Korean J. Food Sci. Ani. Resour.
Vol. 31, No. 2, pp. 207~214(2011)

ARTICLE

Influence of Various Levels of Organic Zinc on the Live Performance, Meat Quality Attributes, and Sensory Properties of Broiler Chickens

Hossan Md. Salim[1,2], Hak Rim Lee[1], Cheorun Jo[1], Soo Kee Lee[1], and Bong Duk Lee[1]*

[1]*Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 305-764, Korea*
[2]*Poultry Science Division, National Institute of Animal Science, Cheonan 330-801, Korea*

Abstract

The influence of supplementing diets with various levels of organic zinc (OZ) on the performance, meat quality attributes, and sensory properties of broiler chickens was investigated. A total of 3,200 1-d-old female broiler chicks were randomly allotted to 16 floor pens (replicates) with 200 birds per pen. A corn-wheat-soybean meal basal diet (control) was formulated and 20 ppm OZ (20 OZ), 40 ppm OZ (40 OZ), or 80 ppm OZ (80 OZ) was added to the basal diet to form four dietary treatments with four replicates per treatment. Live performance of broiler chickens, meat quality, and sensory properties were evaluated. The results showed no significant difference among the treatments for live performance of broiler chickens. Significant increases ($p<0.05$) in thigh skin epidermis and dermis thickness were shown in the OZ supplementation groups; however, no effect of OZ on the thickness of back skin epidermis or dermis was found. Dietary OZ levels did not affect the pH of breast and thigh meat or the water holding capacity (WHC) of thigh meat, but the WHC of breast meat increased significantly ($p<0.05$) when birds were fed 40 OZ and 80 OZ. Results of a sensory analysis showed no differences among the dietary treatments. In conclusion, dietary OZ did not affect live performance or sensory properties of broiler chickens but did increase the WHC of breast meat and thickness of skin layers; thus, improving carcass quality in broiler chickens.

Key words: organic zinc, live performance, meat quality attributes, sensory properties, broilers

Introduction

Zinc is a trace mineral that is required for the normal growth, development and function of all living organisms. In chicken, zinc is needed for growth, feathering, skeletal development, immunity, meat yields, and carcass quality (Bonimi *et al*., 1983; Pinion *et al*., 1995; Stahl *et al*., 1989). Zinc deficiency causes reduction in weight gain, poor bone mineralization, increases skin lesions and poor wound healing in chicken (Scott *et al*., 1982; Young *et al*., 1958). El Swak *et al*. (1992) reported that wound healing was slower in zinc deficient rats than zinc supplemented rats. Moreover, zinc plays a vital role in the production of epithelial cells (Costa, 2005), skin nucleic acid, keratin, and collagen synthesis (Miller *et al*., 1979).

Collagen is the principle structural component of skin which is mainly responsible for the skin layer thickness and strength. Tensile strength of skin is highly correlated to skin tearing which is a costly problem in the broiler industry resulting in downgrades of broilers (Angel *et al*., 1985; Schleifer, 1988). In severe cases frequency of skin tearing increases about 60% in a flock (Cahaner *et al*., 1993) and may cause muscle shredding of up to 5.7% in the female birds (Pitcovski *et al*., 1994). Skin tears also allow carcasses to absorb additional moisture in the chill tank that may reduce shelf life of meat. The superoxide dismutase, one of the zinc-containing antioxidant enzymes, has a critical role in keeping broiler skin healthy and increasing the shelf life of broiler meat (Salim *et al*., 2008). In addition, over the last few years, consumer demands regarding broilers with good quality skin have substantially increased in the markets.

Broiler carcass appearance is the major criterion of evaluation of meat quality and consumer purchase. However, other quality attributes, such as tenderness, cook loss, water holding capacity (WHC), pH and sensory properties are equally important during the preparation of meat and meat products (Cross *et al*., 1986). Raw meat used in further processed products should have good functional properties to ensure a final product of exceptional quality and profitability.

