ejpmr, 2024, 11(11), 69-77

SJIF Impact Factor 7.065

EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

www.ejpmr.com

Research Article

ISSN 2394-3211

EJPMR

EFFICIENCY OF ELECTROLYZED WATER (EW) IN MITIGATING THE MICROBIAL CONTAMINATION OF BEEF MEAT

[1]*Ebtisam M.A. Mesalam, [1]Amira A. Elokle and [2]Mona Momtaz M. Abd el-aziz

[1]Reference Lab for Examination of Food of Animal Origin, Animal Health.
[2]Research Institute (AHRI), Agricultural Research Center (ARC), Giza, Egypt.

***Corresponding Author: Dr. Ebtisam M.A. Mesalam**

Reference Lab for Examination of Food of Animal Origin, Animal Health.

Article Received on 11/09/2024 **Article Revised on 01/10/2024** **Article Accepted on 22/10/2024**

ABSTRACT

As an increasing international need for natural sanitizers and disinfectants especially in food industries, instead of chemical ones, that is due to their known disadvantages as their toxic residues in food as well as their bad effect on nature. There are many studies had been applied on Electrolyzed water (EW), as a novel broad-spectrum disinfectant and cleaner, which has been widely used for several years. As studies on electrolyzed water (EW) for decontamination and shelf- life extension of beef are limited this study was conducted to evaluate the beneficial effects of slightly acidic electrolyzed water (SAcEW) and slightly alkaline electrolyzed water (SAlEW) on the microbiological, chemical, and sensory qualities of fresh beef during cold storage. The results showed reduction in the total bacterial count, *Enterobacteriaceae*, coliform count as well as *E. coli* and *S. aureus* count and decrease amount of TVBN and TBA in treated samples compared to the untreated samples with a significance differences ($p \leq 0,05$) between the SAcEW treated samples and the untreated ones. Also the results demonstrated that SAcEW and SAlEW could effectively extend the shelf life of beef samples to 10 and 8 days at 4°C, respectively in comparison with 5-6 days for the untreated samples.

KEYWORDS: Electrolyzed water – beef meat – microbial contamination- chemical quality.

INTRODUCTION

Food safety has become one of the most prominent challenges even in the industrialized world as more foodborne pathogens and outbreaks are being identified and reported. This issue related to the most important food products such as milk, meats, vegetables, and fruits.

The processing of food products to be safe with long storge periods is one of the main target of food industry. For the reduction of microbial contamination, effective disinfection of both processing enviroment and raw materials is essential.

Fresh beef is easily contaminated by microorganisms that naturally occur from different sources during carcass processing **(Tango *et al.*, 2014)** leading to a reduction in beef quality and shelf life during its storage, and is considered a major factor affecting food safety. Therefore, to prolong the shelf life of fresh beef during storage it is necessary to apply an effective preservation method. refrigeration storage condition is the main and common method of preservation to inhibit the deterioration of fresh meat resulted from microbial growth, chemical and biochemical reactions, resulting in reduction in the microbial activity and increasing the shelf life **(Allende *et al.*, 2009).** However, certain complementary sanitizing processes before refrigeration should be applied to improve both safety and quality of fresh vegetables and meat **(Li, *et al.*, 2017).**

In this regard electrolyzed water (EW) is one of the recent antimicrobial treatments. It is considered as an alternative to physical or chemical methods, without undesirable toxic contaminants (**Feng *et al.*, 2002).** Its applications in different sections have already proved their effects as one of useful sanitizers in different fields including the food industry individually or with some physical and chemical treatment methods **(Mansur; *et al.*, 2015, Li; *et al.*, 2017, Lang; *et al.*, 2019 and Zang; *et al.*, 2019Attia;*et al.*, 2021).**

The pH of slightly acidic electrolyzed water (SAEW) ranged from 5.0–6.5 and oxidation reduction potential "ORP" 800-900 mV, which has a strong antimicrobial effect against pathogenic and spoilage microorganisms due to the presence of hypochlorous acid (HOCl) and hypochlorite ion (ClO-) **(Hricova *et al.*, 2008 and White, 2010).**

Electrolyzed water can be produced on site on demand and no chemicals are needed except NaCl solution, does not leave any residue in food due to low chlorine concentration and it is safe due to its semi-neutral pH.

It is produced by the electrolysis of diluted salt solutions in electrolysis chamber (containing cathode and anode with the help of a diaphragm) resulting in sodium hydroxide (NaOH) and hypochlorous acid as products of electrolysis **(Huang *et al.*, 2007)**. Three forms of the solution can be produced, an acidic form (AEW), a neutral pH form, and an alkaline form. AEW exhibits an acid pH, a high oxidation-reduction potential, and high free chlorine concentrations making it an effective antimicrobial agent resulting in lots of attention for its disinfection effect on both food materials and food-contact surfaces **(Xuan *et al.*, 2017 & Xuan and Ling, 2019).**

According to previously conducted studies, the properties and effectiveness of electrolyzed water either strong (StAEW)or slightly acidic(SAEW) against microorganisms can be greatly affected by the storage conditions as the findings indicated that storage of EW in a closed-dark container was the more favorable than both the open and light condition and SAEW is more stable than StAEW **(Len *et al*., 2002, Rhman *et al*., 2012 and Xuan and Ling 2019).**

Based on this, SAcEW and SAlEW were used on beef meat. The microbiological quality, lipid and protein oxidation as well as their effect on the shelf life were evaluated during the refrigerated storage.

