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Organic Trace Minerals in Environmentally Sustainable Systems

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Overview

Essential trace minerals (Zn, Cu, Fe, Mn, Se and I) are traditionally included as supplements through mineral premixes in poultry feeds. In comparison to other essential nutrients, as well as energy, they are scarcely studied. The essentiality of a nutrient, by definition, refers to the nutrient role in normal body function, such as growth or egg production, and considers that they cannot be synthesized by the body and, therefore, must be supplied from the feed. The references mostly utilized to support poultry nutritionists when daily formulating feeds are suggestions of supplements with the minerals stated above (NRC, 1994, Rostagno et al., 2017, Cobb, 2018, Aviagen, 2022) instead of their actual required content in feeds, as usually done with the other nutrients. Several factors contribute to that practice. The first factor is obviously related to the low cost of the trace minerals when compared to all other nutrients, which makes it much safer to include supplements at levels that surpass any risk of deficiency. Subsequent factors are mostly related to uncertainties related to the trace mineral contents in feedstuffs, as well as their actual availability for birds. The expectation that divalent cations can potentially bind to phytic acid, rendering them unavailable for birds, plays an important role when the decision to supplement or not and at a certain level is to take. Except for Se and I, which have very specific known metabolic functions, the other essential trace minerals are transition metals, which are keen to form coordinated bonds and have a multitude of functions in animal metabolism in this form. The market availability of different supplemental sources of trace minerals for poultry, as salts or organically bound, have brought to attention a wide range of potential benefits. However, the recovery of these supplements in feeds after adequate analyses, remain as an added factor of uncertainty for the decision maker. The growing concerns with sustainability of the practices presently utilized to produce food for the humanity have added importance to the adequate utilization of finite resources as well as the excess deposition of trace minerals in the environment. Regulation on the total trace minerals in animal feeds has been in place (EFSA, 2016), which may overrule the traditional economics of their supplemental sources.

The tables and figures below summarize the research done at the Universidade Federal do Rio Grande do Sul in the last decade for broilers and broiler breeders, investigating trace mineral requirements as well as when investigating the benefits of using complexed amino acid minerals.

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Table 1. Effect of trace mineral treatment on hatchability, shell proportion and shell thickness.[1]

Item[2]	Hatchability of Fertile, %	Shell Proportion, %	Shell Thickness, µm
Control	88,4b	8,96b	382b
ISO	90,6a	9,10a	385a
ON TOP	90,3a	9,17a	386a
Probability	0.0459	0.0164	0.0353

[a–b] Means within the same column with different superscripts differ ($P \leq 0.05$).

[1] Favero et al. (2013).

[2] Control = 100 ppm of ZnSO4, 100 ppm of MnSO4, and 10 ppm of CuSO4; ISO = 60 ppm of ZnSO4, 60 ppm of MnSO4, and 3 ppm of CuSO4 plus 40 ppm of Zn-amino acid complex, 40 ppm of Mn-amino acid complex, and 7 ppm Cu-amino acid complex; on top = 100 ppm of ZnSO4, 100 ppm of MnSO4, and 10 ppm of CuSO4 plus 40 ppm of Zn-amino acid complex, 40 ppm of Mn-amino acid complex, and 7 ppm of Cu-amino acid complex.

Table 2. Broiler breeder hen parameters as affected by increased dietary Mn.[1]

Mn, ppm	Egg Production, %	Hatchability, %	Yolk Mn, ppm	Breaking strength, kg/cm
22.2	58.5b	70.8b	1.81b	3.53b
48.5	64ab	85.9a	2.00ab	3.84ab
77.9	64.1ab	86.3a	2.09ab	3.96a
103.1	64.9a	89.9a	2.37a	4.00a
140.0	64.2ab	89.2a	2.29a	4.06a
168.2	64.1ab	89.2a	2.12ab	4.07a
Probability	0.0289	0.0001	0.0122	0.0023

[a–b] Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Noetzold et al. (2020).

Table 3. Broiler breeder hen parameters as affected by increased dietary Cu.[1]

Cu, ppm	Hatching Eggs	Yolk Cu, ppm	Shell Membrane
2.67	70b	1.30b	58.4b
5.82	80ab	1.80ab	69.9ab
9.38	87a	1.79ab	72.9a
12.92	85a	2.04a	73.0a
16.83	81ab	2.25a	68.8
20.19	82ab	1.98a	72.6
Probability	0.0032	0.0002	0.0059

[a–b] Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Berwanger et al. (2018).

Table 4. Broiler breeder hen parameters as affected by increased dietary Zn.[1]

Zn, ppm	Total Egg Production	Shell, %	Breaking strength, kg/cm	Shell Thickness
18.7	57b	8.6c	3.91	350.4b
50.3	62a	9.0bc	4.30	392.6a
77.3	64a	9.8ab	4.00	399.3a
110.2	64a	10.0a	4.44	393.3a
140.0	63a	10.0a	4.45	400.6a
170.6	63a	9.7ab	4.45	401.0a
Probability	<0.0001	<0.0001	<0.0001	<0.0001

a-c Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Mayer et al. (2019).

