al., (2015)

We are still feeding too much!!

CATTLE NUTRITION

Excess dietary copper

I AM prompted to write following the recent paper in *Veterinary Record* on high liver

Livestock

Edited by Rhian Price | 020 8652 4922 | rhian.price@rbi.co.uk

LOOK OUT FOR
How to tackle coccidiosis p32
New grassland herbicide launched p34
Farmer Focus p38

Warning over copper levels in feed

Dairy cattle could be at risk by feeding too much copper, a recent investigation has found. **Rhian Price** reports

Farmers are being urged to audit the amount of copper being fed to dairy cattle after on-farm investigations found stock is being endangered by feed products that exceed industry copper level guidelines.

Youngstock is increasingly identified as being at high risk from over-supplementation, even when fed at manufacturers recommended rates,

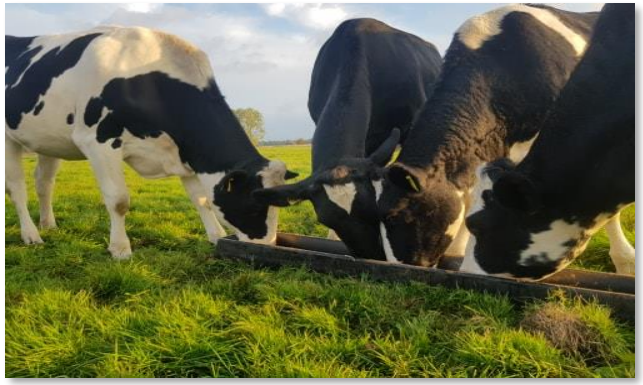
Calves are at particular risk from copper toxicity, with some specialist compound feeds containing high copper levels

28 FARMERS WEEKLY 24 MARCH 2017

Why?

- Don’t know how much is fed?
- Unsure about effect of antagonists
- Feeding excess is better than too little?
- Excess feeding is OK?

Heifer study



- 80 heifers paired at 4 months of age
- Two treatments:
  - Control- 15 mg/kg DM
  - High- 27 mg/kg DM- Cu oxide bolus
- Sampled between 4 months and ~30 months of age
  - Performance- weight, BCS, intake, milk yield
  - Liver biopsies- 7 months, 13.5 months, pre-calving, week 16 of lactation
  - Fertility- pre- and post calving
  - Immune challenge- 17.5 months & week 4 of lactation

Over-feeding copper and performance

Performance from 4 to 22 months of age in heifers fed a recommended (C) or high (H) Cu diet

	Cu supplementation level			Significance[1]
	C	H	s.e.d.	Cu
Intial weight, kg	137	138	1.9	0.593
Final Weight, kg	527	537	7.0	0.154
Weight change, kg/day	**0.76**	**0.79**	**0.014**	**0.033**

[1]P values; Cu= main effect of Cu source supplementation level.

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Intial weight, kg	137	138	1.9	0.593
Final Weight, kg	527	537	7.0	0.154
Weight change, kg/day	**0.76**	**0.79**	**0.014**	**0.033**
Initial Body condition	2.93	2.89	0.037	0.405
Final Body condition	**3.01**	**3.17**	**0.063**	**0.018**
Body condition change	**0.09**	**0.26**	**0.072**	**0.025**

[1]P values; Cu= main effect of Cu source supplementation level.

Maiden heifer fertility

High and low copper supplementation level on replacement dairy heifer fertility.

	Treatment[1]				
	C	H	SED	CI (95%)	P-value
Oestrus onset, d	**359**	**299**	**25.0**		**0.022**

