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Slightly acidic electrolyzed water (SAEW) and its relation with shelf life of chilled shrimps

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Abstract
The study investigated the effect of slightly acidic electrolyzed water (SAEW) as a natural antimicrobial to prolong the shelf life of chilled shrimps. Samples were divided into four groups, 1st group samples were dipped in distilled water for 30 minutes as control, the 2nd, 3rd, 4th groups were dipped in SAEW for 10, 20 and 30 minutes, respectively. The shelf life of shrimps stored in refrigerator at 4±1°C was investigated by measurement of sensory characters or properties [odor, texture and color], hydrogen ion concentration [pH], total volatile basic nitrogen [TVB-N] and thiobarbituric acid [TBA] and microbiological analysis including aerobic plate count (APC) and total psychrotrophic count. From the recorded results, it was found that dipping of the treated groups of shrimps in SAEW for 10, 20 and 30 minutes resulted in reduction of aerobic plate count (APC) on the 4th day of storage by 1.3, 1.76 and 2 log_{10}cfu/g, respectively. as compared with control groups. It was the last day that, the control group samples remain retained its sensory properties and has spoiled on the 6th day of storage. While the 2nd, 3rd and the 4th treated groups remained sound till the 8th, 10th and 11th day of storage period recorded APC of 5±0.2, 5.6±0.09 and 5.7±0.1, respectively. Total psychrotrophic count at the 4th day of storage clarify that the 2nd, 3rd and the 4th treated groups were reduced by 0.57, 0.75 and 1.0 log_{10}cfu/g as compared with the control group, respectively. Overall, SAEW had an effective effect on reduction of both APC and total psychrotrophic count, while its effect was more efficient in reducing APC rather than total psychrotrophic count. Besides, SAEW also prolonged the shelf life of shrimp through retarding the deterioration of odor and color. SAEW treated group samples had lower total volatile basic nitrogen (TVB-N) and Thiobarbituric acid (TBA) values than control samples. The microbiological, chemical and sensory analysis indicated that treatment with SAEW for 30 minutes was the best group of samples (4th group) among treated groups.

Keywords: *SAEW, shrimps, antimicrobial, sensory, TBA, TVB-N, shelf life.*

Introduction

Fresh shrimps have high nutrient content which includes amino acids, peptides, polyunsaturated fatty acids and other useful substances. In addition, shrimp contains a large amount of non-protein nitrogenous compounds and autolytic enzymes which makes it easily to be contaminated by ubiquitous microorganisms. Shrimps are highly perishable and rapidly deteriorate post-mortem which resulted in obvious off-taste and soft texture **(Mastromatteo *et al.*, 2010).**

The shelf life is defined by the period in which a food product remains safe for consumption by maintaining appropriate microbiological, physicochemical, and sensorial characteristics **(Baldwin, 2012).** The short shelf-life of fresh shrimp is brought through biological reactions including lipid oxidation, enzymatic and microbial activities. The inherent susceptibility to deterioration of shrimp makes them more susceptible to food-borne hazards.

Dipping of fish in chemical compounds, such as chlorine or synthetic antioxidants considered widely applied methods to reduce the number of pathogenic or spoilage microorganisms on the surface of fish in order to improve the food safety and to extend the shelf-life of fish.

Slightly acidic electrolyzed water (SAEW) considered a novel sanitizer that has a high antimicrobial effect due to the presence of a high concentration of hypochlorous acid (HOCl), hypochlorite ions ($^{-}$OCL), oxygen gas (O_2), generated chlorine gas (Cl_2) and sodium hydroxide (NaOH) (**Kim *et al.,* 2000a and Hricova *et al.,* 2008**). IT has been increasingly applied during the last decade around the world. The sanitizer effect of SAEW, enables to reduce the corrosion of surfaces of fresh products and minimize the potential damage to human health and the environment. It has been reported that electrolyzed water combined with mild heating was significantly more effective in reducing the number of unwanted organisms on food (**Nan *et al.,* 2010).** The main advantage of using EW is the ability for on-site production, thus circumventing problems associated with chlorination including the transport, storage, and handling of dangerous chlorine **(Jeong *et al.,* 2007).**

Electrolyzed water (EW) has been investigated as a new preservative and has been applied in vegetables, fruits, poultry, meat and seafood **(Huang *et al.,* 2008)**. Besides, EW could also be used in food processing equipment for sanitation purpose, such as seafood processing gloves and surfaces **(Liu and Su, 2006 and Liu *et al.,* 2006)**. Since 2002, it has been authorized for use as a food additive by the Health, Labor and Welfare Ministry in Japan **(Huang *et al.,* 2008).**

Electrolyzed water is active against a broad spectrum of bacteria and possesses nonselective antimicrobial properties. Therefore, it is hypothesized that EW does not promote the growth of bacterial resistance **(Hricova *et al.,* 2008)**. In addition, the sensory quality of food products is not negatively affected by the use of SAEW, neutral electrolyzed water "NEW" and slightly alkaline electrolyzed water "SAEW" **(Hricova *et al.,* 2008; Rahman *et al.,* 2010c, 2011 and 2012).**

SAEW is also eco-friendly and it is generated by electrolysis of NaCl solution and it reverts to plain water after use (**Koide *et al.,* 2009 and Moretro *et al.,* 2012).**

Production of SAEW needs only water and salt (sodium chloride). SAEW have the following advantages over other traditional cleaning agents: A- Effective disinfection, easy operation, relatively inexpensive, and environmentally friendly. B- The main advantage of SAEW is its safety. C- Slightly acidic electrolyzed water contains organic acetic acid which is not corrosive to skin, mucous membrane, or organic material. D- Combination of EW and other measures are also possible. E- It also considered as effective cleaners of food surfaces in food processing plants and the cleaning of animal products and fresh produce **(Ding *et al*., 2015 and Hao *et al.,* 2015)**

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) approximately 95% and hypochlorite ion (ClO^{-}) approximately 5% **(Hricova *et al.,* 2008 and White, 2010).**

The aim of this study was to assess the effectiveness of dipping shrimp for different periods in SAEW and storage at 4±1°C on its shelf life through determining its quality and safety parameters including examination of the sensory characteristics, pH, TVB-N, TBA values and microbial growth.

