Ensuring produce safety: Portable sanitising unit based on green electrolysis

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With the increasing consumption of fresh fruits and vegetables, especially organic ones, it is of great importance to ensure the safety of these produce. To do this, appropriate sanitising treatment should be applied during fruit and vegetable processing. Currently there are some sanitisers that can be applied in our family kitchen, however, as these are deemed to be detergents, they are not received well by the customers. Many are wary of their effects on health. Moreover these chemicals have gone through chemical processes and generally have other harmful source chemicals, thus are not considered 'green'. To date, in the U.S., for example, regulations on organic food are the most complete, and these regulations are also widely accepted by many other countries. According to these regulations, only ozone, low concentration of chlorine-based sanitisers, peracetic acid, hydrogen peroxide, and few others are allowed for use to sanitise equipment and organic food. These chemical sanitisers however have several shortcomings of (a) limited availability, (b) large equipment needed to generate them, (c) short shelf life, and (d) limited sanitising effects (Olmez & Kretzschmar, 2009). It is therefore paramount to develop sanitisers for family use and the organic food industry to meet market needs.

Electrolysed water sanitiser for ensuring microbial food safety

Sanitising solution based on chlorine (a mixture including hypochlorous acid, chlorine gas and hypochlorite salt) has great antimicrobial effects on planktonic microbial cells, microbial cells dried on equipment surface, and biofilms. In addition, it is compatible with the principles for application in organic foods, therefore, it could be applied in organic food sanitisation. It has two general names: electrolysed water (EW) and electrochemically activated water (ECAW); the former was originally developed in Japan while the latter was first developed in Russia (Yang et al., 2012). Their fundamental principles are similar: both are water-based sanitisers for food and food processing equipment and both use an electrolysed diluted salt solution to generate two distinct fractions, anolyte and catholyte. Anolyte which contains chlorine is generated at the anode, as shown in Figure 1 (Hricova et al. 2008). Its effective components are high oxidation-reduction potential (ORP) and chlorine compounds represented by free available chlorine (FAC), thus having antimicrobial properties (Cloete et al., 2009).

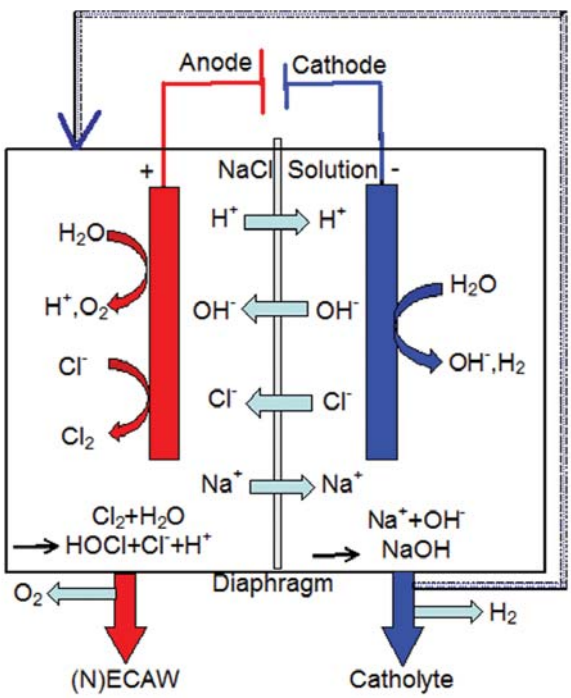

Figure 1. The schematic diagram of (neutral) electrochemically activated water ((N)ECAW). The diagram has been adapted from Hricova et al., 2008

ECAW has already been used for sanitising organic fresh produce. For example, according to Cheng's study

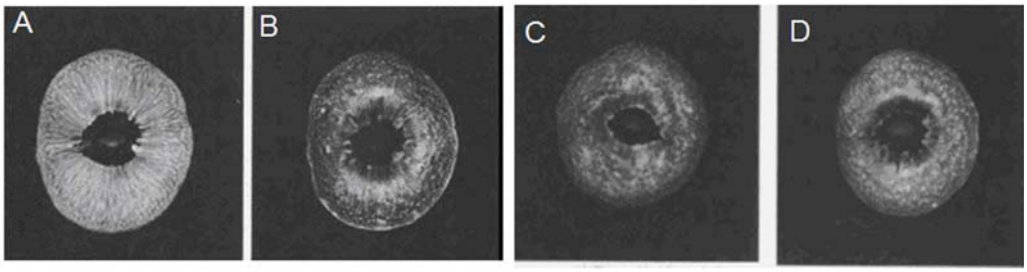

Figure 2. T_2-MAPs made by MRI of fresh peaches (A) and peaches stored for 44 days (B to D) after different treatment conditions. A: Fresh peach; B: Peach stored after water treatment (control); C: Peach treated with slightly acidic electrolysed water; D: Peach treated with slightly acidic electrolysed water and carboxymethyl chitosan (Cited with permission from Zhou et al., 2012)

