ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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OPEN ACCESS International Journal of Poultry Science

ISSN: 1682-8356
DOI: 10.3923/ijps.2017.69.80

Research Article
Effects of Ionized Water on Certain Egg Quality Traits and the Levels of Proteins and Enzymes in the Blood of the Japanese Quail *Coturnix japonica*

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Abstract
Objective: This experiment was conducted to study the effects of ionized water on certain egg quality traits and the levels of proteins and enzymes in the blood of the Japanese quail *Coturnix japonica*. **Materials and Methods:** One hundred 42-day-old quail were randomly distributed among five treatment groups with four replicates for each group. The following treatments were used: T1 (control): The birds were provided normal water, T2: The birds were provided alkaline water (pH = 8), T3: The birds were provided alkaline water (pH = 9), T4: The birds were provided acidic water (pH = 6) and T5: The birds were provided acidic water (pH = 5). A Complete Randomized Design (CRD) was used to investigate the effects of the studied treatments on different traits. **Results:** Significant ($p<0.05$) differences in the total mean length and width of the egg and shell thickness were observed between treatments, T2 and T4 surpassed the other treated groups in egg length, at values of 32.12 and 32.27 mm, respectively. However, T2 and T3 produced the greatest egg widths, which were 25.44 and 25.38 mm, respectively. However, T2 produced the highest mean shell thickness of 0.25 mm. On the other hand, T3 produced the highest blood protein levels compared with the other treated groups, whereas T1 produced the highest blood enzyme levels in this study. A pH of 8 or 9 in drinking water resulted in the best egg quality traits and protein and enzyme levels in the blood. Alkaline and acidic water may provide an effective, safe, non-toxic and relatively inexpensive treatment to produce the best egg quality traits and protein and enzyme levels. **Conclusion:** The inclusion of alkaline and acidic water has beneficial effects on Japanese quail production and may be considered a low-cost option to improve general production parameters.

Key words: Ionized water, egg quality, proteins and enzymes blood, *Coturnix japonica*

Received: November 04, 2016 Accepted: January 16, 2017 Published: February 15, 2017

Citation: Hasanain N. Ezzat, Ihsan M. Shihab and Mohammad A. Hussein, 2017. Effects of ionized water on certain egg quality traits and the levels of proteins and enzymes in the blood of the Japanese quail *Coturnix japonica*. Int. J. Poult. Sci., 16: 69-80.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Poultry companies in developed countries and now Arab countries have begun providing egg and meat from unusual bird sources such as ostriches, ducks, Guinea fowl and Japanese quail[1,2]. Japanese quail are small, lightweight, brown birds with some black spots that exhibit prolific egg production. Twenty species of wild quail exist in the world including the European, African and Asian species. All wild quail belong to one or two species: Japanese quail (*Coturnix japonica*) and common quail (*Coturnix coturnix*)[3,4]. Ionized water is functional water with specialized functions. Ionized water is produced using many methods, such as electrolysis or treatment with a magnetic field. Two types of electrolyzed water are available: Electrolyzed Reduction Water (ERW), which is produced near the cathode and Electrolyzed Oxidizing Water (EOW), which is produced near the anode and is also called acidic water. The EOW has a sterilization activity that is mainly due to hypochloric acid, chlorine gas and ozone[5]. Electrolysis was first used in the soda industry in 1900 to produce sodium hypochlorite[6]. The use of Electrolyzed Water (EW) is an emerging technology with considerable potential[7]. With the development of smaller sized equipment, electrolysis has been applied in several fields and become a promising nonthermal treatment to control health[8]. The acidic water produced by electrolysis is classified as functional water and some researchers refer to it as Electrolyte Oxidizing Water (EOW), Alkaline Electrolyte Water (AEW) or Base Electrolyte Water (BEW)[7]. Water electrolysis apparatuses have many advantages, such as efficient water disinfection, ease of operation, environment maintenance and a low cost, therefore, this kind of water can be obtained safely and inexpensively. Electrolyzed water has been used as a nonthermal method for disinfecting different kind of foods without affecting their physical characteristics, such as color, smell, flavor or consistency[9-12]. The most important feature of electrolyzed water is its ability to stop the activity of pathogens with less impact on the environment due to the lack of chemicals[13]. The administration of Neutral Electrolyzed Water (NEW) to poultry is a new method that has a beneficial effect on health status[14,15]. Therefore, the current study aims to investigate the effects of ionized water on egg quality traits and the blood levels of proteins and enzymes in quail.