Materials and Methods

1-Sample preparation: -

Total six kilograms of fresh shrimps were collected from shops at Giza - Egypt. Samples were transferred under strict hygienic measures to laboratory as soon as possible to carry out the experiment. Samples were divided into four groups (0.5kg for each study), 1st group was dipped in distilled water for 30 minutes as control, while the 2^{nd} ,3^{rd} ,4^{th} groups were dipped in SAEW for 10, 20 and 30 minutes, respectively. The samples were drained, packed in polyethylene bags, and stored at 4±1°C. The experiment was repeated in triplicate.

2- Preparation of Slightly acidic electrolyzed water (SAEW) according to Al-Haq *et al.* (2005); and Hricova *et al.* (2008) and Athayde *et al.* (2018) as follows: -

1. Prepare sufficient amount of potable drinking water with addition of sodium chloride (NaCl) by 2 g for each of 1 liter.
2. A current of 9-10 volt-amber (VA) was passed through the water using an electrolysis cell with two poles of anode (+) and cathode (-). Upon the onset of the electrolysis process, NaCl dissolved in water and dissociated into Na^+ and Cl^-
3. Meanwhile, water was reduced at the cathode pole formed hydroxide (OH^-) and Hydrogen (H^+) ions in the solution according to the following formula: .$2H_2O + 2e^- \longrightarrow H_2^+ + 2OH^-$
4. Negatively charged ions represented by the hydroxyl group (OH^- and Cl^- move towards the anode where electrons are released and hypochlorous acid (HOCl), hypochlorite ions (OCl^-), oxygen gas (O_2) and chlorine gas (Cl_2) are generated.
5. The oxygen gas (O_2) combined with one generated oxygen ion (O) forming ozone ($O_2 + O = O_3$).
6. Positively charges ions (Na^+ and H^+) move toward the cathode where they gain electrons, resulting in the generation of sodium hydroxide (NaOH) and hydrogen gas (H_2)
7. A few drops of vinegar 5% was added to the electrolyzed water to adjust the pH 5.4 – 6.5 to be slightly acidic (SAEW).

3-Sensory evaluation

Sensory evaluation was based on the various sensory characters as odor, texture and color **(Zheng *et al.,* 2019)**. A panel of five judges did sensory analysis of stored samples. The samples were evaluated by a 10-point scoring system. High score indicated good quality and vice versa. The border line of acceptability was four for shrimp. Odor was evaluated as flavor scores of shrimp according to a scale from 1 to 10, where 10=sea and none acid odor; 9-8=typical and none acid odor; 7-6=neutral or little of odor; 5-4= slightly ammonia or acid odor; 3-2=ammonia or obviously acid odor; 1= off-odor or serious acid odor. The tight junction between abdomen and cephalothorax was scored as the texture scores, which scaled from 10 (tight) to 1 (loose). Melanosis and presence of yellow-greenish coloration were evaluated as color scores. Melanosis was evaluated according to a scale of 1 to 10, where 10-9=complete absence of black spots; 8-6 =a few small spots on the carapace; 5-3=considerable spotting on the carapace; 2-1= substantial spotting over the entire shrimp. The presence of yellow-greenish coloration beneath the head cuticle was scored according to a scale from 10 to 1, where 10-9 = typical pink color; 8 – 6 = yellow pale/yellow coloration; 5–3= green pale/green coloration and 2-1=dark. The total sensory scores were the means of shrimp's color, flavor, and texture scores. According to this score, if the final quality score is 4, the samples quality is marginally acceptable. If this score is less than 4, the sample is unacceptable. If the final score is 8 to 10, sample has a very good quality. If the final score is 5-7, the sample is acceptable.

4-Chemical analysis: -

4.1-Determination of pH:- according to AOAC (1990)

Ten grams of shrimp were homogenized and mixed thoroughly with 100 mL of distilled water for measuring of pH using a digital pH meter (Suntex TS-1, Taiwan) equipped with a probe-type combined electrode (Ingold) through direct immersion of electrode into the mixture at room temperature.

4.2-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 300 ml 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 mg/100 gm = (R1-R2) X 14.

4.3-Determination of thiobarbituric acid (TBA): -

Thiobarbituric acid (TBA) was determined according to **ES: 63-10/2006.** In a clean blender, about 10 gm of the examined sample was blended with 50 ml of D. W. for 2 minutes, and then washed in distillation flask with 47.5 ml water. 2.5 ml of 4 M hydrochloric acid was added to bring the pH to 1.5, then was boiled till 50 ml distillate was obtained, 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 S mg/ Kg sample where S = the absorbance.

5- Microbiological examination: -

The microbiological quality of shrimp used as control or that treated with SAEW was assessed on the basis of aerobic plate count (APC) and total psychrotrophic count as per the procedure of **APHA (2001)**.

