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A comparative study on the effect of ozone and acidic water on the chemical parameters of fresh beef during refrigeration

Arafa R. Seifeldeen[1*], Hany M. Youssef[1], Mahmoud M. Arafa[2], Mohamed M. Mousa[1]

[1]*Department of Food Hygiene, Faculty of Veterinary Medicine, Alexandria University, Egypt.*
[2]*Department of Biochemistry and Food Deficiency, Animal Health Research Institute (AHRI), Dokki-Giza; Egypt.*

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*Correspondence:

Corresponding author: Arafa R. Seifeldeen
E-mail address: arafaseif235@gmail.com

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ABSTRACT

Beef is one of the most consumed types of meat all over the world and due to it is rich in nutritional composition; make it very liable to chemical spoilage (lipid and protein oxidation). So, enhancing its preservation techniques is highly recommended. The aim of this work was to evaluate the effect of ozone and acidic electrolyzed water (AEW) on quality attributes of beef (pH, total volatile Basics nitrogen (TVB-N), Thiobarbituric Acid Reactive Substances (TBARS) during storage at 4°C (refrigeration) for 12 days. Results revealed that there were significances differences between ozone and acidic electrolyzed water treated samples in pH value when compared with control samples. AEW showed higher enhancement effects on the physicochemical quality of treated beef and beef samples treated with 30 ppm AEW showed the best impacts on physicochemical quality. Results of TBARS and TVB-N were 1.56 and 21.30; 0.83 and 17.47; 0.85 and 15.33; 0.95 and 14.67; 0.84 and 14.73; 0.53 and 14.40; 0.43 and 14.27 for control, 10ppm ozone, 20ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water on day 12/4°C of storage. The present study showed that with increasing ozone concentration, TBARS increased but it still lower than control. From other side these results demonstrated that AEW and ozone caused significant changes in pH, TVB-N and TBARS and could effectively prolong the shelf life of beef in comparison to control samples. So, AEW and ozone can be used in beef to control lipid and protein oxidation that cause meat spoilage during storage.

Introduction

Meat has many benefits for human nutrition, including a high protein content that includes essential amino acids, essential fatty acids and B complex vitamins like cobalamin and vitamin B12, which are found in higher concentrations in products of animal origin, as well as trace amounts of minerals like iron and zinc (Santos and Oliveira, 2012).

Beef meat is a complex system with a rich nutritional composition, making it very susceptible to bacterial and chemical spoilage and the primary cause of chemical deterioration in meat and meat products is lipid oxidation. Meat undergoes lipid oxidation when polyunsaturated fatty acids react with reactive oxygen species. This process leads to the degradation of lipids, the development of oxidative rancidity, and the potential production of hazardous compounds such as malonaldehyde and cholesterol oxides. This process gradually diminishes the sensory and nutritional qualities of meats, which can impact customer acceptance (Amaral *et al*., 2018). Malondialdehyde (MDA) is an enduring byproduct of the oxidative breakdown of polyunsaturated fatty acids (PUFAs). MDA holds significance in both industry and scientific research as it can be utilized for evaluating lipid peroxidation using the TBARS test (Thiobarbituric Acid Reactive Substances), which is the most commonly employed assay for assessing the impact of lipid oxidation on meat and meat products (Min and Ahn, 2005).

Protein oxidation refers to the covalent alteration of a protein caused by direct reactions with reactive oxygen species (ROS) or indirect reactions with secondary by-products of oxidative stress. ROS can lead to oxidation in amino acid side chains and protein backbones, ultimately resulting in protein fragmentation or protein-protein cross-linkages. These processes ultimately give rise to secondary products such as total volatile basic nitrogen or carbonyl (Zhang *et al*., 2013). Both lipid oxidation and protein oxidation contribute to the degradation of beef and decreasing shelf life during storage.

In recent years, various emerging technologies for food preservation have been introduced. This is due to consumer preference for minimally processed food that is free of chemical preservatives. Additionally, there is concern about undesirable consequences caused by thermal treatments, such as pasteurization, blanching, and sterilization, which can lead to decreases in the nutritional value and physical changes in the food. Among the non-thermal technologies applied to maintain the safety and quality of food products, the main studied procedures include radiofrequency, electrolyzed water, gaseous ozone, and high hydrostatic pressure (HHP) (Giménez *et al*., 2021).

