Effects of organic and inorganic zinc supplementation in breeder hen rations on performance and egg quality*

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Abstract: In this study, the effects of two forms of zinc minerals (organic and inorganic) supplemented to rations for laying breeder hens were investigated relative to body weight, feed intake, feed conversion ratio, egg production, external and internal quality of eggs and egg weight. This 16-week study, which used 216 Barred Rock hens, was initiated when the hens were 48 weeks old. The animals were fed basal diet which is consist of 17% crude protein and 2800 kcal/kg metabolisable energy. The control rations were prepared using a zinc-free mineral mix. The other five treatments received 60 mg/kg of one of the following zinc supplements: Availa-Zn', $ZnSO_4$, Zinc RedoxMin, ZnO and $ZnCl_2$. It is concluded that (1) Zn-Avila added to rations had negative effects on feed consumption, egg shape index and eggshell strength; (2) the ZnSO4 supplement had positive effects on egg shape index, albumen index and Haugh units; (3) the Zn-RedoxMin supplement had positive effects on egg weight and egg shape index but negatively affected albumen index and Haugh units; and (4) the $ZnCl_2$ supplement had positive effects on feed conversion and eggshell strength, but it reduced the value of the index figure.

Keywords: Egg quality, laying hens, organic and inorganic zinc, performance.

Damızlık tavuk rasyonlarında organik ve inorganik çinko uygulamalarının performans ve yumurta kalitesine etkileri*

Öz: Bu çalışmada, damızlık yumurtacı tavuk rasyonlarına farklı iki formda ilave edilen çinko minerallerinin (organik ve inorganik) canlı ağırlık, yem tüketimi, yemden yararlanma oranı, yumurta üretimi, iç ve dış yumurta kalitesi ve yumurta ağırlığı üzerine etkisinin belirlenmesi amaçlanmıştır. Çalışmada 48 haftalık yaşta, 216 adet Barred Rock ırkı yumurtacı tavuk kullanılmış, çalışma 16 hafta sürmüştür. Hayvanlar %17 HP ve 2800 kcal/kg ME içeren temel rasyonla beslendi. Kontrol grubuna çinko ilavesi yapılmamıştır. Diğer beş deneme grubuna sırasıyla Availa-Zn', $ZnSO_4$, Zinc RedoxMin, ZnO and $ZnCl_2$ ilavesi yapılmıştır. Sonuç olarak, (1) Zn-Avila ilavesi yapılan grupta yem tüketimi, yumurta şekil indeksi ve yumurta kabuk mukavemeti üzerine olumsuz etkisi; (2) ZnSO4 içeren grupta yumurta şekil indeksi, albumin indeksi ve Haugh Birimi üzerine olumlu etkisi; (3) Zn-RedoxMin ilave edilen grupta yumurta ağırlığı ve yumurta şekil indeksi üzerine olumlu, albumin indeksi ve Haugh Birimi üzerine

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ise olumsuz etkisi; (4) $ZnCl_2$ ilavesinin ise yemden yararlanma ve yumurta kabuk direnci üzerine olumlu etkisi olduğu fakat indeks değerlerini azalttığı bulunmuştur.

*Anahtar s*özcükler: Organik ve inorganik çinko, performans, yumurtacı tavuk, yumurta kalitesi.

Introduction

Commercial egg production provides an important source of eggs, which are a very valuable nutritional component of human diets (28). In order to obtain maximum egg yield in production, feed rations must both maximise yield and meet daily nutritional requirements of laying hens. Likewise, for breeder hens, nutrient requirements determine optimal reproductive performance, embryogenesis and egg output. Malnutrition in hens negatively influences embryo and chick development, whereas malnutrition in male breeders diminishes their quality of semen and mating activity (32). Therefore, breeding-bird diets are designed to maintain egg yield, protect the health and produce fertilised eggs that provide all the nutrients needed for chick development (19). In addition to providing breeder hens with nutrient-rich rations, it has recently been shown that feeding them trace minerals also affects egg yield.

Most commercially produced poultry rations are formulated as oxides or sulfate salts. Supplementation levels are most frequently provided following recommendations issued by the National Research Council (NRC) (16). Pre-mixed minerals are generally added to feed at concentrations two to ten times higher than that suggested by the NRC (11).

