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Application of slightly acidic electrolyzed water as an alternative sanitizer for disinfection of foods

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Abstract

Foodborne pathogens are one of the risks to food safety and play a main role in causing foodborne diseases. Harmful microorganisms can lead to deterioration of food quality and safety risks. Food safety should be confirmed at each processing stage. However, microbial control technology in food has been ripped and available for this purpose. Thus, slightly acidic electrolyzed water (SAEW) as new green technology to disinfectant agents for microorganisms food control field in the last few years, SAEW can be produced from diluted NaCl or HCl solutions, and demonstrations large broad-spectrum bactericidal efficiency due to the cooperative effect of pH, oxidation-reduction potential (ORP) and free chlorine concentrations. The present review article

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illustrates recent studies of using SAEW in various foods areas, focusing on quality and food safety.

Keywords: Slightly acidic electrolyzed water, Food safety, Microorganisms, Sanitizers, Disinfectant

INTRODUCTION

One of the most prominent food safety challenges is the consumer's desire and demand for a high quality of food, healthy, freshness, flavor, color and good appearance **(Andoni et al., 2021)**. Various molds, yeasts and bacteria can grow in human food, thus destroying its nutrients and act a risk to human health **(Naka, Yakubo, Nakamura, & Kurahashi, 2020)**. Therefore, there is a requirement to develop appropriate methods to maintain the quality and safety of food, such as thermal sterilization and chemical preservatives **(Režek Jambrak, Vukušić, Donsi, Paniwnyk, & Djekic, 2018).** Thermal processing, including pasteurization, microwave sterilization and ultra-high temperature, are often used to reduce the number of microorganisms and inactivate enzymes in foods to increase the safety and prolong the shelf life of the food products. At the same time, thermal processing with high temperature will lead to deterioration of nutrients, color and flavor and cause quality changes of foods. **(Kautkar & Raj, 2020; Hernández-Hernández, Moreno-Vilet, & Villanueva-Rodríguez, 2019; Ekonomou & Boziaris, 2021; Lv *et al.*, 2019) .**At present, various commercial sanitizers such as ozone, benzoic acid, peroxide mixtures, nitrites, quaternary ammonium compounds, potassium sorbate and chlorine compounds are also extensively used for food preservation. However, the prospective health hazards of chemical decontaminators in use are hard to handle, which poses risks to human health and not very effective sanitizers for food preservation **(Zhao, Li, & Yang, 2021; Naka *et al.*, 2020)**. Meanwhile, thermal sterilization and chemical sanitizers possess many disadvantages that need to develop and use appropriate suitable methods without changing food properties and prolonging their shelf life.

SAEW has been used as an alternative and novel method to disinfectant microorganisms in many fields **(Ding, Oh, & Liu, 2019;**

Režek Jambrak *et al.*, 2018). SAEW was used for the first time in Japan as a food additive by the Japanese Ministry of Agriculture and the Ministry of the Environment and forestry, markets fisheries, care homes, kindergartens hospitals, restaurants, households and many other areas where required to personal hygiene management **(Naka *et al.*, 2020).** SAEW with a pH of 5.0 to 6.5 and an oxidation-reduction potential (ORP) of 800–1000mV **(Ding *et al.*, 2019).** This pH decreases the environmental and corrosive impact of processing surface in fresh produce industry. The major chlorine compound in SAEW is HOCl, which leads to damage of biomolecules due to its high antimicrobial activity ***(Tango et al.*, 2017;H.-J. Kim, Tango, Chelliah, & Oh, 2019).** However, many studies reported that SAEW has a great bactericidal effect on foodborne pathogens and bacterial spores even at a low concentration, including *Escherichia coli, Salmonella spp.aureus, Vibrio parahaemolyticus* and *Vibrio vulnificus* **(Rahman, Khan, & Oh, 2016;Hussain, Kwon, *et al.*, 2019;C. Wang *et al.*, 2020;Yang *et al.*, 2021) .**This review illustrated recent studies and information on SAEW developments and their applications for shelf-life prolongation and the quality and safety of foods.

