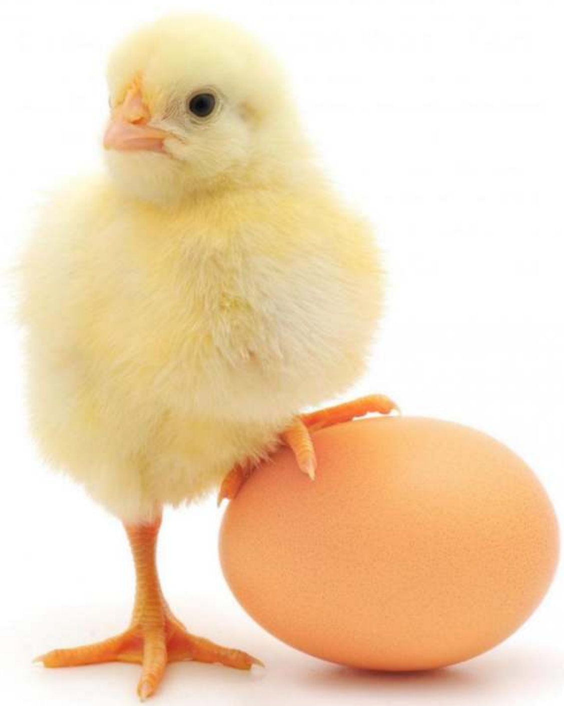
ISSN 1682-8356
ansinet.org/ijps



INTERNATIONAL JOURNAL OF POULTRY SCIENCE

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorijps@gmail.com

International Journal of Poultry Science 13 (11): 619-626, 2014
ISSN 1682-8356

Effect of Sources and Inclusion Levels of Zinc in Broiler Diets Containing Different Vegetable Oils During Summer Season Conditions on Meat Quality

N.A. Selim, Refaie, Amira M., Abeer R. Khosht and A.S. Abd El-Hakim
Animal Production Research Institute, ARC, Dokki, Giza-12618, Egypt

Abstract: The aim of this study was to evaluate the interactions between different dietary fatty acids' (FAs) patterns, zinc sources and levels on carcass and meat quality traits of Cobb 500 broiler chicks. Broilers were fed diets contained two different oil sources (soybean oil mainly composed of unsaturated fatty acids, SO; or palm oil mainly composed of saturated fatty acids, PO) and within each studied FAs source, three sources of zinc (zinc sulphate, ZS; zinc methionine, ZM; or nano-zinc oxide, NZO), each at two levels, Recommended (R) equals to 100 mg Zn/kg diet for both ZS and ZM and 40 mg/kg diet for NZO or high (H) equals to 200 mg Zn/kg diet for both ZS and ZM and 80 mg/kg diet for NZO) in a factorial arrangement of 2 x 3 x 2. Results reveal that chicks fed diets contained SO had significantly lower percentage of thigh skin, while, it had higher drip loss and ultimate pH (pH_u) of breast and thigh muscles and significantly improved all sensory values of cooked meat compared to those fed diets containing PO. While, those fed dietary PO significantly recorded lower MDA in meat compared to the others fed diets contained SO. Birds fed NZO diets significantly recorded the lowest carcass, breast and thigh skin percentages. Also, it significantly reduced breast drip loss and significantly enriched their meat with zinc by 41.4 and 10.6%, respectively relative to other two zinc sources. Concerning zinc levels, there were no significant differences between the two levels in all parameters studied except in muscles Zn content which was significantly increased by increasing dietary Zn level while, high dietary Zn level significantly reduced total lipids in muscles. It could be concluded that among the examined factors using palm oil, nano zinc oxide at level of 80 mg/kg diet improved carcass traits and meat quality of broiler reared under summer season conditions. While more researches concerning using nano-elements in broiler diets and its safety to human consumption are needed.

Key words: Broiler, nano zinc, organic zinc, inorganic zinc, palm oil, soybean oil, meat quality

INTRODUCTION

High air temperature in broiler houses is recognized as one of the main factors negatively influencing avian productivity (Lu *et al.*, 2007) and meat quality (Aksit *et al.*, 2006; Wang *et al.*, 2009). In McKee and Sams (1997) reported that heat-stressed birds are prone to disturbances in muscle energy metabolism, with poultry breast muscles that are the site of glycolytic metabolism being particularly susceptible. Sandercock *et al.* (2001) reported that heat stress leads to acid-base changes in blood, affects postmortem glycogen levels in muscle and decreases pH of meat. The initial muscle pH determines physicochemical traits of meat such as water holding capacity, color, thermal drip and tenderness of heat-treated meat (Young *et al.*, 2004; Aksit *et al.*, 2006; Wang *et al.*, 2009). One of the goals of food scientists is to increase the nutritional value of foods without compromising sensory quality. In this regard, polyunsaturated fatty acids (PUFA), have beneficial effects on human health (Food and Nutrition Board, 2002). Many studies have explored enrichment of chicken meat with PUFA through addition of dietary soybean oil (contains 84.5% of PUFA from total fatty acids); (Smulikowska and Rutkowski, 2005). However, these fatty acids are prone to oxidation and, consequently, their inclusion in diet may produce off-tastes and off-odors, thereby reducing consumer acceptability of meat (Pekel *et al.*, 2012). On the other side, palm oil is rich in saturated fatty acid (46.2% of total fatty acids). Concerning about oxidation of meat lipids, using palm oil in broiler diets is attractive because its content of saturated fatty acids may be associated with a positive influence on meat firmness (Renner and Hill, 1991). In addition according to Egyptian prices, palm oil is relatively cheaper compared to other oils/fats and it possesses many good qualities including more vitamin E content (antioxidant, 143 mg Vit. E/kg palm oil), which makes it more stable (Pesti *et al.*, 2002).