[1]Treatments: Control; 15 mg Cu/kg DM, High; 27 mg Cu/kg DM

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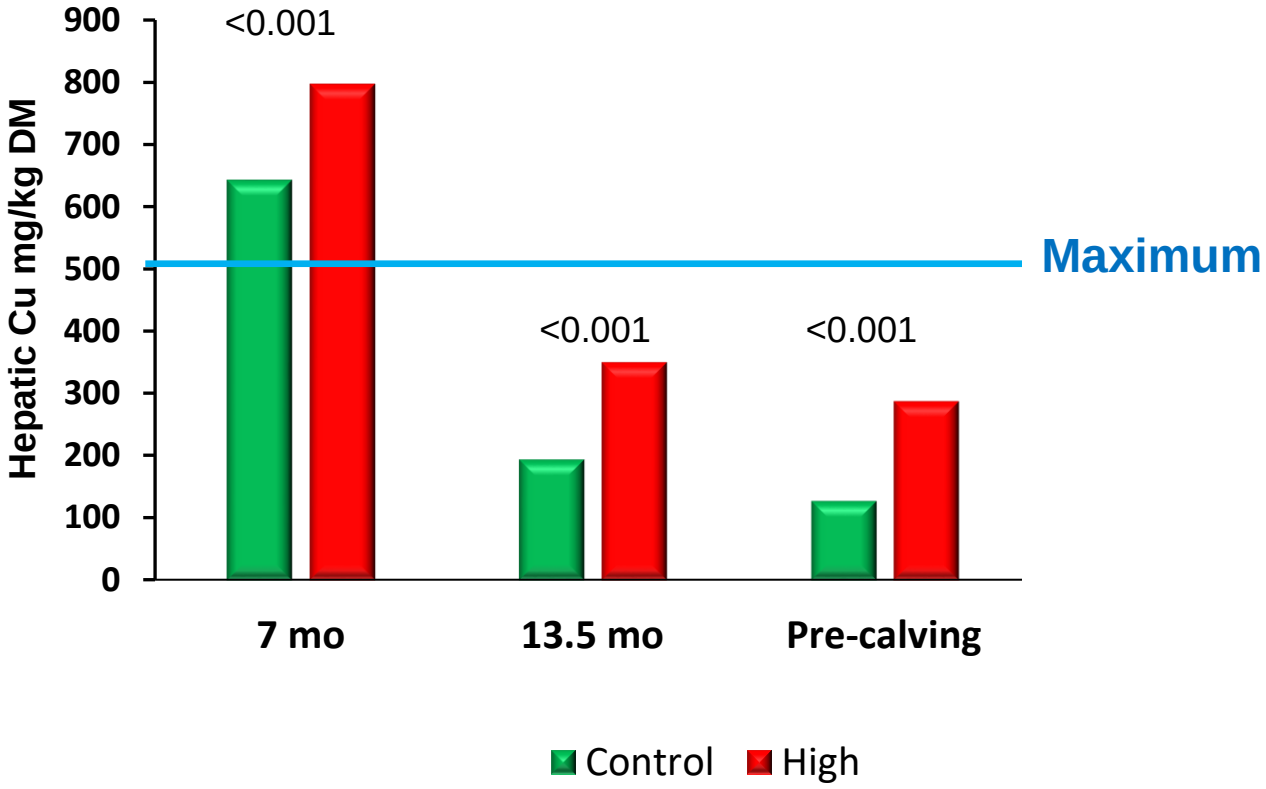
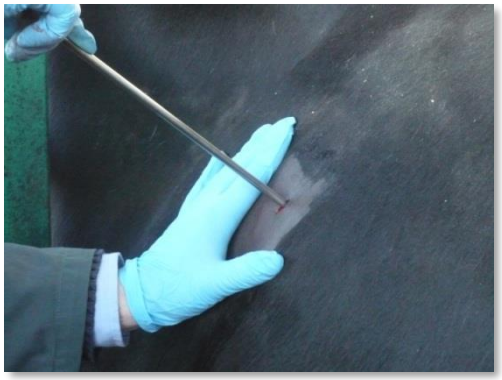
	Treatment[1]				
	C	H	SED	CI (95%)	P-value
Oestrus onset, d	**359**	**299**	**25.0**		**0.022**
Services per conception	**1.4**	**1.9**	**0.23**		**0.040**
Pregnancy to 1st service, %	59.4	46.9		0.44, 1.77	0.486
Pregnancy to 1st and 2nd service, %	**96.9**	**75.0**		**1.35, 6.68**	**0.008**