MODERN TECHNIQUES FOR FOOD PRESERVATION

There are several techniques for food preservation, including thermal sterilization technology and non-thermal sterilization technology. The thermal sterilization technologies (pasteurization, microwave sterilization, ultra-high temperature sterilization) are highly effective inactivating microorganisms. Still, these methods lead to loss of nutrients and possibly changes in the color and flavor due to direct exposure to temperature **(Režek Jambrak, Donsì, Paniwnyk, & Djekic, 2019)**. Currently, non-thermal sterilization technologies (pulse electric field, ozone, ultrasonic, irradiation, ultra-high pressure, cold plasma, ultrasound and electrolytic water sterilization and SAEW) are widely used for food preservation. These methods as known to be highly efficient compared to thermal technology due to their capability to inactivate microorganisms, pathogens and improve the quality of foods, and they have great capability in food disinfection, reduction toxic compounds in the foods and packaging industry, leading to enhanced food quality and nutritional value of foods **(Adebo *et al.*, 2021; Oh, Khan, & Tango, 2019; Olatunde & Benjakul, 2018; Syed, Ishaq, Rahman, Aslam, & Shukat, 2017; Kumar, Agarwal, & Raghav, 2016; de Mendonça Silva & Gonçalves, 2017; Stratakos & Koidis, 2015; Shalaby, Anwar, Sallam, & Emam, 2016).** In particular, the Slightly acidic electrolyzed water (SAEW), known as novel non-thermal sterilization technology **(Olatunde & Benjakul, 2018).** When compared to other disinfectants, SAEW has the added advantage of minimizing human health and safety issues from Cl_2 off-gassing. It is the most environment-friendly potential alternative to broad-spectrum microbial decontaminants **(Xiaowei Sheng, Shu, Tang, & Zang, 2018).** However, a few studies on SAEW for sanitization and shelf-life extension of food are currently being carried out.

SLIGHTLY ACIDIC ELECTROLYZED WATER

SAEW is the third kind of electrolyzed water (EW). As an alternative and novel method with great potential for sterilization, it has recently received a great deal of attention for its sanitizing efficacy and environmentally friendly nature **(Guo *et al.*, 2021).** SAEW, is produced by electrolyzing an aqueous solution of NaCl or HCl using a non-membrane electrolytic cell **(Olatunde & Benjakul, 2018; Naka e*t al.*, 2020).** The electrolysis of dilute hydrochloric acid produces it in a chamber without a membrane**.** SAEW is well recognized as an alternative sanitizer containing a high concentration of hypochlorous acid, with a pH of 5.0–6.5 **(Xiaowei Sheng *et al.*, 2018)**. In this range of pH, 95% of chlorine form in water is HOCl, 5% is OCl - and traces of Cl_2 **(White, 2010).** HOCl is important because the chlorine in Cl_2 form can volatilize **(Cui, Shang, Shi, Xin, & Cao, 2009)*,*** and the efficacy against microorganisms can be lost pH if the hypochlorous acid molecule is neutral. Therefore, neutral pH is a good characteristic against chlorine evaporation, maintenance of HOCl concentration, and activity of SAEW in microorganisms **(Soo-Voon *et al.*, 2002).**

The aqueous HCl solution is supplied to the electrolytic cell, where the following electrolysis reactions take place **(Naka *et al.*2020).**

$$2\ Cl^- \longrightarrow Cl_2 + 2e^-$$

On the anode, the chlorine ion is electrolyzed to chlorine, and it undergoes the following reaction with water. As a result, hypochlorous acid is generated, which is the bactericidal chemical

$$H_2O + Cl_2 \longrightarrow HOCl + H^+ + Cl^-$$

On the cathode, hydrogen gas is generated.

