Using Oxidation Reduction Potential (ORP) for Water Disinfection Monitoring, Control and Documentation

Large volumes of water are commonly used during the postharvest handling and processing of minimally processed fruits and vegetables. Economic considerations and wastewater discharge regulations make water recirculation a common practice in the industry. **Few practices have the capacity of water recirculation to increase the potential risk of food-borne illness by readily distributing a point source contaminant (one lot, one bin, or even one plant) to non-contaminated produce.** Disinfection of water is a critical step to minimize the potential transmission of pathogens from a water source to produce, among produce within a lot, and between lots over time. Water-borne microorganisms whether postharvest plant pathogens or agents of human illness can be rapidly acquired and taken up on plant surfaces. Natural plant surface contours, natural openings, harvest and trimming wounds, and handling injuries can serve as points of entry for microbes. Within these protected sites, microbes are unaffected by common postharvest water treatments such as chlorine, chlorine dioxide, ozone, peroxide, peroxyacetic acid, UV-irradiation and other approved treatments. It is essential, therefore, that the water used for washing, cooling, transporting, postharvest drenches, or other procedures be maintained in a condition suitable for the application. **The standards for microbial quality of the water increase as product moves from the field to final processing.**

Accurate monitoring and recording of disinfection procedures is an important component of a sound postharvest quality and safety program during product cooling and processing. Many fresh cut processors have adopted Oxidation-Reduction Potential (ORP), measured in millivolts (mV), as a primary approach to standardizing water disinfection parameters. Operationally much like a digital thermometer or pH probe, ORP sensors allow the easy monitoring and tracking of critical disinfectant levels in water systems. Coupled with pH sensors, more sophisticated systems use ORP sensors to provide automated “demand-based” injection of hypochlorite (or other approved oxidizing disinfectant) and acid, typically **citric acid** (**See Cautions** below). In this section we provide a brief overview of the application of ORP monitoring to postharvest sanitation processes and describe the relationship of mV values to traditional standards relying on estimates of ppm (parts per million) of active disinfectant.

Benefits of ORP Systems

Oxidation-Reduction Potential (ORP) offers many advantages to “real time” monitoring and recording of water disinfection potential, a critical water quality parameter. Improvements in probe design and continuous analog recording (paper strip or revolving chart) or computer-linked data input are available. Record-keeping can become a largely automated activity. Evaluation of process control by fluctuating water quality, product, and season, for example, are easier with the graphic outputs of available systems. Probes have been integrated to audible, visual and remote alarm systems to notify the operator of out-of-range operation. Hand-held devices are affordable and essential back up to cross-reference the operation of an in-line probe.

A primary advantage is that using ORP for water system monitoring provides the operator with a rapid and single-value assessment of the disinfection potential of water in a postharvest system. Research has shown that at an ORP value of 650 to 700 mV, spoilage bacteria and bacteria such as *E. coli* and *Salmonella* are killed within a few seconds. Spoilage yeast and the more sensitive types of spore-forming fungi are also killed at this level after a contact time of a few minutes or less. Unfortunately, resistant spore-forming decay pathogens and human parasites, such as *Cryptosporidium*, are highly tolerant of chlorine, bromine, iodine and other weak oxidizers or metabolic poisons used for water disinfection. If hazard analysis identifies the potential for the presence of these parasites, treatment with peroxyacetic acid or ozonation of source water would be a suitable control measure. A combination of ORP and chemical indicator monitoring for ozone concentrations would be necessary.

A practical benefit in postharvest uses (such as transport flumes, bin-drenchers, cooling flumes, hydrocoolers, water-spray vacuum cooling, ice production, and ice injection) is that the measured ORP values accurately define the antimicrobial potential of the water for free-floating microbes. More conventional systems of measuring parts per million (ppm) with titration kits or paper test strips can give the same information but these must be combined with a measurement of water pH and reference to a table of hypochlorous acid (HOCl) availability. The water pH becomes an essential variable since the color-based test kits and paper strips detect hypochlorous acid and hypochlorite ion equally. Recent research in commercial and model postharvest water systems has shown that, if necessary, ORP limits can be relied on to determine microbial kill potential across a broad range of water quality.

It is important to point out that monitoring the build up of inorganic and organic particles remains important to prevent the excessive application of chlorine or other disinfectants to maintain a constant ORP set point. This makes sense from a cost, sensory quality, safety, and environmental responsibility perspective.

Disadvantages of ORP Systems

Potential disadvantages of ORP-based systems are largely operational issues related to the routine of equipment maintenance, calibration, and crosschecking of fixed position sensors. **In practical terms, always have a back-up system of calibrated hand-held ORP probes and standard ppm kits.** Sensors become fouled and need periodic cleaning and calibration. ORP probes may become temporarily saturated by over-injection of disinfectant. It can take several minutes or longer for the sensor to come back to equilibrium with the surrounding water, which can limit the response time.

