Table of Contents

1 Hospitals including Dental and Foot Health 10

1.1.1 Cross infection: Electro-chemically activated water in dental unit water line J T Marais1 & V S Brözel2 British Dental Journal 187, 154 - 158 (1999) 10

1.1.2 In-use effect of electrolysed water on transcutaneous oxygen sensors Stephanie J. Dancer · Julie Mallon · Rebecca Murphy · Cliff Murch 10

1.1.3 Hypochlorous Acid - Analytical Methods and Antimicrobial Activity Müjde Eryılmaz1* and İsmail Murat Palabıyık2 1Department of Pharmaceutical Microbiology, 2Department of Analytical Chemistry, ... 10

1.1.4 Hypochlorous Acid: an ideal wound care agent with powerful microbicidal, antibiofilm, and wound healing potency. Sakarya S1, Gunay N2, Karakulak M3, Ozturk B4, Ertugrul B4. 10

1.1.5 Comparison of cleaning efficacy between in-use disinfectant and electrolysed water in an English residential care home N.S. Meakin · C Bowman · M.R. Lewis · S.J. Dancer 10

1.1.6 Efficacy and Safety of neutral pH Super-Oxidized Solution in SEVERE Diabetic Foot Infections 11

1.1.7 Evaluation of the antimicrobial effect of super-oxidized water (Sterilox®) and sodium hypochlorite against Enterococcus faecalis in a bovine root canal model Rossi-Fedele G1, Figueiredo JA, Steier L, Canullo L, Steier G, Roberts APJ Appl Oral Sci. 2010 Sep-Oct;18(5):498-502 11

1.1.8 Bactericidal effects of acidic electrolyzed water on the dental unit waterline. Kohno S1, Kawata T, Kaku M, Fuita T, Tsutsui K, Ohtani J, Tenjo K, Motokawa M, Tohma Y, Shigekawa M,Kamata H, Tanne K. 12

1.1.9 An investigation of the efficacy of super–oxidised water for the disinfection of dental unit water lines. M V Martin1 & M A Gallagher 12

1.1.10 Ultrasonically nebulised electrolysed oxidising water: A promising new infection control programme for impressions, metals and gypsum casts used in dental hospitals ArticleinJournal of Hospital Infection 68(4):348-54 · April 2008 DOI: 10.1016/j.jhin.2008.01.02 12

1.1.11 Endoscope contamination from HBV- and HCV-positive patients and evaluation of a cleaning/disinfection method using strongly acidic electrolyzed water. Sakurai, Y., M. Nakatsu, Y. Sato, and K. Sato. 2003. *Dig. Endosc.* 15:19–24 12

1.1.12 Absolute rate constants for the reaction of hypochlorous acid with protein side chains and peptide bonds. Pattison DI1, Davies MJ. Chem Res Toxicol. 2001 Oct;14(10):1453-64 12

1.1.13 Hypochlorous Acid as a Potential Wound Care Agent Part I. Stabilized Hypochlorous Acid: A Component of the Inorganic Armamentarium of Innate Immunity L Wang, PhD,a M Bassiri, PhD,a R Najafi, PhD,a K Najafi, MD,b J Yang, BS,a B Khosrovi, PhD,a W Hwong, BS,a E Barati, BS,a B Belisle, PhD,a C Celeri, MS,a and MC Robson, MDc 13

1.1.14 Effect of dentin pretreatment with mild acidic HOCl solution on microtensile bond strength and surface pH. Kunawarote S1, Nakajima M, Shida K, Kitasako Y, Foxton RM, Tagami J. J Dent. 2010 Mar;38(3):261-8. doi: 10.1016/j.jdent.2009.11.006. Epub 2009 Nov 27.... 13

1.1.15 Acidic Electrolysed Water in the Disinfection of the Ocular Surface Shigeto Shimmura · Koki Matsumoto · Hiromoto Yaguchi · [...] ·Kazuo Tsubot 13

1.1.16 Use of an electrolyzed sodium chloride solution for disinfection in therapeutic and prophylactic institutions. Nikulin, V. A. 1977. *Sov. Med.* 12:105–108 14

1.1.17 Pre-surgical preparation of surgeon's hands with the products of electrolysis of a 3% solution of sodium chloride. Nikitin, B. A., and L. A. Vinnik. 1965. *Khirurgiia* 41:104–105 14

1.1.18 Efficacy of electrolyzed acid water in reprocessing patient-used flexible upper endoscopes: comparison with 2% alkaline glutaraldehyde. Lee, J. H., P. Rhee, J. H. Kim, J. J. Kim, S. W. Paik, J. C. Rhee, J. H. Song, J. S. Yeom, and N. Y. Lee. 2004. *J. Gastroenterol. Hepatol.* 19:897–903 14

1.1.19 Electrochemically activated solutions: Evidence for antimicrobial efficacy and applications in healthcare environments R. M. S. Thorn & S. W. H. Lee & G. M. Robinson & J. Greenman & D. M. Reynolds 14

1.1.20 Super-Oxidized Solution (SOS) Therapy for Infected Diabetic Foot Ulcers 14

1.1.21 Non-surgical Management of Chronic Wounds in Patients With Diabetes 14

1.1.22 A pilot study on microbial load reduction in peritonitis with a neutral pH – super-oxidized solution 14

1.1.23 Neutral Super-Oxidised Solutions Effective in killing P. aeruginosa biofilms 14

1.1.24 Comparative Efficacy and Tolerability of Microcyn Super-Oxidize Solution (Oxum) against Povidone Iodine Topical Application in the Post-caesarean Section Wound Management 15

1.1.25 Electrochemically activated solutions: Evidence for antimicrobial efficacy and applications in healthcare environments R. M. S. Thorn & S. W. H. Lee & G. M. Robinson & J. Greenman & D. M. Reynolds 15

1.1.26 Diabetic Micro-Vascular Complication Today 15

1.1.27 A Novel Super-Oxidized water with neutral pH and Disinfectant activity 15

1.1.28 Treatment of Diabetic Foot Ulcer: An Overview of Strategies for Clinical Approach 15

1.1.29 Super-Oxidized Solution inhibits IgE-antigen-induced degranulation and cytokine release in mast cells 15

1.1.30 An evaluation of one test product for its antimicrobial properties when challenged with various micro-organism strains using an in-vitro time-kill method 15

1.1.31 Panel Intelligence Report - Diabetic Foot Infection Treatment 15

1.1.32 Allie DE, Super-Oxidized Dermacyn in Lower-Extremity Wounds, WOUNDS, 2006, 18 (Suppl), 3-6. Barrera-Zavala A, Guillen-Rojas M, Escobedo-Anzures J, Rendon J, Ayala O & Gutiérrez AA. A pilot study on source control of peritonitis with a neutral pH – super oxidized solution. Submitted 2006. 16

1.1.33 Bongiovanni, CM, Nonsurgical Management of Chronic Wounds in Patients With Diabetes; The Journal for Vascular Ultrasound, 2006, 30(4): 215-218. 16

1.1.34 Bongiovanni, CM, Superoxidized Water Improves Wound Care Outcomes in Diabetic Patients; Diabetic Microvascular Complications Today, 2006, May-June: 11-14 16

1.1.35 Dalla Paola L, Brocco E, Senesi A, Ninkovic S, Mericvo M & De Vido D. Use of Dermacyn, a new antiseptic agent for the local treatment of diabetic foot ulcers, J Wound Healing 2005, 2:201. 16

1.1.36 Dalla Paola L, Brocco E, Senesi A, et al., Super-Oxidized Solution (SOS) Therapy for Infected Diabetic Foot Ulcers; WOUNDS, 2006, 18(9):262-270. 16

1.1.37 Dalla Paola L, Treating Diabetic foot Ulcers with Super-Oxidized Water, WOUNDS, 2006, 18 (Suppl 1):14-16. 16

1.1.38 Dalla Paola L & Faglia E.Treatment of Diabetic Foot Ulcer: An Overview. Strategies for Clinical Approach Current Diabetes Reviews, 2006, 2, 431-447 431 16

1.1.39 González-Espinosa D, Pérez-Romano L, Guzman Soriano B, Arias E, Bongiovanni CM & Gutiérrez AA. Effects of neutral super-oxidized water on human dermal fibroblasts in vitro. Int Wound Journal (UK) 2007, 4: 241-250. 16

1.1.40 Goretti C, Mazzurco S, Nobili L, Macchiarini S, Tedeschi A, Palumbo F, Scatena A, Rizzo L, Piaggesi A, et al., Clinical Outcomes of Wide Postsurgical Lesions in the Infected Diabetic Foot Managed With 2 Different Local Treatment Regimes Compared Using a Quasi-Experimental Study Design: A Preliminary Communication; Lower Extremity Wounds, 2007, 6(1):22-27. 16

1.1.41 Gutierrez AA, The Science Behind Stable, Super-Oxidized Water. WOUNDS, 2006, 18 (Suppl 1):7-10. L 16

1.1.42 anda-Solis C, Gonzalez-Espinosa D, Guzman-Soriano B, Synder M, Reyes-Teran G, Torres K, Gutierrez AA, et al., Microcyn™ ; a novel super-oxidized water with neutral pH and disinfectant activity; Journal of Hospital Infection, 2005, 61:291-299. 16

1.1.43 Le Duc Q, Breetveld M, Middelkoop E, Scheper RJ, Ulrich MMW, Gibbs S. A cytotoxic analysis of antiseptic medication on skin substitutes and autograft. Br J Dermatology. 2007, 157:33-40. Martínez de Jesús, F. Sterilant for human wounds is changing patient's lives. Infection Control Today. 2004, 11(8). 16

1.1.44 Martínez-De Jesús FR, Ramos-De la Medina A, Remes-Troche JM, Armstrong DG, Wu SC, Lázaro Martínez JL, Beneit-Montesinos JV. Efficacy and safety of neutral pH superoxidised solution in severe diabetic foot infections. Int Wound Journal 2007 Oct 22 16

1.1.45 McCurdy B. Emerging Innovations in Treatment. Podiatry Today 2006, 19: 40-48. 16

1.1.46 Medina-Tamayo J, Balleza-Tapia H, López, X, Cid, ME, González-Espinosa, D. Gutiérrez AA., and González- Espinosa C. Super-oxidized water inhibits IgE-antigen- induced degranulation and cytokine release in mast cells. International Immunophamacology 2007, 7:1013-1024 16

1.1.47 Miranda-Altamirano A, Reducing Bacterial Infectious Complications from Burn Wounds, WOUNDS, 2006, 16(Suppl 1):17-19 16

1.1.48 Wolvos TA, Advanced Wound Care with Stable, Super-Oxidized Water, WOUNDS, 2006, 18 (Suppl 1):11-13. 16

1.1.49 Veverkova L, Jedlicka V, Vesely M, Tejkalova R, Zabranska S, Capov I, Votava M. Methicilinresistent Staphylococcus aureus –problem in health care. J Wound Healing 2005, 2:201-202. 16

1.1.50 Zahumensky E. Infections and diabetic foot syndrome in field practice. Vnitr Lek. 2006;52:411- 416. 16

1.1.51 Stuttgart Congress 2005 (various papers) 16

1.1.52 Electrochemical Water Disinfection: A Short Review ELECTRODES USING PLATINUM GROUP METAL OXIDES Platinum Metals Rev., 2008, 52, (3), 177 doi:10.1595/147106708x329273 16

1.1.53 From experience in the electrolytic decontamination of drinking water. Kunina, L. A. 1967. *Gig. Sanit.* 32:100–101. 16

1.1.54 Quantitative evaluation of the effects of physicochemical and technological factors on the process of water regeneration. Krivobok, N. M., V. B. Gaidadymov, V. V. Nosov, and G. G. Ter-Minasian. 1982. *Kosm. Biol. Aviakosm. Med.* 16:91–93. 17

2 Veterinary 17

2.1.1 The anti-microbial activity of electrolyzed oxidizing water against microorganisms relevant in veterinary medicine. Fenner, D. C., B. Bu¨rge, H. P. Kayser, and M. M. Wittenbrink. 2006. *J. Vet.Med. B* 53:133–137. 17

3 Food Industry General 17

3.1.1 Electrolyzed water and its application in the Food Industry. H Hricova, R Stephan and C Zweilel 2008 Journal of Food Protection Vol 71 No 9 Pages 1934-1947 17

3.1.2 Application of electrolyzed water for food industry in Japan. Yoshida, K., N. Achiwa, and M. Katayose. 2004. 17

3.1.3 Efficacy of electrolyzed oxidizing (EO) and chemically modified water on different types of foodborne pathogens. Kim, C., Y.-C. Hung, and R. E. Brackett. 2000. *Int. J. Food Microbiol.* 61:199–207 17

3.1.4 Cleaning in place with onsite-generated electrolysed oxidizing water for water-saving disinfection in breweries Lu Chen · Rong Chen · Hua Yin · [...] · Hong Lin 17

3.1.5 Roles of oxidation reduction potential in electrolyzed oxidizing and chemically modified water for the inactivation of food-related pathogens. Kim, C., Y.-C. Hung, and R. E. Brackett. 2000. *J. Food Prot.* 63:19–24 17

3.1.6 The efficacy of electrolyzed oxidizing water for inactivating spoilage microorganisms in process water and on minimally processed vegetables. Ongeng, D., F. Devlieghere, J. Debevere, J. Coosemans, and J. Ryckeboer. 2006. *Int. J. Food Microbiol.* 109:187–197....17

3.2 Ready to Eat Meals 18

3.2.1 Application of electrolyzed oxidizing water to reduce *Listeria monocytogenes* on ready-to-eat meats. Fabrizio, K. A., and C. N. Cutter. 2005. *Meat Sci.* 71:327–333. 18

3.3 Surfaces and Cutting Boards....18

3.3.1 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 CouponsLin Zhao · Ying Zhang · Hongshun Yang 18

3.3.2 Bacterial adherence and viability on cutting board surfaces. Abrishami, S. H., B. D. Tall, T. J. Bruursema, P. S. Epstein, and D. B. Shah. 1994. *J. Food Saf.* 14:153–172. 18

3.3.3 Efficacy of electrolyzed oxidizing water in inactivating *Vibrio parahaemolyticus* on kitchen cutting boards and food contact surfaces. Chiu, T.-H., J. Duan, C. Liu, and Y.-C. Su. 2006. *Lett. Appl. Microbiol.*43:666–672. 18

3.3.4 Efficacy of neutral electrolyzed water to inactivate *Escherichia coli*, *Listeria monocytogenes*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* on plastic and wooden kitchen cutting boards. Deza, M. A., M. Araujo, and M. J. Garrido. 2007. *J. Food Prot.* 70:102–108. 18

3.3.5 Inactivation of *Escherichia coli* O157:H7 and *Listeria monocytogenes* on plastic kitchen cutting boards by electrolyzed oxidizing water. Venkitanarayanan, K. S., G. O. Ezeike, Y.-C. Hung, and M. P. Doyle. 1999. *J. Food Prot.* 62:857–860. 18

3.3.6 Inactivation of *Escherichia coli*, *Listeria monocytogenes*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* on stainless steel and glass surfaces by neutral electrolysed water. Deza, M. A., M. Araujo, and M. J. Garrido. 2005. *Lett. Appl. Microbiol.* 40:341–346....19

3.3.7 Effectiveness of electrolyzed water as a sanitizer for treating different surfaces. Park, H., Y.-C. Hung, and C. Kim. 2002. *J. Food Prot.* 65:1276–1280....19

4 Biofilms 19

4.1.1 Enhancing the bactericidal effect of electrolyzed oxidizing water on *Listeria monocytogenes* biofilms formed on stainless steel. Ayebah, B., Y.-C. Hung, and J. F. Frank. 2005. *J. Food Prot.* 68:1375–1380. 19

4.1.2 Efficacy of electrolyzed water in the inactivation of planktonic and biofilm *Listeria monocytogenes* in the presence of organic matter. Ayebah, B., Y.-C. Hung, C. Kim, and J. F. Frank. 2006. *J. FoodProt.* 69:2143–2150....19

4.1.3 Sensitivity of biofilms to antimicrobial agents. Brown, M. R., and P. Gilbert. 1993. *J. Appl. Bacteriol.* 74:87S–97S. 19

4.1.4 Direct measurement of chlorine penetration into biofilms during disinfection.De Beer, D., R. Srinivasan, and P. S. Stewart. 1994. *Appl. Environ. Microbiol.* 60:4339–4344....19

4.1.5 Biofilm penetration and disinfection efficacy of alkaline hypochlorite and chlorosulfamates. Stewart, P. S., J. Rayner, F. Roe, and W. M. Rees. 2001. *J. Appl. Microbiol.* 91:525–532....19

4.1.6 Efficacy of two cleaning and sanitizing combinations on *Listeria monocytogenes* biofilms formed at low temperature on a variety of materials in the presence of ready-to-eat meat residue. Somers, E. B., and A. C. Wong. 2004. *J. Food Prot.* 67:2218–2229 20

4.1.7 Inactivation of *Listeria monocytogenes* biofilms by electrolyzed oxidizing water. Kim, C., Y.-C. Hung, R. E. Brackett, and J. F. Frank. 2001 *J. Food Process. Preserv.* 25:91–100 20

4.1.8 Biofilms: survival mechanisms of clinically relevant microorganisms. Donlan, R. M., and J. W. Costerton. 2002. *Clin. Microbiol. Rev.* 15:167–193. 20

4.1.9 Inactivation of *Listeria monocytogenes* biofilms by electrolyzed oxidizing water. Kim, C., Y.-C. Hung, R. E. Brackett, and J. F. Frank. 2001. *J. Food Process. Preserv.* 25:91–100 20

5 Plants....20

5.1 General 20

5.1.1 Comparison of effects of acidic electrolyzed water and NaOCl on *Telletia indica* teliospore germination. Bonde, M. R., S. E. Nester, J. L. Smilanick, R. D. Frederick, and N. W. Schaad. 1999. *Plant Dis.* 83:627–632....20

5.1.2 Reduction of *Salmonella enterica* on alfalfa seeds with acidic electrolyzed oxidizing water and enhanced uptake of acidic electrolyzed oxidizing water into seeds by gas exchange. Stan, S. D., and M. A. Daeschel. 2003. *J. Food Prot.* 66:2017–2022....20

5.1.3 Grech, N. M., and F. H. Rijkenberg. 1992. Injection of electronically generated chlorine into citrus micro-irrigation systems for the control of certain waterborne root pathogens. *Plant Dis.* 76:457–461. 20

5.2 Fruit 20

5.2.1 A review of microbiological safety of fruits and vegetables and the introduction of electrolyzed water as an alternative to sodium hypochlorite solution Abdulsudi Issa-Zacharia, Yoshinori Kamitani, Happiness S. Muhimbula and Bernadette K. Ndabikunze African Journal of Food Science Vol. 4(13), pp. 778 - 789 December 2010 20

5.3 Strawberry 20

5.3.1 Survival of *Escherichia coli* O157:H7 on strawberry fruit and reduction of the pathogen population by chemical agents. Yu, K. H., M. C. Newman, D. D. Archbold, and T. R. Hamilton- Kemp. 2001. *J. Food Prot.* 64:1334–1340. 20

5.4 Peach 21

5.4.1 Fungicidal effectiveness of electrolyzed oxidizing water on postharvest brown rot of peach. Al-Haq, M. I., Y. Seo, S. Osita, and Y. Kawagoe. 2001. *Hortic. Sci.* 39:1310–1314....21

5.5 Pear....21

5.5.1 Disinfection effects of electrolyzed oxidizing water on suppressing fruit rot of pear caused by *Botryosphaeria berengeriana.* Al-Haq, M. I., Y. Seo, S. Osita, and Y. Kawagoe. 2002. *Food Res. Int.* 35:657–664. 21

5.6 Apples 21

5.6.1 Activity of electrolyzed oxidizing water against *Penicillium expansum* in suspension and on wounded apples. Okull, D. O., and L. E. LaBorde. 2004. *J. Food Sci.* 69:23–27 21

5.7 Figs....21

5.7.1 Article: EFFICACY OF NEUTRALISED ELECTROLYSED WATER AND MILD HEAT AGAINST FOODBORNE PATHOGENS ISOLATED FROM FICUS CARICA Cigdem ileri yamaner · Muavviz Ayvaz · Ramazan Konak · [...] ·Anatoli Dimoglo 21

5.8 Cut Vegetables....21

5.8.1 Electrolyzed water as a disinfectant for fresh-cut vegetables. Izumi, H. 1999. *J. Food Sci.* 64:536–539 21

5.8.2 The effect of available chlorine concentration on the disinfecting potential of acidic electrolyzed water for shredded vegetables. Koseki, S., and K. Itoh. 2000. *J. Jpn. Soc. Food Sci. Technol.* 47:888– 898.....21

5.8.3 Effect of processing conditions on the microflora of fresh-cut vegetables. Garg, N., J. J. Churey, and D. F. Splittstoesser. 1990. *J.Food Prot.* 53:701–703. 22

5.8.4 Prediction of microbial growth in fresh-cut vegetables treated with acidic electrolyzed water during storage under various temperature conditions. Koseki, S., and K. Itoh. 2001. *J. Food Prot.* 64: 1935–1942.....22

5.9 Tomatoes *22*

5.9.1 Effectiveness of electrolyzed acidic water in killing *Escherichia coli* O157:H7, *Salmonella* Enteritidis, and *Listeria monocytogenes* on the surface of tomatoes. Bari, M. L., Y. Sabina, S. Isobe, T. Uemura, and K. Isshiki. 2003. *J. Food Prot.* 66:542–548. 22

5.9.2 Inactivation of *Escherichia coli* O157:H7, *Salmonella enteritidis* and *Listeria monocytogenes* on the surface of tomatoes by neutral electrolyzed water. Deza, M. A., M. Araujo, and M. J. Garrido. 2003*Lett. Appl. Microbiol.* 37:482–487. 22

5.9.3 Elution, detection and quantification of polio I, bacteriophages, *Salmonella* Montevideo, and *Escherichia coli* O157:H7 from seeded strawberries and tomatoes. Lukasik, J., M. L. Bradley, T. M. Scott, W. Y. Hsu, S. R. Farrah, and M. L. Tamplin. 2001. *J. Food Prot.* 64:292–297.....22

5.9.4 Fate of foodborne pathogens on green onions and tomatoes by electrolysed water E-J Park · E Alexander · G.A. Taylor · [...] · D-H Kang 23

5.10 Flowers *23*

5.10.1 Evaluation of acidic electrolyzed water for phytotoxic symptoms on foliage and flowers of bedding plants. Buck, J. W., M. W. van Iersel, R. D. Oetting, and Y.-C. Hung. 2003. *Crop Prot.* 22:73–77. 23

5.11 Cucumber *23*

5.11.1 Efficacy of acidic electrolyzed water for microbial decontamination of cucumbers and strawberries. Koseki, S., Y. Yoshida, S. Isobe, and K. Itoh. 2004. *J. Food Prot.* 67:1247–1251 23

5.12 Lettuce *23*

5.12.1 The effect of pH on inactivation of pathogenic bacteria on fresh-cut lettuce by dipping treatment with electrolyzed water. Yang, H., B. L. Swem, and Y. Li. 2003. *J. Food Sci.* 68:1013–1017. 23

5.12.2 Reduction of bacteria on spinach, lettuce, and surfaces in food service areas using neutral electrolyzed water. Guentzel, J. L., K. L. Lam, M. A. Callan, S. A. Emmons, and V. L. Dunham. 2008. *Food Microbiol.* 25:36–41. 23

5.12.3 Decontamination effect of frozen acidic electrolyzed water on lettuce. Koseki, S., K. Fujiwara, and K. Itoh. 2002. *J. Food Prot.* 65: 411–414. 23

5.12.4 Decontamination of lettuce using acidic electrolyzed water. Koseki, S., Y. Yoshida, S. Isobe, and K. Itoh. 2001. *J. Food Prot.* 64: 652–658. 24

5.12.5 Effect of mild heat pre-treatment with alkaline electrolyzed water on the efficacy of acidic electrolyzed water against *Escherichia coli* O157:H7 and *Salmonella* on lettuce. Koseki, S., Y. Yoshida, K. Kamitani, S. Isobe, and K. Itoh. 2004. *Food Microbiol.* 21:559–566 24

5.12.6 Pathogen reduction and quality of lettuce treated with electrolyzed oxidizing and acidified chlorinated water. Park, C. M., Y.-C. Hung, M. P. Doyle, G. O. Ezeike, and C. Kim. 2001. *J. Food Sci.* 66: 1368–1372 24

5.12.7 Efficacy of acidic electrolyzed water ice for pathogen control on lettuce. Koseki, S., S. Isobe, and K. Itoh. 2004. *J. Food Prot.* 67: 2544–2549 24

5.13 Alfalfa seeds *24*

5.13.1 Efficacy of electrolyzed oxidizing water in inactivating *Salmonella* on alfalfa seeds and sprouts. Kim, C., Y.-C. Hung, R. E. Brackett, and C.-S. Lin. 2003. *J. Food Prot.* 66:208–214.....24

5.14 Rice *24*

5.14.1 An examination of cooked rice with electrolyzed water. Kobayashi, K., N. Tosa, Y. Hara, and S. Horie. 1996. *J. Jpn. Soc. Food Sci. Technol.* 43:930–938 24

5.15 Tofu *24*

5.15.1 Effects of weakly electrolyzed water on properties of tofu. Hara, Y., A. Watanuki, and E. Arai. 2003. *Food Sci. Technol. Res.* 9: 332–337 24

