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Assessment of the Efficiency of Electrochemical Activated Water in Combination of UV in Decontamination of Chicken Meat

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ABSTRACT

A total of 100 random samples of chilled chicken breast and thigh meat cuts (50 of each) that were collected from different retailers and supermarkets in Benha City, Qalubiya Governorate to investigate the prevalence of biofilm forming *E. coli* and *Salmonella* spp. Moreover, an experimental trial for controlling *E. coli* and *S. Typhi* in chicken fillet by application of slightly acidic (AEW) (pH: 5-6.5), and slightly alkaline (AlEW) (pH: 8-10) electrolyzed water of different available chlorine concentration (ACC: 10-30 and 50-60 mg L^{-1}) for different times of exposure (30, 60 and 120 seconds) in combination with ultraviolet rays (UV) were conducted. Results revealed that different serotypes of *E. coli* and *Salmonella enterica* were detected in 24% and 14.0% out of the total examined samples, where thigh samples revealed higher prevalence than breast samples. Out of the detected isolates, biofilm-forming *E. coli* O_{114}:$H_{21,}$ O_{125}:H_{21} and *S. Enteritidis* were detected in the same ratio (2.0%) of the examined breast samples; while, biofilm-forming *E. coli* O_{114}:$H_{21,}$ O_{111}:$H_{2,}$ O_{125}:$H_{21,}$ and *S. Enteritidis* were detected in the prevalence of 4.0, 4.0, 2.0 and 6.0% in the examined thigh samples, respectively. On the other hand, *E. coli* O_{146}:H_{21}, *S. Typhimurium* and *S. Kentucky* isolates revealed no biofilm formation. Application of combined EW with UV treatments on *E. coli* and *S. Typhi* revealed significant reductions in the bacterial counts; where higher ACC revealed higher antibacterial effects that showed total reduction of *E. coli* and *S. Typhi* in the experimentally contaminated samples after 24h of refrigerated storage, for AEW of ACC = 50-60 mg L^{-1}; also, it enhanced the physicochemical parameters of the treated chicken fillet in comparison with the control group; where application of AEW revealed more potent antibacterial effect than AlEW. It is worth noted that the bacterial reductions were directly correlated to the time of exposure and chlorine concentration. In the same line, the treated samples with slightly AEW for 120 seconds and UV combination had the higher bacterial reduction %; where *E. coli* and *Salmonella* counts reduced to be compatible with the Egyptian legislations. Therefore, it

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can be concluded that EW and UV treatments revealed a promising preservative effect in keeping wholesome of chicken fillet during refrigeration storage, that encourage its application as an innovative technique for enhancing the keeping quality and safety of chicken meat.

INTRODUCTION

Chicken meat is essential for its economic and nutritional reasons worldwide. With all nine necessary amino acids and a low saturated fat content, it is a great source of high-quality protein and a good fit for a variety of diets **(Wong et al. 2017)**. Chicken flesh is a good source of vital minerals including phosphorus, selenium, and B vitamins, which help the immune system function, bone health, and energy generation. In addition, its adaptability in the kitchen improves its palatability because various preparation techniques may greatly boost flavor and fragrance **(Mir et al. 2017)**. According to **Wong et al. (2017)**, chicken is among the most reasonably priced meats in the market, making it available to a broad spectrum of customers. This is particularly true in developing nations where it helps ensure food security and generates revenue through local production.

Unfortunately, poultry meats, including chicken meat, are known to be a common vehicle of some foodborne entero-pathogens such as *E. coli* and *Salmonella*e that considered the most important cause of food poisoning outbreaks worldwide **(Noori and Alwan 2016)**.

There have been reports of extra-intestinal pathogenicity in *E. coli* originating from poultry meat. According to certain studies, these extra-intestinal pathogenic avian *E. coli* (ExPEC) strains may be clones of human entero-pathogenic strains, which can infect humans by contaminating their food and causing a number of serious illnesses **(Govindarajan et al. 2024)**. On the same line, salmonellosis is one of the major foodborne infections caused by *Salmonella enterica* contamination of chicken meat, which presents serious health risks. The digestive systems of animals, notably chickens, are frequently inhabited by this pathogen. People can be infected by eating undercooked contaminated chicken products **(Wessels et al. 2021)**.

Additionally, the ability of these foodborne pathogens to form biofilms presents significant food safety hazards. Biofilms provide a protective matrix that shields bacteria from environmental stresses and antimicrobial agents, making them more resilient and difficult to eliminate from food processing surfaces. This increased resistance can also lead to post-processing contamination, ultimately resulting in foodborne illnesses and posing major public health risks **(Liu et al. 2023)**. The economic implications are also considerable, as outbreaks linked to biofilm-forming pathogens can lead to substantial food waste, loss of consumer trust, and costly recalls **(Azari et al. 2024).**

Therefore, many studies were conducted to eliminate and control foodborne bacterial hazards by either traditional preservation way such as using of correct concentrations meat additives of antimicrobial properties, or applying innovative strategies especially of low residual potentiality and environmentally safe, such as electrolyzed water and ultra violet radiation **(Hamed et al. 2024)**.

The combination of ultraviolet (UV) light and electrolyzed water (EW) is a novel way to extend the shelf life of chicken meat products. By combining the antibacterial sanitizing power of EW with the disinfection power of UV light, food safety and quality are greatly improved **(Sheng et al. 2020)**.

Sodium chloride-derived electrolyzed water, even of acidic (AEW) or alkaline (ALEW) pH, has demonstrated significant antibacterial effects, making it a valuable tool in food safety **(Adal et al. 2024)**. Hypochlorous acid and other reactive species produced during the electrolysis process characterize the antibacte-

rial qualities by efficiently disrupting the cellular process, cell membrane damage and denaturation of DNA preventing their development. Studies have shown that EW can significantly reduce microbial loads on food contact surfaces, exhibiting higher efficacy against pathogens like *E. coli* and *Salmonella* **(Naka et al. 2020, Tomasello et al. 2021 and Hamed et al. 2024**).