Table 5. Broiler breeder hen parameters as affected by increased dietary Fe.[1]

Fe, ppm	Total Egg Production	Hematocrit, %	Hemoglobin, g/dL	Yolk Fe, ppm
24.6	78.9b	30.7b	7.3b	83.5c
48.6	83.7ab	31.5ab	8.2a	92.7bc
74.3	85.2ab	31.4ab	8.1a	101.2b
99.6	90.4a	32.4a	8.1a	101.5ab
125.6	87.4ab	32.0ab	8.5a	101.7ab
148.2	89.0ab	32.0ab	8.4a	102.6a
Probability	0.028	0.024	0.001	0.001

a-c Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Taschetto et al. 2017.

Table 6. Growth performance of broilers as affected by feeds with or without phytase and with graded increases of supplemental Fe.[1]

Item[2]	BWG, g	FCR
Phytase, FYT/kg[3]		
0	1,293	1.347
4,000	1,330	1.307
Fe, mg/kg[4]		
57	1,315	1.324
67	1,312	1.318
77	1,310	1.338
87	1,309	1.328
97	1,311	1.326
Phytase	<0.0001	<0.0001
Fe	0.9821	0.4562

[1] Feijo et al. (2023).

[2] BWG = body weight gain; FCR = feed conversion ratio corrected for the weight of dead birds.

[3] Ronozyme HiPhorius 40,000 FYT/g, Novozymes A/S, Bagsvaerd, Denmark; analyzed phytase in the Fe supplemented feeds were (from the lowest to the highest Fe content feeds) 4,452 ± 487 FYT/kg.

[4] Analyzed Fe in the feeds without phytase were 51.9 ± 1.81, 66.0 ± 1.89, 79.2 ± 1.96, 85.8 ± 2.31, 96.3 ± 2.03 whereas in the feeds with phytase were 54.7 ± 1.36, 64.9 ± 1.74, 75.2 ± 2.15, 89.3 ± 1.84, 99.0 ± 2.41.

Table 7. Ileal digestible Fe and retention responses of broilers as affected by increased dietary Fe with or without phytase.[1]

Item	Ileal digestible Fe, %	Retention		Intake	Excretion
		Fe, %	Fe, mg/bird	Fe, mg/bird	
Phytase, FYT/kg[2]					
0	10.6	13.1	5.5	42.1	36.6
4000	11.8	14.2	6.0	42.0	36.0
Fe, mg/kg[3]					
57	11.6	14.1	4.1e	29.1e	25.0e
67	11.2	13.8	4.9d	35.6d	30.7d
77	11.4	13.5	5.9c	43.9c	38.0c
87	11.1	13.4	6.4b	48.1b	41.7b
97	10.8	13.5	7.2a	53.3a	46.1a
Phytase	<0.0001	<0.0001	0.0002	0.8651	0.2927
Fe	0.4071	0.2093	<0.0001	<0.0001	<0.0001

[a-e] Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Feijo et al (2023).

[2] Ronozyme HiPhorius 40,000 FYT/g, Novozymes A/S, Bagsvaerd, Denmark; analyzed phytase in the Fe supplemented feeds were (from the lowest to the highest Fe content feeds) 4,452 ± 487 FYT/kg.

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Table 8. Growth performance of broilers as affected by feeds with or without phytase and with graded increases of supplemental Cu.[1]

Item[2]	BWG, g	FCR
Phytase, FYT/kg[3]		
0	1,384	1.301
2,500	1,453	1.286
Cu, mg/kg[4]		
8	1,405	1.299
11	1,434	1.289
14	1,433	1.293
17	1,419	1.288
20	1,404	1.300
Phytase	<0.001	<0.005
Cu	0.261	0.448

[1] Soster et al (2023).

[2] BWG = body weight gain; FCR = feed conversion ratio corrected for the weight of dead birds.

[3] Ronozyme HiPhos 20,000 FYT/g, Novozymes A/S, Bagsvaerd, Denmark; analyzed phytase in the Cu supplemented feeds were (from the lowest to the highest Cu content feeds) 2,768 ± 135.2.

[4] Formulated Cu in feeding treatments were 8.31, 11.31, 14.31, 17.31, 20.31 mg/kg; analyzed Cu in the feeds without phytase were 7.83 ± 0.2, 11.11 ± 0.4, 14.62 ± 0.1, 16.47 ± 0.2, 18.96 ± 0.1 whereas in the feeds with phytase were 8.28 ± 0.2, 11.36 ± 0.6, 13.77 ± 0.3, 16.63 ± 0.2, 19.94 ± 0.4.

