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Research Reports

Quality Improvement of Chicken Meat Treated with Neutral Electrolyzed Water

Peningkatan Kualitas Daging Ayam yang Diolah dengan Air Elektrolisis Netral

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ABSTRACT

Background: Chicken meat during processing may be exposed to bacterial contamination through several different ways. Electrolyzed water, as a new sanitizer, has gained popularity in food industry among many countries in recent years. The usage of electrolyzed water is a prospective, green conception and has several characteristics over conventional cleaning procedures which are safe for human beings and the environment. **Purpose:** This study was aimed to determine the sensory and bacteriological quality of chicken carcasses treated with different types of electrolyzed water. **Method:** Thirty-seven freshly slaughtered broiler chicken carcasses were completely immersed in clean container containing distilled water and electrolyzed water for 40 minutes, then sensory evaluated. For bacteriological analysis, chicken carcasses were divided into three groups, one for control, another group (Group I and II) and the chicken meat samples treated by immersion in neutral electrolyzed water for 20 and 40 minutes, respectively. **Results:** The mean value of colour scores of treated chicken carcasses was 4.9, 2.8, 4.5 and 3.7, for odour scores of treated chicken carcasses was 4.8, 2.6, 4.6 and 3.4, for general appearance scores of treated chicken carcasses was 4.9, 3.6, 4.6 and 3.9 for control, acidic, neutral and alkaline electrolyzed water, respectively. The bacteriological quality of treated chicken meat with neutral electrolyzed water was assessed. The mean values of aerobic plate counts for control, after treatment for 20 and 40 minutes were 5.40, 3.90 and 3.71 Log_{10} cfu/g, for enterobacteriacea were 3.63, 2.69 and 2.59 Log_{10} cfu/g, for *Staphylococcus aureus* were 2.99, 2.57 and 2.22 Log_{10} cfu/g, for *Escherichia coli* were 2.93, 2.18 and 1.94 Log_{10} cfu/g, respectively. **Conclusion:** The results indicated immersion of chicken carcasses for 20 minutes in neutral electrolyzed water improved their bacteriological quality without adverse effect on sensory quality.

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ABSTRAK

Latar Belakang: Daging ayam selama pemrosesan dapat terpapar kontaminasi bakteri melalui beberapa cara berbeda. Air elektrolisis, sebagai sanitasi baru, telah mendapatkan popularitas dalam industri makanan di antara banyak negara dalam beberapa tahun terakhir. Penggunaan air elektrolisis merupakan konsepsi hijau yang prospektif dan memiliki beberapa karakteristik dibandingkan prosedur pembersihan konvensional yang aman bagi manusia dan lingkungan. **Tujuan:** Penelitian ini bertujuan untuk menentukan kualitas sensorik dan bakteriologis karkas ayam yang diolah dengan berbagai jenis air elektrolisis. **Metode:** Tiga puluh tujuh karkas ayam broiler yang baru disembelih direndam seluruhnya dalam wadah bersih berisi air suling dan air elektrolisis selama 40 menit, kemudian dievaluasi secara sensorik. Untuk analisis bakteriologis, karkas ayam dibagi menjadi tiga kelompok, satu untuk kontrol, kelompok lain (Kelompok I dan II) dan sampel daging ayam yang diolah dengan perendaman dalam air elektrolisis netral masing-masing selama 20 dan 40 menit. **Hasil:** Nilai rata-rata skor warna karkas ayam yang diolah adalah 4,9, 2,8, 4,5 dan 3,7, untuk skor bau karkas ayam yang diolah adalah 4,8, 2,6, 4,6 dan 3,4, untuk skor penampilan umum karkas ayam yang diolah adalah 4,9, 3,6, 4,6 dan 3,9 untuk kontrol, air elektrolisis asam, netral dan basa, berturut-turut. Kualitas bakteriologis daging ayam yang diolah dengan air elektrolisis netral dinilai. Nilai rata-rata hitungan lempeng aerobik untuk kontrol, setelah perlakuan selama 20 dan 40 menit adalah 5,40, 3,90 dan 3,71 Log_{10} cfu/g, untuk Enterobacteriacea adalah 3,63, 2,69 dan 2,59 Log10 cfu/g, untuk *Staphylococcus aureus* adalah 2,99, 2,57 dan 2,22 Log_{10} cfu/g, untuk *Escherichia coli* adalah 2,93, 2,18 dan 1,94 Log_{10} cfu/g, berturut-turut. **Kesimpulan:** Hasil penelitian menunjukkan perendaman karkas ayam selama 20 menit dalam air elektrolisis netral meningkatkan kualitas bakteriologisnya tanpa efek buruk pada kualitas sensoris.

