Fruit Washing & Sanitation
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Disclaimer

Whilst every effort is made to ensure that the information contained in this Guideline is accurate, the IFU cannot accept responsibility for errors.
General Principles

1) Handling and Transportation Practices

Fruits should be correctly handled from the moment they are collected in the field all the way down to the intermediate storage/ripening warehouses and the final processing facility in order to preserve fruit quality and integrity.

Contact with soil should be avoided as much as possible to reduce bacteriological contamination as well as contamination with mud or sand.

The type of container and transportation media utilized to convey fruit to the processing site is of great importance for the final quality of the juice processed.

From the smallest to the largest, the container utilized can vary from:

<table>
<thead>
<tr>
<th>Type of container</th>
<th>Example</th>
<th>Product weight in kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lugs or crates (used for fresh strawberries, berries, grapes)</td>
<td><img src="Lugs_or_crate.png" alt="Image" /></td>
<td>20</td>
</tr>
<tr>
<td>Bins (used for apples, pears, kiwis, bananas, mangos)</td>
<td><img src="Bins.png" alt="Image" /></td>
<td>400-600</td>
</tr>
<tr>
<td>Trucks, side or back tipping (used for apples, oranges, etc,)</td>
<td><img src="Trucks.png" alt="Image" /></td>
<td>up to 30.000</td>
</tr>
</tbody>
</table>

In choosing the correct type of container, the following principles should be noted:

- Pressure exerted on the bottom layers of fruit (the deeper the container, the higher the pressure).
- Aeration of the fruit during transport / storage or ripening (good aeration minimizes fruit spoilage).
- Ability to draining of juice or water from the container.
- Ease of sanitization.
- Material of construction and potential for releasing foreign material into the line (such as pieces of wood).
- Investing in identical containers allows to install an automatic container dumping system reducing labour.

2) Reception, Storing, Washing, and Sorting Practices

**Reception**

Fruit reception varies, depending from the type of container utilized and the reception technique: dry or wet reception and transport.

Crates and bins can be dumped utilizing different technologies depending on the capacity of the line and level of automatization required.

- Crates can be tilted by hand or with an automatic crates tilter.
- Bins are dumped with one of the following techniques:
  - Tilting forklift
  - Semi-automatic single bin tipper
  - Fully automatic bin tipping system with bins de piling and piling stations
- Trucks can be back or side tilters.

*Example of manual crates tilting station*
Example of semi-automatic single bin tilting system

Example of automatic bins tilting system

Example of back tilting truck

Example of side tilting truck

Storing

The fruit delivered to the factory can be processed immediately, stored in ripening rooms until ripened or stored in bunkers / silos in case the feeding of the fruit from the field to the factory doesn’t match with the capacity requirement of the processing line. Typical cases of mismatches between external transport of the fruits and internal capacity of the line can arise, for instance, if the line is designed to work 24 h /day, 7 days/week while the trucks are not allowed to discharge at night or during the weekends.

In these cases, it is necessary to provide some storage capacity for the fruits.

In synthesis, the storage can be necessary for the following reasons:
- Mismatch between external transport schedule from field to factory and internal capacity needs of the line
- Ripening time under controlled atmosphere with temperature and ethanol control (typical of banana processing for instance).
- Necessity to mix different varieties of fruits into the process to meet acidity, color, taste or texture requirements (typical with apple processing).
- Necessity to separate different qualities of fruits to different final products (for instance puree, cloudy juice and clear juice concentrate in the case of apples)

Washing

Fruits dumped from containers should preferably enter a pool with forced circulation of water pushing the fruit forward. The water mass flow rate at this stage is normally calculated at a ratio of 4 to 5 times the mass flow rate of fruit. Air can be injected on the bottom of the flume to increase water turbulence and improve fruit floating. Fruit shape and ability to float in water are parameters to be considered. Should the fruit be heavy with respect to water or should it have the tendency to bridging (see carrots), then pools with goose-neck submerged elevator should be used for the transport in addition to the circulation of the water. Water is separated from the fruits at the end of the transportation phase and is then re circulated with a centrifugal pump. Within the water circuits filters can be installed to remove foreign matters such as leaves, rotten parts, etc. Additionally, a vertical holding tank can be added with the function of separating by decanting any sand.