MATERIALS AND METHODS

Experimental design and bird management: The experiment was conducted at a private farm for the period from 20/4/2016 to 13/7/2016. The birds were raised for 12 weeks. One hundred Japanese quail obtained from a private incubator at the age of 35 days were used in the experiment. The birds were allowed to rest for 1 week and the experiment began when the birds were 42 days old. The birds were randomly distributed among 5 treatment groups with four replicates for each group. The birds were fed a diet with balanced energy and protein levels (Table 1). The birds were housed in metal battery cages purchased from the local market. The cages consisted of six floors with dimensions of 60×70×60 cm. Each cage was supplied with a plastic water and a longitudinal plastic feeder. The following treatments were used in this study:

Table 1: Proportion and calculated chemical compositions of materials in the diet of Japanese quail during the period of egg production

Components	Percentage
Corn	30.00
Wheat	31.90
Soybean	25.00
Concentrated protein*	5.00
Corn oil	2.00
Limestone	5.50
DCP	0.30
NaCl	0.30
Total	100.00
Calculated chemical compositions	
Energy (kg kcal^{-1})	2894.00
Protein (%)	19.50
Lysine (%)	1.20
Methionine (%)	0.57
Ca (%)	2.50
Available P (%)	0.49

The chemical composition of the feed was calculated according to the 1994 guidelines of the NRC. Hold mix type concentrated protein from Jordan was used. *Each kilogram of the feed contained 40% raw protein, 3.5% fat, 1% raw fiber, 6% calcium, 2100 kcal of assimilated energy, 3% phosphorous, 2.20% salt, 3.25% lysine, 3.50% methionine, 3.90% methionine+cysteine, 40,000 IU of vitamin D3, 15 mg of vitamin B1, 300 mg of vitamin B12, 30 mg of vitamin K3, 100 Mcg of biotin, 100 mg of copper, 1200 mg of manganese, 15 mg of iodine, 2 mg of selenium and 10 mg of folic acid

T1 (control) : The birds were provided normal water
T2 : The birds were provided alkaline water (pH = 8)
T3 : The birds were provided alkaline water (pH = 9)
T4 : The birds were provided acidic water (pH = 6)
T5 : The birds were provided acidic water (pH = 5)

Steps used to produce ionized water: Ionized water (alkaline or acidic) was produced by a Bawell apparatus as shown in Fig. 1. The apparatus was made in China and purchased from (Baghdad, Karrada, Iraq) Indimaj company for processing

Fig. 1: Bawell_SM1 water ionizer

water located in the Karrada district. The Bawell apparatus consists of two columns for ionizing water and is sufficient to produce 6000 L of ionized water. It also contains a faucet to control the water stream to obtain a suitable pH. The faucet is linked to a water source and then the water passes through a 3 U filter to remove lingering impurities from the water before it enters the apparatus. After pressing the alkaline level 1 button, alkaline ionized water was obtained, whereas acidic ionized water is obtained in the same way but pressing the acidic weak button. The apparatus contains buttons (alkaline level 2 and alkaline level 3) to produce alkaline ionized water with a pH higher than 9. It also produces strong acidic ionized water when the acidic strong button is pressed, this water cannot be used for drinking, it is used for sterilization and disinfection only.

Lighting: The birds experienced a lighting period of 16 h day^{-1} during the experiment. The light lamps were distributed in the hall to ensure that every bird received an equal amount of light.

Qualitative traits of the eggs produced by Japanese quail: Qualitative egg traits (internal and external) were measured starting from the 8th weeks of age at a rate of once every 2 weeks by weighing 5 eggs from each replicate. The eggs were broken on a glass surface to investigate the traits described by Al-Fayadh and Saad[16].

Height of the yolk and albumin layer: The egg and yolk albumen heights were measured with a special tri-base micrometer (Ames-type micrometer). An average of two values for the thickness of the albumin layer in every egg was calculated from the middle region that extended from the yolk to the external end of the thick albumin layer, whereas the yolks were measured from the highest part in the middle region.

Length and width of egg: The length and width of the eggs were measured with electronic Vernier calipers. Egg length was measured between the pointed and wide ends and the width was measured at the widest area of the egg. Then, the shape coefficient was calculated using the following equation:

$$\text{Shape coefficient} = \frac{\text{Width of the eggs}}{\text{Length of the eggs}} \times 100$$

Yolk index: Yolk diameter (mm) and height (mm) were measured with Vernier calipers to calculate the yolk index using the following equation:

$$\text{Yolk index} = \frac{\text{Yolk height (mm)}}{\text{Diameter (mm)}}$$

Shell thickness: The thickness of the shell with membranes was measured after several days of drying. Curved Vernier calipers were used to measure the shell thickness by calculating the average value of the pointed and wide ends for each egg.

Haugh unit: Haugh unit is one of the most important parameters used to express the quality of egg albumin by measuring the average height of the albumin from two opposite sides of the yolk with a special Maekeromitr (Maes micrometer) after the egg is broken on a glass flat surface. The egg was weighed on an electronic balance to two digits before the egg was broken.

Weights of the egg components: The eggs were broken and placed in transparent plastic dishes. The yolks were separated from the attached albumin and weighed in separate dishes of known weights. The weights of the dried yolk, shell and membranes were measured with a sensitive balance (type SF-400) and the numbers were rounded to the nearest two decimal places. Albumin weight was calculated as the difference between the whole egg weight and the weight of the other components.

Yolk diameter (mm): Yolk diameter was measured with electronic Vernier calipers.