3-MATERIAL AND METHODS

3.1. Sample collection and preparation

A total of 1500 gram of fresh boneless beef was purchased from a shop of Cairo market – Egypt, transferred to the laboratory in a box with cooling packs, and stored at 4±1ºC under hygienic measures. The sample was divided into three parts (500 g each); 1st part was kept as control without any treatment, the 2nd sprayed with SAcEW, 3rd was sprayed with SAlEW. All samples were packed in polyethylene bags and stored at 4±1oC and examined bacteriologically, chemically and sensory till the appearance of the deterioration sings and the experiment was repeated in triplicate.

3.2. Preparation of Slightly acidic and alkaline electrolyzed water (SAcEW and SAlEW) according to (Hricova et al. 2008 and Athayde et al. 2018) as follows

For preparation of SAcEW and SAlEW we use sufficient amount of potable drinking water with 0.2 % sodium chloride (NaCl).

By using an electrolysis cell with two poles of anode (+) and cathode (-)a current of 9-10 volt and 8-10 amber (A) through the water for ten minutes. NaCl was dissociated into Na+ and Cl- and water was reduced into (OH-) and Hydrogen (H+) ions in the solution according to the following formula:

$$2H_2O + 2e \rightarrow H_2^+ + 2OH^-$$

Negatively charged hydroxyl group (OH^-) and Cl^- ions move towards the anode where electrons are released and hypo- chlorous acid (HOCl), hypochlorite ions (- OCl), oxygen gas (O2) and chlorine gas (Cl_2) and HCl were produced. While positively charged ions (Na+ and H+) move toward the cathode where they gain electrons, resulted in the production of sodium hydroxide (NaOH) and hydrogen gas (H2).

A few drops of vinegar 5%, may be added to the electrolyzed water to adjust the pH 5.5 to be slightly acidic (SAEW).

3.3. Bacteriological examination

- Aerobic plate count (APC) (APHA, 2001)

Under aseptic conditions 10 grams of each sample was placed in sterile stomacher bag and 90 ml of sterile physiological saline was added then homogenized for two minutes. Ten-fold serial dilutions were prepared and on standard Plate Count Agar the total bacterial count was determined after incubation at 35°C±1°C for 48 h. Bacterial counts were given in log10 cfu/g.

- Enumeration of Enterobactericeae (ISO 21528/2-2017)

By pouring method enterobactericeae were enumerated using the VRBGA and allowed to set then were incubated at 37c for 24h.

-Enumeration of coliform (FDA, 2020)

Coliform were enumerated by pouring method using VRBA and the plates were inverted and incubated at 35c for 18- 24h.

-Enumeration of *E. coli* (ISO 16649/ 2- 2001)

One ml of each dilution was transferred and distributed over the surface of TBX medium. The plates were inverted and incubated for 18-24 hours at 44c and typical colonies were counted.

-Enumeration of *Staphylococus aureus* (FDA, 2001)

About one ml. of food homogenate was transferred and distributed over the surface of 3 plates of Baired-Parker agar, using sterile bended glass spreader. The plates were retained in upright position until inoculum is absorbed by agar for about 10 mints. The plates were inverted and incubated for 24-48 hours at 35oC and examined for determination of *Staph. aureus* count**.**

3.4. Chemical examination

-Determination of Total Volatile Basic Nitrogen (TVB- N) (According to Egyptian Standard “ES" (63-9/2006)

Ten grams of each examined sample was added to 300ml of distillated water and two grams of magnesium oxide then thoroughly mixed by a blender for 2 minutes and then was boiled till obtained 100 ml of distillate which received in flask contained 25 ml boric acid 2% and 2 drops of indicator. Flask was boiled tell 100 ml distillate was obtained. Sample was titrated with 0.1 M H2SO4

(R1). Steps were repeated using distilled water instead of sample as blank (R2). TVBN expressed as mg/100 gm = (R1-R2) X 14.

-Determination of thiobarbituric acid (TBA) according to Egyptian Standard "ES"(63-10/2006)

In a clean blender, about 10 g of the examined sample was blended with 50 ml of D.W. for 2 minutes, then washed with 47.5 ml water in a distillation flask, 2.5 ml of 4 M HCL was added to adjust the pH to 1.5, boiled till 50 ml distillate was obtained, and then filtrated. Five ml of TBA reagent (0.29 g/100 ml 90% glacial acid) was added to 5 ml of the filtrate in a screw capped test tube. The tubes then heated in a water bath for 35 minutes and the absorbance of the resulting color was measured by using of a spectrophotometer (Spectronic 21 Germany) at wave length 538 nm. The TBA values were recorded as mg malonaldehyde / Kg of the samples. Concentration of malonaldehyde = 7.8 X S mg/ Kg sample where S = the reading of absorbance.

Statistical analysis

Statistical analysis was applied in triplicate, results were reported as mean values and standard deviation (Mean ± SD) using the SPSS Ver. 20 and p-value less than 0.05 ($p \leq 0.05$) was considered statistically significant.