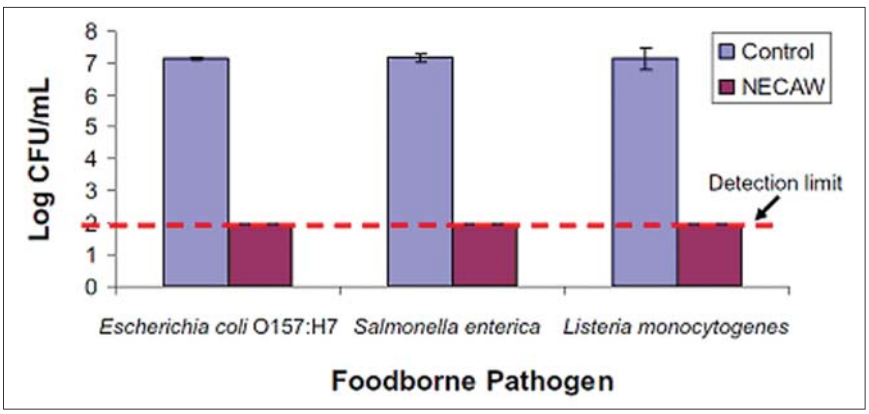

Figure 3. Sanitizing effects of neutral electrochemically activated water (NECAW) on foodborne pathogens. Note: NECAW with free available chlorine (FAC) 100 mg/L, pH 7.0; Control: deionated water, FAC 0 mg/L, pH 7.0 (Yang et al., 2012; 2013)

(Cheng et al., 2002), ECAW had strong bactericidal effects on fresh-cut lettuces during dipping, rinsing and dipping/blowing treatment. In this study, both *Escherichia coli* O157:H7 and *Salmonella typhimurium* were reduced by approximately 2 log CFU/g after the spraying treatment at 10 PSI at room temperature for 90 seconds.

Potentially, ECAW is an environmentally-friendly sanitiser that is promising for sanitising organic fresh produce. However, ECAW or EW is acidic with pH 3.5-5.5. Due to this acidity and the effects on food handlers as well as the foods under treatment, pH-neutral or slightly acidic EW (or ECAW) received more attention recently; the usage of neutral ECAW or EW (NECAW or NEW) as a sanitiser is safer for workers and the environment (Kim et al., 2003; Yang et al., 2012). In addition, NECAW/NEW or slightly acidic ECAW/EW increases the storage life of fruits and vegetables (Issa-Zacharia et al., 2010; Rahman et al., 2010). Fundamentally, they can extend the post-harvest shelf life of fruits and vegetables because this EW treatment can maintain the integrity of fruit flesh and the fruit's water holding ability (Zhou et al., 2012). In addition, treatment with NEW can maintain produce quality such as hardness, soluble solids content and reduce the decay rate and browning index. For example, in Figure 2, the amount of free water and the integrity of fruit flesh were much better maintained under EW treatment group during storage compared to distilled water treatment.

Additionally, the neutral pH of NECAW minimises the loss of chlorine after its generation and thus can maintain antimicrobial activity longer than traditional acidic ECAW (Ayebah et al., 2005). Furthermore, NECAW has great antimicrobial effects. Figure 3 shows sanitising effects of NECAW on inactivating foodborne pathogens including *E. coli* O157:H7, *Listeria monocytogenes* and *Salmonella enterica*. The results revealed a great effectiveness and broad-spectrum activity of NECAW on inactivating foodborne pathogens (Yang et al., 2013).

Using food engineering knowledge to develop a portable unit for effectively controlling foodborne pathogens

Although NECAW and NEW are effective in controlling foodborne pathogens, the current NECAW and NEW producing units are typically quite large and expensive for applications in households and small food industries. In addition, the relative short shelf life of the sanitising solution generated may also limit its wide and convenient application. Thus, a small scale and user-friendly NECAW/NEW generator is necessary in order to meet the market needs and improve the safety of our produce. To date, several companies have developed portable water sanitising equipment. According to their product information, these types of equipment also use some sort of electrolysis for generating sanitising waters. Unfortunately many of these commercial products tested

were not effective in sanitising any of the foodborne pathogens (Yang et al., 2013).

The key to the success of this specific project is to develop and apply small but effective electrodes, which needs engineering and electrochemistry knowledge. A hypothetical proposed portable NECAW sanitising unit for domestic and small-scale industry especially organic food industry use is shown in Figure 4.