Relative weight of the yolk to the whole egg weight (%): This value was calculated using the following equation:

$$\text{Relative weight of the yolk to the whole egg weight (\%)} = \frac{\text{Yolk weight}}{\text{Egg weight}} \times 100$$

Albumin weight relative to the whole egg weight (%): The following equation was used to calculate this value:

$$\text{Albumin weight relative to the whole egg weight (\%)} = \frac{\text{Albumin weight}}{\text{Egg weight}} \times 100$$

Shell thickness (mm): Shell thickness was measured with micrometers on the day after the membranes were removed and the shell was dried. An average of two readings for each egg was calculated from the wide and pointed ends.

Relative weight of the egg shell (%): This value was calculated using the following equation:

$$\text{Relative weight of the egg shell (\%)} = \frac{\text{Shell weight}}{\text{Egg weight}} \times 100$$

Blood tests: Blood samples were collected from three randomly selected female quail from each replicate at the ages of 12 and 18 weeks by puncturing the brachial veins in the wings. Blood was collected in test tubes containing the anti-clotting agent K2EDTA and centrifuged at 300 rpm for 5 min to separate plasma, then, the plasma was transferred to other tubes that were sealed and frozen at -15 to -20°C until testing. The total protein, albumin, globulin levels and activity of liver enzymes (GOT, GPT and ALP) were measured.

Statistical analysis: A Complete Randomized Design (CRD) was used to investigate the effects of the studied treatments on different traits. A polynomial Duncan[17] test was used to compare the means between groups using the SAS[18] program according to the following mathematical model:

$$Yij = \mu + Ti + eij$$

where, Yij is the value of observation j for treatment i, μ is grand mean, Ti is the effect of treatment i (the study included four treatments) and eij is a random error that was distributed normally at the mean equals zero and the variance is e[19].

RESULTS

Table 2 illustrates the significant differences in egg length between the treated groups during the first period of the experiment. The 3rd treatment surpassed the other treatments during the first period of the experiment, whereas the 4th treatment was superior to the other treatments in the 3rd and 4th periods of experiment. No significant difference was observed between the treated groups during the other periods. The overall mean shows the significant differences between the 2nd and 5th treatments.

The results presented in Table 3 show significant differences in egg width (p<0.05) between the treated groups during the first period of the experiment. The third treatment surpassed the other treatments during the 1st and 4th periods of the experiment, whereas the 4th treatment was superior to the other treatments during the 3rd and 6th periods of experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd period of the experiment. The overall mean shows the significant differences between the 2nd and 3rd treatments.

Table 2: Effects of alkaline and acidic ionized water on the average egg length (mm)±the standard error in 6-18 week-old quail

	Egg length (mm)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	32.18±0.76[ab]	30.77±0.48	31.02±0.39[b]	32.39±0.34[ab]	31.74±0.25	29.74±0.24	31.31±0.24[b]
T2	32.62±0.92[ab]	31.74±0.41	32.11±0.40[ab]	31.69±0.29[b]	32.03±1.01	32.53±0.81	32.12±0.27[a]
T3	33.44±0.33[a]	31.28±0.65	32.24±0.49[ab]	32.03±0.32[ab]	31.09±0.48	31.83±0.50	31.98±0.23[ab]
T4	32.29±0.34[ab]	31.92±0.93	32.95±0.77[a]	32.81±0.40[a]	31.32±0.28	32.33±0.55	32.27±0.24[a]
T5	31.41±0.38[b]	32.73±0.82	31.88±0.35[ab]	31.85±0.22[ab]	32.87±0.46	30.52±1.67	31.88±0.34[ab]
	*	NS	*	*	NS	NS	*

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 3: Effects of alkaline and acidic ionized water on the average egg width (mm)±the standard error in 6-18 week-old quail

	Egg width (mm)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	24.97±0.31^{b}	24.70±0.36	25.22±0.22^{ab}	24.85±0.28^{b}	25.00±0.27^{ab}	24.03±0.28^{b}	24.80±0.13
T2	25.51±0.38^{ab}	25.22±0.40	25.41±0.33^{ab}	25.40±0.10^{ab}	25.74±0.39^{a}	25.38±0.23^{a}	25.44±0.12
T3	26.05±0.14^{a}	25.06±0.36	25.47±0.09^{ab}	25.59±0.20^{a}	25.37±0.20^{ab}	24.74±0.25^{ab}	25.38±0.11
T4	25.01±0.17^{b}	24.88±0.35	25.97±0.27^{a}	24.95±0.26^{ab}	24.65±0.10^{b}	25.14±0.21^{a}	25.10±0.12
T5	24.96±0.24^{b}	25.51±0.55	25.05±0.33^{b}	25.17±0.13^{ab}	25.25±0.26^{ab}	24.94±0.43^{a}	25.15±0.13
	*	NS	*	*	*	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 4: Effects of alkaline and acidic ionized water on the average egg shape coefficient±the standard error in 6-18 week-old quail