5.1-Aerobic plate count (APC): -

Aerobic plate count of the SAEW treated and control shrimp' samples were determined. Ten grams of each sample was weighed out under aseptic conditions and placed in sterile "Stomacher" bags for the microbiological analysis. Then, 90 ml of sterile physiological saline was added and homogenized for two minutes. A ten-fold serial dilution were prepared. The total bacterial count was determined on agar medium using Standard Plate Count Agar (Oxoid). Incubation was run at 35°C ±1°C for 48 h. Bacterial counts were given in log_{10} cfu/ g.

5.2-Total Psychrotrophic count: -

Psychrotrophic count was determined in a similar method to that for APC, except that plates were incubated at 7±1°C for 10 days. The colonies were counted and expressed as log_{10}cfu/g of sample.

6-Statistical analysis: -

Statistical analyses were run in triplicate and results were reported as mean values ± standard deviation (SD). Data were subjected to analysis of variance (one-way ANOVA Excel 5.0). A p-value less than 0.05 ($p \leq 0.05$) was considered statistically significant. **(SPSS, 2007).**

Results and Discussion

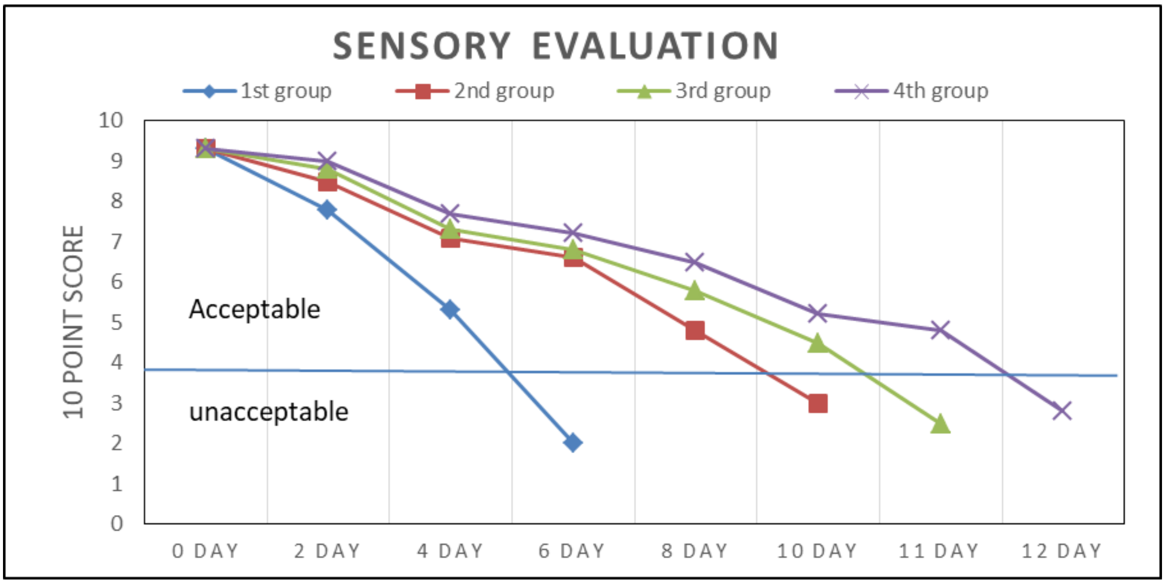

Figure (1): Changes of total sensory properties of treated samples by SAEW and non-treated shrimps stored at 4±1°C. (According to this figure, if the final quality score is 4, the sample's quality is marginally acceptable. If this score is less than 4, the sample is unacceptable. If the final score is 8 to 10, sample has a very good quality. If the final score is 5-7, the sample is acceptable)

Table (1). Mean pH values of control and treated groups (mean of 3 trials ± SD) during storage at 4±1°C

	1st group (control)	2nd group	3rd group	4th group
0 day	$6.43^{a} \pm 0.05$	$6.37^{a} \pm 0.03$	$6.21^{ab} \pm 0.02$	$6.12^{b} \pm 0.15$
2 day	$6.67^{a} \pm 0.04$	$6.47^{a} \pm 0.02$	$6.39^{ab} \pm 0.01$	$6.24^{b} \pm 0.04$
4 day	$6.95^{a} \pm 0.08$	$6.56^{b} \pm 0.05$	$6.44^{bc} \pm 0.15$	$6.31^{c} \pm 0.08$
6 day	Spoiled	$6.68^{a} \pm 0.08$	$6.53^{ab} \pm 0.03$	$6.39^{b} \pm 0.07$
8 day	xx	$6.74^{a} \pm 0.05$	$6.59^{ab} \pm 0.06$	$6.42^{b} \pm 0.03$
10 day	xx	Spoiled	6.61 ±0.07	6.46 ±0.06
11 day	xx	xx	Spoiled	6.53 ±0.05
12 day	xx	xx	xx	Spoiled

No significant difference at ($P< 0.05$) between cells contain same letter in the same row.