While the initial water for fruit receiving can contain chemicals such as chlorine for fruit and water sanitization, the final fruit washing should be done with potable water. In the case where several subsequent circuits (water loops) are used for fruit transportation / washing, the water should move in counter current with respect to the product with the cleanest, potable water used for fruit washing and the dirtiest water used for first unloading. The water consumption can vary from 50 up to 250 liters per metric ton of fruits. A typical circuit for fruit receiving and washing will include:

- Fruit dumping system
- Optional: dry mechanical separation of stones / soil / debris
- Flume with water circulation for fruit transportation
- Roller conveyors with washing spray balls
- Water circulation and filtration systems

The water mass flow rate for fruit transportation is normally calculated at a ratio of 4 to 5 times the mass flow rate of fruit.

The water consumption for fruit washing can vary from 50 up to 250 liters per metric ton of fruits.
Scheme of the basic fruit washing circuit

Roller conveyor detail with rollers conveying fruit forward whilst rotating it under a water jet
3) Water

Water used for the final washing of fruit should be of drinking water quality. This type of water is defined by the WHO Guidelines for drinking-water quality (fourth edition) as well as Council Directive 98/83/EC on the quality of water intended for human consumption.

When more than one loop of flume water is used for receiving, transport and washing of the fruits, drinking water is used for final washing and the water surplus is transferred by overflow from the last (cleaner) loop to the previous (dirtier) one. The final overflow is directed to the waste water treatment.

Disinfection

According to the WHO guideline, “disinfection is of unquestionable importance in the supply of safe drinking water. The destruction of pathogenic microorganisms is essential and very commonly involves the use of reactive chemical agents such as chlorine.”

To disinfect flume water at the point of fruit reception, chlorine can be added and free chlorine can be monitored over time.

The Chlorine value for effective disinfection according to WHO is 5 mg/l with a residual concentration of free chlorine ≥ 0.5 mg/l after at least 30 minutes contact time at pH<8. At the point of delivery, the minimal residual concentration of free chlorine should be 0.2 mg/l.

A commonly used disinfectant for fruits and vegetables processing as well as flume wash water is Chlorine Dioxide ClO₂ which is a highly reactive oxidant. The action of this compound is pH independent and it can be generated on site through different reactions.

According to, Ruzic, C. (1996). Chlorine dioxide-based water treatment in the food industry, the below table summarizes the bacterial reduction effect on several microorganisms using chlorine dioxide.

The Chlorine value for effective disinfection according to WHO is 5 mg/l with a residual concentration of free chlorine ≥ 0.5 mg/l after at least 30 minutes contact time at pH<8. At the point of delivery, the minimal residual concentration of free chlorine should be 0.2 mg/l.
Another commonly used method for disinfection of water is UV light. For the efficacy of these systems, UV light bulb must be inspected regularly. Presence of particles inside the water could generate a shadow effect preventing the light to reach some bacteria.

Water treatment by ozone is another widely used method that gives the advantage of not leaving any type of chemical residue. One disadvantage of such a system is that it does not protect the water during transport for which a small quantity of chlorine is still needed. It has been reported in scientific literature that ozone can reduce drastically the presence of fungicides and pesticides present on the surface of the fruits and vegetables.
The use of chlorine as disinfectant in the food industry has already been prohibited in some European countries (Bilet & Turantas, 2013), due to the potential production of toxic by-product, such chloroform, trihalomethanes, chloramines, and halocetic acids (European Commission, 2007). Although the disinfection with chlorine is widespread, there is a global trend to developing alternative disinfection strategies to minimize it’s environmental and public health impacts providing a better antimicrobial effect. Table 1 provide updated information on alternative methods to replace and/or reduce the use of chlorine (Meireles, Giaouris and Simoes, 2016).