Zinc is an essential mineral for all farmed animals. It is bound to cell proteins and is present in all enzyme classes (27). Of all the minerals provided in feed, zinc affects more aspects of hen biology than any other; it is important for growth, intracellular functions, strengthening of the immune system, protein synthesis, carbohydrate metabolism, acid-base balance and fertility. Zinc is also a structural component of a variety of enzymes (29), such as oxidoreductases, transferases, hydrolases, lyases, isomerases and ribonucleases (30). Zinc is also a structural component of carbonic anhydrase, which is very important for laying hens in that it is needed for the removal of carbon dioxide from the respiratory tract, for calcification, for keratinisation and for wound healing (5). It has been reported that carbonic anhydrase is important for shaping eggshells and that a deficiency of this enzyme leads to a decline in eggshell quality (15). Zinc also decreases plasma lipid peroxidation, increases glutathione levels (4, 17), catalyses DNA and RNA polymerases, catalyses transferase enzymes (22), enters the structure of hormonal functions (5), affects bone development (14) and positively influences growth (3).

The aim of this study is to examine the effects of adding zinc (in organic and inorganic forms) to the diet of breeder hens relative to their performance, egg yield and the quality of the inner and outer of parts of their eggs.

Material and Methods

A total of 216 Barred Rock-1 (BAR-1) hens were used in this 16-week study. (The hens were 48 weeks old when they were obtained from the Ankara Poultry Research Institute.) All food rations were obtained from commercial feed suppliers.

The composition of the main ration is summarised in Table 1. The second period rations, supplied to laying hens, contained 17% HP and 2800 kcal/kg ME. Inorganic zinc minerals were also added to feed. Organic and inorganic zinc provided a commercial company (Bil-Yem- Ankara).

At the beginning of the study, 350 hens were fed primarily with standard feed. During this period, we recorded egg yields and egg weights for all hens. When selecting hens for further study, we chose hens that were similar to one another relative to the parameters we intended to study (Table 2). Hens were then randomly assigned to individual three-storey cages, each of which provided 1300 cm^2 of living space. There were six groups of hens (one group for each treatment), with four subgroups (replicates) in each group and nine hens in each subgroup. The experimental layout was vertically divided into 24 parcels, and three cages (with one hen per cage) were placed on the floor in each parcel. Study groups and hens were randomly distributed among the parcels.

The study was performed at the Ankara Poultry Research Institute. In the study, mainly corn-soy feed was used. The hens' nutritional requirements were determined according to NRC guidelines (21). Feed and water were provided *ad libitum* and 14 hours of light (including natural light) was provided to the hens every day. Nutritional analyses of raw materials used for trial feeds were performed at the Ankara Poultry Research Institute Laboratory. Mixed feeds were then prepared on the basis of the results of these analyses. The analyses of raw feed materials, sugar and starch were determined according to methods specified by AOAC (1).

Table 1: The composition of the basic diet provided to laying hens in this study
***Tablo 1**: Yumurtacı tavuklara verilen temel rasyonun bileşimi*

Ingredients	(%)
Corn	52.65
Full-fat bean	17.40
Soybean meal	6.59
Sunflower meal	8.47
Corn gluten meal	2.33
Limestone	10.20
Dicalcium phosphate	1.5
Salt	0.35
DL-Methionine	0.11
Vitamin premix[1]	0.1
Mineral premix[2]	0.1
Salmonella protective	0.2
Total	100

[1]Each 2.5 kg feeds contains: Vit A 12.000.000 IU; Vit D_3 2.400.000 IU; Vit E 30.000 IU; Vit K_3 2.500 mg; Vit B_1 3.000 mg; Vit 7.000 mg; Niasin 20.000 mg; Cal- D-pant 6.000 mg; Vit B_6 4.000 mg; Vit B_{12} 15 mg; Folic Acid 1000 mg; D-Biotin 45 mg; Cholin chlorid 125.000 mg and Vit C 50.000 mg.[2] Each 1 kg feeds contains: Mn 80.000 mg; Fe 40.000 mg; Zn 60.000 mg; Cu 5.000 mg; Co 500 mg; I 2000 mg; Se 150 mg

Metabolisable energy levels were determined on the basis of data from Vogt et al. (31).