The use of gaseous ozone (GO) offers a multitude of benefits. Ozone is capable of attacking the cellular membrane of bacterial cells, making it an effective germicide. Furthermore, any excess ozone rapidly decomposes into oxygen, leaving no residues in food. These two advantages make ozone a promising and attractive antimicrobial technology for the food industry (Akata *et al*., 2015). Ozone treatment plays a crucial role in enhancing the safety and quality of food products. This chemical decontamination method involves exposing a wide range of food items, including fruits, vegetables, beverages, spices, herbs, meat, and fish to ozone.

In the beginning of 2000s, the US Food and Drug Administration formally documented ozone as GRAS (Generally Recognized As Safe) for use in direct contact with food products including fish, red meat and poultry (Code of Federal Regulations, 2001).

The usage of ozone is gradually taking the place of traditional sanitation methods like steam, chlorine and/or hot water. It's becoming more and more popular in the food processing sector as the safest, most economical, and chemical-free way of managing food safety (Vaz-Velho *et al*., 2006). On the other hand, ozone can influence the oxidative status of meat by promoting lipid oxidation and reducing catalase activity and glutathione peroxide activity in ozone-treated meat samples. Furthermore, the treated meat samples displayed lower levels of redness, believed to be a result of the oxidation of myoglobin and oxy-myoglobin to

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met-myoglobin (Cho *et al*., 2014).

Electrolyzed water is typically used in two forms: acid electrolyzed water (AEW) and slightly acid electrolyzed water (SAEW) (Rahman *et al*., 2016). The AEW with a low pH (2.5–3.5), high oxidation reduction potential (1000–1200 mV) and free chlorine (30–90 ppm) (Park *et al*., 2004) and SAEW with a pH of 5.0–6.5 and an ORP of 800–900 mV (Forghani *et al*., 2015). In Japan, the Ministry of Health, Labor and Welfare has approved the use of EW as a food additive for direct contact with food (Yoshida *et al*., 2004). One of the benefits of AEW is that it's environmentally friendly because it's produced using electrolysis of just water and a diluted salt solution (Kim *et al*., 2000), plus AEW reverts to water after use, hence there is no need for concentrated chemicals that could pose a health risk to handle, store, or transport (Al-Haq *et al*., 2005).

Several research and report have been done to prove if electrolyzed water have antioxidant effect or not, (Rahman *et al*., 2012) reported that slightly acidic electrolyzed water(SAEW) exhibits antioxidant activity and can assist in maintaining the oxidation stability (Thiobarbituric acid, TBA) of fresh chicken breast meat. However, Chen *et al*. (2016) reported that slightly acidic electrolyzed water does not have immediate antioxidant activity and found that the TBARS content of the SAEW treated samples was not better than unwashed control samples. Therefore, it is essential to prove if AEW has antioxidant effect on fresh beef. So this work aimed to study the effect of ozone (with different concentration 10ppm, 20ppm, 40ppm) and acidic electrolyzed water (with different concentration 10ppm, 20ppm, 30ppm) on quality attributes of beef tissue (pH, TVB-N, TBARS) during storage at 4°C (refrigeration) for 12 days.

Materials and methods

Collection of fresh beef samples

A total of 18 kg of fresh beef samples were purchased from one butcher's shop in Cairo governorate, Egypt, who applies high hygienic measure. The fresh beef samples were put in sterile plastic bag and hygienically transported in an ice box to the laboratory of Animal Health Research Institute – Dokki lab and subjected to the following examinations.

Generation of ozone

The ozone gas was generated from cold plasma ozone generator (longevity, Canada) using oxygen at a flow rate of 0.25 liter/minute-with a working voltage of 220V-at ambient temperature. The ozone generator was controlled to generate O3 at a required concentration (10ppm or 20ppm or 40ppm). The concentration of O3 was calibrated by iodometric titration method where generated O3 was injected to KI solution (Chemlab NV, Industriezone "De Arend" 2, B-8210 Zedelgem, Belgium) for 5 minutes and titrated against sodium thiosulfate. The concentration of O3 was calculated from the equation recommended by Chasanah *et al*., (2019): Cozone= R x Vt x Nt / Vgas

Where

Cozone: is the concentration of O3 (g/L).

R: is the ratio of analytical mol and the reactant of a balanced chemical equation.

Vt: is the volume of titration (L).

Nt: is the normality of sodium thiosulfate (mol/L).

Vgas: is the volume of air.