*Corresponding author: Bong Duk Lee, Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 305-764, Korea. Tel: 82-42-821-5778, Fax: 82-42-825-9754, E-mail: leebd@cnu.ac.kr

Recently, a compound containing organic zinc (OZ), zinc proteinate, was made available to the feed industry. It has been reported that the addition of zinc proteinate as OZ to the diets of broilers could increase BW, feed intake, feed efficiency (Ao *et al*., 2009), and carcass quality (Salim *et al*., 2010). In fact, organic minerals chelated to small peptides have much greater bioavailability through increased selective transport of peptides at the gut level (Webb *et al*., 2005) and reduced excretion through droppings (Bao *et al*., 2007). An experiment conducted in our laboratory has shown that dietary OZ was more effective than inorganic zinc in the improvement of skin zinc concentration and skin quality of broiler chickens (Salim *et al*., 2010). Rossi *et al*. (2007) reported that a reduction in skin tearing was observed by the addition of OZ in the broiler diets which would improve carcass appearance. The authors also found that live performance, carcass and cut-up yield of broiler chickens were not influenced by various levels of dietary OZ. On the other hand, Hess *et al*. (2001) concluded that the influence of OZ on broiler chicken live performance, carcass bruising and foot pad quality appeared to vary with environmental conditions. However, various levels of dietary OZ supplementation effects on skin and meat quality attributes, and sensory properties of broiler chickens are not available. Thus, the present experiment was conducted to investigate the influence of supplementing diets with various levels of OZ on the live performance, meat quality, and sensory properties of broiler chickens.

Materials and Methods

Experimental birds, diets and treatments

Three thousand and two hundred 1-d-old female broiler chicks (Ross × Ross 308) were randomly assigned to 16 rice hull-littered floor pens (replicates) with 200 chicks per pen (0.093 m^2/bird). Continuous lighting was provided throughout the experimental period. The initial room temperature was 32°C, and reduced by 3°C each wk until 35 d of age. Chicks were allowed free access to feed and water throughout 5 wk feeding period. All procedures were approved by the Animal Care and Welfare Committee of Chungnam National University, Korea. As shown in Table 1, a corn-wheat-soybean meal basal diet (Control) was formulated and 20 ppm OZ (20 OZ), 40 ppm OZ (40 OZ), and 80 ppm OZ (80 OZ) were added to the basal diet to give four dietary treatments. The basal diet was formulated to either meet or exceed the National Research Council requirements (NRC, 1994) except zinc,

Table 1. Composition of the basal (Control) diet

Ingredients	Amount (%)
Corn	25.78
Wheat	30.00
Soybean meal	22.99
Rape seed meal	3.00
DDGS[1]	10.00
Yellow Grease	4.26
DL-Methionine	0.30
L-Lysine (98%)	0.38
L-Threonine (98%)	0.08
Salt	0.23
Limestone	1.79
Monocalcium phosphate	0.66
Phyzyme	0.05
Mineral mixture[2]	0.20
Vitamin mixture[3]	0.05
Choline chloride	0.12
Salinomysine	0.10
Avylamycine	0.03
Total	100.0
Calculated composition	
Crude protein (%)	20.11
ME (kcal/kg)	3,070
Ca (%)	0.99
Total P (%)	0.55
Available P (%)	0.48
Lysine (%)	1.24
Methionine (%)	0.61

[1]Corn distillers dried grains with soluble
[2]Mineral mixture supplied per kilogram of complete feed: iron, 146 mg; copper, 72 mg; iodine, 0.95 mg; selenium, 0.4 mg; manganese, 89 mg
[3]Vitamin mixture supplied per kilogram of complete feed: vitamin A, 12000 IU; vitamin D_3, 3,000 IU; vitamin E, 32 mg; vitamin K_3, 2.06 mg

Table 2. Analyzed zinc concentrations in the experimental diets for broiler chickens (8 to 35 d)

Treatments[1]	Dietary zinc (ppm)[2]
Control	33.57±0.56
OZ 20	54.56±0.95
OZ 40	74.06±0.78
OZ 80	113.66±1.06

[1]Control, without zinc supplement; OZ 20, organic zinc 20 ppm; OZ 40, organic zinc 40 ppm; OZ 80, organic zinc 80 ppm
[2]Values(means±SD; n = 3) are as-fed basis.

and fed for the first 7 d to all birds. Chicks were fed experimental diets for the next 28 d. The OZ source was zinc proteinate (Bioplex Zn, Alltech Inc., Nichoasville, KY, USA) that contained 15% zinc. Analyzed zinc concentrations of experimental diets by AOAC (2000) are presented in Table 2.