5.16 *Wheat noodles* 24

5.16.1 Effects of weakly electrolyzed water on properties of Japanese wheat noodles. Hara, Y., A. Watanuki, and E. Arai. 2003. *Food Sci. Technol. Res.* 9:320–326........ 24

6 Animals **24**

6.1 *General agriculture and food* 24

6.1.1 Applications of electrolyzed water in agriculture and food industries. Al-Haq, M. I., J. Sugiyama, and S. Isobe. 2005. *Food Sci.Technol. Res.* 11:135–150. 24

6.2 *Cattle & Beef* 24

6.2.1 *Escherichia coli* O157 prevalence and enumeration of aerobic bacteria, *Enterobacteriaceae*, and *Escherichia coli* O157 at various steps in commercial beef processing plants. Arthur, T. M., J. M. Bosilevac, X. Nou, S. D. Shackelford, T. L. Wheeler, M. P. Kent, D. Karoni, B. Pauling, D. M. Allen, and M. Koohmaraie. 2004. *J.Food Prot.* 67:658–665. 24

6.2.2 Electrolyzed oxidizing anode water as a sanitizer for use in abattoirs. Bach, S. J., S. Jones, K. Stanford, B. Ralston, D. Milligan, G. L. Wallins, H. Zahiroddini, T. Stewart, C. Giffen, and T. A. McAllister. 2006. *J. Food Prot.* 69:1616–1622. 24

6.2.3 Beef hide antimicrobial interventions as a means of reducing bacterial contamination. Baird, B. E., L. M. Lucia, G. R. Acuff, K. B. Harris, and J. W. Savell. 2006. *Meat Sci.* 73:245–248. 25

6.2.4 Prevalence of *Escherichia coli* O157 and levels of aerobic bacteria and *Enterobacteriaceae* are reduced when beef hides are washed and treated with cetylpyridinium chloride at a commercial beef processing plant. Bosilevac, J. M., T. M. Arthur, T. L. Wheeler, S. D. Shackelford, M. Rossman, J. O. Reagan, and M. Koohmaraie. 2004. *J. Food Prot.* 67:646–650. 25

6.2.5 Efficacy of ozonated and electrolyzed oxidative waters to decontaminate hides of cattle before slaughter. Bosilevac, J. M., S. D. Shackelford, D. M. Brichta, and M. Koohmaraie. 2005. *J. Food Prot.*68:1393–1398. 25

6.2.6 Post-harvest interventions to reduce/eliminate pathogens in beef. Koohmaraie, M., T. M. Arthur, J. M. Bosilevac, M. Guerini, S. D. Shackelford, and T. L. Wheeler. 2005. *Meat Sci.* 71:79–91. 25

6.2.7 An evaluation of selected methods for the decontamination of cattle hides prior to skinning. Small, A., B. Wells-Burr, and S. Buncic. 2005. *Meat Sci.* 69:263–268 25

6.2.8 Presence of food-borne pathogens on cattle hides. Reid, C.-A., A. Small, S. M. Avery, and S. Buncic. 2002. *Food Control* 13:411–415 25

6.2.9 Sanitizer efficacy against attached bacteria in a milk biofilm. Mosteller, T. M., and J. R. Bishop. 1993. *J. Food Prot.* 56:34–41 25

6.2.10 The relationship between hide cleanliness and bacterial numbers of beef carcasses at a commercial abattoir. McEvoy, J. M., A. M. Doherty, M. Finnerty, J. J. Sheridan, L. McGuire, I. S. Blair, D. A. McDowell, and D. Harrington. 2000. *Lett. Appl. Microbiol.* 30:390–395 25

6.2.11 Determination of the principal points of product contamination during beef carcass dressing processes in Northern Ireland. Madden, R. H., K. A. Murray, and A. Gilmour. 2004. *J. Food Prot.* 67: 1494–1496 25

6.3 *Pigs and Pork* 25

6.3.1 Comparison of electrolyzed water with other antimicrobial interventions to reduce pathogens on fresh pork. Fabrizio, K. A., and C. N. Cutter. 2004. *Meat Sci.* 68:463–468. 25

6.4 *Poultry - Chickens* 25

6.4.1 Application of slightly acidic electrolyzed water for inactivating microbes in a layer breeding house. Hao XX, Li BM, Wang CY, Zhang Q, Cao W. Laboratory of Structure and Environment in Agricultural Engineering, Ministry of Agriculture, China Oct 2013 Poultry Science Oct; 92(10):2560-6 25

6.4.2 The use of electrolyzed water for sanitation control of eggshells and GP center. Achiwa, N., and T. Nishio. 2003. Food Sci. Technol.Res. 9:100–103. 26

6.4.3 Economics of reducing *Campylobacter* at different levels within the Belgian poultry meat chain. Gellynck, X., W. Messens, D. Halet, K. Grijspeerdt, E. Hartnett, and J. Viaene. 2008. *J. Food Prot.* 71:479–485. 26

6.4.4 Comparison of electrolyzed oxidizing water with various antimicrobial interventions to reduce *Salmonella* species on poultry. Fabrizio, K. A., R. R. Sharma, A. Demirci, and C. N. Cutter. 2002. *Poult. Sci.* 81:1598–1605. 26

6.4.5 Efficacy of electrolyzed water in the prevention and removal of fecal material attachment and its microbicidal effectiveness during simulated industrial poultry processing. Kim, C., Y.-C. Hung, and S. M. Russell. 2005. *Poult. Sci.* 84:1778–1784. 26

6.4.6 Spoilage microflora of broiler carcasses washed with electrolyzed oxidizing or chlorinated water using an inside-outside bird washer. Hinton, A., Jr., J. K. Northcutt, D. P. Smith, M. T. Musgrove, andK. D. Ingram. 2007. *Poult. Sci.* 86:123–127 27

6.4.7 The effect of electrolyzed oxidative water applied using electrostatic spraying on pathogenic and indicator bacteria on the surface of eggs. Russel, S. M. 2003. *Poult. Sci.* 82:158–162 27

6.4.8 Electrolysed reduced water decreases reactive oxygen species-induced oxidative damage to skeletal muscle and improves performance in broiler chickens exposed to medium-term chronic heat stress. Azad MA, Kikusato M, Zulkifli I, Toyomizu M. Br Poult Sci. 2013;54(4):503-9. doi: 10.1080/00071668.2013.801067. Epub 2013 Jul 1. 27

6.4.9 Antimicrobial effect of electrolyzed water for inactivating *Campylobacter jejuni* during poultry washing. Park, H., Y.-C. Hung, and R. E. Brackett. 2002. *Int. J. Food Microbiol.* 72:77–83 27

6.4.10 Efficacy of electrolyzed water in inactivating *Salmonella* Enteritidis and *Listeria monocytogenes* on shell eggs. Park, C.-M., Y.-C. Hung, C.-S. Lin, and R. E. Brackett. 2005. *J. Food Prot.* 68:986–990 28

6.4.11 Evaluation of “Neutral Electrolyzed Water” Disinfectant on Inactivation of Avian Influenza Virus and Other Avian Viruses 28

6.4.12 Efficacy of electrolyzed oxidizing water for the microbial safety and quality of eggs. Bailka KL, Demirci A, Knabel SJ, Patterson PH, Puri VM. Department of Agricultural & Biological Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, USA, Poultry Science. 2004 Dec;83(12):2071-8. 28

6.5 Fish and Seafood 28

6.5.1 Application of electrolyzed water on the reduction of bacterial contamination for seafood. Huang, Y.-R., H.-S. Hsieh, S.-Y. Lin, S.-J. Lin, Y.-C. Hung, and D.-F. Hwang. 2006. *Food Control* 17: 987–993 28

6.5.2 Effects of electrolyzed oxidizing water treatment on reducing *Vibrio parahaemolyticus* and *Vibrio vulnificus* in raw oysters. Ren, T., and Y.-C. Su. 2006. *J. Food Prot.* 69:1829–1834 28

6.5.3 Change of hygienic quality and freshness in tuna treated with electrolyzed water and carbon monoxide gas during refrigerated and frozen storage. Huang, Y.-R., C.-Y. Shiau, Y.-C. Hung, and D.-F. Hwang. 2006. *J. Food Sci.* 71:127–134 29

6.5.4 Effects of electrolyzed water on reducing *Listeria monocytogenes* contamination on seafood processing surfaces. Liu, C., J. Duan, and Y.-C. Su. 2006. *Int. J. Food Microbiol.* 106:248–253 29

6.5.5 Efficiency of electrolyzed oxidizing water on reducing *Listeria monocytogenes* contamination on seafood processing gloves. Liu, C., and Y.-C. Su. 2006. *Int. J. Food Microbiol.* 110:149–154 29

6.5.6 Electrolyzed oxidizing water treatment for decontamination of raw salmon inoculated with *Escherichia coli* O157:H7 and *Listeria monocytogenes* Scott A and response surface modeling. Ozer, N. P., and A. Demirci. 2006. *J. Food Eng.* 72:234–241 29

6.5.7 Decontamination effect of electrolyzed NaCl solutions on carp. Mahmoud, B. S., K. Yamazaki, K. Miyashita, S. Il-Shik, C. Dong- Suk, and T. Suzuki. 2004. *Lett. Appl. Microbiol.* 39:169–173 30

6.5.8 Use of electrolyzed water ice for preserving freshness of pacific saury (*Cololabis saira*). Kim, W.-T., Y.-S. Lim, I.-S. Hin, H. Park, D. Chung, and T. Suzuki. 2006. *J. Food Prot.* 69:2199–2204 30

7 Disinfection and general properties 30

7.1 General 30

7.1.1 Stability of electrolyzed water and its efficacy against cell suspensions of *Salmonella* Typhimurium and *Listeria monocytogenes.* Fabrizio, K. A., and C. N. Cutter. 2003 *J. Food Prot.* 66:1379–1384 30

7.1.2 Inactivation of a hepadnavirus by electrolysed acid water Tagawa, M., T. Yamaguchi, O. Yokosuka, S. Matsutani, T. Maeda, and H. Saisho. 2000.. *J. Antimicrob. Chemother.* 46:363–368. 30

7.1.3 Bactericidal activity of disinfectants on *Listeria.* Van de Weyer, A., M. J. Devleeschouwer, and J. Dony. 1993. *J. Appl. Bacteriol.* 74:480–483. 31

7.1.4 The bactericidal effects of electrolyzed oxidizing water on bacterial strains involved in hospital infections. Vorobjeva, N. V., L. I. Vorobjeva, and E. Y. Khodjaev. 2003. *Artif. Organs* 28:590–592. 31

7.1.5 Efficacy of electrolyzed oxidizing water for inactivation of *Escherichia coli* O157:H7, *Salmonella enteritidis*, and *Listeria monocytogenes.* Venkitanarayanan, K. S., G. O. Ezeike, Y.-C. Hung, and M. P. Doyle. 1999. *Appl. Environ. Microbiol.* 65:4276–4279. 31

7.1.6 Different responses of planktonic and attached *Bacillus subtilis* and *Pseudomonas fluorescens* to sanitizer treatment. Lindsay, D., and A. von Holy. 1999. *J. Food Prot.* 62:368–379 31

7.1.7 Decontamination of aflatoxin-forming fungus and elimination of aflatoxin mutagenicity with electrolyzed NaCl anode solution. Suzuki, T., T. Noro, Y. Kawamura, K. Fukunaga, M. Watanabe, M. Ohta, H. Sugiue, Y. Sato, M. Kohno, and K. Hotta. 2002. *J. Agric. Food Chem.* 50:633–641. 31

7.1.8 Inactivation of staphylococcal enterotoxin-A with an electrolyzed anodic solution. Suzuki, T., J. Itakura, M. Watanabe, M. Ohta, Y. Sato, and Y. Yamaya. 2002. *J. Agric. Food Chem.* 50:230–234. 32

7.1.9 Effect of acidified sodium chlorite, chlorine, and acidic electrolyzed water on *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* inoculated onto leafy greens. Stopforth, J. D., T. Mai, B. Kottapalli, and M. Samadpour. 2008*J. Food Prot.* 71:625–628. 32

7.1.10 Effects of water source, dilution, storage, and bacterial and fecal loads on the efficacy of electrolyzed oxidizing water for the control of *Escherichia coli* O157:H7. Stevenson, S. M., S. R. Cook, S. J. Bach, and T. A. McAllister. 2004. *J. Food Prot.* 67:1377–1383. 32

7.1.11 Antimicrobial activity of electrolyzed NaCl solutions: effect on the growth of *Streptomyces* spp. Hotta, K., K. Kawaguchi, F. Saitoh, N. Saitoh, K. Suzuki, K. Ochi, and T. Nakayama. 1994. *Actinomycetologica* 8:51–56....32

7.1.12 Changes in the properties of soft and hard oxidized waters under different storage conditions and when in contact with saliva. Shimada, K., T. Igarashi, and N. Ebihara. 1997. *J. Jpn. Soc. Periodontol.* 39:104–112 33

7.1.13 Determination of phytotoxicity of several volatile organic compounds by investigating the germination patterns of tobacco pollen. Schubert, U., L. Wisanowsky, and U. Kull. 1995. *J. Plant Physiol.* 145:518–541 33

7.1.14 Comparison of sodium hypochlorite and peracetic acid as sanitizing agents for stainless steel food processing surfaces using epifluorescence microscopy. Rossoni, E. M., and C. C. Gaylarde. 2000. *Int. J. Food Microbiol.* 61:81–85....33

7.1.15 Effects of chlorine and pH on efficacy of electrolyzed water for inactivating *Escherichia coli* O157:H7 and *Listeria monocytogenes.* Park, H., Y.-C. Hung, and D. Chung. 2004. *Int. J. Food Microbiol.* 91:13–18 33

7.1.16 The efficiency of disinfection of acidic electrolyzed water in the presence of organic materials. Oomori, T., T. Oka, T. Inuta, and Y. Arata. 2000. *Anal. Sci.* 16:365–369 33

7.1.17 Susceptibility of *Penicillium expansum* spores to sodium hypochlorite, electrolyzed oxidizing water, and chlorine dioxide solutions modified with nonionic surfactants. Okull, D. O., A. Demirci, D. Rosenberger, and L. F. LaBorde. 2006. *J. Food Prot.* 69:1944–1948 34

7.1.18 Durability of bactericidal activity in electrolyzed neutral water by storage. Nagamatsu, Y., K.-K. Chen, K. Tajima, H. Kakigawa, and Y. Kozono. 2002. *Dent. Mater. J.* 21:93–105 34

7.1.19 Disinfection potential of electrolyzed solutions containing sodium chloride at low concentrations. Morita, C., K. Sano, S. Morimatsu, H. Kiura, T. Goto, T. Kohno, W. Hong, H. Miyoshi, A. Iwasawa, Y. Nakamura, M. Tagawa, O. Yokosuka, H. Saisho, T. Maeda, nd Y. Katsuoka. 2000. *J. Virol. Methods* 85:163–174 34

7.1.20 Fundamental properties of electrolyzed water. Koseki, S., and K. Itoh. 2000. *J. Jpn. Soc. Food Sci. Technol.* 47:390–393....34

7.1.21 Electrolyzed water: a new technology for food decontamination—a review. Mahmoud, B. S. 2007. *Dtsch. Lebensm. Rundsch.* 103: 212–221 34

7.1.22 Acid adaptation sensitizes *Salmonella typhimurium* to hypochlorous acid. Leyer, G. J., and E. A. Johnson. 1997. *Appl. Environ. Microbiol* 63:461–467. 34

7.1.23 The generation and inactivation mechanism of oxidation-reduction potential of electrolyzed oxidizing water. Liao, L. B., W. M. Chen, and X. M. Xiao. 2007. *J. Food Eng.* 78:1326–1332 35

7.1.24 Inactivation of surface adherent *Listeria monocytogenes* by hypochlorite and heat. Lee, S.-H., and J. F. Frank. 1991 *J. Food Prot.* 54:4–6. 35

7.1.25 Effects of storage conditions and pH on chlorine loss in electrolyzed oxidizing (EO) water. Len, S.-V., Y.-C. Hung, D. Chung, J. L. Anderson, M. C. Ericksen, and K. Morita. 2002. *J. Agric. Food Chem.* 50:209–212. 35

7.1.26 Ultraviolet spectrometric characterization of bactericidal properties of electrolyzed oxidizing water as influenced by amperage and pH. Len, S.-V., Y.-C. Hung, M. C. Ericksen, and C. Kim. 2000. *J. Food Prot.* 63:1534–1537. 35

7.1.27 A novel electrolyzed sodium chloride solution for the disinfection of dried HIV-1. Kitano, J., T. Kohno, K. Sano, C. Morita, M. Yamaguchi, T. Maeda, and N. Tanigawa. 2003. *Bull. Osaka Med. Coll.* 48:29–36. 35

7.1.28 Bactericidal activity of electrolyzed acid water from solution containing sodium chloride at low concentration, in comparison with that at high concentration. Kiura, H., K. Sano, S. Morimatsu, T. Nakano, C. Morita, M. Yamaguchi, T. Maeda, and Y. Katsuoka. 2002. *J. Microbiol. Methods* 49:285–293. 36

7.1.29 Investigation of the presence of OH radicals in electrolyzed NaCl solution by electron spin resonance spectroscopy. Stan SD, Woods JS, DaeschelMA. Department of Food Science and Technology, Oregon State University, 100 Wiegand Hall, Corvallis, Oregon 97331, USA. 36

1 Hospitals including Dental and Foot Health

1.1.1 Cross infection: Electro-chemically activated water in dental unit water line J T Marais1 & V S Brözel2 British Dental Journal 187, 154 - 158 (1999)

Objective To investigate the effect of electro-chemically activated water on biofilm contamination in dental unit water lines.

Design Thirteen dental units fitted with independent water systems and used for 12 years with distilled water were divided into two groups, A and B. At the start, one week later, and again four weeks later, the bacterial counts in water from all units were determined. Also specimens of tubing were taken from the units at the beginning and at the end of the study for SEM investigation. In Group A distilled water was replaced with electrochemically activated water (a Russian invention), and used continuously for the duration of the study. In group B, distilled water was used as before, until confirmed to be contaminated. For ethical reasons group B was treated, one week into the study with conventional disinfectants.

Setting The project was carried out in a clinic of a department of periodontology of a faculty of dentistry during 1998.

Results Both groups showed a marked reduction in bacterial counts. Under SEM Group A showed a total elimination of the biofilm and Group B a partial removal.

Conclusions Distilled water was ineffective in controlling bacterial counts and biofilm. Electrochemically activated water was effective for this purpose.

Source: British Dental Journal

1.1.2 In-use effect of electrolysed water on transcutaneous oxygen sensors Stephanie J. Dancer · Julie Mallon · Rebecca Murphy · Cliff Murch

Reusable clinical equipment should be decontaminated between patients in order to reduce risk of pathogen transmission. Manufacturers are obliged to offer advice regarding decontamination but occasionally insufficient guidance is provided. Tissue oxygen sensors are reusable, costly and vulnerable to disinfectants. This pilot study describes an in-use protocol using neutral electrolysed water aimed at eliminating infection risk during transcutaneous oxygen monitoring of diabetic feet. Sensor components were screened for microbial contamination before, during, and after monitoring healthy and diabetic volunteers. Exposure to electrolysed water removed original skin commensals and alleviated the risk of transmitting microbial flora without affecting test results. The product is non-toxic, inexpensive and may be useful for decontaminating a wide range of sensitive clinical equipment.

1.1.3 Hypochlorous Acid - Analytical Methods and Antimicrobial Activity Müjde Eryılmaz1* and İsmail Murat Palabıyık2 1Department of Pharmaceutical Microbiology, 2Department of Analytical Chemistry,

Hypoclorous acid (HOCl), a powerful oxidizer and deproteinizer produced by neutrophils, has a good microbicidal activity within these cells. It reacts with many biological molecules, especially thiol, thiolether, heme proteins, amino groups and carbonhydrates, as well as overcomes pathogens and fights infection [1-3]. HOCl has advantages over sodium hypochlorite (NaOCl) and hydrogen peroxide (H2O2) in that within its effective antimicrobial concentration range, it is non-irritating, non-sensitizing and cytotoxicity to mammalian cells is lower.

Source: Paper

1.1.4 Hypochlorous Acid: an ideal wound care agent with powerful microbicidal, antibiofilm, and wound healing potency. Sakarya S1, Gunay N2, Karakulak M3, Ozturk B4, Ertugrul B4.

Chronic wounds and the infections associated with them are responsible for a considerable escalation in morbidity and the cost of health care. Infection and cellular activation and the relation between cells are 2 critical factors in wound healing. Since chronic wounds offer ideal conditions for infection and biofilm production, good wound care strategies are critical for wound healing. Topical antiseptics in chronic wounds remain in widespread use today. These antiseptics are successful in microbial eradication, but their cytotoxcity is a controversial issue in wound healing.

OBJECTIVE: The aim of this study was to investigate the effect of stabilized hypochlorous acid solution (HOCl) on killing rate, biofilm formation, antimicrobial activity within biofilm against frequently isolated microorganisms and migration rate of wounded fibroblasts and keratinocytes.

MATERIALS AND METHODS: Minimal bactericidal concentration of stabilized HOCl solution for all standard microorganisms was 1/64 dilution and for clinical isolates it ranged from 1/32 to 1/64 dilutions.

RESULTS: All microorganisms were killed within 0 minutes and accurate killing time was 12 seconds. The effective dose for biofilm impairment for standard microorganisms and clinical isolates ranged from 1/32 to 1/16. Microbicidal effects within the biofilm and antibiofilm concentration was the same for each microorganism.

CONCLUSION: The stabilized HOCl solution had dose-dependent favorable effects on fibroblast and keratinocyte migration compared to povidone iodine and media alone. These features lead to a stabilized HOCl solution as an ideal wound care agent.

1.1.5 Comparison of cleaning efficacy between in-use disinfectant and electrolysed water in an English residential care home N.S. Meakin · C Bowman · M.R. Lewis · S.J. Dancer

Infection control in hospitals and care homes remains a key issue. They are regularly inspected regarding standards of hygiene, but visual assessment does not necessarily correlate with microbial cleanliness. Pathogens can persist in the inanimate environment for extended periods of time. This prospective study compared the effectiveness of a novel sanitizer containing electrolysed water, in which the active ingredient is stabilized hypochlorous acid (Aqualution™), with the effectiveness of the quaternary ammonium disinfectant in current use for microbial removal from hand-touch surfaces in a care home. The study had a two-period crossover design. Five surfaces were cleaned daily over a four-week period, with screening swabs taken before and after cleaning. Swabs were cultured in order to compare levels of surface microbial contamination [colony-forming units (cfu)/cm(2)] before and after cleaning with each product. Cleaning with electrolysed water reduced the mean surface bacterial load from 2.6 [interquartile range (IQR) 0.30-30.40] cfu/cm(2) to 0.10 (IQR 0.10-1.40) cfu/cm(2) [mean log(10) reduction factor 1.042, 95% confidence interval (CI) 0.79-1.30]. Cleaning with the in-use quaternary ammonium disinfectant increased the bacterial load from 0.90 (IQR 0.10-8.50) cfu/cm(2) to 93.30 (IQR 9.85-363.65) cfu/cm(2) (mean log(10) reduction -1.499, 95% CI -1.87 to -1.12) ($P < 0.0001$). Using two proposed benchmark standards for surface microbial levels in hospitals, electrolysed water resulted in a higher 'pass rate' than the in-use quaternary ammonium disinfectant (80-86% vs 15-21%, $P < 0.0001$). Electrolysed water exerts a more effective bacterial kill than the in-use quaternary ammonium disinfectant, which suggests that it may be useful as a surface sanitizer in environments such as care homes.