Table 7. Ileal digestible Cu and retention responses of broilers as affected by increased dietary Cu with or without phytase.[1]

Item	Ileal digestible Cu, %	Retention Cu, mg/bird	Intake Cu, mg/bird	Excretion Cu, mg/bird
Phytase, FYT/kg[2]				
0	31.8	9.87	14.13	4.26
2,500	34.6	9.72	13.85	4.13
Cu, mg/kg[3]				
8	30.6	5.72d	8.22e	2.50e
11	34.0	7.93c	11.34d	3.41d
14	34.1	10.30b	14.79c	4.27c
17	33.7	11.66b	16.75b	5.09b
20	33.8	13.40a	19.08a	5.68a
Phytase	0.013	0.602	0.594	0.276
Fe	0.238	0.001	0.001	0.001

[a-e] Means with different letters in the same column indicate significant differences ($P < 0.05$).

[1] Soster et al (2023).

[2] Ronozyme HiPhos 20,000 FYT/g, Novozymes A/S, Bagsvaerd, Denmark; analyzed phytase in the Cu supplemented feeds were (from the lowest to the highest Cu content feeds) 2,768 ± 135.2.

[3] Formulated Cu in feeding treatments were 8.31, 11.31, 14.31, 17.31, 20.31 mg/kg; analyzed Cu in the feeds without phytase were 7.83 ± 0.2, 11.11 ± 0.4, 14.62 ± 0.1, 16.47 ± 0.2, 18.96 ± 0.1 whereas in the feeds with phytase were 8.28 ± 0.2, 11.36 ± 0.6, 13.77 ± 0.3, 16.63 ± 0.2, 19.94 ± 0.4.

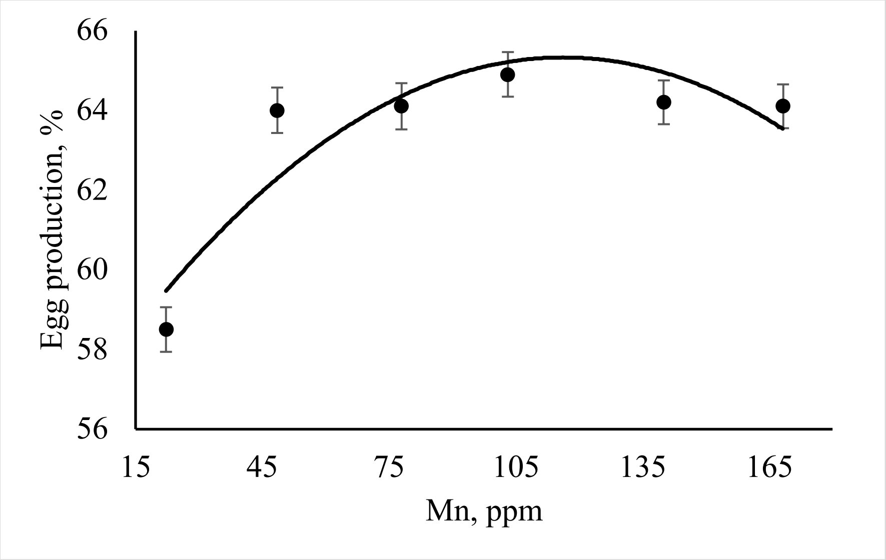

Fig.1. Egg production as a function of dietary Mn in broiler breeder hens. (Noetzold et al., 2020).

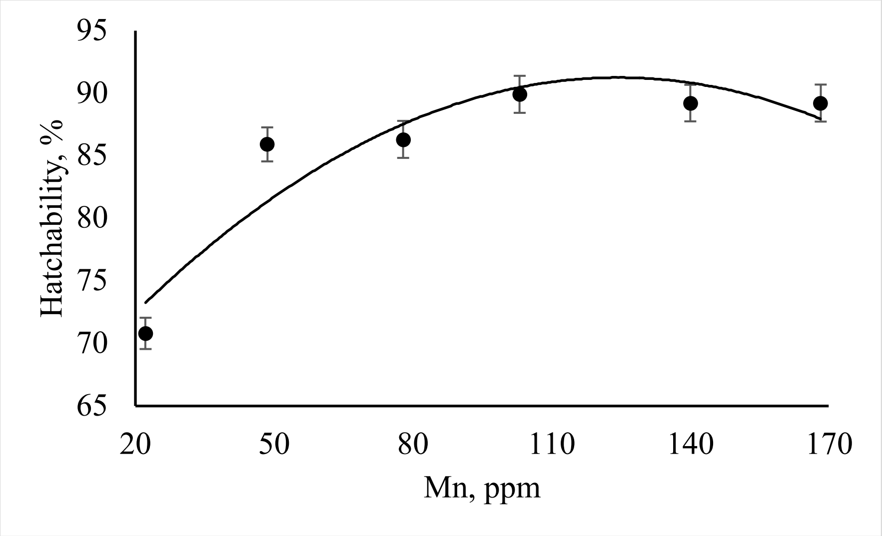

Fig.2. Hatchability as a function of dietary Mn in broiler breeder hens (Noetzold et al, 2020).