Table 1: Disinfectant alternative methods to replace and/or reduce the use of chlorine on the food contact surface, product and water (Adapted from Meireelle et al., 2016).

<table>
<thead>
<tr>
<th>Target</th>
<th>Method</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nisin (6.75x10^4 ppm, 5 min, 20 °C)</td>
<td>Reduction of 2.38 log CFU/cm² of L. monocytogenes on SS surfaces</td>
<td>(Arevalos-Sánchez et al., 2012)</td>
<td></td>
</tr>
<tr>
<td>Nisin (6.75x10^4 ppm, 20 min, 20 °C)</td>
<td>Reduction of 1.92 log CFU/cm² of L. monocytogenes on glass surfaces</td>
<td>(Arevalos-Sánchez et al., 2012)</td>
<td></td>
</tr>
<tr>
<td>Lytic phage (phage § S1)</td>
<td>Reduction of 80% of P. fluorescens biofilm on SS surfaces</td>
<td>(Silinkorva et al., 2004)</td>
<td></td>
</tr>
<tr>
<td>Carvacrol (0.05 to 0.1%, 1 hour)</td>
<td>Reduction of 7 log CFU of Salmonella sp. on PS and SS surfaces</td>
<td>(Somi et al., 2013)</td>
<td></td>
</tr>
<tr>
<td>Carvacrol (2 mM)</td>
<td>Reduction of 2.3 log CFU of bacteria (listeriae and salmonellae) on SS surfaces</td>
<td>(Knowles &amp; Roller, 2001)</td>
<td></td>
</tr>
<tr>
<td>ClO₂ (200 μg/mL)</td>
<td>Reduction of 4.42 log CFU of B. cereus on SS surfaces</td>
<td>(Keske et al., 2006)</td>
<td></td>
</tr>
<tr>
<td>ClO₂ (5%, 10 min)</td>
<td>Reduction of 4.14 log CFU/chip of L. monocytogenes biofilm</td>
<td>(Robbins et al., 2005)</td>
<td></td>
</tr>
<tr>
<td>EOW (56 ppm of free chlorine, 5 min)</td>
<td>Reduction of 9 log CFU/cm² of L. monocytogenes on SS surfaces</td>
<td>(Kim et al., 2001)</td>
<td></td>
</tr>
<tr>
<td>NEOW (63 ppm of free chlorine, 1 min)</td>
<td>Reduction of 6 log CFU/cm² of E. coli, P. aeruginosa, Staphylococcus aureus and L. monocytogenes on SS and glass surfaces</td>
<td>(Deza et al., 2005)</td>
<td></td>
</tr>
<tr>
<td>NEOW (70 ppm of free chlorine, 3 min)</td>
<td>L. monocytogenes biofilms (on SS surfaces) completely inhibited</td>
<td>(Arevalos-Sánchez et al., 2013)</td>
<td></td>
</tr>
<tr>
<td>Aqueous ozone (5 8 ppm, 1 min)</td>
<td>B. subtilis and P. fluorescens were completely eliminated from SS surfaces</td>
<td>(Khadre &amp; Yousef, 2001)</td>
<td></td>
</tr>
<tr>
<td>Sodium bicarbonate (5x10^6 ppm, 1 min)</td>
<td>Reduction of 99.22% of feline calicivirus on food contact surfaces</td>
<td>(Matix &amp; Goyan, 2006)</td>
<td></td>
</tr>
<tr>
<td>US (40 kHz)</td>
<td>30% of E. coli biofilm removal on SS</td>
<td>(Oakland-Lagar et al., 2003)</td>
<td></td>
</tr>
<tr>
<td>α-amylose + Realco B (30 min)</td>
<td>Reduction of 2.98 log CFU/cm² of B. mycoides on SS</td>
<td>(Lequette et al., 2010)</td>
<td></td>
</tr>
</tbody>
</table>
### Sodium bicarbonate (2×10⁴ ppm) + H₂O₂ (2×10⁴ ppm), for 10 min
Reduction of 99.68% of feline calicivirus on food contact surfaces (Malik & Goyal, 2006)