Live performance

The BW and feed intake were measured by pen at weekly intervals. Feed conversion was calculated as the feed to gain ratio. Livability of bird was recorded daily and calculated as percentage within the pen. The European production efficiency factor (EPEF) was calculated according to the following formula (Peric *et al*., 2009):

$$EPEF = (BW\ (g) \times \text{survival rate}\ (\%)) \div (\text{feed conversion} \times \text{duration of trial}\ (d)) \times 10.$$

Measurement of skin layer thickness

At the end of the feeding trial, one broiler chicken from each pen, close to the mean BW, was selected and killed by cervical dislocation. Then about 1 cm^2 of skin samples from the outer side of left and right thigh and the pelvic back region of each broiler chicken were collected. The samples were fixed in 10% neutral formalin (pH 7.4), dehydrated in a graded series of ethanol and embedded in paraffin, after which 4-μm-thick sections were stained with hematoxylin and eosin. Thickness of skin layers (epidermis and dermis) were examined (×100) under a light microscope (Olympus Co. Ltd., BX 50, F-3, Japan) with a camera (Focus Light, Version 2.88). Only the thinnest part of the skin layer was measured on each of skin replicates from a treatment.

Sample collection for carcass evaluation

At the end of the feeding trial, two broiler chickens from each pen, close to the mean BW, were weighed, exsanguinated by cutting the jugular vein, scalded, plucked, and eviscerated manually. Meat samples were collected and stored about one mon at -20°C in a deep freezer (Sanyo Electric Co., Ltd. MDF-492, Japan). Vacuum-packed meat samples were thawed by heating for 20 min at 35°C in a water bath and the WHC, pH, and sensory evaluation were performed.

Determination of water holding capacity (WHC)

The centrifugation method was performed for the determination of WHC of breast and thigh meat as described by Kristensen and Purslow (2001) with some modifications. One gram of ground meat was placed on a round filter paper (No.4, Whatman Ltd. UK). The filter paper with meat was put into centrifuge tubes (Mobicols from MoBiTec, Göttingen) and centrifuged (CR 20B2, Hitachi Koki Co., Ltd., Japan) at 6,710 g for 10 min. The released water content was measured and calculated as percentage of the initial moisture content of meat.

Determination of pH

One gram each of ground breast and thigh meat was homogenized in 900 μL of distilled water and then centrifuged (CR 20B2, Hitachi Koki Co., Ltd. Japan) at 3,000 g for 15 min. The sample was placed on a round filter paper (No.4, Whatman Ltd. UK) and the pH of the homogenate was measured using a pH meter (Model 750 P, ISTEC, Seoul, Korea).

Sensory analysis

Sensory panel tests were carried out for the cooked breast and thigh meat without skin. Ten panelists were selected from the meat science laboratory of our department and all had experience in poultry meat sensory analysis. Criteria for selection were: age between 20 to 40 years, not allergic to chicken, consumption of chicken at least once a wk, and willingness to evaluate meat from experimental chickens. Chicken breast and thigh meat contained in the air tied vinyl bags were thawed by heating for 20 min at 35°C in a water bath. The bags were then opened and pieces of meat (30 g each) were placed in screw-capped flasks. These were heated at 75°C for 20 min in a 177°C electric oven and served to the panelists. Samples from all dietary treatments were randomly presented to each panelist in one session. They were asked to rank the meat samples using a 9-point category hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) (Peryam and Girardot, 1952). Sensory analysis included seven characteristics such as color, odor, taste, tenderness, juiciness, flavor, and acceptability. Water and unsalted crackers were provided to clean their plates between samples.

Statistical analyses

Data from the experiment were analyzed by one-way ANOVA using the General Linear Models procedure of the Statistical Analysis System (SAS, 2003). Pen means were used as the experimental units for all variables evaluated. When significant ($p<0.05$), treatment means were compared using the Duncan's multiple range test procedure.

Results and Discussion

During the entire feeding trial period no significant differences were observed among treatments for any performance parameter or EPEF measurements of birds (Table 3). A numeric, but not significant, difference in feed conversion was observed only for the broilers fed OZ 80 at 35 d of age. Hess *et al*. (2001) reported that feed conversion was improved for broiler chickens fed zinc methionine at 35 d of age, and for male broilers at 21 d of age. These authors also found significant improvement in BW of male broilers at 21 d of age, when birds fed zinc-methionine and zinc-lysine as complexed zinc products. Similarly, Ao *et al*. (2009) reported that dietary supplementation of zinc from organic source was increased BW, feed intake, and feed conversion of chicks. However, previous studies with inorganic zinc (Mehring *et al*., 1956; Wang *et al*., 2002), and with organic zinc (Hudson *et al*., 2004; Rossi *et al*., 2007), indicated that growth performance, leg abnormalities, and carcass yields were unaffected when dietary zinc were provided in excess of the NRC (1994) recommendations of 40 ppm. However, the actual zinc concentrations in the supplemented groups of the present experiment were 54.56, 74.06, and 113.66 ppm, which was higher than the NRC (1994) recommendations.