The synergistic effect of EW and UV light not only extends the shelf life of chicken meat but also maintains its sensory qualities. By lowering lipid oxidation and protein degradation, **Zhong et al. (2024)** shown that this combination may decrease oxidative damage, a frequent problem in meat preservation. This treatment guarantees that chicken flesh will continue to be enticing to customers while extending its freshness. Additionally, this approach provides a chemical-free substitute for conventional preservation methods while adhering to contemporary food safety regulations.

According to data collected by **Lan et al. (2021)**, UV radiation in particular can lower bacterial loads on meat surfaces, increasing the preservation method's overall efficacy when paired with EW.

Therefore, the current study was planned to investigate the prevalence of some foodborne bacteria, particularly that able to produce biofilm. Furthermore, the antibacterial and keeping quality effects of slightly acidic EW (AEW) (pH: 5-6.5), and slightly alkaline EW (AlEW) (pH: 8-10) with UV light application on *E. coli* and *S. Typhi* contaminated chicken fillet was investigated during refrigeration storage.

MATERIAL AND METHODS

Collection of samples

A total of 100 samples of chicken cuts, represented by chicken breast and thighs "50 samples of each", were collected from different retailers in Benha City, Qalubiya Governorate. Samples were transported hygienically to the lab for the following examinations:

Detection, isolation and identification of *E. coli* in the examined samples

It was performed according to **ISO 16649-2 (2001)** included enrichment and plating steps on MacConkey broth and Tryptone Bile X-glucoronide agar (TBX agar) were seen as dark blue green round colonies. Isolates were confirmed biochemically, and serotyped according to **Kok et al. (1996)** by using rapid diagnostic *E. coli* antisera sets (DENKA SEIKEN Co., Japan) for diagnosis of the enteropathogenic types.

Detection, isolation and identification of *Salmonella enterica* in the examined samples according to ISO 6579 (2017)

Prepared sample was incubated in buffered peptone water broth at 37°C ± 1°C for 18 ± 2 hours, then transferred to Rappaport Vassilidis broth (RV broth) and incubated at 41.5°C / 24 hr. Loopful of enriched sample was streaked on selective XLD agar and Brilliant Green agar, and incubated at 37°C\24h, plates were examined for suspected *Salmonella* colonies which then isolated for confirmation biochemically. Furthermore, serotyping was performed according to Kauffman – White scheme **(Kauffman 1974)** for the determination of Somatic (O) and flagellar (H) antigens using *Salmonella* antiserum (DENKA SEIKEN Co., Japan).

Determination the ability of biofilm formation in the detected isolates according to Mathur et al. (2006)

The obtained bacterial strains were enriched on brain heart broth for 24h at 37°C, followed by carefully inoculation into Congo red agar plates (CRA) then incubated for 24-48 hours at 37°C. Isolates were recorded as +ve when black colonies with a dry crystalline consistency appeared.

Experimental part

Preparation of EW (Athayde et al. 2018)

Electrolyzed water was obtained from Food Hygiene Dept., Animal Health Research Institute. It was prepared in a diaphragmless electrolyzer and has slightly acidic and alkaline pH (5.5±0.5 and 10±0.5, respectively), a

relatively low *ORP* (800–900 mV) and a relatively low *ACC* (10–30 mg L^{-1}), and high *ACC* (50-60 mg L^{-1}).

Preparation of bacterial strain

Previously purified field strain of *E. coli* and *Salmonella Typhi* were prepared by applying serial dilution, followed by plating on nutrient agar for counting of the original culture, from which, certain working culture count was adjusted by serial dilution technique on a sterile normal saline (0.9% NaCl) up to nearly 4 log_{10} CFU/ml.

Collection and preparation of chicken fillet samples

Thirty-six pieces of chicken fillet, each weighted about 100g, were collected and subjected to UV irradiation (wave length 385 nm) for 30 min as a controlled way to diminish the background microflora before inoculation of the test strains **(Morsy et al. 2018).** Post-irradiation, chicken meat samples were examined bacteriologically for confirming absence of *E. coli* and *Salmonella* species using a standard method.

Experimentally inoculated chicken fillet samples with *E. coli* were then grouped into eight groups represented by:
G1: Chicken fillet + log 4 CFU/g *E. coli* without any treatment (control positive).
G2: Chicken fillet + log 4 CFU/g *E. coli* treated with slightly AEW for 30 seconds followed by exposure to UV light for 15 minutes.
G3: Chicken fillet + log 4 CFU/g *E. coli* treated with AEW for 60 seconds followed by exposure to UV light for 15 minutes.
G4: Chicken fillet + log 4 CFU/g *E. coli* treated with AEW for 120 seconds followed by exposure to UV light for 15 minutes.
G5: Chicken fillet + log 4 CFU/g *E. coli* treated with AlEW for 30 seconds followed by exposure to UV light for 15 minutes.
G6: Chicken fillet + log 4 CFU/g *E. coli* treated with AlEW for 60 seconds followed by exposure to UV light for 15 minutes.
G7: Chicken fillet + log 4 CFU/g *E. coli* treated with AlEW for 120 seconds followed by exposure to UV light for 15 minutes.
G8: Chicken fillet soaked in sterile Dist. Water and subjected to UV for 15 minutes (Control – ve).

On the other hand, experimentally inoculated chicken fillet samples with nearly 3 logs *S. Typhi* were then grouped into eight groups as mentioned in *E. coli* grouping.