4- RESULTS AND DISCUSSION

4-1-Bacteriobiological examination

Each time all samples were tested for Aerobic plate count (APC), Enterobactericeae count, *E. coli* count, coliform count and *Staph aurous* count which expressed as (mean log10 cfu /g ±SD)

Aerobic plate counts (APC) which indicates microbial load in the product are useful to indicate quality, shelf life, and post processing contamination **(Corrosionpedia, 2019)**.

In this study, the results in Figure (1) revealed that the mean value of total bacterial count decreased from recorded 4.98±0.03 log_{10} cfu/g in the untreated samples and increases along the storage time and remained acceptable until the 4^{th} day of storage with mean count log_{10} cfu/g±SD of 6.01±0.04 and became unacceptable at the 6^{th} day. While the count recorded 4.39±0.1 log_{10} cfu/g and 4.71±0.05 log_{10} cfu/g after treating with SAcEW and SAlEW, respectively and prolonged the shelf life with gradual increase in the count to be 5.74±0.06 log_{10} cfu/g and 5.80±0.01 log_{10} cfu/g at the 8^{th} and 6^{th} days, respectively.

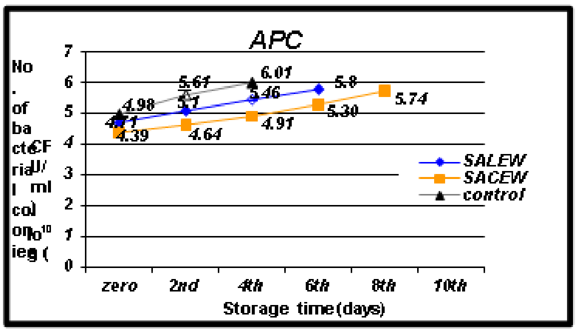

Fig. 1: Effect of electrolyzed water on aerobic plate count (Meanlog_{10}cfu/g) and the shelf-life of meat samples.

Similar results have been reported by previous studies as (Sheng et al., 2018) revealed that the APC in the meat treated with SAEW decreased from 3.06 log_{10} cfu/g to 2.28 ± 0.43 log_{10} cfu/g. The SAEW and SAKEW treatments significantly (p < 0.05) slowed down the increase rate of APC compared with that of the control.

Enterobactericeae area large family of bacteria that can be found in different environments, including food and they are considered as indicators of hygiene, sanitation, and post-processing contamination. Members of the family lead to foodborne disease and some cause food spoilage and therefore contribute to economic losses and food wastage **(Chris Baylis 2011 and FSAI 2016).**

The mean value of Enterobacteriaceae count were 2.17±0.02 log_{10} cfu/g and 2.47±0.02 log_{10} cfu/g in samples treated with SAcEW and SAlEW, respectively compared to 2.73±0.33 in the untreated one then after 4 days of storage the count reached to 2.60±0.01 log_{10} cfu/g and 2.87± 0.02 log_{10} cfu/g, respectively compared to 3.25± 0.01 log_{10} cfu/g in the control sample (Fig. 2).

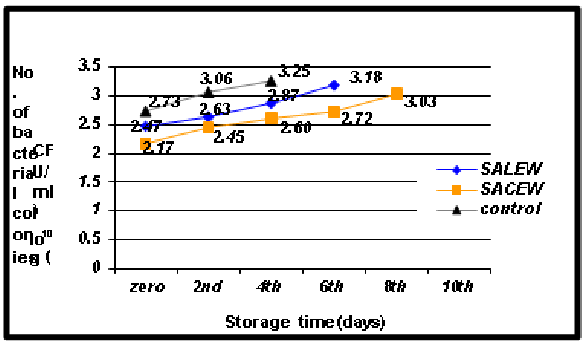

Fig. 2: Effect of electrolyzed water on enterobacteriacea count(Meanlog_{10}cfu/g)and the shelf-life of meat samples.

Also samples without treatment recorded mean coliform count 2.63±0.04 log_{10} cfu/g then increased till reach to 3.21± 0.01 log_{10} cfu/g at the 4^{th} day before spoilage while the count decreased into 2.08±0.04 log_{10} cfu/g and 2.34± 0.05 log_{10} cfu/g by using SAcEW and SAlEW treatment then increased gradually to be 3±0.07 log_{10} cfu/g and 3.12±0.01 log_{10} cfu/g before spoilage at the 10^{th} and 8^{th}

days, respectively as showed in Figure (3).

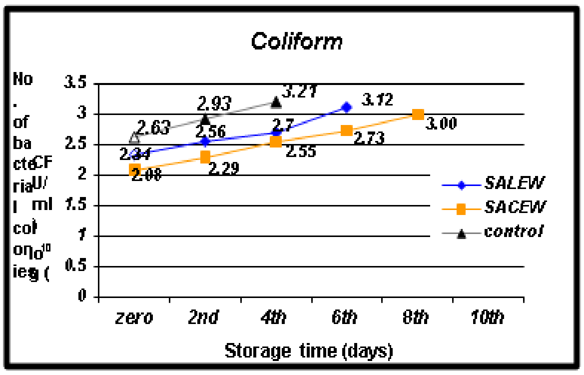

Fig. 3: Effect of electrolyzed water on coliform count (Meanlog$_{10}$cfu/g) and the shelf-life of beef meat samples.