Quality of poultry meat and meat products can be influenced by various production and processing factors. Extending the shelf life of poultry meat and products is a major goal for the poultry industry. Because fresh poultry meat is highly perishable, it is essential to maintain the shelf life of the product as long as possible Salim *et al.* (2012). The changes that occur in poultry meat during storage are generally chemical and microbiological in

Corresponding Author: Refaie, Amira M., Animal Production Research Institute, ARC, Dokki, Giza-12618, Egypt

nature and are primarily influenced by storage factors such as time, temperature, oxygen availability and light (Huis in't Veld, 1996). Little information is available regarding the effects of dietary micronutrient sources and supplementation levels, on broiler chicken carcass, meat quality and shelf life. The limited studies regarding the effect of Zn on carcass traits of poultry measured only skin traits and part of carcass traits. Hess *et al.* (2001) found that organic Zn supplementation (40 mg/kg, as forms of Zn-methionine or Zn-lysine) could reduce skin tearing of the carcass in broilers. Rossi *et al.* (2007) also reported that organic Zn (45 mg of Zn/kg, with addition of 60 mg of Zn/kg ($ZnSO_4$) in the basal diets) could minimize skin tearing and improve carcass appearance of broilers. In another report, Sahin *et al.* (2005) found that Zn supplementation (as forms of $ZnSO_4$ or Zn picolinate) could improve carcass weight of Japanese quail. Tronina *et al.* (2007) concluded in their study that organic Zn (Zn-glycine) could increase proportion of breast and leg muscles, dressing percentage and fat content in the breast and leg muscles of broilers. Recently Ebrahimnezhad *et al.* (2013) confirmed the same effect of Zn when used nano ZnO. They reported that feeding broiler chicks on diet contains 60 or 90 ppm nano-ZO significantly increased breast and thigh weight of Ross 308 broiler chicks compared with birds of control group. The objective of this study was to assess the effects of dietary supplemental Zn sources and levels on carcass traits and meat quality of broilers when inclusion oils containing different PUFA content in broiler diet.

MATERIALS AND METHODS

Sources of supplemental zinc: Three sources of supplemental Zn to broiler diets were used in this study which were: zinc sulphate 98% (ZS; contains 35.5% Zn) as inorganic form of Zn, zinc-methionine 62.8% (ZM; contains 12% Zn) as organic form of Zn or nanoparticles of zinc oxide 90% (NZO; contains 72% Zn) as nano form of Zn. NZO prepared as described by Refaie and Eisa (2014).

Experimental diets and birds: This experiment was conducted in Middle-Egypt Zone during summer season months. Four hundred eighty day-old unsexed Cobb 500 broiler chicks were distributed into 12 treatments each one contained 40 chicks with 10 chicks/replicate and housed in open house. Chicks fed corn-soybean diet according to the experimental design in 3 phases feeding system. All diets were formulated to save all strain nutritional requirements (Table 1). This study was conducted to investigate the efficiency of three different zinc forms: inorganic (ZS), organic (ZM), or nanoparticles (NZO); with two levels of supplementation: recommended (R) or high level (H) on utilization of two different vegetable oils: soybean oil (SO) or palm oil (PO) at the same metabolizable energy contribution for each source, using 3 x 2 x 2 factorial arrangement (Table 2). The vitamin-mineral premixes were free of zinc adjusted for the studied Zn forms and levels, feed and water were provided *ad libitum* and all birds were subjected to the same managerial procedures during the experiment. Daily ambient temperature and relative humidity in broiler house during the experimental period were recorded and ranged between 29.7 and 34°C and 55-59%, respectively. Comparing with strain management recommendations, these values mean that broilers were induced to high environmental temperature during the experimental period.

Slaughtering and carcass characteristics: Four birds around the average live body weight of each treatment were slaughtered at the end of experiment (35 days of age), then carcass characteristics including carcass, abdominal fat, giblets (liver, gizzard and heart), as percentages of live body weight were recorded. Weights of breast muscles, drumstick and thighs of samples were recorded as percentage of carcass weight and skin weight of every part were recorded as percentage of its part. After that all breast and thigh samples (96 samples) were weighed and kept for 24 h at 4°C to complete the physical and chemical analysis of broiler meat.

Physical measurements

Drip loss: A total of 96 samples (48 breast and 48 thigh samples) were used for drip loss analysis. Breast fillets and thigh were individually weighed, placed in Ziploc bags, stored at 4°C for 24 h. Samples were lightly blotted using filter paper before reweighing. Drip loss% was calculated as the percentage of the difference between weights before and after chilling for 24 h. and divided by the first weight as described by Saenmahayak *et al.* (2012).