The back skin epidermis and dermis thickness were not influenced by OZ supplementation, but the thickness of thigh skin epidermis was significantly increased ($P < 0.05$) in OZ 80 as compared with Control and OZ 20 (Table 4). Moreover, significant increases ($P < 0.05$) in thigh skin dermis was observed in response to various levels of OZ supplementations (Table 4; Fig. 1). Another study conducted in our laboratory has shown that dietary OZ supplementation significantly increased the tibia and back skin dermis thickness of broiler chickens (Salim *et al*., 2010). The authors also reported that the epidermis of tibia and back skin were not affected by the zinc supplementation, which is not in agreement with the thigh skin epidermis data of the present experiment. However, Rossi *et al*. (2007) observed that the number of epithelial cell layers was increased with increasing levels of OZ in the diet of broiler chickens.

Zinc is necessary for the production of epithelial cells (Costa, 2005), the first barrier to infection (Johnson *et al*., 2001). Zinc also plays a role in collagen synthesis (Leeson and Summers, 2005) and the thickness of the dermis layer depends on the collagen content in the skin. Normally, the skin has two main layers; a) epidermis which is covering the exterior surface of the body, and b) the deeper layer called the dermis which is mainly composed of connective tissue, collagen. Collagen is the principle structural protein of skin and is responsible for the skin strength in a variety of species (Harkness, 1971; Fjolstad

Table 3. Effect of various levels of organic zinc (OZ) on live performance of broiler chickens (2-5 wk)

Item	Treatment[1]				p value
	Control	OZ 20	OZ 40	OZ 80	
BW gain, g/bird	1,599±4	1,560±7	1,602±7	1,574±2	0.568
Feed intake, g/bird	2,525±18	2,462±19	2,563±42	2,524±43	0.328
Feed/gain	1.59±0.06	1.59±0.02	1.57±0.01	1.55±0.04	0.327
Livability, %	96±1.3	96±1.0	95±1.5	97±1.0	0.232
EPEF	292±16	284±12	294±11	300±10	0.502

[1]See Table 2
[2]Values are expressed as (means±SD; n=800)
[3]EPEF, European production efficiency factor

Table 4. Skin layer thickness (μm) of broiler chickens fed various levels of organic zinc (OZ)

Treatments[1]	Back skin		Thigh skin	
	Epidermis	Dermis	Epidermis	Dermis
Control	21.28±3.91[2]	71.36±3.22	19.15±3.70[b]	65.98±3.88[b]
OZ 20	22.16±0.95	76.19±15.63	18.51±0.86[b]	87.80±10.01[a]
OZ 40	22.07±0.86	78.64±9.25	21.44±1.52[ab]	88.13±5.33[a]
OZ 80	25.79±3.77	82.51±17.93	24.45±1.47[a]	83.22±15.19[a]

[1]See Table 2
[2]Values are expressed as (means±SD; n= 4)
[a-b]Means with different superscripts in the same column differ significantly (p<0.05).

