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Metal oxide nanoparticles alter peanut (*Arachis hypogaea* L.) physiological response and reduce nutritional quality: A life cycle study

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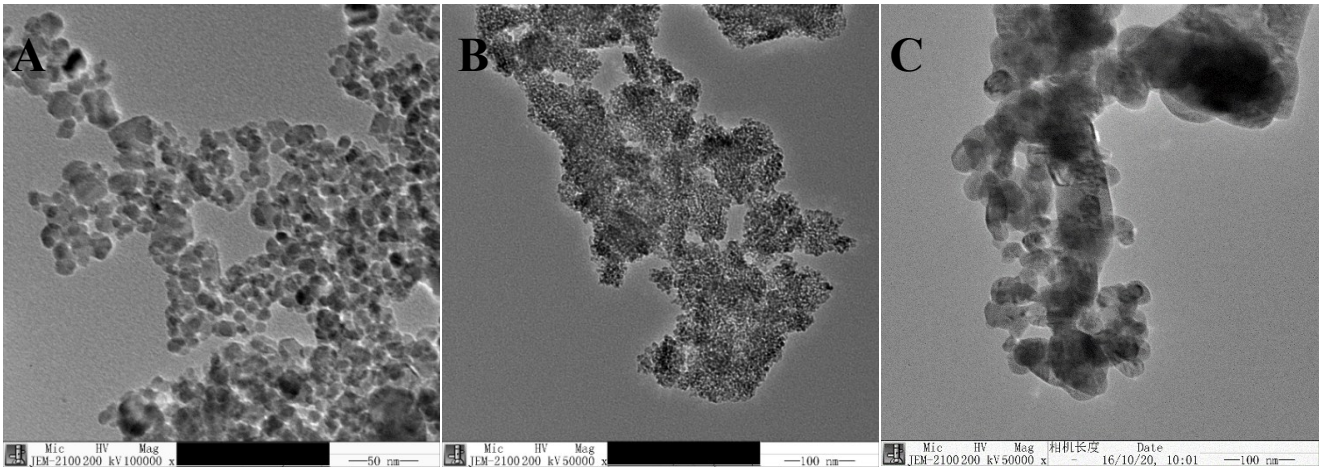

Figure S1 TEM images of Fe_2O_3 NPs (A), TiO_2 NPs (B), and CuO NPs (C).

Table S1. Characterization details of three NPs

NPs	Size nm	Zeta potential mV	Conductivity mS/cm	Dissolution μg L^{-1}	
				pH=7.0	pH=8.1
Fe_2O_3	20	-10.49	0.0516	＜0.2	＜0.2
TiO_2	5	-17.23	0.0492	＜0.2	＜0.2
CuO	40	-12.70	0.0513	627	133

Note：The dissolutions of Fe_2O_3 and TiO_2 NPs were below the limit of detection.

Table S2. The physical and chemical properties of soil

Test indicators	Organic matter g kg^{-1}	Mineral nitrogen mg kg^{-1}	Ammonium nitrogen mg kg^{-1}	Nitrate nitrogen mg kg^{-1}	Available phosphorus mg kg^{-1}	Available potassium mg kg^{-1}	pH
Results	10.1	18.3	15.1	3.2	6.7	74.1	8.1