Escherichia coli, is a widely distributed bacteria in the intestinal environments and have been recognized as a cause of foodborne outbreaks through variety of foods.

According to this study, the mean value of *E. coli* in meat samples that preserved by SAcEW decreased into 1.87±0.02 log$_{10}$ cfu/g then increased to reach 2.77± 0.03 log$_{10}$ cfu/g at the 8th day of storage. As for SAlEW treated samples the count decreased into 2.22±0.02 log$_{10}$ cfu/g and at the 6th day it was 2.88±0.03 log$_{10}$ cfu/g. Compared to 2.51± 0.02 at the zero day and reached to 3.06±0.01 log$_{10}$ cfu/g at the 4th day of storage recorded in the untreated one (Fig.4).

As we noticed the count of examined microorganisms decreased after treatments then by time the count increased in all samples with different rates and as expected, the count in treated samples increased at a slower rate than those of the untreated samples, with high disinfectant effect of SAcEW.

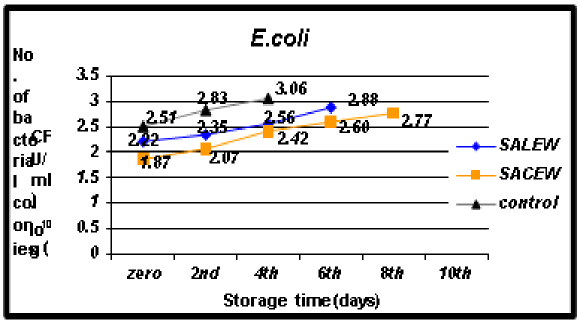

Fig. 4: Effect of electrolyzed water on *E.coli* count (Meanlog$_{10}$cfu/g) and the shelf-life of beef meat samples.

Recently, slightly acidic electrolyzed water has demonstrated in several prior investigations as a very effective bactericides against various types of bacteria so it is increasingly being used in food industry.

Zeng *et al.*, (2010) showed that electrolyzed oxidizing water (EO water) was an efficient and rapid disinfectant towards *E. coli* and *Staphylococcus aureus* and the disinfection mechanism of EO water was composed of several comprehensive factors including the destruction of bacterial protective barriers, the increase of membrane permeability, the leakage of cellular inclusions, and reduction in the activity of some key enzymes.

Also **Sally *and Ibrahim* (2023)** studied the effect of SAEW which showed decreasing in the total bacterial count, *Enterobacteriaceae*, and total *E. coli* count by mean reduction percentages of 88.2%, 85.3%, and 98.4%, respectively. In other study by **Tango *et al* (2014)** the SAEW treatment had a sanitization effect against *S. aureus* and *E. coli O157:H7* in fresh beef with increases in the contact time. Other similar studies reported the decontamination effect of EW for different types of food as fresh red meat, ready-to-eat meat, poultry and shell eggs has been effective in reducing pathogenic microorganisms as **Huda *et al.*, (2022)** who concluded that both SAlEW and SAcEW treatments effectively reduced the bacterial contamination of the treated chicken fillet during cold storage with extending of the shelf life .Also**(Rahman., *et al* 2012)** reported that SAcEW treated chicken meat samples significantly (P < 0.05) reduced the background and inoculated pathogens compared to untreated controls**.**

However, no complete elimination of pathogens on red meat and chicken meat was obtained after their treatment with EW and that may be occurs due to the organic matter and blood residue **(Yan *et al*., 2019).** Previously, **Wang *et al.*, (2018**) recorded that almost 1.0 log CFU/cm2 microbial reduction was achieved by using SAcEW as a novel spraying technology for chicken carcasses.

Staphylococcus aureus, a gram-positive microorganism, its infection associated mainly with its production of different kinds of enterotoxins **(Le Loir *et al*, 2003 and Lowy *et al*, 2003).**The risks associated with consuming foods contaminated with *S. aureus* have caught the attention of major public and governmental organizations in recent years.

Figure (5) showed that the count of *S. aureus* in the untreated sample was 1.89±0.04 log$_{10}$ cfu/g at zero time then the mean count recorded 2.55±0.02 at the 4th day of storage. While, samples that treated with SAcEW and SAlEW recorded 1.20±0.1 and 1.42±0.03 log$_{10}$ cfu/g at zero time and the count increased till the 6th and the 8th days recording 2.31±0.02 and 2.36±0.06, respectively showing a significance (p≤ 0.05) between the results of the treated samples and the untreated one.

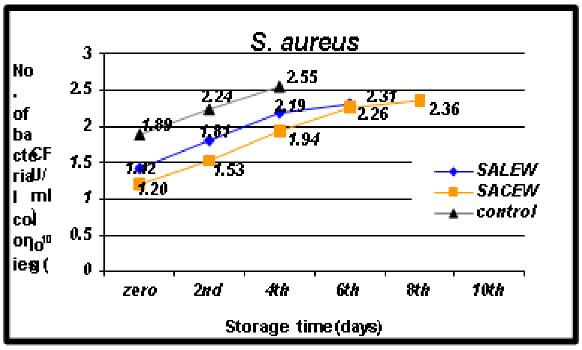

Fig. 5: Effect of electrolyzed water on *S. aureus* count (Meanlog_{10}cfu/g) and the shelf-life of meat samples.