$$2H^+ + 2e^- \longrightarrow H2$$

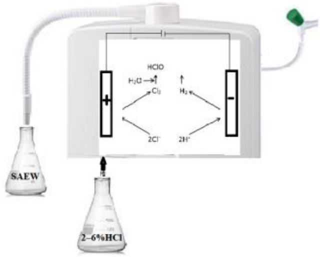

Figure 1: Schematic diagram of the formation of SAEW

Action mechanism of SAEW

It is well known that the active chlorine species (Cl_2, HOCl, and ^-OCl) contribute to the inactivation of microbial cells. Besides active chlorine, other oxidants such as the reactive oxygen species (ozone and hydrogen peroxide) are generated during electrolysis, contributing to EW's antimicrobial efficacy **(Jeong, Kim, & Yoon, 2009; Jeong, Kim, Cho, Choi, & Yoon, 2007).** HOCl and $^-$ OCl can attack the microbial cell from the outside and from within the cell **(Rahman, Jin, & Oh, 2010; Q. Liu *et al.*, 2017),** thereby accelerating the inactivation rate and enhancing the germicidal activity. The germicidal action of HOCl was attributed to its penetration into microbial cells across the cell walls and membranes and penetrating the lipid bilayer in the plasma membrane due to its electrical neutrality. Whereas, ionized ^-OCl cannot penetrate the microbial cell membrane because of the lipid bilayer, which is the hydrophobic layer of the plasma membrane. Moreover, HOCl and ^-OCl play a role in bacterial cell wall surface components and make it easy to penetrate the cell membrane by leaking potassium, leading to inhibition of enzymes (e.g., of dehydrogenases) **(Hussain, Tango, & Oh, 2019).**Occasionally, Mycobacteria and corynebacteria possess a peculiar cell wall structure in which the peptidoglycan is covalently linked to mycolic acids, consisting of long fatty acids up to 90 carbon atoms. The mycolic acids represent a hydrophobic barrier −OCl penetration **(Rahman *et al.,* 2016; Fukuzaki, 2006).** Furthermore, SAEW can rapidly destroy the membrane of harmful microorganisms to increase their permeability or make the cells expand and rupture **(L. B. Liao, Chen, & Xiao, 2007),** due to the strong oxidation of hypochlorous acid it can make the cell's DNA, RNA, protein and other functional compounds lose their normal biochemical activity. The ability sterilization of SAEW mainly depends on the concentration of available chlorine and active chlorine. What is more, the ORP and pH have been observed to play important roles in the inactivation of bacteria **(C. Kim, 2001).** A study conducted by **(L. B. Liao *et al.*, 2007)** reported that ORP of electrolyzed oxidizing water causes an effect and damages the redox state of glutathione disulfide-glutathione couple (GSSG/2GSH), which serve as the main indicator of E. coli O157:H7 redox environment.

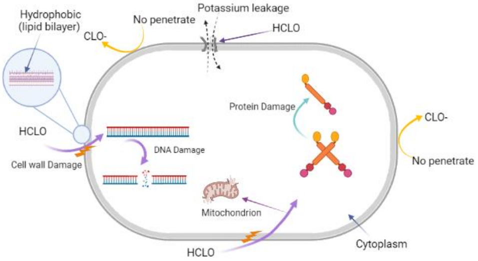

Figure 2: Model explaining the germicidal mechanism of SAEW.

Advantages and disadvantages

SAEW, as a third type of EW shown many advantages over its toxic counterparts in several areas, including food, hospitals, agriculture, food industry and equipment surfaces **(P. Yan, Daliri, & Oh, 2021)** as mentioned previously, SAEW is produced in an environmentally environment-friendly type. Interestingly, SAEW showed less dangerous and no threat to human body and worker health due to its neutral pH and percent of HOCl or −OCl **(Athayde *et al.*, 2018),** and does not showed any equipment corrosion compared with Acidic electrolyzed water (AEW) that has pH value (2.3–2.8) and no promote negative influence on the sensory and quality of food **(W. Yan, Zhang, Yang, & Zhao, 2020)**.The main advantage of using SAEW is the ability for on-site generation, thus circumventing problems associated with chlorination including the transport, storage, and handling of dangerous chlorine **(Rahman *et al.*, 2016).** SAEW is active against a broad-spectrum inactivation ability with high antimicrobial properties and high sterilizing action even at a low concentration; equipment size is small, easy to move and carry **(X. Hao *et al.*, 2013) .** Therefore, it is hypothesized that EW does not promote the growth of bacterial resistance **(Rahman *et al.*, 2016).**

H. Li, Ren, Hao, & Liu (2017) reported that market values and quality enhancement of SAEW more effectively than AEW treatment. The same study conducted by (Guo et al., 2021) showed that SAEW is more effective than sodium hypochlorite (NaOCl) in eliminating or reducing microorganisms. The disadvantages of SAEW that need to be considered are evaporation of Cl_2 and loss of activity, mainly at lower Ph **(Athayde *et al.*, 2018).** Reduction in the concentration of chlorine over time reduces the bactericidal activity of EW **(Block *et al.*, 2020)**. Inapplicable to some food with high porosity and its processing equipment **(Ding et al., 2019).**

