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Effect of Clinoptilolite Coated with Silver Nanoparticles on Meat Quality Attributes of Broiler Chickens during Frozen Storage

Research Article

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ABSTRACT

This study was carried out to assess the effect of clinoptilolite coated with silver nanoparticles on meat quality attributes of broiler chickens during frozen storage. A total of 375 one-day-old broiler chicks were assigned in a completely randomized design to 1 of 5 experimental groups including: basal diet, basal diet supplemented with 1% clinoptilolite and basal diet supplemented with 1% clinoptilolite coated with either 25, 50 or 75 ppm nanosilver. On d 42, five birds per treatment were slaughtered and breast and thigh meat were kept 3 or 7 days at -17 ˚C before assessing meat quality attributes. The addition of nanosilver coated on clinoptilolite at all levels increased water-holding capacity (WHC) in thigh muscles after 7 days frozen storage. The lowest value of springiness and chewiness was for the breast muscle of broilers fed clinoptilolite coated with 25 ppm nanosilver diet. Adhesiveness, cohesiveness and gumminess value were not influenced by treatment (P>0.05). In conclusion, nanosilver coated on clinoptilolite can be used as potential feed additive in the broiler diet without negative implications on meat quality characteristics.

KEY WORDS broiler, clinoptilolite, frozen storage, meat quality, nanosilver, zeolite.

INTRODUCTION

Poultry meat quality attributes may be affected by several factors such as genotype, rearing conditions and feed additives which could affect muscle metabolism as well as chemical composition (Meluzzi *et al*. 2009). Nanotechnology is may be used for assurance of food safety in different food products (Kannan and Subbalaxmi, 2011). Food scientists predicts that nanotechnology will also have a significant impact on food products in a variety of ways both directly and indirectly (Sekhon, 2014). There are various types of nanoparticles such as Ag, Au and Zn. Recently, silver nanoparticles have been shown to have unique antibacterial properties and are widely used as antimicrobial agents and as replacement for antibiotic growth promoter in the poultry industry (Chauke and Siebrits, 2012; Hashemi *et al*. 2014). Despite demonstrated beneficial effects of silver nanoparticles on digestive microbial biodiversity and function in animals (Li *et al*. 2006; Sawosz *et al*. 2004), other effects of silver nanoparticles on physiological status, such as digestive enzymatic activity, immunological status and intestinal structure and their effect on meat quality characteristics are unknown. The use of feed additives and utilization of exogenous compounds is a new nutritional strategies that may help the poultry industry improve the quality of meat (Khalafalla *et al*. 2011). By the exploitation of the use of nanoparticles, poultry products can produce high safety. In previous papers, we have shown that broiler diets supplemented zeolite coated with silver nanoparticles improved water-holding capacity of thigh muscle in broiler chickens (Hashemi *et al*. 2014). Appearance of broiler meat is an important quality criterion when making the decision

to purchase and in final product satisfaction. After slaughter, poultry carcass has to be chilled and / or frozen to ensure a high quality and safe product. Chicken meat is kept cold during distribution to retail stores to prevent the growth of bacteria and to increase its shelf life. The storage time of broiler meat in the refrigerator and freezer can influence meat quality. The objective of this study is to evaluate the effect of clinoptilolite coated with silver nanoparticles on meat quality attributes of broiler chickens during frozen storage.

MATERIALS AND METHODS

A total of 375 one-day-old Ross 308 broilers (male and female) from a commercial hatchery, were randomly assigned to 5 experimental groups. Each group comprised five pens each of 15 birds.

Experimental diets were following:

1) basal diet (control, without nanosilver and clinoptilolite) (C).

2) basal diet supplemented with 1% clinoptilolite (Z).

3) basal diet supplemented with 1% clinoptilolite coated with 25 ppm nanosilver (ZN25).

4) basal diet supplemented with 1% clinoptilolite coated with 50 ppm nanosilver (ZN50).

5) basal diet supplemented with 1% clinoptilolite coated with 75 ppm nanosilver (ZN75).

Natural clinoptilolite (zeolite) used in this research was prepared from well-defined zeolitic stratigraphic units from Semnan province region, Iran. Zeolitic rock was pulverized and sieved to give a particle size of 1-2 mm and then washed with distilled water to remove all the soluble impurities and then and dried in the oven over night at 105 ˚C. The chemical formula of pure clinoptilolite was $(K_2, Na_2, Ca, Mg)_3$ $Al_6Si_{30}O_{72}$. $24H_2O$. Clinoptilolite coated with silver nanoparticles were prepared by Nano Nasb Pars Company (Tehran, Iran). Silver nanoparticles had a maximum diameter of 50 nm.

