


Review

Applications of Electrolyzed Water as a Sanitizer in the Food and Animal-By Products Industry

Juan C. Ramírez Orejel ¹ and José A. Cano-Buendía ^{2,*} 

¹ Facultad de Medicina Veterinaria y Zootecnia, Department of Animal Nutrition and Biochemistry, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria, México D.F. 04510, México; jrorejel@unam.mx

² Facultad de Medicina Veterinaria y Zootecnia, Department of Microbiology and Immunology, Universidad Nacional Autónoma de México (UNAM), Ciudad Universitaria, México D.F. 04510, México

* Correspondence: jcano@unam.mx; Tel.: +52-(55)-5622-5900

Received: 31 March 2020; Accepted: 29 April 2020; Published: 2 May 2020



Abstract: Food demand is increasing every year and, usually animal-derived products are generated far from consumer-places. New technologies are being developed to preserve quality characteristics during processing and transportation. One of them is electrolyzed water (EW) that helps to avoid or decrease the development of foodborne pathogens, or losses by related bacteria. Initially, EW was used in ready-to-eat foods such as spinach, lettuce, strawberries, among others; however, its application in other products is under study. Every product has unique characteristics that require an optimized application of EW. Different sanitizers have been developed; unfortunately, they could have undesirable effects like deterioration of quality or alterations in sensory properties. Therefore, EW is gaining popularity in the food industry due to its characteristics: easy application and storage, no corrosion of work surfaces, absence of mucosal membrane irritation in workers handling food, and it is considered environmentally friendly. This review highlights the advantages of using EW in animal products like chicken, pork, beef, eggs and fish to preserve their safety and quality.

Keywords: electrolyzed water; foodborne pathogens; sanitization

1. Introduction

The human population is continuously growing [1] and, consequently, food demand is also increasing. Animal-based protein plays an important role in the human diet. However, animal products are very susceptible to contamination by foodborne pathogens like *Escherichia coli* [2], *Salmonella* [3,4], *Listeria monocytogenes* [5,6], *Campylobacter jejuni* [7], and so forth which are related with processing plants, slaughterhouses and outbreaks in different countries.

Food can become contaminated during processing, transportation or storage, causing losses of 75% in developing countries [8]. The abundance of biological macromolecules (carbohydrates, proteins, lipids, nucleic acids) offers a perfect environment for the development of different pathogens that can spoil and lead to different diseases, if contaminated food is consumed.

Safety is an important concern for consumers and the food industry, hence different technologies have been developed to preserve quality. The food market is demanding products with less processing and fewer alterations in the organoleptic properties. One alternative is the use of electrolyzed water, considered a non-thermal chemical technology [9].

2. Electrolyzed Water

Electrolyzed water (EW) is a sanitizer that contains mostly hypochlorous acid (HOCl), which is responsible for the bactericidal effect [10]. It is gaining popularity because of its physical and

chemical properties. EW manufacturing requires NaCl and water; it can be applied in different fields. Initially, it was used to disinfect medical supplies (e.g., dialyzers) [11]; afterwards, different applications were reported like disinfection of ready-to-eat foods (fruits and vegetables), where it helps to control food contamination and microbial spoilage, as well as improving safety and shelf life, without affecting organoleptic properties [12]. Different antimicrobial effect against viruses [13,14], bacteria, and toxins [15–17] through short periods of exposure (5 to 20 s) have been reported. EW has many advantages; the most important is that it is considered environmentally friendly; after reaction with bacteria and organic material, it reverts to water and salt and, because EW kills bacteria physically, accordingly, they do not generate resistance [18].

EW is generated by an electrolysis process of saline solution (NaCl or KCl) contained within an electrolytic chamber with positively and negatively charged electrodes, with or without a membrane [19]. During electrolysis, NaCl dissociates into Na^+ and Cl^- ions and water into OH^- and H^+ . Negatively charged ions (Cl^- and OH^-) are attracted to the anode, where these reagents are oxidized and generate hypochlorous acid, hypochlorite ion, hydrochloric acid, oxygen gas, and chlorine gas; positive ions (Na^+ and H^+) are attracted to the cathode and reduced, producing hydrogen and sodium hydroxide (Figure 1).

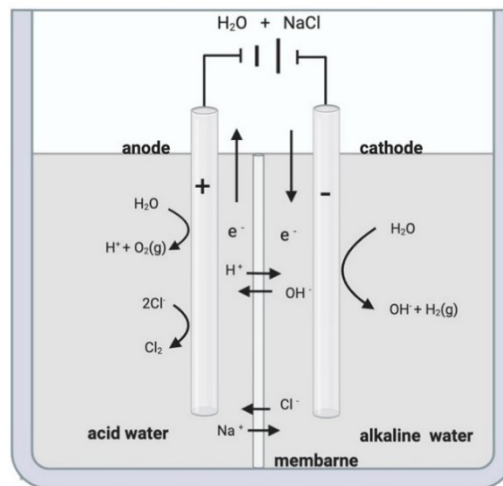


Figure 1. Schematic diagram of electrolyzed water (EW) generation.

There are many factors that affect the generation of all the reagent species [20]. The main species that provide bactericidal characteristics are hypochlorous acid (HOCl) and hypochlorite ions (OCl^-); it has been reported that concentrations of both species are related with pH [10] and oxidation-reduction potential (ORP), which is related to its ability to be oxidized or reduced, generating its bactericidal effect. Loss of bacterial membrane integrity increases permeability and generates bacterial lysis as well as DNA destruction [21].

Electrolysis produces three types of EW [20] (Table 1). Acidic EW (AEW), pH (2.3 to 2.7), and ORP (>1000 mV) is produced at the anode side. Basic EW (BEW), pH (10 to 11.5), and ORP (800 to 900 mV) is generated at the cathode side. Neutral EW (NEW) is produced using different protocols [9]. It could be generated when the electrolytic cell does not have a separative membrane [20] or by mixing the catholyte with a diluted NaCl solution [22,23]. It has been reported that NEW is more stable and keeps its antibacterial activity after storage in comparison to AEW and BEW [24,25].

Table 1. Properties of different types of electrolyzed water.

Type of Electrolyzed Water	pH	ORP ^a (mV)
Acidic electrolyzed water	2–3	>1100
Basic electrolyzed water	10–13	–800 to –900
Neutral electrolyzed water	6.5–7.5	700 to 800

^a Oxidation reduction potential.

The bactericidal effect of EW is a combination of different activities; however, all of them focus on the loss of bacterial membrane integrity. Some reports show this effect against different foodborne pathogens [26,27]. AEW has strong antibacterial activity, which is due to high ORP and low pH. HOCl can penetrate bacterial membranes [28] and oxidizes proteins involved in important metabolic pathways [29]. It can damage bacterial genetic material [20]; however, antibacterial effect by free chlorine decreases with increasing pH [10]. It has been reported that HOCl is produced by phagocytic cells through the oxidative burst pathway, also producing a hydroxyl radical that acts on different pathogens [10,30]. BEW has a pH higher than 11, and its bactericidal effect has been reported to be caused by a strong ORP which reduces free bacterial radicals [18]. ORP causes modifications in metabolic flux and ATP production; it inhibits glucose oxidation; disrupts protein synthesis; and inhibits oxygen uptake and oxidative phosphorylation, which is coupled with the leakage of some macromolecules [31] and damage to bacterial membranes [32]. NEW has been described as the less corrosive EW, and it can be stored longer than AEW [33]. In general, all active chlorine forms (Cl_2 , HOCl and ^-OCl) damage the outer bacterial membrane, allowing HOCl to penetrate bacteria, and oxidize proteins and enzymes involved in metabolic processes (e.g., phosphate acetyltransferase-acetate kinase, ribose-5-phosphate, and others) [34,35] (Figure 2).

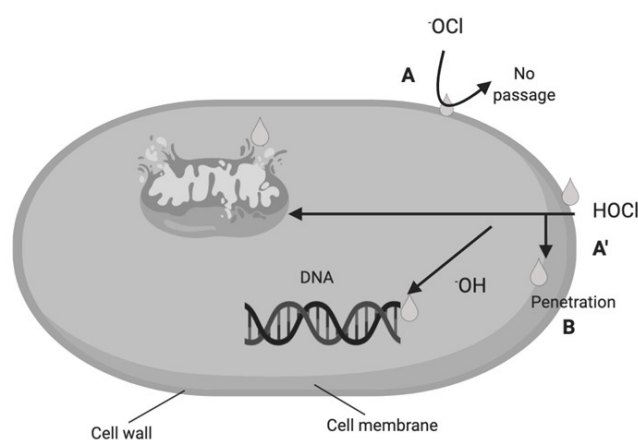


Figure 2. EW bactericidal activity. The hypochlorite ion (^-OCl) cannot penetrate bacterial membrane A. Hypochlorous acid (HOCl) can diffuse through bacterial membrane and disrupt outer membrane A', internal membrane B, and bacterial proteins C. Alteration of bacterial DNA has been reported (Adapted from Rahman [20]).

The use of EW has shown many advantages against other disinfectants; however, some reported limitations are short lifespan; AEW is corrosive [36] to metal [37] and leaves a salt residue on products affecting texture and taste. NEW has not shown these limitations [36]. Len et al. [30] have reported that EW is sensitive to light and should be stored in a closed container.

The use of EW is gaining popularity. In this review, we will put an emphasis on EW use on different animal meats and sub-products to maintain food safety and avoid spoilage.

3. Pork

Pork is a very popular food around the world and its consumption represents about 40% of the global amount, compared to other animal meats [38]. One of the main goals in porciculture is preservation of freshness. To maintain this characteristic, many enhancers are used to improve palatability [39] and preserve quality.

