Indian Journal of Animal Sciences **89**(9): 992–996, September 2019/Article
https://doi.org/10.56093/ijans.v89i9.93780

Effect of inorganic and organic trace minerals in diet on laying performance, egg quality and yolk mineral contents in broiler breeder hens

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Received: 13 July 2018; Accepted: 19 March 2019

ABSTRACT

Two hundred and twenty (20 male and 200 female) 39 weeks old Ross-308 broiler breeder hens were used in this experiment. Birds were placed in a complete randomized design with 4 dietary treatments (A: 100% inorganic, B: 50% organic + 50% inorganic, C: 50% organic, and D: 100% organic source of trace minerals) and 5 replications containing 1 male + 10 females in each having similar body weight and egg production. Results indicated that inclusion of organic and inorganic trace minerals in broiler breeders' diet did not have a significant effect on body weight change, feed intake, feed conversion ratio, and egg production. However, the diets containing organic and/ or inorganic trace minerals had a significant effect on some egg quality parameters such as albumin weight (%), egg shell weight, yolk weight, yolk index, shell strength, shell thickness, and yolk colour. Inclusion of organic and inorganic trace minerals in broiler breeders' diet also affected yolk trace minerals content. It was concluded that egg quality and yolk trace minerals content in broiler breeders can be affected by source of trace minerals in diet.

Key words: Broiler breeder, Egg quality, Trace minerals

Trace minerals are important nutrients which have beneficial effects on male and female broiler breeder chickens' performance, embryo development and also health. It has been reported that fatty acids sources and trace minerals such as iron, manganese, zinc, copper and selenium have significant effect on egg production, egg quality, embryo development and hatchability (Smith and Akinbamijo 2000, Ramadan *et al.* 2010, Olgun *et al.* 2012, Saber and Kutlu 2018). Trace minerals are essential nutrients affecting the quality of egg shell as they contribute to the formation of enzymes that play an important role in egg shell formation or directly help the formation of shell calcite crystals. Manganese has an important impact on the effective glycosyltransferase, which is vital in the formation of egg shell mucopolysaccharides (proteoglycan component). Lysyl oxidase is a cuproenzim that includes copper which can convert lysine to desmosin and isodesmosine (Chowdhury 1990). Zinc is one of the components of the carbonic anhydrase enzyme which is necessary in the structure of carbonate ions to form the egg shell (Nys *et al.* 1999). In iron deficiency, many systems are adversely affected because the oxygen in the tissues decreases due to the reduction in hemoglobin concentration and also it is important to say that egg formation and embryo formation are largely dependent on iron availability (Greengard *et al.* 1964). Selenium has an important role on embryo and post hatch development, formation of immunity, reproduction performance, formation of the antioxidant system in the body (Choct *et al.* 2004, Juniper *et al.* 2011), and muscle function (Zhang *et al.* 2012). Wang *et al.* (2019) reported that inclusion of organic and inorganic trace minerals in broiler breeders' diet do not have a significant effect on feed intake but have a significant effect on laying rate, egg quality and blood profiles. The present study aimed to investigate the effects of broiler breeders' diets, containing different levels and forms (inorganic vs. organic based) of trace mineral sources, on laying performance, egg quality, and yolk minerals contents.

MATERIALS AND METHODS

Two hundred and twenty Ross-308 broiler breeders (200 females + 20 males) aging 36 weeks were used. All birds were placed in experimental pens (2×1.5 × 2 m^2) with wood shaving litter (7–8 cm height), female tubular feeder and 1 individual male feeder. Each pen included 1 male and 10 female broiler breeders. During the 36th to 39th weeks of age, all birds were fed with standard broiler breeders' diet (pre-feeding) and through this period daily egg production and weekly body weight of birds were recorded and at the end of the 39th week of age all birds were divided into 4 treatments. The treatments were A: 100% inorganic, B: 50% organic + 50% inorganic, C: 50% organic, and D: 100% organic with 5 replications based on similar egg production and their body weight. All treatment diets were formulated based on corn and soybean (Table 1) and the content of organic and inorganic trace mineral contents were 0.20%

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Table 1. Composition of the basal diet