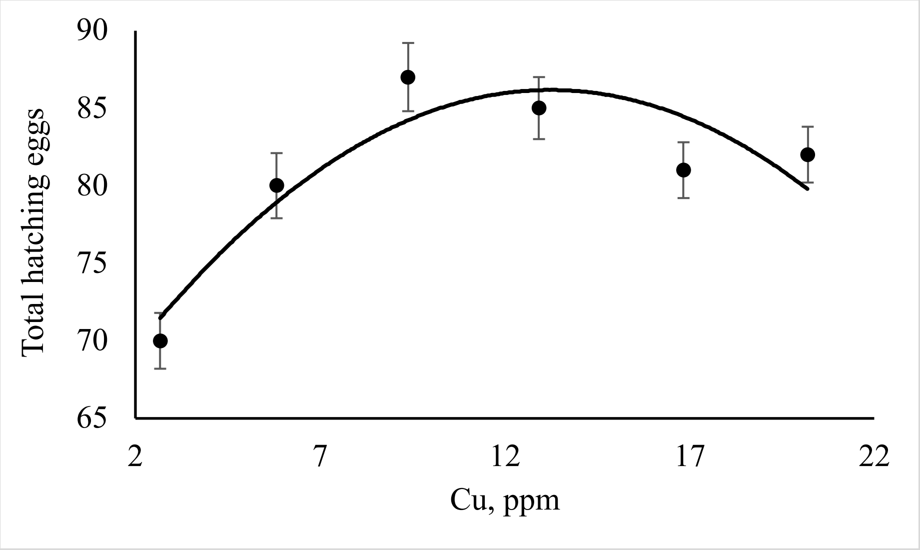

Fig.3. Total hatching eggs as a function of dietary Cu in broiler breeder hens (Berwanger et al., 2018).

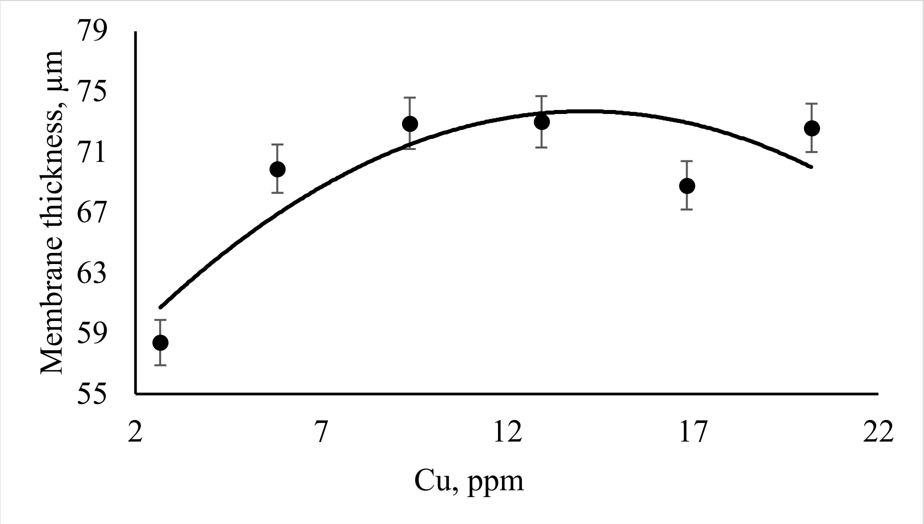

Fig.4. Membrane thickness as a function of dietary Cu in broiler breeder hens (Berwanger et al.,2018).

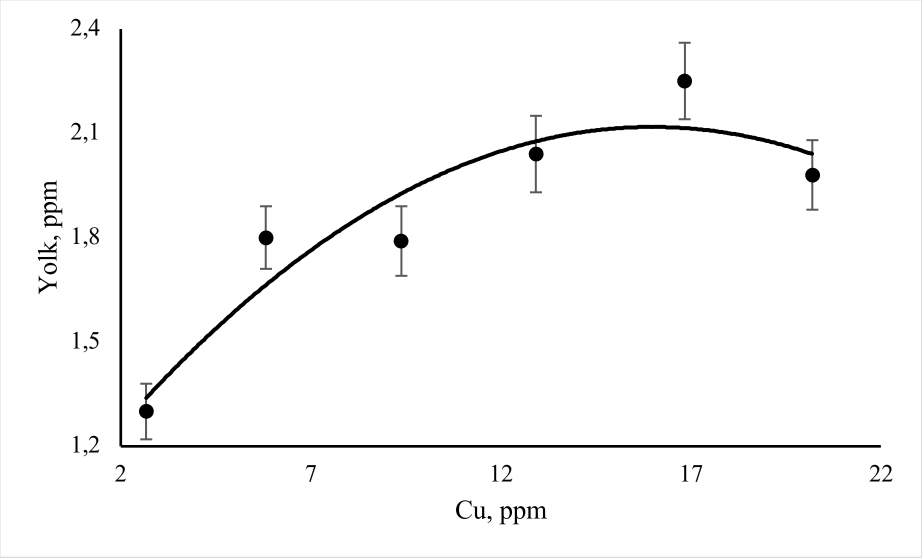

Fig.5. Cu in yolk as a function of dietary Cu in broiler breeder hens (Berwanger et al., 2018).