The same design was applied for *E. coli* and *S. Typhi* experimentally inoculated chicken fillet samples, either treated with EW of ACC = 10-30 mg L^{-1} or 50-60 mg L^{-1}.

Following the noted legislation in **EOS No. 1651 (2019),** samples were examined for zero day of the experiment (immediately after the end of UV light exposure), wrapped, and examined each day for 6 days of storage. Samples were kept in the refrigerator along the experimental period. After preparation of tenth fold serial dilutions according to **ISO 6887-2 (2017)** bacteriologically for *E. coli* and *S. Typhi* counts, according to **ISO 16649-2 (2001)** and **ISO 6579 (2017)**, respectively**.** In addition, drip loss, pH, total volatile nitrogen (TVN) and thiobarbituric acid (TBA) were measured according to the procedure of **Kaić et al. (2021), EOS 63-11 (2006), EOS 63-9 (2006) and EOS 63-10 (2006)**, respectively**.**

Statistical analyses were performed by application of Analysis of Variance (ANOVA) test between more than three groups, and independent samples T test was applied within two groups of treatment using SPSS software v.20**.**

Reduction (%) = $\left(\frac{(R1-R2)}{R1}\right) x\ 100$, where R1 and R2 indicate microbial count of control and treated samples, respectively.

RESULTS

Referring to the recorded results in **Table (1)**, *E. coli* was detected in overall 24% out of the total examined samples, where thigh samples revealed higher prevalence than breast samples. Moreover, *E. coli* isolates were serotype into *E. coli* O_{114}:$H_{21,}$ O_{111}:$H_{2,}$ O_{125}:H_{21} and O_{146}:$H_{21,}$ where *E. coli* O_{114}:H_{21} was the most prevalent strain in breast samples, while O_{111}:H_2 was the most prevalent in the examined thigh samples.

Table 1. Incidence and serotyping of *E. coli* isolated from chicken breast and thigh samples (n=50 of each).

Samples	Positive samples		Samples *E. coli* serotype	Thigh (n=18)		Breast (n=6)		Strain characteristic
	No.	%*		No.	%	No.	%[2]	
Breast (n=50)	6	12.0	O_{114}: H_{21}	5	10.0	4	8.0	EPEC
			O_{111}:H_2	6	12.0	0	0.0	EHEC
Thigh (n=50)	18	36.0	O_{125} :H_{21}	5	10.0	2	4.0	ETEC
			O_{146}:H_{21}	2	4.0	0	0.0	EPEC
Total	24	24**	Total	18	36.0	6	12.0	-

* Incidence was calculated in relation to the number of each product (50)
** Incidence was calculated in relation to the total number of examined samples (100)
EPEC: Enteropathogenic *E. coli*
ETEC: Enterotoxigenic *E. coli*
EHEC= Enterohaemorrhagic *E. coli*

In addition, **Table (2)** showed that *Salmonella* spp. was detected in 14.0% out of the total examined samples, where thigh samples revealed higher prevalence (20.0%) than breast samples (8.0%). Moreover, *Salmonella* spp. isolates were serotype into *S. Typhimurium, S. Enteritidis, S. Kentucky*; where, *S. Enteritidis* was the most prevalent strain

Table 2. Prevalence and serotyping of Salmonellae in examined chicken breast and thigh (n=50 of each).

Products	+ve Samples		*Salmonella* serotyping		
	No.	%*		No.	%*
Thigh	10	20.0	*S. Typhimurium*	3	6.0
			S. Enteritidis	5	10.0
			S. kentucky	2	4.0
Breast	4	8.0	*S. kentucky*	1	2.0
			S. Enteritidis	3	6.0
Total (100)	14	14.0**		14	14.0**

* Percentage in relation to total number of each sample (50).
** Percentage in relation to total number of samples (100).

Out of the detected isolates, biofilm-forming *E. coli* O_{114}:H_{21}, O_{125}:H_{21} and *S. Enteritidis* were detected in 2.0% of the examined breast samples; while, biofilm-forming *E. coli* O_{114}:H_{21}, O_{111}:H_2, O_{125}:H_{21}, and *S. Enteritidis* were detected in the prevalence of 4.0, 4.0, 2.0 and 6.0% in the examined thigh samples, respectively. On the other hand, *E. coli* O_{146}:H_{21}, *S. Typhi*murium and *S.* Kentucky isolates revealed no biofilm formation.

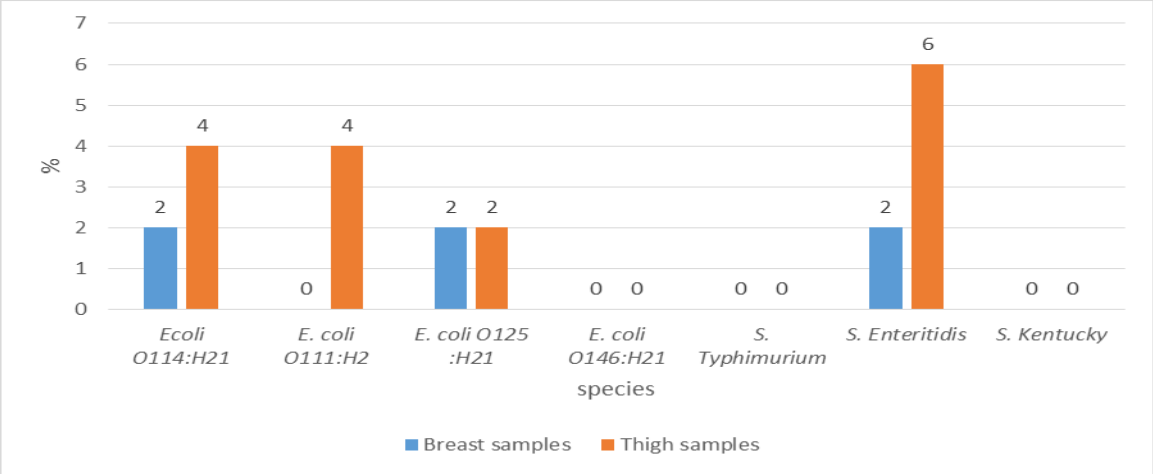

Fig. (1). Prevalence of biofilm-positive isolates
NB. The Incidence was calculated in relation to the number of each examined chicken breast and thigh samples (n=50 of each)