	Egg shape coefficient						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	1.29±0.02	1.25±0.02	1.23±0.02	1.30±0.02^{a}	1.27±0.01^{ab}	1.24±0.01	1.26±0.01
T2	1.28±0.02	1.26±0.01	1.26±0.01	1.25±0.01^{b}	1.24±0.02^{b}	1.28±0.03	1.26±0.01
T3	1.28±0.01	1.25±0.01	1.27±0.02	1.25±0.01^{b}	1.22±0.02^{b}	1.29±0.02	1.26±0.01
T4	1.29±0.01	1.28±0.03	1.27±0.03	1.31±0.01^{a}	1.27±0.02^{ab}	1.29±0.03	1.29±0.01
T5	1.26±0.02	1.28±0.02	1.28±0.02	1.26±0.01^{b}	1.30±0.02^{a}	1.23±0.06	1.27±0.01
	NS	NS	NS	*	*	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 5: Effects of alkaline and acidic ionized water on the average yolk weight (g)±the standard error in 6-18 week-old quail

	Yolk weight (g)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	3.90±0.28	4.20±0.23^{ab}	4.32±0.40	4.24±0.37	3.36±0.15^{b}	3.82±0.25^{c}	3.97±0.12^{b}
T2	3.52±0.10	4.40±0.44^{ab}	4.76±0.28	4.62±0.45	4.16±0.38^{ab}	5.10±0.14^{ab}	4.37±0.16^{ab}
T3	4.18±0.06	4.36±0.32^{ab}	4.22±0.31	4.88±0.33	4.58±0.38^{a}	5.40±0.16^{a}	4.60±0.130^{a}
T4	3.62±0.10	3.80±0.35^{b}	4.26±0.20	3.98±0.48	4.82±0.22^{a}	4.80±0.28^{ab}	4.21±0.14^{ab}
T5	4.18±0.35	5.02±0.43^{a}	3.74±0.39	3.72±0.35	3.96±0.25^{ab}	4.64±0.21^{b}	2.21±0.15^{ab}
	NS	*	NS	NS	*	*	*

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

The results presented in Table 4 show significant differences in the egg shape coefficient (p<0.05) between the treated groups. The 2nd treatment surpassed the other treatments during the 4th and 5th periods of the experiment, whereas the 4th treatment was superior to the other treatments during the 4th and 5th periods. However, no significant differences were observed between the treated groups during the 1st, 2nd, 3rd and 6th periods.

The results presented in Table 5 show significant differences in average yolk weight (p<0.05) between the treated groups during the 2nd period of the experiment. The 3rd treatment surpassed the other treatments during the 5th and 4th periods of the experiment, whereas the 4th treatment was superior to the other treatments during the 5th period of experiment. No significant differences (p<0.05) were observed between the treated groups during the 1st, 3rd and 4th periods of the experiment.

The results presented in Table 6 show significant differences in the average yolk diameter (p<0.05) between the treated groups during the 1st period of the experiment. The 3rd treatment surpassed the other treatments during the 6th period of the experiment, whereas the 5th treatment was superior to the other treatments during the 1st period of the experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd, 3rd, 4th and 5th periods of the experiment. The overall mean shows the significant differences between the 3rd and 5th treatments.

The results presented in Table 7 show significant differences in yolk height (p<0.05) between the treated groups during the experiment. The 3rd treatment surpassed the other treatments during the 6th period of the experiment, whereas the 5th treatment was superior to the other treatments during the 2nd period of experiment. No

Table 6: Effects of alkaline and acidic ionized water on the average yolk diameter (mm)±the standard error in 6-18 week-old quail

	Yolk diameter (mm)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	24.55±0.47[ab]	24.69±0.39	25.32±0.35	25.72±0.39	23.95±0.39	23.42±0.77[b]	24.61±0.23
T2	23.22±0.23[b]	24.86±0.73	24.39±0.81	25.01±0.52	24.71±0.38	24.64±0.25[ab]	24.47±0.23
T3	25.04±1.00[ab]	24.66±0.77	25.55±0.50	24.83±0.08	24.75±0.22	24.97±0.11[a]	24.96±0.22
T4	24.43±0.16[ab]	24.38±0.69	25.81±0.35	24.75±0.41	24.21±0.39	24.22±0.39[ab]	24.64±0.19
T5	25.25±0.63[a]	25.22±0.60	24.57±0.67	24.66±0.35	24.31±0.33	23.58±0.49[ab]	24.60±0.22
	*	NS	NS	NS	NS	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 7: Effects of alkaline and acidic ionized water on the average yolk height (mm)±the standard error in 6-18 week-old quail

	Yolk height (mm)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	11.82±0.46	11.74±0.22[ab]	11.37±0.24	11.45±0.36	11.93±0.22[a]	10.30±0.37[b]	11.43±0.16
T2	11.78±0.26	11.33±0.21[abc]	11.34±0.19	11.30±0.41	11.27±0.39[ab]	11.71±0.20[a]	11.45±0.12
T3	11.21±0.36	10.83±0.26[c]	11.44±0.19	11.17±0.27	10.95±0.23[b]	11.74±0.19[a]	11.22±0.11
T4	11.11±0.32	10.96±0.25[bc]	11.26±0.32	11.51±0.53	11.40±0.20[ab]	10.86±0.22[b]	11.18±0.13
T5	11.08±0.31	11.96±0.36[a]	10.78±0.22	12.09±0.17	10.95±0.21[b]	10.61±0.29[b]	11.25±0.15
	NS	*	NS	NS	*	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 8: Effects of alkaline and acidic ionized water on the average relative yolk weight (%)±the standard error in 6-18 week-old quail