1.1.6 Efficacy and Safety of neutral pH Super-Oxidized Solution in SEVERE Diabetic Foot Infections

Infected foot ulcerations are a frequent cause of morbidity, hospitalisation and amputations among persons with diabetes (1). The attributable cost of caring for a primary healing foot ulcer for 3 years after the initial diagnosis can amount to over $26 000 (2). The survival rate of patients who develop diabetic foot ulcers is reduced by about 15%, and at 5 years, these patients have approximately a 50% survival rate usually after arterial interventions and amputations (3,4). Diabetic patients are prone to develop foot ulcerations because of the lack of neurological sensation and cycles of repetitive stress from ambulation. Rates of ulceration, infection and amputation have declined dramatically in some centres that have developed programmes and teams for foot care. Infection still remains a common problem in diabetic patients (5–8). Ulcerations are pivotal events leading to diabetic foot infection, which has been shown to be the immediate cause of amputations in 25–50% of the cases (2). This is especially true of deep space infection, which is associated with an amputation rate of 52% (2). The resultant amputations are minor in 24–60% of the cases and major in 10–40% (2). The spectrum of foot infections in diabetic patients ranges from simple superficial cellulitis to chronic osteomyelitis. Infections in patients with diabetes are often difficult to treat because of impaired microvascular circulation, which limits the access of phagocytic cells to the infected area and results in a poor concentration of antibiotics in the infected tissues (9). Wound healing is delayed when acute infection persists (10–12). Infection control along with appropriate debridement and good wound care are all essential factors in the treatment of diabetic foot ulcerations. Most of the chemicals disinfectants currently used in wound care can cause damage to the skin or granulating tissue. Topical antiseptics such as hypochlorite (Dakin’s solution), povidone iodine (betadine) and others can cause significant cell damage. This may not only interfere wound healing process (13), but also could be cytotoxic or deleterious for the underlying tissues or proximal skin (14). Furthermore, normal sterile saline or water, although non cytotoxic, do not adequately remove surface contaminates and does not have antiseptic properties. Some products as the wound cleansers help to break the bond between contaminates, necrotic tissue and the surface of the wound (15,16). An effective non toxic antiseptic agent that cleanses the wound and removes bacterial contaminants without damaging healthy tissue is therefore needed to help diminish the bacterial burden and prevent the substantial long-term morbidity associated with amputations. Superoxidized aqueous solution is non toxic, neutral pH water that contains reactive oxygen species (ROS) generated by the electrolysis of sodium chloride and water. Components of this solution includes superoxide – neutral pH water, chlorine ,85 parts per million (ppm), ROS/free radicals, oxidised water H2O; 9999%, sodium hypochlorite (NaOCl) ,50 ppm, hypochlorous acid (HOCl) ,60 ppm, hydrogen peroxide (H2O2) ,4 ppm, ozone (O3) ,02 ppm, chlorine dioxide (ClO2) ,15 ppm, sodium hydroxide (NaOH) ,8 ppm, sodium carbonate (Na2CO3) ,21 ppm, sodium chloride (NaCl) ,110 ppm. The bactericidal advantages and wound healing properties of ROS has been documented (13). Superoxidised water has been shown to be a powerful non toxic bactericidal against a variety of aerobics Gram-negative and Gram-positive rods (17) and is highly effective in treating infectious skin conditions and refractory ulcers associated with diabetes mellitus or peripheral circulatory insufficiency (18,19). In this randomised, controlled, single-blind study, our aim was to assess the efficacy of a non-toxic, neutral pH superoxidised aqueous solution (NpHSS) in terms of infection control, odour reduction and periwound skin…. Source

1.1.7 Evaluation of the antimicrobial effect of super-oxidized water (Sterilox®) and sodium hypochlorite against Enterococcus faecalis in a bovine root canal model Rossi-Fedele G1, Figueiredo JA, Steier L, Canullo L, Steier G, Roberts AP

J Appl Oral Sci. 2010 Sep-Oct;18(5):498-502

Ideally root canal irrigants should have, amongst other properties, antimicrobial action associated with a lack of toxicity against periapical tissues. Sodium hypochlorite (NaOCl) is a widely used root canal irrigant, however it has been shown to have a cytotoxic effect on vital tissue and therefore it is prudent to investigate alternative irrigants. Sterilox's Aquatine Alpha Electrolyte® belongs to the group of the super-oxidized waters; it consists of a mixture of oxidizing substances, and has been suggested to be used as root canal irrigant. Super-oxidized waters have been shown to provide efficient cleaning of root canal walls, and have been proposed to be used for the disinfection of medical equipment.

OBJECTIVE:

To compare the antimicrobial action against Enterococcus faecalis of NaOCl, Optident Sterilox Electrolyte Solution® and Sterilox's Aquatine Alpha Electrolyte® when used as irrigating solutions in a bovine root canal model.

METHODOLOGY:

Root sections were prepared and inoculated with E. faecalis JH2-2. After 10 days of incubation the root canals were irrigated using one of three solutions (NaOCl, Optident Sterilox Electrolyte Solution®and Sterilox's Aquatine Alpha Electrolyte®) and subsequently sampled by grinding dentin using drills. The debris was placed in BHI broth and dilutions were plated onto fresh agar plates to quantify growth.

RESULTS:

Sodium hypochlorite was the only irrigant to eliminate all bacteria. When the dilutions were made, although NaOCl was still statistically superior, Sterilox's Aquatine Alpha Electrolyte® solution was superior to Optident Sterilox Electrolyte Solution®.

CONCLUSIONS:

Under the conditions of this study Sterilox's Aquatine Alpha Electrolyte® appeared to have significantly more antimicrobial action compared to the Optident Sterilox Electrolyte Solution® alone, however NaOCl was the only solution able to consistently eradicate E. faecalis in the model.
Source: Abstract

1.1.8 Bactericidal effects of acidic electrolyzed water on the dental unit waterline. Kohno S1, Kawata T, Kaku M, Fuita T, Tsutsui K, Ohtani J, Tenjo K, Motokawa M, Tohma Y, Shigekawa M,Kamata H, Tanne K.

Many studies have been conducted in the United States regarding the microbial contamination of dental unit waterline, but not in Japan. Recently, acidic electrolyzed water has been used in the medical and dental fields. In this study, we investigated the bactericidal effects of the temporary inflow of acidic electrolyzed water on microbial contamination of the dental unit waterline. First, in order to observe the daily bacterial contamination of the dental unit waterline, water samples were collected at the end of handpieces and three-way syringes before the inflow of acidic electrolyzed water. They were cultured to detect viable bacteria. Later, the inflow of acidic electrolyzed water was conducted through the piping box of the dental unit. Before starting operation on next day, water samples were collected and cultured, as described above. The mean viable bacteria count was 910 -/+ 190 CFU/ml at the end of handpieces, and 521 -/+ 116 CFU/ml at the end of three-way syringes before the inflow of acidic electrolyzed water. However, bacteria were detected in only small numbers at the end of handpieces and three-way syringes on the next day. These results indicated that acidic electrolyzed water could be applied as an appropriate measure against bacterial contamination of the dental unit waterline.
Source: Abstract

1.1.9 An investigation of the efficacy of super–oxidised water for the disinfection of dental unit water lines. M V Martin1 & M A Gallagher

Aims To determine the efficacy of super-oxidised water (Optident/Sterilox) in the decontamination of dental unit water lines.

Methods Dental units (10) were first purged with concentrated super-oxidised water. After purging, a 5% (v/v) super-oxidised water was used as a maintenance dose. Samples for microbiology were taken after 0,1,2,3,4,5,6,7 d, and each week for a further 13 weeks.

Results After purging, 5% (v/v) super-oxidised water was successful in reducing the microbial counts to zero, although in three of the units some bacteria were intermittently isolated in the first week of treatment.

Conclusions Super-oxidised water was successful in the removal of bacteria from dental unit water supplies. Complete removal required the treatment with a purge phase of concentrated disinfectant and a maintenance phase of at least two weeks.
Source: British Medical Journal

1.1.10 Ultrasonically nebulised electrolysed oxidising water: A promising new infection control programme for impressions, metals and gypsum casts used in dental hospitals Article in Journal of Hospital Infection 68(4):348-54 · April 2008 DOI: 10.1016/j.jhin.2008.01.02

Controlling the transmission of infectious diseases by impressions, metals and dental casts in dental hospitals remains a challenge. Current disinfection methods have various drawbacks. This study introduced and provided a preliminary evaluation of the feasibility of using ultrasonically nebulised, electrolysed oxidising water (UNEOW) as a new infection control programme. UNEOW was produced from freshly generated electrolysed oxidising water (EOW). Samples of impressions, titanium and gypsum were subjected to the following treatments: (1) immersion in 1% sodium hypochlorite for 10min; (2) immersion in EOW for 10min; (3) exposure to UNEOW for 15, 30 and 45min; (4) no disinfection (control). Bactericidal efficacy was examined using Staphylococcus aureus and Bacillus subtilis var. niger spores as indicators. Dimensional accuracy, surface quality, and effect of corrosion were also evaluated for the different samples. Results showed that except for B. subtilis var. niger spores on gypsum casts, the bacterial reduction log(10) values after 30-45min treatment with UNEOW were all above 4. The impression dimensional changes showed no difference between control and UNEOW groups, but both were significantly lower than the EOW and sodium hypochlorite groups (P<0.05). The same was true for the surface quality of impressions and gypsum casts. No assessable corrosion was found on the titanium surface after a 45min treatment with UNEOW. The findings indicated that use of UNEOW is a feasible and promising approach for controlling the transmission of infectious diseases by impressions, gypsum casts and denture metals in dental facilities
Source: PubMed

1.1.11 Endoscope contamination from HBV- and HCV-positive patients and evaluation of a cleaning/disinfection method using strongly acidic electrolyzed water. Sakurai, Y., M. Nakatsu, Y. Sato, and K. Sato. 2003. *Dig. Endosc.* 15:19–24

1.1.12 Absolute rate constants for the reaction of hypochlorous acid with protein side chains and peptide bonds. Pattison DI1, Davies MJ. Chem Res Toxicol. 2001 Oct;14(10):1453-64

Hypochlorous acid (HOCl) is a potent oxidant, which is produced in vivo by activated phagocytes. This compound is an important antibacterial agent, but excessive or misplaced production has been implicated in a number of human diseases, including atherosclerosis, arthritis, and some cancers. Proteins are major targets for this oxidant, and such reaction results in side-chain modification, backbone fragmentation, and cross-linking. Despite a wealth of qualitative data for such reactions, little absolute kinetic data is available to rationalize the in vitro and in vivo data. In this study, absolute second-order rate constants for the reactions of HOCl with protein side chains, model compounds, and backbone amide (peptide) bonds have been determined at physiological pH values. The reactivity of HOCl with potential reactive sites in proteins is summarized by the series: Met (3.8 x 10(7) M(-1) x s(-1)) > Cys (3.0 x 10(7) M(-1) x s(-1)) >> cystine (1.6 x 10(5) M(-1) x s(-1)) approximately His (1.0 x 10(5) M(-1) x s(-1)) approximately alpha-amino (1.0 x 10(5) M(-1) x s(-1)) > Trp (1.1 x 10(4) M(-1) x s(-1)) > Lys (5.0 x 10(3) M(-1) x s(-1)) >> Tyr (44 M(-1) x s(-1)) approximately Arg (26 M(-1) x s(-1)) > backbone amides (10-10(-3) M(-1) x s(-1)) > Gln(0.03 M(-1) x s(-1)) approximately Asn (0.03 M(-1) x s(-1)). The rate constants for reaction of HOCl with backbone amides (peptide bonds) vary by 4 orders of magnitude with uncharged peptide bonds reacting more readily with HOCl than those in a charged environment. These kinetic parameters have been used in computer modeling of the reactions of HOCl with human serum albumin, apolipoprotein-A1 and free amino acids in plasma at different molar excesses. These models are useful tools for predicting, and reconciling, experimental data obtained in HOCl-induced oxidations and allow estimations to be made as to the flux of HOCl to which proteins are exposed in vivo.

1.1.13 Hypochlorous Acid as a Potential Wound Care Agent Part I. Stabilized Hypochlorous Acid: A Component of the Inorganic Armamentarium of Innate Immunity L Wang, PhD,a M Bassiri, PhD,a R Najafi, PhD,a K Najafi, MD,b J Yang, BS,a B Khosrovi, PhD,a W Hwong, BS,a E Barati, BS,a B Belisle, PhD,a C Celeri, MS,a and MC Robson, MDc

Objective: Hypochlorous acid (HOCl), a major inorganic bactericidal compound of innate immunity, is effective against a broad range of microorganisms. Owing to its chemical nature, HOCl has never been used as a pharmaceutical drug for treating infection. In this article, we describe the chemical production, stabilization, and biological activity of a pharmaceutically useful formulation of HOCl. Methods: Stabilized HOCl is in the form of a physiologically balanced solution in 0.9% saline at a pH range of 3.5 to 4.0. Chlorine species distribution in solution is a function of pH. In aqueous solution, HOCl is the predominant species at the pH range of 3 to 6. At pH values less than 3.5, the solution exists as a mixture of chlorine in aqueous phase, chlorine gas, trichloride (Cl_3^-), and HOCl. At pH greater than 5.5, sodium hypochlorite (NaOCl) starts to form and becomes the predominant species in the alkaline pH. To maintain HOCl solution in a stable form, maximize its antimicrobial activities, and minimize undesirable side products, the pH must be maintained at 3.5 to 5. Results: Using this stabilized form of HOCl, the potent antimicrobial activities of HOCl are demonstrated against a wide range of microorganisms. The in vitro cytotoxicity profile in L929 cells and the in vivo safety profile of HOCl in various animal models are described. Conclusion: On the basis of the antimicrobial activity and the lack of animal toxicity, it is predicted that stabilized HOCl has potential pharmaceutical applications in the control of soft tissue infection.Go to:

Objective: Hypochlorous acid (HOCl), a major inorganic bactericidal compound of innate immunity, is effective against a broad range of microorganisms. Owing to its chemical nature, HOCl has never been used as a pharmaceutical drug for treating infection. In this article, we describe the chemical production, stabilization, and biological activity of a pharmaceutically useful formulation of HOCl. Methods: Stabilized HOCl is in the form of a physiologically balanced solution in 0.9% saline at a pH range of 3.5 to 4.0. Chlorine species distribution in solution is a function of pH. In aqueous solution, HOCl is the predominant species at the pH range of 3 to 6. At pH values less than 3.5, the solution exists as a mixture of chlorine in aqueous phase, chlorine gas, trichloride (Cl_3^-), and HOCl. At pH greater than 5.5, sodium hypochlorite (NaOCl) starts to form and becomes the predominant species in the alkaline pH. To maintain HOCl solution in a stable form, maximize its antimicrobial activities, and minimize undesirable side products, the pH must be maintained at 3.5 to 5. Results: Using this stabilized form of HOCl, the potent antimicrobial activities of HOCl are demonstrated against a wide range of microorganisms. The in vitro cytotoxicity profile in L929 cells and the in vivo safety profile of HOCl in various animal models are described. Conclusion: On the basis of the antimicrobial activity and the lack of animal toxicity, it is predicted that stabilized HOCl has potential pharmaceutical applications in the control of soft tissue infection.

1.1.14 Effect of dentin pretreatment with mild acidic HOCl solution on microtensile bond strength and surface pH. Kunawarote S1, Nakajima M, Shida K, Kitasako Y, Foxton RM, Tagami J. J Dent. 2010 Mar;38(3):261-8. doi: 10.1016/j.jdent.2009.11.006. Epub 2009 Nov 27.

To evaluate the pretreatment effect of mild acidic HOCl solution on the microtensile bond strength (muTBS) of a two-step self-etch adhesive to dentin and the alteration of dentin surface pH.

METHODS: Thirty-nine flat ground coronal dentin specimens were divided into one control group and 12 experimental groups, which were treated with 6% NaOCl or 50, 100 and 200ppm HOCl (Comfosy) solutions for 5, 15 and 30s. After rinsing with running water for 30s, all the dentin surfaces were bonded with Clearfil SE Bond according to the manufacturer's instructions. After 24h water storage, the bonded specimens were sectioned and trimmed to an hourglass shape with a cross-sectional area of approximately 1.0mm(2) and then subjected to the muTBS test. Thirty-six mid-coronal dentin discs were used for surface pH measurement. Dentin surface pH with or without pretreatment was examined using a pH-imaging microscope (SCHEM-100). The muTBS data were analyzed by one-way ANOVA (Dunnett's T3) and the surface pH data were analyzed by non-parametric statistics (Mann-Whitney U-test).

RESULTS: Pretreatment with Comfosy at concentrations of 50, 100 and 200 ppm did not significantly affect muTBS regardless of the application time compared with the control group, however the 100 and 200ppm Comfosy groups showed significantly lower surface pH values. For the NaOCl pretreatment groups, a longer application time significantly decreased the muTBS and increased the surface pH values compared to the control group.

CONCLUSIONS: The 50ppm Comfosy pretreatments for 5, 15 and 30s did not affect the muTBS of the two-step self-etch adhesive to dentin and dentin surface pH.

1.1.15 Acidic Electrolysed Water in the Disinfection of the Ocular Surface Shigeto Shimmura · Koki Matsumoto · Hiromoto Yaguchi · [...] ·Kazuo Tsubot

Acidic electrolysed water (AEW) is a colorless solution prepared by the electrolysis of sodium chloride solution, which has potent anti-microbial activity against a wide variety of bacteria, fungi and virus. In this study, the safety and efficacy of an isotonic AEW solution (iAEW) was investigated both in vitro and in vivo using denuded corneas of guinea pigs. Povidone iodine (0.01-1.0%) was used as control. Exposure of P. aeruginosa to iAEW for 5 sec caused total inhibition of bacterial growth in vitro. Comparable results were obtained with 1% povidone iodine, while more dilute solutions required longer exposure times for similar effects. Cytotoxicity of iAEW on corneal epithelial cells in vitro was significantly less compared to 1% povidone iodine ($P<0.05$), while minimal damage was observed in vivo by irrigation of the cornea with either iAEW or 1% povidone iodine. Treatment of P. aeruginosa with iAEW (15 sec) significantly inhibited the onset of corneal infection in guinea pigs. iAEW may offer an effective and safe method for disinfection of the ocular surface.

1.1.16 Use of an electrolyzed sodium chloride solution for disinfection in therapeutic and prophylactic institutions. Nikulin, V. A. 1977. *Sov. Med.* 12:105–108

1.1.17 Pre-surgical preparation of surgeon's hands with the products of electrolysis of a 3% solution of sodium chloride. Nikitin, B. A., and L. A. Vinnik. 1965. *Khirurgiia* 41:104–105

1.1.18 Efficacy of electrolyzed acid water in reprocessing patient-used flexible upper endoscopes: comparison with 2% alkaline glutaraldehyde. Lee, J. H., P. Rhee, J. H. Kim, J. J. Kim, S. W. Paik, J. C. Rhee, J. H. Song, J. S. Yeom, and N. Y. Lee. 2004. *J. Gastroenterol. Hepatol.* 19:897–903

1.1.19 Electrochemically activated solutions: Evidence for antimicrobial efficacy and applications in healthcare environments R. M. S. Thorn & S. W. H. Lee & G. M. Robinson & J. Greenman & D. M. Reynolds

Eur J Clin Microbiol Infect Dis April 2011

Due to the limitations associated with the use of existing biocidal agents, there is a need to explore new methods of disinfection to help maintain effective bioburden control, especially within the healthcare environment. The transformation of low mineral salt solutions into an activated metastable state, by electrochemical unipolar action, produces a solution containing a variety of oxidants, including hypochlorous acid, free chlorine and free radicals, known to possess antimicrobial properties. Electrochemically activated solutions (ECAS) have been shown to have broad-spectrum antimicrobial activity, and have the potential to be widely adopted within the healthcare environment due to low-cost raw material requirements and ease of production (either remotely or in situ). Numerous studies have found ECAS to be highly efficacious, as both a novel environmental decontaminant and a topical treatment agent (with low accompanying toxicity), but they are still not in widespread use, particularly within the healthcare environment. This review provides an overview of the scientific evidence for the mode of action, antimicrobial spectrum and potential healthcare-related applications of ECAS, providing an insight into these novel yet seldom utilised biocides.

Source: Abstract

1.1.20 Super-Oxidized Solution (SOS) Therapy for Infected Diabetic Foot Ulcers

Paper from the compendium of Clinical Research and Practice September 2006 Source

1.1.21 Non-surgical Management of Chronic Wounds in Patients With Diabetes

Conclusion : Wounds fail to heal in a timely and orderly manner when regional blood flow is impaired, when infections are present and host immune mechanisms are damaged, and when invading flora are multidrug resistant. In the diabetic patient, the impact of all of these factors is commonly present and can have devastating effects, including limb loss and death. Key to healing wounds in diabetics is the resolution of metabolic issues, restoration of blood flow to ischemic and hypoxic tissues, and elimination of infection. None of these goals is simple, but all are necessary to reduce the staggering economic and social costs of wound care in diabetics. New wound treatment options, including superoxidized water and negative pressure devices,60 antibacterial dressing materials, etc are having a positive effect on healing outcomes in general. New agents for ameliorating diabetes itself are increasingly available and will, hopefully, allow the patient to disrupt the downward spiral so common to the development, and retarded healing, of chronic wounds that occur in patients with diabetes. Source

1.1.22 A pilot study on microbial load reduction in peritonitis with a neutral pH – super-oxidized solution

Intra-abdominal sepsis is a clinical disorder commonly found in Mexican general hospitals. It has been published that from 2% to 14.76 % of patients admitted to the emergency services of these Institutions present abdominal sepsis (Rodea, 1999; Bracho, 2002). The problem is that mortalities rates are higher in certain regions of the country due to the lack of fully equipped intensive care units. But despite major advances in surgery, antibiotics as well as nutritional, ventilatory and hemodynamic supports in developed countries, mortality rates remain in the range of 10-20%. For these reasons, there has been an ongoing interest in reducing the mortality rates in peritonitis by improving source control. The latter includes an efficient eradication of infection, elimination of microbial contamination and restoration of the local environment (Holzheimer, 2001). Adjuvant surgical measures, then, aim at the reduction of the bacterial load in the peritoneal cavity. For this purpose, planned relaparotomy, relaparotomy on demand, and intraoperative peritoneal lavage (IOPL) are all used as necessary. In severe peritonitis, for example, the use of multiple re-explorations and intraoperative lavage with large amounts of saline solution has been recommended to decrease the risk of postoperative infection. Yet, the benefit of adding antimicrobials or antiseptics to the lavage fluid remains controversial. Taurolidine, metronidazol and iodine povidone are some of the products so far tested. The bactericidal and anti-endotoxin product taurolidine, for example, has been shown to reduce the complication rates and length of hospital stay in patients with local peritonitis undergoing laparoscopy treatment (Gortz, 1997). Adjuvant metronidazol lavage has also been suggested as an efficient therapy for the treatment of intraperitoneal abcesses (Saha, 1996). However, no data has been further published on the efficacy and toxicity of these products. In addition, the use of iodine povidone for intraperitoneal lavage in colorectal surgery has been shown to lead to sclerosing encapsulating peritonitis (SEP) (Keating, 1997). In an attempt to reduce chemical-related toxicity to the peritoneum, Inoue et al. (1997), performed lavages with an electrolyzed strong acid aqueous solution to Barrera A et.al. Use of SOS in Peritonitis Final Report Oculus Innovative Sciences 062306 Department of Medical Affairs 3 treat 7 patients with peritonitis and intraperitoneal abscesses. This was an antimicrobial solution that contained reactive oxygen species, high chlorine content (>600 ppm) and, therefore, a high oxidation-reduction potential (ORP). As expected, the four positive cultures found at entry became negative between days 3-7 after irrigation with the solution twice a day. Thus, the concept of using a super-oxidized solution (SOS) for source control in peritonitis resulted attractive. Source

1.1.23 Neutral Super-Oxidised Solutions Effective in killing P. aeruginosa biofilms

Bacteria growing in biofilms can become up to 1000-fold more resistant to antibiotics and biocides as compared to their planktonic counterparts. As a result of this increased resistance, biofilms and biofilm-related infections cannot be effectively treated with conventional antibiotic therapy. The goal of this study was to determine the efficacy of three neutral pH, super-oxidised solutions (nSOSs, OIS-80, OIS-125, OIS-200, Microcyn Technology) varying in oxychlorine concentration (80, 125 and 200 ppm) against P. aeruginosa grown planktonically and as biofilms. Exposure for 20 s of exponential phase cells to any of the three solutions was sufficient to reduce viability by more than five logs. However, only exposure for 10 min to OIS-125 and OIS-200 for 10 min was sufficient to eradicate stationary phase P. aeruginosa cells. The efficacy of nSOSs on P. aeruginosa biofilms, grown to maturity in continuous flow tube reactors, was determined upon treatment up to 60 min. Viability pre- and post-treatment was determined by CFU counts. The effect of these solutions on P. aeruginosa biofilms and biofilm architecture was further visualised by confocal scanning laser microscopy and quantitatively analysed by COMSTAT. Under these experimental conditions, only OIS-125 and OIS-200 achieved a 43-log reduction and biofilm disaggregation within 30 min of exposure. Because OIS-125 and OIS-200 enhance the disaggregation of biofilms, their use in the treatment of surface-related biofilm infections deserves further investigation. Source

1.1.24 Comparative Efficacy and Tolerability of Microcyn Super-Oxidize Solution (Oxum) against Povidone Iodine Topical Application in the Post-caesarean Section Wound Management

Conclusion: Oxum (Microcyn Superoxidized solution) is safe and effective in post-caesarean wound care management and gives better efficacy and faster response as compared to the traditional Povidone-iodine topical application in post caesarean section wound care management Source

1.1.25 Electrochemically activated solutions: Evidence for antimicrobial efficacy and applications in healthcare environments R. M. S. Thorn & S. W. H. Lee & G. M. Robinson & J. Greenman & D. M. Reynolds

Eur J Clin Microbiol Infect Dis April 2011

Due to the limitations associated with the use of existing biocidal agents, there is a need to explore new methods of disinfection to help maintain effective bioburden control, especially within the healthcare environment. The transformation of low mineral salt solutions into an activated metastable state, by electrochemical unipolar action, produces a solution containing a variety of oxidants, including hypochlorous acid, free chlorine and free radicals, known to possess antimicrobial properties. Electrochemically activated solutions (ECAS) have been shown to have broad-spectrum antimicrobial activity, and have the potential to be widely adopted within the healthcare environment due to low-cost raw material requirements and ease of production (either remotely or in situ). Numerous studies have found ECAS to be highly efficacious, as both a novel environmental decontaminant and a topical treatment agent (with low accompanying toxicity), but they are still not in widespread use, particularly within the healthcare environment. This review provides an overview of the scientific evidence for the mode of action, antimicrobial spectrum and potential healthcare-related applications of ECAS, providing an insight into these novel yet seldom utilised biocides.