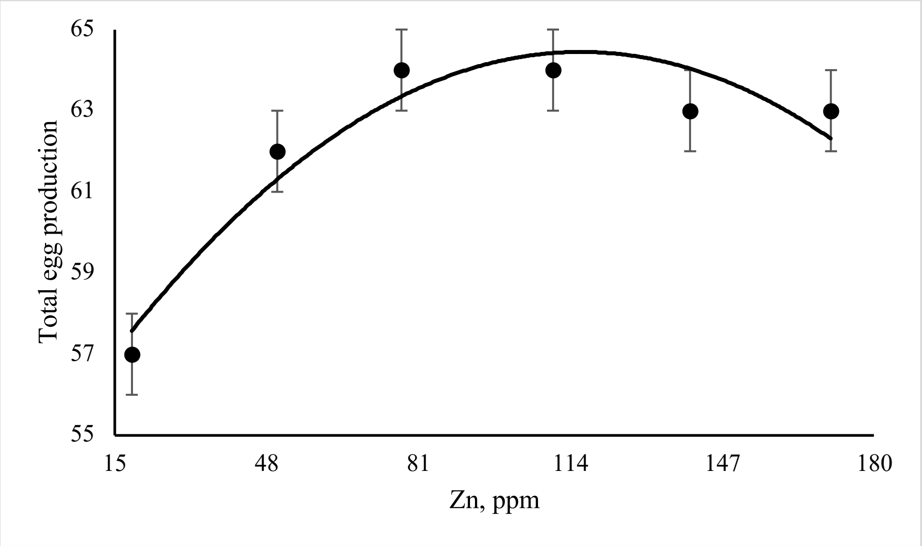

Fig.6. Total egg production in yolk as a function of dietary Zn in broiler breeder hens (Mayer et al., 2019).

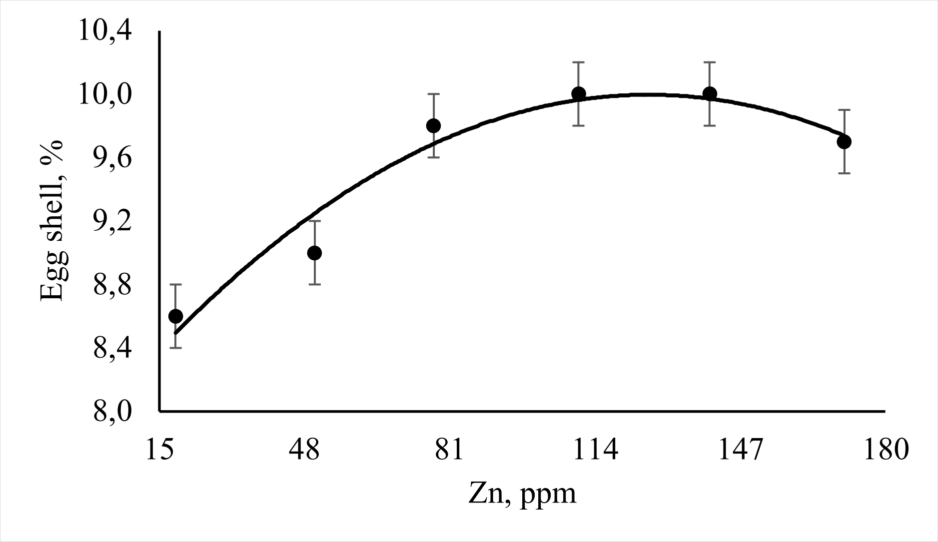

Fig.7. Egg shell as a function of dietary Zn in broiler breeder hens (Mayer et al., 2019).

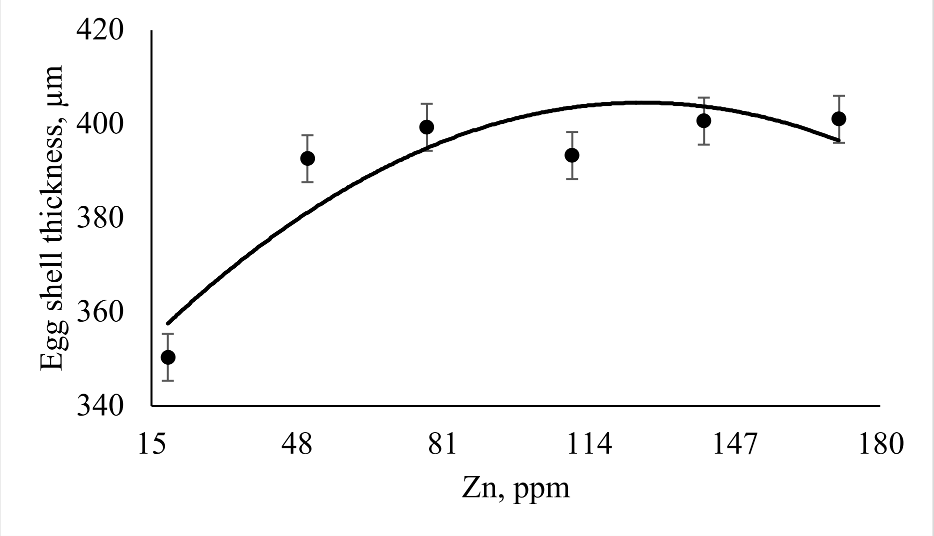

Fig.8. Egg shell thickness as a function of dietary Zn in broiler breeder hens (Mayer et al., 2019).