(Ding *et al.* 2016) reported that slightly acidic electrolyzed water (SAEW), considered as a broad-spectrum bactericide is increasingly applied in food industry and significantly reduced *S. aureus* count. There are several researches published recently showed the strong antimicrobial effect of SAEW. Most of them proved its effect on pure cultures of pathogenic microbes and others were based on specific food products (**Ding *et al*, 2016, Xuan *et al.*, 2017 and Ye *et al.*, 2017).**

From the obtained results, it could be concluded that there was significance difference ($P<0.05$) between SAcEW and the untreated samples and showed a good reduction in microbial count more than SAlEW. This may be due to the sanitizing effect of SAcEW while SAlEW act as a detergent.

That reduction in the bacterial load improved the quality of the sample and increase their shelf life which actually increased in this experiment from 5days (for the untreated sample) compared to 8 and 10 days for the SAlEW and SAcEW treated samples, respectively.

4-2- Sensory properties

Table 1: Sensory changes/Time for examined beef samples.

Time /days	Types of samples		
	Untreated sample	**SAlEW treated sample**	**SAcEW treated sample**
1st-3thday	No change	No change	No change
4th day	-Light discoloration -No odor change	No change	No change
5th day	- Discoloration -Loss of normal odor	No change	No change
6th day	-Discoloration -Unacceptable odor	-Light discoloration -No odor change	No change
7th day	-	-Discoloration -Lossof normal odor	-Light discoloration -No odor change
8th day	-	Discoloration Unacceptable odor	-Discoloration -No odor change
10th day	-	-	-Discoloration -Unacceptable odor

The sensory evaluation including odor and appearance was performed during storage, there was a reduction in the sensory properties of all samples as a progressive loss of meat freshness but with different rates as shown in table (2).

Results in table (2) showed that, at the beginning of the test all samples were rosy red in color and have good odor. But at the 4thday at refrigerator the color of the control samples began to change but with acceptable odor and became completely unacceptable at the 5th day. On the other hand SAlEW and SAcEW treated samples showed signs of spoilage at the 8th and 10th days of storage, respectively.

The obtained results regarding the effect of electrolyzed water (EW) in prolonging the shelf life agreed with (**sheng *et al*, 2018**) who recorded that SAEW could extend the shelf life of beef meat but for 14-16 day. Also **Rahman, *et al.*, (2012) and Huda, *et al.*, (2022)** concluded the role of EW in prolonging the shelf life of treated chicken meat for different period.

The bactericidal effect of SAEW against various foodborne pathogens is widely accepted as a result of the combined actions of high oxidation reduction- potential (ORP) reactions and the dissociated hypochlorous acid (HOCl).

Recently, EW's effectiveness has been reported against different microorganisms as *S. enterica*, *E. coli*, *Yersinia*, and *Staphylococcus aureus*, which are often associated with pork, beef, chicken, and other meat surfaces by using soaking, spray, or immersion techniques resulting in various degrees of success **(wang *et al.* 2018)** and the antimicrobial activity of the effective form of chlorine compounds (HOCl) in SAEW has been reported (**Cao *et al.*, 2009).**

Firstly, HOCl can penetrate the cell membrane by passive diffusion causing changes in bacterial surface from smooth, consecutive, and bright into rough, shrunken, and even lysed after EW treatment. In addition, damage of membrane proteins leading to the agglutination of cellular inclusions and decrease the activity of certain enzymes resulting in the leakage DNA and proteins **(Ding *et al*. 2016, Fukuzaki *et al*. 2006 and Tang *et al.* 2011 and Cheng *et al*. 2016).**

4-3-Chemical examination

1- Total Volatile Basic Nitrogen (TVBN)

Table 2: Mean values of TVB-N (± SD) of examined beef meat samples groups.

Days	Control	SACEW	SALEW
Zero	14.497±0.241^{A}	12.05±0.141^{aB}	13.127± 0.151^{ab}
2nd	16.243±0.549^{A}	12.973±0.252^{a}	13.72±0.280^{a}
4th	18.907±0.885^{A}	14.140±0.505^{aB}	15.51±0.562^{ab}
6th	21.00±0.700^{A}	15.38±0.701^{aB}	17.5±0.70^{ab}
8th	25.20±0.70^{A}	17.126±0.352^{aB}	20.290±0.70^{ab}
10th	29.40±0.70^{A}	20.05±0.352^{aB}	22.40±0.70^{ab}

There are significances differences (P<0.05) between means having the same capital and small letters in the same raw.

SACEW: Slightly acidic electrolyzed water **SALEW:** Slightly alkaline electrolyzed water

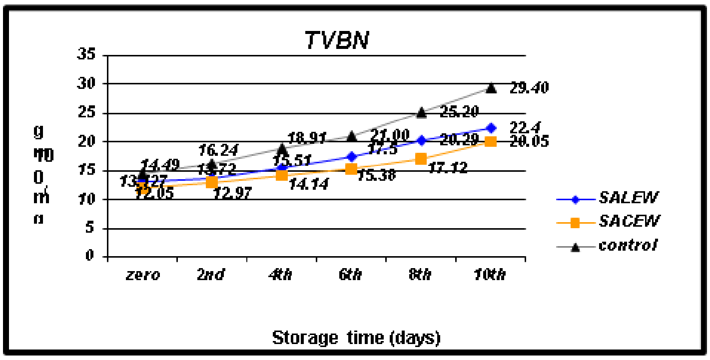

Figure 6: Mean values of TVBN (± SD) of examined meat samples.