### US (40 kH) + trypsin (7600 U/mL)
76% of E. coli biofilm removal on SS (Oualhal-Laghrir et al., 2003)

### Nisin (50 ppm, 1 min)
Reduction of 2.20 and 4.35 log CFU of Listeria monocytogenes on mong bean and broccoli, respectively (Bari et al., 2005)

### Lytic bacteriophages (UAB_Phi 20, UAB_Phi 75, and UAB_Phi 87) (60 min at room temperature)
Reduction of 3.9 and 2.2 log CFU/g for S. Typhimurium and S. Enteritidis, respectively, on lettuce (Spricigo et al., 2013)

### Lytic L. monocytogenes-specific phages
Reduction of 2.0-4.6 log CFU of L. monocytogenes per melon sample (Leverentz et al., 2003)

### Carvacrol (150 ppm)
Reduction of the total viable counts in 4.6 log CFU/g on kiwi (Roller & Seedhar, 2002)

### Cinnamic acid (150 ppm)
Reduction of the total viable counts in 4.6 log CFU/g on kiwi (Roller & Seedhar, 2002)

### Oregano oil (25, 40 and 75 ppm, at 5, 10, 15 and 20 min)
Reduction of 1.92 log CFU/g of S. Typhimurium on lettuce (Gnitch et al., 2010)

### ClO₂ (10 ppm, 5 min)
Reduction of 1.2 log CFU/g of E. coli O157:H7 on lettuce (Singh et al., 2002a)

### ClO₂ (100 ppm)
Reduction of 3.5-4.0 log CFU/g of total bacterial and coliform counts on lettuce (Chung et al., 2011)

### ClO₂ (100 ppm)
Reduction of 1.25 log CFU/g of E. coli O157:H7 on lettuce (Kesiiken et al., 2009)

### AcEW (pH 2.6, at 50 ppm (free chlorine), 2 min)
Reduction of 1.4 log CFU/g of E. coli O157:H7 on lettuce (Kesiiken et al., 2009)

### AcEW (pH 2.6, at 37.5 ppm (free chlorine), 1 min)
Reduction of 4.45 log CFU/g of E. coli O157:H7 on green onions (Park et al., 2008)

### NEOW (89 ppm (free chlorine), 5 min treatment)
Reduction of 6 log CFU/mL of E. coli O157:H7, S. Enteritidis and L. monocytogenes on tomatoes (Deza et al., 2003)

### NEOW (20 ppm (free chlorine), 10 min)
Reduction of 6 log CFU/mL of E. coli, S. Typhimurium, Staphylococcus aureus, L. monocytogenes and Enterococcus faecalis, on lettuce (Guentzel et al., 2008)

### NEW (50 ppm free chlorine)
Reduction of 1-2 log CFU/mL of E. coli O157:H7, Salmonella, L. innocua and Erwinia carotovora on lettuce (Abadías et al., 2008)

### H₂O₂ (3×10⁴ ppm, 5 min)
Reduction of 1.6 log CFU/g reduction of E. coli O157:H7 on baby spinach leaves (Huang et al., 2012)

### H₂O₂ (5×10⁴ ppm, 2 min)
Reduction of 2.0-3.5 log CFU/cm² of L. monocytogenes from melon surfaces (Ukuda & Fett, 2002)

### H₂O₂ (2×10⁴ ppm)
Reduction of 1.5 log CFU/g of E. coli O157:H7 on baby spinach leaves (Huang & Chen, 2011)

### Citric acid (5×10⁴ to 1×10⁵ ppm, at 20°C for 1 to 5 min)
Reduction of 1 log CFU/cm² of Listeria monocytogenes from lettuce (Samara & Koutsoyannis, 2009)

### Acetic acid (20°C for 2-5 min)
Reduction of 2.2 and 1.3 log CFU/g of E. coli and L. monocytogenes respectively, from lettuce (Akbas & Olmez, 2007)

