GEO
Guyana Economic Opportunities

Wash Water Sanitation: Recommendations for the NGMC Packinghouse

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Preface

This publication is part of a series of technical bulletins which seek to provide specific recommendations for the improvement of postharvesting and market preparation for selected non-traditional agricultural products. The intended audience for this series is primarily extension agents.

Initial market assessments in current export markets and visits with producers and exporters in Guyana have shown the quality of fresh produce currently exported is uneven and in some instance very poor. Stages all along the export chain from harvest and pre-harvest to transportation and final export are all in need of improvement. Pre-harvest practices, sanitation at the packinghouse, packaging, bacterial and fungal problems, and transportation were all identified as areas where improvement could benefit the quality and increase the shelf life of Guyana's fresh produce exports. This technical bulletin addresses these issues specific for wash water sanitation at the New Guyana Marketing Corporation Packinghouse. This report includes information on Chlorine sources and the chemistry of chlorination. Specific details are provided on the washing process covering length of product exposure, water temperature depth of submergence and organic matter. Chlorine monitoring devises, water pH regulations and measuring devices, surfactants are also addressed.

The undertaking of these market surveys is a joint effort of the Ministry of Fisheries, Crops and Livestock; Go-Invest, the New Guyana Marketing Corporation (NGMC) and the National Agricultural Research Institute to improve quality, increase production and promote exports. As a team, the four agencies are working on the problems, limitations, and constraints identified in initial reconnaissance surveys, from production and postharvest handling problems, to packaging and transportation, to final market access.

Introduction

Deterioration and postharvest decay are widespread problems affecting all fruits and vegetables in Guyana. Postharvest losses totaling more than 50% have been reported for some commodities. Product bruising injury, inadequate postharvest sanitation practices, and lack of temperature control are all factors contributing to high amounts of postharvest losses. Reducing mechanical damage during handling and packing greatly decreases the likelihood of postharvest decay because many disease-causing organisms must enter through wounds. The probability of a pathogen entering the produce increases with the size of the opening, including the stem scar area. However, even tiny natural openings (such as stomata and lenticels) can serve as entrances for disease organisms. Lowering the temperature of the product also slows postharvest disease development.

Proper sanitation practices at the NGMC packinghouse will help to reduce the amount of postharvest deterioration and decay. Both Barbados and Antigua require fresh produce imports into their countries be washed at the packinghouse. In some cases, diseased product is mixed in with the healthy items in the same wash water tank. This results in contamination of the wash water with bacteria and/or fungal spores which can infect healthy fruit or enter injured sites on the product surface and cause decay.

Chlorination of the wash water is one of the few chemical options available to help manage postharvest bacterial and fungal diseases. It is a commonly used postharvest practice worldwide. When used in combination with other proper postharvest handling practices, chlorination is effective and relatively inexpensive. However, chlorine treatment rarely eliminates all pathogens. Some microbial spores may remain on the product surface to develop later should the conditions permit. Chlorine kills microorganisms upon contact but is effective only on exposed pathogens such as those suspended in water or those on the surface of the product. Chlorine does not kill pathogens below the skin because it is not translocated systemically. Therefore, produce exposed to pathogens after treatment is susceptible to reinfection. However, utilization of the proper amount of chlorine in the wash water along with maintenance of the water pH at the appropriate level will significantly reduce problems with postharvest decay. Furthermore, chlorine leaves no residues and there are no restrictions on its use for export.

Chlorine Sources

Chlorine may be obtained from one of three different forms for use as a wash water sanitizing agent. These include a liquid solution of sodium hypochlorite ($NaOCl$), a soluble granular form of calcium hypochlorite [$Ca(OCl)_2$], and pressurized chlorine gas (Cl_2). The water source used for sanitizing produce should be clean well or municipal water. Water from streams or ponds should never be used.

Sodium Hypochlorite (NaOCl)

NaOCl is the most common form of chlorine used for wash water sanitation in small packinghouse operations. The typical source of NaOCl is standard household bleach, which is widely available in supermarkets and general purpose stores throughout Guyana. NaOCl is typically bottled in 1 gallon containers. Larger volumes may be special ordered. In addition, 12.75 % or 15 % sodium hypochlorite solutions may be specially ordered. Household bleach [i.e. Marvex, (Figure 1)] has a concentration of 5.25% sodium hypochlorite. This is equivalent to 52,500 ppm hypochlorite, which will be almost totally converted to hypochlorous acid at a pH of 6.5. Appropriate dilutions of this stock solution are required to make a 150 ppm hypochlorous acid concentration. Long term storage of NaOCl is not recommended as it slowly degrades with time.

Figure 1. Household bleach (5.25% NaOCl) is sold under various trade names.

The price for a 1 gallon container of household bleach (5.25 % NaOCl) differs between brands and supermarkets, but can be obtained for $2. Therefore, the estimated cost to sanitize a 500 gallon wash tank with 150 ppm hypochlorous acid (which requires 1.5 gallons of bleach) is $3.