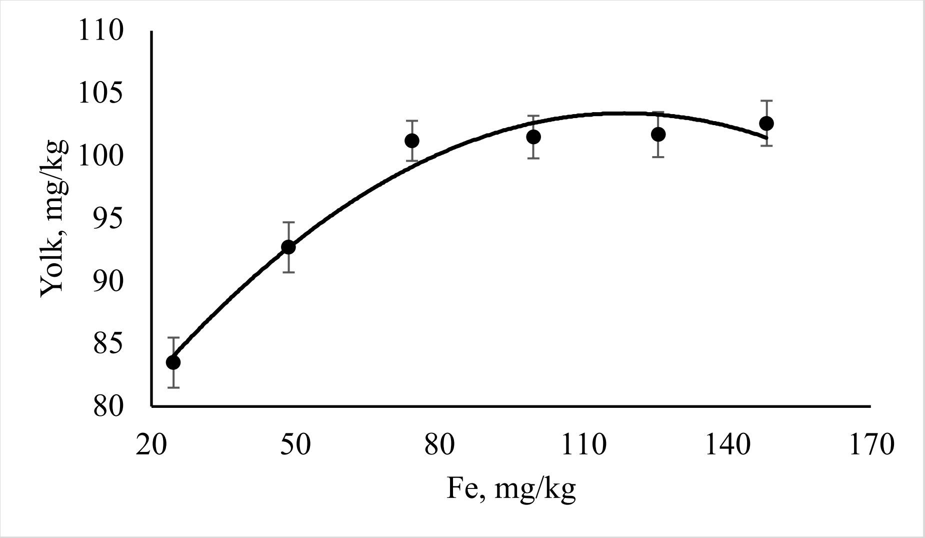

Fig. 9. Fe in yolk as a function of dietary Fe in broiler breeder hens (Taschetto et al., 2017).

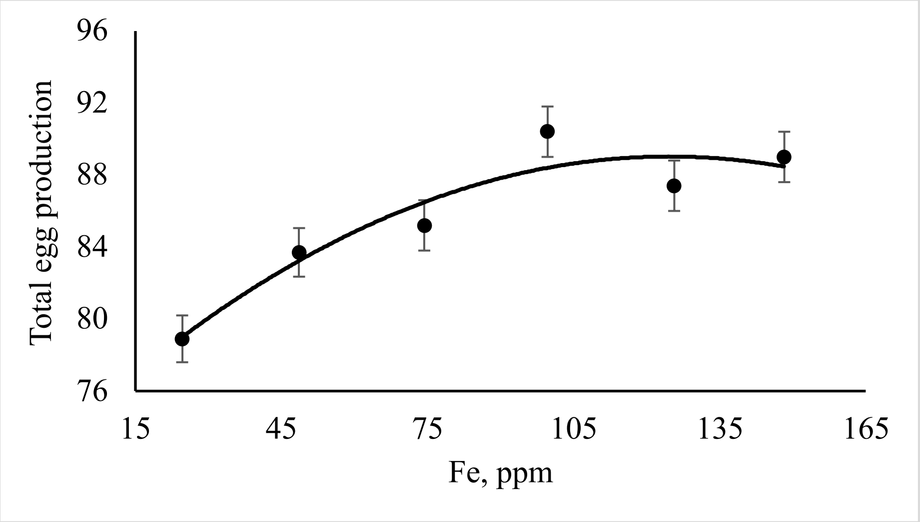

Fig. 10. Total egg production as a function of dietary Fe in broiler breeder hens (Taschetto et al., 2017).