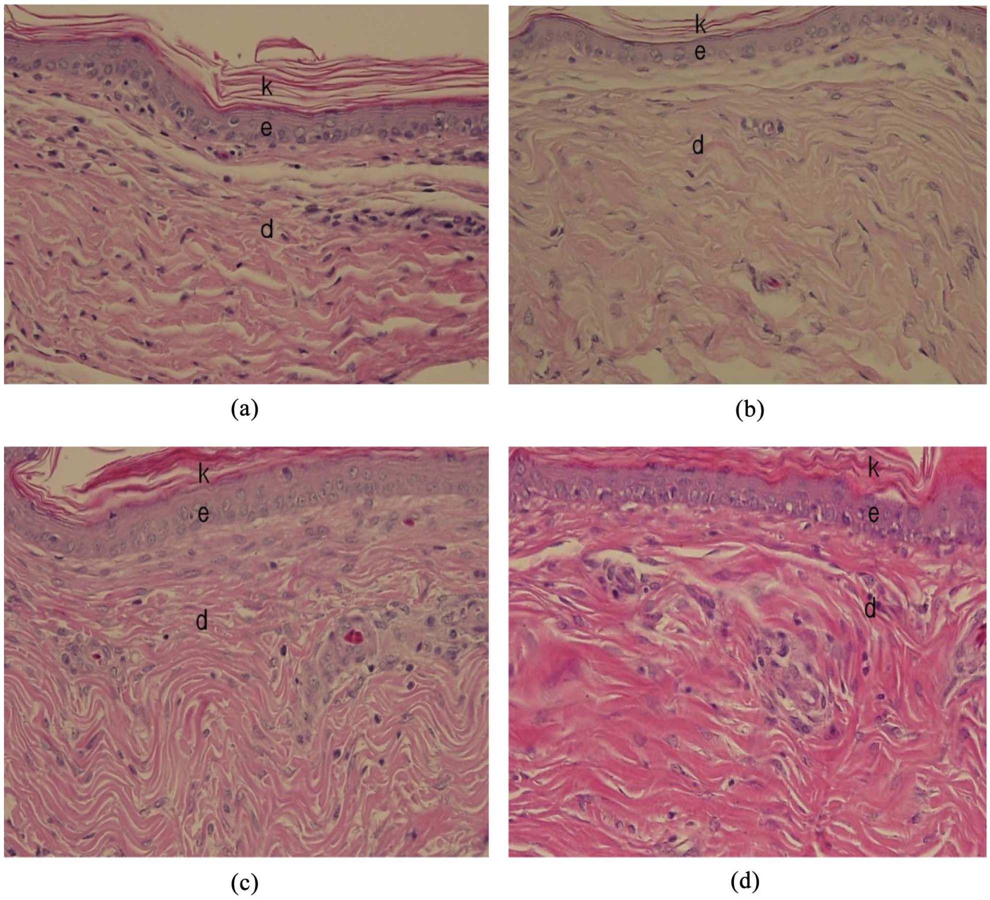

Fig. 1. Slides showing the thickness of epidermis and dermis of thigh skin from broiler chickens fed various levels of organic zinc (OZ) supplementation. (a) Control; (b) OZ 20 ppm; (c) OZ 40 ppm; (d) OZ 80 ppm. (k, keratin; e, epidermis; d, dermis).

and Helle, 1974). Rossi *et al*. (2007) reported that collagen content of skin was increased when birds fed higher levels of OZ. Similarly, a previous study conducted in our laboratory has shown that dietary OZ supplementation significantly increased the collagen contents in the back skin of broiler chickens (Salim *et al*., 2010). Therefore, the thicker epidermis and dermis layers may be due to increased production of epithelial cells and collagen content in the skin, and more developed skin layers may indicate healthy broiler skin with good appearance of carcass.

Dietary OZ levels did not affect the pH of breast and thigh meats, and WHC of thigh meat, but the WHC of breast meat increased significantly ($p<0.05$) when birds fed OZ 40 and OZ 80 (Table 5). The pH and WHC are considered to be important characteristics in evaluating meat quality. Generally, the pH value directly reflects meat acid content, and affects shear force, drip loss, and color of meat. Muscle pH is also related to glycogenolysis, and increased catecholamine secretion in response to an acute stressor just prior to slaughter.

The WHC can affect the taste, tenderness, color, fragrance, and nutrient content of meat and meat products (Tian and Yu, 2001). Lower WHC in meat can increase intracellular fluid out flow, loss of soluble nutrients and flavor. It also reduces the juiciness of the cooked product and makes unfavorable appearance of packaged meat. Saenmahayak (2007) reported that WHC of breast meat was not significantly influenced by different sources of zinc which is not agreement with the present study. The author also indicated that a numerical trend of improvement of WHC of breast meat was observed when birds fed various ratios of supplemental manganese versus zinc (Saenmahayak, 2007). Zinc act as an antioxidant (Rostan *et al*., 2002) that can reduce oxidation in the muscle tissue. Increased levels of oxidation can damage cell membranes, reducing their integrity and allowing seepage of intracellular fluids. Therefore, increased WHC of breast meat in the present experiment may be due to the antioxidant capability of zinc (Aksu *et al*., 2010; Rostan *et al*., 2002), and further research is needed to draw a conclu-

Table 5. The pH and Water holding capacity (WHC) of meats of broiler chickens fed various levels of organic zinc (OZ)

Treatments[1]	pH		WHC (%)	
	Breast meat	Thigh meat	Breast meat	Thigh meat
Control	6.2±0.01[2]	6.7±0.02	56.2±2.32[b]	60.5±2.21
OZ 20	6.0±0.02	6.5±0.01	56.3±5.39[b]	56.7±1.19
OZ 40	6.0±0.01	6.5±0.02	66.0±4.80[a]	54.4±4.35
OZ 80	6.1±0.01	6.5±0.01	62.6±5.19[a]	60.6±6.49

[1]See Table 2.
[2]Values are expressed as (means±SD; n= 8).
[a,b]Means with different superscripts in the same column differ significantly (p<0.05).