Survival was determined for each experimental group on the basis of the population at the start of the study. All hens weighed at the beginning of the study were classified into six weight classes (based on live weight), each with four subgroups (i.e. a total of 24 subgroups). Each subgroup contained 9 hens (i.e. n = 36 hens per group). Changes in the live weights were determined by subtracting the hens' weights at the beginning of the study from the hens' weights at the end. Feed consumption was determined by weighing each hen every 15 days. On day 15 of the study, any remaining feed was collected before providing fresh rations, and so the 15-day feed consumption was calculated by subtracting the remaining feed weight from the total amount administered. Then, daily feed consumption (the weight of feed/hen/day) was determined for each subgroup. Egg yield (the number of hens/day/100) was determined by counting eggs at the same time each day. Daily mortality was recorded and considered when calculating the mean daily feed consumption and egg yield. The 15-day feed consumption and egg yield for all subgroups were calculated in order to determine the feed conversion ratio (FCR), which was done by dividing the consumed feed by the quantity of eggs produced. All eggs were collected on the last two days of each two-week period, and their weights were determined with a digital balance sensitive to 0.01 g. Egg masses were calculated after determining egg weights, and percentage egg yields were determined at the end of the four-week experimental period.

Table 2: Trial scheme
Tablo 2: *Deneme dizaynı*

Treatment groups	Supplement
Control	Non supplement Zn
Zn-Avila	Organic 60 ppm Zn suppl.
ZnSO4.7H2O	Inorganic 60 ppm Zn suppl.
Zn-RedoxMin	Organic 60 ppm Zn suppl.
ZnO	Inorganic 60 ppm Zn suppl.
$ZnCl_2$	Inorganic 60 ppm Zn suppl.

Egg mass = egg weight x egg yield / 100

A shape index was calculated by dividing egg width by egg height and multiplying by 100. Shape indices were determined once every four weeks from 20 eggs obtained from each group, using a measuring tool developed by Rauch. These eggs were left at room temperature for 24 hours and then eggshell thicknesses were measured using a digital micrometer (mm). Eggshell thickness values were calculated from the sharp, blunt and middle part of each eggshell sample after removing the membrane; mean values were then calculated. Another 20 eggs were collected from each group every four weeks, stored at room temperature for 24 hours and then measured for eggshell strength. Eggshell strength was digitally measured using a strength-measuring device, with force values reported in newtons (N). The internal-quality characteristics of eggs were measured for another 20 eggs collected from each group every four weeks. These measurements were performed after eggs were broken on a glass table. In these measurements, yolk colour was determined using a yellow-colour Roche Color Fan, which displays yellow-colour tones from 1 to 15 according to a standard colorimetric system. Egg albumen length and width were measured using a caliper; albumen and yolk height were measured using an electronic measuring device.

Haugh units, calculated from albumen height, were determined from another 20 eggs selected from each group once every four weeks. (A Haugh unit is a feature that predicts the freshness and shelf life of an egg.) Albumen height (Haugh unit) predicts the freshness and quality of an egg. Haugh unit values were calculated with an egg quality analysis programme using the following equation (10):

Haugh unit = 100 Log (Egg albumen height + 7.57 – 1.7 Egg weight x $^{0.37}$*)*

Statistical Analyses: Minitab 17, a statistics programme, was used to perform statistical analyses. Differences between groups were determined using a one-way analysis of variance (one-way ANOVA). Tukey multiple comparison test was then performed in order to determine which groups differed significantly from others. When a p-value was lower than 0.05 ($p < 0.05$), the difference was accepted as being statistically significant. Data were represented as mean ± standard deviation.

Results

Nutrient concentrations of feed rations and metabolic energy values for hens calculated for the second period are provided in Table 3. Changes in live weights are summarised in Table 4. There was no significant change in live weights among the groups during the study period. All groups gained weight; there was a 130 g weight gain in the control group, a 151.7 g weight gain in the Zinc-Avila group, a 169.2 g weight gain in the $ZnSO_4.7H_2O$ group, a 138.1 g weight gain in the Zinc-RedoxMin group, a 93.6 g weight gain in the ZnO group and a 165 g weight gain in the $ZnCl_2$ group.

Mean of daily feed consumption, feed conversion ratio and egg weight for all groups are summarised in Table 5. Unlike our results for live weight gain, there were significant differences among the study groups relative to these factors. The lowest feed consumption rate was observed in the $ZnCl_2$ group ($p < 0.05$). The feed conversion ratio of the control group was higher than in any of the other study groups. The maximum egg weight occurred in the Zinc-RedoxMin group, which received a Zn mineral supplement.

Egg yields of the experimental groups are presented in Table 5. There was no difference in egg yield among the various sources of Zn supplements tested. During the study, egg yield values were calculated as 84% for the control group, 83% for the Zinc-Avila group, 83% for the $ZnSO_{4.}7H_2O$ group, 81% for the Zn-RedoxMin group, 82% for the ZnO group and 81% for the $ZnCl_2$ group. Therefore, supplementing the feed with 60 ppm organic or inorganic zinc did not affect egg yield.