Ingredient	(%)	Nutrient composition	(%)
Yellow corn	54.49	Dry matter	88.52
Soybean meal	10.00	Crude protein (N 6.25)	19.00
Full fat soybean	9.64	Crude fibre	3.58
Limestone (GRN)	7.61	Crude fat	3.71
Sunflower meal-36	7.46	Ash	13.35
Corngluten meal-60	3.86	Starch	34.99
Meat-bone35	2.48	ME. POU	2.68
DCP-18	1.57	Ca	3.64
Soybean oil	2.00	Total phosphorus	0.78
Salt	0.24	AVE-P	0.50
Sodium bicarbonate	0.10	Met	0.37
L-Lysine	0.06	Meth+Cys	0.70
Choline-60	0.05	Try	0.20
DL-Methionine	0.04	Thr	0.70
Vitamin premix1	0.20	Na	0.16
Total	100.00	Lys	0.87

*Vitamin premix (per 2 kg of diet): 15,000 IU vitamin A, 5,000 IU vitamin D3, 100 mg vitamin E, 3 mg vitamin K_3, 3 mg vitamin B_1, 8 mg vitamin B_2, 60 mg niacin, 15 mg Ca-D-pantotenat, 5 mg vitamin B_6, 20 mg vitamin B_{12}, 2 mg folic acid, 200 mg D-biotin, and 100 mg vitamin C.

inorganic, 0.10% inorganic + 0.10% organic, 0.10% organic + 0.10% woods havings, and 0.20% organic in control, A, B, C and D groups respectivly. Also sources and contents of trace mineral premixes in organic or inorganic form were shown in Table 2.

The birds were fed the test diets from 40 to 45 weeks of age, during which light and feed (female: 156 gram/day, male: 130 g/day) were supplied according to recommendations of Ross Breeding company (Ross, 2016) without drinking water restriction. The environmental temperature (18–22°C) and humidity (55–60% RH) were maintained within the animal comfort zone using foggers and tunnel ventilation. During the experimental period (40th to 45th weeks of age), feed intake, feed conversion ratio, hen-day egg production and egg yield were recorded weekly. Body weight of birds was recorded at 39th and 45th weeks of age in order to calculate the changes in body weight. At the 44th and 45th weeks of age, eggs were collected twice a week (5 eggs from each replication) and analyzed for external + internal quality, and yolk trace minerals content by using Mars Express Feed Grain, XprAG-3, rev. date:/6/04.

The data obtained were analyzed using GLM (General Linear Model) procedure of the Statistical Analysis System (SAS, 2005), and Duncan's New Multiple Range Test in SAS was used to identify significant differences among treatments means. Results obtained in this study are presented as means per bird with standard errors of the difference between means (SED) with P values, except for feed intake as feed was given to the birds in equal amounts according to the recommendation of the Breeding Company (Ross, 2016).

RESULTS AND DISCUSSION

The inclusion of trace minerals in different forms and

Table 2. Sources and contents of trace mineral premixes in organic or inorganic form used in the experiment

Trace mineral	Source	Source amount in mix	Trace mineral amount in mix
Inorganic form (Per 2 kg)			
Manganese	$MnSO_4$ (32%)	250 mg	80 mg
Iron	$FeSO_4$ (30%)	200 mg	60 mg
Zinc	ZnO (72%)	83.333 mg	60 mg
Copper	$CuSO_4$ (77%)	6.494 mg	5 mg
Selenium	Na_2SeO_3 (45%)	4.444 mg	0.200 mg
Cobalt	$CoSO_4$ (20%)	1 mg	0.200 mg
Iodine	$Ca(IO_3)_2$ (62%)	1.613 mg	1 mg
Filling Mat.	Limestone	1.453 mg	
	Total	2000 mg	
Organic form (per 2 kg)			
Manganese	Mintrex Mn (Metionin-Hid. Analog Mn Chelate 15.5%)	516.129 mg	80 mg
Iron	Mintrex Fe (Methionine-Hid. Analog Fe Chelate 16.0%)	375 mg	60 mg
Zinc	Mintrex Zn (Metionin-Hid. Analog Zn Chelate 17.5%)	342.857 mg	60 mg
Copper	Mintrex Cu (Metionin-Hid. Analog Cu Chelate 18.0%)	27.777 mg	5.000 mg
Selenium	ZORIEN (SeY, % 2 Se)	10 mg	0.200 mg
Cobalt*	$CoSO_4$ (20%)	1.000 mg	0.200 mg
Iodine*	Ca $(IO_3)_2$ (62%)	1.613 mg	1.000 mg
Filling Mat.	Limestone	735614 mg	
	Total	2,000,000 mg	

*not organic form.

full or half amount in broiler breeders' diet did not have any effect on body weight, egg production, feed conversion ratio and egg weight of birds (P>0.05) (Table 3).