In order to study the chemical composition of the clinoptilolite sample were analyzed using X-ray Fluorescence (XRF) technique and the XRF data was collected on a PHILIPSPW1480 XRF spectrometer with Rh tube (Nikpey *et al*. 2013) (Table 1). Field emission scanning electron microscopy (FESEM, Mira, 3-XMU) was employed for the detailed study of morphology and additionally, Energy dispersive X-ray spectroscopy (EDX) and elemental mapping analyses were used to investigate the materials composition at Razi Metallurgical Research Center, Iran (Figure 1).

The silver (Ag) content of clinoptilolite was measured by the method as described by Kulthong *et al*. (2010). In brief, 0.2-0.3 g sample was weighed and then digested by a microwave digestion system in 5 mL of 14.4 M HNO_3 to dissolve all the silver content. The microwave irradiation cycles were 250 W for 5 min, 400 W for 5 min and 600 W for 5 min. The digested sample was then cooled and diluted up to 25 mL with deionized water to enable quantification of silver by a graphite furnace atomic absorption spectroscopy or GFAAS (Perkin Elmer Analyst 300, Waltham, MC).

Table 1 The summarized chemical composition of the used clinoptilolite by means of X-ray Fluorescence (XRF)[1] technique

Semnan natural clinoptilolite-rich tuffs	
Constituents	**% by weight**
SiO_2	68.95
Al_2O_3	11.14
Fe_2O_3	0.97
CaO	4.83
Na_2O	0.95
K_2O	0.90
MgO	0.79
TiO_2	0.201
MnO	0.011
P_2O_5	0.012
SO_3	0.068
L.O.I[2]	10.64
Si/Al	4.81
Ag[3]	< 5 ppm

[1] XRF PHILIPS PW1480 XRF spectrometer with Rh tube.
[2] LOI: loss on ignition.
[3] The silver content was measured by a graphite furnace atomic absorption spectroscopy (GFAAS).

Diets were formulated to meet broiler nutrient requirements according to the Ross 308 management guideline and proximate analyses confirmed formulated values for all critical nutrients in the diets fed (Table 2). The birds had free access to water and all diets were fed *ad libitum*. Birds had access to light according to a 23 L/1 D program. The basal diet ingredients and composition of the control diet are presented in Table 1. All experimental protocols were reviewed and approved by the Animal Care Committee of the Gorgan University of Agricultural Sciences and Natural Resources.

On d 42, five birds from each treatment, close to the mean weight of all birds in each pen were selected, slaughtered and were plucked, kept in a chiller for approximately 30-45 minutes until the internal temperature of the birds reach 2-3 ˚C and then, eviscerated and cut in parts and the breast muscles (pectoralis major) and right thigh. Then the samples were packaged in low-density polyethylene and stored in the freezer (-17±1 ˚C) until meat quality attributes (moisture, pH, oxidative stability, water-holding capacity, texture profile analysis and color) at d 3 and 7 after the slaughter.

For pH analyses portable pH-meter (Model pH 211; Hanna Instruments,Woonsocket, RI, USA) was used. A total of 10 g of sample was weighed and homogenized with 10 mL of distilled water.