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Kata kunci: Air Elektrolisis; Daging Ayam; Evaluasi Bakteri; Evaluasi Sensoris

INTRODUCTION

Chicken meat is one of the most significant sources of animal protein. It is characterised by good nutritional value, protein rich with essential amino acids, low fat content and adequate vitamins content (Choi *et al.,* 2023). The chicken meat is exposed to contamination through and after slaughtering process, the bacteria from gut microbiota, the equipment used in slaughtering and the slaughterhouse environment contaminate carcasses. Some of these bacteria can proliferate and survive during chicken meat processing and storage (Rouger *et al.,* 2017).

Electrolyzed water (EW) is a safe, easily produced and cheap methods of disinfection. It is one of the most appropriate methods used to decrease the count of microorganisms on chicken carcasses (Wang *et al.,* 2018). Electrolyzed water has a potential as a good green cleaner and sanitizer. Electrolyzed water was classified according pH to acidic, neutral and alkaline. Acidic EW (AEW) and neutral EW (NEW) have been reported to have a strong bactericidal effect on various types of foodborne pathogens for many types of food products and food equipment surfaces, while alkaline EW (AlEW) is a powerful sanitation medium for alkaline wash (Khalid *et al.,* 2018). Electrolyzed water with neutral or near neutral pH can delay microbiological and chemical alterations, increase the chicken meat shelf life and improve the flavour, colour, texture and acceptability of chicken meat. Electrolyzed water has antimicrobial effects against a wide range of microorganisms including viruses, bacteria, spores and fungi on both animate and inanimate objects (Takeda *et al.,* 2020).

The decontamination process (bacterial cell death) of electrolyzed water can occur through destruction of bonds join between amino acids in the cell wall and cell membrane, increasing the cellular permeability leading to cell damage. AEW shows a potent antibacterial activity against wide range of Gram-positive, Gram-negative and several foodborne pathogenic bacteria as *Salmonella spp.* Electrolyzed water is a new broad-spectrum disinfectant can be used in several forms as in food processing practices (Yan *et al.,* 2021). Neutral EW is obtaining importance in the food processing practices particularly because of its effective antimicrobial activity, safe manufacturing, noncorrosiveness, environment-friendly characters and low cost (Aider *et al.,* 2012). Therefore, this study evaluated the effect of electrolyzed water (as a new chemical decontamination method) on the sensory and bacteriological quality of chicken meat treated with it.

MATERIAL and METHOD

Preparation and Application of Electrolyzed Water

Electrolyzed water was generated by electrolysis with Envirolyte ELA generator for water electrolysis (ELA-3000), Estonia, Europe. The electrolysis unit with power supply (380-415V, 3 phase) works at ambient temperature, located in Envirolyte Industries International Ltd, Cairo, Egypt. The Envirolyte Solutions produced were Acidic EW (pH 2-3.5, ORP/REDOX 1000 - 1200), Neutral EW (pH 6-8, ORP/REDOX 700 - 900) and Alkaline EW (pH 10-13, ORP/REDOX 900 -950). Four chicken carcasses were immersed in distilled water, AEW, NEW and AlEW, for sensory evaluation. Chicken carcasses (33 samples) were treated with NEW for 20 and 40 minutes for further bacteriological evaluation.

Sample

A total of 37 freshly slaughtered broiler chicken carcasses (weight about 2000 ±100 g) were randomly purchased from different local chicken shops at Port-Said Province, Egypt, just after slaughtering before chilling and transported without delay, kept in sterile polyethylene bags and preserved in ice-box, then immediately conveyed to Animal Health Research Institute, Port-Said, for sensory and bacteriological analysis.

Sensory Evaluation of Fresh Chicken Carcasses

The whole chicken carcass was immersed completely in a clean container containing electrolyzed water (either acidic or neutral or alkaline) for 40 minutes then evaluated. Four freshly slaughtered broiler chicken carcasses, were used, one control and the others treated with (AEW, NEW and AlEW). Six members of trained panellists were used to evaluate sensory characteristics (colour, odour and general appearance), then expressed through 5-point hedonic scales, 1. very poor; 2. poor; 3. common; 4. good and 5. very good (Szczesniak, 1987).

Bacteriological Evaluation of the Samples

Fresh chicken carcasses were divided into three groups (control, group I and group II), the three groups were immersed into distilled water, NEW for 20 min and NEW for 40 min, respectively, then examined for determination of Aerobic Plate count by pour plating technique using standard Plate Count Agar (ISO, 4833-1:2013/AMD 1:2022). Enterobacteriaceae counts were determined by pour plate method using Violet Red Bile Glucose Agar (ISO, 21528-2:2017). Determination of *Staphylococcus aureus* count was carried out using dried Baird Parker Media with Egg Yolk-Tellurite Emulsion (ISO, 6888-1:2021/Amd1:2023). *Escherichia coli* count was determined using Tryptone Bile-X-Glucuronate Agar (ISO, 16649-2: 2001). Detection of *Salmonella spp* was carried out using Xylose Lysine Desoxycholate (XLD) agar and Hektoen enteric (HE) agar (ISO, 6579-1:2017/Amd1: 2020).