MODEL OF SAEW IN COMBINATION WITH OTHER NON-THERMAL TREATMENT

The application of hurdle technology involving EW and non-thermal technologies has become more prevalent in food preservation, the quality of the final product is as important as microbial reduction **(Oh *et al.*, 2019).** SAEW, alone and in combination with other techniques, has shown promising results in controlling microbial growth in food and enhancing the shelf life (Table1). The combination of SAEW with calcium oxide (CaO) and fumaric acid (FA) led to a microbial reduction in fruits, such as tomato, apple and mandarin. However, CaO alone showed better results than SAEW+FA treatment (**X. Chen, Tango, Daliri, Oh, & Oh, 2019**). In addition, the efficiency of SAEW with ultraviolet-C light-emitting diodes and ultrasounds (US), in reduction of *Staphylococcus aureus* and *Escherichia coli* in carrots, celery, paprika, and cabbage presented higher than a single treatment

(Lee, Yang, & Yoon, 2021). The SAEW treatment with UVC-LED significantly enhances Salmonella reduction on lettuce **(Han, Liao, Ai, Ding, & Wang, 2021).** Two types of *Bacillus cereus* biofilms on beet, lettuce and spinach leaves were reduced by SAEW treatment. In contrast, a combination of SAEW with ultrasound and mild heat showed a reduction of only one type of *Bacillus cereus biofilms* **(Hussain, Kwon, *et al.*, 2019).** Treatment with the combination of SAEW with ultraviolet-light emitting diode (UV-LED) led to an increase in Salmonella and E. coli reduction **(Jiang, Ai, Liao, Liu, & Ding, 2020).** The combination of FA+ CaO +SAEW+ultrasounds treatment could confirm a high microbial reduction on fruits (apple and tomato) compared to SAEW +FA+ CaO treatment **(Tango *et al.*, 2017).** Besides, SAEW combination with plasma-activated water significantly reduced total microorganisms, and improved the quality of beef **(X. Liao *et al.*, 2020).** The combination of SAEW with UV light and ultrasound (US) improved the egg's internal quality during the storage period (6-wk at 25°C) by inactivating microorganisms **(XW Sheng et al., 2020).** A similar result was found on the surface of eggshells since the UV-C light +SAEW combination led to reducing *S. enteritidis* **(Bing, Zang, Li, & Shu, 2019).** Another study reported that the US+SAEW combination improved the reduction of mesophilic bacteria, enterobacteria, psychrotrophic bacteria, and lactic acid bacteria on chicken breast ***(Cichoski et al.*, 2019).** Another study reported that the SAEW combination with epigallocatechin-3-gallate reduced *Escherichia coli, Salmonella spp.,* and *Vibrio parahaemolyticus* to less than 6 logs during soaking oyster at refrigeration temperature for 13 days **(Tantratian & Kaephen, 2020).** A similar result showed that SAEW combination with ascorbic acid extended the shelf life of freshwater prawn (*Macrobrachium rosenbergii*) for 3 days during storage at 4°C ***(*W. Yan *et al.*, 2020).** However, SAEW efficiency is mainly affected by the concentration and time treatment of SAEW. According to mentioned studies, the combination with other preservatives may increase SAEW efficiency since the combined treatment procedures may impart a preservative effect or even synergistic bactericidal effect.

Table 1 The application of SAEW combined with other non-thermal technologies in food preservation.

Combined treatments	**Food Materials**	**Target microorganisms**	**Microorganisms (reduction log CFU/g)**	**Other effects**	**Refs**
SAEW+ Calcium oxide (CaO) and fumaric acid (FA)	apple, mandarin, and tomato	*Escherichia coli O157:H7* *Listeria monocytogenes*	2.85 -5.35 log CFU/fruit,	improved the quality of fresh fruit	**(Chen, Tango, Daliri, Oh, & Oh, 2019)**
SAEW+Ultraviolet-C light-emitting diodes (UV-C LED; 275 nm), ultrasounds (US)	carrots, celery, paprika, cabbage	*Escherichia coli*, *Staphylococcus aureus*	0.97~2.17 log CFU/g	extended the shelf life	**(Lee *et al.*, 2021)**
SAEW+ UVC light-emitting diodes (UVC-LEDs 50–200 µ W/cm 2 , 1–30 min)	Lettuce	Salmonella	2.56–2.97 log 10 CFU/g	Result did not showed any changes in quality of lettuce	**(Han *et al.*, 2021)**
SAEW+Ultrasound and mild heat	spinach, beet and lettuce leaves	*Bacillus cereus biofilms*	1.63, 1.39, and 1.49 log CFU/cm 2	NA*	**(Hussain, Kwon, *et al.*, 2019)**
SAEW+ultraviolet-light	Coriander	Salmonella *E. coli*	2.72 logCFU/g 2.42 log CFU/g	extended the shelf-life of coriander	**(Jiang *et al.*, 2020)**
SAEW+ tea polyphenols (Tpp)	Beef	Total bacteria	exhibited higher disinfectant efficacy	extend the shelf life	**(Xiaowei Sheng *et al.*, 2018)**
SAEW+ ultrasounds (US 25 and 130 kHz),	chicken breast	lactic acid bacteria, psychrotrophic bacteria, enterobacteria, mesophilic bacteria	0.76 0.81 0.98 log	NA	**(Cichoski *et al.*, 2019)**
SAEW+ UV-C light	Eggs	*Salmonella enteritidi*	6.54 log CFU/g	NA	**(Bing *et al.*, 2019)**
SAEW+UV light	Eggs			quality parameter of eggs during a 6-weeks storage time	**(XW Sheng *et al.*, 2020)**
SAEW+epigallocatechin 3-gallate (EGCG)	Oyster	*Salmonella spp.*, *V. parahaemolyticus* and *E. coli*	NA	NA	**(Tantratian & Kaephen, 2020)**
(SAEW) and ascorbic acid (AA)	prawn (Macrobrachium rosenbergii)	Total bacteria	1.42 log 10 CFU/g	prolonged the shelf life, delayed the increase of melanosis scores	**(W. Yan *et al.*, 2020)**