In the following evaluations, most have been made using AEW (Table 2). Fabrizio [40] evaluated the treatment of pork belly artificially inoculated with 8 mL of manure with *Listeria monocytogenes*, *Salmonella typhimurium* and *Campylobacter coli*. One modification was the evaluation of aged AEW to identify any difference with fresh AEW. EW effect was compared with the bactericidal effect of lactic acid, chlorinated water, and plain water. There was no significant difference between treatments, the only difference was between the use of treatment and no treatment with respect to total viable counts (TVC): *E. coli*, *Salmonella typhimurium*, *Listeria monocytogenes* and total coliform survival numbers after zero, two, and seven days post treatment. In the case of *Campylobacter coli*, AEW showed similar patterns as described previously at days zero and two, no significant difference was detected at day 7. This work showed that 15 s spray treatment can eliminate bacterial contamination; however, for other pathogens, it is necessary to increase contact time over 10 min. In a follow up of this study by the same researchers, they showed the effect of AEW and BEW on frankfurters and ham, given their popularity as a food type. Dipping versus spraying treatments were compared using *Listeria monocytogenes*, *Salmonella typhimurium* and *Campylobacter coli* as contaminants [41]. AEW decreased the *L. monocytogenes* population at days zero and seven; however, there was no significant difference between treatments when they were evaluated against aerobic mesophilic bacteria. AEW did not change bacterial counts on frankfurters after seven days of treatment. Treated ham showed a slight decrease in the *L. monocytogenes* survival population after treatments ($\sim 0.5 \log_{10}$ CFU/g) at days zero, three and seven; AEW did not affect the color of ham. Once more, this group confirmed that 15 s exposure time is enough to eliminate *Campylobacter sp* but it is not enough time to eliminate other pathogens attached to the surface of pork.

Mansur et al. [42] evaluated the use of AEW and slightly AEW (SAEW) (pH 6.29) on 10 g of fresh pork loins. As a novelty, they evaluated the combination of SAEW with 0.5% fumaric acid (FA). Pork samples were contaminated with 100 μ L of a bacterial cocktail containing 8 Log CFU/mL of *E. coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus* and *Salmonella Typhimurium*. Meat was stored at 4 °C or 10 °C. Samples were dipped in evaluated solutions for 3 min. There was no significant difference between AEW and SAEW treatments. This result suggested that the bactericidal effect of EW is due to the concentration of available chlorine rather than pH and ORP. The combination of FA with SAEW yielded higher reductions ($\geq 2.5 \log$ CFU/g) against all evaluated pathogens compared to all treatments. At the same time, this combination increased shelf life in pork by five to six days.

Other research group [43] evaluated the effect of sprayed AEW on pork loins at different pressures and time of treatments. AEW decreased lactic acid-producing bacteria at day one after treatment. No differences were reported on the rest of the sampling days. Additionally, AEW decreased mesophilic bacterial counts at day one but not at days 15 and 29. When BEW was evaluated in combination with AEW or SAEW, the combination worked much better against mesophilic and psychrotrophic bacteria. EW did not affect pH, ORP or the red color of pork, and EW did not accelerate lipid oxidation. However, AEW and SAEW oxidize pork protein shortly after application.

Table 2. Evaluations of electrolyzed water in pork.

Material	Type of Electrolyzed Water	Concentration of EW (ppm)	Microorganisms	Inoculum Concentration ^b	Type of Treatment	Duration of Treatment	Reference
Pork belly	AEW, AEW + lactic acid	50	<i>L. monocytogenes</i> <i>Salmonella</i> Typhimurium <i>Campylobacter coli</i>	7 log CFU/mL	Spray	15 s	[40]
Frankfurters Ham	AEW and BEW	50	<i>L. monocytogenes</i>	5 log CFU/mL	Spray, dip	15 s	[41]
Fresh pork loin	AEW + fumaric acid	30	<i>E. coli</i> <i>L. monocytogenes</i> <i>Staph. Aureus</i> <i>Salmonella sp</i>	8 log CFU/mL	Dip	5 min	[42]
Carcass	low concentration EW (NEW)	10	<i>E. coli O157:H7</i>	9 log CFU/mL	Dip	5 min	[38]
Pork loin	AEW and slight AEW	74	<i>L. monocytogenes</i> Mesophilic and psychrotrophs	4.12 log ₁₀ CFU g ⁻¹	Spray	20–40 s	[43]
Pork loin	BEW	ND ^a	ND	ND	Injection	15 min	[44]
Pork loin	NEW	16.6	Aerobic bacteria Psychrotrophs Yeast and moulds	0.55 to 0.57 log CFU/cm ⁻² 0.49 to 0.54 log CFU/cm ⁻² 0.52 to 0.60 log CFU/cm ⁻²	Spray	120 s	[45]

^a Non determined; ^b For mesophilic, psychrotrophs, yeast and mould, inoculum concentration values were obtained from the no-treatment group.

EW has been tested as an enhancer [44] to improve water holding capacity. However, AEW did not improve pork tenderness or sensorial characteristics.

In 2013, a new EW was evaluated [38]. It was called low concentration EW (pH 6.8), but it can be considered a form of NEW. This solution was evaluated with 3% calcium lactate (CaL) on contaminated carcasses. Treatments were performed by immersion at room temperature for 5 min. The greatest bactericidal reduction (2.2 log CFU/g) was achieved with a combination of the EW with CaL. Shelf life was increased from six to 12 days with treatment. The combination of EW with CaL did not alter pH during pork storage at 4 °C. The combination retarded microbial growth during storage and reduced surface microbial counts. Another research group [45] evaluated NEW at different concentrations on pork (*Longissimus thoracis*). They evaluated different concentrations, the highest of which (0.1%) inactivated the highest number of bacteria on pork surfaces at days zero and seven. Previously, we described how Fabrizio [40] reported that 15 s exposure time reduced *Campylobacter* counts. However, this evaluation showed that treatment affected total haem pigment (THP) content and the variability of myoglobin forms in pork. Treatment decreased THP values by 8.3% and 14.2% at days zero and seven of storage, respectively. These results mean that the bright red fresh color was lost (discoloration). This effect could be due to the available chlorine concentration because available chlorine oxidized myoglobin into metmyoglobin. Treatment also affected *L* value from CIELab space. They reported an effect of lowest *L* value when NaCl concentration decreased and an opposite effect was observed on *a* value. However, these color changes were not significant for consumers after seven days of treatment. Treated pork had the best sensory scores (color, odor, and appearance).

4. Fish

Fish is an important food worldwide because of its nutritional components [46]; this characteristic increases its demand in wealthy countries. This could be the reason why this product has the higher number of studies with EW (Table 3), especially with AEW. All the cited studies reported two types of treatments: immersion in solution and immersion in ice. This could be due to the way fish is produced/captured. In this document, we divided treatment method by fish type.

Table 3. Evaluations of electrolyzed water in fish.

Material	Type of Electrolyzed Water	Concentration of EW (ppm)	Microorganisms	Inoculum Concentration ^b	Type of Treatment	Duration of Treatment	Reference
Salmon	AEW and BEW	76.9	<i>E. coli</i> O157:H7	8.7 log CFU/mL	Immersion	64 min	[47]
Salmon, mahi mahi (<i>Coryphaena hippurus</i>)	AEW	50	<i>L. monocytogenes</i>	4.47 log CFU/g	Immersion	5 min	[48]
Salmon	AEW	65	<i>L. monocytogenes</i> Aerobic bacteria Coliforms Yeast and moulds	4.02 log CFU/g 6 log CFU/mL 4.2 to 5.9 log CFU/g 2.8 to 4 log CFU/g 1.3 to 2.9 log CFU/g	Immersion	5 min	[49]
Salmon	AEW, NEW	60	<i>L. monocytogenes</i>	7.70 log CFU/g	Immersion	10 min	[50]
Smoked salmon	AEW	60	<i>L. monocytogenes</i>	8.48 log CFU/mL	Immersion	10 min	[51]
Salmon, tuna fish skin	AEW	100	<i>Enterobacter aerogenes</i> <i>Enterobacter cloacae</i> <i>Klebsiella pneumoniae</i> <i>Morganella morganii</i> <i>Proteus hauser</i>	8 to 9 log CFU/mL	Soaking in ice	120 min to 24 h	[52]
Tuna	AEW + CO gas	10, 50 and 100	Aerobic bacteria	3.14 log CFU/g	Immersion	5 min	[53]
Tuna	AEW	41	Aerobic bacteria	< 3 log CFU/mL	Immersion	15 min	[54]
Catfish	AEW	300	<i>L. monocytogenes</i> <i>Salmonella spp</i>	5 log CFU/g	Wash	3 min	[55]
Catfish	BEW + polyphosphate	ND ^a	ND	ND	Immersion	2 h	[56]
Tilapia	AEW	120	<i>E. coli</i> <i>Vibrio parahaemolyticus</i>	8 log CFU/mL	Immersion	10 min	[57]
Tilapia	NEW + PROSAN	150	<i>Listeria innocua</i> <i>E. coli</i> K12 <i>Pseudomona putida</i>	6 to 7 log CFU/g	Soaking in ice	72 h	[58]
Carp	BAE AEW	0.87 40.8	Aerobic bacteria	6 log CFU/mL	Immersion	15 min	[59]
Pacific saury (<i>Cololabis saira</i>)	weak AEW	34.2 to 47.2	Aerobic bacteria Psychrotrophic bacteria	3 log CFU/g	Soaking in ice	30 days	[60]
Trout	AEW	38	Aerobic bacteria	9 log CFU/mL	Immersion	5 to 10 min	[61]
American shad (<i>Alosa sapidissima</i>)	AEW + chitosan	70 to 80	Aerobic bacteria	3.71 to 3.94 log CFU/g	Immersion	15 min	[62]
Bombay duck	slightly AEW +ebony-bamboo leaves complex extracts	27.37	Aerobic bacteria	1.5 log CFU/g	Immersion	5 min	[63]
(<i>Harpadon nehereus</i>) Shrimp	AEW	66	<i>V. parahaemolyticus</i>	9 log CFU/mL	Immersion	2.5 min	[64]
Shrimp	AEW	44	Aerobic bacteria	6.04 log CFU/g	Soaking in ice	7 days	[65]
Oyster	AEW	30	<i>V. parahaemolyticus</i> <i>Vibrio vulnificus</i>	8.94 log CFU/mL	Immersion	4 to 6 h	[66]
Clams and mussels	AEW BEW	20 10	<i>E. coli</i> O104:H4 <i>L. monocytogenes</i> <i>V. parahaemolyticus</i> <i>Aeromonas hydrophila</i>	9 log CFU/mL	Immersion	1 to 2 h	[67]

^a Non determined; ^b For aerobic, coliforms, yeast and mould, inoculum concentration values were obtained from the no-treatment group.