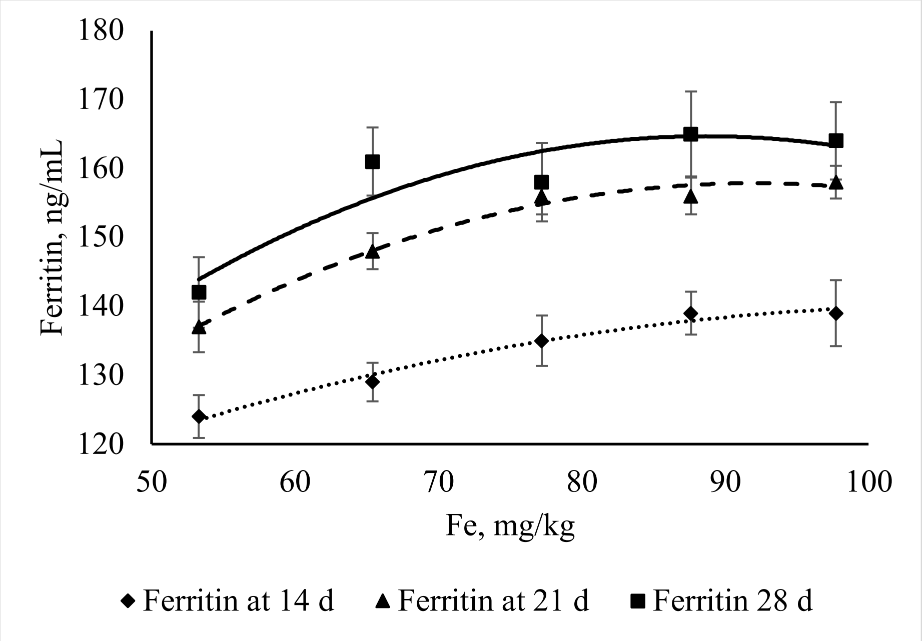

Fig.11. Ferritin as a function of dietary iron in broiler chickens (Feijo et al., 2023).

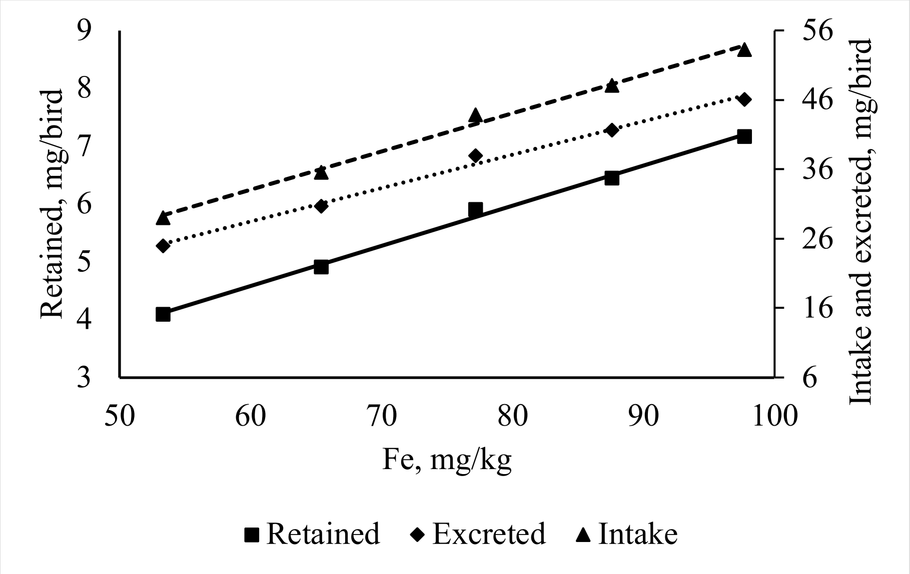

Fig. 12. Intake, excretion and retention Fe as a function of dietary Fe in broiler chickens (Feijo et al., 2023).

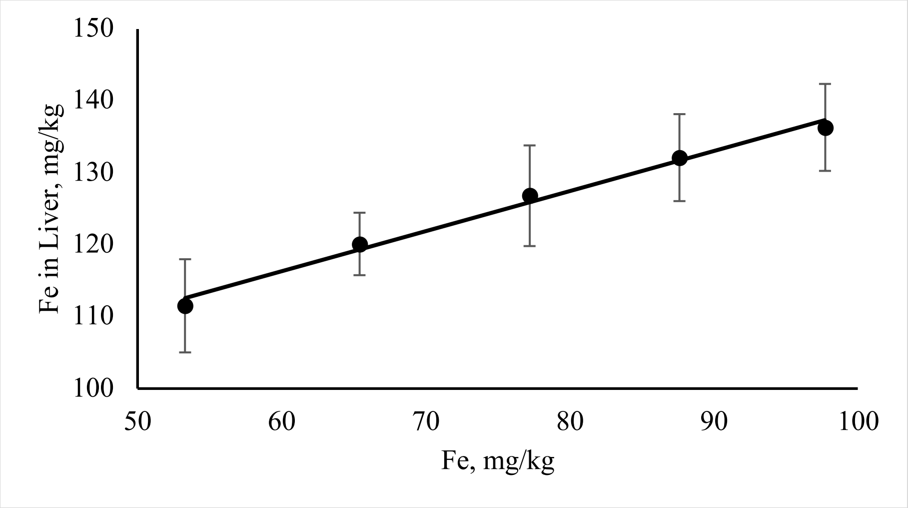

Fig. 13. Fe in liver as a function of dietary Fe in broiler chickens (Feijo et al., 2023).