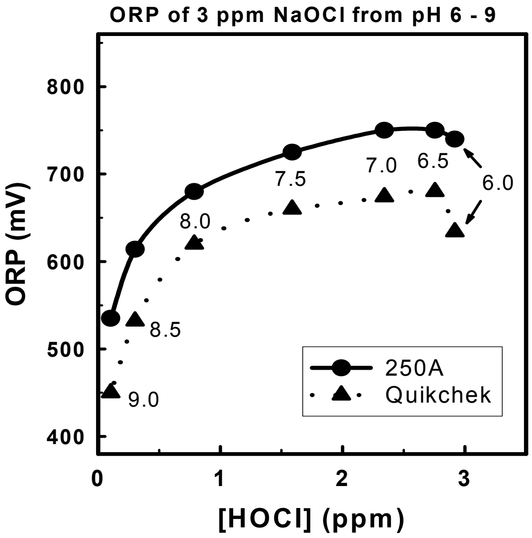
It is important to use ORP as a “window” of operation rather than a fixed point. Sensors rarely establish a fixed point in a real system. The ‘bounce” observed in the sensor readout may be as much as 25 mV, especially in hand held units, depending on whether the probe is stationary or in movement. The size of the sensing surface will also influence the fluctuations in readings. Better sensors have a larger detection area. The best approach is to standardize a uniform method for taking measurements and set thresholds for a window of operation that achieves the microbial reduction objectives appropriate for the operation.

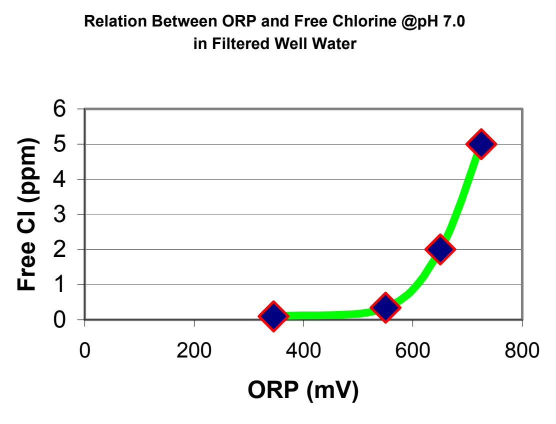
ORP and Ozone

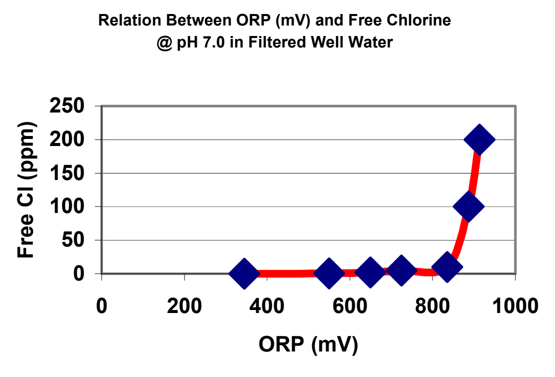
In a clean water system, using ORP to measure the dissolved ozone status works well. In our experience, however, the strong oxidizing power of ozone in complex (even moderate turbidity) systems can result in ORP values far below expected and even negative (reducing) values. In general, monitoring ozone with ORP at the generator source works well but measuring wash water becomes unreliable. Ozone detection kits are available and work well at the limit of approved concentrations for produce cooling and washing operations

ORP, pH, and ppm

The routine measurement of ORP in millivolts is not a linear relation at typical use rates in the produce industry. In general, a ten-fold increase in total or free chlorine concentrations will not result in a corresponding proportional increase in millivolts. This is predominantly a familiarity and comfort issue rather than one that impacts safety standards. For clean water, 3 to 5 ppm free chlorine will provide more than adequate microbial control for free floating bacteria in a very short contact time. This water quality will likely result in measurements of 650-700 mV ORP if the water pH is 6.5 to 7. Lowering the pH to 6.0 will raise the ORP as more hypochlorous acid becomes available. Raising the pH to 8.0 will lower the ORP value as more hypochlorite ion is present. Maintaining constant pH but adding more chlorine will raise the ORP to a plateau of 900 to 950 mV, generally around 25 ppm free chlorine. Doubling the free chlorine will not result in a sizeable gain in ORP and may result in undesirable disinfection-by-products, product damage, and flavor tainting. Excessive chlorination, especially at pH below 6.8, will often create an uncomfortable and potentially unhealthy environment for workers. For most postharvest systems, it is unnecessary to operate above 800 mV, a set point used in primary wash and cooling systems where high concentrations of inorganic and organic matter, or harvest and processing wound exudates are released to the water.