Regarding the antibacterial effect of different combined EW (10-30 mg L^{-1}) with UV treatments on *E. coli* and *S. Typhi*, **Tables (3 and 4) and Figs. (2 and 3)** on the 6th day of storage revealed significant reductions in the bacterial counts; where application of slightly AEW revealed more potent antibacterial effect than slightly AlEW. It is worth noted that the bacterial reductions were directly correlated to the time of exposure. In the same line, the treated samples with slightly AEW for 120 sec and UV combination (G4) had the higher bacterial reduction of *E. coli* and complete reduction of *S. Typhi* (since the 4th day of storage).

Table 3. Mean counts of *E. coli* (log_{10} CFU/g ± SE) in the examined groups during storage at 4±1°C

Day	G1	G2	G3	G4	G5	G6	G7	G8
Zero day	4.60 ± 0.1^{Aa}	4.0 ± 0.1^{Ac}	3.7 ± 0.1^{Ad}	3.5 ± 0.1^{Ae}	4.2 ± 0.1^{Ab}	4.0 ± 0.1^{Ac}	3.8 ± 0.1^{Ad}	ND
2nd day	4.65 ± 0.1^{Aa}	3.8 ± 0.1^{Bc}	3.5 ± 0.1^{Bd}	3.1 ± 0.1^{Be}	4.0 ± 0.2^{Bb}	3.5 ± 0.1^{Bd}	3.2 ± 0.1^{Be}	ND
3rd day	4.72 ± 0.1^{Aa}	3.5 ± 0.1^{Cc}	3.2 ± 0.2^{Cd}	2.5 ± 0.1^{Cf}	3.7 ± 0.1^{Cb}	3.2 ± 0.1^{Cd}	2.8 ± 0.2^{Ce}	ND
4th day	4.80 ± 0.1^{Aa}	3.3 ± 0.2^{Dc}	2.7 ± 0.2^{De}	2.2 ± 0.1^{Dg}	3.5 ± 0.2^{Db}	3.0 ± 0.1^{Dd}	2.5 ± 0.1^{Df}	ND
5th day	5.00 ± 0.1^{Aa}	3.0 ± 0.1^{Ec}	2.5 ± 0.1^{Ee}	1.6 ± 0.1^{Eg}	3.2 ± 0.1^{Eb}	2.8 ± 0.2^{Ed}	2.1 ± 0.1^{Ef}	ND
6th day	5.10 ± 0.1^{Aa}	2.7 ± 0.1^{Fc}	2.2 ± 0.1^{Fd}	1.2 ± 0.1^{Ff}	3.0 ± 0.2^{Fb}	2.5 ± 0.2^{Fc}	1.7 ± 0.1^{Fe}	ND

Results were presented as mean ± SE of triple trials
^{abcd} different superscript letters within the same row means statistical significant difference when ($P \leq 0.05$).
^{ABCD} different superscript letters within the same column means statistical significant difference when ($P \leq 0.05$).

Table 4. Mean counts of *S. Typhi* (log_{10} CFU/g ± SE) in the examined groups during storage at 4±1°C

Day	G1	G2	G3	G4	G5	G6	G7	G8
Zero day	3.5 ± 0.1^{Da}	3.0 ± 0.1^{Ac}	2.5 ± 0.1^{Ae}	2.3 ± 0.1^{Af}	3.2 ± 0.1^{Ab}	2.7 ± 0.1^{Ad}	2.5 ± 0.1^{Ae}	ND
2nd day	3.53 ± 0.1^{Da}	2.6 ± 0.1^{Bc}	2.1 ± 0.1^{Be}	1.7 ± 0.1^{Bf}	3.0 ± 0.1^{Bb}	2.5 ± 0.1^{Bd}	2.2 ± 0.1^{Be}	ND
3rd day	3.60 ± 0.1^{Ca}	2.3 ± 0.1^{Cc}	1.8 ± 0.1^{Ce}	1.2 ± 0.1^{Cf}	2.6 ± 0.1^{Cb}	2.3 ± 0.1^{Cc}	2.0 ± 0.1^{Cd}	ND
4th day	3.65 ± 0.2^{Ca}	1.9 ± 0.1^{Dc}	1.5 ± 0.1^{Dd}	<1	2.2 ± 0.1^{Db}	2.0 ± 0.1^{Dc}	1.9 ± 0.1^{Cc}	ND
5th day	3.71 ± 0.1^{Ba}	1.5 ± 0.1^{Ed}	1.3 ± 0.1^{Ee}	<1	2.5 ± 0.1^{Eb}	1.8 ± 0.1^{Ec}	1.8 ± 0.1^{CDc}	ND
6th day	3.9 ± 0.1^{Aa}	1.3 ± 0.1^{Fe}	1.1 ± 0.1^{Ff}	<1	2.7 ± 0.2^{Cb}	1.9 ± 0.2^{DEc}	1.7 ± 0.1^{Dd}	ND

Results were presented as mean±SE of triple trials
^{abcd} different superscript letters within the same row means statistical significant difference when ($P \leq 0.05$).