The external qualities of the eggs, such as egg shape, eggshell thickness and eggshell strength, are shown in Table 6. We found statistically significant differences among treatments in egg shape indices ($p < 0.05$). The highest values were found in the $ZnSO_4$ and Zinc-RedoxMin groups, whereas the lowest indices were observed in the Zinc-Avila and $ZnCl_2$ groups. There was no significant difference between the ZnO and the control groups. Likewise, mean values of eggshell thickness did not significantly differ among the groups. However, eggshell strength was significantly affected by the form of zinc supplement added to the feed. The highest eggshell strength value was seen in the $ZnCl_2$ and ZnO groups. There was no significant difference between the control, the $ZnSO_4$ and the Zinc-RedoxMin groups, whereas the lowest eggshell strength value was observed in the Zinc-Avila group.

Our results on egg yolk indices, albumen indices, Haugh units and yolk colour are provided in Table 7. Egg yolk index values did not differ among the groups. However, there were significant differences among the groups relative to albumen index and Haugh unit values ($p < 0.05$). The highest value was obtained from the $ZnSO_4$ group (in which the inorganic form of zinc was supplemented), whereas the lowest value was obtained from the Zinc-RedoxMin group (in which organic zinc was supplemented). There were also significant differences between the groups in terms of egg yolk colour ($p < 0.05$). There was no difference between the control group and the Zinc-RedoxMin group in terms of yolk colour, and the lowest value was obtained from the $ZnCl_2$ group.

Discussion

In our study, supplementing different forms of organic and inorganic minerals to feeds of laying hens did not relate to any significant differences among treatments in weight gain. In this respect, our findings are similar to those of other studies. For example, there was no significant difference between the live weights of hens in our study and those fed with feed supplemented with Eggshell-49 (1g/kg) as a zinc source (8). Similar to our results, Sahin et al. (26) found that 30 mg/kg $ZnSO_4$ added to the feed of 32-week-old laying hens (HyLine) (at low air temperature) led to a significant ($p < 0.05$) weight gain in the hens. Furthermore, in a similar study, Mohanna and Nys (20) showed broiler hens gained significant weight when their feed was supplemented with 40 mg/kg $ZnSO_4$ and Zn-methionine.

Yenice et al. (33) stated that different amounts of trace mineral supplements did not lead to any significant differences between their experimental treatments relative to feed consumption and feed conversion ratios. Similarly, Keshavarz (12) reported that a mixture of Mn and Zn-protein supplements in feed did not significantly influence the amount of feed consumption in quail. Therefore, our results differed from the results of these studies, perhaps owing to differences among bird species, ages of animals used in the studies and amounts of zinc added to the feed.

In our study, feed conversion efficiency was affected by the origin of the supplemented zinc (e.g. whether it was organic or inorganic). The effect was positive for the $ZnCl_2$ group of hens compared with the other groups, whereas the maximum feed conversion ratio occurred in the

Table 3: Metabolisable energy values and concentrations of nutrients in feed rations

***Tablo 3:** Rasyonların besin madde içerikleri ve metabolize olabilir enerji değerleri*

Dry Matter,%[3]	91.2
Crude Protein,%[3]	16.9
Crude Fiber,%[3]	3.5
Crude Ash,%[3]	12.8
Ether Extract,%[3]	5.5
ME,kcal/kg[3]	2835
Ca, %	4.1
Digest. P,%	0.38
Methionine,%	0.40
Met.+cystine,%	0.72
Lizine,%	0.80
Tryptophane,%	0.19
Linoleic acid,%	2.71
Zinc, ppm	60

[3] *Calculated by using values of analyses.*

Table 4: Initial body weight (IBW), final body weight (FBW) and body weight change (BWC) of animals in the study

***Tablo 4:** Hayvanların başlangıç-bitiş canlı ağırlıkları (BCA) ve canlı ağırlık artışları (CAA)*

Treatment Groups	N	IBW (g)	FBW (g)	BWC (g)
		X±Sx	X±Sx	X±Sx
Control	36	1817.2±167.7	1947.2±187.0	130.0±116.6
Zn-Avila	36	1808.9±120.8	1960.6±158.8	151.7±103.2
ZnSO4.7H2O	36	1786.4±170.2	1955.6±189.9	169.2±91.6
Zn-RedoxMin	36	1797.8±138.1	1935.8±158.6	138.1±121.2
ZnO	36	1783.3±145.2	1876.9±184.1	93.6±174.8
$ZnCl_2$	36	1816.1±164.5	1981.1±208.0	165.0±166.5
P		0.889-	0.238-	0.168 -