Source: Abstract

1.1.26 Diabetic Micro-Vascular Complication Today

Conclusion: Superoxidized water is effective in reducing bacterial load,5 enhancing local blood supply, accelerating development of neovascularity and providing a wound environment that is hostile to opportunistic organisms. Although superoxidized water is an extremely effective agent in wound management, it will not replace administration of good wound care practices. A multidisciplinary approach to wound care will include assertion of glycemic control, appropriate systemic antibiosis, nutritional amendment and attention to the overall social, medical and economic needs of the patient. Source

1.1.27 A Novel Super-Oxidized water with neutral pH and Disinfectant activity

Conclusion: … the concept of SOW to create a highlevel disinfectant (or sterilant) maintains its appeal because the basic materials, saline solution and electricity, are inexpensive. In addition, the end product is non-flammable and there are no special requirements for handling or disposal. Therefore, SOWs such as Microcyn are environmentally safe agents and the costs derived from the disposal of toxic chemicals in hospitals could diminish by simply discarding them locally. Altogether, these data suggest that Microcyn could play a significant role as an effective and safe disinfectant in hospital practice. Additional studies are now being conducted to determine if this solution may be used as an antiseptic and highlevel disinfectant. Source

1.1.28 Treatment of Diabetic Foot Ulcer: An Overview of Strategies for Clinical Approach

Mention on page 14 of published paper of prospects for ionised water or super oxidised water (highlighted). Source

1.1.29 Super-Oxidized Solution inhibits IgE-antigen-induced degranulation and cytokine release in mast cells

Activation of the high affinity IgE receptor (Fc εRI) through IgE-antigen complexes induces mast cell degranulation, synthesis 11 of lipid mediators and cytokine production. These effects are involved in Type I hypersensitivity reactions and controlling them has 12 been the main objective of many anti-allergic therapies. Here we report that pretreatment of murine bone marrow derived mast cells 13 (BMMC) with super-oxidized solution (SOS) inhibits Fc εRI dependent- β hexosaminidase and cytokine release. This effect is 14 exerted without altering total protein tyrosine phosphorylation, MAPK activation, cytokine mRNA accumulation or calcium 15 mobilization after Fc εRI triggering. Our data suggest that this neutral pH-SOS acts like a mast cell-membrane stabilizer inhibiting 16 the cell machinery for granule secretion without altering the signal transduction pathways induced by IgE-antigen receptor 17 crosslinking. Source

1.1.30 An evaluation of one test product for its antimicrobial properties when challenged with various micro-organism strains using an in-vitro time-kill method

Source

1.1.31 Panel Intelligence Report - Diabetic Foot Infection Treatment

Source

1.1.32 **Allie DE, Super-Oxidized Dermacyn in Lower-Extremity Wounds, WOUNDS, 2006, 18 (Suppl), 3-6. Barrera-Zavala A, Guillen-Rojas M, Escobedo-Anzures J, Rendon J, Ayala O & Gutiérrez AA. A pilot study on source control of peritonitis with a neutral pH – super oxidized solution. Submitted 2006.**

1.1.33 **Bongiovanni, CM, Nonsurgical Management of Chronic Wounds in Patients With Diabetes; The Journal for Vascular Ultrasound, 2006, 30(4): 215-218.**

1.1.34 **Bongiovanni, CM, Superoxidized Water Improves Wound Care Outcomes in Diabetic Patients; Diabetic Microvascular Complications Today, 2006, May-June: 11-14**

1.1.35 **Dalla Paola L, Brocco E, Senesi A, Ninkovic S, Mericvo M & De Vido D. Use of Dermacyn, a new antiseptic agent for the local treatment of diabetic foot ulcers, J Wound Healing 2005, 2:201.**

1.1.36 **Dalla Paola L, Brocco E, Senesi A, et al., Super-Oxidized Solution (SOS) Therapy for Infected Diabetic Foot Ulcers; WOUNDS, 2006, 18(9):262-270.**

1.1.37 **Dalla Paola L, Treating Diabetic foot Ulcers with Super-Oxidized Water, WOUNDS, 2006, 18 (Suppl 1):14-16.**

1.1.38 **Dalla Paola L & Faglia E.Treatment of Diabetic Foot Ulcer: An Overview. Strategies for Clinical Approach Current Diabetes Reviews, 2006, 2, 431-447 431**

1.1.39 **González-Espinosa D, Pérez-Romano L, Guzman Soriano B, Arias E, Bongiovanni CM & Gutiérrez AA. Effects of neutral super-oxidized water on human dermal fibroblasts in vitro. Int Wound Journal (UK) 2007, 4: 241-250.**

1.1.40 **Goretti C, Mazzurco S, Nobili L, Macchiarini S, Tedeschi A, Palumbo F, Scatena A, Rizzo L, Piaggesi A, et al., Clinical Outcomes of Wide Postsurgical Lesions in the Infected Diabetic Foot Managed With 2 Different Local Treatment Regimes Compared Using a Quasi-Experimental Study Design: A Preliminary Communication; Lower Extremity Wounds, 2007, 6(1):22-27.**

1.1.41 **Gutierrez AA, The Science Behind Stable, Super-Oxidized Water. WOUNDS, 2006, 18 (Suppl 1):7-10. L**

1.1.42 **anda-Solis C, Gonzalez-Espinosa D, Guzman-Soriano B, Synder M, Reyes-Teran G, Torres K, Gutierrez AA, et al., Microcyn™ ; a novel super-oxidized water with neutral pH and disinfectant activity; Journal of Hospital Infection, 2005, 61:291-299.**

1.1.43 **Le Duc Q, Breetveld M, Middelkoop E, Scheper RJ, Ulrich MMW, Gibbs S. A cytotoxic analysis of antiseptic medication on skin substitutes and autograft. Br J Dermatology. 2007, 157:33-40. Martínez de Jesús, F. Sterilant for human wounds is changing patient's lives. Infection Control Today. 2004, 11(8).**

1.1.44 **Martínez-De Jesús FR, Ramos-De la Medina A, Remes-Troche JM, Armstrong DG, Wu SC, Lázaro Martínez JL, Beneit-Montesinos JV. Efficacy and safety of neutral pH superoxidised solution in severe diabetic foot infections. Int Wound Journal 2007 Oct 22**

1.1.45 **McCurdy B. Emerging Innovations in Treatment. Podiatry Today 2006, 19: 40-48.**

1.1.46 **Medina-Tamayo J, Balleza-Tapia H, López, X, Cid, ME, González-Espinosa, D. Gutiérrez AA., and González- Espinosa C. Super-oxidized water inhibits IgE-antigen- induced degranulation and cytokine release in mast cells. International Immunophamacology 2007, 7:1013-1024**

1.1.47 **Miranda-Altamirano A, Reducing Bacterial Infectious Complications from Burn Wounds, WOUNDS, 2006, 16(Suppl 1):17-19.**

1.1.48 **Wolvos TA, Advanced Wound Care with Stable, Super-Oxidized Water, WOUNDS, 2006, 18 (Suppl 1):11-13.**

1.1.49 **Veverkova L, Jedlicka V, Vesely M, Tejkalova R, Zabranska S, Capov I, Votava M. Methicilinresistent Staphylococcus aureus –problem in health care. J Wound Healing 2005, 2:201-202.**

1.1.50 **Zahumensky E. Infections and diabetic foot syndrome in field practice. Vnitr Lek. 2006;52:411- 416.**

1.1.51 **Stuttgart Congress 2005 (various papers)**
Digest of papers

1.1.52 **Electrochemical Water Disinfection: A Short Review ELECTRODES USING PLATINUM GROUP METAL OXIDES Platinum Metals Rev., 2008, 52, (3), 177 doi:10.1595/147106708x329273**

Conclusion Electrochemical water disinfection has many advantages compared with conventional disinfection technologies. It has proven its reliability in several practical applications, mainly for the disinfection of drinking water, swimming pool water and industrial cooling water. Electrochemical water disinfection has also been used or tested for the reduction of bacterial contamination in dental water supplies (32), and for the disinfection of contact lenses (33) and ion exchange resins (34) etc. However, only a few electrochemical water disinfection products are currently available on the market. This is due to the relative unfamiliarity of the technology, and to fierce market competition with other technologies. Eventually, the cost and performance advantages of electrochemical technology should lead to its wider use.
Source: Abstract

1.1.53 **From experience in the electrolytic decontamination of drinking water. Kunina, L. A. 1967. *Gig. Sanit.* 32:100–101.**
Russian text

1.1.54 Quantitative evaluation of the effects of physicochemical and technological factors on the process of water regeneration. Krivobok, N. M., V. B. Gaidadymov, V. V. Nosov, and G. G. Ter-Minasian. 1982. *Kosm. Biol. Aviakosm. Med.* 16:91–93.

2 Veterinary

2.1.1 The anti-microbial activity of electrolyzed oxidizing water against microorganisms relevant in veterinary medicine. Fenner, D. C., B. Bu¨rge, H. P. Kayser, and M. M. Wittenbrink. 2006. *J. Vet.Med. B* 53:133–137.

Standards of the German Association of Veterinary Medicine (DVG) for the evaluation of chemical disinfectants were used to assess the anti-microbial efficacy of electrolysed oxidizing water (EOW). Enterococcus faecium, Mycobacterium avium subspecies avium, Proteus mirabilis, Pseudomonas aeruginosa, Staphylococcus aureus and Candida albicans were exposed to anode EOW (pH, 3.0+/-0.1; oxidation-reduction potential (ORP), +1100+/-50 mV; free chlorine, 400+/-20 mg/l Cl2) and combined EOW (7:3 anode:cathode, v/v; pH, 8.3+/-0.1; ORP, 930-950 mV; free chlorine, 271+/-20 mg/l Cl2). In water of standardized hardness (WSH), all bacterial strains were completely inactivated by a 30 min exposure to maximum 10.0% anode EOW (approximately 40.0 mg/l Cl2) or 50.0% combined EOW (approximately 135.5 mg/l Cl2). The sensitivity ranking order for anode EOW to the bacterial test strains was P. mirabilis>S. aureus>M. avium ssp. avium>E. faecium>P. aeruginosa. P. mirabilis and S. aureus decreased to undetectable levels after 5 min of exposure to 7.5% anode EOW (approximately 30.0 mg/l Cl2). Candida albicans was completely inactivated by a 5-min exposure to 5.0% anode EOW. Both, anode and combined EOW exhibited no anti-microbial activities in standardized nutrient broth or after addition of 20.0% bovine serum to the WSH. Further research is necessary to evaluate the efficacy of EOW as a disinfectant under operating conditions in animal production facilities.
Source: Abstract

Source:

3 Food Industry General

3.1.1 Electrolyzed water and its application in the Food Industry. H Hricova, R Stephan and C Zweilel 2008 Journal of Food Protection Vol 71 No 9 Pages 1934-1947

Electrolyzed water (EW) is gaining popularity as a sanitizer in the food industries of many countries. By electrolysis, a dilute sodium chloride solution dissociates into acidic electrolyzed water (AEW), which has a pH of 2 to 3, an oxidation-reduction potential of >1,100 mV, and an active chlorine content of 10 to 90 ppm, and basic electrolyzed water (BEW), which has a pH of 10 to 13 and an oxidation-reduction potential of -800 to -900 mV. Vegetative cells of various bacteria in suspension were generally reduced by > 6.0 log CFU/ml when AEW was used. However, AEW is a less effective bactericide on utensils, surfaces, and food products because of factors such as surface type and the presence of organic matter. Reductions of bacteria on surfaces and utensils or vegetables and fruits mainly ranged from about 2.0 to 6.0 or 1.0 to 3.5 orders of magnitude, respectively. Higher reductions were obtained for tomatoes. For chicken carcasses, pork, and fish, reductions ranged from about 0.8 to 3.0, 1.0 to 1.8, and 0.4 to 2.8 orders of magnitude, respectively. Considerable reductions were achieved with AEW on eggs. On some food commodities, treatment with BEW followed by AEW produced higher reductions than did treatment with AEW only. EW technology deserves consideration when discussing industrial sanitization of equipment and decontamination of food products. Nevertheless, decontamination treatments for food products always should be considered part of an integral food safety system. Such treatments cannot replace strict adherence to good manufacturing and hygiene practices.
Source: Abstract

3.1.2 Application of electrolyzed water for food industry in Japan. Yoshida, K., N. Achiwa, and M. Katayose. 2004.
Source:

3.1.3 Efficacy of electrolyzed oxidizing (EO) and chemically modified water on different types of foodborne pathogens. Kim, C., Y.-C. Hung, and R. E. Brackett. 2000. *Int. J. Food Microbiol.* 61:199–207
Source:

3.1.4 Cleaning in place with onsite-generated electrolysed oxidizing water for water-saving disinfection in breweries Lu Chen · Rong Chen · Hua Yin · [...] · Hong Lin

The use of acid electrolysed water (AcEW) is a relatively new sanitizing technique for brewery equipment. Experiments showed that a 30% AcEW (a free chlorine concentration of above 17 mg/L) was a sufficient and effective alternative to conventional sanitizers such as peracetic acid (2%). On the basis of the results of industrial-scale clean-in-place tests, an effective AcEW-based clean-in-place procedure, which requires only 10 min of cleaning and does not require final water rinsing after sanitation, was established for the bright beer tank.
Copyright © 2013 The Institute of Brewing & Distilling

3.1.5 Roles of oxidation reduction potential in electrolyzed oxidizing and chemically modified water for the inactivation of food-related pathogens. Kim, C., Y.-C. Hung, and R. E. Brackett. 2000. *J. Food Prot.* 63:19–24
Source:

3.1.6 The efficacy of electrolyzed oxidizing water for inactivating spoilage microorganisms in process water and on minimally processed vegetables. Ongeng, D., F. Devlieghere, J. Debevere, J. Coosemans, and J. Ryckeboer. 2006. *Int. J. Food Microbiol.* 109:187–197

The efficacy of Electrolysed Oxidising Water (EOW) for inactivating spoilage microorganisms in process water and on minimally processed vegetables was investigated. The direct effect of EOW on three important spoilage bacteria namely; Pseudomonas fluorescens, Pantoea agglomerans or Rahnella aquatilis was determined by inoculating tap water or "artificial process water" with approximately 8 log CFU/ml pure culture and electrolysing the resultant solutions. The three bacteria were each reduced to undetectable levels at low (0.5 A) and relatively higher levels (1.0 A) of current in tap water and "artificial process water", respectively. The residual effect of EOW on P. fluorescens, P. agglomerans or R. aquatilis was determined by incubating at room temperature 1 ml (approximately 9 log CFU/ml) pure culture suspensions in 9 ml of EOW-T (EOW produced from tap water), EOW-A (EOW produced from "artificial process water" supplemented with approximately 60.7 mg Cl(-)/l and 39.3 mg Na(+)/l) or deionised water (control) for 0, 15, 45 or 90 min. The bactericidal activity of both EOW-T and EOW-A increased with the concentration of free oxidants and incubation period and the three bacteria were completely reduced at free oxidants-incubation period combinations of 3.88 mg/l-45 min and 5.1 mg/l-90 min in EOW-T and EOW-A, respectively. Two types of industrial vegetable process water; salad-mix and soup process water, which had each a total psychrotrophic count of approximately 8 log CFU/ml were then electrolysed. Without any NaCl addition, only 1.2 and 2.1 log reductions of the psychrotrophs in soup and salad-mix process water was attained respectively. Supplementation of the process water with approximately 60.7 mg Cl(-)/l and 39.3 mg Na(+)/l afterwards resulted in complete reduction of the psychrotrophic count in both process waters, but soup process water required relatively higher levels of current compared to salad-mix water. Finally, fresh-cut lettuce was washed in EOW-T containing 3.62 mg free oxidants/l, EOW-IP (EOW produced from industrial process water) containing 2.8 mg free oxidants/l or tap water (control) for 1 or 5 min. Washing the vegetables for 1 min in EOW-T resulted in 1.9, 1.2, and 1.3 log reductions of psychrotrophs, lactic acid bacteria and Enterobacteriaceae, respectively, which increased to 3.3, 2.6, and 1.9 log reductions after washing for 5 min instead. EOW-IP tested in this work had no bactericidal effect on the microflora of fresh-cut lettuce. Electrolysis could therefore be used to decontaminate process water for vegetable pre-washing and to sanitise tap water for final rinsing of vegetables, respectively.

Source: Abstract

3.2 Ready to Eat Meals

3.2.1 Application of electrolyzed oxidizing water to reduce *Listeria monocytogenes* on ready-to-eat meats. Fabrizio, K. A., and C. N. Cutter. 2005. *Meat Sci.* 71:327–333.

Source:

3.3 Surfaces and Cutting Boards

3.3.1 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 CouponsLin Zhao · Ying Zhang · Hongshun Yang

The sanitising effect of low concentration neutralised electrolysed water (LCNEW, pH: 7.0, free available chlorine (FAC): 4 mg/L) combined with ultrasound (37 kHz, 80 W) on food contact surface was evaluated. Stainless steel coupon was chosen as attachment surface for Escherichia coli ATCC 25922, Pichia pastoris GS115 and Aureobasidium pullulans 2012, representing bacteria, yeast and mold, respectively. The results showed that although LCNEW itself could effectively reduce survival population of E. coli ATCC 25922, P. pastoris GS115 and low concentration A. pullulans 2012 in planktonic status, LCNEW combined with ultrasound showed more sanitising efficacy for air-dried cells on coupons, with swift drops: 2.2 and 3.1 log CFU/coupon reductions within 0.2 min for E. coli ATCC 25922 and P. pastoris GS115, respectively and 1.0 log CFU/coupon reductions within 0.1 min for A. pullulans 2012. Air-dried cells after treatment were studied by atomic force microscopy (AFM)/optical microscopy (OM) and protein leakage analyses further. All three strains showed visible cell damage after LCNEW and LCNEW combined with ultrasound treatment and 1.41 and 1.73 μg/mL of protein leakage were observed for E. coli ATCC 25922 and P. pastoris GS115, respectively after 3 min combination treatment, while 6.22 μg/mL of protein leakage for A. pullulans 2012 after 2 min combination treatment. For biofilms, LCNEW combined with ultrasound also significantly reduced the survival cells both on coupons and in suspension for all three strains. The results suggest that LCNEW combined with ultrasound is a promising approach to sanitise food equipment.

3.3.2 Bacterial adherence and viability on cutting board surfaces. Abrishami, S. H., B. D. Tall, T. J. Bruursema, P. S. Epstein, and D. B. Shah. 1994. *J. Food Saf.* 14:153–172.

Source:

3.3.3 Efficacy of electrolyzed oxidizing water in inactivating *Vibrio parahaemolyticus* on kitchen cutting boards and food contact surfaces. Chiu, T.-H., J. Duan, C. Liu, and Y.-C. Su. 2006. *Lett. Appl. Microbiol.*43:666–672.

Source:

3.3.4 Efficacy of neutral electrolyzed water to inactivate *Escherichia coli, Listeria monocytogenes, Pseudomonas aeruginosa,* and *Staphylococcus aureus* on plastic and wooden kitchen cutting boards. Deza, M. A., M. Araujo, and M. J. Garrido. 2007. *J. Food Prot.* 70:102–108.

Source:

3.3.5 Inactivation of *Escherichia coli* O157:H7 and *Listeria monocytogenes* on plastic kitchen cutting boards by electrolyzed oxidizing water. Venkitanarayanan, K. S., G. O. Ezeike, Y.-C. Hung, and M. P. Doyle. 1999. *J. Food Prot.* 62:857–860.

Source:

3.3.6 Inactivation of *Escherichia coli, Listeria monocytogenes, Pseudomonas aeruginosa* and *Staphylococcus aureus* on stainless steel and glass surfaces by neutral electrolysed water. Deza, M. A., M. Araujo, and M. J. Garrido. 2005. *Lett. Appl. Microbiol.* 40:341–346

AIM: To ascertain the efficacy of neutral electrolysed water (NEW) in reducing Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus and Listeria monocytogenes on glass and stainless steel surfaces. Its effectiveness for that purpose is compared with that of a sodium hypochlorite (NaClO) solution with similar pH, oxidation-reduction potential (ORP) and active chlorine content.

METHODS AND RESULTS: First, the bactericidal activity of NEW was evaluated over pure cultures (8.5 log CFU ml-1) of the abovementioned strains: all of them were reduced by more than 7 log CFU ml-1 within 5 min of exposure either to NEW (63 mg l-1 active chlorine) or to NaClO solution (62 mg l-1 active chlorine). Then, stainless steel and glass surfaces were inoculated with the same strains and rinsed for 1 min in either NEW, NaClO solution or deionized water (control). In the first two cases, the populations of all the strains decreased by more than 6 log CFU 50 cm-2. No significant difference (P<or=0.05) was found between the final populations of each strain with regard to the treatment solutions (NEW or NaClO solution) or to the type of surface.

CONCLUSIONS: NEW was revealed to be as effective as NaClO at significantly reducing the presence of pathogenic and spoilage bacteria (in this study, E. coli, L. monocytogenes, P. aeruginosa and S. aureus) on stainless steel and glass surfaces.

SIGNIFICANCE AND IMPACT OF THE STUDY: NEW has the advantage of being safer than NaClO and easier to handle. Hence, it represents an advantageous alternative for the disinfection of surfaces in the food industry.

Source: Abstract

3.3.7 Effectiveness of electrolyzed water as a sanitizer for treating different surfaces. Park, H., Y.-C. Hung, and C. Kim. 2002. *J. Food Prot.* 65:1276–1280

The effectiveness of electrolyzed (EO) water at killing Enterobacter aerogenes and Staphylococcus aureus in pure culture was evaluated. One milliliter (approximately 10(9) CFU/ml) of each bacterium was subjected to 9 ml of EO water or control water (EO water containing 10% neutralizing buffer) at room temperature for 30 s. Inactivation (reduction of > 9 log10 CFU/ ml) of both pathogens occurred within 30 s after exposure to EO water containing approximately 25 or 50 mg of residual chlorine per liter. The effectiveness of EO water in reducing E. aerogenes and S. aureus on different surfaces (glass, stainless steel, glazed ceramic tile, unglazed ceramic tile, and vitreous china) was also evaluated. After immersion of the tested surfaces in EO water for 5 min without agitation, populations of E. aerogenes and S. aureus were reduced by 2.2 to 2.4 log10 CFU/ cm2 and by 1.7 to 1.9 log10 CFU/cm2, respectively, whereas washing with control water resulted in a reduction of only 0.1 to 0.3 log10 CFU/cm2. The washing of tested surfaces in EO water with agitation (50 rpm) reduced populations of viable cells on the tested surfaces to < 1 CFU/cm2. For the control water treatment with agitation, the surviving numbers of both strains on the tested surfaces were approximately 3 log10 CFU/cm2. No viable cells of either strain were observed in the EO water after treatment, regardless of agitation. However, large populations of both pathogens were recovered from control wash solution after treatment.

Source: Abstract pdf

4 Biofilms

4.1.1 Enhancing the bactericidal effect of electrolyzed oxidizing water on *Listeria monocytogenes* biofilms formed on stainless steel. Ayebah, B., Y.-C. Hung, and J. F. Frank. 2005. *J. Food Prot.* 68:1375–1380.

Biofilms are potential sources of contamination to food in processing plants, because they frequently survive sanitizer treatments during cleaning. The objective of this research was to investigate the combined use of alkaline and acidic electrolyzed (EO) water in the inactivation of Listeria monocytogenes biofilms on stainless steel surfaces. Biofilms were grown on rectangular stainless steel (type 304, no. 4 finish) coupons (2 by 5 cm) in a 1:10 dilution of tryptic soy broth that contained a five-strain mixture of L. monocytogenes for 48 h at 25 degrees C. The coupons with biofilms were then treated with acidic EO water or alkaline EO water or with alkaline EO water followed by acidic EO water produced at 14 and 20 A for 30, 60, and 120 s. Alkaline EO water alone did not produce significant reductions in L. monocytogenes biofilms when compared with the control. Treatment with acidic EO water only for 30 to 120 s, on the other hand, reduced the viable bacterial populations in the biofilms by 4.3 to 5.2 log CFU per coupon, whereas the combined treatment of alkaline EO water followed by acidic EO water produced an additional 0.3- to 1.2-log CFU per coupon reduction. The population of L. monocytogenes reduced by treatments with acidic EO water increased significantly with increasing time of exposure. However, no significant differences occurred between treatments with EO water produced at 14 and 20 A. Results suggest that alkaline and acidic EO water can be used together to achieve a better inactivation of biofilms than when applied individually.

Source: Abstract

4.1.2 Efficacy of electrolyzed water in the inactivation of planktonic and biofilm *Listeria monocytogenes* in the presence of organic matter. Ayebah, B., Y.-C. Hung, C. Kim, and J. F. Frank. 2006. *J. FoodProt.* 69:2143–2150.

Source:

4.1.3 Sensitivity of biofilms to antimicrobial agents. Brown, M. R., and P. Gilbert. 1993. *J. Appl. Bacteriol.* 74:87S–97S.

Source:

4.1.4 Direct measurement of chlorine penetration into biofilms during disinfection.De Beer, D., R. Srinivasan, and P. S. Stewart. 1994. *Appl. Environ. Microbiol.* 60:4339–4344.

Source:

4.1.5 Biofilm penetration and disinfection efficacy of alkaline hypochlorite and chlorosulfamates. Stewart, P. S., J. Rayner, F. Roe, and W. M. Rees. 2001. *J. Appl. Microbiol.* 91:525–532.