Calcium Hypochlorite [$Ca(OCl)_2$]

$Ca(OCl)_2$ is the most common form of chlorine used for wash water sanitation in large packinghouse operations. It is available in the form of either a granulated powder or large tablets. Most commercial formulations are 65 percent $Ca(OCl)_2$, with the balance consisting of stabilizers and inert materials. This is equivalent to 650,000 ppm hypochlorite, which will be almost totally converted to hypochlorous acid at a pH of 6.5. Appropriate dilutions of this stock solution are required to make a 150 ppm concentration. Calcium hypochlorite is relatively stable and may be stored for extended periods if it is kept dry. However, it may lose its strength under high humidity storage conditions after the container has been open. $Ca(OCl)_2$ is difficult to dissolve completely in water. Adding granulated calcium hypochlorite directly to the water often results in undissolved particles that adhere to the produce, causing undesirable bleaching and chlorine burns. Warming the water makes it easier to dissolve.

$Ca(OCl)_2$ can be ordered through several hardware stores in Georgetown, including Spads Inc. (phone: 225-4672). The average price for 50 lb (23 kg) is about $100. Therefore, the estimated cost to sanitize a 500 gallon wash tank with 150 ppm hypochlorous acid (which requires about 405 gm or 0.90 lb of 65% $Ca(OCl)_2$ powder) is $1.80.

Chlorine Gas (Cl_2)

Cl_2 is a very irritating, greenish-yellow gas with a strong, pungent odor. The usual source of Cl_2 is from high pressure industrial gas cylinders, which contain 150 lbs. net weight Cl_2 and typically have a purity of nearly 100%. There is no loss of chlorine activity with time and the cylinders remain at full strength regardless of how long they are stored. Chlorine in the gaseous form is a very potent disinfectant, although it is seldom used in this form. Sanitation is accomplished by adding the appropriate weight (volume) of Cl_2 gas through a metering valve into the water tank or overhead spray wash line. The Cl_2 gas mixes with the water to form hypochlorous acid. The correct amount of Cl_2 gas to add is based on the volume (weight) of the water in the wash tank. One gallon of water weighs 8.33 lbs., and in order to provide 150 ppm hypochlorous acid in 500 gallons of water, 0.625 lbs. of Cl_2 gas is required. The cost of a 150 lb cylinder with a high pressure regulator and flowmeter is about $250. Therefore, the estimated cost to sanitize a 500 gallon wash tank with 150 ppm hypochlorous acid is $1.04.

Due to the potential hazards of chlorine gas leakage and the relatively sophisticated mixing equipment required, the use of Cl_2 gas is usually appropriate for only large-scale operations. For example, the Guyana Water Authority disinfects the Georgetown municipal water supply using chlorine gas. Currently, the limited amount of chlorination required by the NGMC packinghouse and at other postharvest fruit and vegetable operations in Guyana makes the use of chlorine gas impractical and therefore it is not recommended.

Adding Chlorine to the Wash Water

Solutions of NaOCl or $Ca(OCl)_2$ can be added to the wash water in one of two methods; manually or at a continuous and measured rate using chemical injectors. Injector systems consist of a feed tank and an electrically operated pump with a variable output. Chlorine injectors should always be isolated from water supply lines with a properly functioning check valve to prevent backflow into the fresh water system. The water in the wash tank should be stirred after adding chlorine in order evenly distribute it throughout the tank. This can be done manually with a hand paddle for small wash tanks or automatically with a recirculating pump for large tanks.

Chemistry of Chlorination for Effective Sanitation

When NaOCl, $Ca(OCl)_2$, or chlorine gas is added to water, each will generate chlorine gas (Cl_2), hypochlorous acid (HOCl), and hypochlorite ions (OCl^-) in various proportions, depending on the pH of the solution. Chlorine gas volatilizes out of the solution, causing worker discomfort. The form desired for effective sanitation is HOCl. This form is a fast oxidizer and it acts as a strong biocide. The HOCl form is also referred to as free, active, or available chlorine. On the other hand, the OCl^- form is a mostly inactive and a slow oxidizer that has very limited sanitizing activity. In order for chlorine to have maximal strength, it must exist in the HOCl form. The chemical form in which chlorine exists depends on the pH of the water, as indicated below.

pH	HOCl	OCl^-
6.0	97%	3%
6.5	95%	5%
7.0	80%	20%
7.5	50%	50%
8.0	20%	80%

At a pH slightly above neutral (e.g. 7.5), about half of the chlorine will be in the HOCl form and the remaining half will be in the OCl^- form. At a neutral pH of 7.0, about 80% of the chlorine will be in the HOCl form. Solutions that are increasingly acidic will have a higher percentage of hypochlorous acid, but become more unstable and allow more of the chlorine to escape from the solution as a gas. To maximize the proportion of HOCl and hence the effectiveness of the solution, the pH should be kept at about 6.5. The pH should not be allowed to fall below 6.0 because Cl_2 gas is formed and liberated into the air, making working conditions uncomfortable. In addition, at pH values less than 6.0 the HOCl becomes very corrosive to any metal parts and equipment.

Water pH can be adjusted by adding the proper amount of acidifying agent or alkalinity agent to the wash water. If the water pH is above 7.0, it can be lowered by adding a small amount of vinegar (acetic acid) or citric acid. These acidifying agents are readily available in all Georgetown supermarkets. If the water pH is below 6.5, it can be raised by adding a small amount of lye (NaOH), also widely available from local hardware stores. The exact amount of material to add to the wash water tank depends on the initial water pH and the volume of the tank.