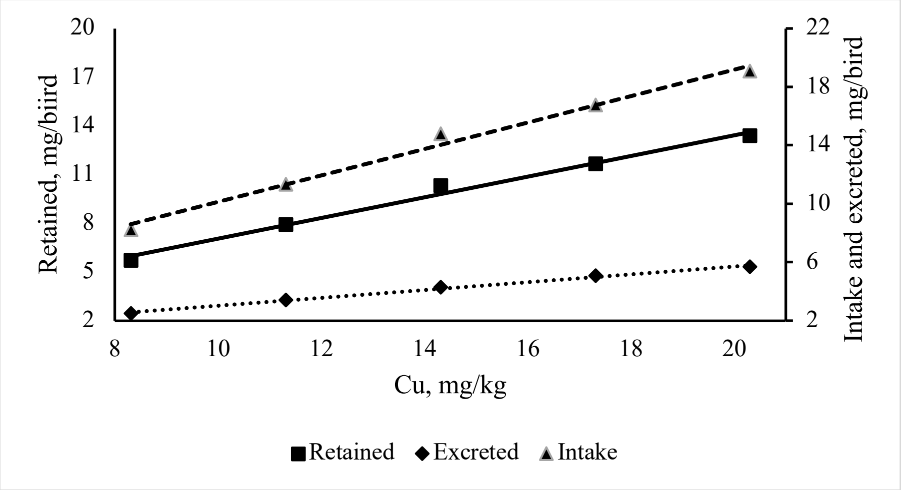

Fig. 14. Intake, excretion and retention Cu as a function of dietary Cu in broiler chickens (Soster et al., 2023).

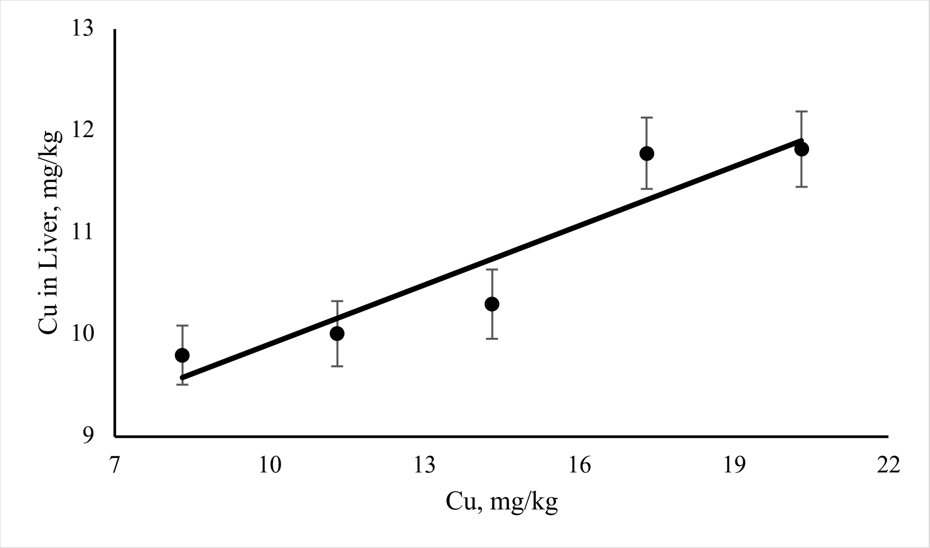

Fig. 15. Cu in liver as a function of dietary Cu in broiler chickens (Soster et al., 2023).

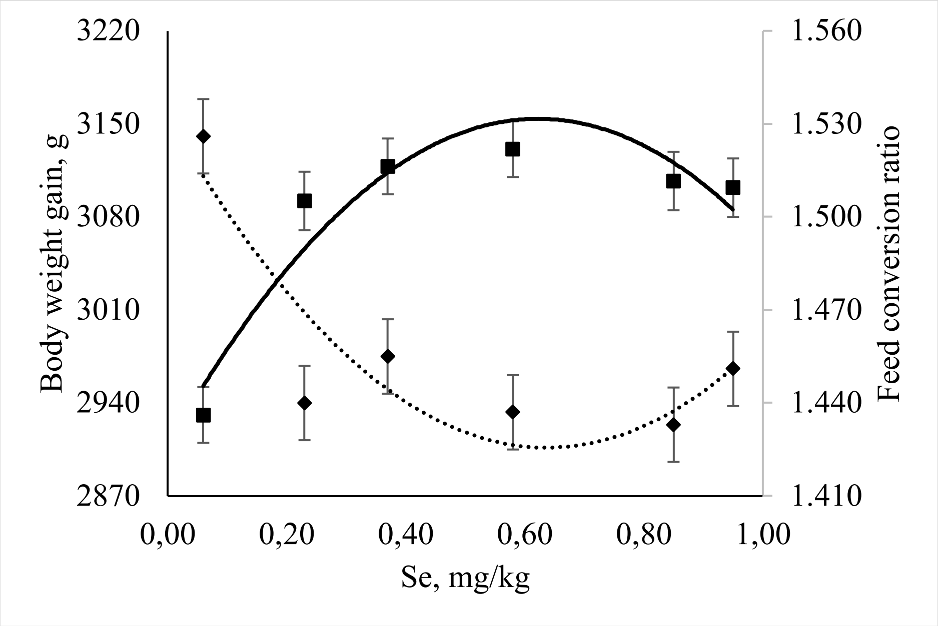

Fig. 16. Body weight gain and feed conversion ratio as a function of dietary Se in broiler chickens (Cemin et al., 2018).