NA*=NOT AVAILABLE

APPLICATION OF SLIGHTLY ACIDIC ELECTROLYZED WATER

The slightly acidic electrolyzed water has many applications in the food industry, such as preserving vegetables, fruits, seafood and meats, leading to improve their stability during storage(Table2). **Y. Chen *et al.* (2020),** found that the properties of longan fruit such as browning, respiration rate, and pulp breakdown were improved during storage by SAEW treatments. A similar study was found by **(Kuljaroensub, Whangchai, & Chanasut, 2019),** where they stated that sanitization with SAEW at 4°C for 20 min was the best method to disinfect fresh-cut banana leaves and improved stability of their properties such as color. In vegetables. The treatment of 4 types of vegetables (endive leaf, lettuce leaf, kale leaf and perilla leaf) with SAEW led to oxidation-inhibition and reduction of total microbial count **(Park, Lim, Jung, & Jeong, 2017)**. Furthermore, the stability of bioactive phytochemicals (anthocyanins) in broccoli sprouts was enhanced by SAEW treatment **(L. Li *et al.*, 2018).** In flour products, the SAEW diminished the total plate and yeast/mold counts with improved chemical and biological characteristics of flour **(Y.-X. Chen, Guo, Xing, Sun, & Zhu, 2020).** In meats, the shelf life of beef was extended by approximately 8d at 4°C by SAEW treatment **(Xiaowei Sheng *et al.*, 2018).** In eggs, the SAEW could prolong the shelf life of shelled eggs by reduction ($P < 0.05$) of *E. coli* and *S. Enteritidis* **(YT Zang *et al.*, 2019).**

In seafood, the shelf life of pomfret was extended by 9d, and the microorganism was reduced after slightly acidic electrolyzed water treatment **(Huang *et al.*, 2021).** A similar result conducted by **Xuan *et al.* (2017)** showed the reduction of microorganisms and prolonged squid's shelf life. The SAEW with ACC has improved the quality of pea sprouts by reduction of coliform, total bacteria, mold and yeast **(Zhang *et al.*, 2019).**

Table 2 Applications of SAEW on various food products.