Summary of Results from Various Lab Simulation and Commercial Hydrocooler Survey Studies

Pathogen/Indicator	Survival at ORP (mV)		
	< 485	550 < x < 620	> 665
E. coli O157:H7	> 300 s	< 60 s	< 10 s
Salmonella spp.	>300 s	> 300 s	< 20 s
L. monocytogenes	>300 s	> 300 s	< 20 s
Thermotolerant coliform	> 48h	> 48h	< 30 s

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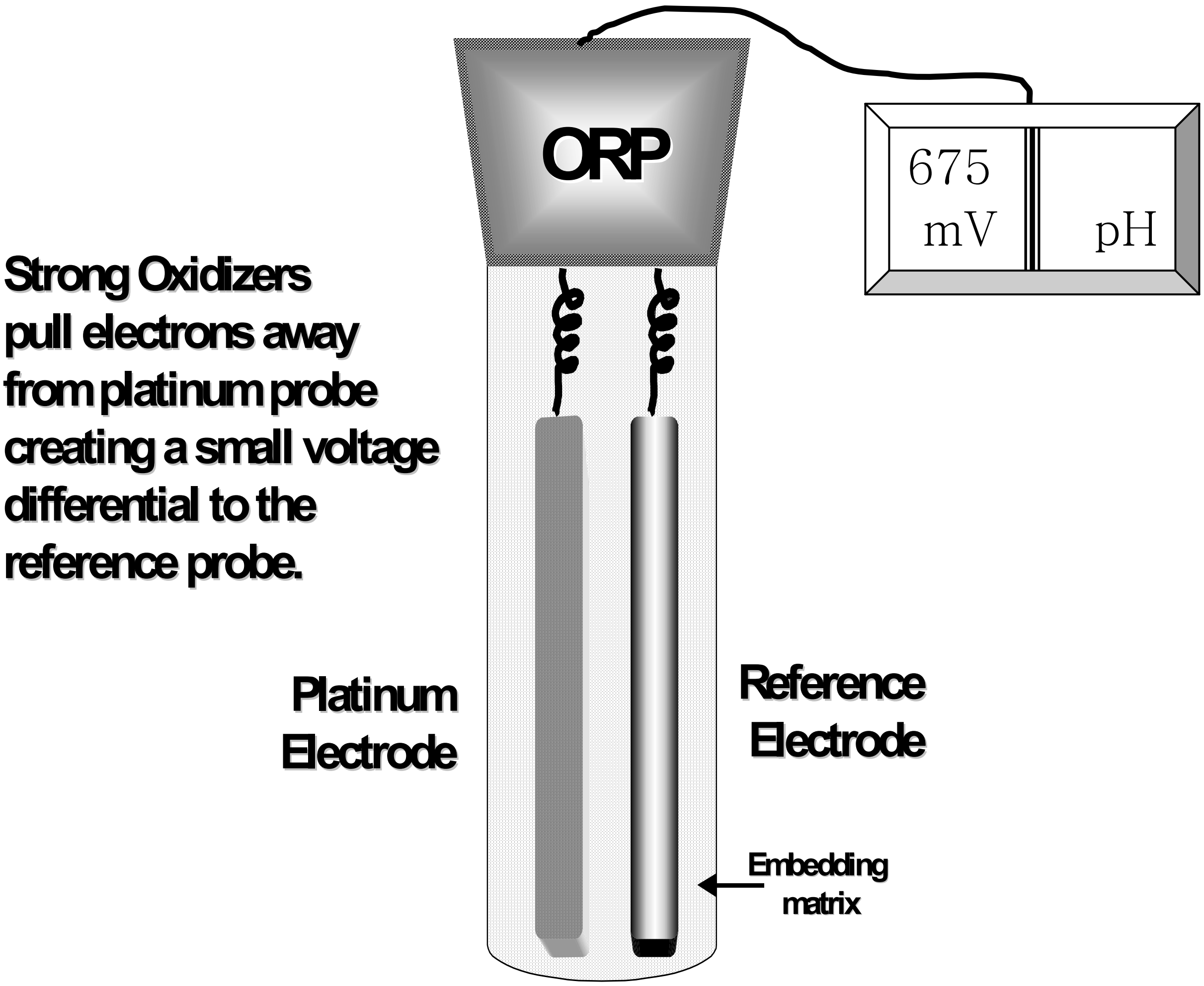
CAUTION: Recent evidence from USDA/ARS strongly suggests that citric acid may interfere with the lethal action of hypochlorous acid at levels likely to result in ORP ≤ 650-700 mV. Consider using inorganic food grade acids (ex. muriatic or phosphoric)



Strong Oxidizers pull electrons away from platinum probe creating a small voltage differential to the reference probe.