4.1. Salmon

This fish type has high economical value. Ozer evaluated the use of AEW or a bitreatment of BEW + AEW by immersion at different times and temperatures against *E. coli* and *L. monocytogenes*. AEW decrease bacterial counts after treatments at 35 °C and 64 min; furthermore, the use of BEW did not increase the anti-microbial effect [47]. Another study evaluated the use of AEW against various strains of *L. monocytogenes* and *Morganella morganii* on artificially contaminated salmon and mahi-mahi fish (*Coryphaena hippurus*); here, in contrast, EW treatment did not reduce bacterial counts on fish [48].

Miks-Krajnik [49] performed a similar study where EW treatment was combined with ultrasound (US), UV, or US+UV. Treatments were evaluated against *L. monocytogenes* and natural microbiota. Their results showed that US+UV and US+UV+AEW caused bacterial reduction in salmon.

In another study, they use of AEW or AEW+NEW was evaluated on raw Atlantic salmon fillets contaminated with *L. monocytogenes*. Results showed that NEW has better bactericidal activity than AEW. NEW caused reductions of 5.6 log CFU/g after a 10 min treatment at 65 °C. An important characteristic was that NEW has less negative impact on salmon protein than AEW; this could be due to the pH of each solution. This group detected that temperature and time of contact are important factors that affect bactericidal activity of EW [50]. Cold smoked salmon is very popular; therefore AEW was evaluated with this food; it was inoculated with *L. monocytogenes* at different temperatures and contact times. A different research group [51] concluded that treatment at 40 °C for 10 min, before curing, can reduce bacterial numbers by 3.0 log/g without affecting sensorial properties. If treatment was performed at different temperatures, bactericidal effect can decrease to 1.5 to 2.0 log/g.

A different approach was used when AEW was evaluated during ice treatment against histamine-producing bacteria found on Atlantic salmon and yellowfin tuna fish skins [52]. Fish skin was soaked in 50 ppm AEW and *Enterobacter cloacae*, *Kebsiela pneumoniae* and *Proteus hauseri* did not survive after treatment; however, *Enterobacter aerogenes* and *Morganella morganii* did survive. In a second experiment, researchers increased concentration and exposure time. They evaluated EW in ice solution at 50 and 100 ppm during different exposure times against *E. aerogenes* and *M. morganii*. *M. morganii* counts were reduced after 6 h of treatment by 0.91 and 1.4 log CFU/cm² using 50 or 100 ppm treatment solutions, respectively. *E. aerogenes* showed better reduction counts (1.27 and 1.62 log CFU/cm²) using 50 and 100 ppm treatments after 24 h, respectively. Results were similar when experiments were performed with yellowfin tuna skin.

4.2. Tuna Fish

Tuna is used to prepare sashimi, and to preserve the quality of this fish, tuna was soaked using different concentrations of AEW in combination with CO₂ treatment. AEW at 50 ppm with CO₂ showed the best antibacterial effect because aerobic bacterial counts were lower compared to the other treatment groups and total volatile basic nitrogen (TVB-N) values were the lowest during storage. This combination did not affect tuna color [53]. In a different study [54], AEW was combined with an edible solution containing 0.5% eugenol and 0.5% linalool (essential oils). TVB-N values were lower in treated tuna after 20 days of storage and treatment extended shelf life of semi fried tuna fillets.

4.3. Catfish

Near neutral EW (pH 6.4) was evaluated on catfish fillets at 300 ppm. A solution was used to wash fillets, but treatment did not reduce *L. monocytogenes* counts. However, near neutral EW treatment 3 min treatment showed a bactericidal effect against *Salmonella sp* and this reduction was maintained through 13 days after treatment [55]. In another study [56], BEW (pH 11.6) was combined with polyphosphate which has properties such as moisture retention, oxidation prevention, and cryoprotectant, and it extends shelf life. BEW alone or in combination were used to treat catfish fillets before the freezing process. Both treatments helped catfish muscle to retain water after 90 days of storage; this effect was not detected when no treatment or tap water was used. BEW treatment helped reduce water loss during cooking after freezer storage. BEW + triphosphate did not affect color and caused lower lipid oxidation (TBARS) production in comparison to no treatment or tap water treatment. The combination of BEW with polyphosphate improved weight gain, moisture retention, and oxidation resistance after freezer storage.

4.4. Tilapia

Tilapia fillets are gaining popularity, and its production is cheaper when compared to other types of fish. To study the bactericidal effect on tilapia, fillets were artificially contaminated with *Escherichia*

coli and *Vibrio parahaemolyticus*. Fish were soaked for 10 min with AEW. Treatment caused reduction values of 0.7 and 1.5 log CFU/cm² for *E. coli* and *V. parahaemolyticus*, respectively. This study established that agitation helps EW to react with bacterial cells more efficiently [57]. Feliciano evaluated the combination of NEW and an organic acidic sanitizer PRO-SAN [58], both as ice flakes on filleted tilapia fish. Fillets were inoculated with *Listeria innocua*, *E. coli* K-12, and *Pseudomonas putida*. The initial finding was that tap water ice melted faster than NEW- and PRO-SAN-treated ice. When fish were kept in ice, bacterial numbers were smaller for *E. coli* and *P. putida*; however, no significant difference was detected. In the case of *L. innocua* there was no difference found. Water collected from treated melted ice showed lower bacterial counts than non-treated ice. Authors concluded that EW has the potential to reduce bacterial load when it is used as ice; however, results showed no significant reduction.

4.5. Other Types of Fish

AEW (pH 2.22) and BEW (pH 11.6) were evaluated on carp fillets [59]. Fillets were dipped in EW and 16 pure cultures of aerobic bacteria were used to evaluate treatment. The use of both solutions caused important bacterial reductions; however, under AEW treatment, bacterial counts were below the detection limit (10² CFU/mL).

Weak AEW (pH 5.1) was evaluated as ice on pacific saury fish (*Cololabis saira*) [60]. When ice (pH 4.9) was formed, 30% of the active chlorine was lost, thus explaining the change in pH. Aerobic and psychrotropic bacterial counts were lower than tap water ice treatment. EW as ice showed a bactericidal effect on pacific saury fish during refrigerated storage; TVB-N content was lower and lipid oxidation was suppressed on ice-treated fish.

AEW was evaluated on raw trout skin [61]. Trout was inoculated with *Salmonella* Typhimurium, *E. coli* O157:H7 and *L. monocytogenes*; the skin was soaked at room temperature and bacterial survival count was performed. Bacteria were susceptible to treatment; *E. coli* was found to be the most susceptible (1 to 1.5 log CFU/g). The authors described a time dependent inhibitory pattern when AEW was used against *Salmonella sp.* The authors also concluded that it is important to reduce organic matter present on fish before treatment; they suggest pre-treating fish with clean water to remove cell debris prior to treatment with EW.

A sensorial evaluation was performed with American shad (*Alosa sapidissima*) treated with AEW and chitosan by immersion [62]. Treatment inhibited bacterial growth (total viable counts), protein decomposition, and lipid oxidation. At the same time, AEW treatment extended shelf life by nine to 10 days under refrigerated storage. During sensory analysis, treated fish received high scores and non-treated fish received unacceptable scores on days 10 and 20. In a different study [63], bombay duck (*Harpadon nehereus*) was treated with slightly AEW (pH 5.5) and ebony-bamboo leaves complex extracts (EBLCE). Fish were dipped for 5 min at 25 °C with shaking. The non-treated group showed a total viable count of 1.5 log₁₀ CFU/g higher than the treated group. The increase in TVB-N in the treated group was slower than the non-treated group and lipid oxidation was inhibited in the treated group. In this study, AEW with EBLCE extended shelf life 16 days, while shelf life without treatment was only 4 days. This study demonstrated the use of EW on a fish that, generally, does not have a long shelf life.

4.6. Shrimp

Vibrio parahaemolyticus has a negative impact in shrimp production. AEW was evaluated in inoculated shrimp to test for susceptibility to different strains of *V. parahaemolyticus*. Shrimp that were immersed in AEW for 2.5 min, completely suppressed bacterial proliferation at 4 °C [64].

AEW can be used as ice. Wang [65] included shrimp muscle fiber analysis, and the experimental design included TVC analysis and protein degradation by an SDS-PAGE fingerprint. AEW as ice was renewed every 12 h. Results included reduction of TVC from days 0 to 3, showing potential to delay bacterial growth. Bacterial diversity analysis showed less diversity with AEW than without

treatment. There was no protein degradation, and melanosis was observed to a lower degree with EW than without treatment. These results show a promising use for AEW in the shrimp industry.

4.7. Bivalve Mollusk

Oysters are consumed raw in many countries and can be contaminated or spoiled by different bacteria. Ren [66] evaluated the use of AEW on infected oysters with *V. parahaemolyticus* and *V. vulnificus*. In vitro analysis showed that EW decreased >6.6 log CFU/mL in 15 s. Inoculated oysters were immersed in AEW, and the best treatment exposure time was determined to be 4 to 6 h. Treatments longer than 12 h were detrimental to oysters. AEW at 30 ppm caused a decrease in bacterial numbers by 1.58 and 0.83 most probable numbers (MPN) / g of *V. parahaemolyticus* and *V. vulnificus* respectively.

AEW (pH 3.55) and a strong AEW (pH 3.1) were used on *E. coli*, *L. monocytogenes*, *V. parahaemolyticus*, *C. jejuni* and *Aeromonas hydrophila* contaminated clams and mussels [67]. Clams and mussels were kept in EW for 1 or 2 h. Results showed that there was significant difference between treatment time; however, strong AEW showed better results at 10 to 20 ppm during 2 h treatment in live clams and mussels without affecting quality. This showed that the bactericidal effect could be due to the available chlorine concentration rather than exposure time.