[1]Treatments: Control; 15 mg Cu/kg DM, High; 27 mg Cu/kg DM

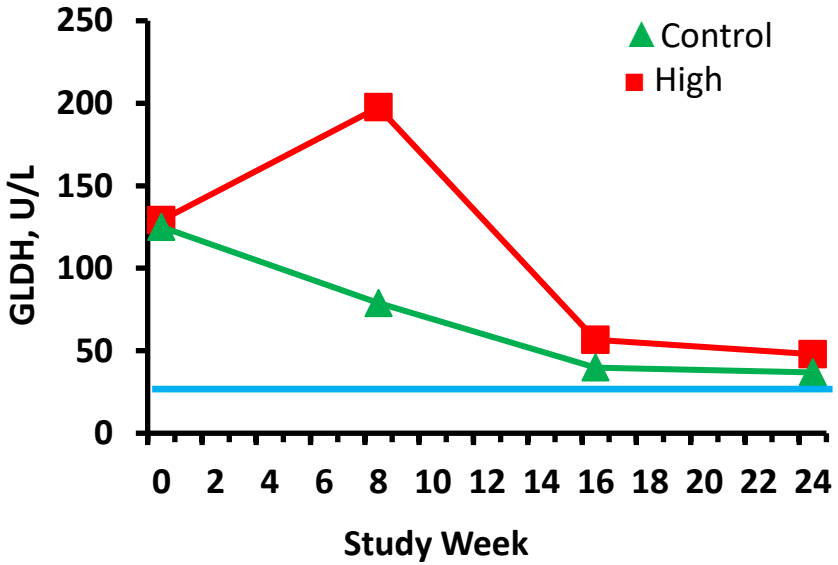
Hepatic Cu concentration (mg/kg DM)