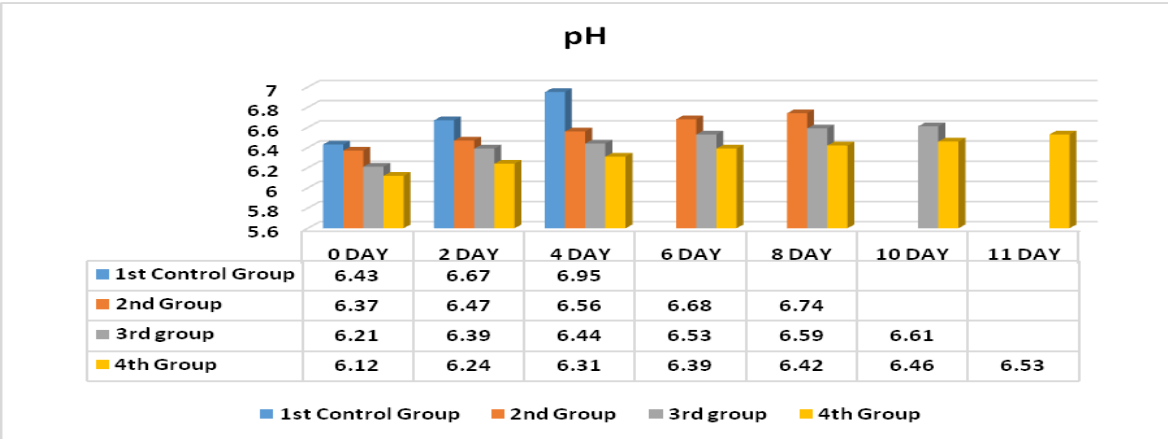

Figure (2). Effect of SAEW on PH value of shrimps during refrigeration storage (4±1°C)

Table (2): Mean values of TVB-N (mg/100 g) of control and treated groups (mean of 3 trials ± SD) during storage at 4±1°C.

	1st group (control)	2nd group	3rd group	4th group
0 day	$20.3^{a} \pm 0.5$	$20.3^{a} \pm 0.5$	$20.3^{a} \pm 0.5$	$20.3^{a} \pm 0.5$
2 day	$26.9^{a} \pm 0.9$	$23.8^{b} \pm 0.8$	$22.8^{c} \pm 0.6$	$22.1^{d} \pm 0.9$
4 day	$33.8^{a} \pm 0.5$	$25.7^{b} \pm 0.7$	$25.2^{c} \pm 0.7$	$24.5^{d} \pm 0.5$
6 day	Spoiled	$29.4^{a} \pm 0.5$	$28^{b} \pm 0.5$	$26.6^{c} \pm 0.4$
8 day	xx	$33.6^{a} \pm 0.6$	$30.1^{b} \pm 0.6$	$29.4^{c} \pm 0.8$
10 day	xx	Spoiled	32.2 ±0.9	31.1 ±0.6
11 day	xx	xx	Spoiled	32.5±0.9
12 day	xx	xx	Xx	Spoiled

No significant difference at ($P< 0.05$) between cells contain same letter in the same row

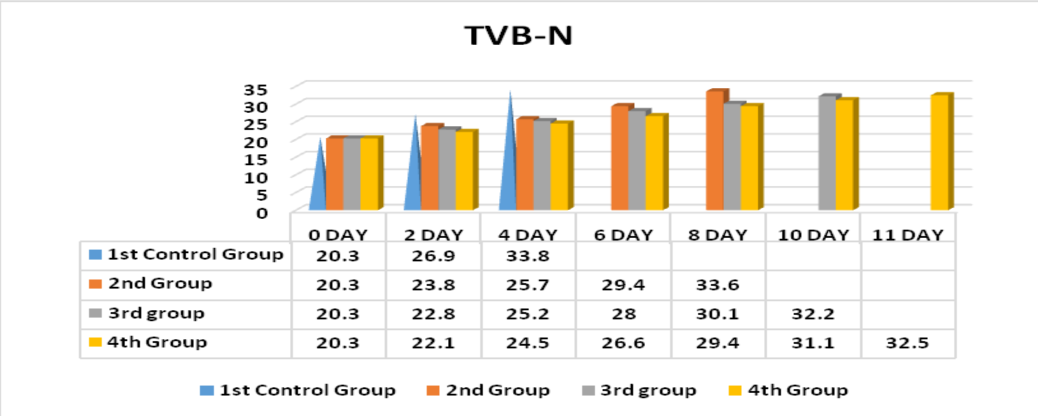

Figure (3). Changes in total volatile basic nitrogen (TVB-N) of treated and non-treated shrimp stored at 4±1°C

Table (3). Mean values of TBA (mg MDA/kg) of control and treated groups (mean of 3 trials ± SD) during storage at 4±1°C

	1st group (control)	**2nd group**	**3rd group**	**4th group**
0 day	0.31^{a}±0.02	0.31 ^{a} ±0.02	0.31 ^{a} ±0.02	0.31 ^{a} ±0.02
2 day	0.52^{a} ±0.04	0.45^{a}±0.06	0.43^{a} ±0.05	0.39 ^{a} ±0.07
4 day	0.63 ^{a} ±0.08	0.52 ^{b} ±0.08	0.50^{b}±0.08	0.47^{b}±0.03
6 day	Spoiled	0.64^{a} ±0.03	0.62^{a} ±0.08	0.59^{a}±0.08
8 day	xx	0.73^{a} ±0.05	0.70^{a} ±0.04	0.66^{a} ±0.05
10 day	xx	Spoiled	0.78 ±0.06	0.78 ±0.05
11 day	xx	xx	Spoiled	0.89 ±0.04
12 day	xx	xx	xx	Spoiled