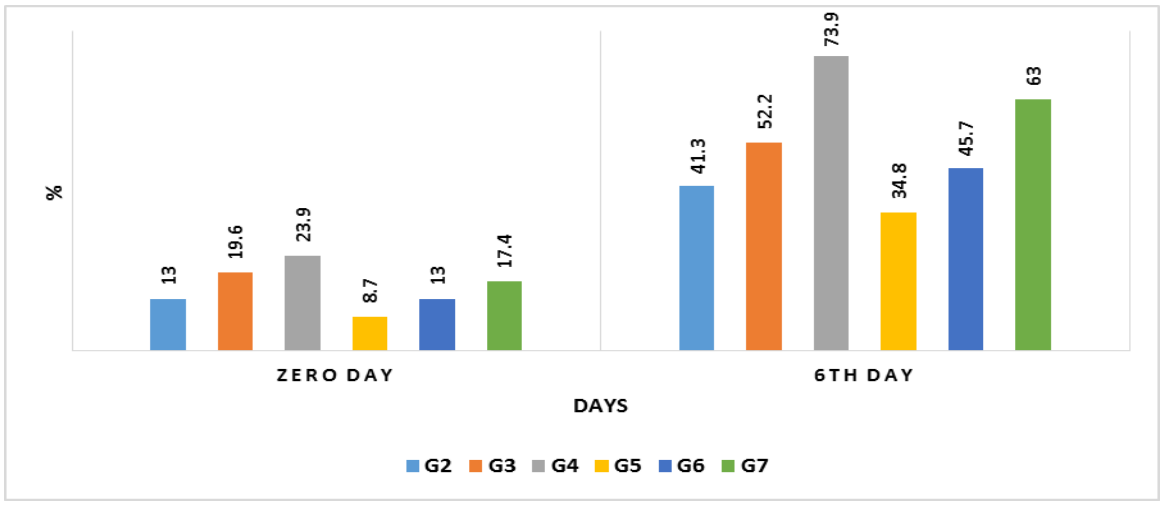

Fig. (2). Reduction (%) in *E. coli* mean counts during the experimental period

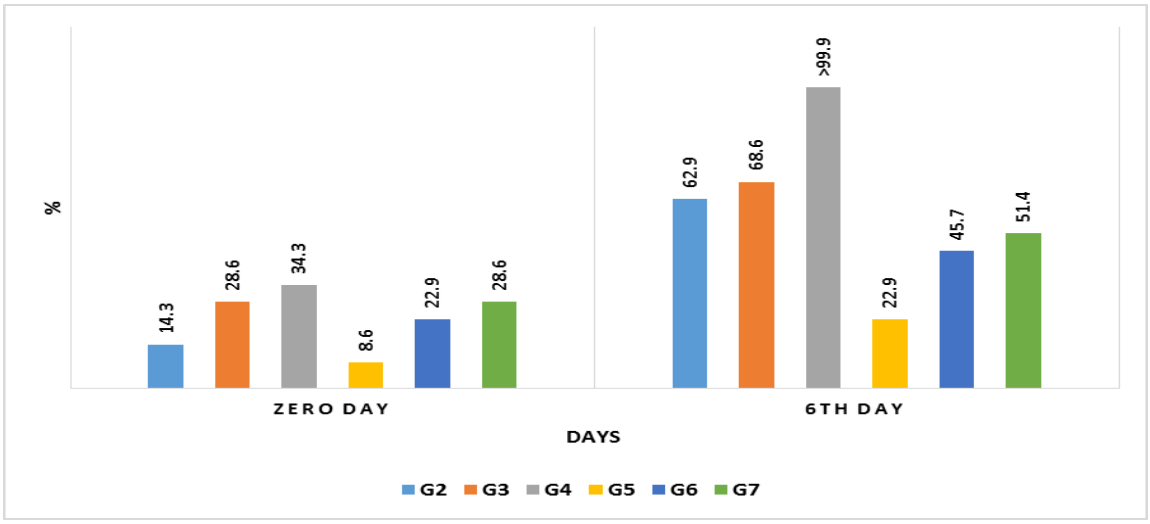

Fig. (3). Reduction (%) in *S. Typhi* mean counts during the experimental period

Regarding the antibacterial effect of different combined EW (50-60 mg L^{-1}) with UV treatments on *E. coli* and *S. Typhi*, **Tables (5 and 6),** revealed higher reductions in relation to the higher chlorine concentration. Results revealed total reduction of *E. coli* and *Salmonella Typhi* after 24h of storage in all of the treated groups. Slightly AEW revealed more antibacterial effect against the examined bacteria than slightly AlEW, which appeared as higher reduction in the bacterial count at zero time of the experiment.

Table 5. Mean counts of *E. coli* (log_{10} CFU/g ± SE) in the examined groups during storage at 4±1°C

Day	G1	G2	G3	G4	G5	G6	G7	G8
Zero day	4.60 ± 0.1^{a}	3.2 ± 0.1^{c}	2.1 ± 0.1^{f}	1.5 ± 0.1^{e}	3.5 ± 0.1^{b}	3.0 ± 0.1^{d}	2.5 ± 0.1^{e}	ND
2nd day	<1	<1	<1	<1	<1	<1	<1	ND
3rd day	<1	<1	<1	<1	<1	<1	<1	ND
4th day	<1	<1	<1	<1	<1	<1	<1	ND
5th day	<1	<1	<1	<1	<1	<1	<1	ND
6th day	<1	<1	<1	<1	<1	<1	<1	ND

Results were presented as mean ± SE of triple trials
^{abcd} different superscript letters within the same row means statistical significant difference when ($P \leq 0.05$).