Ultimate pH (pH_u): After 24 h of chilling samples of breast meat and thigh on 4°C, ultimate pH (pH_u) was measured using pH meter, provided by a temperature control system, by probe method. The minimum depth to adopt was 1 cm after incision of the muscles as described by Selim *et al.* (2013).

Chemical measurements: Mixture (of equal weight) of breast and thigh meat of each bird were stored on -20°C for 60 days before chemical measurements, then total lipids, zinc (Zn) and malondialdehyde (MDA) contents were determined by colorimetric methods using analytical kits produced by Biodiagnostic Company, Egypt.

Sensory evaluation of cooked meat: Samples of thigh of each bird were packed before keeping at -20°C for 60

Table 1: Feed ingredients and calculated analysis of the experimental diets

	---- Starter 1-10 days -----		---- Grower 11-22 days ----		---- Finisher 23-35 days ----	
Ingredients	SO	PO	SO	PO	SO	PO
Yellow corn	56.35	55.72	64.36	63.54	67.52	66.97
Soybean meal (44%)	30.59	29.24	23.27	21.78	20.32	18.6
Corn gluten (60%)	6.20	7.30	5.73	6.91	5.73	6.91
Soybean oil (SO)	2.50	-	2.5	-	2.5	-
Palm oil (PO)	-	3.62	-	3.62	-	3.62
Mono-calcium phosphate	1.69	1.71	1.58	1.49	1.58	1.49
Limestone	1.45	1.42	1.39	1.43	1.18	1.22
NaCl	0.45	0.42	0.42	0.42	0.42	0.42
Vit. Min. pre-mix*	0.30	0.30	0.3	0.3	0.3	0.3
DL Methionine	0.12	0.11	0.15	0.13	0.15	0.13
L-Lysine HCl	0.35	0.16	0.3	0.38	0.3	0.34
Total	100	100	100	100	100	100
Calculated analysis**						
Crude protein (%)	22.04	21.89	19.11	19.19	18.06	18.02
ME (kcal/kg diet)	3024	3008	3111	3097	3152	3140
Crude fiber (%)	3.65	3.56	3.29	3.19	3.15	3.04
Ether extract (%)	5.23	6.33	5.42	6.51	5.49	6.59
Calcium (%)	0.91	0.90	0.85	0.85	0.77	0.76
Available P (%)	0.50	0.51	0.47	0.45	0.46	0.44
Lysine (%)	1.3	1.2	1.1	1.2	1.1	1.1
Methionine (%)	0.53	0.53	0.52	0.51	0.51	0.5
Methionine+Cystene (%)	0.90	0.90	0.84	0.83	0.81	0.8
Sodium (%)	0.19	0.18	0.18	0.18	0.18	0.18

*Each 3 kg vit. and min. premix contained: Vit. A 12000000 IU, Vit. D_3 4000000 IU, Vit. E 30000 IU, Vit. K_3 4000 mg, Vit. B_1 4000 mg, Vit B_2 9000 mg, Vit. B_{12} 20 mg, Vit B_6 4000 mg, Niacin 60000 mg, Pantothenic acid 15000 mg, Folic acid 1500 mg, Biotin 150 mg, Choline Chloride 400000 mg, Copper 20000 mg, Iodine 1000 mg, Iron 40000 mg, Manganese 120000 mg, Selenium 300 mg and Cobalt 100 mg. **According to NRC (1994)

Table 2: Experimental feeding treatments

Treatment	1	2	3	4	5	6	7	8	9	10	11	12
Oil sources												
SO	*	*	*	*	*	*						
PO							*	*	*	*	*	*
Zinc sources												
ZS	*	*					*	*				
ZM			*	*					*	*		
NZO					*	*					*	*
Zinc levels												
R	100 ppm		100 ppm		40 ppm		100 ppm		100 ppm		40 ppm	
H		200 ppm		200 ppm		80 ppm		200 ppm		200 ppm		80 ppm

SO: Soybean oil; PO: Palm oil; ZS: Zinc sulphate; ZM: Zinc methionine; NZO: Nano-zinc oxide; R: Recommend and H: High

days. The panel test was carried out to evaluate the main characteristics of chicken meat properties as taste, aroma, texture and overall acceptability. Samples were boiled (at 100°C for 20 min.) individually in water without addition of any flavor enhancers. In this test, 10 participants were served diced chicken samples with water in between to remove the remaining flavor. The panelists were requested to evaluate the cooked samples with 3 digit code for taste, aroma, texture and overall acceptability on a 9 point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely) as described by Lopez-Ferrer *et al.* (1999).

Statistical analysis: Data collected were subjected to analysis of variance using the general liner model (GLM) procedure of SAS User's guide (SAS, 2001) to detect the effect of main factors (oil sources, zinc sources and levels). Duncan's Multiple Range test (Duncan's, 1955) was used to separate means when separation was relevant. Statistical significance was accepted at probability level of ($p \leq 0.05$).