Recommended Chlorine Concentration

Decay-causing organisms are killed by minute concentrations of available chlorine. However, higher chlorine concentrations are required to offset changes caused by the accumulation of organic material during processing of large amounts of product. Therefore, it is recommended to maintain a free chlorine concentration of 150 parts per million (ppm) in the wash water for fresh fruit and vegetables. Chlorine concentrations below 50 ppm may not be strong enough to sanitize the surface of the product as organic matter accumulates in the water. On the other hand, free chlorine concentrations above 300 ppm may cause surface color discoloration and discomfort to packinghouse workers. The amount of NaOCl or $Ca(OCl)_2$ to add to the water to obtain a specified chlorine concentration depends on the wash tank volume and desired chlorine concentration. Table 1 shows the appropriate amounts of each source of chlorine to add to the wash tank to obtain concentrations of HOCl ranging from 25-150 ppm. For example, adding 2.4 pints of 5.25% sodium hypochlorite per 100 gallons of wash tank water will give a 150 ppm HOCl solution. (For smaller wash tanks, this is equivalent to adding 0.24 pints of 5.25% sodium hypochlorite per 10 gallons of water). Expressed in the metric system, this is equivalent to adding 3.0 liters of 5.25% sodium hypochlorite per 1000 liter wash tank water volume. (For smaller wash tanks, this is equivalent to adding 0.30 liters of 5.25% sodium hypochlorite per 100 liters of water).

Table 1. Amounts of 5.25 % NaOCl solution or 65 % $Ca(OCl)_2$ granules required to obtain a specified concentration of HOCl in 100 gallons of water at pH 6.6.

Approximate HOCl concentration (ppm) .	Pints of 5.25 % NaOCl solution per 100 gallons of water	Ounces of 65 % $Ca(OCl)_2$ granules per 100 gallons of water
25	0.4	0.5
50	0.8	1.0
75	1.2	1.5
100	1.6	2.0
125	2.0	2.5
150	2.4	3.0

Length of Product Exposure Time

The effectiveness of chlorination depends on the length of time the produce is exposed to the chlorine solution coupled with the sanitizing strength of the solution. The sanitizing strength of a solution can be quantified in terms of ppm free chlorine concentration and/or millivolts (mV) of oxidation-reduction potential (ORP). The higher the ORP, the quicker the microorganisms will be killed. A correlation exists between free chlorine concentration and mV of ORP, although the relationship is not linear. Free chlorine concentrations of 150 ppm will have > 650 mV of ORP. Free chlorine concentrations < 50 ppm generally have < 600 mV of ORP. Table 2 shows the relationship between ORP of the wash solution and kill time of *E. coli* bacteria. This assumes there is physical contact of the wash solution with the bacterial cells. If so, freely suspended bacteria exposed to wash solutions $\geq$ 650 mV of ORP will result in death of the bacteria after a few seconds or less. As the sanitizing strength of the wash solution diminishes, the length of pathogen exposure must be increased in order to achieve bacterial mortality. Ten seconds of bacterial exposure time is needed at 600 mV of ORP and 100 seconds at 550 mV to obtain mortality. When ORP levels fall below 550 mV, the wash solution is essentially ineffective in killing the bacteria since too long of an exposure time is needed.

In order to disinfect the wash water from decay-causing bacteria, it is recommended to expose the entire surface of the fruit or vegetable for at least several seconds in wash water containing 150 ppm free chlorine and at least 650 mV of ORP. However, exposure times of up to 30 seconds would better in order to ensure total product surface coverage with the sanitized wash water. On the other hand, prolonged exposure of more than several minutes to strong chlorine solutions (> 300 ppm) should be avoided, as it has been known to cause surface bleaching in some commodities.

Table 2. Relationship between wash water ORP and kill time of *E. coli* bacteria.

Wash Water ORP (mV)	Time Required to Kill *E.coli*
450	Infinite
500	1 Hour
550	100 Seconds
600	10 Seconds
650	< 1 Second

Water Temperature

The sanitizing effect of chlorine is greater at higher water temperatures. However, the wash tank water temperature can range between 60-80°F for effective sanitation of a 150 ppm chlorine solution. The temperature of municipal or well water in Guyana should fall within this range.

Use of cool water relative to the temperature of the produce can be problematic. When products are submerged in water of a lower temperature, the air inside the product contracts and water is drawn in through the stem scar or any openings in the tissue. If the water is contaminated with microorganisms they will also enter the product. Growth cracks, bruises, and damaged areas of the cuticle will permit the entrance of decay organisms. Water will not be drawn into the product if its temperature is higher than the pulp temperature of the product. Fruits and vegetables arriving at the NGMC packinghouse vary widely in temperature, depending on when it was harvested and whether it was exposed to sun or shade after harvest. Keeping harvested products in the shade is highly recommended to minimize an increase in pulp temperature. Ideally, it is recommended to heat the wash tank water temperature 10°F higher than the produce temperature. At the least, the water temperature should not be less than the pulp temperature of the product.

Depth of Submergence

The depth of product submergence inside the wash tank influences the infiltration rate of water into the product. Water infiltration increases with increasing depth of submergence. This is due to a greater water pressure exerted on the surface of the commodity with increasing depth. Significant water infiltration may occur through open areas of the skin if the product is kept submerged for several minutes at depths greater than 2.5 feet. It is recommended to keep the depth of product submergence at less than 2 feet when dumped into the wash tank. Following equilibration in the water, the products should be maintained as a single layer for the duration of their time in the wash tank.