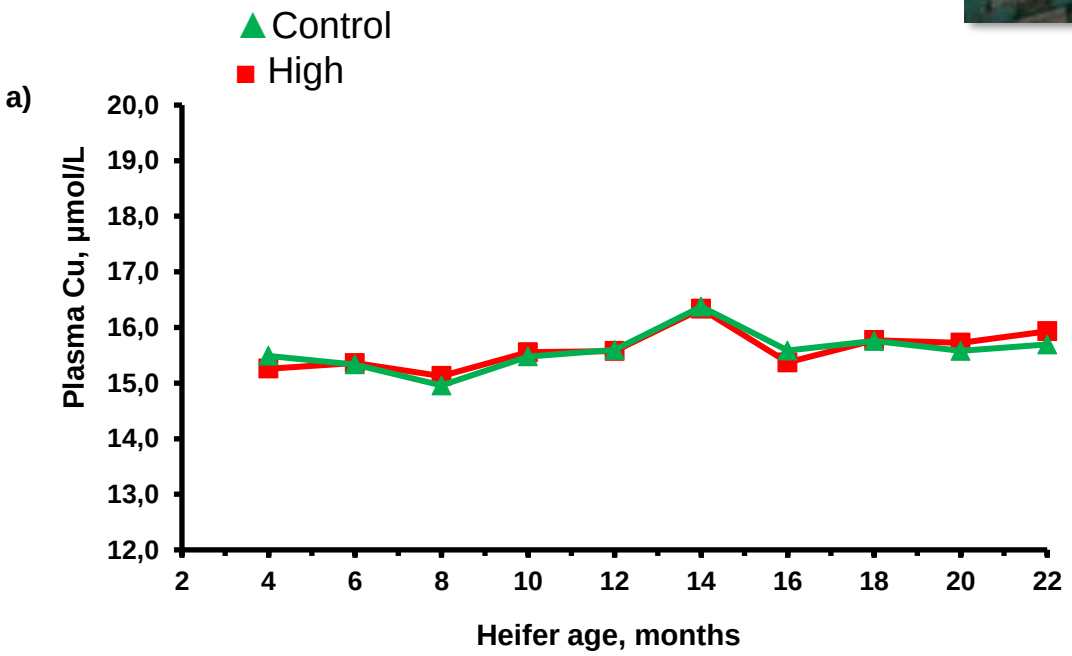


Significant liver damage from over-feeding copper

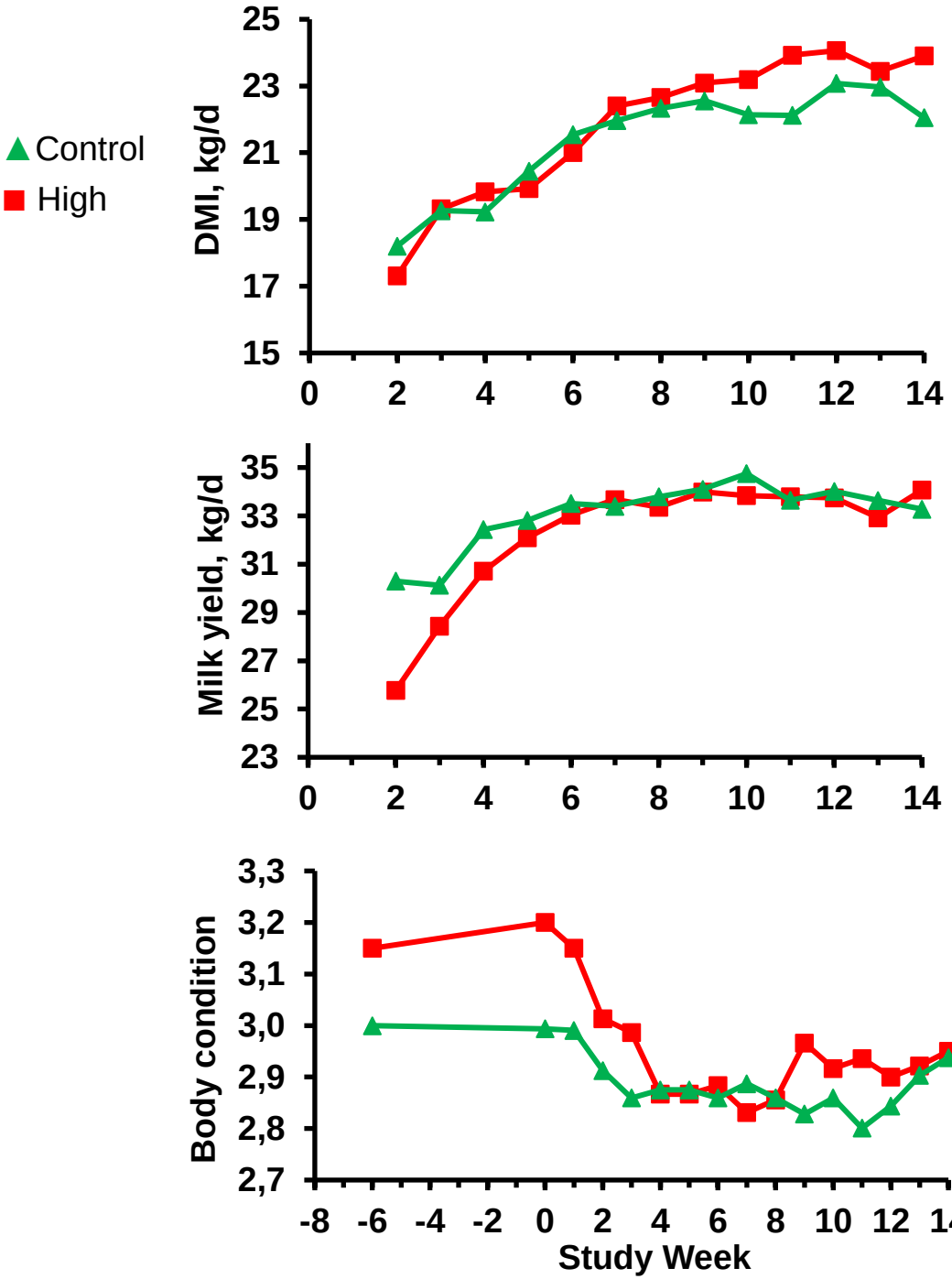
- Indicators of liver damage (AST, GGT, GLDH) very high in all heifers
- Declined with time but remained high for longer in heifers fed high Cu