Table S3. The total content of 17 amino acids in fresh peanut grains

Amino acid	Cu			Fe			Ti (mg·kg^{-1})		
	Control	50	500	Control	50	500	Control	50	500
Asp	1.76 ± 0.06a	1.07 ± 0.02c	1.36 ± 0.03b	1.76 ± 0.06a	1.34 ± 0.03c	1.51 ± 0.10b	1.76 ± 0.06a	1.65 ± 0.30a	1.36 ± 0.16a
Thr	0.37 ± 0.02a	0.25 ± 0.01c	0.29 ± 0.01b	0.37 ± 0.02a	0.30 ± 0.004 b	0.32 ± 0.02b	0.37 ± 0.02a	0.35 ± 0.07a	0.29 ± 0.02a
Ser	0.73 ± 0.03a	0.46 ± 0.02c	0.59 ± 0.03b	0.73 ± 0.03a	0.61 ± 0.03b	0.66 ± 0.04a b	0.73 ± 0.03a	0.74 ± 0.14a	0.62 ± 0.08a
Glu	2.92 ± 0.09a	1.80 ± 0.05c	2.30 ± 0.07b	2.92 ± 0.09a	2.26 ± 0.09c	2.54 ± 0.14b	2.92 ± 0.09a	2.84 ± 0.51a	2.27 ± 0.26a
Gly	0.89 ± 0.03a	0.62 ± 0.03c	0.69 ± 0.04b	0.89 ± 0.03a	0.73 ± 0.04b	0.83 ± 0.08a b	0.89 ± 0.03a	0.90 ± 0.15a	0.74 ± 0.06a
Ala	0.59 ± 0.01a	0.39 ± 0.02c	0.47 ± 0.02b	0.59 ± 0.01a	0.47 ± 0.01c	0.51 ± 0.03b	0.59 ± 0.01a	0.57 ± 0.11a b	0.45 ± 0.04b
Cys	0.21 ± 0.02a	0.18 ± 0.006 b	0.17 ± 0.01b	0.21 ± 0.02a	0.22 ± 0.01a	0.22 ± 0.04a	0.21 ± 0.02b	0.27 ± 0.03a	0.31 ± 0.02a
Val	0.76 ± 0.03a	0.51 ± 0.02c	0.59 ± 0.03b	0.76 ± 0.03a	0.58 ± 0.02b	0.65 ± 0.04b	0.76 ± 0.03a	0.71 ± 0.14a b	0.55 ± 0.04b
Met	0.13 ± 0.007 a	0.08 ± 0.004 b	0.06 ± 0.01b	0.13 ± 0.007 a	0.12 ± 0.004 a	0.13 ± 0.006 a	0.13 ± 0.007 a	0.15 ± 0.03a	0.14 ± 0.01a
Ile	0.49 ± 0.02a	0.33 ± 0.01c	0.38 ± 0.02b	0.49 ± 0.02a	0.39 ± 0.01b	0.43 ± 0.03b	0.49 ± 0.02a	0.48 ± 0.09a	0.38 ± 0.03a
Leu	1.08 ± 0.03a	0.70 ± 0.02c	0.82 ± 0.04b	1.08 ± 0.03a	0.85 ± 0.03b	0.94 ± 0.07b	1.08 ± 0.03a	1.04 ± 0.19a	0.83 ± 0.08a
Try	0.49 ± 0.02a	0.33 ± 0.02c	0.40 ± 0.03b	0.49 ± 0.02a	0.40 ± 0.02b	0.43 ± 0.03b	0.49 ± 0.02a	0.49 ± 0.07a	0.49 ± 0.02a
Phe	0.75 ± 0.01a	0.47 ± 0.003 c	0.58 ± 0.03b	0.75 ± 0.01a	0.58 ± 0.03c	0.66 ± 0.05b	0.75 ± 0.01a	0.72 ± 0.14a b	0.56 ± 0.07b
Lys	0.54 ± 0.04a	0.38 ± 0.003 c	0.44 ± 0.02b	0.54 ± 0.04a	0.48 ± 0.01b	0.51 ± 0.03a b	0.54 ± 0.04a	0.56 ± 0.10a	0.44 ± 0.02a
His	0.35 ± 0.01a	c	0.27 ± 0.01b	0.35 ± 0.01a	0.27 ± 0.01c		0.35 ± 0.01a	0.34 ± 0.06a	0.27 ± 0.02a
Arg	1.78 ± 0.10a	0.23 ± 0.001	1.52 ± 0.05b	1.78 ± 0.10a	1.43 ± 0.05b	0.31 ± 0.02b	1.78 ± 0.10a	1.75 ± 0.31a	1.34 ± 0.14b
Pro	0.55 ± 0.04a	c	0.40 ± 0.02b	0.55 ± 0.04a	0.42 ± 0.02b	1.57 ± 0.09b	0.55 ± 0.04a	b	0.40 ± 0.05b
Sum			11.36 ± 0.43						11.46 ± 1.06

1.07 ± 0.06c	c	0.46 ± 0.03b	0.50 ± 0.09a
0.33 ± 0.001		12.67 ± 0.76	b
c		b	14.07 ± 2.50
9.19 ± 0.07c			a