Preparation of acidic electrolyzed water

Acidic electrolyzed water (pH of 2.7) and free available chlorine ACC of 10, 20 and 30 ppm was produced by electrolysis of tape water brined with sodium chloride3%. The electrolysis chamber with 2 poles, anode (aluminum) and cathode (carbon) were separated into 2 sides. (Huang *et al*., 2008). The exchange of ions occurs between two separate sides through a bridge containing a saturated solution of sodium chloride where electrode provided with direct current voltage (9-10V and 8-10A) run for 10 minutes. At the anode side, the acidic electrolyzed water was formed which was used for the experiment. The pH level of formed acidic electrolyzed water was estimated using a digital pH meter (3510, JENWAY, U.K) according to FSSAI. (2015). Also, the available chlorine was estimated by chlorine test kit (Hydrion Chlorine indicator strips, Micro Essential Laboratory, Brooklyn, New York 11210) according to Farah and Ali, (2021).

Preparation of samples

Samples were divided into three groups:

The first group was the control group without any treatment about 800 grams, each 100 grams represented an examination sample for one day during refrigeration and stored separately in a plate.

The second group was the ozone group that included different concentration of ozone, (10 ppm, 20 ppm, 40 ppm), each concentration of ozone was exposed to 800 grams of beef samples. Samples were prepared to stimulate retail conditions, where thick beef slices weighing (100 g each) were placed in perforated foam plates separately and wrapped with a plastic net. The study was conducted using 24 perforated foam plates. 24 perforated foam plates were divided into three groups; each group contains 8 plates, each plate (100 gram) represents an examination sample for one day during storage. The first group (8 plates) was submitted to 10 ppm of ozone, the second group (8 plates) was submitted to 20 ppm of ozone and the third group8 plates) was submitted to 40 ppm of ozone. Each 8 foam plates were placed in a vacuum package bags separately and treated with ozone. Before passing ozone gas, the bags were evacuated from air by using a suction plumb then connected to the current of ozone for five minutes. While samples were exposed to ozone, the bags were agitated to allow all surfaces to be adequately exposed to ozone gas. Ozone was left to react for twenty minutes, and then the bags were evacuated via a tube into a 2% KI solution to prevent passing excess ozone to the environment.

The third group was the acidic water group that exposed to different concentration of acidic water (10 ppm, 20 ppm, 30 ppm), each concentration was exposed to 800 grams of beef samples.

All samples were examined on day zero, and then during refrigeration at 4°C on days 1, 2, 4, 6, 8, 10, 12 for pH, total volatile nitrogen (TVB-N), and thiobarbituric acid Reactive substances (TBARS) levels in meat samples were conducted according to EOS 63-11 (2006), EOS: 63-9 (2006), and EOS 63-10 (2006), respectively. The experiment was performed in triplicate.

Statistical analysis

Data were statistically analyzed General Linear Model's procedures of SAS GLM (SAS, 2004). Duncan's multiple range tests (Duncan, 1955) has been used for multiple comparison between means at $P<0.05$. Kolmogorov-Smirnov's test has been used to test the normal distribution of data.

Results and Discussion

Changes in pH during refrigeration at 4°C

pH value of meat increased with storage time. This agrees with the results of other studies (Ouattara *et al*., 1997). The increase in pH has a relationship with food spoilage due to microbial action. The degradation of proteins and production of ammonia can increase pH. In Table 1, relatively low initial pH values of 5.33±0.15, 5.06±0.15, 4.93±0.21, 5.10±0.09, 4.17±0.15, 4.10±0.10 and 4.07±0.06 were obtained for control, 10ppm ozone, 20ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water on day zero, respectively, reflecting the

good condition of beef. The mean value of pH increased in all samples but with different rate, the highest rate was for control samples and the lowest rate for 30ppm acidic electrolyzed water samples. Value of pH increased from 5.30±010 to 6.47±0.15, from 4.77±0.12 to 6.01±0.17, from 4.83±0.12 to 5.60±0.10, from 4.70±0.10 to 5.50±0.17, from 4.23±0.06 to 5.20±0.10, from 4.20±0.10 to 4.93±0.06 and from 4.07±0.12 to 4.53±0.06, for control, 10ppm ozone, 20ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water from day1 to day 12 during refrigeration storage at 4°C, respectively. This mean that with the use of ozone and acidic electrolyzed water, pH value increased (slowly increased) and were not increased as control samples. The results agree with findings of Dondo *et al.* (1992) who reported that with the use of ozone for meat during refrigeration over the course of several days of storage, found that ozone reduced the synthesis of total volatile N compounds, enhanced sensory quality, and prevented the proliferation of surface contaminant. The results suggested that acidic electrolyzed water has effects against spoilage microorganisms, slowing down the increase in pH and retarding the production of basic nitrogen compounds, which was better than those of ozone and this in agreement with the findings of Sheng *et al.* (2018) who reported that slightly acidic electrolyzed water has inhibitory effects on spoilage microorganisms and delaying the generation of volatile basics nitrogen (slowing down the increase in pH).