Organic Matter

Chlorine has a strong affinity for soil particles and organic matter. Dumping dirty produce in the wash tank will reduce the free or active chlorine concentration much faster than adding relatively clean produce. The free chlorine concentration will decrease as organic matter and suspended solids (i.e. leaves, soil particles, debris) accumulate in the wash tank or overhead wash spray. This is the result of soil particles, dirt, debris, and the produce itself lowering the free chlorine concentration over time. Therefore, it is very important to keep the water as clean as possible throughout the washing process. This will reduce the chemical demand and improve the sanitizing effectiveness of the water. As free chlorine reacts with organic matter, it forms non-biocidal compounds known as combined chlorine, which are not effective as sanitizers. The sum of free and combined forms of chlorine equals total chlorine. However, measurement of the total chlorine concentration does not provide an accurate estimate of the sanitation potential of the wash water.

If the same wash water is being re-used for extended periods of time, vigilant monitoring of the free chlorine level in the water is advised. Checks and adjustments of the chlorine concentration should be made at least hourly, or with more frequency if the water is particularly dirty. Additional chlorination of the water will be necessary in order to maintain a 150 ppm chlorine concentration as dirt and organic matter accumulate. Extremely dirty produce (such as sweetpotatoes, yams, cassava, eddoe) should be washed with clean water before placement in the wash tank.

Chlorine Monitoring Devices

Several monitoring devices are available for quantifying the chlorine concentration in the wash water. They may be test strips, test kits, or meters. All of these devices are capable of measuring either free or total chlorine. However, it is the free form that is active as a sanitizing agent and this is the form that should be measured. Measurement of total chlorine concentration does not give an accurate assessment of sanitizing potential. Total chlorine consists of the sum of the free form plus the combined bound) form. Therefore, it may be possible to have a high total chlorine concentration with a low level of free chlorine. It should be emphasized that many conventional chlorine test strips or colorimetric test kits do not distinguish between free and total chlorine. In addition, it must be remembered that the free chlorine value alone does not give an indication of fungicidal activity, since the pH of the water determines the form (i.e. HOCl or OCl) in which the free chlorine will exist. The pH of the water needs to be < 7.0 for the free chlorine to exist predominantly in the desired HOCl form.

Test Strips

Figure 2. Test strips for measuring free chlorine concentration.

Test strips are small pieces of elongated paper impregnated with the appropriate chemicals to serve as indicators of free chlorine concentration (Figure 2). They are extremely simple to use. The procedure consists of submerging the indicator end of the test strip in the wash water solution for 1 second followed by air drying for 30 to 60 seconds. The indicator end of the test strip will change color according to the free chlorine concentration. A color guide for comparison comes with the test strips to estimate the chlorine concentration.

Sources and Costs

International Ripening Company
1185 Pineridge Road
Norfolk, VA 23502
Tel: 757-855-3094
Fax: 757-855-4155

The cost for a pack of 50 disposable single-use free chlorine test strips (item # 2006036) is $13.95. Therefore, the cost per analyses is approximately $0.28.

Colorimetric Test Kits

Colorimetric test kits are liquid solutions of an indicator dye which is added to the wash water for visual estimation of the free chlorine concentration. The specific indicator dye used for quantifying free chlorine is N,N-diethyl-p-phenylenediamine (DPD).

Colorimetric test kits have the limitation of only being able to measure chlorine in the range of 1-10 ppm, so a dilution of the wash water must be made in order to estimate higher chlorine concentrations. Specifically, a 1:20 dilution of the wash water (1 part wash water to 19 parts bottled drinking water) is needed to free chlorine concentrations in the range of 0 to 200 ppm. The testing procedure involves filling a test cell (test tube) with the 1:20 dilution of wash water to a pre-marked level on the test cell. The wash water should be free of sediment or turbidity. If it is too cloudy, fill a small bottle with wash water and let it stand for a few minutes to allow the particulate matter to settle to the bottom prior to dilution. A specified amount of indicator dye (DPD) is added to the test cell filled with the 1:20 dilution of wash water solution. After mixing, the color of the test cell is matched with the printed color card standards of known free chlorine concentration (Figure 3). This value is multiplied by 20 to determine the amount of free chlorine in the undiluted wash water. For example, if a reading of 5 was obtained from the diluted solution, the undiluted wash water will have 100 ppm free chlorine. When free chlorine is measured using a DPD test kit, it is the total of hypochlorous acid and hypochlorite ion that are measured. As previously noted, it must be remembered this free chlorine value by itself does not give an indication of fungicidal activity, since the pH of the water determines the form (i.e. HOCl or OCl) in which the free chlorine will exist.

Figure 3. Colorimetric test kit for determining free chlorine concentration.

Sources and Costs

The following companies offer colorimetric test kits:

Taylor Technologies
31 Loveton Circle
Sparks, Maryland (USA) 21152
Phone: 410-472-4340
Fax: 419-771-4291

The cost for Kit # K-1289 is $83 (plus shipping). This kit will detect free chlorine in the range of 1-10 ppm. A dilution of 1 part wash water to 20 parts total water should be made. This will allow the kit to determine free chlorine concentrations in the range of 20 to 200 ppm. A total of 288 samples can be tested per kit. Therefore, the cost per analyses is approximately $0.30.