Table 6. Mean counts of *S. Typhi* (log_{10} CFU/g ± SE) in the examined groups during storage at 4±1°C

Day	G1	G2	G3	G4	G5	G6	G7	G8
Zero day	3.5 ± 0.1^{a}	2.3 ± 0.1^{c}	1.8 ± 0.1^{e}	1.2 ± 0.1^{f}	2.8 ± 0.1^{b}	2.4 ± 0.1^{c}	2.0 ± 0.1^{d}	ND
2nd day	<1	<1	<1	<1	<1	<1	<1	ND
3rd day	<1	<1	<1	<1	<1	<1	<1	ND
4th day	<1	<1	<1	<1	<1	<1	<1	ND
5th day	<1	<1	<1	<1	<1	<1	<1	ND
6th day	<1	<1	<1	<1	<1	<1	<1	ND

Results were presented as mean±SE of triple trials
^{abcd} different superscript letters within the same row means statistical significant difference when ($P \leq 0.05$).

Regarding the effect of the different applied treatments with EW (*ACC:* 50-60 mg/L) on the physicochemical properties of the examined groups, **Tables (7 and 8)** revealed significant differences within the treated samples based on the time of exposure, type of treatment and the time of storage. Although, pH value correlated inversely with dripping loss (DL: %), it was directly correlated with TVN and TBA mean values. Results revealed that all of the treated samples showed better physicochemical properties appeared as slower rate of protein decomposition and lipid oxidation, that appeared as significant lower TVN and TBA values in comparing with the control groups. On the other hand, *E. coli* contaminated samples showed higher DL (%), TVN and TBA values than those of *S. Typhi*.

Table 7. Mean values of the physicochemical properties of the examined *E. coli* contaminated groups during storage at 4±1°C

	G1		G2		G3		G4		G5		G6		G7		G8	
	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day
DL	1.8±0.1^{b*}	16.8±0.4^{a}	2.1±0.1^{a*}	8.6±0.1^{a}	2.2±0.1^{a*}	8.8±0.1^{a}	2.2±0.1^{a*}	9.0±0.1^{b}	2.0±0.1^{b*}	7.8±0.1^{c}	1.9±0.2^{c*}	7.5±0.1^{d}	2.0±0.1^{c*}	7.7±0.1^{e}	1.74±0.1^{b*}	10.3±0.1^{b}
pH	5.4±0.1^{b*}	6.9±0.2^{a}	5.0±0.1^{d*}	6.2±0.1^{c}	5.0±0.1^{d*}	6.0±0.1^{f}	5.1±0.1^{d*}	5.9±0.1^{f}	5.5±0.1^{a*}	6.5±0.1^{d}	5.5±0.2^{a*}	6.2±0.1^{d}	5.5±0.2^{a*}	6.4±0.1^{c}	5.2±0.2^{c*}	6.5±0.1^{b}
TVN	6.5±0.1^{a*}	20.2±0.2^{a}	6.5±0.1^{a*}	17.3±0.2^{f}	6.5±0.1^{a*}	16.8±0.2^{g}	6.5±0.2^{a*}	16.2±0.1^{h}	6.5±0.1^{a*}	17.1±0.2^{e}	6.5±0.1^{a*}	17.5±0.2^{d}	6.5±0.1^{a*}	17.8±0.2^{c}	6.5±0.1^{a*}	19.6±0.2^{b}
TBA	0.14±0.02^{a*}	0.92±0.01^{a}	0.14±0.02^{a*}	0.68±0.03^{c}	0.14±0.01^{a*}	0.64±0.01^{f}	0.14±0.02^{a*}	0.60±0.04^{g}	0.14±0.02^{a*}	0.72±0.01^{d}	0.14±0.01^{a*}	0.69±0.03^{c}	0.14±0.01^{a*}	0.67±0.01^{b}	0.14±0.01^{a*}	0.83±0.02^{a}

Results were presented as mean±SE of triple trials

^{abcd} different superscript letters within the same row in the same time of examination means statistical significant difference when ($P \leq 0.05$).

*- superscript star within the same row within the same group in each parameter means statistical significant difference when ($P \leq 0.05$)

Table 8. Mean values of the physicochemical properties of the examined *S. Typhi* contaminated groups during storage at 4±1°C

	G1		G2		G3		G4		G5		G6		G7		G8	
	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day	Zero day	6th day
DL	1.8±0.1^{b*}	15.4±0.4^{a}	2.0±0.1^{a*}	7.5±0.1^{a}	2.1±0.1^{a*}	7.6±0.1^{a}	2.0±0.1^{a*}	8.0±0.1^{b}	1.8±0.1^{b*}	5.8±0.1^{c}	1.6±0.2^{c*}	5.6±0.1^{d}	1.5±0.1^{c*}	5.4±0.1^{e}	1.74±0.1^{b*}	10.3±0.1^{b}
pH	5.4±0.1^{b*}	6.7±0.4^{a}	5.0±0.1^{d*}	6.0±0.1^{e}	5.0±0.1^{d*}	5.8±0.1^{f}	5.1±0.1^{d*}	5.7±0.1^{f}	5.5±0.1^{a*}	6.1±0.1^{d}	5.5±0.2^{a*}	6.2±0.1^{d}	5.5±0.2^{a*}	6.4±0.1^{c}	5.2±0.2^{c*}	6.5±0.1^{b}
TVN	6.5±0.1^{a*}	19.0±0.2^{a}	6.5±0.1^{a*}	15.6±0.2^{f}	6.5±0.1^{a*}	15.2±0.2^{g}	6.5±0.2^{a*}	14.9±0.1^{h}	6.5±0.1^{a*}	16.1±0.2^{e}	6.5±0.1^{a*}	16.5±0.2^{d}	6.5±0.1^{a*}	16.8±0.2^{c}	6.5±0.1^{a*}	18.6±0.2^{b}
TBA	0.14±0.02^{a*}	0.85±0.01^{a}	0.14±0.02^{a*}	0.64±0.03^{e}	0.14±0.01^{a*}	0.62±0.01^{f}	0.14±0.02^{a*}	0.60±0.04^{g}	0.14±0.02^{a*}	0.67±0.01^{d}	0.14±0.01^{a*}	0.69±0.03^{c}	0.14±0.01^{a*}	0.72±0.01^{b}	0.14±0.01^{a*}	0.83±0.02^{a}

Results were presented as mean±SE of triple trials

^{abcd} different superscript letters within the same row in the same time of examination means statistical significant difference when ($P \leq 0.05$).