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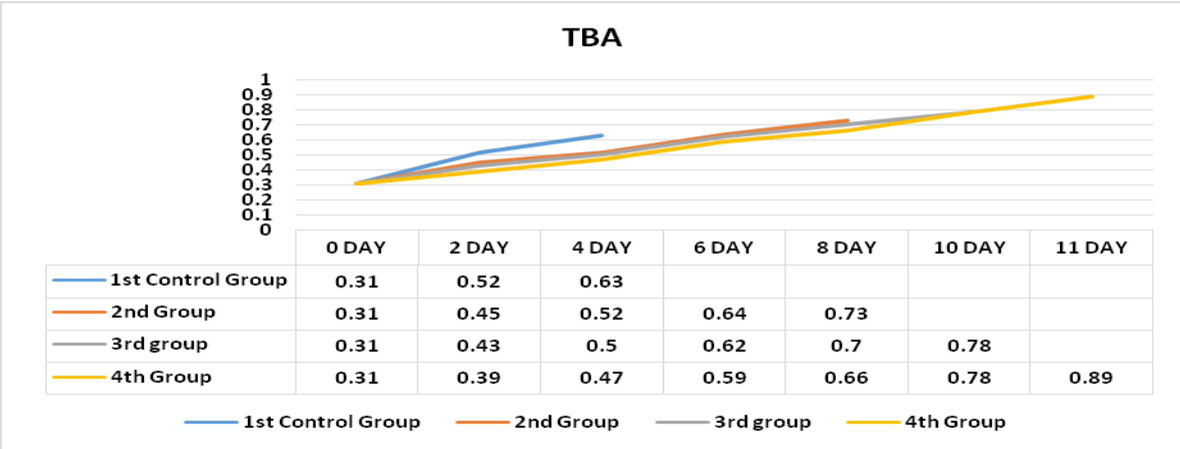

Figure (4). Changes in thiobarbituric acid (TBA) of treated and non-treated shrimps stored at 4±1°C

Table (4). Mean of aerobic plate count (APC) (log_{10} cfu/g ± SD) of the examined groups during storage at 4±1^{o}C

	1st group (Control)	2nd group	3rd group	4th group
0 day	3.65^{a}±0.2	3.3^{b}±0.1	3.17^{b} ± 0.3	3.08^{b}±0.1
2 day	4.3^{a} ±0.1	3.78^{b} ±0.1	3.47^{c}±0.1	3.1^{d} ±0.08
4 day	5.6^{a} ±0.09	4.3^{b} ±0.3	3.84^{c} ± 0.2	3.6^{c}±0.3
6 day	Spoiled	4.7^{a} ±0.5	4.25^{b} ± 0.1	3.9^{c} ±0.2
8 day	xx	5^{a} ±0.2	4.6^{b} ± 0.3	4.3^{c} ±0.1
10 day	xx	Spoiled	5.6 ± 0.09	5.2 ±0.09
11 day	xx	Xx	Spoiled	5.7±0.1
12 day	xx	Xx	xx	Spoiled

No significant difference at (P< 0.05) between cells contain same letter in the same row.

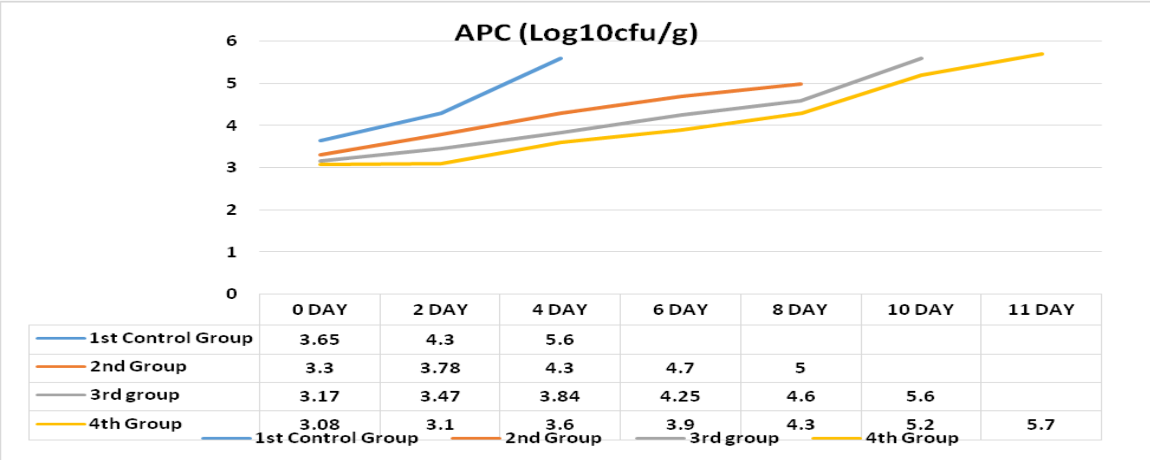

Figure (5). Changes in aerobic plate count (APC) of treated and non-treated shrimp stored at 4±1^{o}C:

Table (5). Mean of total psychrotrophic count (log_{10}cfu/g ± SD) of the examined groups during storage at 4±1^{o}C

	1st group (Control)	2nd group	3rd group	4th group
0 day	2.3^{a}±0.1	2.11^{a} ±0.09	2^{b} ±0.07	1.9^{b} ±0.1
2 day	3.48^{a} ±0.2	2.85^{b}±0.1	2.69^{b} ±0.1	2.28^{c}±0.09
4 day	3.98^{a} ±0.3	3.41^{b} ±0.2	3.23^{b} ±0.3	2.99^{c} ±0.2
6 day	Spoiled	3.74^{a} ±0.1	3.5^{b}±0.3	3.23^{c} ±0.1
8 day	xx	3.98^{a}±0.2	3.8^{a} ±0.1	3.59^{b}±0.1
10 day	xx	Spoiled	4.3±0.09	4.07±0.2
11 day	xx	xx	Spoiled	4.8±0.2
12 day	xx	xx	xx	Spoiled

No significant difference at (P< 0.05) between cells contain same letter in the same row.