	Relative yolk weight (%)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	36.15±2.63[ab]	41.49±2.37	40.12±2.96	38.78±3.14	31.35±1.77[c]	41.50±3.02[b]	38.23±1.20
T2	30.58±0.82[b]	37.53±2.71	43.16±3.97	42.01±4.58	36.17±3.29[bc]	45.69±1.80[ab]	39.19±1.49
T3	35.15±0.67[ab]	41.57±3.77	37.23±2.67	43.16±3.93	43.26±3.03[ab]	51.78±2.06[a]	42.03±1.46
T4	32.74±0.82[ab]	36.29±2.98	36.38±1.60	34.85±2.79	46.33±2.67[a]	43.52±2.58[b]	38.35±1.26
T5	38.77±3.46[a]	43.25±2.74	35.18±2.87	33.26±3.15	35.71±2.41[bc]	43.99±2.45[b]	38.36±0.31
	*	NS	NS	NS	*	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

significant differences (p<0.05) were observed between the treated groups during the 1st, 3rd and 4th periods of the experiment.

The results presented in Table 8 show significant differences in relative yolk weight (p<0.05) between the treated groups during the 1st period of the experiment. The 3rd treatment surpassed the other treatments during the 5th and 6th periods of the experiment, whereas the 4th treatment was superior to the other treatments during the 5th period of experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd, 3rd and 4th periods of the experiment.

Table 9 shows significant differences in the average yolk index (p<0.05) between the treated groups during the 1st period of the experiment. The 2nd treatment surpassed the other treatments during the 1st period of the experiment, whereas the 1st treatment was superior to the other treatments during the 5th period of experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd, 3rd and 4th periods of the experiment.

Table 10 shows significant differences in the average albumin weight (p<0.05) between the treated groups during the 1st period of the experiment. The 2nd treatment surpassed the other treatments during the 1st and 5th periods of the experiment, whereas the 1st treatment was superior to the other treatments during the 5th period of experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd, 3rd, 4th and 6th periods of the experiment.

The results presented in Table 11 show significant differences in the average albumin height (p<0.05) between the treated groups during the 1st period of the experiment.

Table 9: Effects of alkaline and acidic ionized water on the average yolk index±the standard error in 6-18 week-old quail

Treatments	Yolk index 6-8	8-10	10-12	12-14	14-16	16-18	6-18
	(weeks)						
T1	0.48±0.01[ab]	0.48±0.01	0.45±0.01	0.45±0.02	0.50±0.01[a]	0.44±0.01	0.47±0.01
T2	0.50±0.01[a]	0.46±0.02	0.47±0.02	0.45±0.02	0.46±0.02[b]	0.47±0.01	0.47±0.01
T3	0.45±0.01[bc]	0.44±0.02	0.45±0.01	0.45±0.01	0.44±0.01[b]	0.47±0.01	0.45±0.01
T4	0.45±0.01[bc]	0.45±0.01	0.44±0.02	0.46±0.02	0.47±0.01[ab]	0.45±0.01	0.45±0.01
T5	0.44±0.01[c]	0.48±0.01	0.44±0.01	0.49±0.01	0.45±0.01[b]	0.45±0.01	0.46±0.01
	*	NS	NS	NS	*	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 10: Effects of alkaline and acidic ionized water on the average albumin weights (g)±the standard error in 6-18 week-old quail

Treatments	Albumin weight (g) 6-8	8-10	10-12	12-14	14-16	16-18	6-18
	(weeks)						
T1	6.52±0.47[ab]	5.16±0.45	5.54±0.24	5.86±0.34	6.60±0.32[a]	4.74±0.48	5.74±1.19
T2	7.42±0.48[a]	5.78±0.17	5.54±0.65	5.68±0.62	6.48±0.53[a]	5.30±0.34	6.03±0.23
T3	7.12±0.15[ab]	5.52±0.56	6.16±0.34	5.72±0.64	5.20±0.33[bc]	4.24±0.31	5.60±0.23
T4	6.86±0.20[ab]	5.90±0.48	6.58±0.33	6.50±0.13	4.80±0.38[c]	5.44±0.30	6.01±0.18
T5	6.12±0.52[b]	5.72±0.34	6.02±0.20	6.60±0.42	6.26±0.29[ab]	5.18±0.46	5.60±0.17
	*	NS	NS	NS	*	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 11: Effects of alkaline and acidic ionized water on the average albumin height (mm)±the standard error in 6-18 week-old quail