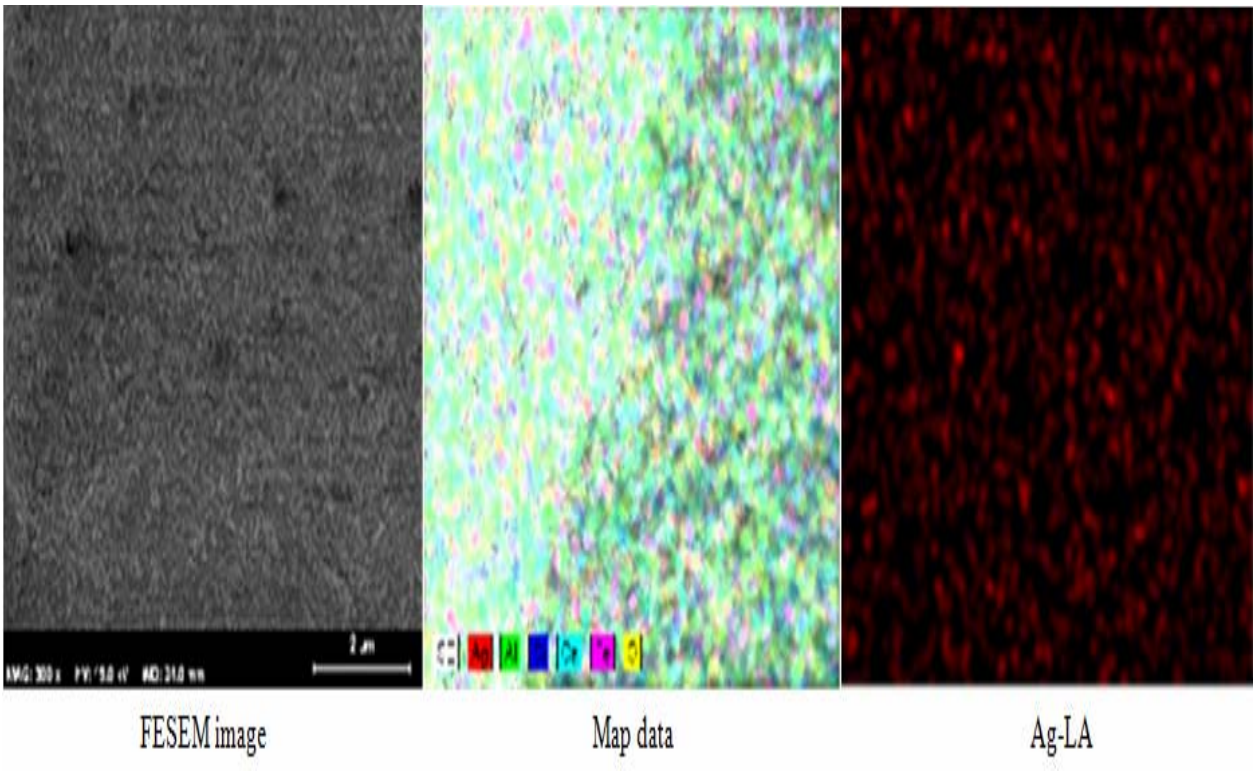

Figure 1 Field emission scanning electron microscopy (FESEM) micrographs and energy dispersive X-ray spectroscopy (EDX) for elemental mapping analyses of the nanosilver coated on clinoptilolite

Table 2 Composition and analysis of the diets (g kg^{-1} as-fed)

Ingredients	Control diet		Exprimental diet	
	Starter (1-21)	Grower (22-42)	Starter (1-21)	Grower (22-42)
Yellow corn	53.70	59.96	51.6	57.84
Soybean meal (44%)	39.52	33.25	39.95	33.68
Soybean oil	3	3.41	3.69	4.11
Coated nanosilver on zeolite	0	0	1	1
Dicalcium phosphate	1.47	1.09	1.47	1.09
Limestone	1.19	1.29	1.18	1.28
Salt	0.43	0.32	0.43	0.32
Vitamin premix[1]	0.25	0.25	0.25	0.25
Mineral premix[1]	0.25	0.25	0.25	0.25
DL-methionine	0.13	0.05	0.13	0.05
L-lysine	0.06	0.13	0.05	0.13
Analysis (dry matter basis)				
Metabolizable energy (ME) (kcal kg−1)	2950	3050	2950	3050
Crude protein (CP) (%)	21.2	19.06	21.2	19.06
Calcium (%)	0.92	0.86	0.92	0.86
Phosphorus (%)	0.41	0.33	0.41	0.33
Sodium (%)	0.18	0.14	0.18	0.14
Lysine (%)	1.01	0.95	1.01	0.95
Methionine (%)	0.47	0.36	0.47	0.36
Cystine (%)	0.36	0.37	0.36	0.37
Arginine (%)	1.45	1.27	1.45	1.27
Threonine (%)	0.84	0.74	0.84	0.74

[1] Supplied per kilogram of diet: vitamin A: 1500 IU; Cholecalciferol: 200 IU; vitamin E: 10 IU; Riboflavin: 3.5 mg; Pantothenic acid: 10 mg; Niacin: 30 mg; Cobalamin: 10 µg; Choline chloride: 1000 mg; Biotin: 0.15 mg; Folic acid: 0.5 mg; Thiamine: 1.5 mg; Pyridoxine: 3.0 mg; Iron: 80 mg; Zinc: 40 mg; Manganese: 60 mg; Iodine: 0.18 mg; Copper: 8 mg and Selenium: 0.15 mg.