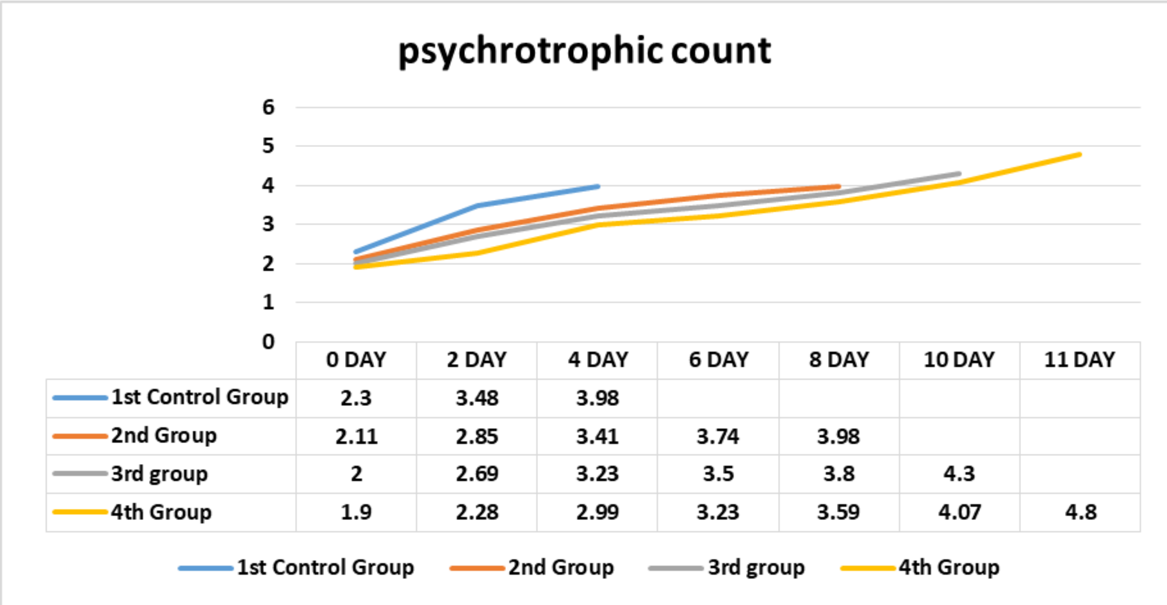

Figure (6). Changes in psychrotrophic count of treated and non-treated groups stored at 4±1°C

The quality of local market shrimp reflects the hygienic measures applied during capture, storage and transportation of raw shrimp. Bad hygienic conditions lead to rapid deterioration of stored shrimp and failing to retain the quality until it reached the consumer. The protein rich shrimps must be supplied to the consumer without losing their freshness. Hence, there is a need to improve storage condition of chilled shrimp.

Sensory evaluation:
The sensory scores of both the control and treated shrimp samples dipped in SAEW for 10, 20 and 30 minutes were decreased with storage period. The observed data regarding the shelf life of the 1st control group of shrimp as determined by panelists indicated that the shrimp was found spoiled on the 6th day while the obtained data indicated sound samples until the 4th day of storage period, while the 2st, 3nd and the 4th treated groups for 10, 20 and 30 minutes were spoiled on the 10th, 11th and 12th day of storage, respectively. So, the analytical data was recorded till the 8th, 10th and 11th day of storage only. The panelists rejected the shrimp samples of both untreated and treated groups at the time of its spoilage throughout the storage period as it considered unaccepted for the consumers even though the microbial load did not exceed the permissible limit of 6 log_{10}cfu/g **(ES:5021/2005)**. The sensory scores of the 1st, 2nd, 3rd and the 4th groups were differed significantly between each other when stored for the same periods. Group 4 of shrimps showed higher score than the other treated shrimp at ($p < 0.05$). Moreover, the 2nd, 3rd and 4th groups scored higher than the 1st group at ($p < 0.05$) during the storage period, while retaining its natural properties and fitness for human consumption **(Fig 1)**. From the obtained data, it can be concluded that all treated groups maintained better sensory quality for the shrimp rather than the untreated group samples.

The obtained results in the present study were coincided with **Wang *et al.* (2014)** who pointed out that acidic Electrolyzed Water (AcEW) ice was able to delay muscle contraction and it had no adverse effects on the firmness of shrimp. Moreover, AcEW inhibit the browning of shrimp which associated with deleterious changes in sensory properties that occurs when Polyphenol oxidase (PPO) oxidizes phenols to quinones, quinones polymerise and finally form black pigment. In this respect, **Sun *et al.* (2017)** mentioned that EW was effective in preserving the quality of shrimp as it delayed its browning discoloration by inhibit the formation of Polyphenol oxidase(PPO) which is an essential enzyme for browning. In the same way, **Lin *et al.* (2013**) said that AcEW could significantly (p<0.05) retarded the changes of color difference and had no adverse effects on the firmness of shrimp and it was clearly more efficient in maintaining the initial attachments between muscle fibers in shrimp. Moreover, they added that AcEW ice can be a new alternative of traditional sanitizer to better preserve the quality of seafood in the future. These results agreed with that obtained in the present study. Using of AcEW increasing the sensory shelf-life and the electrolysis process capable for the efficient disinfection of water and recycled water would allow reducing wastewater and have less impact on the environment **Gil-Maria *et al.* (2015).**