TVBN is a compound composed mainly of ammonia in addition to primary, secondary, and tertiary amines **(Gill, 1983)** and results from the degradation of proteins and non-protein nitrogenous compounds chiefly due to the microbial activity and their proteolytic enzymes. So it is regarded as an important and sensitive indicator of freshness of meat during its storage **(Veberg *et al.*, 2006 and Pérez-Palacios *et al.* 2008).**

The results in table (3) and Figure (3) revealed that the TVBN values (measured in mg/100gm) within the control group ranged from 14.497±0.241 to 21.00±0.70 between day 0 and day 6. In the SALEW group, the values ranged from 13.127± 0.151 to 20.290±0.70 between day 0 and day 8. While, in the SALEW group, the values ranged from 12.05±0.141 to 20.05±0.352 between day 0 and day 10, respectively.

On the 6th day of the experiment, the control group exhibited spoiled results, while the SALEW treated group spoiled on 8th of the experiment and SACEW showed a slow increase of values and remained below the permissible limit of 20mg/100gm as per EOS No. 1522 (2020) till 10th day.

Our findings revealed that SALEW and SACEW decrease protein decomposition and decrease the TVBN values at day 8 and 10 of storage, respectively and SACEW had the higher effect. Similar finding was reported by **(Xiaowei Sheng, *et al*, 2018)**, who found that SAEW significantly extended the shelf life of beef and effectively suppressed the production of TVB-N in treatment samples.

2- Thiobarbituric acid (TBA)

Table 3: Mean values of TBA (± SD) of examined beef meat samples.

Days	Control	SACEW	SALEW
Zero	0.351±0.155	0.331±0.0076	0.341±0.0091
2nd	0.601±0.155^{A}	0.359±0.0075^{aB}	0.460±0.155^{ab}
4th	0.803±0.135^{A}	0.401±0.197^{aaB}	0.585±0.160^{ab}
6th	0.994±0.195^{A}	0.470±0.196^{aB}	0.668±0.197^{ab}
8th	1.674±0.393^{A}	0.736±0.027^{aB}	1.021±0.196^{ab}
10th	2.691±0.048^{A}	0.991±0.023^{aB}	1.73±0.0245^{ab}

There are significances differences (P<0.05) between means having the same capital and small letters in the same raw.

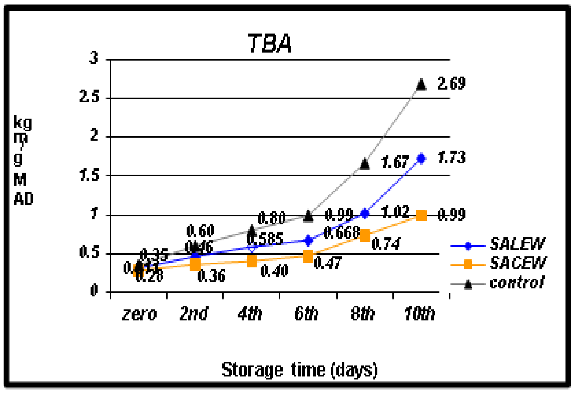

Figure 7: Mean values of TBA (± SD)of examined meat sample.

Lipid oxidation is an important factor of oxidative deterioration of meat is a result of lipid oxidation that leading to change of flavor and odor of meat, thus limiting the shelf life of meat **(Patsias, Chouliara, Badeka, Savvaidis and Kontominas, (2006).** TBA is indicator of that oxidation and its amount indicates how much of lipids have been oxidized **(Campo *et al*., 2006).**

Our results revealed that the content of TBA of all the tested samples was similar at the beginning of storage and according to the data presented in table (4) and Figure (4), it can be observed that the control group had TBA values ranging from 0.351±0.155 to 0.994±0.195 on day zero and day 6, respectively. Conversely, SACEW group had values ranging from 0.331±0.0076 to 0.991±0.023 on day zero and day 10, while SALEW treated group had values ranging from 0.341±0.0091 to1.021±0.196 on day zero and day 8, respectively.

The spoilage of the control group occurred on the 6th day, meanwhile, in the SACEW and SALEW treated groups, the TBA values increased slowly and remained below the permissible limit of 0.9 MDA/kg according to **EOS No. 1522**, indicating a lower degree of lipid oxidation. The SACEW treated group had the lowest mean values of mg MDA/kg meat, particularly on the 6th and 8th days of storage. These findings were consistent with those of Rahman et al.(2012), who reported that SAEW (containing $^{-}$OH and HOCl) has antioxidant effect and can maintain the oxidation stability.

CONCLUSION

This study provides the application of slightly acidic and slightly alkalin electrolyzed water in meat industry and according to the obtained results both of SAcEW and SAlEW treatments showed antimicrobial effects but SAcEW was more effective compared to the untreated beef samples. More over the results indicated that the antimicrobial effect of them not only decrease the bacterial load and decrease the hazard of foodborne disease but also the quality of beef samples that treated by SAcEW and SAlEW were maintained up to10 and 8 days, respectively.