Treatments	Albumin height (mm) 6-8	8-10	10-12	12-14	14-16	16-18	6-18
	(weeks)						
T1	4.38±0.33[b]	5.11±0.24	4.93±0.22[ab]	4.16±0.22	4.50±0.23	4.19±0.27[b]	4.54±0.11
T2	5.09±0.16[a]	4.91±0.28	5.13±0.25[a]	4.34±0.41	4.34±0.23	4.23±0.20[b]	4.67±0.12
T3	4.62±0.18[ab]	4.85±0.16	4.94±0.19[ab]	4.77±0.44	5.00±0.28	4.21±0.30[b]	4.73±0.11
T4	4.68±0.16[ab]	5.06±0.29	4.32±0.16[b]	5.11±0.23	4.31±0.22	5.13±0.27[a]	4.77±0.11
T5	4.62±0.16[ab]	4.90±0.35	4.32±0.27[b]	4.97±0.29	4.96±0.14	4.71±0.32[ab]	4.75±0.11
	*	NS	*	NS	NS	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 12: Effects of alkaline and acidic ionized water on the average relative albumin weight (%)±the standard error in 6-18 week-old quail

Treatments	Relative albumin weight (%) 6-8	8-10	10-12	12-14	14-16	16-18	6-18
	(weeks)						
T1	59.96±2.78	50.52±3.08	51.84±2.73	53.72±3.20	61.21±1.63[a]	50.80±3.18[a]	54.68±1.30
T2	63.97±1.44	54.52±2.24	49.10±4.28	50.92±4.63	55.97±3.38[ab]	47.16±1.70[ab]	53.61±1.57
T3	59.82±0.40	51.78±3.68	54.30±2.67	49.63±4.14	49.36±3.10[bc]	40.36±2.07[b]	50.87±1.54
T4	61.99±0.97	56.15±3.01	56.08±1.67	57.89±2.69	45.80±2.85[c]	49.23±2.37[a]	54.52±1.34
T5	56.37±4.05	49.57±2.83	75.23±2.75	58.87±3.12	56.36±2.30[ab]	48.45±2.42[a]	54.48±1.33
	NS	NS	NS	NS	*	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

The 2nd treatment surpassed the other treatments during the 1st and 3rd periods of the experiment, whereas the 3rd treatment was superior to the other treatments during the 6th period of experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd, 4th and 5th periods of the experiment.

Table 12 shows significant differences in the relative albumin weight (p<0.05) between the treated groups. The 1st treatment surpassed the other treatments during the 5th and 6th periods of the experiment, whereas the 4th and 5th treatments were superior to the other treatments during the 6th period of the experiment. No significant differences

Table 13: Effects of alkaline and acidic ionized water on the average Haugh unit±the standard error in 6-18 week-old quail

	Haugh unit						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	89.33±1.62	93.78±1.02	92.40±1.19[ab]	88.06±1.30	90.13±1.28[ab]	89.65±1.29	90.56±0.60
T2	92.68±0.85	92.33±1.47	93.12±1.15[a]	88.83±2.21	88.61±1.37[b]	88.32±1.03	90.65±0.65
T3	89.92±1.10	92.19±0.61	92.04±0.92[abc]	90.86±2.44	92.90±1.36[a]	88.64±1.84	91.09±0.62
T4	90.90±0.86	93.23±1.53	88.39±1.08[c]	92.97±1.10	89.31±1.11[ab]	93.19±1.33	91.33±0.57
T5	90.73±0.93	91.60±1.76	89.22±1.52[bc]	92.27±1.40	92.32±0.82[ab]	91.21±2.35	91.23±0.61
	NS	NS	*	NS	*	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 14: Effects of alkaline and acidic ionized water on the average shell weight (g)±the standard error in 6-18 week-old quail

	Shell weight (g)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	0.42±0.04	0.80±0.07	0.86±0.04[ab]	0.82±0.05	0.80±0.04	0.70±0.05	0.73±0.03
T2	0.62±0.05	0.84±0.04	0.86±0.05[ab]	0.78±0.04	0.90±0.01	0.80±0.03	0.80±0.02
T3	0.60±0.10	0.70±0.03	0.96±0.02[a]	0.82±0.02	0.78±0.04	0.82±0.05	0.78±0.03
T4	0.58±0.05	0.78±0.06	0.88±0.04[ab]	0.82±0.04	0.82±0.05	0.80±0.03	0.78±0.02
T5	0.52±0.07	0.84±0.09	0.80±0.04[b]	0.88±0.04	0.88±0.04	0.80±0.04	0.79±0.03
	NS	NS	*	NS	NS	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 15: Effects of alkaline and acidic ionized water on the average shell thickness (mm)±the standard error in 6-18 week-old quail

	Shell thickness (mm)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	0.19±0.01[b]	0.22±0.01	0.28±0.04[b]	0.22±0.01[ab]	0.20±0.01	0.19±0.01[b]	0.21±0.01[b]
T2	0.22±0.01[ab]	0.23±0.01	0.35±0.02[a]	0.19±0.01[b]	0.24±0.03	0.26±0.04[a]	0.25±0.01[a]
T3	0.23±0.02[ab]	0.26±0.02	0.25±0.03[b]	0.21±0.01[ab]	0.19±0.01	0.18±0.01[b]	0.22±0.01[ab]
T4	0.26±0.03[a]	0.28±0.03	0.22±0.01[b]	0.23±0.02[ab]	0.20±0.01	0.17±0.01[b]	0.23±0.01[ab]
T5	0.24±0.02[ab]	0.24±0.03	0.22±0.01[b]	0.26±0.03[a]	0.22±0.02	0.21±0.01[ab]	0.23±0.01[ab]
	*	NS	*	*	NS	*	*

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

(p<0.05) were observed between the treated groups during the 1st, 2nd, 3rd and 4th periods of the experiment.