The probe of the pH meter was dipped into the solution and the pH values recorded according to the AOAC (1995). The pH meter was calibrated by measuring buffer solutions (pH=4 and pH=7) after every 5 observations. Moisture content of chicken thighs and breast muscle were determined according to the Association Official Analytical Chemists (AOAC, 1998), by drying about 10 g of the sample at 105 ˚C in the oven until a constant weight was recorded. The method used for determining the water-holding capacity (WHC) was a modification of the high speed centrifugation method (Jang *et al*. 2008). Oxidative stability in the meat samples is based on the reaction of one molecule malondialdehyde (MDA) with 2 molecules of thiobarbituric acid (TBA). The color of the final complex is pink and the absorbance of the complex is measured spectrophotometrically. MDA is a major degradation product of oxidation of polyunsaturated fatty acids. Evaluation of TBA was performed.

Texture profile analyses (adhesiveness, chewiness, springiness, hardness, gumminess and cohesiveness) were assessed using a texture analyzer (Brookfield, LFRA. 4500 Texture Analyser, USA) as described by Santhi and Kalaikannan (2014) and defined in our previous study (Hashemi *et al*. 2014). Briefly, samples were allowed to equilibrate at room temperature for 20 mins and then cut into uniformly sized cubes of 1 cm (width) × 1 cm (thickness) × 1 cm (length). Each sample was compressed twice to 80% of the original height using a compression probe (TA 11/1000, 20 mm). A crosshead speed of 10 mm/s was used. The values were recorded based on the software available in the instrument. Color analysis, the lightness (L*), redness (a*) and yellowness (b*) were measured using a colorimeter (Lovibond CAM-system 500). Briefly, after exiting samples from the freezer, thigh and breast were taken out of the bags and rinsed thoroughly with tap water. Breast and thigh skins were raised up carefully and kept at room temperatures for 30 minutes. Then, the surfaces of meat samples (thigh and breast) were photographed from the similar sections. A Hunter Lab spectrophotometer model Color Quest II was used, calibrated with white standard and gray standard. A completely randomized design with 5 treatments and 5 replicates of 15 birds was employed. Statistical analyses were performed using the GLM procedure of SAS software (SAS, 2004). Significant differences were further separated using Duncan's multiple range test. Statistical significance was considered at ($P \leq 0.05$).

RESULTS AND DISCUSSION

The effect of different treatment diets on selected quality characteristics of broiler breast meat and meat color intensity is shown in Table 3.

No significant differences were noted on selected quality and meat color intensity between the different treatment diets at 3 and 7 days frozen storage($P>0.05$).

Table 4 presents the values of selected quality of broiler thigh meat and meat color intensity. The birds fed diets containing various levels of nanosilver coated on clinoptilolite (ZN25, ZN50 and ZN75) had lower MDA concentrations than the control group on d 3 after frozen storage ($P<0.05$). Thigh meat water-holding capacity (WHC) 7 days frozen storage was significantly affected by the dietary treatments.

Broilers fed diet containing 1% clinoptilolite and control diet had lower WHC value than the other groups. Also, on d 7 after refrigerated storage, MDA concentration of birds' thigh meat in ZN25 and ZN50 diets was lower than that of birds in the control group ($P<0.05$) but similar to that of birds in Z and ZN75 ($P>0.05$). However, no effect of diet on other thigh meat selected quality and meat color intensity was observed ($P>0.05$).

The texture profile of broiler chicken thigh meat is presented in Table 5. On d 3, there were no significant differences between treatments on hardness, adhesiveness, springiness, cohesiveness and gumminess ($P>0.05$), while chewiness value was influenced by treatment diets ($P<0.05$). The lowest value of chewiness was recorded by birds fed control diet. On d 7, the springiness, cohesiveness, gumminess and chewiness value were affected by treatment diets ($P<0.05$) and at the same time as hardness and adhesiveness were not influenced by dietary treatment ($P>0.05$). The effect of different experimental diets on texture profile analyses of broiler chicken breast muscle is offered in Table 6.