5. Chicken

Easy production, price, low fat content, high nutritional value, and easy access make chicken a popular meat around the world. These characteristics force the poultry industry to find new methodologies to preserve chicken without affecting organoleptic qualities and production cost. Different applications on poultry products are depicted in Table 4. Chicken breast has been treated with slightly (pH 6.2–6.5) or strong (pH 2.54) AEW by immersion for 10 min at 22 °C [68]. Chicken samples were stored at 5 °C mimicking retail display. Treatment decreased TVC by 1.5 log CFU/g and at day 10 never reached the limit of 7.0 log CFU/g. There was no statistical difference between strong and slight AEW treatments; however, *L. monocytogenes* was more susceptible than *Salmonella* Typhimurium. pH and TBARS were kept at low levels in the treated group and shelf life was extended from 1 to 4 days without affecting sensory quality. Shimamura [69] evaluated BEW and strong AEW dipping treatment on fresh chicken breast contaminated with *Salmonella enteritidis*, *E. coli* and *Staphylococcus aureus*. Treatment was applied at 4 °C and 25 °C for 3 min. Treatment with both solutions inhibited transcription of staphylococcal enterotoxin A and significantly reduced bacterial counts. There were no differences between the treated group and non-treated group for pH, lipid oxidation, color, and amino acid content. A different approach on prechilled chicken breast cylinders was the use of slightly AEW (pH 6.0) with ultra sound treatment [70] for 10 min at 10 °C. No significant differences between disinfection solutions and tap water treatment were detected for psychrotropic, lactic acid, enterobacteria, and mesophilic bacteria. This could be because of the size of the produced bubbles during cavitation. All treatments presented low levels of lipid and protein oxidation with no modifications in muscle fiber structure.

Table 4. Evaluations of electrolyzed water in poultry.

Material	Type of Electrolyzed Water	Concentration of EW (ppm)	Microorganisms	Inoculum Concentration ^b	Type of Treatment	Duration of Treatment	Reference
Chicken breast	Slightly AEW	10	<i>L monocytogenes</i>	9 log CFU/mL	Immersion	10 min	[68]
	strong AEW	50	<i>S. Typhimurium</i>				
Chicken breast	AEW 4 °C	30	<i>Salmonella</i> <i>Enteritidis</i>	9 log CFU/mL	Immersion	3 min	[69]
	AEW 25 °C	14	<i>E. coli</i>				
Chicken breast	Slightly AEW + ultrasound	5	<i>Staph. aureus</i> Mesophilic bacteria	3.8 log CFU/g	Immersion	30 min	[70]
			Psychrotrophic bacteria	3.47 log CFU/g			
			Lactic acid bacteria	3.22 log CFU/g			
			Enterobacteria	2.1 log CFU/g			
			<i>Staph. aureus</i>	2.25 log CFU/g			
Chicken carcass	AEW, BEW	50	<i>S. Typhimurium</i>	5 log CFU/mL	Immersion	45 min	[71]
			<i>E. coli</i>		Spray wash	15 s	
			Total coliforms				
Chicken carcass	AEW, slightly AEW	58	Aerobic bacteria	4 log CFU/cm ²	Spray wash	15 s	[72,73]
		30	Total coliforms				
Chicken carcass	NEW + lactic acid	50	<i>C. jejuni</i>	9 log CFU/g	Immersion Spray wash	3 min	[74]
Chicken wings	AEW	50	<i>C. jejuni</i>	7 to 8 log CFU/mL	Immersion	10 or 30 min	[75]
Egg	AEW	8	<i>S. Typhimurium</i> <i>Staph. aureus</i> <i>L monocytogenes</i> <i>E. coli</i>	Different values	Spray	4 × 15 s	[76]
Egg	slightly AEW	26	<i>Salmonella</i> <i>Enteritidis</i> <i>E. coli</i>	8 log CFU/mL	Immersion	3 min	[77]
Egg	AEW, BAW	70 to 80	<i>Salmonella</i> <i>Enteritidis</i> <i>E. coli</i> K12	6 log CFU/mL	Immersion	1 to 5 min	[78]
Egg	AEW	ND	Enterobacteriaceae Aerobic bacteria	3.5 log CFU/cm ²	Spray	ND ^a	[79]
Egg	NEW	46	<i>L monocytogenes</i>	6 log CFU/mL	Spray	30 s	[27]
Egg	NEW	60	<i>Salmonella enterica</i> <i>E. coli</i>	6 log CFU/mL	Spray	30 s	[26]

^a Non determined; ^b For aerobic mesophilic, psychrotrophic bacteria, *Staph. aureus*, Enterobacteriaceae and total coliforms, inoculum concentration values were obtained from the no-treatment group.

For chicken carcass disinfection, Fabrizio tested different solutions like AEW (pH 2.6), BEW (pH 11.6), ozonated water, acetic acid, and trisodium phosphate solution against *Salmonella* Typhimurium, *E. coli* and total coliforms [71]. Carcasses were submerged in tested solutions for 45 min at 4 °C or spray washed for 15 s at 85 psi at 25 °C or a combination of both treatments (multiple intervention) were used. The immersion chilling AEW treatment was more effective than chlorinated water (control treatment) after seven days of refrigeration storage. Spray treatment showed no statistical difference with the control treatment. Authors explained that this performance could be the result of a 15 s interaction versus a 45 min immersion treatment. However, multiple intervention treatment showed better bactericidal effect against *Salmonella* at days 0 and 7. In a similar study, chicken carcasses from white and yellow feathered flocks were treated by spraying different solutions like chlorine dioxide, 2% lactic acid, sodium hypochlorite, AEW or slightly AEW for 15 s [72]. TVC and coliform counts were monitored. Both types of EW showed TVC reductions by 0.63 log CFU/cm²; similar results were obtained from samples from different parts of evaluated carcasses. Lactic acid and AEW treatments showed lower counts compared to slightly AEW during the storage period and pH dropped due to their acidic origin/nature. Furthermore, these treatments maintained lower TVB-N levels during storage. Slightly AEW showed no pH alteration and AEW and slightly AEW did not show pro-oxidant potential. As a conclusion of this study, AEW helped maintain the quality of chicken carcasses. Authors

recommended decontaminating chicken after chilling. In a continuation of this study, they evaluated the use of AEW in a newly designed spray cabinet [73], and the treatment reduced microbial numbers by 1.0 log CFU/cm².

NEW and lactic acid (pH 2.0) were evaluated by Rasschaert [74] on carcasses. Chickens were submerged or sprayed after scalding. Unfortunately, this treatment showed no significant effect on carcasses contaminated with *Campylobacter*. Authors explained that bacteria may be in crevices and feather follicles. These regions are difficult to reach by EW.

AEW was evaluated in chicken wings against *C. jejuni* during the washing process [75]. Treatment was applied by immersion for 10 to 30 min at different temperatures. EW reduced *C. jejuni* counts by 3.0 log CFU/g after 30 min of immersion. Bacterial counts after 30 min of treatment were lower than with 10 min of treatment; however, no significant difference was detected. No viable cells were detected in wash solution and bacteria were detected in wash control solution.

6. Egg

Egg is an important source of protein; however, its contamination with *Salmonella sp* is related with the natural production process (laying) and there are related factors such as the equipment used during the handling of eggs. Therefore, the use of a sanitizer in this industry has great relevance to eliminate foodborne pathogens that can cause cross-contamination and produce further infection through their dispersion in the environment of the hatchery.

AEW was evaluated on the surface of eggs containing *Listeria monocytogenes*, *Escherichia coli*, *Staphylococcus aureus* and *Salmonella* Typhimurium. EW was applied using an electrostatic atomization technique. Treatments were evaluated on complete eggs and four repetitions were performed. AEW completely eliminated *Salmonella* Typhimurium on ranges from 6.7 to 53.3%. In average, *Salmonella* reduction counts were 4.0 log₁₀. *Staphylococcus aureus* was completely eliminated on ranges from 80 to 73.3% and reduction counts were around 3.0 log₁₀. *L. monocytogenes* was totally eliminated in 93.3 to 53.3%. Authors explained that the antibacterial mechanism of action of AEW is based on its composition and can be considered an electrical method in conjunction with electrostatic atomization, involving conductance and impedance [76].

In another study, the bactericidal activity of slightly AEW (sAEW) (pH 6.53), AEW (pH 2.81), and sodium hypochlorite (pH 10.12) solutions were evaluated against *Salmonella* Enteritidis and *Escherichia coli* on artificially inoculated eggshells. The best result was in the detection of smaller amounts of survival populations obtained after treatments with sAEW. Internal egg quality attributes like Haugh units, yolk index, weight loss, yolk pH, and albumin were evaluated.

The best results were obtained with sAEW, indicating that it could be a sanitizing method for eggs to not only decrease microbial load, but also preserve egg quality and thus its shelf life. This is attributed to the less corrosive effects exerted by sAEW on the eggshell, compared to other treatments, without affecting the egg's internal composition. However, in this work, there was no cuticle analysis; researchers compare initial weight versus the end of storage. Weight loss was used as an indicator for cuticle damage. For this reason, they suggest the usage of sAEW in combination with other techniques such as UV light, coating, and freezer storage [77].

Bialka et. al. [78] evaluated the effect of applying BEW (pH 11.4) first and AEW (pH 2.7) after, during the egg washing process. Bactericidal effect was compared using a commercial detergent/sanitizer. Different temperatures and treatment times were evaluated. From the in vitro evaluation, the best treatment was applied at 45 °C for 3 min. The best bactericidal results were obtained using both EW against *Salmonella* Enteritidis and *E. coli* K12, when the treatment was compared against single solution treatment or commercial detergent. Afterwards, they performed a pilot commercial scale evaluation using a commercial egg washer and they only evaluated the bactericidal effect against *E. coli*. However, results showed that the combination of BEW and AEW, as well as the use of a commercial detergent could affect cuticle integrity.

Another research group evaluated AEW on hatching eggs [79]. They evaluated a sprayed treatment and quantified the total aerobic bacteria on eggshells. AEW treatment decreased bacterial counts on eggshells by 1.0 log CFU/cm². This group claimed no effect on cuticle and broiler mortality decreased in the treated group; cuticle integrity was evaluated by egg weight.

The bactericidal effect of NEW (pH 6.86) on contaminated eggshells with *Listeria monocytogenes* [27], *Salmonella enterica* and *Escherichia coli* [26] has been evaluated. Treatments were applied by spraying for 15 s. *L. monocytogenes* counts were reduced by 2.0 Log₁₀/egg meanwhile *E. coli* and *S. enterica* counts were reduced by 6.3 and 1.4 Log₁₀/egg respectively. Additionally, cuticle analysis was performed by electron microscopy where the structure of NEW-treated eggshells looked like non-treated and NaCl-treated eggshells.