The results presented in Table 13 show significant differences in the Haugh unit (p<0.05) between the treated groups. The 2nd treatment surpassed the other treatments during the 3rd period of the experiment, whereas the 3rd treatment was superior to the other treatments during the 5th period of the experiment. No significant differences (p<0.05) were observed between the treated groups during the 1st, 2nd and 6th periods of the experiment.

Table 14 shows significant differences in shell weight (p<0.05) between the treated groups. The 3rd treatment surpassed the other treatments during the 3rd period of the experiment. No significant differences (p<0.05) were observed between the treated groups during other periods of the experiment.

The results presented in Table 15 show significant differences in the average shell thickness (p<0.05) between the treated groups during the 1st period of the experiment. The 4th treatment surpassed the other treatments during the 1st period of the experiment, whereas the 2nd treatment was superior to the other treatments during the 3rd and 6th periods and the 5th treatment was superior to the other treatments during the 4th period of the experiment. No significant differences (p<0.05) were observed between the treated groups during the 2nd and 5th periods of the experiment.

The results presented in Table 16 do not show significant differences in relative shell weight (p<0.05) between the treated groups.

Table 17 shows significant differences in the blood levels of proteins (p<0.05) between the treated groups during the

Table 16: Effects of alkaline and acidic ionized water on the average relative shell weight (%)±the standard error in 6-18 week-old quail

	Shell weight (%)						
	6-8	8-10	10-12	12-14	14-16	16-18	6-18
Treatments	(weeks)						
T1	3.90±0.35	7.99±0.96	8.03±0.38	7.50±0.37	7.43±0.37	7.70±0.90	7.09±0.35
T2	5.45±0.64	7.95±0.54	7.74±0.52	7.06±0.40	7.86±0.34	7.15±0.24	7.20±0.23
T3	5.03±0.18	6.65±0.33	8.48±0.23	7.21±0.31	7.38±0.12	7.86±0.49	7.10±0.26
T4	5.27±0.50	7.56±0.82	7.54±0.40	7.27±0.29	7.87±0.52	7.25±0.25	7.13±0.24
T5	4.85±0.72	7.19±0.57	7.58±0.41	7.87±0.36	7.93±0.32	7.56±0.35	7.16±0.26
	NS	NS	NS	NS	NS	NS	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 17: Effects of alkaline and acidic ionized water on the blood protein levels (mg/100 mL)±the standard error in 12-18 week-old quail

	12 weeks			18 weeks		
Treatments	Total protein	Albumin	Globulin	Total protein	Albumin	Globulin
T1	36.00±5.31^{b}	16.67±2.44^{b}	16.67±1.67^{c}	31.44±3.33	17.02±1.62^{b}	17.68±1.45^{b}
T2	38.43±3.88^{b}	23.57±0.8^{ab}	19.33±1.45^{bc}	31.75±2.02	19.05±0.93^{ab}	18.68±1.76^{b}
T3	52.03±4.00^{a}	28.87±2.80^{a}	28.67±1.45^{a}	38.08±2.34	22.87±1.51^{a}	25.00±2.31^{a}
T4	42.40±2.31^{b}	21.26±1.75^{b}	23.33±0.88^{b}	38.25±1.12	19.54±2.04^{ab}	20.68±2.85^{ab}
T5	39.20±3.48^{b}	23.50±2.28^{ab}	24.00±2.51^{a}	35.81±4.06	18.36±1.91^{ab}	19.33±0.88^{a}
	*	*	*	NS	*	*

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

Table 18: Effects of alkaline and acidic ionized water on the blood enzyme levels (mg/100 mL)±the standard error in 12-18 week-old quail

	12 weeks			18 weeks		
Treatments	GOT	GPT	ALP	GOT	GPT	ALP
T1	549.00±88.01^{a}	8.07±2.24	553.66±91.34^{a}	343.26±58.16^{a}	12.33±1.28^{a}	706.7±136.02
T2	405.00±56.31^{ab}	5.67±0.96	308.67±7.54^{b}	280.17±41.52^{ab}	8.67±1.41^{ab}	726.3±177.18
T3	299.00±11.53^{b}	5.60±0.51	268.67±28.96^{b}	220.28±18.10^{b}	7.24±1.19^{b}	605.7±92.410
T4	337.00±30.79^{b}	6.03±0.79	367.33±36.79^{b}	218.11±18.44^{b}	7.21±1.86^{b}	604.7±103.45
T5	366.67±33.59^{b}	7.80±2.04	343.67±44.75^{b}	266.60±37.71^{ab}	7.48±1.79^{b}	896.3±172.72
	*	NS	*	*	*	NS

*Different letters in the same column indicate significant differences between treatments at p<0.05. NS: No significant difference between treatments, T1: Control treatment, T2: Alkaline ionized water pH = 8, T3: Alkaline ionized water pH = 9, T4: Acidic ionized water pH = 6 and T5: Acidic ionized water pH = 5

1st period of the experiment. The 3rd treatment surpassed the other treatments regarding the total protein, albumin and globulin levels. During the 2nd period of the experiment, significant differences in the total protein levels were not observed between the treated groups, whereas significant differences in the albumin and globulin levels were observed between the treated groups and Third treatment was superior to the other treatments. The overall mean shows significant differences between the 3rd treatment and the other treatments.