Meters

Several types of instruments or meters are available to quantify the disinfection potential of water. The simplest types are small hand-held meters with a platinum electrode which measures the oxidation-reduction potential (ORP) of the water (Figure 4). Measurement is made by simply dipping the electrode in the wash water. A digital display shows the OPR reading in millivolts (mV), which is a measure of the sanitizing activity and effectiveness of the water. A stable reading is normally reached within a minute or less. The ORP reading is influenced by the free chlorine concentration.

Figure 4. Portable meter for measuring ORP of water.

Oxidation-reduction potential is a reliable and precise method of measuring a solution's sanitizing ability. When measuring ORP, we are measuring the oxidation potential of the solution. ORP has proven to be a reliable method of measuring water disinfection and provides the operator with a single value of measurement regardless of which commodity, washing system, or sanitizer is used. In chlorinated wash water, oxidation occurs when HOCl pulls electrons from microorganisms (and organic matter in general), causing a disruption in cellular integrity. The transfer of electrons creates an electrical potential in the wash water solution that is measured in mV. Testing has shown that most microorganisms are killed almost immediately in solutions where the ORP level is above 650 mV. The background mV reading of potable water without chlorine added is typically in the range of 190-230 mV.

The small portable ORP testers typically have a useable life of less than 1 year. Longer lasting portable testers are available, but at a significantly higher cost with little increase in accuracy or resolution. Larger commercial instruments are also available to measure the water ORP. They are relatively expensive stationary units typically mounted near the wash water tank for continuous and very accurate monitoring of ORP. These instruments may be used solely as monitoring devices to obtain the ORP reading, followed by manually dosing in the appropriate amount of chlorine. However, more sophisticated monitoring instruments are used to automatically inject the appropriate amount of chlorine and maintain the wash water at a set ORP reading. These systems also provide a continuous record of the ORP level for automated record keeping. They allow for efficient use of chlorine, minimize chemical waste, and save time and labor. They may also satisfy the food safety guidelines of the buyer.

All ORP meters and electrodes need to be kept moist and require periodic cleaning and calibration with standards of known value to ensure reliability and accuracy. A simple cleaning procedure involves dipping the electrode tip in dilute (1:100) acidic solution for two minutes and rinsing with clean water. Then the electrode is dipped in a known standard mV solution to verify accuracy of the reading. Some ORP meters allow calibration adjustment, but most do not. Inaccurate ORP readings are usually a result of electrode contamination, which may be corrected by cleaning, or from depletion of the platinum sensor, which requires replacement of the electrode. Some ORP meters allow slight slope offset adjustments to accommodate these errors. Unlike a pH measurement that follows a logarithmic curve and requires more calibration adjustments, ORP follows a linear relationship and does not need instrument adjustment as much as it needs electrode maintenance.

Sources and Costs

Hand-held testers:

Hanna Instruments
584 Park East Drive
Woonsocket, Rhode Island 02895 (USA)
Phone: 401-765-7500
Fax: 401-765-7575
Model: HI 98201
Cost: $84.50

This portable ORP tester has a digital readout display of ± 999 mV. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 months and 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

Model: HI 98150
Cost: $420

This portable tester has the capability of measuring both ORP and pH. However, it is necessary to switch probes in order to accomplish this. Probe lifespan is several years. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 months and 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

Hach Company
P.O. Box 389
Loveland, Colorado (USA) 80539
Phone: 970-669-3050
Fax: 970-461-3939
Item # : 2727300 (Pocket Pal ORP tester)
Cost: $70.00

This portable ORP tester is made by Hanna Instruments, but re-labeled under the Hach brand name. It has a digital readout display of ± 999 mV. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 months and 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

International Ripening Company
1185 Pineridge Road
Norfolk, Virginia (USA) 23502
Tel: 757-855-3094
Fax: 757-855-4155
Item # : 2009935
Cost: $84.50

This portable ORP tester is made by Hanna Instruments, but re-sold by International Ripening Co. It has a digital readout display of ± 999 mV. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 months and 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

Stationary meters:

Pulse Instruments
16117 Covello Street
Van Nuys, CA 91406
Phone: 818-909-0800
Fax: 818-909-7057
Model 12E-ORP (with electrode)
Cost: $320

Figure 5. Panel-mounted stationary ORP meter.

This company makes a panel-mounted stationary meter with electrode for manual monitoring of ORP levels in the wash water (Figure 5). It is more durable than the small portable ORP meter, but requires a sub-sample of the wash water to be brought to the site of the stationary meter where it is measured. A weatherproof wall-mounted version of this meter (Model 12SE-ORP) with electrode is available for $570.

Systems:

Several companies make semi- and/or fully automated chlorine control and monitoring systems for larger volume packinghouses that accurately control and record the chlorine levels and water pH in dump tanks, flumes, and/or hydrocoolers.

Pulse Instruments
16117 Covello Street
Van Nuys, CA 91406
Phone: 818-909-0800
Fax: 818-909-7057
Model: System 2
Cost: $2000

This is a relatively inexpensive automated chlorine and water pH control system. The system has two digital displays that continually show ORP levels and pH of the water (Figure 6). Control set points are programmed into the unit at the desired pH and sanitation levels. Chemical metering pumps will automatically add citric acid to adjust the pH, and chlorine to adjust the ORP level.