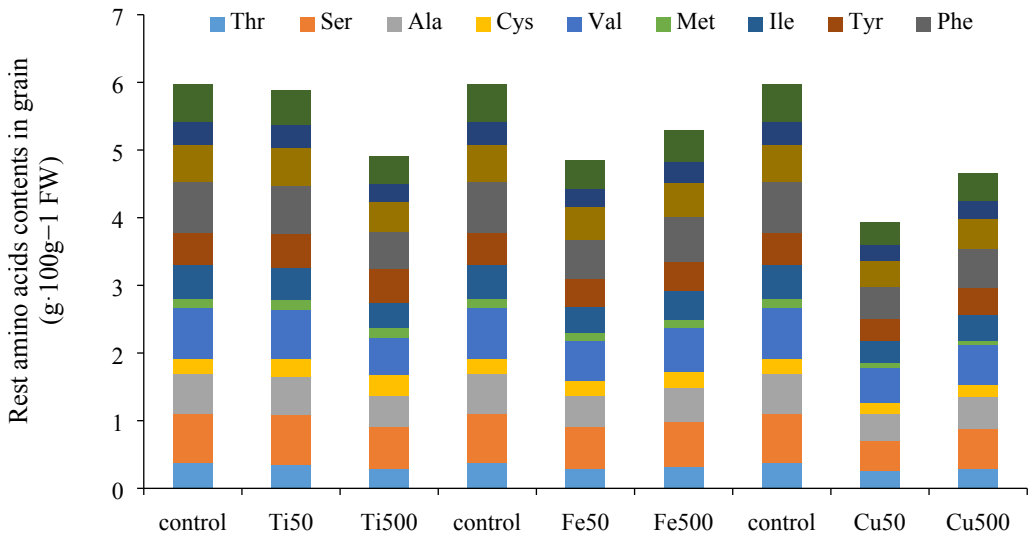

Figure S2. The content of the remaining amino acids in NP treated peanut grains

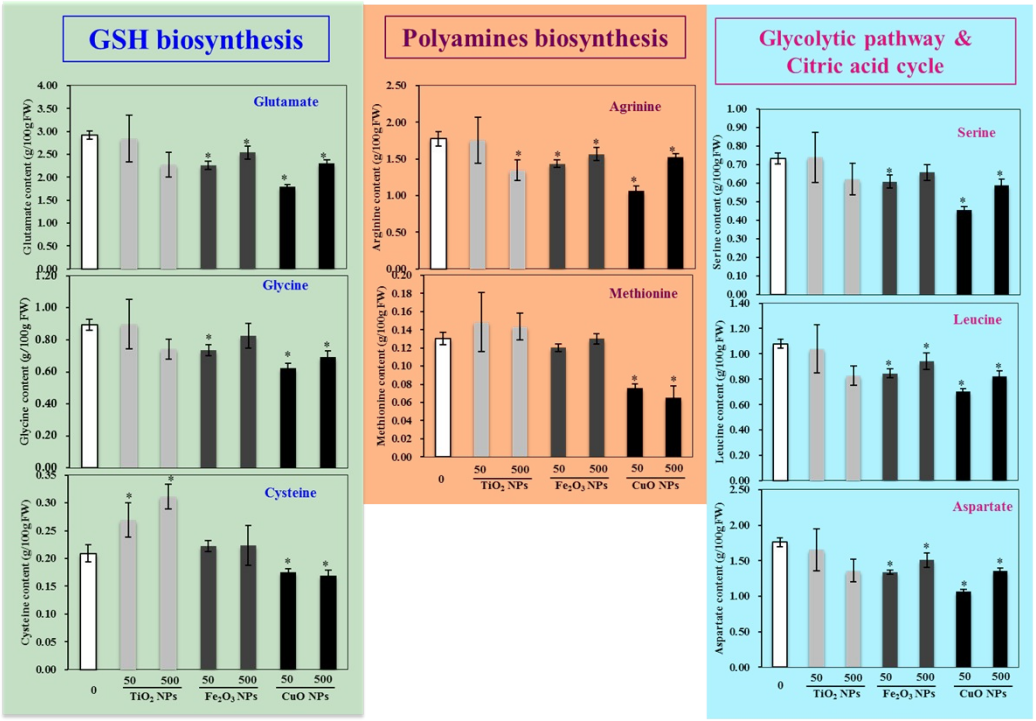

Figure S3. Summary of the amino acid content in NP treated peanut grains involved GSH biosynthesis, polyamine biosynthesis, as well as the glycolytic pathway and the citric acid cycle.