Statistical Analysis

The data were analysed using GraphPad Prism 2008. Parameters were given as maximum, minimum, mean, and standard error. The differences in parameters between samples were investigated using a one-way-ANOVA test.

RESULTS

Sensory Evaluation

This study revealed the effect of treatment of chicken carcasses with different types of EW (AEW, NEW and AlEW) on sensory attributes (colour, odour and general appearance and texture).

Table 1. Statistical Analytical Results for The Effect of EWs on the Sensory Quality of Chicken Carcass.

	Colour				Odour				General Appearance and Texture			
	Control	AEW	NEW	AlEW	Control	AEW	NEW	AlEW	Control	AEW	NEW	AlEW
Min.	4	2	4	3	4	1	4	2	4	2	4	3
Max.	5	4	5	5	5	4	5	4	5	5	5	5
Mean	4.9^{b}	2.8^{a}	4.5^{b}	3.7^{c}	4.8^{b}	2.6^{a}	4.6^{b}	3.4^{c}	4.9^{b}	3.6^{a}	4.6^{b}	3.9^{ab}
±SE	±0.10	± 0.25	± 0.17	± 0.21	±0.13	±0.27	±0.16	±0.22	±0.10	±0.27	±0.16	±0.23

Note: AEW= Acidic Electrolyzed water, NEW= Neutral Electrolyzed water, AlEW= Alkaline Electrolyzed water. Mean values in the same raw with different letters are significantly different (p>0.05). Appearance and texture scale from 1 to 5 (1=very poor and 5= very good).

Table 2. Statistical Analytical Results of The Effect of NEW on Bacteriological Quality of Tested Chicken Meat Samples.

	Aerobic Plate Count (APC) (Log_{10} cfu/g)			Enterobacteriaceae (Log_{10} cfu/g)			*Staphilococcus aureus* (Log_{10} cfu/g)			*Escherichia coli* (Log_{10} cfu/g)		
	Control	Group I	Group II	Control	Group I	Group II	Control	Group I	Group II	Control	Group I	Group II
Min.	3.95	3.00	2.65	3.28	2.38	2.08	2.72	2.30	2.00	2.80	1.72	1.54
Max.	5.89	4.56	4.38	3.86	2.92	2.88	3.08	2.74	2.40	3.15	2.88	2.60
Mean	5.40^{a}	3.90^{b}	3.71^{b}	3.63^{a}	2.69^{b}	2.59^{b}	2.99^{a}	2.57^{b}	2.22^{c}	2.93^{a}	2.18^{b}	1.94^{b}
±S.E.	±4.91	±3.46	±3.29	±2.79	±1.77	±1.81	+1.75	±1.51	±1.17	±1.79	±1.78	±1.50

Note: AEW= Acidic Electrolyzed water, NEW= Neutral Electrolyzed water, AlEW= Alkaline Electrolyzed water. Mean values in the same raw with different letters are significantly different (p>0.05). Group I = treatment samples for 20 min., Group II = treatment samples for 40 min.

The colour scores of chicken carcasses for control ranged from 4 to 5 with a mean value 4.9±0.10, for carcasses treated with AEW ranged from 2 to 4 with a mean value of 2.8±0.25, for carcasses treated with neutral electrolyzed water (NEW) ranged from 4 to 5 with a mean value of 4.5±0.17, while for carcasses treated with alkaline electrolyzed waterAEW ranged from 3 to 5 with mean a value of 3.7±0.21; there were no significant differences (p>0.05) between control group and carcass treated with NEW (Table 1).

The odours score for control ranged from 4 to 5 with a mean value 4.8±0.13 treated carcasses with AEW ranged from 1 to 4 with a mean value of 2.6±0.27; the treatment with NEW recorded odour scores ranged from 4 to 5 with a mean value of 4.6±0.16, while the treatment with AlEW recorded odour scores ranged from 2 to 4 with a mean value of 3.4±0.22, there were no significant differences (p>0.05) between control group and carcass treated with NEW (Table 1).

The general appearance and texture scores for control ranged from 4 to 5 with a mean value 4.9±0.10, for carcasses treated with AEW ranged from 2 to 5 with a mean value of 3.6±0.27; for chicken carcasses treated with NEW ranged from 4 to 5 with a mean value of 4.6+0.16, while texture scores for chicken carcasses treated with AlEW ranged from 3 to 5 with a mean value of 3.9±0.23, there were no significant differences (p>0.05) between control group and carcasses treated with NEW and AlEW (Table 1). The best treatment for chicken carcasses which didn't affect the sensory quality was NEW treatment.