Source:

4.1.6 Efficacy of two cleaning and sanitizing combinations on *Listeria monocytogenes* biofilms formed at low temperature on a variety of materials in the presence of ready-to-eat meat residue. Somers, E. B., and A. C. Wong. 2004. *J. Food Prot.* 67:2218–2229
Source:

4.1.7 Inactivation of *Listeria monocytogenes* biofilms by electrolyzed oxidizing water. Kim, C., Y.-C. Hung, R. E. Brackett, and J. F. Frank. 2001 *J. Food Process. Preserv.* 25:91–100
Source:

4.1.8 Biofilms: survival mechanisms of clinically relevant microorganisms. Donlan, R. M., and J. W. Costerton. 2002. *Clin. Microbiol. Rev.* 15:167–193.
Source:

4.1.9 Inactivation of *Listeria monocytogenes* biofilms by electrolyzed oxidizing water. Kim, C., Y.-C. Hung, R. E. Brackett, and J. F. Frank. 2001. *J. Food Process. Preserv.* 25:91–100
Source:

5 Plants

5.1 General

5.1.1 Comparison of effects of acidic electrolyzed water and NaOCl on *Telletia indica* teliospore germination. Bonde, M. R., S. E. Nester, J. L. Smilanick, R. D. Frederick, and N. W. Schaad. 1999. *Plant Dis.* 83:627–632.
Source:

5.1.2 Reduction of *Salmonella enterica* on alfalfa seeds with acidic electrolyzed oxidizing water and enhanced uptake of acidic electrolyzed oxidizing water into seeds by gas exchange. Stan, S. D., and M. A. Daeschel. 2003. *J. Food Prot.* 66:2017–2022.
Source:

5.1.3 Grech, N. M., and F. H. Rijkenberg. 1992. Injection of electronically generated chlorine into citrus micro-irrigation systems for the control of certain waterborne root pathogens. *Plant Dis.* 76:457–461.
Source:

5.2 Fruit

5.2.1 A review of microbiological safety of fruits and vegetables and the introduction of electrolyzed water as an alternative to sodium hypochlorite solution Abdulsudi Issa-Zacharia, Yoshinori Kamitani, Happiness S. Muhimbula and Bernadette K. Ndabikunze African Journal of Food Science Vol. 4(13), pp. 778 - 789 December 2010

Over the past few years, food safety has become and continues to be the number one public concern. Considerable progress to strengthen food safety systems has been achieved in many countries, highlighting the opportunities to reduce and prevent food-borne disease. However, unacceptable rates of food-borne illness still remain and new hazards continue to enter the food supply chain. Contaminations in food and agricultural products may occur in every stage of the food supply chain, from the field to the table, that is production, harvesting, processing, storage and distribution, calling for proper decontamination and insuring food safety at each of these stages using an effective antimicrobial agent. Several commercial products are available for this purpose, however, most of available products are seriously hindered by a number of work and environmental safety limitations calling for the development of a new product which is both safe for environment and workers. In this accord, the use of acidic electrolyzed water (AEW), a new concept developed in Japan, which is now gaining popularity in other countries has been introduced. The principle behind its sterilizing effect is still explored, but it has shown to have strong and significant bactericidal and virucidal and moderate fungicidal properties. Some studies have been carried out in Japan, China, Korea, Canada, Europe and the USA on its pre- and post-harvest application in the field of food processing. This review provides an overview of microbiological safety of food and agricultural produces, points out the burdens of food borne diseases; highlights the drawbacks of currently employed sanitizers and introduces electrolyzed water as a novel non-thermal food sanitizer with potential of application in agriculture and food industry
Source: pdf

5.3 Strawberry

5.3.1 Survival of *Escherichia coli* O157:H7 on strawberry fruit and reduction of the pathogen population by chemical agents. Yu, K. H., M. C. Newman, D. D. Archbold, and T. R. Hamilton- Kemp. 2001. *J. Food Prot.* 64:1334–1340.

Survival of Escherichia coli O157:H7 was studied on strawberry, a fruit that is not usually washed during production, harvest, or postharvest handling. Two strains of the bacteria were tested separately on the fruit surface or injected into the fruit. Both strains of E. coli O157:H7 survived externally and internally at 23 degrees C for 24 h and at 10, 5, and -20 degrees C for 3 days. The largest reduction in bacterial population occurred at -20 degrees C and on the fruit surface during refrigeration. In all experiments, the bacteria inside the fruit either survived as well as or better than bacteria on the surface, and ATCC 43895 frequently exhibited greater survival than did ATCC 35150. Two strains of E. coli also survived at 23 degrees C on the surface and particularly inside strawberry fruit. Chemical agents in aqueous solution comprising NaOCl (100 and 200 ppm), Tween 80 (100 and 200 ppm), acetic acid (2 and 5%), Na_3PO_4 (2 and 5%), and H_2O_2 (1 and 3%) were studied for their effects on reduction of surface-inoculated (10(8) CFU/ml) E. coli O157:H7 populations on strawberry fruit. Dipping the inoculated fruit in water alone reduced the pathogen population about 0.8 log unit. None of the compounds with the exception of H_2O_2 exhibited more than a 2-log CFU/g reduction of the bacteria on the fruit surface. Three percent H202, the most effective chemical treatment, reduced the bacterial population on strawberries by about 2.2 log CFU/g.

Source: [Abstract]

5.4 Peach

5.4.1 Fungicidal effectiveness of electrolyzed oxidizing water on postharvest brown rot of peach. Al-Haq, M. I., Y. Seo, S. Osita, and Y. Kawagoe. 2001. *Hortic. Sci.* 39:1310–1314.
Source:

5.5 Pear

5.5.1 Disinfection effects of electrolyzed oxidizing water on suppressing fruit rot of pear caused by *Botryosphaeria berengeriana.* Al-Haq, M. I., Y. Seo, S. Osita, and Y. Kawagoe. 2002. *Food Res. Int.* 35:657–664.
Source:

5.6 Apples

5.6.1 Activity of electrolyzed oxidizing water against *Penicillium expansum* in suspension and on wounded apples. Okull, D. O., and L. E. LaBorde. 2004. *J. Food Sci.* 69:23–27
Spores of *Penicillium expansum*, the primary organism responsible for the occurrence of patulin in apple juice, were exposed to electrolyzed oxidizing (EO) water in an aqueous suspension and on wounded apples. Full-strength and 50% EO water decreased viable spore populations by greater than 4 and 2 log units, respectively. Although EO water did not prevent lesion formation on fruit previously inoculated with *P. expansum*, cross-contamination of wounded apples from decayed fruit or by direct addition of spores to a simulated dump tank was substantially reduced. EO water, therefore, has potential as an alternative to chlorine disinfectants for controlling infection of apples by *P. expansum* during handling and processing operations.
Source: [Abstract]

5.7 Figs

5.7.1 Article: EFFICACY OF NEUTRALISED ELECTROLYSED WATER AND MILD HEAT AGAINST FOODBORNE PATHOGENS ISOLATED FROM FICUS CARICA Cigdem ileri yamaner · Muavviz Ayvaz · Ramazan Konak · [...] ·Anatoli Dimoglo
Problems with microorganism toxins in dried fig exports are becoming very important. Chlorine-based sanitizers are effective way of controlling microorganisms, but on the other hand their reaction with natural organic and inorganic matter may potentially form carcinogenic products. Therefore, different sanitizers for the disinfection of food and food contact surfaces are required as an alternative to chlorine-based sanitizers. Some earlier studies revealed that neutralised electrolysed water (NEW) may be a potential substitute for cleaning and sanitizing agents in packaged products. In order to make a contribution to solve toxins problems, the antibacterial and antifungal effect of neutralised electrolysed water (NEW) on the foodborne pathogens were evaluated in this study. Spores of Aspergillus flavus and Penicillium expansum were isolated from the surface of fig fruits. Escherichia coli and Bacillus cereus known to occur on the surface of figs were also evaluated. Vegetative cells and spores of bacterium and fungi were exposed to five different concentrations of NEW (100, 75, 25, 5 and 1%) at three different temperatures (22, 50 and 70°C) for 1, 3 and 5 min. According to the results, at 22°C, 1% neutralised electrolysed water exposure for 1 min effectively decreased the number of vegetative cells of E. coli and B. cereus by approximately 8.5 log cfu/ml and 6.3 log cfu/ml, respectively. At 50°C, 5% neutralised electrolysed water exposure for 1 min significantly reduced the A. flavus and P. expansum spore numbers by 5.54 log cfu/ml and 7 log cfu/ml, respectively. With the effect of mild temperature (22-50°C), low chlorine neutralised electrolysed water (9.22 mg/l-33.85 mg/l available chlorine concentrations) showed a strong antibacterial and antifungal activity against foodborne pathogens. As a conclusion, neutralised electrolysed water can be used widely as a sanitizer in fig enterprises, instead of high cost chlorine based disinfectants.

5.8 Cut Vegetables

5.8.1 Electrolyzed water as a disinfectant for fresh-cut vegetables. Izumi, H. 1999. *J. Food Sci.* 64:536–539
The effect of electrolyzed water on total microbial count was evaluated on several fresh-cut vegetables. When fresh-cut carrots, bell peppers, spinach, Japanese radish, and potatoes were treated with electrolyzed water (pH 6.8, 20 ppm available chlorine) by dipping, rinsing, or dipping/blowing, microbes on all cuts were reduced by 0.6 to 2.6 logs CFU/g. Rinsing or dipping/blowing were more effective than dipping. Electrolyzed water containing 50 ppm available chlorine had a stronger bactericidal effect than that containing 15 or 30 ppm chlorine for fresh-cut carrots, spinach, or cucumber. Electrolyzed water did not affect tissue pH, surface color, or general appearance of fresh-cut vegetables.
Source: [Abstract] [pdf]

5.8.2 The effect of available chlorine concentration on the disinfecting potential of acidic electrolyzed water for shredded vegetables. Koseki, S., and K. Itoh. 2000. *J. Jpn. Soc. Food Sci. Technol.* 47:888– 898
The main factor contributing to the disinfecting potential of acidic electrolyzed water(AcEW) is deduced to be the oxidizing power of available chlorine. In this study, we compared the reliability of two different methods for measuring the available chlorine concentration(ACC). Several AcEW solutions with different levels of ACC to which various reducing agents (ascorbic acid, ammonium iron(II) sulfate, and iron(II) chloride) had been added were prepared. These ACC levels were quantified by iodometry and the DPD (N,N-diethyl-p-phenylenediamine) method. In the case of AcEW with iron(II) ions, iodometry did not show the correct ACC. On the other hand, the DPD method correctly quantified ACC even in the case of AcEW with iron(II) ions. Thus, the DPD method is an appropriate method for measuring ACC in AcEW. Moreover, we investigated the effect of the available chlorine concentration(ACC) in AcEW on its disinfecting

potential. First, we examined the disinfectant effects of AcEW on shredded vegetables. We found that there was no difference in the disinfectant effects between AcEW with high ACC (40ppm) and low ACC (0.4ppm). The similar effect was detected in AcEW with 0ppm of ACC, a solution that seemed to be the same as hydrochloric acid. Moreover, tap water with pH adjusted to 2.4 showed the same disinfectant effect as that of AcEW. These results indicated that AcEW is a solution in which available chlorine is activated in a low pH condition. Next, we examined the disinfectant effects of AcEW on a suspension obtained from shredded vegetables in vitro. The disinfecting potential became weaker, but did not completely disappear, when ACC was reduced to 0ppm..

Source: Abstract

5.8.3 Effect of processing conditions on the microflora of fresh-cut vegetables. Garg, N., J. J. Churey, and D. F. Splittstoesser. 1990. *J.Food Prot.* 53:701–703.

5.8.4 Prediction of microbial growth in fresh-cut vegetables treated with acidic electrolyzed water during storage under various temperature conditions. Koseki, S., and K. Itoh. 2001. *J. Food Prot.* 64: 1935–1942

Effects of storage temperature (1, 5, and 10 degrees C) on growth of microbial populations (total aerobic bacteria, coliform bacteria, Bacillus cereus, and psychrotrophic bacteria) on acidic electrolyzed water (AcEW)-treated fresh-cut lettuce and cabbage were determined. A modified Gompertz function was used to describe the kinetics of microbial growth. Growth data were analyzed using regression analysis to generate "best-fit" modified Gompertz equations, which were subsequently used to calculate lag time, exponential growth rate, and generation time. The data indicated that the growth kinetics of each bacterium were dependent on storage temperature, except at 1 degrees C storage. At 1 degrees C storage, no increases were observed in bacterial populations. Treatment of vegetables with AcEW produced a decrease in initial microbial populations. However, subsequent growth rates were higher than on nontreated vegetables. The recovery time required by the reduced microbial population to reach the initial (treated with tap water [TW]) population was also determined in this study, with the recovery time of the microbial population at 10 degrees C being <3 days. The benefits of reducing the initial microbial populations on fresh-cut vegetables were greatly affected by storage temperature. Results from this study could be used to predict microbial quality of fresh-cut lettuce and cabbage throughout their distribution.

Source: Abstract

5.9 Tomatoes

5.9.1 Effectiveness of electrolyzed acidic water in killing *Escherichia coli* O157:H7, *Salmonella* Enteritidis, and *Listeria monocytogenes* on the surface of tomatoes. Bari, M. L., Y. Sabina, S. Isobe, T. Uemura, and K. Isshiki. 2003. *J. Food Prot.* 66:542–548.

A study was conducted to evaluate the efficacy of electrolyzed acidic water, 200-ppm chlorine water, and sterile distilled water in killing Escherichia coli O157:H7, Salmonella, and Listeria monocytogenes on the surfaces of spot-inoculated tomatoes. Inoculated tomatoes were sprayed with electrolyzed acidic water, 200-ppm chlorine water, and sterile distilled water (control) and rubbed by hand for 40 s. Populations of E. coli O157:H7, Salmonella, and L. monocytogenes in the rinse water and in the peptone wash solution were determined. Treatment with 200-ppm chlorine water and electrolyzed acidic water resulted in 4.87- and 7.85-log10 reductions, respectively, in Escherichia coli O157:H7 counts and 4.69- and 7.46-log10 reductions, respectively, in Salmonella counts. Treatment with 200-ppm chlorine water and electrolyzed acidic water reduced the number of L. monocytogenes by 4.76 and 7.54 log10 CFU per tomato, respectively. This study's findings suggest that electrolyzed acidic water could be useful in controlling pathogenic microorganisms on fresh produce.

Source: Abstract

5.9.2 Inactivation of *Escherichia coli* O157:H7, *Salmonella enteritidis* and *Listeria monocytogenes* on the surface of tomatoes by neutral electrolyzed water. Deza, M. A., M. Araujo, and M. J. Garrido. 2003*Lett. Appl. Microbiol.* 37:482–487.

AIMS: To determine the efficacy of neutral electrolyzed water (NEW) in killing Escherichia coli O157:H7, Salmonella enteritidis and Listeria monocytogenes, as well as nonpathogenic E. coli, on the surface of tomatoes, and to evaluate the effect of rinsing with NEW on the organoleptic characteristics of the tomatoes.

METHODS AND RESULTS: The bactericidal activity of NEW, containing 444 or 89 mg l(-1) of active chlorine, was evaluated over pure cultures (8.5 log CFU ml(-1)) of the above-mentioned strains. All of them were reduced by more than 6 log CFU ml(-1) within 5 min of exposure to NEW. Fresh tomatoes were surface-inoculated with the same strains, and rinsed in NEW (89 mg l(-1) of active chlorine) or in deionized sterile water (control), for 30 or 60 s. In the NEW treatments, independent of the strain and of the treatment time, an initial surface population of about 5 log CFU sq.cm(-1) was reduced to <1 log CFU sq.cm(-1), and no cells were detected in the washing solution by plating procedure. A sensory evaluation was conducted to ascertain possible alterations in organoleptic qualities, yielding no significant differences with regard to untreated tomatoes.

SIGNIFICANCE AND IMPACT OF THE STUDY: Rinsing in NEW reveals as an effective method to control the presence of E. coli O157:H7, S. enteritidis and L. monocytogenes on the surface of fresh tomatoes, without affecting their organoleptic characteristics. This indicates its potential application for the decontamination of fresh produce surfaces

Source: Abstract pdf

5.9.3 Elution, detection and quantification of polio I, bacteriophages, *Salmonella* Montevideo, and *Escherichia coli* O157:H7 from seeded strawberries and tomatoes. Lukasik, J., M. L. Bradley, T. M. Scott, W. Y. Hsu, S. R. Farrah, and M. L. Tamplin. 2001. *J. Food Prot.* 64:292–297

This study compared the effect of different physical and chemical treatments of strawberries and tomatoes to determine their ability to recover seeded viral and bacterial pathogens from produce surfaces. Solutions of salts, amino acids, complex media, and detergents were compared as eluants. Phosphate-buffered saline (PBS) containing 0.1% Tween 80 eluted the highest number of seeded microorganisms. Elution with this defined solution was then compared under different conditions of physical agitation. Rotary shaking for 20 min at 36 degrees C eluted higher numbers of viruses and bacteria than did low- or high-speed stomaching. Commercially available and laboratory prepared bacteriological differential media were compared for their ability to recover and distinguish eluted Salmonella Montevideo and

Escherichia coli O157:H7 strains from seeded produce. The recovery of seeded bacterial pathogens was low when differential media containing selective ingredients were used (MacConkey sorbitol agar, XLD agar, MacConkey agar). Highest recoveries were obtained on a medium consisting of tryptic soy agar supplemented with sodium thiosulfate and ferric ammonium citrate compared with selective media that inhibited up to 50% of the growth of the eluted microorganisms.

Source: Abstract

5.9.4 Fate of foodborne pathogens on green onions and tomatoes by electrolysed water E-J Park · E Alexander · G.A. Taylor · [...] · D-H Kang

To investigate the efficacy of electrolysed water (EW) in killing Escherichia coli O157:H7, Salmonella typhimurium and Listeria monocytogenes on the surfaces of spot-inoculated green onions and tomatoes. Green onions and tomatoes were inoculated with a cocktail of three strains each of E. coli O157:H7, Salm. typhimurium and L. monocytogenes and treated with acidic electrolysed water (AC-EW), alkaline electrolysed water (AK-EW), alkaline electrolysed water followed by acidic electrolysed water (AK-EW + AC-EW), deionized water followed by acidic electrolysed water (DW + AC-EW) and deionized water (control, DW) for 15 s, 30 s, 1 min, 3 min and 5 min at room temperature (22 +/- 2 degrees C). The relative efficacy of reduction was AC-EW > DW + AC-EW approximately AK-EW + AC-EW > AK-EW > DW. Acidic EW treatment was able to significantly reduce populations of the three tested pathogens from the surfaces of green onions and tomatoes with increasing exposure time. Rinsing in acidic EW reveals an effective method to control the presence of E. coli O157:H7, Salm. typhimurium and L. monocytogenes on the surfaces of fresh green onions and tomatoes, without affecting their organoleptic characteristics. This indicates its potential application for the decontamination of fresh produce surfaces.

5.10 Flowers

5.10.1 Evaluation of acidic electrolyzed water for phytotoxic symptoms on foliage and flowers of bedding plants. Buck, J. W., M. W. van Iersel, R. D. Oetting, and Y.-C. Hung. 2003. *Crop Prot.* 22:73–77.

Acidic electrolyzed oxidizing (EO) water quickly kills a variety of fungi and shows promise as a broad-spectrum contact fungicide for control of foliar diseases of greenhouse-grown ornamentals. One requirement for use in the greenhouse is that EO water will not cause excessive phytotoxic symptoms on a wide variety of species. In one experiment, two applications of EO water did not damage 15 species of bedding plants. In a second experiment, EO water applied as a foliar spray three times per week for 4–7 weeks did not produce any visible phytoxicity on seven of the 12 species tested. Small, white spots were observed on flowers of geranium (Pelargonium x hortorum), impatiens (Impatiens walleriana), and vinca (Catharanthus roseus). Slight necrosis was observed on some leaf edges of petunia (Petunia x hybrida), and snapdragon (Antirrhinum majus). EO water generated from magnesium chloride produced more phytotoxicity than EO water generated by potassium chloride or sodium chloride. Phytotoxicity ratings of greater than 3 (0–10 scale) were not observed on any of the species tested. EO water caused slight damage to some plant species but, in general, appears to be safe to use as a foliar spray on a wide variety of bedding plants grown under greenhouse conditions

Source: Abstract

5.11 Cucumber

5.11.1 Efficacy of acidic electrolyzed water for microbial decontamination of cucumbers and strawberries. Koseki, S., Y. Yoshida, S. Isobe, and K. Itoh. 2004. *J. Food Prot.* 67:1247–1251

An examination was made of the efficacy of acidic electrolyzed water (AcEW, 30 ppm free available chlorine), ozonated water (5 ppm ozone), and a sodium hypochlorite solution (NaOCl, 150 ppm free available chlorine) for use as potential sanitizers of cucumbers and strawberries. AcEW and NaOCl reduced the aerobic mesophiles naturally present on cucumbers within 10 min by 1.4 and 1.2 log CFU per cucumber, respectively. The reduction by ozonated water (0.7 log CFU per cucumber) was significantly less than that of AcEW or NaOCl (P < or = 0.05). Cucumbers washed in alkaline electrolyzed water for 5 min and then treated with AcEW for 5 min showed a reduction in aerobic mesophiles that was at least 2 log CFU per cucumber greater than that of other treatments (P < or = 0.05). This treatment was also effective in reducing levels of coliform bacteria and fungi associated with cucumbers. All treatments offered greater microbial reduction on the cucumber surface than in the cucumber homogenate. Aerobic mesophiles associated with strawberries were reduced by less than 1 log CFU per strawberry after each treatment. Coliform bacteria and fungi associated with strawberries were reduced by 1.0 to 1.5 log CFU per strawberry after each treatment. Microbial reduction was approximately 0.5 log CFU per strawberry greater on the strawberry surface than in the strawberry homogenate. However, neither treatment was able to completely inactivate or remove the microorganisms from the surface of the cucumber or strawberry.

Source: Abstract

5.12 Lettuce

5.12.1 The effect of pH on inactivation of pathogenic bacteria on fresh-cut lettuce by dipping treatment with electrolyzed water. Yang, H., B. L. Swem, and Y. Li. 2003. *J. Food Sci.* 68:1013–1017.

Source:

5.12.2 Reduction of bacteria on spinach, lettuce, and surfaces in food service areas using neutral electrolyzed water. Guentzel, J. L., K. L. Lam, M. A. Callan, S. A. Emmons, and V. L. Dunham. 2008. *Food Microbiol.* 25:36–41.

Source:

5.12.3 Decontamination effect of frozen acidic electrolyzed water on lettuce. Koseki, S., K. Fujiwara, and K. Itoh. 2002. *J. Food Prot.* 65: 411–414.