### Lactic acid (20°C for 2-5 min)
Reduction of 2.8 and 2.1 log CFU/g of E. coli and L. monocytogenes respectively, from lettuce (Akbas & Olmez, 2007)

### PAA (120 ppm)
Reduction of the microbial load in 1.2 log CFU/g on fresh-cut iceberg lettuce (Vanderkinderen et al., 2009)

### PAA (40 ppm, 5 min)
Reduction of 0.99 log CFU/g of S. Typhimurium on lettuce (Ge et al., 2013)

### Propionic acid (1×10⁴ ppm, 10 min)
Reduction of 0.93-1.52 log CFU/g of E. coli O157:H7, S. Typhimurium, and L. monocytogenes on organic fresh lettuce (Park et al., 2011)

### Acetic acid (1×10⁴ ppm, 10 min)
Reduction of 1.13-1.74 log CFU/g of E. coli O157:H7, S. Typhimurium, and L. monocytogenes on organic fresh lettuce (Park et al., 2011)

### Lactic acid (1×10⁴ ppm, 10 min)
Reduction of 1.87-2.54 log CFU/g of E. coli O157:H7, S. Typhimurium, and L. monocytogenes on organic fresh lettuce (Park et al., 2011)

### Malic acid (1×10⁴ ppm, 10 min)
Reduction of 2.32-2.98 log CFU/g of E. coli O157:H7, S. Typhimurium, and L. monocytogenes on organic fresh lettuce (Park et al., 2011)

### Citric acid (1×10⁴ ppm, 10 min)
Reduction of 1.85-2.86 log CFU/g of E. coli O157:H7, S. Typhimurium, and L. monocytogenes on organic fresh lettuce (Park et al., 2011)

### Benzoalkonium chloride (2 ppm)
Growth of B. cereus, Staphylococcus aureus and E. coli (isolated from fresh vegetables) completely inhibited (Park et al., 2013)

### Cetylpyridinium chloride (5×10⁴ ppm)
Reduction of 3.70, 3.15 and 1.56 log CFU/g for L. monocytogenes, S. Typhimurium and E. coli respectively, from broccoli, cauliflower, and radishes (Wang et al., 2001)

### Aqueous ozone (5 ppm, 5 min)
Reduction of 1.8 log CFU of Shigella sonnei from shredded lettuce (Selma et al., 2007)
| Physico-chemical properties and main applications of ozone as disinfectant in fruit washing and sanitation |

Ozone is a friendly environment sanitizer that has been used as an alternative to chlorine in different steps of processing with pros and cons (see table 2). Ozone (from the Greek ozein, smell) is an unstable molecule and is the third strongest oxidant agent after fluorine and persulfate, which explains its high reactivity.
Table 2: Advantages and disadvantages of some disinfectants used in food process (according to Fleming 1991, Troller 1993 e Wirtanen 1995).