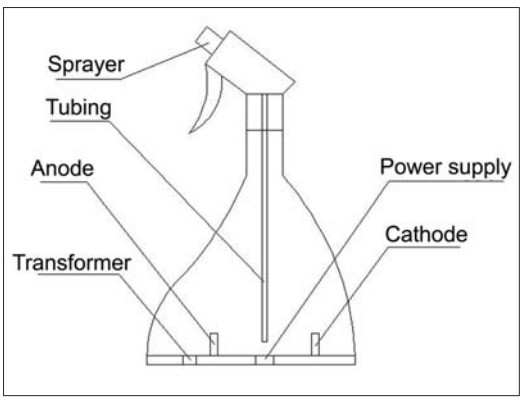

Figure 4. Schematics of proposed portable neutral electrochemically activated water sanitising unit

Conclusion

Portable NECAW units have several advantages including 1) source materials contain no harmful chemicals, only water and salt (sodium chloride) are needed and sanitising agent can be generated by electricity; 2) no necessity to handle, distribute, or store toxic and corrosive chemicals; and 3) portability and affordability for most consumers as well as small-scale food industries especially the organic food industry. The usage of portable NECAW as a sanitiser is also safer for workers and the food treated as compared to many currently available sanitisers. The neutral pH of NECAW minimises the loss of chlorine due to evaporation and thus maintains a longer antimicrobial activity. In this paper, a portable NECAW unit is proposed and will be designed and tested collaboratively with cutting edge knowledge and technology. The authors from National University of Singapore are currently collaborating and interested in more collaborations with industrial partners to improve food safety and nutrition.

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References

Ayebah, B., Hung, Y.C., and Frank, J.F. 2005. Enhancing the bactericidal effect of electrolysed water on Listeria monocytogenes biofilms formed on stainless steel. Journal of Food Protection, 68:1375-1380.

Cheng, Y., Yang, H., Swem, B.L., Ruan, C., and Li, Y. 2002. Antimicrobial treatment of fresh-cut lettuces with electrochemically activated water using a lab-scale sprayer. IFT Annual Meeting and Food Expo, Anaheim, CA, USA

Cloete, T. E., M. S. Thantsha, M. R. Maluleke, and R. Kirkpatrick. 2009. The antimicrobial mechanism of electrochemically activated water against *Pseudomonas aeruginosa* and *Escherichia coli* as determined by SDS-PAGE analysis. Journal of Applied Microbiology, 107:379-384.

Hricova, D., Stephan, F and Zweifel, C. 2008. Electrolysed water and its application in the food industry. Journal of Food Protection, 71:1934-1947.

Issa-Zacharia, A., Kamitani, Y., Morita, K., and Iwasaki, K. 2010. Sanitization potency of slightly acidic electrolysed water against pure cultures of *Escherichia coli* and *Staphylococcus aureus*, in comparison with that of other food sanitizers. Food Control, 21:740-745.

Kim, C., Hung Y.C., Brackett R.E., and Lin C.S. 2003. Efficacy of electrolysed oxidizing water in inactivating Salmonella on alfalfa seeds and sprouts. Journal of Food Protection, 66:208-214.

Li, H., Zheng, S., Song, S., Li. J, Li, L., and Liu, H. 2011. Study on sterilization and preservation of fruits and vegetables using acidic electrolysed oxidizing water. Modern Food Science and Technology, 27:1-8.

Olmez, H., and Kretzschmar, U. 2009. Potential alternative disinfection methods for organic fresh-cut industry for minimizing water consumption and environmental impact. LWT-Food Science and Technology, 42: 686-693.

Rahman, S.M.E., Ding, T., and Oh, D.H. 2010. Inactivation effect of newly developed low concentration electrolysed water and other sanitizers against microorganisms on spinach. Food Control, 21:1383-1387.

Yang H. 2012. Evaluating the antimicrobial mechanism of neutral electrochemically activated water on foodborne pathogens and their biofilms. Ph.D. dissertation. University of Minnesota, St. Paul, MN, USA.

Yang, H., Feirtag, J.M., and Diez-Gonzalez, F. 2013. Sanitizing effectiveness of commercial 'active water' technologies on *Escherichia coli* O157:H7, *Salmonella enterica* and *Listeria monocytogenes*. Food Control, 33:232-238.

Zhou, R, Xie, J., Gao, Q., and Chen, Q. 2012. Effects of slightly acidic electrolysed water and carboxymethyl chitosan preservative on flesh discoloration of peaches. Transactions of the Chinese Society of Agricultural Engineering, 28(18):281-286.