Source:

5.12.4 **Decontamination of lettuce using acidic electrolyzed water. Koseki, S., Y. Yoshida, S. Isobe, and K. Itoh. 2001. *J. Food Prot.* 64: 652–658.**
Source:

5.12.5 **Effect of mild heat pre-treatment with alkaline electrolyzed water on the efficacy of acidic electrolyzed water against *Escherichia coli* O157:H7 and *Salmonella* on lettuce. Koseki, S., Y. Yoshida, K. Kamitani, S. Isobe, and K. Itoh. 2004. *Food Microbiol.* 21:559–566**
Source:

5.12.6 **Pathogen reduction and quality of lettuce treated with electrolyzed oxidizing and acidified chlorinated water. Park, C. M., Y.-C. Hung, M. P. Doyle, G. O. Ezeike, and C. Kim. 2001. *J. Food Sci.* 66: 1368–1372**
Source:

5.12.7 **Efficacy of acidic electrolyzed water ice for pathogen control on lettuce. Koseki, S., S. Isobe, and K. Itoh. 2004. *J. Food Prot.* 67: 2544–2549**
Source:

5.13 Alfalfa seeds

5.13.1 **Efficacy of electrolyzed oxidizing water in inactivating *Salmonella* on alfalfa seeds and sprouts. Kim, C., Y.-C. Hung, R. E. Brackett, and C.-S. Lin. 2003. *J. Food Prot.* 66:208–214**
Source:

5.14 Rice

5.14.1 **An examination of cooked rice with electrolyzed water. Kobayashi, K., N. Tosa, Y. Hara, and S. Horie. 1996. *J. Jpn. Soc. Food Sci. Technol.* 43:930–938**
Source:

5.15 Tofu

5.15.1 **Effects of weakly electrolyzed water on properties of tofu. Hara, Y., A. Watanuki, and E. Arai. 2003. *Food Sci. Technol. Res.* 9: 332–337**
Source:

5.16 Wheat noodles

5.16.1 **Effects of weakly electrolyzed water on properties of Japanese wheat noodles. Hara, Y., A. Watanuki, and E. Arai. 2003. *Food Sci. Technol. Res.* 9:320–326**
Source:

6 Animals

6.1 General agriculture and food

6.1.1 **Applications of electrolyzed water in agriculture and food industries. Al-Haq, M. I., J. Sugiyama, and S. Isobe. 2005. *Food Sci.Technol. Res.* 11:135–150.**
Microbial control of postharvest diseases has been extensively studied and appears to be a viable technology. Food safety must be ensured at each postharvest processing step, including handling, washing of raw materials, cleaning of utensils and pipelines, and packaging. Several commercial products are available for this purpose. The time is ripe for developing new techniques and technologies. The use of electrolyzed water (EW) is the product of a new concept developed in Japan, which is now gaining popularity in other countries. Little is known about the principle behind its sterilizing effect, but it has been shown to have significant bactericidal and virucidal and moderate fungicidal properties. Some studies have been carried out in Japan, China, and the USA on the pre- and postharvest application of EW in the field of food processing. EW may be produced using common salt and an apparatus connected to a power source. As the size of the machine is quite small, the water can be manufactured on-site. Studies have been carried out on the use of EW as a sanitizer for fruits, utensils, and cutting boards. It can also be used as a fungicide during postharvest processing of fruits and vegetables, and as a sanitizer for washing the carcasses of meat and poultry. It is cost-effective and environment-friendly. The use of EW is an emerging technology with considerable potential.
Source: pdf

6.2 Cattle & Beef

6.2.1 ***Escherichia coli* O157 prevalence and enumeration of aerobic bacteria, *Enterobacteriaceae*, and *Escherichia coli* O157 at various steps in commercial beef processing plants. Arthur, T. M., J. M. Bosilevac, X. Nou, S. D. Shackelford, T. L. Wheeler, M. P. Kent, D. Karoni, B. Pauling, D. M. Allen, and M. Koohmaraie. 2004. *J.Food Prot.* 67:658–665.**
Source:

6.2.2 **Electrolyzed oxidizing anode water as a sanitizer for use in abattoirs. Bach, S. J., S. Jones, K. Stanford, B. Ralston, D. Milligan, G. L. Wallins, H. Zahiroddini, T. Stewart, C. Giffen, and T. A. McAllister. 2006. *J. Food Prot.* 69:1616–1622.**
Source:

6.2.3 Beef hide antimicrobial interventions as a means of reducing bacterial contamination. Baird, B. E., L. M. Lucia, G. R. Acuff, K. B. Harris, and J. W. Savell. 2006. *Meat Sci.* 73:245–248.
Source:

6.2.4 Prevalence of *Escherichia coli* O157 and levels of aerobic bacteria and *Enterobacteriaceae* are reduced when beef hides are washed and treated with cetylpyridinium chloride at a commercial beef processing plant. Bosilevac, J. M., T. M. Arthur, T. L. Wheeler, S. D. Shackelford, M. Rossman, J. O. Reagan, and M. Koohmaraie. 2004. *J. Food Prot.* 67:646–650.
Source:

6.2.5 Efficacy of ozonated and electrolyzed oxidative waters to decontaminate hides of cattle before slaughter. Bosilevac, J. M., S. D. Shackelford, D. M. Brichta, and M. Koohmaraie. 2005. *J. Food Prot.*68:1393–1398.
Source:

6.2.6 Post-harvest interventions to reduce/eliminate pathogens in beef. Koohmaraie, M., T. M. Arthur, J. M. Bosilevac, M. Guerini, S. D. Shackelford, and T. L. Wheeler. 2005. *Meat Sci.* 71:79–91.
Source: pdf

6.2.7 An evaluation of selected methods for the decontamination of cattle hides prior to skinning. Small, A., B. Wells-Burr, and S. Buncic. 2005. *Meat Sci.* 69:263–268
Source:

6.2.8 Presence of food-borne pathogens on cattle hides. Reid, C.-A., A. Small, S. M. Avery, and S. Buncic. 2002. *Food Control* 13:411–415

6.2.9 Sanitizer efficacy against attached bacteria in a milk biofilm. Mosteller, T. M., and J. R. Bishop. 1993. *J. Food Prot.* 56:34–41
Source:

6.2.10 The relationship between hide cleanliness and bacterial numbers of beef carcasses at a commercial abattoir. McEvoy, J. M., A. M. Doherty, M. Finnerty, J. J. Sheridan, L. McGuire, I. S. Blair, D. A. McDowell, and D. Harrington. 2000. *Lett. Appl. Microbiol.* 30:390–395
Source:

6.2.11 Determination of the principal points of product contamination during beef carcass dressing processes in Northern Ireland. Madden, R. H., K. A. Murray, and A. Gilmour. 2004. *J. Food Prot.* 67: 1494–1496
To determine the principal points of microbial contamination of carcasses during beef carcass dressing in Northern Ireland, 190 carcasses were sampled by swabbing 1,000 cm2 of the brisket. A detailed survey of one abattoir was initially conducted, with sampling of a total of 100 carcasses immediately after hide removal (H), after carcass splitting (S), and immediately after washing (W) before dispatch to the chiller. The total bacterial counts after incubation at both 22 and 37 degrees C indicated that there was no significant increase in the numbers of bacteria after the first sampling point, H ($P > 0.05$). To determine whether this was the case in the majority of Northern Ireland abattoirs, 15 carcasses were then sampled at each of an additional six abattoirs, at points H and W only. Total bacterial counts were significantly higher ($P < 0.05$) at H than at W, indicating that hide pulling was the major point of bacterial contamination of beef carcasses and hence a critical control point for the final microbiological quality of the carcasses. Mean counts of Enterobacteriaceae at both incubation temperatures were very low (< 10 CFU/cm2) but were higher at W than at H, probably indicating that washing was redistributing bacteria from the posterior to the anterior region.
Source: Abstract

6.3 Pigs and Pork

6.3.1 Comparison of electrolyzed water with other antimicrobial interventions to reduce pathogens on fresh pork. Fabrizio, K. A., and C. N. Cutter. 2004. *Meat Sci.* 68:463–468.
To date, the effectiveness of electrolyzed oxidizing (EO) water against bacteria associated with fresh pork has not been determined. Using a hand-held, food-grade garden sprayer, distilled water (W), chlorinated water (CL; 25 ppm), 2% lactic acid (LA), acidic EO water (EOA), or "aged" acidic EO water (AEOA; stored at 4 °C for 24 h) was sprayed (15 s) onto pork bellies inoculated with feces containing Listeria monocytogenes (LM), Salmonella typhimurium (ST), and Campylobacter coli (CC). Remaining bacterial populations were determined immediately following treatment, after 2 days of aerobic storage, and again after 5 days of vacuum-packaged, refrigerated storage (day 7). While LA and EOA significantly reduced ($p<0.05$) populations of CC at days 0 and 7, there was no significant difference ($p>0.05$) between antimicrobial treatments when applied to pork inoculated with ST or LM. This study demonstrates that a 15-s spray with EOA has the ability to reduce CC associated with fresh pork surfaces. However, longer contact times may be necessary to reduce other microbial contaminants.
Source: Abstract

6.4 Poultry - Chickens

6.4.1 Application of slightly acidic electrolyzed water for inactivating microbes in a layer breeding house. Hao XX, Li BM, Wang CY, Zhang Q, Cao W. Laboratory of Structure and Environment in Agricultural Engineering, Ministry of Agriculture, China Oct 2013 Poultry Science Oct; 92(10):2560-6
Lots of microorganisms exist in layer houses can cause bird diseases and worker health concerns. Spraying chemical disinfectants is an effective way to decontaminate pathogenic microorganisms in the air and on surfaces in poultry houses. Slightly acidic electrolyzed water (SAEW, pH 5.0-6.5) is an ideal, environmentally friendly broad-spectrum disinfectant to prevent and control bacterial or viral infection in layer farms. The purpose of this work was to investigate the cleaning effectiveness of SAEW for inactivating the microbes in layer houses. The effect of SAEW was evaluated by solid materials and surface disinfection in a hen house. Results indicate

that SAEW with an available chlorine concentration of 250 mg/L, pH value of 6.19, and oxygen reduction potential of 974 mV inactivated 100% of bacteria and fungi in solid materials (dusts, feces, feather, and feed), which is more efficient than common chemical disinfectant such as benzalkonium chloride solution (1:1,000 vol/vol) and povidone-iodine solution (1:1,000 vol/vol). Also, it significantly reduced the microbes on the equipment or facility surfaces ($P < 0.05$), including floor, wall, feed trough, and water pipe surfaces. Moreover, SAEW effectively decreased the survival rates of Salmonella and Escherichia coli by 21 and 16 percentage points. In addition, spraying the target with tap water before disinfection plays an important role in spray disinfection.

Source: Abstract

NB: This one is very interesting and not only shows the Chinese are into this area but that they are investigating lots of possible applications.

6.4.2 The use of electrolyzed water for sanitation control of eggshells and GP center. Achiwa, N., and T. Nishio. 2003. Food Sci. Technol.Res. 9:100–103.

The use of electrolyzed water for washing and sanitizing eggshells and an egg washer was evaluated for its effectiveness at a Grade & Packing Center adjacent to a poultry farm for a period of nine months. The test results indicate improvement in sanitation control. Dissolving yolks of broken eggs with electrolyzed alkaline water followed by sanitizing with electrolyzed acidic water produced favorable effects. Also, the use of electrolyzed water has an advantage in that it simplifies the conventional washing and sanitizing process and motivates operators to employ the process more frequently. This sense developed in operators may be a significant factor in the improvement of sanitation control.

Source: Abstract pdf

6.4.3 Economics of reducing *Campylobacter* at different levels within the Belgian poultry meat chain. Gellynck, X., W. Messens, D. Halet, K. Grijspeerdt, E. Hartnett, and J. Viaene. 2008. *J. Food Prot.* 71:479–485.

Campylobacter infections pose a serious public health problem in Belgium. Poultry meat is most likely responsible for 40% of human campylobacteriosis cases in Belgium. On a yearly basis, consumption of poultry meat causes at least 22,000 campylobacteriosis cases, with a cost of illness of Euro 10.9 million. Several intervention measures have been proposed in literature, aiming to reduce the contamination of poultry meat and thus lead to significant reductions of human campylobacteriosis cases. This study aimed to evaluate the cost-benefit ratio, i.e., the ratio of reduced costs of illness on intervention costs of various intervention measures. These measures were selected by representatives from the poultry meat sector and experts in the field of poultry science. The selection comprised measures at the farm level (phage therapy), at the processing plant (spraying of carcasses with lactic acid or electrolyzed oxidizing water, crust freezing, or irradiation), and at the consumer level (improving kitchen hygiene and application of home freezing). Among these measures, the decontamination of carcasses with electrolyzed oxidizing water applied in the processing plant was the most efficient (17.66), followed by the use of lactic acid (4.06). In addition, phage therapy generated a positive cost-benefit ratio (2.54). Irradiation indicated the highest efficacy, but its cost-benefit ratio was rather low (0.31). There seems to be less gain by trying to improve food handling in the kitchen. The cost to reach consumers is large, while only a very limited fraction of the consumers is willing to change its behavior. The outcome of this study poses valuable information for future risk-management decisions in Belgium.

Source: http://www.ncbi.nlm.nih.gov/pubmed/18389689

6.4.4 Comparison of electrolyzed oxidizing water with various antimicrobial interventions to reduce *Salmonella* species on poultry. Fabrizio, K. A., R. R. Sharma, A. Demirci, and C. N. Cutter. 2002. *Poult. Sci.* 81:1598–1605.

Foodborne pathogens in cell suspensions or attached to surfaces can be reduced by electrolyzed oxidizing (EO) water; however, the use of EO water against pathogens associated with poultry has not been explored. In this study, acidic EO water [EO-A; pH 2.6, chlorine (CL) 20 to 50 ppm, and oxidation-reduction potential (ORP) of 1,150 mV], basic EO water (EO-B; pH 11.6, ORP of -795 mV), CL, ozonated water (OZ), acetic acid (AA), or trisodium phosphate (TSP) was applied to broiler carcasses inoculated with Salmonella Typhimurium (ST) and submerged (4 C, 45 min), spray-washed (85 psi, 25 C, 15 s), or subjected to multiple interventions (EO-B spray, immersed in EO-A; AA or TSP spray, immersed in CL). Remaining bacterial populations were determined and compared at Day 0 and 7 of aerobic, refrigerated storage. At Day 0, submersion in TSP and AA reduced ST 1.41 log10, whereas EO-A water reduced ST approximately 0.86 log10. After 7 d of storage, EO-A water, OZ, TSP, and AA reduced ST, with detection only after selective enrichment. Spray-washing treatments with any of the compounds did not reduce ST at Day 0. After 7 d of storage, TSP, AA, and EO-A water reduced ST 2.17, 2.31, and 1.06 log10, respectively. ST was reduced 2.11 log10 immediately following the multiple interventions, 3.81 log10 after 7 d of storage. Although effective against ST, TSP and AA are costly and adversely affect the environment. This study demonstrates that EO water can reduce ST on poultry surfaces following extended refrigerated storage.

Source: Abstract

6.4.5 Efficacy of electrolyzed water in the prevention and removal of fecal material attachment and its microbicidal effectiveness during simulated industrial poultry processing. Kim, C., Y.-C. Hung, and S. M. Russell. 2005. *Poult. Sci.* 84:1778–1784.

This study was undertaken to investigate the efficacy of alkaline and acidic electrolyzed (EO) water in preventing and removing fecal contaminants and killing Campylobacter jejuni on poultry carcasses under simulated industrial processing conditions. New York dressed and defeathered chicken carcasses spot-inoculated with cecal material or C. jejuni were subjected to spraying treatment with alkaline EO or 10% trisodium phosphate (TSP)water or combinations of spraying and immersion treatments with acidic EO and chlorinated water, respectively. Prespraying chicken carcasses with alkaline EO water significantly lowered cecal material attachment scores (3.77) than tap water (4.07) and 10% TSP (4.08) upon treatment of the dorsal area. Combinations of pre- and postspraying were significantly more effective than postspraying only, especially when using alkaline EO waterin removing fecal materials on the surface of chicken carcasses. Although treatment by immersion only in EO and chlorinated water significantly reduced the initial population (4.92 log10 cfu/g) of C. jejuni by 2.33 and 2.05 log10 cfu/g, respectively, combinations of spraying and immersion treatment did not improve the bactericidal effect of sanitizers. The results indicated that alkaline EO water might provide an alternative to TSP in preventing attachment and removal

of feces on the surface of chicken carcasses. The results also suggested that chicken carcasses containing pathogenic microorganisms may contribute to the cross-contamination of whole batches of chickens during processing in the chiller tank and afterward.
Source: Abstract

6.4.6 Spoilage microflora of broiler carcasses washed with electrolyzed oxidizing or chlorinated water using an inside-outside bird washer. Hinton, A., Jr., J. K. Northcutt, D. P. Smith, M. T. Musgrove, andK. D. Ingram. 2007. *Poult. Sci.* 86:123–127

The effect of acidic, electrolyzed oxidizing (EO) water and chlorinated water on the spoilage microflora of processed broiler carcasses was examined. Carcasses were sprayed for 5 s at 80 psi with tap, chlorinated, or EO water in an inside-outside bird washer. Treated carcasses were then stored at 4 degrees C for 0, 3, 7, or 14 d, and the microbial flora of the carcasses was sampled using the whole-carcass rinse procedure. Populations of psychrotrophic bacteria and yeasts in the carcass rinsates were enumerated. Results indicated that immediately after spraying the carcasses, significantly fewer psychrotrophic bacteria were recovered from carcasses sprayed with chlorinated or EO water than from carcasses sprayed with tapwater. Furthermore, significantly fewer yeasts were recovered from carcasses sprayed with EO water than from carcasses sprayed with tap or chlorinated water. The population of psychrotrophic bacteria and yeasts increased on all carcasses during refrigerated storage. However, after 14 d of storage, significantly fewer psychrotrophic bacteria and yeasts were recovered from carcasses sprayed with EO water than from carcasses sprayed with tap or chlorinated water, and significantly fewer microorganisms were recovered from carcasses sprayed with chlorinated water than from carcasses sprayed with tap water. Pseudomonas spp. and Candida spp. were the primary microbial isolates recovered from the broiler carcasses. Findings from the present study indicate that EO water can effectively be used in inside-outside bird washers to decrease the population of spoilage bacteria and yeasts on processed broiler carcasses.
Source: Abstract

6.4.7 The effect of electrolyzed oxidative water applied using electrostatic spraying on pathogenic and indicator bacteria on the surface of eggs. Russel, S. M. 2003. *Poult. Sci.* 82:158–162

Research was conducted to compare the effectiveness of electrolyzed oxidative (EO) water applied using an electrostatic spraying system (ESS) for killing populations of bacteria that are of concern to the poultry industry. Populations of pathogenic bacteria (Salmonella typhimurium, Staphylococcus aureus, and Listeria monocytogenes), and the indicator bacterium Escherichia coli were applied to eggs and allowed to attach for 1 h. EO water completely eliminated all Salmonella typhimurium on 3, 7, 1, and 8 out of 15 eggs in Repetitions (Rep) 1, 2, 3, and 4, respectively, even when very high inoculations were used. EO water completely eliminated all Staphylococcus aureus on 12, 11, 12, and 11 out of 15 eggs in Rep 1, 2, 3, and 4, respectively. EO water completely eliminated all Listeria monocytogenes on 8, 13, 12, and 14 out of 15 eggs in Reps 1, 2, 3, and 4, respectively. EO water completely eliminated all Escherichia coli on 9, 11, 15, and 11 out of 15 eggs in Reps 1, 2, 3, and 4, respectively. Even when very high concentrations of bacteria were inoculated onto eggs (many times higher than would be encountered in industrial situations), EO water was found to be effective when used in conjunction with electrostatic spraying for eliminating pathogenic and indicator populations of bacteria from hatching eggs.
Source: Abstract

6.4.8 Electrolysed reduced water decreases reactive oxygen species-induced oxidative damage to skeletal muscle and improves performance in broiler chickens exposed to medium-term chronic heat stress. Azad MA, Kikusato M, Zulkifli I, Toyomizu M. **Br Poult Sci. 2013;54(4):503-9. doi: 10.1080/00071668.2013.801067. Epub 2013 Jul 1.**

The present study was designed to achieve a reduction of reactive oxygen species (ROS)-induced oxidative damage to skeletal muscle and to improve the performance of broiler chickens exposed to chronic heat stress. 2. Chickens were given a control diet with normal drinking water, or diets supplemented with cashew nut shell liquid (CNSL) or grape seed extract (GSE), or a control diet with electrolysed reduced water (ERW) for 19 d after hatch. Thereafter, chickens were exposed to a temperature of either 34°C continuously for a period of 5 d, or maintained at 24°C, on the same diets. 3. The control broilers exposed to 34°C showed decreased weight gain and feed consumption and slightly increased ROS production and malondialdehyde (MDA) concentrations in skeletal muscle. The chickens exposed to 34°C and supplemented with ERW showed significantly improved growth performance and lower ROS production and MDA contents in tissues than control broilers exposed to 34°C. Following heat exposure, CNSL chickens performed better with respect to weight gain and feed consumption, but still showed elevated ROS production and skeletal muscle oxidative damage. GSE chickens did not exhibit improved performance or reduced skeletal muscle oxidative damage. 4. In conclusion, this study suggests that ERW could partially inhibit ROS-induced oxidative damage to skeletal muscle and improve growth performance in broiler chickens under medium-term chronic heat treatment.
Source: Abstract

6.4.9 Antimicrobial effect of electrolyzed water for inactivating *Campylobacter jejuni* during poultry washing. Park, H., Y.-C. Hung, and R. E. Brackett. 2002. *Int. J. Food Microbiol.* 72:77–83

The effectiveness of electrolyzed (EO) water for killing Campylobacter jejuni on poultry was evaluated. Complete inactivation of C. jejuni in pure culture occurred within 10 s after exposure to EO or chlorinated water, both of which contained 50 mg/l of residual chlorine. A strong bactericidal activity was also observed on the diluted EO water (containing 25 mg/l of residual chlorine) and the mean population of C. jejuni was reduced to less than 10 CFU/ml (detected only by enrichment for 48 h) after 10-s treatment. The diluted chlorine water (25 mg/l residual chlorine) was less effective than the diluted EO water for inactivation of C. jejuni. EO water was further evaluated for its effectiveness in reducing C. jejuni on chicken during washing. EOwater treatment was equally effective as chlorinated water and both achieved reduction of C. jejuni by about 3 log10 CFU/g on chicken, whereas deionized water (control) treatment resulted in only 1 log10 CFU/g reduction. No viable cells of C. jejuni were recovered in EO and chlorinated waterafter washing treatment, whereas high populations of C. jejuni (4 log10 CFU/ml) were recovered in the wash solution after the control treatment. Our study demonstrated that EO water was very effective not only in reducing the populations of C. jejuni on chicken, but also could prevent cross-contamination of processing environments.

Source: Abstract

6.4.10 Efficacy of electrolyzed water in inactivating *Salmonella* Enteritidis and *Listeria monocytogenes* on shell eggs. Park, C.-M., Y.-C. Hung, C.-S. Lin, and R. E. Brackett. 2005. *J. Food Prot.* 68:986–990

The efficacy of acidic electrolyzed (EO) water produced at three levels of total available chlorine (16, 41, and 77 mg/ liter) and chlorinated water with 45 and 200 mg/liter of residual chlorine was investigated for inactivating Salmonella Enteritidis and Listeria monocytogenes on shell eggs. An increasing reduction in Listeria population was observed with increasing chlorine concentration from 16 to 77 mg/liter and treatment time from 1 to 5 min, resulting in a maximal reduction of 3.70 log CFU per shell egg compared with a deionized water wash for 5 min. There was no significant difference in antibacterial activities against Salmonella and Listeria at the same treatment time between 45 mg/liter of chlorinated water and 14-A acidic EO water treatment (P > or = 0.05). Chlorinated water (200 mg/liter) wash for 3 and 5 min was the most effective treatment; it reduced mean populations of Listeria and Salmonella on inoculated eggs by 4.89 and 3.83 log CFU/shell egg, respectively. However, reductions (log CFU/shell egg) of Listeria (4.39) and Salmonella (3.66) by 1-min alkaline EO water treatment followed by another 1 min of 14-A acidic EO water (41 mg/liter chlorine) treatment had a similar reduction to the 1-min 200 mg/liter chlorinated water treatment for Listeria (4.01) and Salmonella (3.81). This study demonstrated that a combination of alkaline and acidic EO water wash is equivalent to 200 mg/liter of chlorinated water wash for reducing populations of Salmonella Enteritidis and L. monocytogenes on shell eggs.

Source: http://www.ncbi.nlm.nih.gov/pubmed/15895731

6.4.11 Evaluation of "Neutral Electrolyzed Water" Disinfectant on Inactivation of Avian Influenza Virus and Other Avian Viruses

The Avian Virology Section of the Animal Diagnostic Laboratory at Penn State University has conducted a research study on the "Anolyte Water" or "Neutral Electrolyzed Water" disinfectant solution on inactivation of avian influenza virus and other important avian viruses. The AKUA KT Inc. of South Korea has provided newly produced and fresh Anolyte Water solutions for this research study. Preliminary results indicated that the Anolyte Water solution effectively inactivated or killed a variety of avian respiratory and enteric viruses tested including avian influenza virus (AIV), Paramyxoviruses (PMV) and Newcastle disease virus (NDV, or PMV-1), infectious bronchitis virus (IBV), fowl adenovirus (FAV), avian reovirus, and pigeon herpesvirus. Effective dilutions of the Anolyte Water were found between 1:2 and 1:5 with sterile distilled water or doinized water.

Source: pdf

6.4.12 Efficacy of electrolyzed oxidizing water for the microbial safety and quality of eggs. Bailka KL, Demirci A, Knabel SJ, Patterson PH, Puri VM. Department of Agricultural & Biological Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, USA, Poultry Science. 2004 Dec;83(12):2071-8.

During commercial processing, eggs are washed in an alkaline detergent and then rinsed with chlorine to reduce dirt, debris, and microorganism levels. The alkaline and acidic fractions of electrolyzed oxidizing (EO) water have the ability to fit into the 2-step commercial egg washing process easily if proven to be effective. Therefore, the efficacy of EO water to decontaminate Salmonella Enteritidis and Escherichia coli K12 on artificially inoculated shell eggs was investigated. For the in vitro study, eggs were soaked in alkaline EO water followed by soaking in acidic EO water at various temperatures and times. Treated eggs showed a reduction in population between > or = 0.6 to > or =2.6 log10 cfu/g of shell for S. Enteritidis and > or =0.9 and > or =2.6 log10 for E. coli K12. Log10 reductions of 1.7 and 2.0 for S. Enteritidis and E. coli K12, respectively, were observed for typical commercial detergent-sanitizer treatments, whereas log10 reductions of > or =2.1 and > or =2.3 for S. Enteritidis and E. coli K12, respectively, were achieved using the EO water treatment. For the pilot-scale study, both fractions of EO water were compared with the detergent-sanitizer treatment using E. coli K12. Log10 reductions of > or = 2.98 and > or = 2.91 were found using the EO water treatment and the detergent-sanitizer treatment, respectively. The effects of 2 treatments on egg quality were investigated. EO water and the detergent-sanitizer treatments did not significantly affect albumen height or eggshell strength; however, there were significant affects on cuticle presence. These results indicate that EO water has the potential to be used as a sanitizing agent for the egg washing process.

Source: Abstract pdf

6.5 Fish and Seafood

6.5.1 Application of electrolyzed water on the reduction of bacterial contamination for seafood. Huang, Y.-R., H.-S. Hsieh, S.-Y. Lin, S.-J. Lin, Y.-C. Hung, and D.-F. Hwang. 2006. *Food Control* 17: 987–993

For reducing bacterial contamination, electrolyzed oxidizing water (EO water) has been used to reduce microbial population on seafood and platform of fish retailer. The specimens of tilapia were inoculated with Escherichia coli and Vibrio parahaemolyticus, and then soaked into EO water for up to 10 min. EO water achieved additional 0.7logCFU/cm2 reduction than tap water on E. coli after 1 min treatment and additional treatment time did not achieved additional reduction. EO water treatment also reduced V. parahaemolyticus, by 1.510g CFU/cm2 after 5 min treatment and achieved 2.6logCFU/cm2 reduction after 10 min. The pathogenic bacteria were not detected in EO water after soaking treatment. In addition, EO water could effectively disinfect the platform of fish retailer in traditional markets and fish markets.