<table>
<thead>
<tr>
<th>Disinfectant type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>Effective against vegetative cells, non-toxic, easy-to-use, colourless, harmless on skin, soluble in water, volatile</td>
<td>Microbistatic, ineffective against spores</td>
</tr>
<tr>
<td>Peroxide</td>
<td>Effective in low concentration, broad microbial spectrum, kills spores, penetrates biofilms, non-toxic (→ acetic acid and water)</td>
<td>Corrosive, unstable</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Decomposes to water and oxygen, relatively non-toxic, easy to use, weakens biofilms and supports detachment</td>
<td>High concentrations needed, corrosive</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Effective in low concentration, broad microbial spectrum, easy to use, supports microbial detachment, cheap</td>
<td>Toxic by-products, resistance development, residues, corrosive, reacts with EPS, discoloration, explosive gas</td>
</tr>
<tr>
<td>Hypochlorite</td>
<td>Cheap, effective in a broad microbial spectrum, easy to use, supports detachment</td>
<td>Unstable, toxic, oxidative, corrosive, rapid regrowth, no prevention of adhesion, discoloration of products</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td>Effective in low concentration, can be produced on-site, low dependency in pH</td>
<td>Toxic by-products, explosive gas</td>
</tr>
<tr>
<td>Quaternary ammonium agents</td>
<td>Effective, non-toxic, prevents regrowth, supports microbial detachment, non-irritating, non-corrosive, odourless, flavourless</td>
<td>Inactivated in low pH and by salts (Ca^{2+} and Mg^{2+}), resistance development, ineffective against Gram-negative bacteria</td>
</tr>
<tr>
<td>Iodophor</td>
<td>Non-corrosive, easy to use, non-irritating, broad activity spectrum</td>
<td>Expensive, flavour, odour, forms purple compounds with starch</td>
</tr>
<tr>
<td>Ozone</td>
<td>Similar effect as chlorine, decomposes to oxygen, no residues, decomposes biofilm</td>
<td>Corrosive, inactivated easily, reacts with organics (→ epoxides)</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Effective in low concentrations, cheap, non-corrosive</td>
<td>Low penetration in biofilms, degrades to formic acid, increased DOC</td>
</tr>
</tbody>
</table>

Ozone (O3) is artificially produced from the oxygen using special generators, by means of UV radiation, plasma silent discharge, or electrolysis. Its reaction is reversible therefore ozone decomposes spontaneously. This is the reason why it cannot be stored and has to be produced on site. Also, the half-life of an ozone molecule depends on temperature: at 30°C its concentration is halved in 25 minutes, at 20°C in 40 minutes, and at -50°C after 3 months. Once produced, ozone, as a gas, can be injected into a specially confined atmosphere or dissolved into water for rinsing or washing applications. In the latter form, constant ozone dissolution needs to be maintained or used in a combination with lower quantities of a second disinfecting agent.

Ozone has strong biocidal properties, it is used worldwide for making water potable and, since 1906 for the treatment of effluents (CHO et al, 2003). Compared to other disinfectants, it is 1.5 times more oxidising than chlorine and 3000 times more than hypochlorous acid (Suslow, 1998). It has also proven to be very effective at low concentrations on a wide range of microorganisms (Khadre and Yousef, 2011) including on viruses (Kekez and Sattar, 1997) and
it does not leave toxic residues or by-products (such THMs, for example) like other disinfectants (Fan et al, 2007).
Several studies have highlighted the bactericidal and antimycotic effectiveness of gaseous ozone as a disinfectant in food processing facilities (Moore, Griffith and Peters 2000; Robbins, Fisher, Moltz and Martin 2004, Tapp and Sopher, 2002; Campos et al, 2005).
The use of ozone can be economically advantageous: the cost of purchasing and maintenance of ozone delivery units is lower than the cost of procuring disinfectant products (Greene, Few and Serafini 1993). Rice, Graham, and Lowe (2002) described a financial study conducted in an American food plant (20 processing lines operating 24 h a day, 300 days a year) that introduced a mobile ozonated disinfection system. The new system enabled the processor to cut the previous four disinfection to only two and thereby reduce water use from 56.8 to 22.7 m$^3$/day.
In 2001, the FDA (Food and Drug Administration) amended its rules on additives to permit the use of ozone, both in aqueous and gaseous phase, as an antimicrobial agent in the treatment, storage and processing of food, including bovine and poultry meat (Muthukumar and Muthychamny, 2013).
The applications for which it is recommended in the food industry are numerous (Silva & Brandao, 2013): from disinfection of equipment and packaging, elimination of patulin toxin in juices, reduction of aflatoxin and others mycotoxins (see table 3, Karaca, 2010), recycling of process water till the treatment of industrial effluent (Majchrowicz 1998). As a fumigant, it prevents deterioration of fresh food, eliminates insects and other parasites in stored grains and sanitises beehives (James, 2011).