On d 3, adhesiveness and gumminess were not influenced by dietary treatment ($P>0.05$) while other traits were affected most strongly by experimental diets ($P<0.05$). Seven days after storage of broiler chicken breast in the freezer only springiness and chewiness value were affected by the dietary treatments ($P>0.05$). The lowest value of springiness and chewiness were measured in the broilers fed ZN25 diet. Hardness, adhesiveness, cohesiveness and gumminess value werenot influenced by treatment ($P>0.05$).

The present results showed that the addition of nanosilver particles coated on clinoptilolite at all levels increased WHC in thigh muscles 7 days after frozen storage. Many variables, such as broiler genotype, age, sex, nutrition, rearing system, carcass dressing and type of meat, can affect the nutritional value of meat. Dabes (2001) claimed that lower WHC indicated losses in the nutritional value through exudates that were released and this resulted in drier and tougher meat. Offer and Knight (1989) showed that muscle pH and protein denaturation are considered to be the main determinants of WHC in meat.

Table 3 Selected quality of broiler pectoralis major muscle fed different treatments diet

Selected quality traits	Treatments					SEM
	Control	Z	ZN25	ZN50	ZN75	
3 days storage at -17±1 ˚C						
Moisture (%)	74.11	73.25	73.79	74.81	73.62	4.1
pH	5.32	5.49	5.38	5.41	5.44	0.13
WHC (%)	75.23	73.92	75.81	77.90	74.93	3.8
TBA-RS (mg MDA/kg)	2.50	2.53	2.48	2.02	2.51	0.27
Color parameters						
L* (Lightness)	59.22	57.78	59.74	64.74	67.45	4.1
a* (Redness)	11.40	12.02	12.26	12.56	12.80	0.56
b* (Yellowness)	6.81	6.72	7.76	6.86	6.71	0.39
7 days storage at -17±1 ˚C						
Moisture (%)	67.61	68.23	67.96	67.10	68.22	3.8
pH	5.37	5.51	5.42	5.43	5.46	0.12
WHC (%)	63.93	65.92	64.21	64.18	63.81	4.3
TBA-RS (mg MDA/kg)	4.61	4.58	6.37	4.49	4.71	0.28
Color parameters						
L* (Lightness)	59.71	58.04	60.36	65.58	67.60	5.2
a* (Redness)	12.18	12.24	13.16	13.08	13.02	0.64
b* (Yellowness)	10.52	9.02	9.16	9.08	9.12	0.48

Z: basal diet supplemented with 1% zeolite.
ZN25, ZN50 and ZN75: basal diet supplemented with 1% zeolitecoated with 25, 50 and 75 ppm nanosilver respectively.
TBA-RS: thiobarbituric acid reactive substances and WHC: water holding capacity.
SEM: standard error of the means.

Table 4 Selected quality of broiler thigh muscles fed different treatments diet

Selected quality traits	Treatments					SEM
	Control	Z	ZN25	ZN50	ZN75	
3 days storage at -17±1 ˚C						
Moisture (%)	76.70	76.32	75.61	75.80	74.63	3.7
pH	5.57	5.63	5.42	5.38	5.39	0.18
WHC (%)	78.00	74.91	79.83	73.41	68.75	6.1
TBA-RS (mg MDA/kg)	2.35^{a}	2.94^{ab}	2.81^{b}	2.84^{b}	2.78^{b}	0.12
Color parameters						
L* (Lightness)	54.36	58.28	57.28	62.73	61.18	4.2
a* (Redness)	13.56	13.52	14.12	14.08	14.21	0.39
b* (Yellowness)	8.84	8.12	7.92	7.78	7.76	0.21
7 days storage at -17±1 ˚C						
Moisture (%)	74.01	70.42	71.54	71.61	71.32	5.2
pH	5.61	5.64	5.43	5.37	5.42	0.13
WHC (%)	64.31^{b}	60.76^{b}	75.32^{a}	77.13^{a}	76.25^{a}	3.4
TBA-RS (mg MDA/kg)	4.36^{a}	3.98^{ab}	3.22^{b}	3.41^{b}	3.82^{ab}	0.18
Color parameters						
L* (Lightness)	56.36	58.73	58.12	64.52	65.06	3.9
a* (Redness)	13.52	13.94	14.74	14.96	14.34	0.21
b* (Yellowness)	10.44	9.04	9.82	9.61	10.04	0.50

Z: basal diet supplemented with 1% zeolite.
ZN25, ZN50 and ZN75: basal diet supplemented with 1% zeolitecoated with 25, 50 and 75 ppm nanosilver respectively.
TBA-RS: thiobarbituric acid reactive substances and WHC: water holding capacity.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Hence, the decrease in net protein charge results in diminished WHC due to the availability of fewer charged protein sites for binding water which forces more of the immobilized water into the free water compartment (Bowker and Zhuang, 2015). It is demonstrated that early postmortem events including rate and extent of pH decline, proteolysis and even protein oxidation are key in influencing the ability of meat to retain moisture.