RESULTS AND DISCUSSION

Carcass traits: The carcass traits reported in this study were not affected ($p>0.05$) by oil source (Table 3). Incorporation of oil did not affect ($p>0.05$) carcass percentage, percentage of breast or thigh muscles, or percentage of abdominal fat, but affected ($p<0.05$) percentage of thigh skin (Table 3). Birds fed diets contained soybean oil had lower ($p<0.05$) percentage of thigh skin than those fed diets contained palm oil and no significant differences ($p>0.10$) were found in these parameters between the two zinc level treatments. In this respect Ferrini *et al.* (2008) declared that broiler carcass percentages were not affected by dietary unsaturated fatty acids treatment.

Table 3: Effect of main factors and their interactions on carcass characteristics

				Breast		Thigh		
Main effects	Carcass (%)	+AF (%)	Giblets (%)	Meat (%)	Skin (%)*	Drum stick (%)	Thigh (%)	Skin (%)**
Oil sources								
SO	69.3	1.6	4.4	15.6	7.0	4.6	7.3	7.6^{b}
PO	69.3	1.5	4.4	15.6	6.8	4.5	7.6	8.4^{a}
MSE	0.50	0.09	0.09	0.17	0.16	0.14	0.30	0.20
p-value	0.90	0.29	0.26	0.71	0.360	0.40	0.22	0.0045
Zinc sources								
ZS	70.1^{a}	1.5	4.4^{ab}	16.4	7.1^{b}	4.4	7.4	8.7^{a}
ZM	69.4^{ab}	1.6	4.6^{a}	15.0	7.7^{a}	4.8	7.5	7.6^{b}
NZO	68.3^{b}	1.6	4.3^{b}	15.4	5.9^{c}	4.4	7.5	7.7^{b}
MSE	0.60	0.11	0.11	0.20	0.20	0.17	0.37	0.24
p-value	0.05	0.93	0.03	0.06	0.0001	0.09	0.93	0.005
Zinc levels* **								
R	69.5	1.6	4.4	15.6	7.1	4.4	7.7	8.1
H	69.1	1.4	4.4	15.6	6.7	4.6	7.3	7.9
MSE	0.50	0.09	0.09	0.18	0.16	0.14	0.30	0.20
p-value	0.55	0.09	0.64	0.68	0.074	0.23	0.19	0.2609
Interaction effects								
Oil source* Zinc source	0.21	0.28	0.14	0.12	0.406	0.06	0.47	0.2849
Oil source* Zinc level	0.44	0.01	0.10	0.42	0.953	0.12	0.18	0.0355
Zinc source* Zinc level	0.09	0.13	0.002	0.20	0.009	0.26	0.08	0.412
Oil source* Zinc source* Zinc level	0.003	0.36	0.13	0.10	0.007	0.60	0.02	0.2755

SO: Soybean oil; PO: Palm oil; ZS: Zinc sulphate; ZM: Zinc methionine; NZO: Nano-zinc oxide; R: Recommended and H: High

a,b,c: Means in each column, within each item, bearing the same superscripts are not significantly different. *skin%: breast skin weight/breast weight×100, **skin% = thigh skin weight/thigh weight × 100. ***R = 100 mg Zn of ZS, ZM or 40 mg Zn of NZO, H = 200 mg Zn of ZS, ZM or 80 mg Zn of NZO, + AF = Abdominal fat

Table 4: Effect of main factors and their interactions on physical measurements of breast and thigh

	Breast		Thigh	
Main effects	Drip loss (%)	pH	Drip loss (%)	pH
Oil sources				
SO	1.17^{a}	5.9^{a}	0.70	5.8^{a}
PO	0.78^{b}	5.5^{b}	0.74	5.5^{b}
MSE	0.05	0.05	0.04	0.06
p-value	0.0001	0.0001	0.1350	0.0003
Zinc sources				
ZS	1.11^{a}	5.9^{a}	0.89^{a}	5.9^{a}
ZM	1.11^{a}	5.6^{b}	0.67^{b}	5.5^{b}
NZO	0.65^{b}	5.6^{b}	0.59^{b}	5.5^{b}
MSE	0.06	0.06	0.05	0.07
p-value	0.001	0.0001	0.0001	0.0013
Zinc levels				
R	0.98	5.7	0.71	5.7^{a}
H	0.97	5.7	0.73	5.6^{b}
MSE	0.05	0.05	0.04	0.06
p-value	0.9447	0.3290	0.3656	0.0402
Interaction effects				
Oil source* Zinc source	0.0026	0.0007	0.1110	0.1426
Oil source* Zinc level	0.5293	0.027	0.0034	0.4498
Zinc source* Zinc level	0.0909	0.0111	0.0008	0.0103
Oil source* Zinc source* Zinc level	0.2338	0.0052	0.0001	0.1344

SO: Soybean oil, PO: Palm oil, ZS: Zinc sulphate, ZM: Zinc methionine, NZO: Nano-zinc oxide, R: recommended and H: High

a,b,c: Means in each column, within each item, bearing the same superscripts are not significantly different

Table 5: Effect of main factors and their interactions on muscles zinc, MDA and total lipids