*- superscript star within the same row within the same group in each parameter means statistical significant difference when ($P \leq 0.05$)

DISCUSSION

Bacterial contamination in chicken meat arises primarily during slaughtering, processing, and improper handling, with pathogens such as *Salmonella* spp. and *E. coli* frequently implicated **(Klaharn et al. 2022)**. Scalding processes without temperature control and cross-contamination during evisceration—where intestinal contents leak onto carcasses—are key contributors **(Tahir et al. 2023)**.

Salmonella and *E. coli* represent two of the most consequential pathogens due to their prevalence and public health impact. *Salmonella enterica*, a leading cause of foodborne illnesses characterized by gastroenteritis, fever, and systemic infections **(CDC 2024)**. Similarly, *E. coli* strains, including Shiga toxin-producing variants, can induce severe abdominal cramps, hemolytic uremic syndrome, and kidney failure **(Tahir et al. 2023)**. These bacteria thrive in poultry due to their adaptability to avian hosts and resilience in processing environments, where biofilm formation on equipment perpetuates contamination cycles **(Klaharn et al. 2022).**

Human GIT infections in many countries are commonly caused due to foodborne bacterial contaminations. *Salmonella enterica* represent for over 60% of all documented cases of bacterial food poisoning worldwide. **Thorns (2000)** reported that poultry and poultry products were the main cause of foodborne disease caused by these bacteria. *S. enteritidis* was considered as pandemic in both human and poultry during the latter half of the 20th century. In addition, Shiga toxin producing *E. coli* (STEC) is recognized as a famous cause of diarrhea. STEC has the ability to cause serious and probable life threating disease infection so considered as an important public health threat. The main reservoirs of STEC are thought to be the intestinal tracts of animal **(CDC 2021)**.

In the current study, *E. coli* came in higher prevalence than *Salmonella* spp.; where, thigh samples revealed higher contamination levels than breast samples. Moreover, enteropathohenic *E. coli* (*E. coli* O_{114}:H_{21}) and *S. Enteritidis* were the most detected serotypes.

The recorded results came in line with **Moawad et al. (2017)** who recorded higher contamination levels with *E. coli* and *Salmonella* spp. in thigh samples with superiority of *E. coli* over *Salmonella* as the most prevalent bacteria in the examined samples; while they recorded lower prevalence of *E. coli* and *Salmonella* in the examined samples (11.7% and 8.3%), respectively; and **Julqarnain et al. (2022)** who recorded higher prevalence of *E. coli* in the examined chicken cut samples in Bangladesh, while higher prevalence was detected for *E. coli* and *Salmonella*, 43.2% and 20.0%, respectively. On the other hand, higher records were reported by **Guran et al. (2017)** for *Salmonella* spp. (12.3 and 22.8%) of breast and thigh meat samples, respectively, **Shaltout et al. (2019)** recorded *Salmonella* spp. in 13.3 and 20.0% of breast and thigh samples, respectively. Moreover, the present results disagreed with those of **Shaltout et al. (2020)** who found higher contamination levels with *E. coli* in the examined breast samples than thigh samples.

Variation between different records may be attributed to the variation in the sanitary conditions during slaughtering and packaging, variation in the site of collection and the epidemiological pattern of the bacteriological profile of the production area **(Buzdugan et al. 2021).**

Regarding the biofilm forming isolates, **Fig. (1)** revealed ability of different *E. coli* and *Salmonella* isolates, especially *S. Enteritidis*, to initiate biofilm formation making them a possible health threat in the poultry meat and meat products industry. In Brazil, **Crecencio et al. (2020)** found that 70.4% of *E. coli* isolated revealed forming moderate to strong biofilms. Moreover, **Akinola et al. (2020) and Ashrafudoulla et al. (2021)** found that 54.2% of *Salmonella* isolates formed biofilms, where *S. Enteritidis* revealed strong biofilm formation when incubated at 37^{o}C.

Biofilm formation by foodborne *E. coli* and *Salmonella* poses significant health risks due to their resilience and resistance to sanitization **(Galié et al. 2018)**. These pathogens initiate biofilm development through irreversible adhesion, forming microcolonies embedded in protective extracellular matrices that

shield them from disinfectants and environmental stressors **(Zhao et al. 2017)**. This persistence facilitates crossly contaminating food products, leading to outbreaks of gastroenteritis, hemolytic uremic syndrome, and antibiotic-resistant microbial generation **(Abebe 2020)**. Their ability to thrive on nutrient-rich meat surfaces exacerbates spoilage and recurrent contamination, underscoring the urgent need for advanced biofilm control strategies in food processing **(Arunachalam et al. 2023).**

The preservation of meat and meat products is critical for ensuring food safety, extending shelf life, and maintaining quality. Two innovative technologies that have gained attention in recent years are electrolyzed water (EW) and Ultraviolet (UV) light treatments. Both methods aim to reduce microbial contamination while preserving the physicochemical attributes of meat products.