7. Cattle Products

7.1. Beef

Microbial contamination is an important public concern in the food industry because it can shorten shelf life and increase the risk of food safety in fresh meat and its derived products.

Temperature is the most important environmental factor that affects bacterial growth in beef; this factor constantly changes during processing, storage, and distribution of meat products. Therefore, the most commonly used disinfectants in this area are those based on chlorine, such as sodium hypochlorite, due to its antimicrobial efficacy, convenience, and low price. However, some previous studies have warned users about the limited efficacy of chlorine for reducing microorganisms in meat and surfaces that come into contact with meat [80–82]. Furthermore, there is a potential health risk in chlorine consumption for consumers, e.g., cancer [82]. *Listeria monocytogenes* is an important organism because it has been identified in many ready-to-eat meat products. In order to eliminate this pathogen, the food industry should apply a post-lethality treatment to the product to inhibit or reduce bacterial growth before packaging [41,81,82]. Different studies of EW in meat and milk are listed in Table 5.

Table 5. Evaluations of electrolyzed water on cattle products.

Material	Type of Electrolyzed Water	Concentration of EW (ppm)	Microorganisms	Inoculum Concentration ^b	Type of Treatment	Duration of Treatment	Reference
Beef meat	Slightly AEW	38	<i>E. coli</i> O157:H7 <i>S. Typhimurium</i>	9 log CFU/mL	Immersion	10 min	[61]
Fresh meat	NEW	27 to 39, 50	<i>L. monocytogenes</i> <i>L. monocytogenes</i> <i>E. coli</i> O157:H7 <i>Salmonella sp</i>	8 log CFU/mL	Spray	30 s	[81]
Rib meat	AEW, slightly AEW	50 5	<i>E. coli</i> O157:H7	9 log CFU/mL	Immersion	3 min	[83]
Meat	AEW, slightly AEW	ND ^a	Aerobic bacteria Fungi and yeast	4.78 log CFU/g 3.71 log CFU/g	Immersion	ND	[84]
Beef meat	Slightly AEW + tea polyphenols	40	Aerobic bacteria	3.06 log CFU/g	Immersion	5 min	[85]
Beef fillets	BEW	100	Aerobic bacteria Total coliforms Yeast Lactic acid bacteria	3.82 log CFU/cm ² 1.94 log CFU/cm ² 2.21 log CFU/cm ² 2.64 log CFU/cm ²	Spray	90 s	[86]
Beef head	AEW	60	<i>E. coli</i> O157:H7	6 log CFU/cm ²	Spray	12 s	[87]
Bovine carcass	BEW, AEW	400	Aerobic bacteria <i>E. coli</i> O157:H7 Coliforms	5 log CFU/400 cm ² 0.60 log CFU/400 cm ² 0.83 log CFU/400 cm ²	Spray	ND ^a	[88]
Milk	AEW	ND	Aerobic bacteria	2.48 log CFU/mL	Mix	15 min	[89]

^a Non determined; ^b For aerobic mesophilic, total coliforms, lactic acid bacteria, fungi and yeast, inoculum concentration values were obtained from the no-treatment group.

One study reported the evaluation of AEW and slight AEW on contaminated meat with *Escherichia coli* O157:H7 using 5.0 log UFC/g. Both treatments reduced 3.36 log UFC/g and 3.28 log UFC/g,

respectively. Authors worked on a mathematical model to study the effect of storage temperature; however, further studies were needed to accomplish this goal [83]. In a different study, AEW was used on fresh meat, processed meat (frankfurters), and meat-contact surfaces having *L. monocytogenes*, *E. coli* O157:H7, and *Salmonella sp.* No bactericidal effect was observed in meat and frankfurters due to the presence of organic matter buffering the action of hypochlorous acid against bacteria. The bactericidal analysis on surfaces of equipment handling ready-to-eat meat products compared the effect on clean and dirty stainless-steel cutting blades. AEW was applied using three different concentrations: 5, 25, and 250 ppm. On clean blades, *L. monocytogenes* had bacterial reductions of 1.4, 3.6, and 5.7 log (CFU/mL) when 5, 25, and 250 ppm AEW were used, respectively. Unlike these results, for dirty blades, *L. monocytogenes* reductions were 0, 0.64, and 3.3 log (CFU/mL) using the same concentrations previously mentioned. These results showed again that the presence of organic matter significantly reduces the effectiveness of EW. Despite these results, the authors believe that the best use for AEW in fresh meat and ready-to-eat meat is by applying EW directly to the product wrapped in waterproof containers, where there can be a minimum of organic material in contact with EW [81].

In another study, the use of AEW was compared against conventional defrosting methods (air, tap water, and microwaves) to assess microbiological safety and quality attributes of thawed meat [84]. TVC, fungi, and yeast counts were significantly reduced by 0.83 log UFC/g and 1.16 log UFC/g, respectively, compared to the control group. AEW showed effectiveness as a thawing medium for controlling microbial contamination during thawing. Regarding the physicochemical characteristics of thawed meat, AEW has a negligible impact on moisture loss, surface meat color was paler than control, but internal color did not show differences. Lipid and protein oxidation were retarded as well as protein aggregation and degradation.

A similar study was performed using slight AEW on beef stored by refrigeration. Microbicidal efficacy and shelf life were evaluated. The results showed that the TVC of the treated group decreased to 2.28 log CFU/g and control group viable counts were 3.06 log CFU/g. After three days, the microbial population increased in all samples but, in different proportions, since the TVC of the sAEW treated group was 2.89 log CFU/g, being the lowest value obtained in the results. Bacterial counts in the sAEW group were acceptable by day 14 after treatment, indicating that the use of sAEW in beef could preserve meat. sAEW showed an ability to keep meat in good condition for a longer period of time. Its bactericidal effect could be because it slows the increase of pH and generation of TVB-N. Sensory scores for odor, appearance, texture, and acceptability were better when EW was used [85]. In a different study, sAEW was used on trout, chicken, and beef. Its application caused *E. coli* O157:H7, *Salmonella* Typhimurium, and *L. monocytogenes* reductions compared to the non-treated group or the sterile distilled water treated group [61].

Near NEW was evaluated against *Salmonella* Typhimurium DT104 and *E. coli* O157:H7 on fresh hides. Treatments involve use of near NEW (pH 6.5 at room temperature), BEW (pH 11.6), hot BEW (43 °C), BEW spray followed by NEW spray (both at room temperature), 0.02% peroxyacetic acid (room temperature), 5% lactic acid (pH 2.04 at room temperature), deionized water (W), and no treatment. All these strategies were evaluated because near NEW has bactericidal activity but, it is not corrosive and is stable. Results showed that *S. Typhimurium* DT104 and *E. coli* O157:H7 were reduced by 1.09 y 0.65 log UFC/cm², respectively [61].

Another study evaluated the influence of BEW on the microbiota present in beef fillets. Meat was treated with EW before being vacuum packed and stored at 4 °C. Results showed that there was no impact on the initial microbiological situation after treatment or during storage; this could be due to the fact that the analysis did not consider the initial microbiota composition, which can react with EW. Some of the identified microorganisms before treatment were *Pseudomonas sp.*, *Brochothrix sp.*, *Psychrobacter sp.*, *Lactobacillus sp.*, and *Acinetobacter sp.* Which are commonly reported as meat contaminants from processing environments. After treatment, during the first day, *Psychrobacter sp.* And *Acinetobacter Iwoffii* were able to survive. However, *Pseudomonas fragi* was active and predominated.

Though, after day 5, lactic acid bacteria, *Lactobacillus sakei*, *Leuconostoc gasicomitatum*, and *Lactococcus piscium* were the most abundant population, probably due to limited oxygen conditions [86].

EW can be applied sequentially to optimize its antimicrobial activity. This methodology was carried out during the treatment of fresh hides, where BEW and AEW were used sequentially. This strategy reduced aerobic bacteria and Enterobacteriaceae counts to 3.5 and 4.3 log CFU/100 cm², respectively, while *E. coli* O157:H7 was reduced from 82 to 35%. The effect of time and temperature of EW treatments was also evaluated, showing that they contributed to some extent to the bactericidal effect.

Some AEW evaluations have shown poor results. When AEW was used in the treatment of bovine heads (hide removed), *E. coli* O157:H7 was reduced by less than 0.5 log CFU/cm² [87]; in another report, EW was used to decontaminate bovine carcasses, but unfortunately, EW did not reduce aerobic bacterial counts significantly [88].

7.2. Milk

There is only one report about the use of AEW in milk. Kalit et al. [89] used a commercial EW on milk against aerobic mesophilic bacteria. In this study, EW was diluted, and treatments were applied for 15 min. Results showed that the highest concentration of AEW caused the highest bactericidal effect. Bacterial counts were reduced from 2.48 log CFU/mL to 0.33 log CFU/mL. The requirement of high concentration of AEW is due to available chlorine reacts with proteins and vitamins of milk. However, it is useful in organic production/processing of milk or in areas where water resources are limited because EW can be used to disinfect and rinse equipment.

8. Conclusions

The importance of the use of electrolyzed water lies in its easy production and the versatility of its presentations (i.e., concentrations) that it can have, depending on the production methods. EW can be produced on-site, decreasing storage, and transportation cost. An important attribute of EW is that its bactericidal effect is maintained at different temperatures, allowing its application under cold or warm environments. The most important characteristic is that it can be applied in different products from the food industry. In this document, different applications were reviewed. The most common evaluated procedures were immersion and spray. Immersion is a common practice in poultry and fish industry; however, this practice requires the use of large volumes of water; if EW solutions are used for immersion treatments, it is important to know the residual effect of a used EW; nevertheless, there are no reports about the efficacy of residual effect after EW been used more than once with animal by products. The fish industry uses spray treatments frequently, though there are no reports of the use of sprayed EW on fish, which allow the use of smaller amounts of water compared with dip treatments. The use of EW as ice is an interesting approach for fish and shrimp, however, it needs to be evaluated for every type of food because EW is affected by intrinsic components. In different studies, it has been reported that fish were treated at different temperatures and/or with agitation; fish is a delicate product and it is important to evaluate if this treatment is feasible to apply in this industry. The importance of the beef, pork, and poultry industry has impulse studies to evaluate spray treatments. These industries are exploring new uses as enhancement solutions or evaluating the use with different food types like milk. Although there have already been many studies on the use of EW, more scientific work is still needed to elucidate certain details, such as the possible food sensory changes caused by its use. One possible use is by sequential application (for example, BEW followed by AEW), or in combination with other bactericidal substances to obtain better disinfection and conservation results without affecting quality. However, it is still highly relevant to venture into the use of other cleaning methods, through specific studies, that in combination with EW could achieve optimal performance. The use of electrolyzed water is a promising strategy to preserve different raw, ready-to-eat meat, chicken, fish and others without affecting sensory characteristics. EW uses can be applied in different types of food and against different pathogens. It could be interesting to see its effect

on virus contaminated food like milk and expand its uses. A variety of products can be candidates for the application of EW to increase shelf life and decrease the incidence of foodborne diseases.