In accordance with the Egyptian Organization of Standards (EOS-3602/2013) which stated that pH value of chilled meat didnot exceed 6. Based on this, the treatment with ozone and acidic electrolyzed water significantly prolonged the shelf life of beef, from 6 days (control group) to 10 days in 10 ppm ozone treated samples and to more than 12 days in samples treated with 20, 40 ppm ozone and all acidic water group.

Changes in TVB-N during refrigeration at 4°C

The TVB-N consists primarily of up of ammonia and primary, secondary, and tertiary amines (Gill, 1983). It comes from the degradation of proteins and nonprotein nitrogenous substances, which is mostly caused by microbial activity. It is recognized as an essential and sensitive indication of meat freshness during storage (Veberg *et al.*, 2006). The TVB-N values of the samples during storage are shown in Table 2. The initial TVB-N values on day 1 were 14.37±0.15, 13.63±0.15, 13.43±0.15, 12.93±0.12, 13.40±0.20, 13.17±0.15 and 12.90±0.10 mg/100 g for control, 10 ppm ozone, 20 ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water, respectively. The TVB-N gradually increased with storage time in all the treatment groups. However, the increase in TVB-N was substantially ($p < 0.05$) slower in the ozone and acidic water treated samples than in the control sample. With the 20 and 30ppm acidic electrolyzed water treated samples presenting the lowest increasing rate and control samples presenting highest increasing rate. The concentration of TVB-N of the control group rapidly increased to 21.30±0.30a mg/100 g on day 12 of storage, whereas lower values of 17.47±0.15, 15.33±0.15, 14.67±0.06, 14.73±0.06, 14.40±0.10 and 14.27±0.12 mg/100 g were observed in 10ppm ozone, 20ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water, respectively. The acidic electrolyzed water results were better than ozone results. The treatment with ozone and acidic water decreased the production of TVB-N most efficiently, this agrees with findings of Dondo *et al.* (1992) and with the findings of Sheng *et al.* (2018) who reported that slightly acidic electrolyzed water was able to preserve meat for an extended length of time. Its bactericidal effect could be because it slows the increase of pH and generation of TVB-N.

In accordance with the Egyptian Organization of Standards (EOS-3602/2013) which stated that the maximum permissible upper TVB-N limit for beef is 20 mg/100 g. Based on this acceptability limit, the treat-

Table 1. Means value of pH of the examined beef samples during refrigeration condition at 4°C.

Time	Control samples	Ozone			Acidic water		
		10 ppm	20 ppm	40 ppm	10 ppm	20 ppm	30 ppm
Day zero	5.33±0.15^{a}	5.06±0.15^{b}	4.93±0.21^{b}	5.10±0.09^{ab}	4.17±0.15^{c}	4.10±0.10^{c}	4.07±0.06^{c}
Day 1	5.30±010^{a}	4.77±0.12^{bc}	4.83±0.12^{bc}	4.70±0.10^{c}	4.23±0.06^{d}	4.20±0.10^{d}	4.07±0.12^{d}
Day 2	5.41±0.13^{a}	4.97±0.12^{b}	4.70±0.10^{c}	4.47±0.06^{d}	4.33±0.12^{de}	4.23±0.06^{e}	4.03±0.06^{f}
Day 4	5.47±0.14^{a}	4.97±0.12^{b}	4.73±0.12^{c}	4.57±0.06^{cd}	4.50±0.10^{d}	4.17±0.15^{e}	4.13±0.06^{e}
Day 6	5.87±0.15^{a}	5.13±0.15^{b}	4.87±0.06^{c}	4.77±0.06^{c}	4.70±0.10^{c}	4.47±0.12^{d}	4.17±0.06^{e}
Day 8	6.07±0.15^{a}	5.83±0.15^{b}	5.07±0.15^{c}	4.80±0.10^{d}	4.73±0.06^{d}	4.63±0.12^{d}	4.27±0.06^{e}
Day 10	6.30±0.10^{a}	5.93±0.06^{b}	5.27±0.12^{c}	5.17±0.15^{c}	5.10±0.10^{c}	4.77±0.06^{d}	4.33±0.06^{e}
Day 12	6.47±0.15^{a}	6.01±0.17^{b}	5.60±0.10^{c}	5.50±0.17^{c}	5.20±0.10^{d}	4.93±0.06^{e}	4.53±0.06^{f}