Aerobic Plate Count (APC)

Neutral electrolyzed water is considered as a novel broad-spectrum bactericidal agent that has gained a great popularity over the last few years. Aerobic plate counts were used as indicator for the hygienic measures applied during slaughtering and processing of chicken. The effect of NEW on APC (Log_{10} cfu/g), shown in Table 2, on tested chicken meat samples for control were ranged from 3.95 to 5.89 with mean value 5.40±4.91, while after treatment with NEW for 20 min the APC was ranged from 3.00 to 4.56 with mean value 3.90± 3.46; meanwhile APC after treatment with NEW for 40 min was ranged from 2.65 to 4.38 with mean value 3.71±3.29. There was a significant difference (p>0.05) in means of the control and group I and II, while there was no significant difference between group I and II, as revealed in Table 2.

Enterobacteriaceae Counts in Chicken Meat

The higher enterobacteriaceae counts in the chicken carcasses traded at the live bird shops might result from contamination with intestinal content and faecal matter during slaughtering operations, evisceration and unhygienic measures applied during conversion of live bird into carcasses and products. The effect of NEW on enterobacteriaceae counts (Log_{10} cfu/g) in tested chicken meat samples given in Table 2 showed that the count for the control group was ranged from 3.28 to 3.86 with mean value 3.63±2.79, while after treatment with NEW for 20 min were ranged from 2.38 to 2.92 with mean value 2.69 ±1.77; meanwhile after treatment with NEW for 40 min were ranged from 2.08 to 2.88 with mean value 2.59±1.81. There was a significant difference (p>0.05) in means of the control and the other groups I and II, while there was no significant difference between group I and II.

Staphylococcus aureus Counts in Chicken Meat

The results showing the effect of NEW on *S. aureus* count (Log_{10} cfu/g) in tested chicken meat samples was given in (Table 2), where the count for the control was ranged from 2.72 to 3.08 with mean value 3.99±1.75, while after treatment with NEW for 20 min the count ranged from 2.30 to 2.74 with mean value 2.57±1.51; meanwhile after treatment with NEW for 40 min the count was ranged from 2 to 2.40 with mean value 2.22±1.17. There was a significant difference (p>0.05) between the mean values of the three groups (control, group I and group II).

Escherichia coli Counts in Chicken Meat

Escherichia coli growth and proliferation can be enhanced due to unhygienic procedures during slaughtering and transportation, and cross-contamination with faecal matter and intestinal contents. The effect of NEW on *E. coli* count in tested chicken meat samples, for control ranged from 2.80 to 3.15 with a mean value of 2.93±1.79 Log_{10} cfu/g, while after treatment with NEW for 20 min the count ranged from 1.72 to 2.88 with a mean value of 2.18±1.78 Log_{10} cfu/g; meanwhile after treatment with NEW for 40 min the count was ranged from was 1.54 to 2.60 with a mean value of 1.94±1.50 Log_{10} cfu/g. There was a significant difference ($p>0.05$) in means of the control and the other groups I and II, while there was no significant difference between group I and II as explained in Table 2. Immersion of chicken meat in NEW treatment diminished the count of *E. coli* by 1.2 and 0.98 Log_{10} cfu/g as recorded by Hernández-Pimentel *et al.,* (2020) and Rosario-Pérez *et al.,* (2023), respectively, which agree with our results.

Detection of *Salmonella spp.* in Chicken Meat

In this study, *Salmonella spp.* was not detected in the examined chicken meat samples by traditional methods. Foodborne illnesses caused by Salmonella species represent a major public health problem worldwide (Sousa, 2008). The application of NEW on fresh chicken carcasses decreased the count of *Salmonella enteritidis* by 3.3 Log_{10} cfu/g (Shimamura *et al.,* 2016).

CONCLUSION

Application of NEW on chicken meat by immersion for 20 minutes improves the bacteriological quality (markedly diminishing the Aerobic Plate Count (APC) and foodborne pathogens as *S. aureus* and *E. coli*) without adversely affecting sensory quality (colour, odour and texture). The antibacterial effect of NEW emphasises their importance for the future of chicken meat technology and consumers' health. It can be used as natural sanitizer for chicken carcasses, detergent at poultry slaughtering house and natural preservative for chicken meat.

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CONFLICT of INTEREST

The authors declare that there are no conflicts of interest with any of the parties involved in this study.

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ETHICAL APPROVAL

This research activity has approval from The Faculty of Veterinary Medicine, Suez Canal University, Egypt (ethics approval number; 49/11/)

AUTHORS' CONTRIBUTIONS

Conception and design of the study: AMA, TAH. Acquisition of data: MMME, NIHA. Analysis and/or interpretation of data: IMF, HMS. Drafting the manuscript: MMME.
Critical review/revision: AMA

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