The results obtained in Table (1) and Fig. (2) revealed that pH of the examined groups increased gradually, probably due to the formation of alkaline compounds like amines**,** the pH of the shrimp control group samples increased throughout the studied period from an initial pH of 6.43 to 6.95 at the 4th day of storage, while the 1st control group samples were found spoiled at the 6th day of storage. On the other hand, the 2nd, 3rd, and the 4th treated groups were recorded a pH of 6.74±0.05 at the 8th day, 6.61±0.07 at the 10th day and 6.53±0.05 at the 11th day of storage, while these groups were found spoiled at 10th, 11th and 12th day of storage, respectively. Significant difference (p<0.05) in pH was noticed between the 1st group and the other treated groups during the storage period. Spoilage of shrimp and the formation of alkaline compounds mostly due to autolysis and accumulation of bacterial metabolites **Atrea *et al.* (2009).** The obtained data agreed with **Wang *et al.* (2014)** who mentioned that acidic Electrolyzed Water (AEW) ice found to be effective in delay the elevation of pH towards the alkaline side, which is meant by beginning of deterioration of shrimp. In this respect, the obtained results agreed with **Lin *et al.* (2013)** who concluded that AEW had a potential ability in limiting the pH changes of shrimp flesh. Moreover, **Huang *et al.* (2008)** and **Katayose *et al.* (2007)** announced that AEW is a novel nonthermal bactericidal technology and has less adverse impact on human body as well as the environment. The antimicrobial activity of AcEW is associated with the formation and combination of free chlorine, low pH (**Liu *et al.*, 2006**) and high oxidation-reduction potential (ORP) (**Abbasi and Lazarovitis, 2006** and **Liao *et al.*, 2007**)

TVB-N is a product of bacterial spoilage and the action of endogenous enzymes, and its content is often used as an index to assess the keeping quality and shelf life of food **(Bahmani *et al.,* 2011**). TVB-N is a general term that measuring of volatile basic nitrogenous compounds associated with seafood spoilage. In this study, TVB-N values of all groups are shown in **Table (2) and Fig. (3)**revealed that TVB-N content of all groups increased with storage period, at the beginning of storage period, the initial TVB-N value of flesh was 20.3 mg /100g. This agreed with **Chinivasagam *et al.* (1996)** who found an initial value of shrimps was 22 mg/100g while, **Lopez *et al.* (2007)** found an elevation of TVB-N initial value reached to 30 mg/100 g in pink shrimp. Similarly, **Zeng *et al.* (2005)** reported an initial value of 33.5 mg/ 100 g in shrimp *(Pandalus borealis)*. The mean value of TVB-N of control group samples was recorded 33.8 mg /100 g. on the 4th day of storage period, while the examination was not continued on the 6th day of storage because the control group samples were found in a state of complete spoilage.

Furthermore, TVB-N values recorded 33.6 ± 0.6, 32.2 ± 0.9 and 32.5 ± 0.9 at the 8th, 10th and the 11th day of the storage for the 2nd, 3rd and the 4th treated groups respectively, such levels considered below the permissible level of TVB-N (65 mg /100 g) of fresh shrimp according to **ES. 5021/2005**. **Wang *et al.* (2014)** concluded that Acedic Electrolyzed Water (AEW) retarded the accumulation of total volatile basic nitrogen (TVB-N). Also, **Lin *et al.* (2013)** concluded that AEW could significantly (P<0.05) inhibit the formation of total volatile basic nitrogen (TVB-N). These results coincide with that in the present study.

Malondialdehyde (MDA) is a degradation product of lipid oxidation not only influenced the quality, but also has harmful effects on the human health, this product criticized as a carcinogenic factor in food **(Djenane and Roncales, 2018).** Lipid peroxidation, corresponding to oxidative deterioration of polyunsaturated fatty acids in muscle, leads to the production of off-flavors and off-odors, thereby shortening the shelf-life of seafood **(Zhang *et al.,* 2015).**

TBA was used as indicators of lipid oxidation (**Erkan and Özden, 2008**). According to **(ES:5021/2005)** which recommended that TBA of fresh shrimp should not exceed 4.5 malondialdehyde /Kg. The obtained data in Table (3) and Fig. (4) revealed that the mean TBA value of the control group samples recorded 0.63±0.08 at the 4th day of storage, while TBA values of treated samples were recorded 0.73±0.05, 0.78±0.06 and 0.89±0.04 for the 2nd, 3rd, and 4th group samples at 8th, 10th and 11th day of storage period respectively, which considered below the permissible limit. The obtained results of TBA were agreed with **Rahman *et al.* (2012)** who reported that SAEW contains OH^- and HOCl which has antioxidant effect and that can help fresh chicken breast meat to maintain oxidation stability. While, **Sheng *et al.* (2018)** Concluded that there were no significant differences ($p > 0.05$) between the untreated and SAEW-treated group in the content of thiobarbituric acid, suggesting that SAEW does not possess antioxidant activity. In this respect, **Chen *et al.*(2016)** have reported that SAEW does not have immediate antioxidant activity and found that TBA content of the SAEW-treated samples was not better than untreated control samples. These differences in results might be due to the effect of air, light and temperature which had marked effect on degradation and lipid oxidation in shrimp oils. Also, fresh shrimps flesh is particularly have the ability for rapid oxidation because it contains relatively high levels of unsaturated fatty acids and. **Xuan *et al.* (2017)** have reported that SAEW in the form of ice can maintain relatively low TBA contents during the preservation of squid. This indicates that SAEW ice might be a new approach to ensure the antioxidant activity and control the deterioration of quality and further studies are required to increase the antioxidant activity of SAEW.