Referring to the obtained results, **Tables (3 - 6)** revealed significant reductions in the bacterial counts; where application of slightly AEW revealed more potent antibacterial effect than slightly AlEW. It is worth noted that the bacterial reductions were directly correlated to the ACC and time of exposure; where higher ACC and longer time of exposure revealed higher antibacterial effect. In the same line, the treated samples with AEW (ACC = 10-30 mg L^{-1}) for 120 sec and UV combination could reduce the bacterial count of *E. coli* and *S. Typhi* to be compatible with the Egyptian legislations for the chilled poultry meat, (*E. coli*: not more than 10^2 CFU/g, and free from *Salmonella*), in the 5th and 4th day of storage for ACC = 10-30 mg L^{-1} EW, respectively; while higher ACC (50-60 mg L^{-1}) showed total reduction (*E. coli* and *S. Typhi* were not detected) after 24h of refrigerated storage proved that higher ACC revealed more potent antibacterial effect against the examined bacteria; which came in line with the recorded findings of **Muhandiramlage et al. (2020)** and **Shivaji et al. (2022)**.

The inhibitory effect of EW combined with UV treatment indicated the powerful synergism between both treatments which came in line with **Safwa et al. (2024) and Hamed et al. (2024)** who reported that the combination of these two methods has been shown to effectively reduce bacterial pathogens while preserving sensory attributes. Studies suggest that using EW in conjunction with UV light can maximize antimicrobial effects while minimizing oxidative damage.

EW is produced by electrolyzing a diluted sodium chloride (NaCl) solution, resulting in a solution contains a mixture of hypochlorous acid (HOCl), hypochlorite ions (OCl) and chlorine gas (Cl_2). This solution has been shown to possess antimicrobial properties effective against a range of pathogens commonly found in meat and meat products; which was previously recorded by **Speranza et al. (2021)** who indicated that AEW can significantly reduce microbial loads on meat surface, making it a promising alternative to traditional chemical sanitizers, that may be attributed to its ability to disrupt microbial cell membranes and damage of DNA, leading to cell lysis and death. Moreover, AEW has been reported to cause no or minimal changes to the sensory attributes of meat products.

Furthermore, UV light treatment is another non-thermal technology that has been extensively studied for its effectiveness in food preservation through its powerful antimicrobial efficacy by damaging the DNA of microorganisms, rendering them incapable of reproduction **(Tchonkouang et al. 2023)**. Studies have shown that UV-C can effectively reduce pathogens such as *E. coli* and other foodborne pathogens on meat fillets **(Ahmed and Amin 2019)**.

It is worth noted that AEW-treated chicken fillet revealed higher reduction in the bacterial counts in comparing with the AlEW-treated samples; which came in line with **Tomasello et al. (2021)** who concluded that AlEW is rich in sodium hydroxide (NaOH) and has strong detergent properties. However, it is less effective as a disinfectant compared to AEW, it can still contribute to reducing bacterial loads by physically disrupting biofilms rather than through direct chemical action against bacteria **(Schalenbach et al. 2016).**

Regarding the effect of the different applied treatments on the physicochemical prop-

erties of the examined groups, **Tables (7 and 8)** revealed significant differences ($P \leq 0.05$) within the treated samples based on the time of exposure, type of treatment and the time of storage. Although, pH value correlated inversely with dripping loss (DL: %), it was directly correlated with TVN and TBA mean values. Results revealed that all of the treated samples showed better physicochemical properties, in relation to the control untreated group, appeared as slower rate of protein decomposition and lipid oxidation, that appeared as significant lower TVN and TBA values in comparing with the control groups. On the other hand, *E. coli* contaminated samples showed higher DL (%), TVN and TBA values than those of *S. Typhi*. The obtained results may be attributed to the previously noticed significant inhibitory effect of EW and UV on the bacterial multiplication that has a direct correlation with the acceleration of protein and fat degradation and raising TVN and TBA up consequently; which came in line with the recorded attribution mentioned by **Speranza et al. (2021)**.

Regarding the obtained results of drip loss (DL), variation in the dripping loss can be correlated to pH and UV treatment. The relationship between pH and drip loss in meat products is consistently characterized by a negative correlation, where lower pH values (more acidic meat) are associated with higher drip loss, that explain the higher DL in AEW treated groups in comparison with AlEW treated groups **(Przybylski et al. 2021)**. In addition, UV may have an indirect effect on the DL through its antibacterial action **(Teng *et al.*, 2023).** This pattern holds across different types of meat, as evidenced by multiple studies that were conducted by **Wyrwisz et al. (2012) and Wenying et al. (2014).**

It is worth noted that UV-C light is a well-known effective technique for reducing microbial loads, but its application must be carefully controlled due to preventing the adverse effect of high doses or prolonged exposure that can lead to oxidative degradation of lipids and proteins in seafood, negatively impacting color, texture, and flavor. Therefore, combining UV-C with other preservation methods may help mitigate these adverse effects while enhancing safety **(Baligad et al. 2023).**

In the current study, *E. coli*-contaminated groups showed higher TVN and TBA levels in the same time in comparing with the *Salmonella*-contaminated groups that may be attributed the more potent proteolytic activity of *E. coli* as was recorded by **Lazdunski (1989).** In addition, results of pH, TVN and TBA can be correlated; where higher pH (>6.0) may enhance the proteolysis bacteria and accelerate TVN accumulation during storage **(Al-Najada, 2019)**

CONCLUSION

Escherichia coli and *Salmonella* could be isolated from chicken meat cuts, where thigh samples revealed higher contamination levels, besides that *E. coli* was more prevalent than *Salmonella* spp. Moreover, positive detection of biofilm forming strains in the current study strongly recommends application of innovative effective disinfectant technique with regular monitoring safety and bacteriological quality of chicken meat cuts. The application of EW and UV light, especially of higher ACC (50-60 mg L^{-1}) represents a promising frontier in poultry meat preservation. Both technologies offer significant advantages in enhancing food safety without compromising the sensory qualities of meat products; where the combined AEW and UV treatment revealed synergistic impacts on the bacteriological and physicochemical quality of the treated chicken fillet; therefore, it is recommended to apply this combination as a routine treatment before cold storage for safer and longer shelf-life meat production.

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