Application	**Microorganism**	**Exposure time (min)**	**Shelf life**	**Reduction (log CFU)**	**ACC (mg/L)**	**PH**	**ORP (mV)**	**Temp. (°C)**	**Refs**
spinach, beet and lettuce leaves	*Bacillus cereus* (10987 and ATCC 14579)	15	NA*	3.0 and 3.4 log CFU/cm	80	5.74 ± 0.16	832–855	NA	**(Hussain, Kwon, *et al.*, 2019)**
coriander	Salmonella *E.coli*	5	NA	1.69 log CFU/g - 1.87 log CFU/g	60	NA	NA	**NA**	**(Jiang *et al.*, 2020)**
lettuce	Salmonella	1–7	NA	1.0 $\log_{10}$ CFU/g 1.44 $\log_{10}$ CFU/g	20 80	NA	NA	NA	**(Han *et al.*, 2021)**
lettuce and carrot	NA	NA	29.5 25	NA	30.0 ± 1.0	5.65 ± 0.06	935.0 ± 5.0	NA	**(L. Wang, Xia, Huang, & Li, 2016)**
cherry tomatoes strawberries	Molds, yeasts, total aerobic bacteria	NA	NA	1.45log CFU/g 1.10log CFU/g 0.93 and 0.96 log	34.33 ± 0.67	6.49 ± 0.03	853.7 ± 0.78	NA	**(Ding *et al.*, 2015)**
fresh-cut cilantro	total aerobic bacteria	NA	NA	5.43 log cfu/g	19.46 ± 0.32	5.85 ± 0.05	815 ± 12	NA	**(J. Hao, Li, Wan, & Liu, 2015)**
fresh-cut bell pepper	*Listeria monocytogenes* *Salmonella enterica* serovar Typhimurium	1	NA	1.72 log CFU/g	28-30	5.0-5.2	930-950	60	**(Luo & Oh, 2015)**
carrots, celery, paprika, and cabbage	*Escherichia coli* *Staphylococcus aureus*	3	NA	0.49–1.39 log CFU/g	30	5.5	NA	NA	**(Lee *et al.*, 2021)**
endive leaf ,lettuce leaf, ,	total microbial	NA	NA	3 log CFU/g	30	6.4	562±23 mV	20±1	**(Park *et al.*, 2017)**

kale leaf and perilla leaf									
	coliform, total bacteria, mold and yeast	NA	NA	0.99–1.58 log CFU/g, 0.57–1.02 log CFU/g, 1.01–1.22 log CFU/g	35 70	5.57 ± 0.02 5.46 ± 0.01	912 ± 2.16 927 ± 3.56	NA	**(Zhang *et al.*, 2019)**
buckwheat sprouts	*E. coli O78* *L. monocytogenes*	NA	NA	1.10–2.74 and 1.85–2.46 log 10 CFU/g	10, 28 , 92	6.0	NA	NA	**(Liang, Wang, Zhao, Han, & Hao, 2019)**
Kashk is a dairy product	*Staphylococcus aureus*, *Bacillus cereus*, *Escherichia coli*, Aspergillus fumigatus	3 and 5	NA	1.42, 1.13, 1.24, 1.37log CFU/mL	20-22	5.3-5.5	545-600	22±2	**(Forghani, Eskandari, & Oh, 2015)**
Bombay duck (Harpadon nehereus)	NA	NA	8	NA	27.37 ± 2	5.5 ± 0.2	836 ± 5	NA	**(J. Chen, Xu, Deng, & Huang, 2016)**
shelled eggs	*S. Enteritidis E. coli.*	3 and 4	30	NA	26	6.37± 0.02	675.9 ± 7.0	25	***(YT Zang et al.*, 2019)**
Seafood pomfret	Microorganism	NA	9	1.27 log 10 CFU/g	22±0	6.42±0.03	822±2	4 storage time	**(Huang *et al.*, 2021)**
oyster	*Escherichia coli, Salmonella spp. ,Vibrio parahaemolyticus*	NA	13	less than 6 log	60	6.14	NA	refrigeration temperature	**(Tantratian & Kaephen, 2020)**
squid	total bacterial	NA	NA	1.46 ± 0.10 log 10 CFU/g	25 ± 5	6.48 ± 0.02	882 ± 2	NA	**(Xuan *et al.*, 2017)**
brown sole (Pleuronectes herzensteini)	NA	NA	11–12	NA	45	5.07	NA	NA	**(Jung, Ko, Jang, Park, & Oh, 2018)**
prawn (*Macrobrachium rosenbergii*)	NA	NA	3	NA	20	5.92	ORP, 810 mV	4 storage time	**(W. Yan *et al.*, 2020)**
milking systems	total bacteria	9.9	NA	NA	60	NA	NA	NA	**(Liu, Wang, Shi, & Li, 2017)**
equipment surfaces	*Salmonella enteritidis*	NA	NA	2.362 log 10 CFU/cm^2 .	220	6.0-6.5	NA	NA	**(Yitian Zang *et al.*, 2017)**

NA*= Not available

CONCLUSION

SAEW treatment is used as an alternative method for reducing microorganism's pollution on food products and food processing surfaces, floors, stainless steel, hospitals, care homes, kindergartens, restaurants, households and many other places. This treatment is not using heating as the main resource for inactivating microorganisms and enzymes in processing the food products. Furthermore, if we compare this method with thermal technologies, like pasteurisation, evaporation, or drying, SAEW treatment takes shorter treatment times, and it got the highest levels of safety, or/and longer shelf-life for foods.

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