Table 5 Effect of treatments on texture profile analyses (TPA) of broiler chicken thigh muscle

Treatments	TPA					
	Hardness (g)	Adhesiveness	Springiness (cm)	Cohesiveness (ratio)[1]	Gumminess[2]	Chewiness[3]
3 days storage at -17±1 ˚C						
Control	1553.11	-35.44	1.23	0.41	636.73	783.19^{c}
Z	1642.16	-37.73	1.84	0.50	821.02	1510.64^{a}
ZN25	1481.34	-43.17	1.64	0.49	725.69	1190.13^{b}
ZN50	1588.65	-42.19	1.53	0.53	841.64	1287.71^{ab}
ZN75	1475.14	-45.56	1.62	0.56	826.11	1338.12^{ab}
SEM	61.72	5.45	0.03	0.05	41.98	58.15
7 days storage at -17±1 ˚C						
Control	1267.11	-31.17	1.99^{b}	0.71^{a}	899.57^{a}	1790.15^{a}
Z	1512.32	-36.31	1.87^{c}	0.66^{a}	997.92^{a}	1866.11^{a}
ZN25	1235.46	-39.52	2.92^{a}	0.47^{b}	580.45^{b}	1694.91^{a}
ZN50	1465.12	-42.22	2.23^{ab}	0.41^{b}	600.65^{b}	1339.44^{b}
ZN75	1378.19	-42.35	2.50^{a}	0.49^{b}	675.27^{b}	1668.05^{a}
SEM	72.11	4.88	0.04	0.03	48.12	61.11

[1] Cohesiveness is: area under second curve / area under first curve.
[2] Gumminess was calculated as: hardness × cohesiveness.
[3] Chewiness was calculated as: hardness × springiness × cohesiveness.
Z: basal diet supplemented with 1% zeolite.
ZN25, ZN50 and ZN75: basal diet supplemented with 1% zeolitecoated with 25, 50 and 75 ppm nanosilver respectively.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 6 Effect of treatments on texture profile analyses (TPA) of broiler chicken pectoralis major muscle

Treatments	TPA					
	Hardness (g)	Adhesiveness	Springiness (cm)	Cohesiveness (ratio)[1]	Gumminess[2]	Chewiness[3]
3 days storage at -17±1 ˚C						
Control	1160.12^{b}	-43.25	1.44^{a}	0.48^{a}	556.81	801.79^{a}
Z	1281.34^{b}	-33.52	1.53^{a}	0.51^{a}	653.32	999.57^{a}
ZN25	1231.56^{b}	-36.79	1.12^{c}	0.42^{c}	529.33	592.57^{b}
ZN50	1588.15^{a}	-44.62	1.33^{ab}	0.43^{c}	682.84	908.16^{a}
ZN75	1575.22^{a}	-46.21	1.27^{bc}	0.46^{bc}	724.49	920.12^{a}
SEM	51.90	6.25	0.03	0.01	46.11	52.11
7 days storage at -17±1 ˚C						
Control	1105.11	-34.10	1.68^{a}	0.44	530.88	891.87^{a}
Z	1220.56	-36.77	1.45^{a}	0.57	695.40	1008.33^{a}
ZN25	1227.22	-41.48	0.99^{b}	0.50	613.52	607.36^{b}
ZN50	1165.56	-46.67	1.40^{a}	0.62	722.31	1011.22^{a}
ZN75	1112.78	-41.71	1.33^{a}	0.53	589.36	783.84^{ab}
SEM	48.30	5.12	0.02	0.03	39.13	54.98

[1] Cohesiveness is: area under second curve / area under first curve.
[2] Gumminess was calculated as: hardness × cohesiveness.
[3] Chewiness was calculated as: hardness × springiness × cohesiveness.
Z: basal diet supplemented with 1% zeolite.
ZN25, ZN50 and ZN75: basal diet supplemented with 1% zeolitecoated with 25, 50 and 75 ppm nanosilver respectively.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