These systems are designed for large-scale packinghouses and would not be necessary in the current NGMC packinghouse. However, as export volume expands and packinghouse renovations are made, or if larger scale packinghouses are built in the future then these systems may be economically justified.

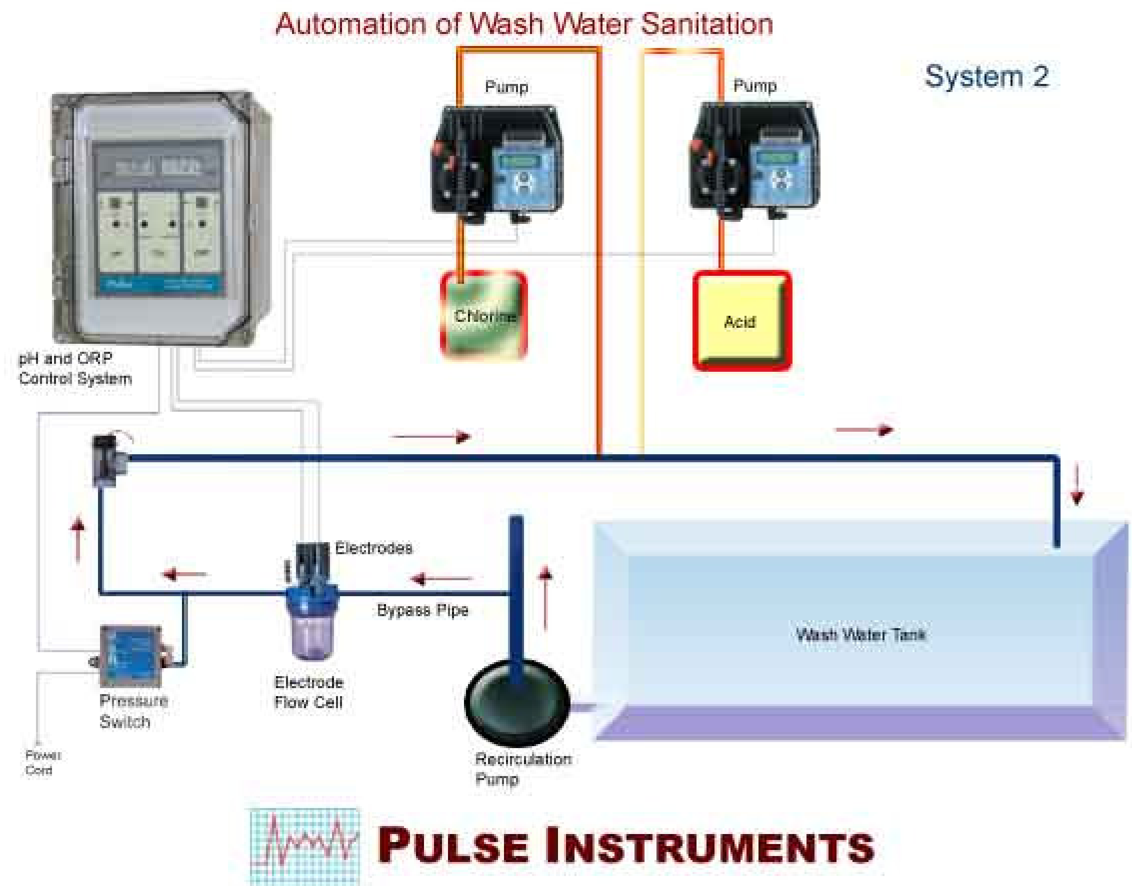

Figure 6. System 2 automated chlorine and water pH control unit.

Brogdex Company
1441 W. Second Ave.
Pomona, California (USA) 91766
Tel: 909-622-1021
Fax: 909-629-4564
Model: BF2000
Cost: $8000

This is an expensive automated chlorine control and monitoring system. The system has two digital displays that continually show pH and ORP levels in the water (Figure 7). Control set points are programmed into the unit at the desired pH and sanitation levels. Chemical metering pumps will automatically add an acidifying agent to adjust the pH, and chlorine to adjust the ORP level. Continuous strip chart recorders maintain a permanent history of the chemical levels in the water system.

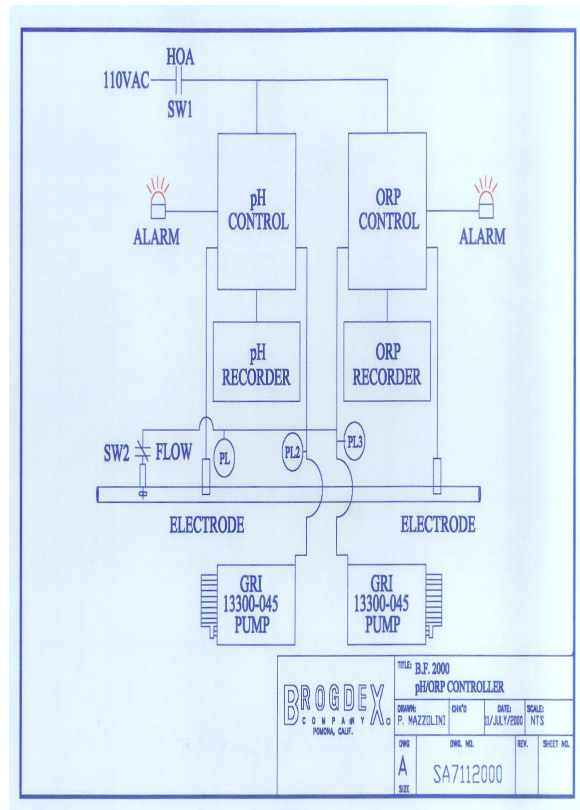

Figure 7. Automated chlorine control and monitoring system that accurately controls and records the chlorine levels in packinghouse wash water.