Values are expressed as means ± SD, standard deviations. Means in the same row with different superscript letters are significantly different ($P< 0.05$). Maximum permissible limit of pH according to EOS-3602/2013=6

Table 2. Means value of TVB-N of the examined beef samples during refrigeration condition at 4°C.

Time	Control samples	Ozone			Acidic water		
		10 ppm	20 ppm	40 ppm	10 ppm	20 ppm	30 ppm
Day zero	13.33±0.15^{a}	13.00±0.10^{bc}	12.73±0.06^{de}	12.63±0.15^{e}	13.10±0.10^{b}	12.93±0.12^{bcd}	12.83±0.15^{cde}
Day 1	14.37±0.15^{a}	13.63±0.15^{b}	13.43±0.15^{b}	12.93±0.12^{de}	13.40±0.20^{bc}	13.17±0.15^{cd}	12.90±0.10^{e}
Day 2	14.97±0.21^{a}	14.17±0.15^{b}	13.97±0.06^{b}	13.57±0.06^{c}	13.33±0.06^{d}	13.30±0.17^{de}	13.10±0.10^{e}
Day 4	15.23±0.25^{a}	14.43±0.15^{b}	14.13±0.15^{c}	13.77±0.06^{d}	13.73±0.06^{d}	13.53±0.06^{d}	13.10±0.10^{e}
Day 6	16.30±0.20^{a}	14.50±0.20^{b}	14.27±0.06^{c}	13.90±0.10^{de}	14.03±0.06^{d}	13.77±0.06^{e}	13.53±0.06^{f}
Day 8	16.80±0.20^{a}	14.93±0.06^{b}	14.17±0.15^{c}	14.03±0.06^{c}	14.13±0.12^{c}	14.03±0.06^{c}	13.70±0.10^{d}
Day 10	18.20±0.20^{a}	15.33±0.15^{b}	14.70±0.10^{c}	14.13±0.06^{d}	14.63±0.06^{c}	14.17±0.06^{d}	14.00±0.10^{d}
Day 12	21.30±0.30^{a}	17.47±0.15^{b}	15.33±0.15^{c}	14.67±0.06^{de}	14.73±0.06^{d}	14.40±0.10^{ef}	14.27±0.12^{f}

Values are expressed as means ± SD, standard deviations. Means in the same row with different superscript letters are significantly different ($P< 0.05$). Maximum permissible limit of TVB-N according to EOS-3602/2013= 20 mg/100 grams.

Table 3. Means value of TBARS of the examined beef samples during refrigeration condition at 4°C.

Time	Control samples	Ozone			Acidic water		
		10 ppm	20 ppm	40 ppm	10 ppm	20 ppm	30 ppm
Day zero	0.28±0.04^{c}	0.35±0.02^{a}	0.34±0.01^{a}	0.33±0.02^{ab}	0.29±0.02^{c}	0.30±0.02^{c}	0.27±0.02^{c}
Day 1	0.35±0.01^{a}	0.34±0.01^{bc}	0.34±0.01^{b}	0.36±0.01^{a}	0.32±0.01^{c}	0.30±0.01^{d}	0.29±0.02^{d}
Day 2	0.63±0.01^{a}	0.38±0.02^{cd}	0.39±0.04^{cd}	0.41±0.05^{c}	0.47±0.02^{b}	0.35±0.01^{de}	0.31±0.01^{e}
Day 4	0.67±0.01^{a}	0.42±0.05^{c}	0.42±0.06^{c}	0.45±0.08^{bc}	0.52±0.01^{b}	0.38±0.01^{cd}	0.34±0.01^{d}
Day 6	0.73±0.01^{a}	0.65±0.07^{a}	0.69±0.10^{a}	0.72±0.14^{a}	0.55±0.01^{b}	0.39±0.01^{c}	0.33±0.01^{c}
Day 8	0.94±0.14^{a}	0.66±0.06^{cd}	0.77±0.06^{bc}	0.80±0.03^{b}	0.63±0.01^{d}	0.43±0.02^{e}	0.35±0.01^{e}
Day 10	1.29±0.16^{a}	0.64±0.13^{c}	0.78±0.03^{bc}	0.87±0.03^{b}	0.81±0.01^{b}	0.47±0.02^{d}	0.38±0.02^{d}
Day 12	1.56±0.12^{a}	0.83±0.12^{b}	0.85±0.11^{b}	0.95±0.16^{b}	0.84±0.09^{b}	0.53±0.01^{c}	0.43±0.03^{c}