The results presented in Table 18 show significant differences in the blood enzyme levels (p<0.05) between the treated groups during the 1st period of the experiment. The 1st treatment produced higher levels of GOT and ALP during the 1st period of the experiment than the other treatments, whereas no significant differences were observed in the GPT levels between the treated groups. Significant differences between the treated groups (p<0.05) were also observed during the 2nd period. The first produced higher GOT and GPT levels than the other treatments, whereas no significant differences were observed in the ALP levels between the treated groups.

DISCUSSION

The results of the study of the qualitative traits were consistent with the results reported by Ohno and Reminick[20] and EarthPulse Tech LLC[21] who observed an increase in the egg product quality when the magnetic technique was used to treat the water. According to the study by Olteanu *et al.*[22], the use of ionized water improved the productive traits. Magnetically treated water stimulates the thyroid to secrete thyroxin hormone[23] which in its turn increases feed consumption, the metabolism of fats and proteins, the absorption of sugars and subsequently and egg weight[24]. As magnetically treated water contains small particles, this type of water carries more nutrient elements, salts and vitamins, generating positive effects on metabolism and supporting amino acid and protein synthesis[25,26]. Magnetically treated water also increases egg production and the egg weight by increasing the yolk and albumin height as well as the yolk and albumen index, which increases the Haugh unit, a good scale used to measure egg quality[24,27]. These results were consistent with the results reported by Thaker *et al.*[19]. In the study conducted by Aziz *et al.*[28], the administration of magnetically treated water significantly increases the levels of blood parameters. In the study conducted by Veeramani *et al.*[29], the use of alkaline and acidic water resulted in significant differences in blood parameters between the alkaline water and acidic water treatments. High concentrations of total protein in blood serum are due to an increase in protein synthesis and a decrease in protein degradation[30]. Uric acid is the major product of degrading proteins[31]. As shown in the studies by Al-Darraji[32] and Al-Hassani[33], changes in the serum glucose, protein and uric acid levels are a direct reflection of the changes in the serum corticosteroid hormone levels. In the study conducted by Khan *et al.*[34], the use of drinking water with a low proportion of moderate acidity yielded a better improvement in product performance of broiler chicken. According to Daskiran *et al.*[35], the use of acidic water limits the economic losses in broiler chicken caused by heat stress. In the study conducted by Christian and Kai-Jens[36], acidic water has beneficial effects on the productive performance and reduces the mortality of broiler chickens, moreover, magnetically treated water promotes the cell proliferation and growth, increases ion solvation to allow it pass through cell membranes and increases the movement and flow of calcium ions in the blood[37]. In the study conducted by Kim *et al.*[12], the use of either alkaline or acidic electrolyzed water prevented the formation of and eliminated contaminants and *Escherichia coli* from broiler chickens. According to the Samudovska and Demeterova[38], the use of acidic water produced significant differences in the productive performance and affected the health status of the birds during the experimental period. The studies conducted by Davis and Rawls[39] and Lynch[40] suggested that magnetically treated water activates the enzymes by acting as a coenzyme to increase enzyme efficiency and activate the enzyme at specific locations. The decrease in the effectiveness of the GOT and GPT enzymes in blood serum under different conditions at the end experiment may be due to the higher total protein concentrations in the blood serum as Kaplan and Larsen[41] observed an inverse correlation between the total protein concentrations and activity of the GPT and GPT enzymes in blood serum. In contrast, the use of magnetically treated water may have reduced the body's requirement for protein-dependent energy synthesis and then reduced the activities of the GOT and GPT enzymes in serum. According to the study by Siegel[42], these two enzymes transfer the amine group from amino acids to ketone acids.

SIGNIFICANCE STATEMENT

The poultry industry is always searching for a new feed supplement to improve feed effectiveness and chicken health. Alkaline and acidic water reduce the growth of microorganisms in the feed and thus preserve the microbial balance in the gastrointestinal tract. By modifying the intestinal pH, organic acids also enhance the solubility of the feed ingredients as well as the digestion and absorption of the nutrients. One recent discovery is the possibility of using ionized water as a sanitizer. Alkaline ionized water is generated by electrically splitting filtered tap water into alkaline ionic water and acid water. Today, nursery farmers that supply cut flowers use acid water to store flowers longer before delivery to florists. Alkaline ionized would also immensely improve the quality of life for many people who suffer pain and inflammation. It is widely used for disinfection purposes in Japanese hospitals and dental clinics. A brief account of its uses in the agriculture and food industries has been provided. The heightened immunity produced by drinking alkaline ionized water will assist the body in combating disease. Alkaline ionized water will promote higher levels of energy as the body’s systems become more balanced. Japan is the largest manufacturer of the machines used to generate alkaline ionized water. The use of ionized water is an emerging technology with great possibilities for further research and development.

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