Another manufacturer of expensive automated chlorination and pH control systems for large packinghouses is:

U.S. Filter, Stranco Products
595 Industrial Drive
Bradley, Illinois (USA) 60915
Tel: 815-932-8154
Fax: 815-932-0674

Water pH Regulation

The pH of a solution is a measure of its acidity or alkalinity. It is typically expressed using a scale of 1 to 14. Solutions with pH numbers less than 7.0 are acid and numbers greater than 7.0 are alkaline. The further away the number is from 7.0, the greater its acidity (< 7) or alkalinity (>7). A solution that is neutral (neither acid nor alkaline) has a pH of 7.0.

The pH of the water significantly influences the effectiveness of chlorine as a sanitizing agent. It is recommended to maintain a wash water pH of 6.5. This pH will maximize the sanitation effect of chlorine and minimize its corrosiveness to metal parts.

pH Measuring Devices

Wash water pH should be checked frequently to ensure it is maintained at the desired level. The pH of municipal and well water sources may vary from day to day, and addition of NaOCl or $CaOCl_2$ to the wash water will increase the pH. The pH of the municipal wash water (provided by the Guyana Water Authority) at the NGMC packinghouse was measured multiple times (August-September, 2002) and ranged from 6.6 to 6.7. After addition of 150 ppm chlorine it increased to about 7.4.

Several measuring devices are available for determining the pH of the wash water. They include test strips, test kits, and meters. The water pH should be checked at the same time as the chlorine concentration is monitored.

Test Strips

Test strips are small pieces of elongated paper impregnated with the appropriate chemicals to serve as indicators of wash water pH (Figure 8). Sometimes these test strips are referred to as litmus paper. Test strips are extremely simple to use. The procedure consists of submerging the indicator end of the test strip in the wash water solution for about 1 minute followed by air drying for 30 to 60 seconds. The indicator end of the test strip will change color according to the pH of the water. A color guide for comparison comes with the test strips to estimate the water pH.

Figure 8. Test strips used for determining water pH.

Sources and Costs

International Ripening Company
1185 Pineridge Road
Norfolk, VA 23502
Tel: 757-855-3094
Fax: 757-855-4155
Item # : 2006046
Cost : $13.95

A total of 50 disposable single-use pH test strips are included in a pack. Therefore, the cost per analyses is approximately $0.28.

There are several other sources of pH test strips, including:

LaMotte Co.
802 Washington Avenue
Chestertown, MD 21620
Tel: 410-778-3100
Fax: 410-778-6394

The cost for a pack of 50 disposable single-use pH test strips (item # 2974) is $6.95. Therefore, the cost per analyses is approximately $0.14.

Sigma-Aldrich Corp.
P.O. Box 2060
Milwaukee, Wisconsin 53201
Tel: 414-273-3850
Fax: 414-273-4979

The cost for a pack of 100 disposable single-use pH test strips (item # Z26,478-4) is $10.05. Therefore, the cost per analyses is approximately $0.10.

Colorimetric Test Kits

Colorimetric test kits are liquid solutions of indicator dyes to which wash water is added for visual estimation of the pH. They typically utilize bromthymol blue as the indicator dye for pH measurement in the range of 6.0-7.4, usually in 0.2 unit increments. The pH is determined by comparing the color of the wash water solution with printed color card standards which are provided in the test kit.

The testing procedure involves filling a test cell (test tube) with wash water to a marked level. The wash water should be free of sediment or turbidity. If it is too cloudy, fill a small bottle with wash water and let it stand for a few minutes to allow the particulate matter to settle to the bottom. A specified amount of indicator dye is added to the test cell filled with the wash water solution. After mixing, the color of the test cell is matched with the printed color card standards of known pH.

Sources and Costs

The following companies offer colorimetric test kits:

Taylor Technologies
31 Loveton Circle
Sparks, Maryland (USA) 21152
Phone: 410-472-4340
Fax: 419-771-4291

The cost for Kit # K-1285-4 is $44 (plus shipping). This kit will measure pH in the range of 6.0-7.4 in increments of 0.2 units. A total of 88 samples can be tested per kit. Therefore, the cost per analyses is approximately $0.50.

Meters

Several types of instruments or meters are available to measure the pH of the water. The simplest types are small hand-held meters with a digital display indicating the pH (Figure 9). More expensive stationary laboratory instruments are also available. The meters have a probe which is submerged in the water and measures the hydrogen ion activity (H^+). The H^+ activity is directly correlated to the solution pH. A stable pH reading is obtained usually within a minute of submergence.

Figure 9. Portable hand-held digital pH meter.