Table S4. The relative contents (%) of 18 fatty acids in fresh peanut grains

Fatty acid	Cu			Fe			Ti (mg·kg^{-1})		
	Control	50	500	Control	50	500	Control	50	500
C10:0	0.02 ± 0.01a	0.03 ± 0.01a	0.03 ± 0.01a	0.02 ± 0.01a	0.03 ± 0.01a	0.03 ± 0.01a	0.02 ± 0.01a	0.03 ± 0.01a	0.02 ± 0.01a
C12:0	0.01 ± 0.002a	0.02 ± 0.005a	0.02 ± 0.004a	0.01 ± 0.002a	0.02 ± 0.004a	0.02 ± 0.003a	0.01 ± 0.002a	0.01 ± 0.003a	0.02 ± 0.005a
C14:0	0.05 ± 0.01a	0.04 ± 0.003a	0.04 ± 0.002a	0.05 ± 0.01a	0.04 ± 0.001a	0.04 ± 0.01a	0.05 ± 0.01a	0.04 ± 0.004a	0.04 ± 0.004a
C15:0	0.011 ± 0.001	0.077 ± 0.12a	0.016 ± 0.01a	0.011 ± 0.001	0.009 ± 0.0004	0.009 ± 0.001	0.011 ± 0.001	0.008 ± 0.001	0.009 ± 0.0004
C16:0	a	10.80 ± 0.33a	10.46 ± 0.39a	a	b	b	a	b	b
C16:1	10.98 ± 0.43a	0.07 ± 0.01a	0.06 ± 0.003a	10.98 ± 0.43a	10.77 ± 0.24a	10.46 ± 0.27a	10.98 ± 0.43a	10.22 ± 0.39a	10.41 ± 0.34a
C17:0	0.07 ± 0.02a	0.06 ± 0.01b	0.08 ± 0.01ab	0.07 ± 0.02a	0.06 ± 0.002a	0.06 ± 0.004a	0.07 ± 0.02a	0.06 ± 0.001a	0.05 ± 0.002a
C18:0	0.10 ± 0.02a	5.34 ± 0.26a	5.01 ± 0.68a	0.10 ± 0.02a	0.07 ± 0.005a	0.08 ± 0.01a	0.10 ± 0.02a	0.07 ± 0.005a	0.07 ± 0.01a
C18:1n9c	4.63 ± 0.45a	44.87 ± 2.02a	46.18 ± 0.95a	4.63 ± 0.45a	4.57 ± 0.28a	4.76 ± 0.05a	4.63 ± 0.45a	5.29 ± 0.51a	4.70 ± 0.25a
C18:2n6c	45.60 ± 0.77a	32.95 ± 1.18a	32.03 ± 0.69a	45.60 ± 0.77a	46.62 ± 1.53a	47.45 ± 0.47a	45.60 ± 0.77b	49.09 ± 0.93a	46.44 ± 0.91b
C18:3n3	32.69 ± 0.21a	0.07 ± 0.01a	0.09 ± 0.02a	32.69 ± 0.21a	32.32 ± 1.31a	31.71 ± 0.35a	32.69 ± 0.21a	30.23 ± 0.91b	32.87 ± 0.58a
C20:0	0.08 ± 0.004a	1.66 ± 0.10a	1.66 ± 0.05a	0.08 ± 0.004a	0.07 ± 0.01a	0.09 ± 0.04a	0.08 ± 0.004a	0.06 ± 0.01b	0.06 ± 0.003b
C20:1	1.55 ± 0.04a	0.73 ± 0.04a	0.77 ± 0.09a	1.55 ± 0.04a	1.51 ± 0.03a	1.54 ± 0.03a	1.55 ± 0.04a	1.52 ± 0.08a	1.53 ± 0.02a
C21:0	0.78 ± 0.03a	0.033 ± 0.01a	0.028 ± 0.01a	0.78 ± 0.03a	0.74 ± 0.09a	0.70 ± 0.03a	0.78 ± 0.03a	0.65 ± 0.05b	0.72 ± 0.03ab
C20:2	0.034 ± 0.002	0.018 ± 0.001	0.021 ± 0.002	0.034 ± 0.002	0.035 ± 0.002a	0.027 ± 0.01a	0.034 ± 0.002	0.019 ± 0.001	0.018 ± 0.01b
C22:0	a	a	a	a	0.018 ± 0.001b	0.018 ± 0.001	a	b	0.015 ± 0.001b
C22:1n9	0.021 ± 0.001	2.11 ± 0.19a	2.30 ± 0.29a	0.021 ± 0.001	2.03 ± 0.25a	b	0.021 ± 0.001	0.015 ± 0.001	1.93 ± 0.02ab
C24:0	a	0.05 ± 0.01a	0.07 ± 0.02a	a	0.04 ± 0.02ab	1.95 ± 0.10a	a	b	0.03 ± 0.01b
	2.17 ± 0.15a	1.09 ± 0.07a	1.14 ± 0.15a	2.17 ± 0.15a	1.03 ± 0.12a	0.03 ± 0.001b	2.17 ± 0.15a	1.74 ± 0.14b	1.05 ± 0.07ab
	0.07 ± 0.02a			0.07 ± 0.02a		1.02 ± 0.06a	0.07 ± 0.02a	0.03 ± 0.002b	
	1.13 ± 0.07a			1.13 ± 0.07a			1.13 ± 0.07a	0.92 ± 0.06b	