Main effects	Zn (mg/100 g)	MDA (mmol/100 g)	Total lipid (mg/100 g)
Oil sources			
SO	142.8	1.95^{a}	522.8^{b}
PO	137.8	0.87^{b}	549.3^{a}
MSE	0.65	0.07	4.85
p-value	0.06	0.0001	0.0001
Zinc sources			
ZS	135.6^{b}	2.04^{a}	559.9^{a}
ZM	135.5^{b}	1.22^{b}	565.2^{a}
NZO	150.0^{a}	0.96^{b}	483.1^{b}
MSE	0.80	0.09	5.94
p-value	0.0001	0.0001	0.0001
Zinc levels*			
R	134.9^{b}	1.49	545.8^{a}
H	145.8^{a}	1.32	526.3^{b}
MSE	0.65	0.07	4.85
p-value	0.0001	0.13	0.001
Interaction effect			
Oil source* Zinc source	0.0001	0.0001	0.0005
Oil source* Zinc level	0.0005	0.5700	0.0900
Zinc source* Zinc level	0.0001	0.6000	0.0005
Oil source* Zinc source* Zinc level	0.0005	0.7900	0.0010

SO: Soybean oil, PO: Palm oil, ZS: Zinc sulphate, ZM: Zinc methionine, NZO: Nano-zinc oxide, R: Recommended and H: High

a,b,c: Means in each column, within each item, bearing the same superscripts are not significantly different. *R = 100 mg Zn of ZS, ZM or 40 mg Zn of NZO, H = 200 mg Zn of ZS, ZM or 80 mg Zn of NZO

Regarding the diets containing Zinc sulphate, the chicks fed diets containing NZO recorded the lowest carcass, edible parts, breast skin and thigh skin percentage. Skin represented approximately 60% of total body fat of broilers, while abdominal fat represented 12% only (Ferrini *et al.*, 2008). According to Abd El-Hakim *et al.* (2014) and Refaie and Eisa (2014) incorporating NZO to broiler diet at level of 80 mg/kg diet can improve lipid metabolism. Thus, percentage of fat in skin is reduced. These results are in contrast with those reported by Ebrahimnezhad *et al.* (2013) who indicated that in comparison to the control group 60 and 90 ppm nano-

Table 6: Effect of main factors and their interactions on sensory score of cooked broiler meat

Main effects	Taste	Color	Aroma	Texture	Overall acceptability
Oil sources					
SO	8.1[a]	8.1[a]	8.0[a]	7.1[a]	7.0[a]
PO	7.1[b]	6.1[b]	6.1[b]	6.1[b]	6.1[b]
MSE	0.07	0.07	0.06	0.06	0.06
p-value	0.0001	0.0001	0.0001	0.0001	0.0001
Zinc sources					
ZS	7.6	7.1	7.0	6.6	6.6
ZM	7.5	7.1	7.1	6.6	6.6
NZO	7.6	7.1	7.0	6.6	6.5
MSE	0.09	0.09	0.07	0.08	0.08
p-value	0.8059	0.8824	0.8992	0.9745	0.6991
Zinc levels*					
R	7.6	7.1	7.1	6.6	6.5
H	7.6	7.1	7.0	6.6	6.6
MSE	0.07	0.07	0.06	0.06	0.06
p-value	0.7913	0.8306	0.6638	0.4731	0.1467
Interaction effects					
Oil source* Zinc source	0.7285	0.8979	0.9961	0.5077	0.6532
Oil source* Zinc level	0.7112	1.000	0.8520	0.8101	0.3902
Zinc source* Zinc level	0.8624	0.6162	0.9961	0.8118	0.9215
Oil source* Zinc source* Zinc level	0.6592	0.8927	0.7816	0.3987	0.5623

SO: Soybean oil, PO: Palm oil, ZS: Zinc sulphate, ZM: Zinc methionine, NZO: Nano-zinc oxide, R: Recommended and H: High
a,b,c: Means in each column, within each item, bearing the same superscripts are not significantly different. *R: 100 mg Zn of ZS, ZM or 40 mg Zn of NZO, H: 200 mg Zn of ZS, ZM or 80 mg Zn of NZO

ZO/kg fed birds were resulted in significantly increased breast and thigh weight. On the other hand, Sharma *et al.* (2012) reported that no obvious difference was observed in the organ weights (liver, kidney and brain) of control mice and ZnO nanoparticles treated mice. Salim *et al.* (2012) found that zinc protenate supplementation increased the total thickness of broiler chicks skin in both sexes and males had thicker skin than females. Organic Zn supplementation had higher breast fillet and total breast (fillet+tender) yields as compared to the inorganic treatment (Saenmahayak *et al.*, 2010).