Source: pdf

6.5.2 Effects of electrolyzed oxidizing water treatment on reducing *Vibrio parahaemolyticus* and *Vibrio vulnificus* in raw oysters. Ren, T., and Y.-C. Su. 2006. *J. Food Prot.* 69:1829–1834

Contamination of Vibrio parahaemolyticus and Vibrio vulnificus in oysters is a food safety concern. This study investigated effects of electrolyzed oxidizing (EO) water treatment on reducing V. parahaemolyticus and V. vulnificus in laboratory-contaminated oysters. EO water exhibited strong antibacterial activity against V. parahaemolyticus and V. vulnificus in pure cultures. Populations of V. parahaemolyticus (8.74 x 10(7) CFU/ml) and V. vulnificus (8.69 x 10(7) CFU/ml) decreased quickly in EO water containing 0.5% NaCl to nondetectable levels (> 6.6 log reductions) within 15 s. Freshly harvested Pacific oysters were inoculated with a five-strain cocktail of V.

parahaemolyticus or V. vulnificus at levels of 10(4) and 10(6) most probable number (MPN)/g and treated with EO water (chlorine, 30 ppm; pH 2.82; oxidation-reduction potential, 1131 mV) containing 1% NaCl at room temperature. Reductions of V. parahaemolyticus and V. vulnificus in oysters were determined at 0 (before treatment), 2, 4, 6, and 8 h of treatment. Holding oysters inoculated with V. parahaemolyticus or V. vulnificus in the EO water containing 1% NaCl for 4 to 6 h resulted in significant (P < 0.05) reductions of V. parahaemolyticus and V. vulnificus by 1.13 and 1.05 log MPN/g, respectively. Extended exposure (> 12 h) of oysters in EO water containing high levels of chlorine (> 30 ppm) was found to be detrimental to oysters. EO water could be used as a postharvest treatment to reduce Vibrio contamination in oysters. However, treatment should be limited to 4 to 6 h to avoid death of oysters. Further studies are needed to determine effects of EO water treatment on sensory characteristics of oysters.
Source: Abstract

6.5.3 Change of hygienic quality and freshness in tuna treated with electrolyzed water and carbon monoxide gas during refrigerated and frozen storage. Huang, Y.-R., C.-Y. Shiau, Y.-C. Hung, and D.-F. Hwang. 2006. *J. Food Sci.* 71:127–134

Among different fish slices used for sashimi preparation, tuna is the most popular and preferable fish type for Taiwanese people. To improve the hygienic quality of fish slices, electrolyzed (EO) water containing 10, 50, and 100 mg/L chlorine, was used in combination with CO gas treatment. Effect of different treatment on aerobic plate count (APC), volatile basic nitrogen (VBN), K value, and Hunter L*, a*, b* values of yellow-fin tuna steak during storage (4 °C and −20 °C) were evaluated. It was found that APC, VBN, and K values increased with storage time for all treatment. Except for K value, APC and VBN of tuna steak treated with the combination of more than 50 mg/L chlorine EO water and CO gas had the lowest value after 8 d of refrigerated storage. Hunter a* value of tuna steak treated with only CO gas was the highest, followed by those treated with EO water and CO gas. These results demonstrated that EO water containing 50 mg/L chlorine combined with CO gas treatment in tuna fish steak would be an effective method for enhancing the hygienic quality and freshness for tuna meat and extending refrigerated storage time. Tuna treated with EO water containing 100 mg/L chlorine and CO gas combination had the lowest APC immediately after treatment and reduced further to below detection limit after 1 mo frozen storage at −20 °C.
Source: Abstract

6.5.4 Effects of electrolyzed water on reducing *Listeria monocytogenes* contamination on seafood processing surfaces. Liu, C., J. Duan, and Y.-C. Su. 2006. *Int. J. Food Microbiol.* 106:248–253

The effects of electrolyzed oxidizing (EO) water on reducing Listeria monocytogenes contamination on seafood processing surfaces were studied. Chips (5 x 5 cm(2)) of stainless steel sheet (SS), ceramic tile (CT), and floor tile (FT) with and without crabmeat residue on the surface were inoculated with L. monocytogenes and soaked in tap or EO water for 5 min. Viable cells of L. monocytogenes were detected on all chip surfaces with or without crabmeat residue after being held at room temperature for 1 h. Soaking contaminated chips in tap water resulted in small-degree reductions of the organism (0.40-0.66 log cfu/chip on clean surfaces and 0.78-1.33 log cfu/chip on dirty surfaces). Treatments of EO water significantly (p<0.05) reduced L. monocytogenes on clean surfaces (3.73 log on SS, 4.24 log on CT, and 5.12 log on FT). Presence of crabmeat residue on chip surfaces reduced the effectiveness of EO water on inactivating Listeria cells. However, treatments of EO water also resulted in significant reductions of L. monocytogenes on dirty surfaces (2.33 log on SS and CT and 1.52 log on FT) when compared with tap water treatments. The antimicrobial activity of EO water was positively correlated with its chlorine content. High oxidation-reduction potential (ORP) of EO water also contributed significantly to its antimicrobial activity against L. monocytogenes. EO water was more effective than chlorine water on inactivating L. monocytogenes on surfaces and could be used as a chlorine alternative for sanitation purpose. Application of EO water following a thorough cleaning process could greatly reduce L. monocytogenes contamination in seafood processing environments.
Source: Abstract

6.5.5 Efficiency of electrolyzed oxidizing water on reducing *Listeria monocytogenes* contamination on seafood processing gloves. Liu, C., and Y.-C. Su. 2006. *Int. J. Food Microbiol.* 110:149–154

Food processing gloves are typically used to prevent cross-contamination during food preparation. However, gloves can be contaminated with microorganisms and become a source of contamination. This study investigated the survival of Listeria monocytogenes on gloves and determined the efficacy of electrolyzed oxidizing (EO) water for reducing L. monocytogenes contamination on seafood processing gloves. Three types of reusable gloves (natural rubber latex, natural latex, and nitrile) and two types of disposable gloves (latex and nitrile) were cut into small pieces (4 x 4 cm(2)) and inoculated with 5-strain L. monocytogenes cocktail (5.1 x 10(7) CFU/cm(2)) with and without shrimp meat residue attached to surfaces. L. monocytogenes did not survive well on clean reusable gloves and its populations decreased rapidly to non-detectable levels within 30 min at room temperature. However, high levels of Listeria cells were recovered from clean disposable gloves after 30 min of inoculation. Presence of shrimp meat residue on gloves enhanced the survival of L. monocytogenes. Cells of L. monocytogenes were detected on both reusable and disposal gloves even after 2 h at room temperature. Soaking inoculated gloves in EO water at room temperature for 5 min completely eliminated L. monocytogenes on clean gloves (>4.46 log CFU/cm(2) reductions) and significantly (p<0.05) reduced the contamination on soil-containing gloves when compared with tap water treatment. EO water could be used as a sanitizer to reduce L. monocytogenes contamination on gloves and reduce the possibility of transferring L. monocytogenes from gloves to RTE seafoods.
Source: Abstract

6.5.6 Electrolyzed oxidizing water treatment for decontamination of raw salmon inoculated with *Escherichia coli* O157:H7 and *Listeria monocytogenes* Scott A and response surface modeling. Ozer, N. P., and A. Demirci. 2006. *J. Food Eng.* 72:234–241

Raw fish is prone to the risk of microbial outbreaks due to contamination by pathogenic microorganisms, such as Escherichia coli O157:H7 and Listeria monocytogenes. Therefore, it is essential to treat raw fish to inactivate pathogenic microorganisms. Electrolyzed Oxidizing Water (EO) is a novel antimicrobial agent containing acidic solution with a pH of 2.6, Oxidation Reduction Potential (ORP) of 1150 mV, and 70–90 ppm free chlorine, and alkaline solution with a pH of 11.4 and ORP of −795 mV. This study was undertaken to evaluate the efficacy of acidic EO water treatment and alkaline EO water treatment followed by acidic EO water treatment at various temperatures for the inactivation of E. coli O157:H7 and L. monocytogenes Scott A on the muscle and skin surfaces of inoculated salmon fillets. Inoculated

salmon fillets were treated with acidic EO water at 22 and 35 °C and 90 ppm free-chlorine solution as control at 22 °C for 2, 4, 8, 16, 32, and 64 min. The acidic EO water treatments resulted in a reduction of L. monocytogenes Scott A population in the range of 0.40 log10 CFU/g (60%) at 22 °C to 1.12 log10 CFU/g (92.3%) at 35 °C. Treatment of inoculated salmon fillets with acidic EO water reduced E. coli O157:H7 populations by 0.49 log10 CFU/g (67%) at 22 °C and 1.07 log10 CFU/g (91.1%) at 35 °C. The maximum reduction with chlorine solution (control) was 1.46 log10 CFU/g (96.3%) for E. coli O157:H7 and 1.3 log10 CFU/g (95.3%) for L. monocytogenes Scott A at 64 min. A response surface model was developed for alkaline treatment followed by acidic EO water treatment to predict treatment times in the range of 5–30 min and temperatures in the range of 22–35 °C for effective treatment with alkaline EO water followed by acidic water, alkaline and acidic water treatments. Response surface analysis demonstrated maximum log reductions of 1.33 log10 CFU/g (95.3%) for E. coliO157:H7 and 1.09 log10 CFU/g (91.9%) for L. monocytogenes Scott A. Data collected from the treatments was used to develop empirical models as a function of treatment times and temperature for prediction of population of E. coli O157:H7 and L. monocytogenes Scott A. Correlations (R2) of 0.52 and 0.77 were obtained between model predicted and experimental log10 reduction for E. coli O157:H7 and L. monocytogenes Scott A reductions, respectively. These results clearly indicated that EO water has a potential to be used for decontamination of raw fish.
Source: Abstract pdf

6.5.7 Decontamination effect of electrolyzed NaCl solutions on carp. Mahmoud, B. S., K. Yamazaki, K. Miyashita, S. Il-Shik, C. Dong- Suk, and T. Suzuki. 2004. *Lett. Appl. Microbiol.* 39:169–173

AIMS: To evaluate the efficacy of electrolysed NaCl solutions (EW) for disinfecting bacterial isolates from carp, and the potential application of EW to reducing the bacterial load in whole carp and carp fillets.
METHODS AND RESULTS: EW was produced by using a two-compartment batch-type electrolysed apparatus. Pure cultures (in vitro), whole carp (skin surface) and carp fillets were treated with EW to detect its antimicrobial effects. The anodic solution [EW (+)] completely inhibited growth of the isolates. Furthermore, dipping the fish samples in EW (+) reduced the mean total count of aerobic bacteria on the skin of whole carp and in fillets by 2.8 and 2.0 log(10), respectively. The cathodic solution [EW (-)] also reduced growth of the isolates from carp by ca 1.0 log(10). Moreover, the total counts of aerobic bacteria in whole carp (on the skin) and fillets were reduced by 1.28 and 0.82 log(10), respectively.
CONCLUSIONS: EW (+) has a strong bactericidal effect on bacteria isolated from carp.
SIGNIFICANCE AND IMPACT OF THE STUDY: Treatment with EW (+) could extend the shelf life of these fish. Source

6.5.8 Use of electrolyzed water ice for preserving freshness of pacific saury (*Cololabis saira*). Kim, W.-T., Y.-S. Lim, I.-S. Hin, H. Park, D. Chung, and T. Suzuki. 2006. *J. Food Prot.* 69:2199–2204

The effects of electrolyzed water ice (EW-ice), compared with traditional tap water ice (TW-ice), on the microbiological, chemical, and sensory quality of Pacific saury (Cololabis saira) stored for a period of up to 30 days at 4 degrees C were evaluated. EW-ice with active chlorine at a concentration of 34 mg/kg was prepared from weak acidic electrolyzed water, whose pH, oxidation-reduction potential, and chlorine content were 5, 866 mV, and 47 mg/liter, respectively. Microbiological analysis showed that EW-ice, compared with TW-ice, markedly inhibited the growth of both aerobic and psychrotrophic bacteria in saury flesh during refrigerated storage, primarily because of the action of active chlorine. Chemical analysis revealed that EW-ice retarded the formation of volatile basic nitrogen and thiobarbituric acid-reactive substances and reduced the accumulation of alkaline compounds in the fish flesh in comparison with TW-ice. Sensory analysis confirmed that the freshness of saury was better preserved in EW-ice than in TW-ice and showed that the saury stored in EW-ice had a shelf life that was about 4 to 5 days longer than the fish stored in TW-ice. Source

7 Disinfection and general properties

7.1 General

7.1.1 Stability of electrolyzed water and its efficacy against cell suspensions of *Salmonella* Typhimurium and *Listeria monocytogenes*. Fabrizio, K. A., and C. N. Cutter. 2003 *J. Food Prot.* 66:1379–1384.

Electrolyzed oxidizing (EO) water has proved to be effective against foodborne pathogens attached to cutting boards and poultry surfaces and against spoilage organisms on vegetables; however, its levels of effectiveness against Listeria monocytogenes and Salmonella Typhimurium in cell suspensions have not been compared with those of other treatments. In this study, the oxidation reduction potentials (ORPs), chlorine concentrations, and pHs of acidic and basic EO water were monitored for 3 days at 4 and 25 degrees C after generation. There were no differences between the pHs or ORPs of acidic and basic EO waters stored at 4 or 25 degrees C. However, the free chlorine concentration in acidic EO water stored at 4 degrees C increased after 24 h. In contrast, the free chlorine concentration in acidic EO water stored at 25 degrees C decreased after one day. Cell suspensions of Salmonella Typhimurium and L. monocytogenes were treated with distilled water, chlorinated water (20 ppm), acidified chlorinated water (20 ppm, 4.5 pH), acidic EO water (EOA), basic EO water (EOB), or acidic EO water that was "aged" at 4 degrees C for 24 h (AEOA) for up to 15 min at either 4 or 25 degrees C. The largest reductions observed were those following treatments carried out at 25 degrees C. EOA and AEOA treatments at both temperatures significantly reduced Salmonella Typhimurium populations by > 8 log10 CFU/ml. EOA and AEOA treatments effectively reduced L. monocytogenes populations by > 8 log10 CFU/ml at 25degrees C. These results demonstrate the stability of EO water under different conditions and that EO water effectively reduced Salmonella Typhimurium and L. monocytogenes populations in cell suspensions. Source

7.1.2 Inactivation of a hepadnavirus by electrolysed acid water Tagawa, M., T. Yamaguchi, O. Yokosuka, S. Matsutani, T. Maeda, and H. Saisho. 2000.. *J. Antimicrob. Chemother.* 46:363–368.

Glutaraldehyde is used as a disinfectant for endoscopes, but is an irritant and so should be replaced by an alternative. Electrolysed acid water (EAW) has a bactericidal effect, and an endoscopic washing device using EAW has been developed in Japan. To investigate the effect of EAW on the infectivity of viruses, we treated duck hepatitis B virus (DHBV), which has similar properties to hepatitis B virus, with EAW, and determined the number of remaining infectious virus particles in a bioassay system. One-day-old Pekin ducks were inoculated with duck serum containing 10(5.5) ID(50) DHBV; the serum had previously been incubated with 100 volumes of EAW or ion-exchanged water at room temperature for 7 min. DHBV infection was indicated by detection of viral DNA in duck serum samples 1-8 weeks after inoculation. Treatment of serum with EAW diminished DHBV infectivity whereas treatment with ion-exchanged water did not. The virus load was estimated to have been reduced to 10(1)-10(3) ID(50) during the first 1 min and to <10(0.5) ID(50) in the next 6 min of incubation when compared with the control. Thus, EAW directly inactivates DHBV and its clinical application is recommended. Source

7.1.3 Bactericidal activity of disinfectants on *Listeria.* Van de Weyer, A., M. J. Devleeschouwer, and J. Dony. 1993. *J. Appl. Bacteriol.* 74:480–483.

The bactericidal activity on Listeria spp. of nine disinfectants used in the food industry was studied by previously published methods. The disinfectants were diluted to the test concentration in sterile standard hard water. Various types of chemical agents were evaluated, including phenolic compounds, alcohols, quaternary ammonium compounds, surface-active agents, aldehydes and dischlorine tablets. The following strains isolated from cheese were studied: Listeria innocua, L. welshimeri, L. monocytogenes 1/2a, 1/2b, 1/2c and 4b. The results show that the listerias are not particularly resistant to disinfectants but the efficacy of some agents is affected by organic matter.

7.1.4 The bactericidal effects of electrolyzed oxidizing water on bacterial strains involved in hospital infections. Vorobjeva, N. V., L. I. Vorobjeva, and E. Y. Khodjaev. 2003. *Artif. Organs* 28:590–592.

The study is designed to investigate bactericidal actions of electrolyzed oxidizing water on hospital infections. Ten of the most common opportunistic pathogens are used for this study. Cultures are inoculated in 4.5 mL of electrolyzed oxidizing (EO) water or 4.5 mL of sterile deionized water (control), and incubated for 0, 0.5, and 5 min at room temperature. At the exposure time of 30 s the EO water completely inactivates all of the bacterial strains, with the exception of vegetative cells and spores of bacilli which need 5 min to be killed. The results indicate that electrolyzed oxidizing water may be a useful disinfectant for hospital infections, but its clinical application has still to be evaluated. Source

7.1.5 Efficacy of electrolyzed oxidizing water for inactivation of *Escherichia coli* O157:H7, *Salmonella enteritidis,* and *Listeria monocytogenes.* Venkitanarayanan, K. S., G. O. Ezeike, Y.-C. Hung, and M. P. Doyle. 1999. *Appl. Environ. Microbiol.* 65:4276–4279.

The efficacy of electrolyzed oxidizing water for inactivating Escherichia coli O157:H7, Salmonella enteritidis, and Listeria monocytogenes was evaluated. A five-strain mixture of E. coli O157:H7, S. enteritidis, or L. monocytogenes of approximately 10(8) CFU/ml was inoculated in 9 ml of electrolyzed oxidizing water (treatment) or 9 ml of sterile, deionized water (control) and incubated at 4 or 23 degrees C for 0, 5, 10, and 15 min; at 35 degrees C for 0, 2, 4, and 6 min; or at 45 degrees C for 0, 1, 3, and 5 min. The surviving population of each pathogen at each sampling time was determined on tryptic soy agar. At 4 or 23 degrees C, an exposure time of 5 min reduced the populations of all three pathogens in the treatment samples by approximately 7 log CFU/ml, with complete inactivation by 10 min of exposure. A reduction of >/=7 log CFU/ml in the levels of the three pathogens occurred in the treatment samples incubated for 1 min at 45 degrees C or for 2 min at 35 degrees C. The bacterial counts of all three pathogens in control samples remained the same throughout the incubation at all four temperatures. Results indicate that electrolyzed oxidizing water may be a useful disinfectant, but appropriate applications need to be validated. Source

7.1.6 Different responses of planktonic and attached *Bacillus subtilis* and *Pseudomonas fluorescens* to sanitizer treatment. Lindsay, D., and A. von Holy. 1999. *J. Food Prot.* 62:368–379

Three commercial sanitizers containing iodophor (I), peracetic acid/ hydrogen peroxide (PAH), or chlorhexidine gluconate (CG) were evaluated in vitro against planktonic and sessile Bacillus subtilis or Pseudomonas fluorescens cells grown in Standard One Nutrient Broth. Sessile cells were attached to stainless steel or polyurethane test surfaces. Planktonic and attached cells of both bacteria were enumerated by plate counts after sanitizer treatment for 1, 3, or 5 min. Sessile cells were dislodged from test surfaces by shaking them with beads. Cell morphologies were monitored by scanning electron microscopy (SEM). Attached B. subtilis and P. fluorescens cells on both surface types were less susceptible to all three sanitizers than their planktonic counterparts. PAH, I, and CG were equally effective against planktonic P. fluorescens cells, which were reduced by 99.999% after 1, 3, and 5 min exposure. PAH was the only sanitizer effective against attached P. fluorescens cells on both surface types; it reduced counts by < or = 99.9% after 1, 3, and 5 min exposure. PAH was also the most effective sanitizer against planktonic B. subtilis cells, reducing counts by 99.9% after 1, 3, and 5 min. Sessile B. subtilis cells on both surface types were the least susceptible to all sanitizers; counts were reduced by only 99.5% or less after exposure to PAH for 5 min. SEM revealed that planktonic and attached cells of both bacteria exhibited symptoms of surface roughness, indentations, and shape distortions after treatment with any of the sanitizers. Source

7.1.7 Decontamination of aflatoxin-forming fungus and elimination of aflatoxin mutagenicity with electrolyzed NaCl anode solution. Suzuki, T., T. Noro, Y. Kawamura, K. Fukunaga, M. Watanabe, M. Ohta, H. Sugiue, Y. Sato, M. Kohno, and K. Hotta. 2002. *J. Agric. Food Chem.* 50:633–641.

Electrolysis of a 0.1% (17.1 mM) solution of NaCl using separate anode and cathode compartments gives rise to solutions containing active chemical species. The strongly acidic "anode solution" (EW+) has high levels of dissolved oxygen and available chlorine in a form of hypochlorous acid (HOCl) with a strong potential for sterilization, which we have investigated here. Exposing Aspergillus parasiticus at an initial density of 10(3)spores in 10 microL to a 50-fold volume (500 microL) of EW+ containing ca. 390 micromol HOCl for 15 min at room temperature resulted in a complete inhibition of fungal growth, whereas the cathode solution (EW-) had negligible inhibitory effects. Moreover, the mutagenicity of aflatoxin B(1) (AFB(1)) for Salmonella typhimurium TA-98 and TA-100 strains was strongly reduced after AFB(1) exposure to the EW+ but not with the EW-. In high-performance liquid chromatography analysis, the peak corresponding to AFB(1) disappeared after treatment with the EW+, indicating decomposition of the aflatoxin. In contrast, the routinely used disinfectant sodium hypochlorite, NaOCl, of the same available chlorine content as that of EW+ but in a different chemical form, hypochlorite (OCl-) ion, did not decompose AFB(1) at pH 11. However, NaOCl did decompose AFB(1) at pH 3, which indicated that the principle chemical formula to participate in the decomposition of AFB(1) is not the OCl- ion but HOCl. Furthermore, because the decomposition of AFB(1) was suppressed by pretreating the EW+ with the OH radical scavenger thiourea, the chemical species responsible for the AFB(1)-decomposing property of the EW+ should be at least due to the OH radical originated from HOCl. The OH in EW+ was proved by electron spin resonance analysis. Source

7.1.8 Inactivation of staphylococcal enterotoxin-A with an electrolyzed anodic solution. Suzuki, T., J. Itakura, M. Watanabe, M. Ohta, Y. Sato, and Y. Yamaya. 2002. *J. Agric. Food Chem.* 50:230–234.

Electrolyzed anodic NaCl solutions [EW+], prepared by the electrolysis of 0.1% NaCl, have been shown to instantly inactivate most pathogens that cause food-borne disease. Elimination of food-borne pathogens does not necessarily guarantee food safety because enterotoxins produced by pathogens may remain active. We have tested whether EW+ can inactivate Staphylococcal enterotoxin A (SEA), one of the major enterotoxins responsible for food poisoning. Fixed quantities of SEA were mixed with increasing molar ratios of EW+, and SEA was evaluated by reversed-phase passive latex agglutination (RPLA) test, immunoassay, native polyacrylamide gel electrophoresis (PAGE), and amino acid analysis after 30 min incubations. Exposure of 70 ng, or 2.6 pmol, of SEA in 25 microL of PBS to a 10-fold volume of EW+, or ca. 64.6 x 10(3)-fold molar excess of HOCl in EW+, caused a loss of immuno-reactivity between SEA and a specific anti-SEA antibody. Native PAGE indicated that EW+ caused fragmentation of SEA, and amino acid analysis indicated a loss in amino acid content, in particular Met, Tyr, Ile, Asn, and Asp. Staphylococcal enterotoxin-A excreted into culture broth was also inactivated by exposure to an excess molar ratio of EW+. Thus, EW+ may be a useful management tool to ensure food hygiene by food processing industries. Source

7.1.9 Effect of acidified sodium chlorite, chlorine, and acidic electrolyzed water on *Escherichia coli* O157:H7, *Salmonella*, and *Listeria monocytogenes* inoculated onto leafy greens. Stopforth, J. D., T. Mai, B. Kottapalli, and M. Samadpour. 2008*J. Food Prot.* 71:625–628.

Recent foodborne outbreaks implicating spinach and lettuce have increased consumer concerns regarding the safety of fresh produce. While the most common commercial antimicrobial intervention for fresh produce is wash water containing 50 to 200 ppm chlorine, this study compares the effectiveness of acidified sodium chlorite, chlorine, and acidic electrolyzed water for inactivating Escherichia coli O157:H7, Salmonella, and Listeria monocytogenes inoculated onto leafy greens. Fresh mixed greens were left uninoculated or inoculated with approximately 6 log CFU/g of E. coli O157:H7, Salmonella, and L. monocytogenes and treated by immersion for 60 or 90 s in different wash solutions (1:150, wt/vol), including 50 ppm of chlorine solution acidified to pH 6.5, acidic electrolyzed water (pH 2.1 +/- 0.2, oxygen reduction potential of 1,100 mV, 30 to 35 ppm of free chlorine), and acidified sodium chlorite (1,200 ppm, pH 2.5). Samples were neutralized and homogenized. Bacterial survival was determined by standard spread plating on selective media. Each test case (organism x treatment x time) was replicated twice with five samples per replicate. There was no difference (P > or = 0.05) in the time of immersion on the antimicrobial effectiveness of the treatments. Furthermore, there was no difference (P > or = 0.05) in survival of the three organisms regardless of treatment or time. Acidified sodium chlorite, resulted in reductions in populations of 3 to 3.8 log CFU/g and was more effective than chlorinated water (2.1 to 2.8 log CFU/g reduction). These results provide the produce industry with important information to assist in selection of effective antimicrobial strategies. Source

7.1.10 Effects of water source, dilution, storage, and bacterial and fecal loads on the efficacy of electrolyzed oxidizing water for the control of *Escherichia coli* O157:H7. Stevenson, S. M., S. R. Cook, S. J. Bach, and T. A. McAllister. 2004. *J. Food Prot.* 67:1377–1383.