It is noteworthy to say that according to the broiler breeders' management program, the amount of daily food given to per animal in this period was 156 g; so the statistical analysis was not performed for feed intake and total feed intake parameters. Jegede *et al.* (2015) demonstrated that using of high levels of copper in layer hens' diet increased egg production but did not have significant effect on feed intake. They also reported that copper proteinate is biologically more effective than copper sulphate pentahydrate. Idowu *et al.* (2011) used 140 mg/kg zinc in the form of inorganic (oxide, sulphate, and carbonate) or organic (proteinate) in layer hens' diet and they observed that egg production and zinc accumulation in organism and fecal zinc excretion were higher in the group, which received a diet containing zinc proteinate. In addition, they reported that organic zinc source was biologically more effective than inorganic zinc sources. It was stated that using of organic or inorganic trace minerals at 72 to 80th weeks of age in layer hens' diets reduced egg losses and increased egg weight and egg production (Maciel *et al.* 2010).

The inclusion of different forms and levels of trace minerals did not have significant effects on external egg parameters such as egg weight, albumen weight and yolk weight (P>0.05) but egg shell weight was affected by dietary trace mineral (P<0.05), which was higher in group D than the other experimental groups (Table 4).

There were no significant differences in egg shape index, albumin index, and Haugh unit (P>0.05). But yolk index, shell strength and shell thickness were affected by dietary forms and levels of trace minerals (P<0.05) as yolk index was higher in group D. The results displayed that the eggs obtained from group A (100% inorganic form) had higher shell strength (3.65 kg/cm^2), shell thickness (335.62 μm), and higher yolk index values than those of other experimental groups (P<0.05). Amem and Al-Darji (2012) reported that adding of zinc in broiler breeders' diet had a beneficial effect on egg quality and also increased egg

Table 3. Effects of diet's trace minerals on broiler breeders laying performance.

Parameter	Group				SED	P value
	A	B	C	D		
Initial body weight (g/hen)	4291	4458	4532	4355	21.48	0.081
Final body weight (g/hen)	4466	4513	4532	4481	30.32	0.865
Body weight change (g/hen)	174.72	54.61	134.60	126.45	26.84	0.478
Feed conversion ratio (g feed/g egg)	3.70	3.48	3.87	3.32	0.10	0.324
Egg production (number/hen/28 day)	17.50	18.52	17.02	19.11	0.43	0.337
Egg production (%)	62.50	66.14	60.78	68.25	1.54	0.337
Egg weight (g/egg)	69.31	69.53	68.73	69.48	0.56	0.954

A, 100% inorganic; B, 50% organic + 50% inorganic; C, 50% organic; D, 100% organic. The amount of food given per animal per day is 156 g; therefore no statistical analysis were performed. ^{a,b}Mean in same row with different superscript letters are significantly different (P<0.05).