Values are expressed as means ± SD, standard deviations. Means in the same row with different superscript letters are significantly different (P< 0.05). Maximum permissible limit of TBARS according to EOS-3602/2013= 0.9 mg MDA/kg.

ment with ozone and acidic electrolyzed water significantly prolonged the shelf life of beef from 10 days (control group) to more than 12 days in samples treated with ozone and acidic water.

Changes in TBARS content during refrigeration at 4°C

The content of TBARS represents the degree of lipid oxidation of food (Campo *et al*., 2006). Lipid oxidation is an important factor of oxidative deterioration of meat, leading to the formation of off flavor and off-odor, thus limiting the shelf life (Patsias *et al*., 2006). The changes in the content of TBARS of the control, ozone and acidic electrolyzed water treated beef samples during storage are depicted in Table 3. The mean values of TBARS of ozone treated samples on day zero were more than control results and there were no significances differences between acidic water and control results. With the time the content of TBARS increased in all samples, but with different rate. The highest rate of increase in TBARS was in control samples and the lowest rate of increase was in 20 and 30ppm acidic water treated samples. The mean value of TBARS reach to 1.56±0.12, 0.83±0.12, 0.85±0.11, 0.95±0.16, 0.84±0.09, 0.53±0.01 and 0.43±0.03 mg MDA/kg for control, 10ppm ozone, 20ppm ozone, 40ppm ozone, 10ppm acidic water, 20ppm acidic water and 30 ppm acidic water on day 12, respectively. There were significances differences ($p < 0.05$) between the untreated (control) and ozone treated samples results on day 12, however with the increase of ozone concentration from 10 to 40ppm, the content of TBARS increased (but with no significance difference) and it still better than control samples, which is consistent with the findings of a previous study (Rice *et al*., 1982) who reported that using too much ozone could cause food to oxidize on its surface, the authors emphasized that ozone is not always advantageous and can even encourage oxidative deterioration in certain situations.

The presented data also showed that there were significances differences ($p < 0.05$) between the untreated (control) and acidic electrolyzed water treated samples on day 12, suggesting that acidic electrolyzed water has antioxidant activity. This is different from the findings of Chen *et al.* (2016) who reported that slightly acidic electrolyzed water has no immediate antioxidant activity and Sheng *et al.* (2018) who showed that during storage at 4°C, slightly acidic electrolyzed water was unable to support fresh beef in maintaining oxidative stability (e.g., thiobarbituric acid [TBA] reduced). The difference in the results may be due to acidic electrolyzed water has more active clorine and low pH than slightly acidic electrolyzed water. However, this is constitent with the findings of Rahman *et al.* (2012) who found that slightly acidic electrolyzed water has an antioxidant effect and can support the maintenance of oxidative stability in fresh chicken breast meat (Thiobarbituric acid, TBA).

In accordance with the Egyptian Organization of Standards (EOS-3602/2013) which stated that Maximum permissible upper TBARS limit for beef is 0.9 mg MDA/kg. Based on this acceptability limit, the treatment with ozone and acidic electrolyzed water significantly prolonged the shelf life of beef from 6 days (control group) to 12 days in samples treated with10 ppm ozone, 20ppm ozone and 10ppm acidic water , to 10 days in 40ppm ozone and to more than 12 days in 20 and 30 ppm acidic electrolyzed water.

Conclusion

Ozone and acidic electrolyzed water have shown to be a promising food preservative, that have an enhancement effect on the physicochemical quality of fresh beef (pH, TBARS and TVB-N) during the refrigerator storage and the result suggest that AEW is a potential method to extend the shelf life of fresh beef better than ozone.

Conflict of interest

The authors declare that they have no conflict of interest.

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