Sources and Costs

The following companies offer hand-held pH meters:

Hanna Instruments
584 Park East Drive
Woonsocket, Rhode Island 02895
Phone: 401-765-7500
Fax: 401-765-7575
Item #: HI 98127
Cost : $70.00

This portable pH meter has a digital readout display of 0 to 14 ±0.1. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 to 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

International Ripening Company
1185 Pineridge Road
Norfolk, Virginia (USA) 23502
Tel: 757-855-3094
Fax: 757-855-4155
Item # : 2006091
Cost: $59.00

This portable pH tester is made by Hanna Instruments, but re-sold by International Ripening Co. It has a digital readout display of 0 to 14 pH units ± 0.1 units. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 months and 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

Cole-Parmer
625 East Bunker Court
Vernon Hills, Illinois (USA) 60061
Phone: 847-549-7600
Fax: 847-247-2929
Item # : 35624-22
Cost : $74.00

This portable pH meter has a digital readout display of 0 to 14 ±0.1. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 to 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

Hach Company
P.O. Box 389
Loveland, Colorado (USA) 80539
Phone: 970-669-3050
Fax: 970-461-3939
Item # : 44350-01
Cost : $42.00

This portable pH meter (Pocket-Pal) has a digital readout display of 0 to 14 ±0.1. Numerous measurements can be taken daily, and the average effective life of the tester varies between 6 to 12 months. Therefore, the approximate cost per analyses is potentially less than $0.01.

The distributor for Hach products in Guyana is:

Swansea Industrial Associates
166 Waterloo Street
North Cummingsburg
Georgetown
Tel: 225-8845
Fax: 225-8843

Surfactants

A small amount of detergent added to the wash water will lower its surface tension and increase the ability of chlorine to completely cover the surface of the commodity. It will also provide more effective pathogen control as movement of chlorine into the small openings on the product surface is improved. The addition of 1 tablespoon of dishwater or laundry detergent per 10 gallons of water is usually adequate. However, the amount of detergent to add may need to be reduced if too much foaming occurs.

Chlorine Effectiveness Influenced by Type of Microorganism

Microorganism species differ in their susceptibility to chlorine. In addition, the cellular developmental stage of the microorganism influences the effectiveness of chlorine. Actively growing cells in the vegetative state are significantly more susceptible to chlorine. Dormant microorganisms in the spore stage are the most resistant to chlorine.

In general, a higher wash water ORP is needed to kill fungal pathogens compared to *E. coli*, *Erwinia*, and other bacterial spoilage organisms. *Botrytis*, *Rhizopus*, yeasts, and molds typically require ≥ 750 mV to be killed, while bacterial soft rots (i.e. *Erwinia*) require ≥ 650 mV. Therefore, it is recommended to maintain a 150 ppm free chlorine concentration in the wash water coupled with at least 750 mV of ORP to obtain effective control of a wide range of spoilage pathogens. However, it should be noted that wash water chlorination is not capable of completely eliminating all spoilage pathogens. Some decay-causing microorganisms will be present in the resistant spore form and others will be located in a protected microenvironment area hidden from the sanitized water.

General Packinghouse Sanitation

The wash water is not the only area of the packinghouse that needs to be kept properly sanitized. The inside of the building and the surrounding outside area also needs to be kept clean and free of decay-spreading inoculum. Rotting produce should not be brought into the building nor allowed to accumulate in the vicinity of the packinghouse. Unmarketable culled product should be removed from the packinghouse immediately.

Pathogens brought into the packinghouse along with the produce will quickly contaminate all working surfaces.

Disease-causing organisms may remain viable for many weeks on surfaces such as wash tank walls, brushes, drying tables, conveyors, and storage areas. All produce handling equipment and wash tanks should be thoroughly cleaned at the end of each day to remove dirt, debris, and pieces of decayed produce. The wash tanks and drying tables should be disinfected daily with a strong chlorine solution (i.e. 500 ppm).

Proper wash water chlorination and pH control, coupled with good packinghouse sanitation practices will help to minimize postharvest decay of Guyanese fruits and vegetables. This will result in a higher quality product with a longer shelf life. Ultimately, this should be beneficial in helping growers and marketers obtain a stronger market position.

ANNEX I

PUBLICATIONS IN THE POSTHARVEST HANDLING TECHNICAL BULLETIN SERIES

PH Bulletin No. 1	Pineapple: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 2	Plantain: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 3	Mango: Postharvest Care and Market Preparation, November 2002.
PH Bulletin No. 4	Bunch Covers for Improving Plantain and Banana Peel Quality, November 2002.
PH Bulletin No. 5	Hot Water Treatment for Reducing Anthracnose Decay of Mangoes, November 2002.

PLANNED PUBLICATIONS - 2003

Cassava: Postharvest Care and Market Preparation.

Eggplant (Boulanger): Postharvest Care and Market Preparation.

Papaya: Postharvest Care and Market Preparation.

Sweet Potato: Postharvest Care and Market Preparation.

Wash Water Sanitation: Recommendations for the NGMC Packing House.

Watermelon: Postharvest Care and Market Preparation.

Peppers: Postharvest Care and Market Preparation.

Yam: Postharvest Care and Market Preparation.

Okra: Postharvest Care and Market Preparation.

Tomato: Postharvest Care and Market Preparation.

Orange: Postharvest Care and Market Preparation.