Physical measurements: Results in Table 4 show that chicks fed diets contained SO recorded higher drip loss and pH_u of breast and thigh muscles comparing to those fed dietary PO.
Among Zn sources, samples of NZO group recorded significant reduction of breast drip loss being 41.4% comparing to both ZS and ZM, also it reduced drip loss of thigh sampls by 33.7 and 11.9% comparing to the determined values in samples of both inorganic zinc and organic zinc, respectively. Zn is necessary for the structure and function of Cu-Zn superoxide dismutase, which is widely distributed and composes 90% of the total superoxide dismutase, protecting the brain, lungs and other tissues from oxidation (Noor *et al.*, 2002). We could speculate that dietary Zn might increase antioxidant function of the muscle then decrease the drip loss of muscle, in this connection, Liu *et al.* (2011) found that supplemental Zn decreased drip loss in broiler breast and thigh muscle. On the other hand, Saenmahayak *et al.* (2012) reported that drip loss was significantly ($p<0.05$) increased in fillets from birds fed diets supplemented with Zn at 24 h post-deboning.
Ultimate pH was significantly affected by dietary zinc sources (Table 4) where the group of chicks fed diets contained either ZM or NZO recorded a reduction in pH_u of breast and thigh muscles by 5.1 and 6.8%, respectively comparing to those fed diets contained ZS. Muscles pH plays an important role in rate of microbial spoilage (Rey *et al.*, 1976). High muscle pH produced conditions that make dark-colored fillets more susceptible to bacterial spoilage than light-colored fillets (found in low muscle pH) when held at the same refrigerated storage conditions (Allen *et al.*, 1997). Meat with low pH has also been reported to decrease tenderness (Barbut, 1993) which is due to a combination of the degradation of large protein by μ-calpain and smaller proteins by cathepsins at latter ageing periods. Also, low muscle pH increase shelf-life of broiler meat (Allen *et al.*, 1997).
All of the physical parameters studied was not affected by zinc levels (Table 4) except pH_u of thigh muscles which was significantly reduced in high zinc level. While Liu *et al.* (2011) reported that supplemental Zn significantly increased pH values in broiler thigh muscle.

Chemical measurements: Effect of oil sources, zinc sources and levels on chicken muscles chemical analysis are presented in Table 5. Chicks fed diets incorporated with PO recorded significantly lower MDA while, increased total lipid in muscles comparing to those fed dietary SO. These results in agreement with (Smulikowska and Rutkowski, 2005; Pekel *et al.*, 2012), who reported high content of PUFA in SO which led to more lipid oxidation of poultry meat and producing more of MDA. Also reports of Renner and Hill (1991) and Pesti *et al.* (2002) showed that the richness of saturated fatty acids in PO reducing the oxidation of lipids in broiler meats and make it more stable.

Chicks fed dietary NZO recorded significantly higher muscles content of zinc by 10.6% comparing to either dietary ZS or ZM. By increasing NZO cellular uptake Yu *et al.* (2011) zinc retention in meat is increased, which indicate that these chicken muscles enriched with an important element such as Zn. Meat products are one of the main sources of Zn (Subar *et al.*, 1998) with a high bioavailability (Fairweather-Tait, 1992). Although, this element is involved in a wide range of biochemical functions while, several communities do not achieve the recommended daily intakes of some elements, even in developed countries (Bou *et al.*, 2004). So, by enriching broiler muscles with Zn, it could be one solution for this problem. In this respect Salim *et al.* (2012) reported that zinc proteinate supplementation increased the zinc contents of broilers thigh meat.

Chicks fed dietary ZM and NZO significantly reduced MDA level in muscles by 40.2% and more than twice folds, respectively comparing to chicks fed dietary ZS. Altan *et al.* (2003) reported that heat stress caused collision balance in blood antioxidant, increased oxidation lipids in broiler meat. While, increasing dietary antioxidants decreased TBARS values of broiler thigh muscle Vakili and Rashidi (2011).

Chicks fed diets contained NZO recorded significantly lower muscles total lipids by 13.7 and 14.5% comparing to those fed diets contained ZS and ZM, respectively. Comparing to recommended zinc level, chicks fed high zinc level recorded significantly higher muscle Zn while, it reduced total lipids. These results are in contrary with Salim *et al.* (2012) who concluded that zinc concentration in broiler meat was not significantly influenced by supplementation with organic zinc (Zinc proteinate).

Sensory evaluation of cooked meat: Results detected in Table 6 show that there were a significant difference between oil sources, where the group of chicks fed diets contained SO achieved higher degrees of taste, color, aroma, texture and overall acceptability. These results are in contrary with Bou *et al.* (2005) who found that consumer acceptability scores of cooked dark chicken meat after 74 day or after 18 month of frozen storage were not affected by fat source.

Neither zinc source nor zinc level affect any of the cooked meat parameters. This effect may be due to the ability of Zn to bind myoglobin and increase its oxygenation. Zinc also inhibits mitochondrial respiration and decreases the production of free radicals by acting as an antioxidant, thus facilitating the maintenance of meat color (Powell, 2000). These results are in agreement with Bou *et al.* (2005) who found that consumer acceptability scores of cooked dark chicken meat after 74 day or after 18 month of frozen storage were not affected by dietary zinc sources or levels. Also, these results are inversely correlated with sensory scores (Mielche, 1995; Bou *et al.*, 2001). Liu *et al.* (2011) concluded that Supplemental Zn to broiler diets significantly increased the redness value in breast muscle.

The overall results of this study showed beneficial effects of using palm oil and nano zinc oxide in broiler diets at level 80 mg/kg diet, where they could enhance the physical and chemical measurements of broiler meat and could reduce lipid oxidation.