Aerobic plate count (APC) for all tested samples are presented in Table (4) and Fig (5), the control group samples recorded 5.6±0.09 at the 4th day of storage, whereas the analysis was stopped at the 6th day of chilled storage as the samples were spoiled. Also, the lowest mean APC was recorded in 4th treated group samples dipped in SAEW for 30 minutes (5.7±0.1 log_{10}cfu/g) at the 11th day of storage, followed by the 3rd treated group (5.6±0.09) at the 10th day and finally, the 2nd group treated samples which recorded 5±0.2 at the 8th day. There was a significant difference ($P<0.05$) between control and all treated groups from the beginning of storage period. Moreover, treated groups dipped in SAEW for 10, 20, 30 minutes were retaining its APC permissible limit till the 8th, 10th and 11th days of storage, respectively **(ES: 5021/2005).** APC increased with the storage period for all groups with a different rate. As expected, APC values of the untreated samples increased at a faster rate than those of all treated ones, indicating antimicrobial effect of SAEW, which agreed with those reported by **(Chen *et al.* (2013 & 2016).** In this regard**, Wang *et al.* (2014)** stated that Acadic Electrolyzed Water (AcEW) ice found to be able to inhibit the growth of bacteria in raw shrimp**.** This substantiates the findings obtained in the present investigation. Also, **Lin *et al.* (2013)** proved that AcEW ice could remarkably inhibit the proliferation of bacteria and the maximum reduction of bacterial growth (APC) on raw shrimp as it reached > 1.o log cfu/g > 90% reduction limit. They also concluded that AcEW ice can be a new better alternative of traditional sanitizer to preserve the quality of seafood in the future. Furthermore, **Rahman *et al.* (2012)** concluded that concentration of EW remains stable for long time, through which the antimicrobial potential property against food-borne pathogens will remain constant without any decline in its efficiency.

Table (5) and Fig. (6) showed the total psychrotrophic count (log_{10} cfu/g ± SD) of the examined samples during refrigerated storage at 4±1°C. On the initial zero day, the TPC in the 1st control group, 2nd, 3rd and 4th group samples were 2.3±0.3, 2.11±0.09, 2±0.07 and 1.9±0.1 log_{10}cfu/g, respectively. While, the four groups recorded 3.98±12, 3.98±0.2, 4.3±0.09 and 4.8±0.2 on the 4th, 8th, 10th and 11th day of cold storage for the 1st, 2nd, 3rd and 4th groups, respectively. From the above-mentioned results, the shrimp's group samples incorporated with SAEW had the lowest microbial load during the storage period compared to the control group. These results could be correlated with the results of TVB-N. This may be attributed to the antimicrobial effect of SAEW. In this respect, **Huang *et al.* (2008)** stated that AcEW found to have strong bactericide activity and could be able to limitation of the growth and multiplication of food spoilage microorganisms over the surface of food products including shrimp. Moreover, AcEW and neutral electrolyzed water (NEW) have been reported to have a strong bactericidal effect on various types of foodborne pathogens as well as food spoilage microorganisms for many types of food products and food equipment surfaces and the shelf life of electrolyzed water was investigated to obtain the best quality electrolyzed water for a long duration (**Khalid *et al.*, 2018**). Various studies have been conducted on the antimicrobial activity AcEW on shrimp; (**Lin *et al.*, 2013; Ratana-Arporn and Jommark 2014);** fish as whole (**Al-Holy and Rasco, 2015**), beef (**Al-Holy** and **Rasco, 2015; Mansur *et al.*, 2015b**), pork (**Rahman *et al.*, 2016)** and poultry carcasses (**Rahman *et al.*, 2012** and **Al-Holy and Rasco, 2015**)

Furthermore, AcEW provide sanitizing processes prior to the refrigeration storage to improve the safety and quality of fresh meat (**Li *et al.,* 2017).** SAEW recognized as an alternative sanitizer, containing a high concentration of hypochlorous acid, with a pH of 5.0–6.5. SAEW has the added advantage of minimized adverse human health effect and safety issues from Cl_2 off-gassing. It is the most environment-friendly potential alternative to broad-spectrum microbial decontaminants (**Zang *et al.,* 2015).** Several investigators have demonstrated that SAEW could be used as a sanitizer to reduce microbial contamination and extend the shelf life of aquatic products (**Hricova *et al.,* 2008 and Zang *et al.,* 2017)**

Conclusion and recommendation

Overall, the microbial, chemical and sensory properties correlated highly with the freshness of shrimp. The obtained results by this article indicated that:

1. Treatment of shrimp using SAEW for 30 minutes was the best way to keep the quality and safety parameters of shrimp as SAEW significantly reduced the APC and psychrotrophic as well as hindering the deterioration of shrimp stored at chilling temperature (4±1^{O}C).
2. Finally, it is recommended to use SAEW as an effective agent for extending the shelf-life of all food products including fresh shrimp throughout protection of the product quality from deterioration as well as protection of consumer health from any risk arises from such products.
3. Also, SAEW found to have many other uses serve the food safety and quality.

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