Table 4. Effects of trace minerals in diet on egg quality in broiler breeders

Parameter	Group				SED	P value
	A	B	C	D		
Egg weight (g)	67.58	67.32	67.74	67.73	0.23	0.917
Egg shell weight (g)	6.51^b	6.42^b	6.50^b	6.78^a	0.04	0.004
Egg shape index	76.23	75.35	75.48	76.22	0.21	0.297
Albumin weight (%)	57.71^{ab}	58.13^a	57.72^{ab}	56.91^b	0.15	0.038
Albumin index	5.15	5.37	5.27	5.35	0.10	0.841
Yolk weight (%)	32.63	32.33	32.67	33.06	0.15	0.414
Yolk index	39.76^b	40.87^{ab}	41.05a^b	41.72^a	0.25	0.049
Haugh unit	65.51	66.94	65.51	66.92	0.74	0.821
Shell strength (kg/cm²)	3.65^a	3.32^b	3.35^b	3.41^{ab}	0.01	0.068
Shell thickness (μm)	335.62^a	325.93^b	325.75^b	324.46^b	1.28	0.009
Yolk color						
l (Lightness)	60.06	59.79	59.32	59.70	0.13	0.219
a (Redness)	10.12^a	9.75^{ab}	9.73^{ab}	9.52^b	0.07	0.034
b (Yellowness)	62.83^a	60.95^b	62.05^{ab}	60.75^b	0.24	0.009

A, 100% inorganic; B, 50% organic + 50% inorganic; C, 50% organic; D, 100% organic. The amount of food given per animal per day is 156 g; therefore no statistical analysis was performed. ^{a,b}Mean in same row with different superscript letters are significantly different (P<0.05).

Table 5. Effects of diet's trace minerals on egg yolk trace minerals content

Week of age	Parameter	Group				SED	P value
		A	B	C	D		
44	Fe (mg/kg)	126.35^{c}	161.70^{b}	163.09^{b}	211.62^{a}	3.118	<.0001
	Zn (mg/kg)	66.62^{c}	81.47^{b}	77.60^{b}	107.96^{a}	1.107	<.0001
	Cu (mg/kg)	1.31^{c}	5.61^{a}	3.97^{b}	5.03^{a}	0.150	<.0001
	Mn (mg/kg)	3.30^{c}	4.38^{b}	3.78^{cb}	6.07^{a}	0.160	<.0001
45	Fe (mg/kg)	153.70^{b}	146.28^{b}	156.12^{b}	171.16^{a}	2.175	<.0012
	Zn (mg/kg)	72.26	78.10	73.95	77.30	0.712	<.2091
	Cu (mg/kg)	1.72^{b}	1.88^{ab}	1.71^{b}	2.06^{a}	0.020	<.0016
	Mn (mg/kg)	2.39^{b}	2.55^{ab}	2.15^{b}	2.64^{a}	0.045	<.0001

A, 100% inorganic; B, 50% organic + 50% inorganic; C, 50% organic; D, 100% organic. The amount of food given per animal per day is 156 g; therefore no statistical analysis was performed. ^{a,b}Mean in same row with different superscript letters are significantly different (P<0.05).

production and fertility parameters. Amino acid chelate form of zinc in broiler breeders' diet increased egg shell thickness and egg weight (Favero *et al.* 2013). Carvalho *et al.* (2015) reported that replacing of 70% of inorganic copper, manganese and zinc with organic sources in layer hens' diet did not affect performance and egg quality but reduced fecal excretion of these trace minerals.

Inclusion of dietary trace minerals in broiler breeders' diet had significant effect on yolk mineral contents (Table 5). The content of Fe, Zn and Mn at 44 weeks of age were higher in group D, and Cu content was higher in group B. At 45th week of age, the group fed diet containing 100% organic based trace mineral had high contents of Fe, Cu and Mn, and the group B had a higher Zn content in yolk. Pekel and Alp (2011) reported that feeding of 250 ppm copper sulphate reduced egg weight and feed intake and also copper sulphate and copper lysine reduced egg shell thickness. According to Bess *et al.* (2012), using of 60 mg/kg iron in the form of amino acid chelate in broiler breeders' diet increased iron content in egg yolk but egg production was not positively affected by dietary iron source. Ramadan *et al.* (2010) explained that use of different levels of inorganic iron, zinc, and copper had a significant effect on egg production, egg quality, feed conversion ratio, and yolk trace minerals contents, specially due to the addition of copper and zinc, the iron content in yolk was decreased.

The data obtained from this study revealed that using of organic and/or inorganic form of trace minerals in broiler breeders' diet did not have any significant effect on laying performance (P>0.05). Shell weight, shell thickness, yolk index, and yolk colour were significantly affected by the diet trace minerals form and levels (P<0.05) as using of 100% organic trace mineral source increased shell weight and shell thickness. Using 100% inorganic trace mineral source induced brighter, ruddy, and denser yolks.

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