-: *The difference between groups was not statistically significant (p<0.05).*

control group. There was no significant difference between the $ZnSO_4$, ZnO and Zinc-RedoxMin and Zn-Avila groups owing to the addition of other zinc sources. It has been assumed that feed conversion should be negatively affected in control groups (no supplement) because the increment in the feed consumption and egg yield decreases. Plaimast et al. (23) reported that supplementing inorganic ($ZnSO_4$) and organic (Zn amino acid chelate) did not affect feed conversion efficiencies. Similarly, it was also shown that feed supplemented with $ZnSO_4$ and Zinc-RedoxMin did not significantly increase feed conversion efficiencies in hens. Yenice et al. (33) also did not detect any significant differences

Table 5: Effects of different forms of zinc supplement on feed intake, feed conversion ratio, egg weight and egg yield

Tablo 5: *Farklı formdaki çinko ilavesinin yem tüketimi, yemden yararlanma oranı, yumurta ağırlığı ve yumurta verimi üzerine etkisi*

Treatment Groups	N	Feed Intake (g)	Feed Conversion Ratio (g feed/g egg)	Egg weight (g)	Egg Yield (d/hen/100)
		X±Sx	X±Sx	X±Sx	X±Sx
Control	32	118.30±9.99^{a}	2.39±0.20^{a}	58.52±1.69^{b}	0.84±0.05
Zn-Avila	32	108.76±10.98^{b}	2.21±0.26^{ab}	59.39±2.44^{ab}	0.83±0.06
ZnSO4.7H2O	32	113.96±11.46^{ab}	2.28±0.22^{ab}	59.93±1.50^{ab}	0.83±0.04
Zn-RedoxMin	32	111.83±11.16^{ab}	2.27±0.21^{ab}	60.84±2.24^{a}	0.81±0.05
ZnO	32	112.94±12.37^{ab}	2.28±025^{ab}	59.52±1.95^{ab}	0.82±0.04
$ZnCl_2$	32	107.12±13.57^{b}	2.18±0.28^{b}	60.04±2.03^{ab}	0.81±0.05
P		0.009*	0.024*	0.015*	0.254^{-}

*a,b: the difference between values which are represented with different letters in the same column is statistically significant. *:p<0.05*

-: The difference between groups was not statistically significant (p<0.05).

among treatments in terms of feed conversion for various trace mineral feed supplements. It is generally thought that the differences among study results in feed conversion efficiencies are due either to differences among the breeds and ages of the animals or to different amounts of zinc being added to the feed.

In this study, egg weight was significantly affected by zinc relative to its origin (inorganic vs organic), and there was a significant difference between the control group and the organic zinc supplement group (Zinc-RedoxMin). Similarly, Park et al. (22) found that 10 g/kg of Zn-propionate added to the feed of 66-week-old laying hens (Single Comb White Leghorn) increased their egg weights ($p < 0.05$). Also, egg weight increased as a result of supplementing organic trace minerals (Se + Zn + Mn) to the rations for ISA Brown laying hens in their second period (25). In another study, Plaimast et al. (23) found that egg weight was not significantly affected when the feed of 36-week-old ISA Brown laying hens was supplemented with inorganic ($ZnSO_4$) and organic (Zn amino acid chelate). In addition, it has also been shown that there is no alteration in egg weight following the supplementation of various concentrations of trace minerals (33).

In this study, the type of Zn added (at 60 ppm) did not influence egg yield. Our results are similar to those by Guo et al. (9), who showed that egg yield was not influenced by 0 and 160 mg/kg of Zn added to the main ration. On the other hand, Rapp et al. (25) found that egg yield increased when organic trace minerals were added to the feed of ISA Brown laying hens in their second period.