REFERENCES

1. **APHA: American public health association**. APHA committee on microbiological methods for foods. Compendium of methods for the microbiological examination of food, Ed. Washington, **2001;** 676.
2. **Athayde; D., Flores; D., Silva; J., Silva; M., Genro; A., Wagner; R. Campagnol; P., Menezes; C., Cichoski; A.,** Characteristics and use ofelectrolyzed water in food industries. Int Food Res J., **2018;** 25(1): 11-6.
3. **Allende, A. Tomás-Barberán, F. A., Gil, M. I**: Minimal processing for healthy traditional foods. Trends in Food Science & Technology, **2006;** 17(9): 513–519.
4. **AttiaIram, Xinmiao Wang, and Ali Demirci:** Electrolyzed Oxidizing Water and Its Applications as Sanitation and Cleaning Agent Food Eng Rev., **2021;** 13(2): 411–427.
5. **Baylis; C., Uyttendaele; M., Joosten; H. and Davie; A.(2011)**: The *Enterobacteriaceae* and their significance to the food industry, commissioned by the Europe emerging microbiological issues task force, December 2011.
6. **Campo MM, Nute GR, Hughes SI, Enser M, Wood JD & Richardson RI.** Flavour perception of oxidation in beef. Meat Science, **2006;** 72(2): 303–311. 10.1016/j.meatsci.2005.07.015.
7. **Cao,W., Z. W. Zhu, Z. X. Shi, C. Y. Wang, and B. M. Li,** "Efficiency of slightly acidic electrolyzed water for inactivation of Salmonella enteritidis and its contaminated shell eggs," Inter. J. Food Microbiol, **2009;** 130(2): 88–93.
8. **Corrosionpedia (2019)**: Seafood. oregonstate.edu/sites/agscid7/files/snic/ compendium/ chapter 9 a https://www.corrosionpedia.com/definition / 4798 /total-bacteria-count-tbc.
9. **Ding; T., Xuan; X., Li; J.,** Disinfection efficacy and mechanism of slightly acidic electrolyzed water on *Staphylococcus aureus* in pure culture. *Food Control.*, **2016;** 60: 505–510.
10. **Egyptian Organization for Standardization "ES 63-9".** Methods of analysis and testing for meat and meat products. 2006; part 9. Determination of Total Volatile Nitrogen.
11. **Egyptian Organization for Standardization "ES 63-10".** Methods of analysis and testing for meat and meat products. 2006; part 10. Determination of Thiobarbituric acid (TBA).
12. **FDA,** BAM; Chapter 4: Enumeration of *Escherichia. coli* and the Coliform Bacteria, **2020.**
13. **FDA,** BAM; Chapter 12: *Staphylococcus aureus,* **2001.**
14. **Feng; P., Weagent; S., Grant; M. (2002):** Bacteriological Analytical Manual Online.www.lib.ncsu.edu/pubweb/www/ETDdbweb root/collection/available/etd -04102005- 213953/ unrestricted/ etd.pdf.
15. **Food Safety Authority of Ireland *"FSAI"*.**

Guidelines for the Interpretation of Results of Microbiological Testing of Ready-to-Eat Foods Placed on the Market (Revision 2), Guidance Note No., **2016;** 3: 24-25.