Author Contributions: Conceptualization, J.C.R.O. and J.A.C.-B.; writing—original draft preparation, J.C.R.O. and J.A.C.-B.; writing—review and editing, J.A.C.-B. All authors have read and agreed to the published version of the manuscript.

Funding: This manuscript received no external funding.

Acknowledgments: We are very thankful to Jesus Guzman for providing language help and discussion of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Department of Economic and Social Affairs, UN. *World Population Prospects 2019. Volume II: Demographic Profiles*; United Nations: New York, NY, USA, 2019; Volume 2, ISBN 9789211483284.
2. Mylius, M.; Dreesman, J.; Pulz, M.; Pallasch, G.; Beyrer, K.; Claußen, K.; Allerberger, F.; Fruth, A.; Lang, C.; Prager, R.; et al. Shiga toxin-producing *Escherichia coli* O103:H2 outbreak in Germany after school trip to Austria due to raw cow milk, 2017—The important role of international collaboration for outbreak investigations. *Int. J. Med. Microbiol.* **2018**, *308*, 539–544. [[CrossRef](#)] [[PubMed](#)]
3. Morton, V.K.; Kearney, A.; Coleman, S.; Viswanathan, M.; Chau, K.; Orr, A.; Hexemer, A. Outbreaks of Salmonella illness associated with frozen raw breaded chicken products in Canada, 2015–2019. *Epidemiol. Infect.* **2019**, *147*, 2019–2021. [[CrossRef](#)] [[PubMed](#)]
4. Friesema, I.; de Jong, A.; Hofhuis, A.; Heck, M.; van den Kerkhof, H.; de Jonge, R.; Hameryck, D.; Nagel, K.; van Vilsteren, G.; van Beek, P.; et al. Large outbreak of Salmonella Tompson related to smoked salmon in the Netherlands, August to December 2012. *Eurosurveillance* **2014**, *19*, 1–8. [[CrossRef](#)] [[PubMed](#)]
5. Tchatchouang, C.K.; Fri, J.; De Santi, M.; Ateba, C.N. Listeriosis Outbreak in South Africa: A Comparative Analysis with Previously Reported Cases Worldwide. *Microorganisms* **2020**, *8*, 135. [[CrossRef](#)] [[PubMed](#)]
6. Cabal, A.; Allerberger, F.; Huhulescu, S.; Kornschöber, C.; Springer, B.; Schlagenhaufen, C.; Wassermann-Neuhold, M.; Fötschl, H.; Pless, P.; Krause, R.; et al. Listeriosis outbreak likely due to contaminated liver pâté consumed in a tavern, Austria, December 2018. *Euro Surveill.* **2019**, *24*, 1–6. [[CrossRef](#)]
7. Sinulingga, T.S.; Aziz, S.A.; Bitrus, A.A.; Zunita, Z.; Abu, J. Occurrence of *Campylobacter* species from broiler chickens and chicken meat in Malaysia. *Trop. Anim. Health Prod.* **2019**, *52*, 151–157. [[CrossRef](#)]
8. Lung, H.M.; Cheng, Y.C.; Chang, Y.H.; Huang, H.W.; Yang, B.B.; Wang, C.Y. Microbial decontamination of food by electron beam irradiation. *Trends Food Sci. Technol.* **2015**, *44*, 66–78. [[CrossRef](#)]
9. Deng, L.Z.; Mujumdar, A.S.; Pan, Z.; Vidyarthi, S.K.; Xu, J.; Zielinska, M.; Xiao, H.W. Emerging chemical and physical disinfection technologies of fruits and vegetables: A comprehensive review. *Crit. Rev. Food Sci. Nutr.* **2019**, 1–28. [[CrossRef](#)]
10. Len, S.V.; Hung, Y.C.; Erickson, M.; Kim, C. Ultraviolet spectrophotometric characterization and bactericidal properties of electrolyzed oxidizing water as influenced by amperage and pH. *J. Food Prot.* **2000**, *63*, 1534–1537. [[CrossRef](#)]
11. Tanaka, H.; Hirakata, Y.; Kaku, M.; Yoshida, R.; Takemura, H.; Mizukane, R.; Ishida, K.; Tomono, K.; Koga, H.; Kohno, S.; et al. Antimicrobial activity of superoxidized water. *J. Hosp. Infect.* **1996**, *34*, 43–49. [[CrossRef](#)]
12. Khan, I.; Tango, C.N.; Miskeen, S.; Lee, B.H.; Oh, D.H. Hurdle technology: A novel approach for enhanced food quality and safety—A review. *Food Control* **2017**, *73*, 1426–1444. [[CrossRef](#)]
13. Morita, C.; Sano, K.; Morimatsu, S.; Kiura, H.; Goto, T.; Kohno, T.; Hong, W.; Miyoshi, H.; Iwasawa, A.; Nakamura, Y.; et al. Disinfection potential of electrolyzed solutions containing sodium chloride at low concentrations. *J. Virol. Methods* **2000**, *85*, 163–174. [[CrossRef](#)]
14. Tagawa, M.; Yamaguchi, T.; Osamu, Y.; Matsutani, S.; Maeda, T.; Saisho, H. Inactivation of a hepadnavirus by electrolysed acid water. *J. Antimicrob. Chemother.* **2000**, *46*, 363–368. [[CrossRef](#)]

15. Gómez-Espinosa, D.; Cervantes-Aguilar, F.J.; Río-García, J.C.; Villarreal-Barajas, T.; Vázquez-Durán, A.; Méndez-Albores, A. Ameliorative effects of neutral electrolyzed water on growth performance, biochemical constituents, and histopathological changes in Turkey poult during aflatoxicosis. *Toxins* **2017**, *9*, 104. [[CrossRef](#)] [[PubMed](#)]
16. Fan, S.; Zhang, F.; Liu, S.; Yu, C.; Guan, D.; Pan, C. Removal of aflatoxin B1 in edible plant oils by oscillating treatment with alkaline electrolysed water. *Food Chem.* **2013**, *141*, 3118–3123. [[CrossRef](#)] [[PubMed](#)]
17. Suzuki, T.; Itakura, J.; Watanabe, M.; Ohta, M.; Sato, Y.; Yamaya, Y. Inactivation of staphylococcal enterotoxin-A with an electrolyzed anodic solution. *J. Agric. Food Chem.* **2002**, *50*, 230–234. [[CrossRef](#)]
18. Al-Haq, M.I.; Sugiyama, J.; Isobe, S. Applications of Electrolyzed Water in Agriculture & Food Industries. *Food Sci. Technol. Res.* **2005**, *1*, 135–150.
19. Ngnitcho, P.F.K.; Khan, I.; Tango, C.N.; Hussain, M.S.; Oh, D.H. Inactivation of bacterial pathogens on lettuce, sprouts, and spinach using hurdle technology. *Innov. Food Sci. Emerg. Technol.* **2017**, *43*, 68–76. [[CrossRef](#)]
20. Rahman, S.; Khan, I.; Oh, D.H. Electrolyzed Water as a Novel Sanitizer in the Food Industry: Current Trends and Future Perspectives. *Compr. Rev. Food Sci. Food Saf.* **2016**, *15*, 471–490. [[CrossRef](#)]
21. Hati, S.; Mandal, S.; Minz, P.S.; Vij, S.; Khetra, Y.; Singh, B.P.; Yadav, D. Electrolyzed Oxidized Water (EOW): Non-Thermal Approach for Decontamination of Food Borne Microorganisms in Food Industry. *Food Nutr. Sci.* **2012**, *3*, 760–768. [[CrossRef](#)]
22. Yang, H.; Feirtag, J.; Diez-Gonzalez, F. Sanitizing effectiveness of commercial “active water” technologies on *Escherichia coli* O157:H7, *Salmonella enterica* and *Listeria monocytogenes*. *Food Control* **2013**, *33*, 232–238. [[CrossRef](#)]
23. Zhao, L.; Zhang, Y.; Yang, H. Efficacy of low concentration neutralised electrolysed water and ultrasound combination for inactivating *Escherichia coli* ATCC 25922, *Pichia pastoris* GS115 and *Aureobasidium pullulans* 2012 on stainless steel coupons. *Food Control* **2017**, *73*, 889–899. [[CrossRef](#)]
24. Cui, X.; Shang, Y.; Shi, Z.; Xin, H.; Cao, W. Physicochemical properties and bactericidal efficiency of neutral and acidic electrolyzed water under different storage conditions. *J. Food Eng.* **2009**, *91*, 582–586. [[CrossRef](#)]
25. Nagamatsu, Y.; Chen, K.K.; Tajima, K.; Kakigawa, H.; Kozono, Y. Durability of Bactericidal Activity in Electrolyzed Neutral Water by Storage. *Dent. Mater. J.* **2002**, *21*, 93–104. [[CrossRef](#)] [[PubMed](#)]
26. Medina-Gudiño, J.; Rivera-Garcia, A.; Santos-Ferro, L.; Ramirez-Orejuel, J.C.; Agredano-Moreno, L.T.; Jimenez-Garcia, L.F.; Paez-Esquiliano, D.; Martinez-Vidal, S.; Andrade-Esquivel, E.; Cano-Buendia, J.A. Analysis of Neutral Electrolyzed Water anti-bacterial activity on contaminated eggshells with *Salmonella enterica* or *Escherichia coli*. *Int. J. Food Microbiol.* **2020**, *320*, 108538. [[CrossRef](#)] [[PubMed](#)]
27. Rivera-Garcia, A.; Santos-Ferro, L.; Ramirez-Orejuel, J.C.; Agredano-Moreno, L.T.; Jimenez-Garcia, L.F.; Paez-Esquiliano, D.; Andrade-Esquivel, E.; Cano-Buendia, J.A. The effect of neutral electrolyzed water as a disinfectant of eggshells artificially contaminated with *Listeria monocytogenes*. *Food Sci. Nutr.* **2019**, *7*, 2252–2260. [[CrossRef](#)] [[PubMed](#)]
28. Albrich, J.M.; Gilbaugh, J.H.; Callahan, K.B.; Hurst, J.K. Effects of the putative neutrophil-generated toxin, hypochlorous acid, on membrane permeability and transport systems of *Escherichia coli*. *J. Clin. Invest.* **1986**, *78*, 177–184. [[CrossRef](#)]
29. Hurst, J.K.; Barrette, W.C.; Michel, B.R.; Rosen, H. Hypochlorous acid and myeloperoxidase-catalyzed oxidation of iron-sulfur clusters in bacterial respiratory dehydrogenases. *Eur. J. Biochem.* **1991**, *202*, 1275–1282. [[CrossRef](#)]
30. Len, S.V.; Hung, Y.C.; Chung, D.; Anderson, J.L.; Erickson, M.C.; Morita, K. Effects of storage conditions and pH on chlorine loss in electrolyzed oxidizing (EO) water. *J. Agric. Food Chem.* **2002**, *50*, 209–212. [[CrossRef](#)]
31. Huang, Y.R.; Hung, Y.C.; Hsu, S.Y.; Huang, Y.W.; Hwang, D.F. Application of electrolyzed water in the food industry. *Food Control* **2008**, *19*, 329–345. [[CrossRef](#)]
32. Liao, L.B.; Chen, W.M.; Xiao, X.M. The generation and inactivation mechanism of oxidation-reduction potential of electrolyzed oxidizing water. *J. Food Eng.* **2007**, *78*, 1326–1332. [[CrossRef](#)]
33. Rahman, S.M.E.; Jin, Y.G.; Oh, D.H. Combined Effects of Alkaline Electrolyzed Water and Citric Acid with Mild Heat to Control Microorganisms on Cabbage. *J. Food Sci.* **2010**, *75*, 111–115. [[CrossRef](#)] [[PubMed](#)]
34. Liu, Q.; Wu, J.; Lim, Z.Y.; Aggarwal, A.; Yang, H.; Wang, S. Evaluation of the metabolic response of *Escherichia coli* to electrolysed water by ¹H NMR spectroscopy. *LWT Food Sci. Technol.* **2017**, *79*, 428–436. [[CrossRef](#)]
35. Liu, Q.; Wu, J.; Lim, Z.Y.; Lai, S.; Lee, N.; Yang, H. Metabolite profiling of *Listeria innocua* for unravelling the inactivation mechanism of electrolysed water by nuclear magnetic resonance spectroscopy. *Int. J. Food Microbiol.* **2018**, *271*, 24–32. [[CrossRef](#)] [[PubMed](#)]