Table 6. Sensory properties of breast meat of broiler chickens fed various levels of organic zinc (OZ)

Properties	Treatments[1]				*p* value
	Control	OZ 20	OZ 40	OZ 80	
Color	4.89±0.60[2]	4.89±1.76	4.56±1.88	5.11±1.96	0.660
Odor	5.00±1.32	5.00±1.58	5.22±1.86	5.67±1.22	0.427
Taste	4.89±1.05	5.11±1.69	5.22±1.39	5.89±1.05	0.445
Tenderness	5.00±1.00	5.67±1.41	5.22±1.20	5.33±1.41	0.428
Juiciness	4.56±1.24	5.67±1.66	4.89±1.27	5.11±1.36	0.201
Flavor	4.67±1.50	5.22±1.39	5.44±1.42	6.00±0.71	0.732
Acceptability	4.78±0.97	5.56±1.51	5.00±1.50	5.67±1.22	0.334

[1]See Table 2.
[2]Values are expressed as (means±SD; n = 10).

Table 7. Sensory properties of thigh meat of broiler chickens fed various levels of organic zinc (OZ)

Properties	Treatments[1]				*p* value
	Control	OZ 20	OZ 40	OZ 80	
Color	3.78±1.39[2]	4.22±1.20	4.44±1.56	4.56±1.42	0.634
Odor	4.44±1.42	4.89±1.36	4.44±1.81	5.00±1.94	0.732
Taste	5.11±1.17	5.33±1.50	5.33±0.71	5.56±1.88	0.427
Tenderness	6.33±1.32	6.33±0.87	6.11±1.05	6.44±1.51	0.399
Juiciness	5.78±1.09	5.89±0.78	6.44±0.88	6.00±1.66	0.445
Flavor	5.00±1.12	5.42±1.42	5.22±1.09	6.22±2.05	0.428
Acceptability	5.33±1.32	5.33±1.41	5.67±0.71	6.33±2.12	0.201

[1]See Table 2.
[2]Values are expressed as (means±SD; n = 10).

sion on the effect of organic zinc in the WHC, pH, and thiobarbituric acid reactive substances (TBARS) values of broiler meats. However, Petrovic *et al.* (2009) reported that the peroxide and TBARS value decreased in breast and thigh meat of broiler chickens were fed proteinated forms of trace minerals including zinc. Furthermore, previous experiments have shown that feeding organic Se can reduce drip loss in broilers (Edens *et al*., 1996; Deniz *et al*., 2005), and breast meat has better WHC than chicken thigh meat (Smolinksa and Korzeniowska, 2005).

The effects of OZ supplementation on sensory properties (color, odor, taste, tenderness, juiciness, flavor, and acceptability) of breast and thigh meat were shown in Table 6 and Table 7. There were no significant differences in sensory properties of breast and thigh meats among all treatments. Bou *et al*. (2004) reported that zinc supplementation showed no effect on consumer acceptability and 2-thiobarbituric acid (TBA) values of cooked dark chicken meat after 5 mon of storage at -20°C. Similarly, in a later study, Bou *et al*. (2005) also found that zinc supplementation did not affect the sensory quality or TBA values for either storage time. Therefore, our sensory analysis data are consistent with these studies conducted by Bou *et al*. (2004 and 2005). It is concluded that dietary OZ does not affect live performance and sensory properties of broiler chickens, but increases WHC of breast meat and skin layer thickness. The thickened skin layer could improve skin strength and shelf life of meat, thereby improving meat quality of broiler chickens.

Acknowledgments

The authors thank Dr. S. W. Cho, Department of Pathology, College of Veterinary Medicine, Chungnam National University for his supervision in skin tissue preparation and reading. Support from the Meat Science Laboratory of the Department of Animal Science and Biotechnology for analyze the experimental sample is highly appreciated.

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(Received 2010.12.28/Revised 2011.3.30/Accepted 2011.3.31)