16. **Fukuzaki, S. "**Mechanisms of actions of sodium hypochlorite in cleaning and disinfection processes," *Biocontrol Science*, **2006;** 11(4): 147–157.
17. **Gill, C. O.** Meat spoilage and evaluation of the potential storage life of fresh meat. *Journal of Food Protection*, **1983;** *46*(5): 444–452. https://doi.org/10.4315/0362-028X-46.5.444
18. **Hao, J., J. Zhang, X. Zheng, and D. Zhao,** "Bactericidal efficacy of slightly acidic electrolyzed water (SAEW) against Listeria monocytogenes planktonic cells and biofilm on food-contact surfaces," *Food Quality and Safety*, **2022;** 6.
19. **Hricova D, Stephan R, Zweifel C.** Electrolyzed water and its application in the food industry. J. Food Prot., **2008;** 71(9): 1934–1947.
20. **Huang; YR., Hung; YC., Hsu; SY, Huang; YW. and Hwang; DF.** Application of electrolyzed water in the food industry. Food Control, 2008; 19: 329-345.
21. **Huda Elsayed, Nashwa M. Zaki, Yosra Samy Aleslamboly:** Impact of slightly acidic and alkaline electrolyzed water on shelf-life of the chilled chicken fillet. Eg. J. Anim. Health, 2022; 2(4): 1-10. **ISO 21528/2- 2017:** Microbiology of food chain - Horizontal Method for the Detection of *Enterobactericeae.* **ISO 16649/ 2- 2001:** Horizontal Method for the Enumeration of B glucuronidase-positive *E.coli.*
22. **Lan, L. S., Zhang, R., Zhang, X. L., et al.** Sublethal injury and recovery of *Listeria monocytogenes* and *Escherichia coli* O157:H7 after exposure to slightly acidic electrolyzed water. Food Control, **2019;** 106: 106746.
23. **Lowy; F. D.** Antimicrobial resistance: the example of *Staphylococcus aureus*. *J. Clin. Invest.*, **2003;** 111: 1265–1273.
24. **Le Loir; Y., Baron; F., Gautier;** M. *Staphylococcus aureus* and food poisoning. *Genet. Mol. Res.*, **2003;** 2: 63–76.
25. **Len; S., Hung; Y., Chung; D., Anderson; J., Erickson; M. and Morita; K.:** "Effect s of storage conditions and pH on chlorine loss in electrolyzed oxidizing (EO) water," *Journal of Agricultural and Food Chemistry*, **2002;** 50(1): 209–212.
26. **Li, J., Ding, T., Liao, X. Y., et al.** Synergetic effects of ultrasound and slightly acidic electrolyzed water against *Staphylococcus aureus* evaluated by flow cytometry and electron microscopy. Ultrasonics Sonochemistry, **2017;** 38: 711–719.
27. **Mansur, A. R., Tango, C. N., Kim, G. H., etal.,** Combined effects of slightly acidic electrolyzed water and fumaric acid on the reduction of foodborne pathogens and shelf- life extension of fresh pork. Food Control, **2015;** 47: 277–284.
28. **Patsias, A., Chouliara, I., Badeka, A., Savvaidis, I. N., & Kontominas, M. G.** Shelf-life of a chilled precooked chicken product stored in air and under modified atmospheres: Microbiological, chemical, sensory attributes. *Food Microbiology*, **2006;** *23*(5): 423–429. https://doi. org/10.1016/j.fm.2005.08.004
29. **Pérez-Palacios T., Ruiz J., Martín D., Muriel E., and Antequera T.** Comparison of different methods for total lipid quantification in meat and meat products. Food chemistry, **2008;** 110(4): 1025-1029. https://doi.org/10.1016/j.foodchem.2008.03.026
30. **Ouattara, B., Simard, R. E., Holley, R. A., Piette, G. J. P., &Bégin, A.** Antibacterial activity of selected fatty acids and essential oils against six meat spoilage organisms. International journal of food microbiology, **1997;** 37(2–3): 155–162. https://doi.org/10.1016/S0168 1605(97)00070-6
31. **Rahman; S., Park; J., Song; K., Naif A Al-Harbi and Deog-Hwan Oh**: Effects of slightly acidic low concentration electrolyzed water on microbiological, physicochemical, and sensory quality of fresh chicken breast meat. J. Food Sci., **2012;** 77(1): M35-41.
32. **Sally; A.A. Mahran, and Ibrahim; M.** Efficacy of Electrolyzed water in controlling microbial contamination of fresh chicken carcasses. Egy. J. Animal Health, **2023;** 3(3): 28-40.
33. **Sheng; X., Shu; D., Tang; X.and Zang; Y.** Effects of slightly acidic electrolyzed water on the microbial quality and shelf life extension of beef during refrigeration ·Food Sci. Nutr., **2018;** 6(7): 1975–1981.
34. **Tango; C., Mansur; A, Kim; G., and Oh;D.** "Synergetic effect of combined fumaric acid and slightly acidic electrolyzed water on the inactivation of food‐borne pathogens and extending the shelf life of fresh beef," *Journal of Applied Microbiology*, **2014;** 117(6): 1709–1720.
35. **Veberg, A., Sørheim, O., Moan, J., Iani, V., Juzenas, P., Nilsen, A. N., & Wold, J. P.** Measurement of lipid oxidation and porphyrins in high oxygen modified atmosphere and vacuum-packed minced turkey and pork meat by fluorescence spectra and images. *Meat Science*, **2006;** *73*(3): 511–515. https://doi.org/10.1016/j.
36. **Wang, H., Qi; J. Duan; D., DONG; Y., Xu; X. and Zhou; G.** Combination of a novel designed spray cabinet and electrolyzed water to reduce microorganisms on chicken carcasses. Food Control, **2018;** 86: 200-206.
37. **White, G.C.** Chemistry of Aqueous Chlorine. In: White's handbook of chlorination and alternative disinfectants. 5th ed, **2010;** 152-153. New Jersey: John Wiley and Sons.
38. **Xuan, X. T., Ding, T., Li, J.** Estimation of growth parameters of *Listeria monocytogenes* after sublethal heat and slightly acidic electrolyzed water (SAEW) treatment. Food Control, **2017a**; 71: 17–25.
39. **Xuan; X., Fan; Y., and Ling; J.** Preservation of squid by slightly acidic electrolyzed water ice. *Food Control*, **2017b**; 73: 1483–1489.
40. **Xuan and Ling*:*** Generation of Electrolyzed Water.

In Electrolyzed Water in Food: Fundamentals and Applications; Springer Science and Business Media LLC: Cham, Switzerland, 2019; 1-16.

41. **Yan, H., Niu, L. and Xiang, Q.** Application of Electrolyzed Water in Red Meat and Poultry Processing. In book: Electrolyzed Water in Food: Fundamentals and Applications, **2019;** 113-156.
42. **Ye; Z., Wang; S. and Chen; T.,** Inactivation mechanism of e*scherichia coli* induced by slightly acidic electrolyzed water. *Sci Rep.*, **2017;** 7: 1–10.
43. **Zeng; X. Wenwel; T. and Ye; G.** Studies on Disinfection Mechanism of Electrolyzed Oxidizing Water on *E. coli* and *Staphylococcus aureus***.** J. Food Sci., **2010;** 75(5): M253-6.