No effect on plasma copper



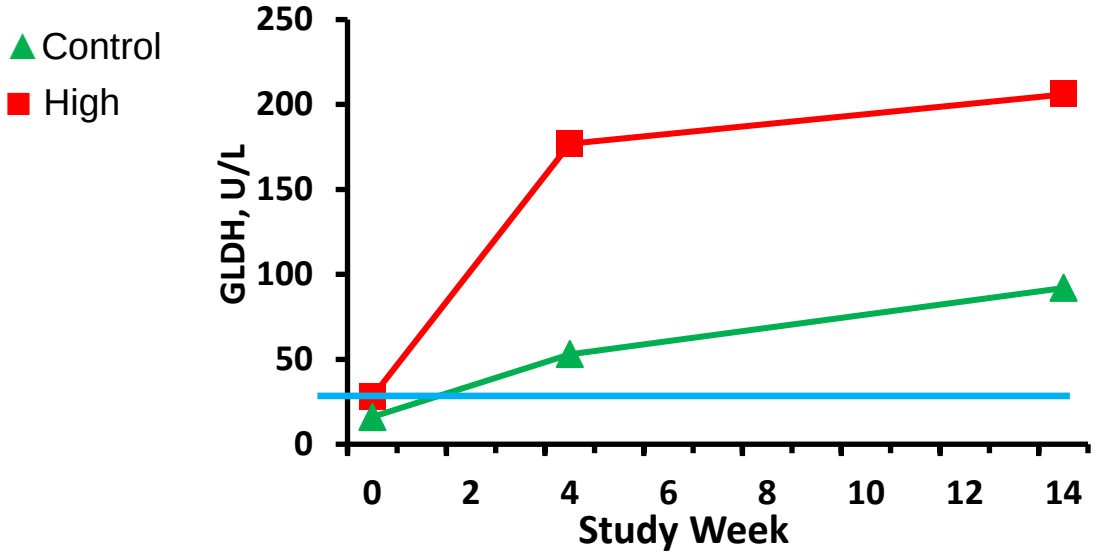
Post-calving



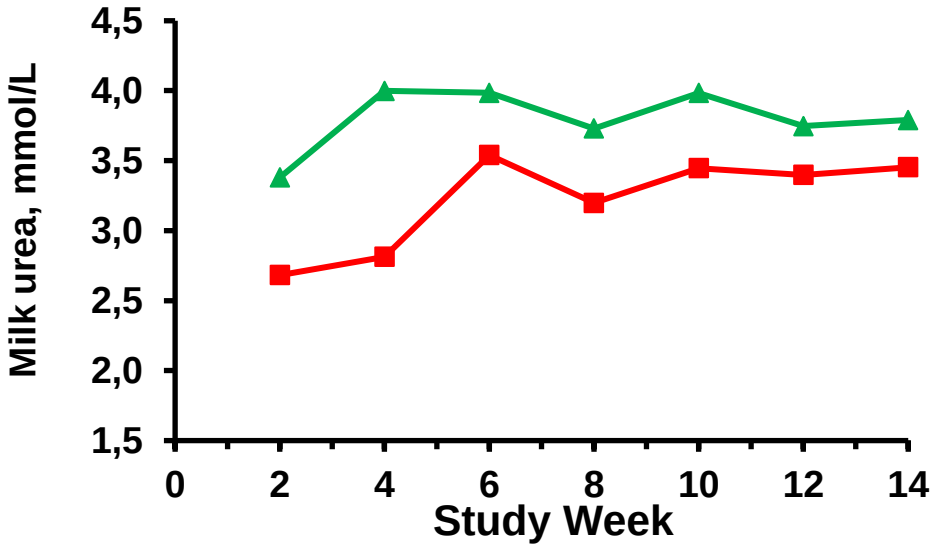
Pooled SED = 0.96. Copper, P = 0.532, time, P <0.001, copper x time, P = 0.144.

Pooled SED = 1.72. Copper, P = 0.624, time, P <0.001, copper x time, P = 0.010.

Pooled SED = 0.061. Copper, P = 0.344, time, P <0.001, copper x time, P = 0.042.