To evaluate the potential of using electrolyzed oxidizing (EO) water for controlling Escherichia coli O157:H7 in water for livestock, the effects of water source, electrolyte concentration, dilution, storage conditions, and bacterial or fecal load on the oxidative reduction potential (ORP) and bactericidal activity of EO water were investigated. Anode and combined (7:3 anode:cathode, vol/vol) EO waters reduced the pH and increased the ORP of deionized water, whereas cathode EO water increased pH and lowered ORP. Minimum concentrations (vol/vol) of anode and combined EO waters required to kill 10(4) CFU/ml planktonic suspensions of E. coli O157:H7 strain H4420 were 0.5 and 2.0%, respectively. Cathode EO water did not inhibit H4420 at concentrations up to 16% (vol/vol). Higher concentrations of anode or combined EO water were required to elevate the ORP of irrigation or chlorinated tap water compared with that of deionized water. Addition of feces to EO water products (0.5% anode or 2.0% combined, vol/vol) significantly reduced (P < 0.001) their ORP values to < 700 mV in all water types. A relationship between ORP and bactericidal activity of EO water was observed. The dilute EO waters retained the capacity to eliminate a 10(4) CFU/ml inoculation of E. coli O157:H7 H4420 for at least 70 h regardless of exposure to UV light or storage temperature (4 versus 24 degrees C). At 95 h and beyond, UV exposure reduced ORP, significantly more so (P < 0.05) in open than in closed containers. Bactericidal activity of EO products (anode or combined) was lost in samples in which ORP value had fallen to < or = 848 mV. When stored in the dark, the diluted EO waters retained an ORP of > 848 mV and bactericidal efficacy for at least 125 h; with refrigeration (4 degrees C), these conditions were retained for at least 180 h. Results suggest that EO water may be an effective means by which to control E. coli O157:H7 in livestock water with low organic matter content.
Source: Abstract

7.1.11 Antimicrobial activity of electrolyzed NaCl solutions: effect on the growth of *Streptomyces* spp. Hotta, K., K. Kawaguchi, F. Saitoh, N. Saitoh, K. Suzuki, K. Ochi, and T. Nakayama. 1994. *Actinomycetologica* 8:51–56

An acidic solution (pH 2.5~2.6) with a high oxidation-reduction potential (ORP; about +1,170 mV) and an alkaline solution (pH 11.5~11.7) with a low ORP (about −880mV) that resulted from electrolysis of 20 mM NaCl (dissolved in a pure water) were tested for their effect on the growth of Streptomyces spp. When spores (~2×107) were exposed to the electrolyzed solutions (2 ml) for 1 minute, colony formation was totally inhibited by the acidic solution, but little by the alkaline solution although extending the exposure (10 minutes) resulted in a marked inhibition. The 1 minute exposure to their mixture (1:1, v/v) showed a strong inhibition (but weaker than that of the acidic solution). When the unexposed spores were streaked and incubated on ISP No. 4 (inorganic salts - starch medium) agar plate containing a cross density gradient of the acidic and alkaline solutions, a biased growth inhibition toward the acidic solution side was observed although the pH range of the acidic solution end of the plate was around 6.2. It seemed thus unlikely that low pH value contributed to the antimicrobial activity of the acidic solution. It was notable that S. griseus SS-1198 formed a unique morphology on the cross gradient plate. In addition, clear growth inhibition by the acidic solution was observed without direct contact with spores, probably because of chlorine

gas release. Acidic solutions (pH 2.6~2.7) resulting from the electrolysis of 20 mM of Na2SO4 show no significant antimicrobial activity

when tested by the cross gradient plate method. It thus seemed likely that chlorine played a key role for the antimicrobial activity of the acidic electrolyzed NaCl solution.
Source: Abstract

7.1.12 Changes in the properties of soft and hard oxidized waters under different storage conditions and when in contact with saliva.
Shimada, K., T. Igarashi, and N. Ebihara. 1997. *J. Jpn. Soc. Periodontol.* 39:104–112
Soft oxidized water (SOW) is produced by elec-trolysis of water with NaCl and HCl. It has been reported that SOW has bactericidal effects on oral microorganisms. Therefore, SOW is considered to be useful for the control of plaque formation. However, when SOW is used for the control of plaque formation, the influences of storage condi-tions and saliva may cause qualitative changes in SOW. When SOW was stored in sealed and shaded bottles at 4°C or room temparature or in sealed bottles at room temparature, the temporal changes of pH, oxidation-reduction potential (ORP), chlo-rine concentration and bactericidal effects on three species of oral microorganisms were examined. In order to investigate the changes of SOW folliwing contact with saliva, saliva was added to SOW, and measured in the same manner. Hard oxidized water (HOW) was also examined in the same way. Both SOW and HOW stored in sealed and shaded bottles at 4°C showed slight changes in pH, ORP, and chlorine concentration. While SOW retained the same bactericidal effect during the whole exper-imental period, the bactericidal effect of HOW decreased with time. When saliva was added to SOW or HOW, the pH, ORP, and chlorine concentration were significantly changed, but the bacte-ricidal effect of SOW was unchanged. In conclusion, with both SOW and HOW the best storage condition is sealed and shaded bottles at 4°C. When saliva was added to SOW or HOW, the results indicated that SOW retained better bacte-ricidal effects than HOW.
Source: Abstract

7.1.13 Determination of phytotoxicity of several volatile organic compounds by investigating the germination patterns of tobacco pollen.
Schubert, U., L. Wisanowsky, and U. Kull. 1995. *J. Plant Physiol.* 145:518–541
Hydrated pollen of Nicotiana tabacum L. (var. xanthi nc) was exposed to different concentrations of several volatile organic compounds. The germination rate of the pollen was determined by applying a modified test procedure originally developed by Kappler and Kristen (1990). A stimulation of pollen germination resulting through a rise in pCO2 was avoided by using a short exposure period. In the series of chlorinated ethanes, the ED50 (and ED25) values decrease with increasing number of chlorine atoms, which are correlated to a rise of the octanol-water partition coefficient. For the chlorinated ethenes a similar effect is probable, but less obvious. The toxicity of compounds with the same number of chlorine atoms is higher for ethane derivatives than for derivatives of ethene.The ED50 and ED25 values are compared with threshold values of physiological effects obtained after the application of 1,1,1-trichloroethane for 24 h to tobacco leaves. We presume that chlorinated hydrocarbons may cause stress even at lower concentrations than those suggested by the pollen test. Therefore the listed ED values (Table 1) should be considered as maximum tolerable values regarding phytotoxic effects in experimental investigations. For the important solvent 1,1,1-trichloroethane the ED25 value of phytotoxicity is lower than 4 mg/L; according to literature the concentration supposedly having no effect on man is 1.9 - 5.2 mg/L.
Source: Abstract

7.1.14 Comparison of sodium hypochlorite and peracetic acid as sanitizing agents for stainless steel food processing surfaces using epifluorescence microscopy. Rossoni, E. M., and C. C. Gaylarde. 2000. *Int. J. Food Microbiol.* 61:81–85

7.1.15 Effects of chlorine and pH on efficacy of electrolyzed water for inactivating *Escherichia coli* O157:H7 and *Listeria monocytogenes.* Park, H., Y.-C. Hung, and D. Chung. 2004. *Int. J. Food Microbiol.* 91:13–18
The effects of chlorine and pH on the bactericidal activity of electrolyzed (EO) water were examined against Escherichia coli O157:H7 and Listeria monocytogenes. The residual chlorine concentration of EO water ranged from 0.1 to 5.0 mg/l, and the pH effect was examined at pH 3.0, 5.0, and 7.0. The bactericidal activity of EO water increased with residual chlorine concentration for both pathogens, and complete inactivation was achieved at residual chlorine levels equal to or higher than 1.0 mg/l. The results showed that both pathogens are very sensitive to chlorine, and residual chlorine level of EO water should be maintained at 1.0 mg/l or higher for practical applications. For each residual chlorine level, bactericidal activity of EO water increased with decreasing pH for both pathogens. However, with sufficient residual chlorine (greater than 2 mg/l), EO water can be applied in a pH range between 2.6 (original pH of EO water) and 7.0 while still achieving complete inactivation of E. coli O157:H7 and L. monocytogenes. Source

7.1.16 The efficiency of disinfection of acidic electrolyzed water in the presence of organic materials. Oomori, T., T. Oka, T. Inuta, and Y. Arata. 2000. *Anal. Sci.* 16:365–369
Acidic electrolyzed water (acidic EW), which is prepared by the electrolysis of an aqueous NaCl solution, has recently become of great importance for disinfection in a variety of fields, including medicine, the food industry and agriculture. In a previous paper we showed

that: 1) acidic EW is a mixture of hypocholorite ion, hypochlorous acid and chlorine, depending upon the pH; 2) hypochlorous acid is primarily responsible for disinfection in the case of Escherichia coli K12 and Bacillus subtilis PCI219, both in clean culture media. In practice, however. the use of acidic EW is in many cases severely hampered due to the presence of a variety of non-selective reducing agents. In view of the salient nature of acidic EW, it is therefore strongly urged to establish an optimum way to use acidic EW in a variety of systems. The present paper is the first report on our attempt along this line in order to characterize The nature of the chemical changes that the bactericidal activity of the acidic EW deteriorates in the presence of organic materials, which include amino acids and proteins.
Abstract

7.1.17 Susceptibility of *Penicillium expansum* spores to sodium hypochlorite, electrolyzed oxidizing water, and chlorine dioxide solutions modified with nonionic surfactants. Okull, D. O., A. Demirci, D. Rosenberger, and L. F. LaBorde. 2006. *J. Food Prot.* 69:1944–1948

The use of water flotation tanks during apple packing increases the risk of contamination of apples by spores of Penicillium expansum, which may accumulate in the recirculating water. Routine addition of sanitizers to the water may prevent such contamination. Sodium hypochlorite (NaOCl), chlorine dioxide (ClO2), and electrolyzed oxidizing (EO) water have varied activity against spores of P. expansum, and their effectiveness could be enhanced using surfactants. The objective of this study was to determine the ability of three nonionic surfactants, polyoxyethylene sorbitan monooleate (Tween 80), polyoxyethylene sorbitan monolaurate (Tween 20), and sorbitan monolaurate (Span 20), to enhance the efficacy of NaOCl, ClO2, and EO water against spores of P. expansum in aqueous suspension at various temperatures and pH conditions. The efficacy of NaOCl solutions was enhanced by the addition of surfactants at both pH 6.3 and pH 8 (up to 5 log CFU reduction). EO water and ClO2 were effective against P. expansum spores (up to 5 log CFU and 4 log CFU reduction, respectively), but addition of surfactants was not beneficial. All solutions were less effective at 4 degrees C compared to 24 degrees C irrespective of the presence of surfactants. Nonionic surfactants could potentially be used with NaOCl to improve control of P. expansum in flotation tanks, but the efficacy of such formulations should be validated under apple packing conditions.
Source: Abstract

7.1.18 Durability of bactericidal activity in electrolyzed neutral water by storage. Nagamatsu, Y., K.-K. Chen, K. Tajima, H. Kakigawa, and Y. Kozono. 2002. *Dent. Mater. J.* 21:93–105

Electrolyzed strong and weak acid waters have been widely used for sterilization in clinical dentistry because of their excellent bactericidal activities. Electrolyzed neutral water was recently developed with a new concept of long-term good durability in addition to the excellent bactericidal activity similar to acid waters. The present study, evaluated the storage life of this water compared with the acid waters in terms of the changes in pH, oxidation-reduction potential (ORP), residual chlorine and bactericidal activity under several conditions using Staphylococcus aureus 209P. The strong acid water showed a rapid deterioration of its bactericidal activity. The weak acid and neutral waters exhibited excellent durability. Although all the bacteria were annihilated by the contact with the waters even stored for 40 days in the uncapped bottle, the neutral water was superior in further long-term duration.
Source: Abstract

7.1.19 Disinfection potential of electrolyzed solutions containing sodium chloride at low concentrations. Morita, C., K. Sano, S. Morimatsu, H. Kiura, T. Goto, T. Kohno, W. Hong, H. Miyoshi, A. Iwasawa, Y. Nakamura, M. Tagawa, O. Yokosuka, H. Saisho, T. Maeda, and Y. Katsuoka. 2000. *J. Virol. Methods* 85:163–174

Electrolyzed products of sodium chloride solution were examined for their disinfection potential against hepatitis B virus (HBV) and human immunodeficiency virus (HIV) in vitro. Electrolysis of 0.05% NaCl in tap water was carried out for 45 min at room temperature using a 3 A electric current in separate wells installed with positive and negative electrodes. The electrolyzed products were obtained from the positive well. The oxidation reduction potential (ORP), pH and free chlorine content of the product were 1053 mV, pH 2.34 and 4.20 ppm, respectively. The products modified the antigenicity of the surface protein of HBV as well as the infectivity of HIV in time- and concentration-dependent manner. Although the inactivating potential was decreased by the addition of contaminating protein, recycling of the product or continuous addition of fresh product may restore the complete disinfection against bloodborne pathogens.
Source: Abstract

7.1.20 Fundamental properties of electrolyzed water. Koseki, S., and K. Itoh. 2000. *J. Jpn. Soc. Food Sci. Technol.* 47:390–393

Electrolyzed Water (Acidic Electrolyzed Water, Alkaline Electrolyzed Water) has recently attracted the interest of researchers in various fields such as medicine, agriculture and food processing. In this study, we investigated the preservability of Electrolyzed Water produced in a two-cell batch-type apparatus. It was found that Acidic Electrolyzed Water could be preserved for one year under shaded and sealed conditions. However, Acidic Electrolyzed Water became inert after three days when exposed to light, although pH remained stable for one year. It was found out that the quality of Alkaline Electrolyzed Water changes easily regardless of preservation conditions.
Source: Abstract

7.1.21 Electrolyzed water: a new technology for food decontamination—a review. Mahmoud, B. S. 2007. *Dtsch. Lebensm. Rundsch.* 103: 212–221

Electrolyzed water (EW) has attracted much recent attention as a high-performance, new technology for potential use in the food industry. However, this is the first review which examines the potential of the antimicrobial effect of electrolyzed water solutions in many different food models such as vegetable, fruits, meat, poultry, fish, and other products. Production, theoretical of the chemical reactions in the production of EW, theories of disinfectant effect of EW and advantage of using EW would be reviewed. The purpose of this review is to introduce simple information about the use of this new technology in the field of food disinfection, for both readers and food industry.
Source: Abstract

7.1.22 Acid adaptation sensitizes *Salmonella typhimurium* to hypochlorous acid. Leyer, G. J., and E. A. Johnson. 1997. *Appl. Environ. Microbiol* 63:461–467.

Acid adaptation of Salmonella typhimurium at a pH of 5.0 to 5.8 for one to two cell doublings resulted in marked sensitization of the pathogen to halogen-based sanitizers including chlorine (hypochlorous acid) and iodine. Acid-adapted S. typhimurium was more resistant

to an anionic acid sanitizer than was its nonadapted counterpart. A nonselective plating medium of tryptose phosphate agar plus 1% pyruvate was used throughout the study to help recover chemically stressed cells. Mechanisms of HOCl-mediated inactivation of acid-adapted and nonadapted salmonellae were investigated. Hypochlorous acid oxidized a higher percentage of cell surface sulfhydryl groups in acid-adapted cells than in nonadapted cells, and sulfhydryl oxidation was correlated with cell inactivation. HOCl caused severe metabolic disruptions in acid-adapted and nonadapted S. typhimurium, such as respiratory loss and inability to restore the adenylate energy charge from a nutrient-starved state. Sensitization of S. typhimurium to hypochlorous acid by acid adaptation also involved increased permeability of the cell surface because nonadapted cells treated with EDTA became sensitized. The results of this study establish that acid-adapted S. typhimurium cells are highly sensitized to HOCl oxidation and that inactivation by HOCl involves changes in membrane permeability, inability to maintain or restore energy charge, and probably oxidation of essential cellular components. This study provides a basis for improved practical technologies to inactivate Salmonella and implies that acid pretreatment of food plant environments may increase the efficacy of halogen sanitizers.
Source: Abstract

7.1.23 The generation and inactivation mechanism of oxidation-reduction potential of electrolyzed oxidizing water. Liao, L. B., W. M. Chen, and X. M. Xiao. 2007. *J. Food Eng.* 78:1326–1332

The objective of this study was to determine the efficacy of acidic electrolyzed (AEO) and near neutral electrolyzed (NEO) water produced from different generators and principles in inactivating Escherichia coli O167:H7. AEO and NEO water were produced using EAU, Hoshizaki, Purester, and Radical Waters generators and used to treat E. coli O157:H7 for up to five min before and after storage for 48 h at 22ºC. The properties of respective AEO and NEO water produced from different generators were similar, except for Purester. The efficacy of AEO water from different generators in inactivating E. coli O157:H7 was not significantly different. AEO water inactivated more E. coli O157:H7 viable cells than NEO. The most effective NEO water for inactivation of E. coli O157:H7 was NEO water from EAU generator, followed by NEO water from Radical Waters and Purester. The free chlorine levels and antimicrobial activity of AEO water significantly decreased after storage. The properties of NEO water were relatively stable and their ability in inactivating E. coli O157:H7 did not changed significantly after storage for 48 h in open bottles, except for NEO water from Purester. The results of this study can be used to determine the choice of generators and type of electrolyzed water to be produced, depending on the resources, purpose and need. Source: pdf

7.1.24 Inactivation of surface adherent *Listeria monocytogenes* by hypochlorite and heat. Lee, S.-H., and J. F. Frank. 1991 *J. Food Prot.* 54:4–6.

Inactivation by hypochlorite of Listeria monocytogenes cells adherent to stainless steel was determined. Adherent cell populations were prepared by incubating stainless steel slides with a 24 h culture of L. monocytogenes for 4 h at 21 degrees C. Adherent microcolonies were prepared by growing L. monocytogenes on stainless steel slides submerged in a 1:15 dilution of tryptic soy broth at 21 degrees C. The slides were then rinsed and transferred to fresh sterile broth every 2 d with a total incubation time of 8 d. Although the 4 h and 8 d adherent populations were at similar levels, 8 d adherent cells were over 100 times more resistant than the 4 h adherent cell population when exposed to 200 ppm hypochlorite for 30 s. When stainless steel slides containing adherent cells were heated at 72 degrees C both adherent cell populations were inactivated after 1 min. Detectable numbers of L. monocytogenes remained on stainless steel slides after treatment at 65 degrees C for 3 min when adherent 8 d cells were tested but not when adherent 4 h cells were used
Source: Abstract

7.1.25 Effects of storage conditions and pH on chlorine loss in electrolyzed oxidizing (EO) water. Len, S.-V., Y.-C. Hung, D. Chung, J. L. Anderson, M. C. Ericksen, and K. Morita. 2002. *J. Agric. Food Chem.* 50:209–212.

The chlorine loss of electrolyzed oxidizing (EO) water was examined during storage under different light, agitation, and packaging conditions. The chlorine loss of pH-adjusted EO water was also examined. Under open conditions, the chlorine loss through evaporation followed first-order kinetics. The rate of chlorine loss was increased about 5-fold with agitation, but it was not significantly affected by diffused light. Under closed conditions, the chlorine loss did not follow first-order kinetics, because the primary mechanism of chlorine loss may be self-decomposition of chlorine species rather than chlorine evaporation. The effect of diffused light was more significant compared to agitation after two months of storage under closed conditions. The chlorine loss of EO water and commercial chlorinated water decreased dramatically with the increase of pH from the acidic (pH 2.5) to the alkaline (pH 9.0) region.
Source: Abstract pdf

7.1.26 Ultraviolet spectrometric characterization of bactericidal properties of electrolyzed oxidizing water as influenced by amperage and pH. Len, S.-V., Y.-C. Hung, M. C. Ericksen, and C. Kim. 2000. *J. Food Prot.* 63:1534–1537.

To identify the primary component responsible in electrolyzed oxidizing (EO) water for inactivation, this study determined the concentrations of hypochlorous acid (HOCl) and hypochlorite ions (OCl-) and related those concentrations to the microbicidal activity of the water. The ultraviolet absorption spectra were used to determine the concentrations of HOCl and OCl- in EO water and the chemical equilibrium of these species with change in pH and amperage. EO water generated at higher amperage contained a higher chlorine concentration. The maximum concentration of HOCl was observed around pH 4 where the maximum log reduction (2.3 log10 CFU/ml) of Bacillus cereus F4431/73 vegetative cells also occurred. The high correlation (r = 0.95) between HOCl concentrations and bactericidal effectiveness of EO water supports HOCl's role as the primary inactivation agent. Caution should be taken with standard titrimetric methods for measurement of chlorine as they cannot differentiate the levels of HOCl present in EO water of varying pHs
Source: Abstract

7.1.27 A novel electrolyzed sodium chloride solution for the disinfection of dried HIV-1. Kitano, J., T. Kohno, K. Sano, C. Morita, M. Yamaguchi, T. Maeda, and N. Tanigawa. 2003. *Bull. Osaka Med. Coll.* 48:29–36.

Electrolyzed products of a sodium chloride solution contain free residual chlorine and have been proved to be effective for disinfection. Electrolyzed strong acid water containing a low sodium chloride concentration (ESW-L) is prepared by the electrolysis of a solution containing a low sodium chloride concentration (0.1% or less). Although ESW-L has been confirmed to be an effective disinfectant, disinfective efficacy against dried HIV-1 and a target of ESW-L against HIV-1 have not been clarified. In this study, we attempted to demonstrate the efficacy of ESW-L against dried HIV-1 which relatively resists disinfection and to analyze disinfection target. We demonstrated that ESW-L inactivated the infectivity of dried HIV-1. In the analysis of the mechanism of disinfection, although the HIV-1 structural protein, p24 within the virus particle, was not inactivated by ESW-L, the enzymatic activity of reverse transcriptase (RT) and genomic RNA within the particle, however, were inactivated after the treatment with ESW-L. These findings suggest that the enzymatic activity of RT and genomic RNA are the target of ESW-L.

Source: Abstract pdf

7.1.28 Bactericidal activity of electrolyzed acid water from solution containing sodium chloride at low concentration, in comparison with that at high concentration. Kiura, H., K. Sano, S. Morimatsu, T. Nakano, C. Morita, M. Yamaguchi, T. Maeda, and Y. Katsuoka. 2002. *J. Microbiol. Methods* 49:285–293.

Electrolyzed strong acid water (ESW) containing free chlorine at various concentrations is becoming to be available in clinical settings as a disinfectant. ESW is prepared by electrolysis of a NaCl solution, and has a corrosive activity against medical instruments. Although lower concentrations of NaCl and free chlorine are desired to eliminate corrosion, the germicidal effect of ESW with low NaCl and free-chlorine concentrations (ESW-L) has not been fully clarified. In this study, we demonstrated that ESW-L possesses bactericidal activity against Mycobacteria and spores of Bacillus subtilis. The effect was slightly weaker than that of ESW containing higher NaCl and free-chlorine concentrations (ESW-H), but acceptable as a disinfectant. To clarify the mechanism of the bactericidal activity, we investigated ESW-L-treated Pseudomonas aeruginosa by transmission electron microscopy, a bacterial enzyme assay and restriction fragment length polymorphism pattern (RFLP) assay. Since the bacterium, whose growth was completely inhibited by ESW-L, revealed the inactivation of cytoplasmic enzyme, blebs and breaks in its outer membrane and remained complete RFLP of DNA, damage of the outer membrane and inactivation of cytoplasmic enzyme are the important determinants of the bactericidal activity

Source: pdf

7.1.29 Investigation of the presence of OH radicals in electrolyzed NaCl solution by electron spin resonance spectroscopy. Stan SD, Woods JS, DaeschelMA. Department of Food Science and Technology, Oregon State University, 100 Wiegand Hall, Corvallis, Oregon 97331, USA.

In the anode side of a two-chamber electrolyzer, electrolysis of a NaCl solution generates acidic electrolyzed oxidizing (EO) water, which exhibits bactericidal effects against a large number of pathogens. This study was undertaken to investigate whether OH radical species are present in EO water or are formed when EO water reacts with iron ions. Electron spin resonance spectroscopy (ESR) coupled with the spin trapping technique was used for the detection of free radicals. Samples of EO water were collected at 0.5, 1, 2, 3, and 5 min of electrolysis and immediately mixed with the spin trapping agent 5,5-dimethyl-1-pyrroline-N-oxide (DMPO). The 5,5-dimethyl-2-hydroxypyrrolidine-N-oxyl (DMPO-OH) spin adduct, characteristic of OH radicals, was not observed. Starting with 2-min electrolysis, a seven-line spectrum characteristic of 5,5-dimethyl-2-pyrrolidone-N-oxyl (DMPOX) was formed. The reactions of EO water with Fe3+ and Fe2+ in the presence of DMPO yielded the spin adduct DMPO-OH. However, the addition of OH radical scavengers (ethanol and methanol) did not generate the characteristic DMPO-alkyl spin adducts. This indicated that the DMPO-OH spectrum was due to a nucleophilic addition of water to DMPO and not to trapping of OH radicals.

Source: Abstract