The water holding capacity of foods can be defined as the ability to hold its own and added water during the application of forces, pressing, centrifugation, or heating. Hermansson (1986) defined WHC as a physical property and is the ability of a food structure to prevent water from being released from the three-dimensional structure of the protein. Unacceptable water-holding capacity costs the meat industry millions of dollars annually (Huff-Lonerganand Lonergan, 2005). Much of the water in the meat is entrapped in the structures of the cell, within the

myofibrils, between the myofibrils and between the myofibrils and the cell membrane (sarcolemma), between muscle cells and between muscle bundles (Honikel, 2004). Therefore, key changes in the intracellular architecture of the cell influence the ability of muscle cells to retain water. As rigor progresses, the space for water to be held in the myofibrils is reduced and fluid can be forced into the extra-myofibrillar spaces where it is more easily lost as drip. Lateral shrinkage of the myofibrils occurring during rigor can be transmitted to the entire cell if proteins that link myofibrils together and myofibrils to the cell membrane (such as desmin) are not degraded. Limited degradation of cytoskeletal proteins may result in increased shrinking of the overall muscle cell, which is ultimately translated into drip loss. Recent evidence suggests that degradation of key cytoskeletal proteins by calpain proteinases has a role to play in determining water-holding capacity (Huff-Lonerganand Lonergan, 2005).

The present study also indicated that the addition of nanosilver coated on clinoptilolite at all levels 3 and 7 days after frozen storage of thigh muscles decreased malonaldehyde (MDA) production. Malonaldehyde, a product of lipid peroxidation, which is used as an indicator of oxidative damage to cells and tissues and in directly indicates the degree of oxidative stress. Lipid oxidation is one of the main factors limiting the quality and acceptability of meats and meat products. Oxidative damage to lipids occurs in the living animal because of an imbalance between the production of reactive oxygen species and the animal's defense mechanisms (Jiang *et al*. 2007). It is reported that silver nanoparticles showed an efficient cellular electron exchange mechanism, which arrest electron leakage, reducing the reactive oxygen species (ROS) production and MDA levels (Lu *et al*. 2002; Hatami and Ghorbanpour, 2013). Lower oxidative damage is associated with an improved ability of the sample to bind more water (Melody *et al*. 2004).

In this study, lower oxidative damage improved WHC suggest an improved ability of the sample to bind water. The observed relation between WHC, less oxidative damage and nanosilver particles coated on clinoptilolite in the diet may be due to reducing proteolysis and protein oxidation and thus quality characteristics influenced by proteolysis such as water holding capacity. There are, however, other possible explanations and there is insufficient evidence of effects of silver nanoparticles on meat quality.

CONCLUSION

Poultry research and food production are aimed at increasing the meat nutritional value without lowering the sensory quality or consumer's acceptability. Based on the data gathered from this trial, it can be concluded the use of nanosilver coated on clinoptiloliteas feed additive had a beneficial effect on broiler meat. Texture profile analysis showed that nanosilver coated on clinoptilolite had no any negative effects on texture or sensory attributes of chicken meat. Although more research is required in this area to confirm this finding and to assess the safety of the meat produced in this way. However, basic information about the meat quality attributes and nanosilver and clinoptilolite as feed additives in the chicken diets is poorly documented.

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REFERENCES

AOAC. (1995). Official Methods of Analysis. Vol. I. 16th Ed. Association of Official Analytical Chemists, Arlington, VA, USA.

AOAC. (1998). Official Methods of Analysis. Vol. I. 18th Ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Bowker B.C. and Zhuang H. (2015). Relationship between water-holding capacity and protein denaturation in broiler breast meat. *Poult. Sci*. **94,** 1657-1664.

Chauke N. and Siebrits F.K. (2012). Evaluation of silver nanoparticles as a possible coccidiostat in broiler production. *South African J. Anim. Sci*. **42,** 493-497.

Dabes A.C. (2001). Propriedades da carne fresca. *Rev. Nac. Carne*. **25,** 32-40.

Hashemi S.R., Davoodi D., Dastar B., Bolandi N., Smaili M. and Mastani R. (2014). Meat quality attributes of broiler chickens fed diets supplemented with silver nanoparticles coated onzeolite. *Poult. Sci. J*. **2,** 183-193.

Hatami M. and Ghorbanpour M. (2013). Effect of nanosilver on physiological performance of pelargonium plants exposed to dark storage. *J. Hort. Res*. **21,** 15-20.