36. Zhang, J.; Yang, H.; Chan, J.Z.Y. Development of Portable Flow-Through Electrochemical Sanitizing Unit to Generate Near Neutral Electrolyzed Water. *J. Food Sci.* **2018**, *83*, 780–790. [[CrossRef](#)]
37. Abadias, M.; Usall, J.; Oliveira, M.; Alegre, I.; Viñas, I. Efficacy of neutral electrolyzed water (NEW) for reducing microbial contamination on minimally-processed vegetables. *Int. J. Food Microbiol.* **2008**, *123*, 151–158. [[CrossRef](#)] [[PubMed](#)]
38. Rahman, S.M.E.; Wang, J.; Oh, D.H. Synergistic effect of low concentration electrolyzed water and calcium lactate to ensure microbial safety, shelf life and sensory quality of fresh pork. *Food Control* **2013**, *30*, 176–183. [[CrossRef](#)]
39. Tyszkiewicz, I.; Kłossowska, B.M.; Wieczorek, U.; Jakubiec-Puka, A. Mechanical Tenderisation of Pork Meat: Protein and Water Release due to Tissue Damage. *J. Sci. Food Agric.* **1997**, *73*, 179–185. [[CrossRef](#)]
40. Fabrizio, K.A.; Cutter, C.N. Comparison of electrolyzed oxidizing water with other antimicrobial interventions to reduce pathogens on fresh pork. *Meat Sci.* **2004**, *68*, 463–468. [[CrossRef](#)]
41. Fabrizio, K.A.; Cutter, C.N. Application of electrolyzed oxidizing water to reduce *Listeria monocytogenes* on ready-to-eat meats. *Meat Sci.* **2005**, *71*, 327–333. [[CrossRef](#)]
42. Mansur, A.R.; Oh, D.H. Combined effects of thermosonication and slightly acidic electrolyzed water on the microbial quality and shelf life extension of fresh-cut kale during refrigeration storage. *Food Microbiol.* **2015**, *51*, 154–162. [[CrossRef](#)] [[PubMed](#)]
43. Athayde, D.R.; Flores, D.R.M.; da Silva, J.S.; Genro, A.L.G.; Silva, M.S.; Klein, B.; Mello, R.; Campagnol, P.C.B.; Wagner, R.; de Menezes, C.R.; et al. Application of electrolyzed water for improving pork meat quality. *Food Res. Int.* **2017**, *100*, 757–763. [[CrossRef](#)]
44. Rigdon, M.; Hung, Y.C.; Stelzleni, A.M. Evaluation of alkaline electrolyzed water to replace traditional phosphate enhancement solutions: Effects on water holding capacity, tenderness, and sensory characteristics. *Meat Sci.* **2017**, *123*, 211–218. [[CrossRef](#)] [[PubMed](#)]
45. Brychcy, E.; Malik, M.; Drozdowski, P.; Ulbin-Figlewicz, N.; Jarmoluk, A. Low-concentrated acidic electrolysed water treatment of pork: Inactivation of surface microbiota and changes in product quality. *Int. J. Food Sci. Technol.* **2015**, *50*, 2340–2350. [[CrossRef](#)]
46. Belton, B.; Bush, S.R.; Little, D.C. Not just for the wealthy: Rethinking farmed fish consumption in the Global South. *Glob. Food Sec.* **2018**, *16*, 85–92. [[CrossRef](#)]
47. Ozer, N.P.; Demirci, A. Electrolyzed oxidizing water treatment for decontamination of raw salmon inoculated with *Escherichia coli* O157:H7 and *Listeria monocytogenes* Scott A and response surface modeling. *J. Food Eng.* **2006**, *72*, 234–241. [[CrossRef](#)]
48. McCarthy, S.; Burkhardt, W. Efficacy of electrolyzed oxidizing water against *Listeria monocytogenes* and *Morganella morganii* on conveyor belt and raw fish surfaces. *Food Control* **2012**, *24*, 214–219. [[CrossRef](#)]
49. Miks-Krajnik, M.; Feng, L.X.J.; Bang, W.S.; Yuk, H.-G. Inactivation of *Listeria monocytogenes* and natural microbiota on raw salmon fillets using acidic electrolyzed water, ultraviolet light or/and ultrasounds. *Food Control* **2017**, *74*, 54–60. [[CrossRef](#)]
50. Ovissipour, M.; Shiroodi, S.G.; Rasco, B.; Tang, J.; Sablani, S.S. Electrolyzed water and mild-thermal processing of Atlantic salmon (*Salmo salar*): Reduction of *Listeria monocytogenes* and changes in protein structure. *Int. J. Food Microbiol.* **2018**, *276*, 10–19. [[CrossRef](#)]
51. Ghorban Shiroodi, S.; Ovissipour, M.; Ross, C.F.; Rasco, B.A. Efficacy of electrolyzed oxidizing water as a pretreatment method for reducing *Listeria monocytogenes* contamination in cold-smoked Atlantic salmon (*Salmo salar*). *Food Control* **2016**, *60*, 401–407. [[CrossRef](#)]
52. Phuvasate, S.; Su, Y. Effects of electrolyzed oxidizing water and ice treatments on reducing histamine-producing bacteria on fish skin and food contact surface. *Food Control* **2010**, *21*, 286–291. [[CrossRef](#)]
53. Huang, Y.R.; Shiau, C.Y.; Hung, Y.C.; Hwang, D.F. Change of hygienic quality and freshness in tuna treated with electrolyzed water and carbon monoxide gas during refrigerated and frozen storage. *J. Food Sci.* **2006**, *71*, M127–M133. [[CrossRef](#)]
54. Abou-Taleb, M.; Kawai, Y. Shelf life of semifried tuna slices coated with essential oil compounds after treatment with anodic electrolyzed NaCl solution. *J. Food Prot.* **2008**, *71*, 770–774. [[CrossRef](#)] [[PubMed](#)]
55. Rajkowski, K.T.; Sommers, C.H. Effect of anolyte on background microflora, salmonella, and listeria monocytogenes on catfish fillets. *J. Food Prot.* **2012**, *75*, 765–770. [[CrossRef](#)] [[PubMed](#)]