Although, using NZO resulted in decreasing drip loss, pH, MDA and lipids contents of broiler meat samples and increasing their Zn content. There is lack of studies concerning safety of using nano-elements in broiler diets. Also there are no international guide lines to it yet.

Conclusion: Using nano zinc oxide at 80 mg/kg diet in broiler diets with palm oil during summer season has positive effects on carcass traits and meat quality. Further researches concerning using nano-elements in broiler diets and its safety to human consumption are needed.

REFERENCES

Abd El-Hakim, A.S., M. Refaie, Amira, N.A. Selim and Abeer R. Khosht, 2014. Alternative motivation of zinc supplementation (Nano vs. Organic) in broiler diets: Effect on performance and lipid metabolism under summer season conditions. 4th mid. Poult. Summit-Beirut, Lebanon, 2-5 September.

Aksit, M., S. Yalcin, S. Ozkan, K. Metin and D. Ozdemir, 2006. Effects of temperature during rearing and crating on stress parameters and meat quality of broilers. Poult. Sci., 85: 1867-1874.

Allen, C.D., S.M. Russell and D.L. Fletcher, 1997. The Relationship of Broiler Breast Meat Color and pH to Shelf-Life and Odor Development. Poult. Sci., 76: 1042-1046.

Altan, O., A. Pabuccuoglu, A. Altan, S. Konyalioglu and H. Bayraktar, 2003. Effect of heat stress on oxidative stress, lipid peroxidation and some stress parameters in broilers. Br. Poult. Sci., 44: 545-550.

Barbut, S., 1993. Colour measurements for evaluating the pale soft exudative (PSE) occurrence in turkey meat. Food Res. Int., 26: 39-43.

Bou, R., F. Guardiola, A.C. Barroeta and R. Codony, 2005. Effect of Dietary Fat Sources and Zinc and Selenium Supplements on the Composition and Consumer Acceptability of Chicken Meat. Poult. Sci., 84: 1129-1140.

Bou, R., F. Guardiola, A. Grau, S. Grimpa, A. Manich, A. Bar-Roeta and R. Codony, 2001. Influence of dietary fat source, α-tocopherol and ascorbic acid supplementation on sensory quality of dark chicken meat. Poult. Sci., 80: 800-807.

Bou, R., F. Guardiola, A. Padro, E. Pelfort and R. Codony, 2004. Validation of mineralization procedures for the determination of selenium, zinc, iron and copper in chicken meat and feed samples by ICP-AES and ICP-MS. J. Anal. At. Spectrom, 19: 1361-1369.

Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics, 11: 1-42.

Ebrahimnezhad, Y., J. Gheiasi, N. Maheri Sis, M. Mohammadi Khah and F. Ahmadi, 2013. Influence of zinc oxide nanoparticles on growth perfor-mance, carcass quality and growth index of immune organs of broiler chickens. Poult. Sci., 92: 98.

Fairweather-Tait, S.J., 1992. Bioavailability of trace elements. Food Chem., 43: 213-217.

Ferrini, G., M.D. Baucells, E. Esteve-Garci and A.C. Barroeta, 2008. Dietary Polyunsaturated Fat Reduces Skin Fat as Well as Abdominal Fat in Broiler Chickens. Poult. Sci., 87: 528-535.

Food and Nutrition Board, 2002. Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Protein and Amino Acids (Macronutrients).National Academy Press, Washington, DC.

Hess, J.B., S.F. Bilgili and A.M. Parson, 2001. Influence of com-plexed zinc products on live performance and carcass grade of broilers. J. Appl. Anim. Res., 19: 49-60.

Huis in't Veld, J.H.J., 1996. Microbial and biochemical spoilage of foods: An overview. Int. J. Food Microbiol., 33: 1-18.

Liu, Z.H., L. Lu, S.F. Li, L.Y. Zhang, L. Xi, K.Y. Zhang and X.G. Luo, 2011. Effects of supplemental zinc source and level on growth performance, carcass traits and meat quality of broilers. Poult. Sci., 90: 1782-1790.

Lopez-Ferrer, S., M. Baucells, A. Barroeta and M. Grashorn, 1999. n-3 Enrichment of chicken meat using fish oil: Alternative substitution with rapeseed and linseed oils. Poult. Sci., 78: 356-365.

Lu, Q., J. Wen and H. Zhang, 2007. Effect of chronic heat exposure on fat deposition and meat quality in two genetic types of chicken. Poult. Sci., 86: 1059-1064.

McKee, S.R. and A.R. Sams, 1997. The effect of seasonal heat stress on rigor development and the incidence of pale, exudative turkey meat. Poult. Sci., 76: 1616-1620.

Mielche, M.M., 1995. Development of warmed-over flavour in ground turkey, chicken and pork meat during chill storage. A model of the effects of heating temperature and storage time. Z. Lebensm-Unters. Forsch., 200: 186-189.

National Research Council, (NRC), 1994. Nutrient requirements of poultry. 9th revised edition. National Academy Press. Washington, D.C., USA.