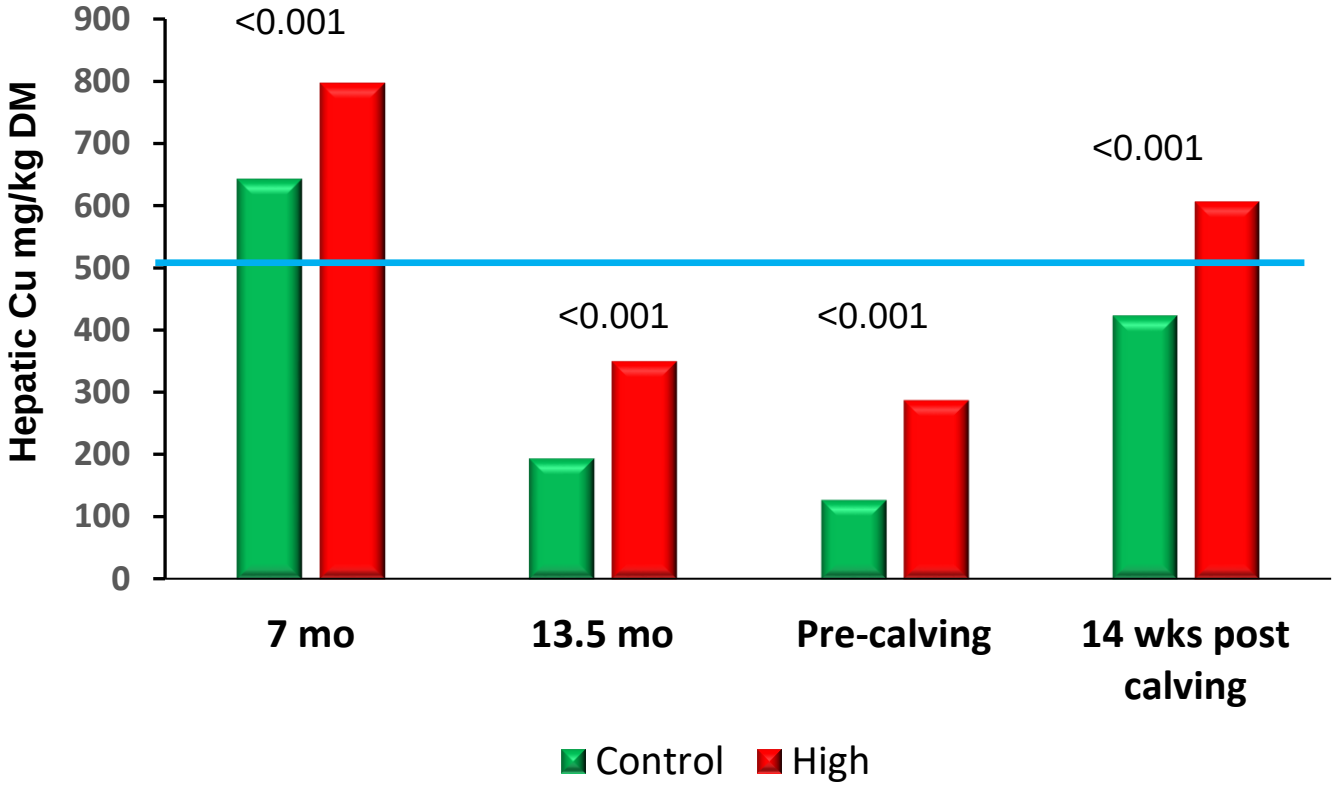


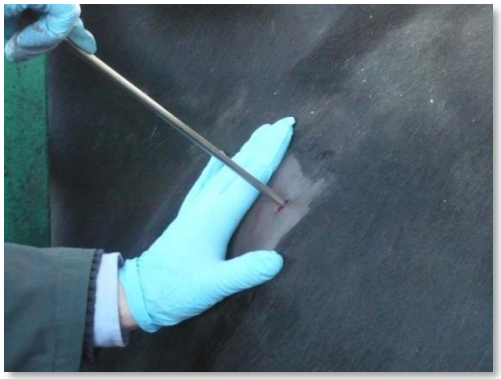
Pooled SED = 54.7 Cu = 0.042; time = P < 0.001; copper x time = 0.211



Pooled SED = 0.016. Copper, P = 0.006, time, P = 0.031, copper x time, P = 0.320.

Hepatic Cu concentration (mg/kg DM)





Possible benefits of over-feeding minerals?

- Action of antagonists
  - e.g. K and Mg
  - Zn and Cu
  - Sulfur/Mo and Cu
  - Iodine and goitrogens in brassicas
- Increase milk concentrations of minerals and vitamins
  - e.g. Selenium enhanced milk
  - Higher iodine concentrations
  - Vitamin B_{12}
  - Vitamin E
- Improvement in immune response/fertility?

What about organic/chelated minerals?

- Most mineral supplements are inorganic (e.g. $CuSO_4$, ZnO)
- Naturally, minerals mainly present as part of organic compounds

- Supplements available that also supply trace minerals in organic form
  - attached to protein or amino acid
  - attached to sugar

Claimed to be more “bioavailable”, particularly in pigs and poultry

Evidence	strong	Se (e.g. Surai et a., 2019)
	increasing	Zn (e.g. Cope et al., 2009; Faulkner et al., 2017)
	poor	Cu (e.g. Sinclair et al., 2013)

Take Home Message

- Over feeding minerals on most dairy farms:
  - often from several sources
  - often nobody knows how much is being fed
- Underfeeding minerals affects performance and health
- Over feeding minerals affects diet cost, environment and can also alter health, fertility and performance

Analyse forage/concentrates for minerals, take all sources into account and one person responsible

If you don’t measure it, you can’t manage it

References

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