56. Lin, H.-M.; Hung, Y.-C.; Deng, S.-G. Effect of partial replacement of polyphosphate with alkaline electrolyzed water (AEW) on the quality of catfish fillets. *Food Control* **2020**, *112*, 1–8. [[CrossRef](#)]
57. Huang, Y.R.; Hsieh, H.S.; Lin, S.Y.; Lin, S.J.; Hung, Y.C.; Hwang, D.F. Application of electrolyzed oxidizing water on the reduction of bacterial contamination for seafood. *Food Control* **2006**, *17*, 987–993. [[CrossRef](#)]
58. Feliciano, L.; Lee, J.; Lopes, J.A.; Pascall, M.A. Efficacy of Sanitized Ice in Reducing Bacterial Load on Fish Fillet and in the Water Collected from the Melted Ice. *J. Food Sci.* **2010**, *75*, 231–238. [[CrossRef](#)]
59. Mahmoud, B.S.M.; Yamazaki, K.; Miyashita, K.; Il-Shik, S.; Dong-Suk, C.; Suzuki, T. Decontamination effect of electrolysed NaCl solutions on carp. *Let. Appl. Microbiol.* **2004**, *39*, 169–173. [[CrossRef](#)]
60. Kim, W.T.; Lim, Y.S.; Shin, I.S.; Park, H.; Chung, D.; Suzuki, T. Use of electrolyzed water ice for preserving freshness of pacific saury (*Cololabis saira*). *J. Food Prot.* **2006**, *69*, 2199–2204. [[CrossRef](#)]
61. Al-holy, M.A.; Rasco, B.A. The bactericidal activity of acidic electrolyzed oxidizing water against *Escherichia coli* O157:H7, *Salmonella* Typhimurium, and *Listeria monocytogenes* on raw fish, chicken and beef surfaces. *Food Control* **2015**, *54*, 317–321. [[CrossRef](#)]
62. Xu, G.; Tang, X.; Tang, S.; You, H.; Shi, H.; Gu, R. Combined effect of electrolyzed oxidizing water and chitosan on the microbiological, physicochemical, and sensory attributes of American shad (*Alosa sapidissima*) during refrigerated storage. *Food Control* **2014**, *46*, 397–402. [[CrossRef](#)]
63. Chen, J.; Xu, B.; Deng, S.; Huang, Y. Effect of Combined Pretreatment with Slightly Acidic Electrolyzed Water and Botanic Biopreservative on Quality and Shelf Life of Bombay Duck (*Harpadon nehereus*). *J. Food Qual.* **2016**, *39*, 116–125. [[CrossRef](#)]
64. Wang Jing, J.; Sun, W.S.; Jin, M.T.; Liu, H.Q.; Zhang, W.; Sun, X.H.; Pan, Y.J.; Zhao, Y. Fate of *Vibrio parahaemolyticus* on shrimp after acidic electrolyzed water treatment. *Int. J. Food Microbiol.* **2014**, *179*, 50–56. [[CrossRef](#)] [[PubMed](#)]
65. Wang, M.; Wang, J.J.; Sun, X.H.; Pan, Y.J.; Zhao, Y. Preliminary mechanism of acidic electrolyzed water ice on improving the quality and safety of shrimp. *Food Chem.* **2015**, *176*, 333–341. [[CrossRef](#)]
66. Ren, T.; Su, Y.C. Effects of electrolyzed oxidizing water treatment on reducing *Vibrio parahaemolyticus* and *Vibrio vulnificus* in raw oysters. *J. Food Prot.* **2006**, *69*, 1829–1834. [[CrossRef](#)]
67. Al-Qadiri, H.M.; Al-Holy, M.A.; Shiroodi, S.G.; Ovissipour, M.; Govindan, B.N.; Al-Alami, N.; Sablani, S.S.; Rasco, B. Effect of acidic electrolyzed water-induced bacterial inhibition and injury in live clam (*Venerupis philippinarum*) and mussel (*Mytilus edulis*). *Int. J. Food Microbiol.* **2016**, *231*, 48–53. [[CrossRef](#)]
68. Rahman, S.M.E.; Park, J.; Song, K.B.; Al-Harbi, N.A.; Oh, D.H. Effects of slightly acidic low concentration electrolyzed water on microbiological, physicochemical, and sensory quality of fresh chicken breast meat. *J. Food Sci.* **2012**, *77*, M35–M41. [[CrossRef](#)]
69. Shimamura, Y.; Shinke, M.; Hiraishi, M.; Tsuchiya, Y.; Masuda, S. The application of alkaline and acidic electrolyzed water in the sterilization of chicken breasts and beef liver. *Food Sci. Nutr.* **2016**, *4*, 431–440. [[CrossRef](#)]
70. Cichoski, A.J.; Flores, D.R.M.; De Menezes, C.R.; Jacob-Lopes, E.; Zepka, L.Q.; Wagner, R.; Barin, J.S.; de Moraes Flores, É.M.; da Cruz Fernandes, M.; Campagnol, P.C.B. Ultrasound and slightly acid electrolyzed water application: An efficient combination to reduce the bacterial counts of chicken breast during pre-chilling. *Int. J. Food Microbiol.* **2019**, *301*, 27–33. [[CrossRef](#)]
71. Fabrizio, K.A.; Sharma, R.R.; Demirci, A.; Cutter, C.N. Comparison of electrolyzed oxidizing water with various antimicrobial interventions to reduce *Salmonella* species on poultry. *Poult. Sci.* **2002**, *81*, 1598–1605. [[CrossRef](#)] [[PubMed](#)]
72. Duan, D.; Wang, H.; Xue, S.; Li, M.; Xu, X. Application of disinfectant sprays after chilling to reduce the initial microbial load and extend the shelf-life of chilled chicken carcasses. *Food Control* **2017**, *75*, 70–77. [[CrossRef](#)]
73. Wang, H.; Qi, J.; Duan, D.; Dong, Y.; Xu, X.; Zhou, G. Combination of a novel designed spray cabinet and electrolyzed water to reduce microorganisms on chicken carcasses. *Food Control* **2018**, *86*, 200–206. [[CrossRef](#)]
74. Rasschaert, G.; Piessens, V.; Scheldeman, P.; Leleu, S.; Stals, A.; Herman, L.; Heyndrickx, M.; Messens, W. Efficacy of electrolyzed oxidizing water and lactic acid on the reduction of *Campylobacter* on naturally contaminated broiler carcasses during processing. *Poult. Sci.* **2013**, *92*, 1077–1084. [[CrossRef](#)] [[PubMed](#)]
75. Park, H.; Hung, Y.-C.; Brackett, R.E. Antimicrobial effect of electrolyzed water for inactivating *Campylobacter jejuni* during poultry washing. *Int. J. Food Microbiol.* **2002**, *72*, 77–83. [[CrossRef](#)]
76. Russell, S.M. The effect of electrolyzed oxidative water applied using electrostatic spraying on pathogenic and indicator bacteria on the surface of eggs. *Poult. Sci.* **2003**, *82*, 158–162. [[CrossRef](#)]

77. Zang, Y.T.; Bing, S.; Li, Y.J.; Shu, D.Q.; Huang, A.M.; Wu, H.X.; Lan, L.T.; Wu, H.D. Efficacy of slightly acidic electrolyzed water on the microbial safety and shelf life of shelled eggs. *Poult. Sci.* **2019**, *98*, 5932–5939. [[CrossRef](#)]
78. Bialka, K.; Demirci, A.; Knabel, S.; Patterson, P.; Puri, V. Efficacy of electrolyzed oxidizing water for the microbial safety and quality of eggs. *Poult. Sci.* **2004**, *83*, 2071–2078. [[CrossRef](#)]
79. Fasenko, G.M.; O’Dea Christopher, E.E.; McMullen, L.M. Spraying hatching eggs with electrolyzed oxidizing water reduces eggshell microbial load without compromising broiler production parameters. *Poult. Sci.* **2009**, *88*, 1121–1127. [[CrossRef](#)]
80. Killinger, K.M.; Kannan, A.; Bary, A.I.; Cogger, C.G. Validation of a 2 percent lactic acid antimicrobial rinse for mobile poultry slaughter operations. *J. Food Prot.* **2010**, *73*, 2079–2083. [[CrossRef](#)]
81. Veasey, S.; Muriana, P. Evaluation of Electrolytically-Generated Hypochlorous Acid (‘Electrolyzed Water’) for Sanitation of Meat and Meat-Contact Surfaces. *Foods* **2016**, *5*, 42. [[CrossRef](#)]
82. Wang, H.; Duan, D.; Wu, Z.; Xue, S.; Xu, X.; Zhou, G. Primary concerns regarding the application of electrolyzed water in the meat industry. *Food Control* **2019**, *95*, 50–56. [[CrossRef](#)]
83. Ding, T.; Rahman, S.M.E.; Purev, U.; Oh, D.H. Modelling of *Escherichia coli* O157:H7 growth at various storage temperatures on beef treated with electrolyzed oxidizing water. *J. Food Eng.* **2010**, *97*, 497–503. [[CrossRef](#)]
84. Liao, X.; Xiang, Q.; Cullen, P.J.; Su, Y.; Chen, S.; Ye, X.; Liu, D.; Ding, T. Plasma-activated water (PAW) and slightly acidic electrolyzed water (SAEW) as beef thawing media for enhancing microbiological safety. *LWT* **2020**, *117*, 108649. [[CrossRef](#)]
85. Sheng, X.; Shu, D.; Tang, X.; 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*, 1975–1981. [[CrossRef](#)] [[PubMed](#)]
86. Botta, C.; Ferrocino, I.; Cavallero, M.C.; Riva, S.; Giordano, M.; Cocolin, L. Potentially active spoilage bacteria community during the storage of vacuum packaged beefsteaks treated with aqueous ozone and electrolyzed water. *Int. J. Food Microbiol.* **2018**, *266*, 337–345. [[CrossRef](#)]
87. Kalchayanand, N.; Arthur, T.M.; Bosilevac, J.M.; Brichta-Harhay, D.M.; Guerini, M.N.; Wheeler, T.L.; Koohmaraie, M. Evaluation of Various Antimicrobial Interventions for the Reduction of *Escherichia coli* O157:H7 on Bovine Heads during Processing. *J. Food Prot.* **2008**, *71*, 621–624. [[CrossRef](#)]
88. Signorini, M.; Costa, M.; Teitelbaum, D.; Restovich, V.; Brasco, H.; García, D.; Superno, V.; Petroli, S.; Bruzzone, M.; Arduini, V.; et al. Evaluation of decontamination efficacy of commonly used antimicrobial interventions for beef carcasses against Shiga toxin-producing *Escherichia coli*. *Meat Sci.* **2018**, *142*, 44–51. [[CrossRef](#)] [[PubMed](#)]
89. Kalit, S.; Kos, T.; Kalit, M.T.; Kos, I. The Efficacy of Electrolysed Oxidizing Water as a Disinfectant in the Dairy Industry. *J. Hyg. Eng. Des.* **2015**, *12*, 28–32.