Other studies also have shown that the external qualities of eggs, such as eggshell thickness, were not affected by whether the trace mineral supplement was inorganic or organic (8, 18). In addition, it has been shown that organic and

Table 6: Effects of different forms of zinc supplement on shell thickness, shape index and eggshell strength

***Tablo 6**: Farklı formdaki çinko ilavesinin kabuki kalınlığı, şekil indeksi ve yumurta kabuğu mukavemeti üzerine etkisi*

Treatment Groups	N	Shell Thickness (10^{-2} m)	Shape Index (%)	Egg Shell Strength (kg-cm^2)
		X±Sx	X±Sx	X±Sx
Control	80	0.324±0.02	76.01±3.62^{abc}	39.24±7.07^{ab}
Zn-Avila	80	0.321±0.03	74.93±2.58^{c}	36.50±7.45^{b}
ZnSO4.7H2O	80	0.322±0.026	76.79±3.78^{a}	39.06±6.55^{ab}
Zn-RedoxMin	80	0.320±0.028	76.55±2.57^{ab}	38.44±7.91^{ab}
ZnO	80	0.323±0.02	76.04±2.80^{abc}	40.14±6.18^{a}
$ZnCl_2$	80	0.328±0.24	75.35±2.09^{bc}	40.45±7.18^{a}
P		0.417^{-}	0.001*	0.008*

-: The difference between groups was not statistically significant (p<0.05).
*a,b,c: the difference between values which are represented with different letters in the same column is statistically significant. *:p<0.05*

Table 7: Effects of different forms of zinc supplement on the egg yolk index, albumen index, Haugh unit and colour of the egg yolk

***Tablo 7:** Farklı formdaki çinko ilavesinin yumurta sarı indeksi, albumen indeksi, Haugh Birimi ve yumurta sarısı rengi üzerine etkisi*

Treatment Groups	N	Yolk index (%)	Albumen Index (%)	Haugh Unit	Egg Yolk Colour
		X±Sx	X±Sx	X±Sx	X±Sx
Control	80	46.88±2.96	7.79±1.78^{ab}	79.20±8.55^{ab}	13.08±0.72^{ab}
Zn-Avila	80	47.39±2.65	7.78±1.48^{ab}	79.89±6.71^{ab}	13.12±0.70^{a}
ZnSO4.7H2O	80	47.62±2.42	8.09±1.87^{a}	80.14±8.55^{a}	13.13±0.79^{a}
Zn-RedoxMin	80	46.83±2,77	7.19±1.56^{b}	76.30±7.81^{b}	12.90±0.76^{ab}
ZnO	80	47.20±3.01	7.72±1.85^{ab}	77.74±8.92^{ab}	13.12±0.69^{a}
$ZnCl_2$	80	47.20±2.64	7.73±1.42^{ab}	78.48±6.84^{ab}	12.75±0.90^{b}
P		0.445^{-}	0.034*	0.024*	0.006*

-: The difference between groups was not statistically significant (p<0.05).
*a,b,c: the difference between values which are represented with different letters in the same column is statistically significant. *:p<0.05*

inorganic micro-supplements did not affect eggshell thickness (33). Furthermore, Culfadar (6) reported that inorganic zinc and phytase added to corn and soybean rations did not affect eggshell thickness or weight. However, Qiujuan et al. (24) stated that organic copper, manganese and zinc supplements increased eggshell thickness in laying hens. Zamani et al. (34) examined the effects of zinc and mangan combinations on the eggshell quality of laying hens, and they showed that Zn supplements did not affect eggshell breaking strength. Differences in results among these studies might be due to differences in the content of adjunct ingredients, breed, age of animals and/or differences in utilisation rates.

In our study, Mn and Zn supplemented as inorganic and organic mineral sources did not affect Haugh measurements, which supports the results of Rapp et al. (25) but is at odds with a study by Keshavaraz et al. (13). Unlike our findings, Aliarabi et al. (2) found that albumen height and Haugh measurements in hens that consumed organic Zn sources were higher than in hens that did not receive supplements. In another study, it was specified that various amounts of trace mineral supplements did not lead to differences in internal egg quality, determined by albumen height and Haugh unit (33). Differences in results among these studies may be due to differences in the content of organic and inorganic sources of Zn added to the feed and/or in the breed and age of the experimental animals.

Conclusions

In this study, characteristics such as performance and egg quality were examined in Barred Rock brown laying hens fed by rations supplemented with organic and inorganic sources of zinc at 60 mg/kg. We found that;

- supplementing $ZnSO_4$ as a Zn source positively affected the egg shape index, albumen index and Haugh unit;
- adding Zn-RedoxMin (organic) positively affected egg weight (heavier) and egg shape index; and
- adding $ZnCl_2$ to the feed increased the feed conversion rate and eggshell strength.

In conclusion, commercial growers should supplement the feed rations for laying breeder hens with zinc (in either organic and inorganic forms). In addition, further studies should be conducted on the effects of different organic Zn sources added to the diet of laying breeder hens.

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