Noor, R., S. Mittal and J. Iqbal, 2002. Superoxide dismutase applications and relevance to human disease. Med. Sci. Monit., 8: 210-215.

Pekel, A.Y., G. Demirel, M. Midilli, H. Yalcintan, B. Ekiz and M. Alp, 2012. Comparison of broiler meat quality when fed diets supplemented with neutralized sunflower soapstock or soybean oil. Poult. Sci., 91: 2361-2369.

Pesti, G.M., R.I. Bakalli, M. Qiao and K.G. Sterling, 2002. A comparison of 8 grades of fat as broiler feed ingredients. Poult. Sci., 81: 382-390.

Powell, S.R., 2000. The antioxidant properties of zinc. J. Nutr., 130: 1447-1454.

Refaie, Amira M. and W.H. Eisa, 2014. A new approach of zinc supplementation in broiler diets: Effect on performance and lipid metabolism under summer season conditions. 4th mid. Poult. Summit-Beirut, Lebanon, 2-5 September.

Renner, R. and F.W. Hill, 1991. Factors affecting the absorbability of saturated fatty acids in the chick. J. Nutr., 74: 254-258.

Rey, C.R., A.A. Kraft, D.G. Topel, F.C. Parrish, Jr. and D.K. Hotchkiss, 1976. Microbiology of pale, dark and normal pork. J. Food Sci., 41: 111-116.

Rossi, P., F. Rutz and M.A. Anciuti, 2007. Influence of graded levels of organic zinc on growth performance and carcass traits of broilers. J. Appl. Poult. Res., 12: 219-225.

Saenmahayak, B., M. Singh, S.F. Bilgili and J.B. Hess, 2012. Influence of Dietary Supplementation with Complexed Zinc on Meat Quality and Shelf Life of Broilers. Int. J. Poult. Sci., 11: 28-32.

Saenmahayak, B., S.F. Bilgili, J.B. Hess and M. Singh, 2010. Live and processing performance of broiler chickens fed diets supplemented with complexed zinc. J. Appl. Poult. Res. (proceeding).

Sahin, K., M.O. Smith, M. Onderci, N. Sahin, M.F. Gursu and O. Kucuk, 2005. Supplementation of zinc from organic or inorganic source improves performance and antioxidant status of heat-dis-tressed quail. Poult. Sci., 84: 882-887.

Salim, H.M., H.R. Lee, C. Jo, S.K. Lee and B.D. Lee, 2012. Effect of dietary zinc proteinate supplementation on growth performance and skin and meat quality of male and female broiler chicks. Br. Poult. Sci., 53: 116-124.

Sandercock, D.A., R.R. Hunter, G.R. Nute, M.A. Mitchel and P.M. Hocking, 2001. Acute heat stress-induced alterations in blood acid-based status and skeletal muscle membrane in broiler chickens at two ages: Implications for meat quality. Poult. Sci., 80: 418-425.

SAS, Statistical Analysis System, 2001. User's Guide Version 8.2, Cary NC. USA.

Selim, N.A., Sh. A. Nada, A.F. Abdel-Salam and S.F. Youssef, 2013. Evaluation of Some Natural Antioxidant Sources in Broiler Diets: 2-Effect on Chemical and Microbiological Quality of Chilled and Frozen Broiler Meat. Int. J. Poult. Sci., 12: 572-581.

Sharma, V., S. Poonam, K.P. Alok and D. Alok, 2012. Induction of oxidative stress, DNA damage and apoptosis in mouse liver after sub-acute oral exposure to zinc oxide nanoparticles. Mutation Res., 745: 84-91.

Smulikowska, S. and A. Rutkowski, 2005. Nutrient Recommendations and Nutritive Value of Feedstuffs. Nutritional Standards for Poultry (in Polish). The Kielanowski Institute of Animal Physiology and Nutrition (Editor). Jablonna (Poland), pp: 136.

Subar, A.F., S.M. Krebs-smith, A. Cook and L.L. Kahle, 1998. Dietary sources of nutrients among US adults. J. Am. Diet. Assoc., 98: 537-547.

Tronina, W., S. Kinal and B. Lubojemska, 2007. Effect of various forms of zinc applied in concentrate mixtures for broiler chickens on its bioavailability as well as meat composition and quality. Poult. J. Food Nutr. Sci., 57: 577-581.

Vakili, R. and A.A. Rashidi, 2011. The effects of dietary fat, vitamin E and zinc supplementation on fatty acid composition and oxidative stability of muscle thigh in broilers under heat stress. Afr. J. Agric. Res., 6: 2800-2806.

Wang, R.R., X.J. Pan and Z.Q. Peng, 2009. Effects of heat exposure on muscle oxidation and protein functionalities of pectoralis majors in broilers. Poult. Sci., 88: 1078-1084.

Young, O.A., J. West, A.L. Hart and F.F.H. Van Otterdijk, 2004. A method for determination of meat ultimate pH. Meat Sci., 66: 493-498.

Yu, J., M. Baek, H.E. Chung and S.J. Choi, 2011. Effects of physicochemical properties of zinc oxide nanoparticles on cellular uptake. J. Phys. Conf. Series, 304-309.