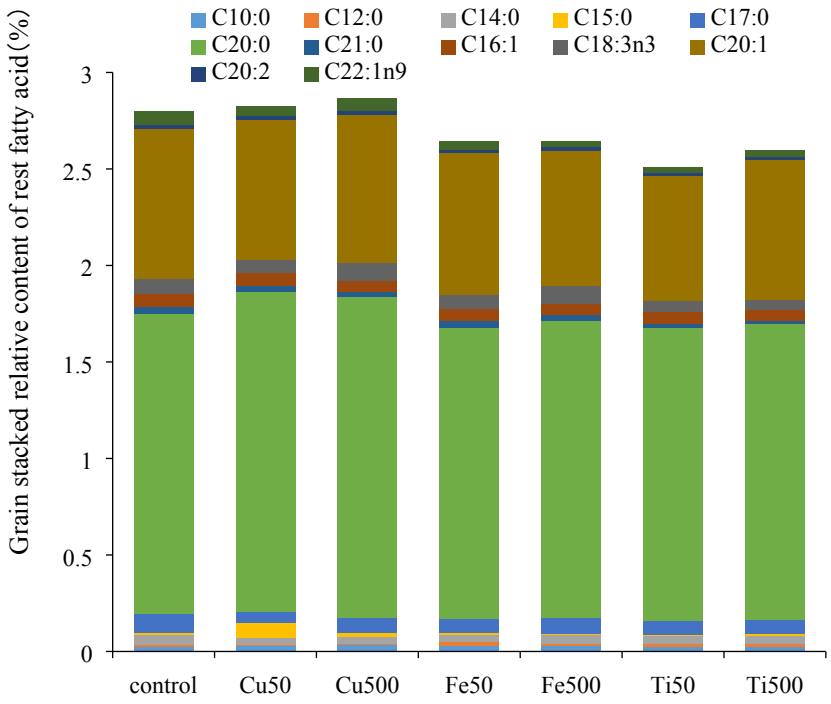

Figure S4. The remaining fatty acid content in NP treated peanut grains

Table S5. The resveratrol content in fresh peanut grains

Replicate number	Control	Fe		Ti		Cu (mg/kg)	
		50	500	50	500	50	500
1	< 0.1	< 0.1	< 0.1	1.6	2.1	1.7	2.7
2	< 0.1	< 0.1	< 0.1	1.5	2.5	1.7	2.1
3	< 0.1	< 0.1	< 0.1	1.8	2.0	2.1	2.2
Average	< 0.1c	< 0.1	< 0.1	1.63 ± 0.15	2.20 ± 0.26	1.83 ± 0.23b	2.33 ± 0.32a