Hermansson A.M. (1986). Water-and fat holding. Pp. 31-38 in Functional Properties of Food Macromolecules. R. Mitchell, and D.A. Ledward, Eds. Elsevier Applied Science Publishers, London, UK.

Honikel K.O. (2004). Water-holding capacity of meat. Pp. 389-400 in Muscle Developmentof Livestock Animals: Physiology, Genetics and Meat Quality. M.F. tePas, M.E. Everts and H.P. Haagsman, Eds. CABI Publishing, Cambridge, USA.

Huff-Lonergan E. and Lonergan S.M. (2005). Mechanisms of water-holding capacity of meat: the role of postmortem biochemical and structural changes. *Meat Sci*. **71,** 194-204.

Jang A., Liu X.D., Shin M.H., Lee B.D., Lee S.K., Lee J.H. and Jo

C. (2008). Antioxidative potential of raw breast meat from broiler chicks fed a dietary medicinal herb extract mix. *Poult. Sci*. **87,** 2382-2389.

Jiang S.Q., Jiang Z.Y., Lin Y.C., Xi P.B. and Ma X.Y. (2007). Meat quality and antioxidative property of male broilers fed oxidized fish oil. *Asian-Australasian J. Anim. Sci*. **20,** 1252-1257.

Kannan N. and Subbalaxmi S. (2011). Green synthesis of silver nanoparticles using *Bacillus subtillus* IA751 and its antimicrobial activity. *Res. J. Nanosci. Nanotechnol*. **1,** 87-94.

Khalafalla F.A., Ali F.H.M., ZahranDalia A. and Mosa A.M.M.A. (2011). Influence of feed additives in quality of broiler carcasses. *J. World's Poult. Res*. **2,** 40-47.

Kulthong K., Srisung S., Boonpavanitchakul K., Kangwansupamonkon W. and Maniratanachote R. (2010). Determination ofsilver nanoparticle release from antibacterial fabrics into artificial sweat. *Part. Fibre. Toxicol*. **7,** 1-9.

Li Y., Leung P., Yao L., Song K.W. and Newton E. (2006). Antimicrobial effect of surgical masks coated with nanoparticles. *J. Hosp. Infect*. **62,** 58-63.

Lu C.M., Zhang C.Y., Wen J.Q. and Wu G.R. (2002). Research on the effect of nanometer materials on germination and growth enhancement of glycine max and its mechanism. *Soybean Sci*. **21,** 68-171.

Melody J.L., Lonergan S.M., Rowe L.J., Huiatt T.W., Mayes M.S. and Huff-Lonergan E. (2004). Early postmortem biochemical-factors influence tenderness and water-holding capacity of threeporcine muscles. *Anim. Sci*. **82,** 1195-1205.

Meluzzi A., Sirri F., Castellini C., Roncarati A., Melotti P. and Franchini A. (2009). Influence of genotype and feeding on chemical composition of organic chicken meat. *Italian J. Anim. Sci*. **8,** 766-768.

Nikpey A., Kazemian H., Safari-Varyani A., Rezaie M. and Sirati-Sabet M. (2013). Protective effct of microporous natural clinoptilolite on leadinduced learning and memory impairment in rats. *Health Scope*. **2,** 52-57.

Offer G., Knight P., Jeacocke R., Almond R., Cousins T., Elsey J., Parsons N., Sharp A., Starr R. and Purslow P. (1989). The structural basis of the water-holding, appearance, and toughness ofmeat and meat products. *Food Microstruct*. **8,** 151-170.

Santhi D. and Kalaikannan A. (2014). The effect of the addition of oat flour in low-fat chicken nuggets. *J. Nutr. Food Sci*. **4,** 260.

SAS Institute. (2004). SAS®/STAT Software, Release 9.1. SAS Institute, Inc., Cary, NC. USA.

Sawosz E., Binek M., Grodzik M., Zielinska M., Sysa P., Szmidt M., Niemec T., Sondi I. and Salopek-Sondi B. (2004). Silver nanoparticles as antimicrobial agent: a case study on *E. Coli*as a model for Gram-negative bacteria. *J. Colloid Interf. Sci*. **275,** 177-182.

Sekhon B.S. (2014). Nanotechnology in agri-food production: an overview. *Nanotechnol. Sci. Appl*. **7,** 31-53.