<table>
<thead>
<tr>
<th>Table 3: Ozone treatment studies for mycotoxin degradation in various products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food/Matrix</strong></td>
</tr>
<tr>
<td>Model system</td>
</tr>
<tr>
<td>Dried fig</td>
</tr>
<tr>
<td>Apple juice</td>
</tr>
<tr>
<td>Red pepper</td>
</tr>
<tr>
<td>Model system</td>
</tr>
<tr>
<td>Pistachio</td>
</tr>
<tr>
<td>Peanut</td>
</tr>
<tr>
<td>Corn</td>
</tr>
</tbody>
</table>

Ozone is unstable and it decomposes spontaneously into O2 minimizing human health hazards linked to chemical residues in “food and effluents”, but any application of ozone should be designed specifically for each application (sustained by an R&D study), preferably following guidelines (Fortini et al., 2016) and health standards limiting human exposure to ozone. For the evaluation of medical-environmental conditions, it is normal practice to refer to the threshold
limit values (TLV) (TRESHOLD LIMIT VALUES-TLV) of ACGIH (American Conference of Governmental Industrial Hygienists.
Safety limits for workers exposed to ozone, such as TLV-TWA, is related to the physical activity they perform (as the volume of air inhaled varies).

The indicated values by ACGIH are:
➢ For heavy, moderate or light work carried out for a period of up to 2 hours:
   - TLV-TWA is set at 0.2 ppm, equivalent to 0.39 mg/m3.

➢ For work lasting over 2 hours:
   - Light work - TLV-TWA is set at 0.1 ppm, equivalent to 0.2 mg/m3.
   - Moderate work - TLV-TWA is set at 0.08 ppm, equivalent to 0.16 mg/m3.
   - Heavy work - TLV-TWA is set at 0.05 ppm, equivalent to 0.1 mg/m3.

According to Rice, R.G., Farquhar, J.W. and Bollyky, L.J. (1982) ozone residues must be removed from the environment by installing special extractors equipped with "destructors or catalyzers". Disinfection with ozone must be carried out in unoccupied, duly enclosed areas. To reduce hazards, sound and/or acoustic devices must be installed at every point of access during treatment; similarly, free access indicators must be provided.

Filtering

To remove fruit debris, leaves, stems and seeds as well as sand and foreign materials, it is necessary to provide water filtering within the water recirculation loops. Rotary wire mesh cylindrical filters with 0.5 to 1 mm gaps and a brass scraper are normally used. Metal grid belts with brushes on the return side are also an option.

Example of a cylindrical filtering unit installed on a decantation tank
For mechanically harvested fruits such as tomatoes, vine removal systems are necessary as green vines and grass represent a large portion of the harvest collected by mechanical harvesting machines. Finally, for those tubers such as carrots or beets, attention should be given to the removal of sand and stones (see Specific Applications Paragraph under this document).

For all those products where sand is a main contaminant that cannot be fully removed during washing, de-sanding cyclones can be used after the juice extraction phase. This approach is typical for the processing of tomato juice as well as for refrigerated berries transported in refrigerated tank trucks. These cyclones need to operate with a given infeed pressure to generate the cyclone effect and can separate as much as 70% of the incoming sand with a granulometry in the range 10-100 µm.

4) Contaminants reduction

4.1) Patulin

The topic of Patulin is treated in the Codex Alimentarius Code of Practice for the prevention and reduction of Patulin in apple juice and apple juice ingredients CAC/RC P50-2003.
Below a summary:

**Patulin** is a mycotoxin metabolite produced by a variety of fungal species in particular *Aspergillus, Byssochlamys* and *Penicillium Expansum*, producing a soft rot and blue mold on fruits, vegetables, cereals and other foods. The major sources of patulin contamination are apples and apple products and generally it occurs in mould damaged fruits resulting from insect invasion or fruit badly exposed to ambient conditions.

It has been reported that:

- Ascorbic acid can make patulin disappear from apple juice
- Short-time, high temperature treatment (150°C / 302°F) can reduce patulin concentration by 20%. However, thermal treatment alone is not sufficient
- Washing of fruit or removal of moldy tissue, immediately prior to pressing will not necessarily remove all the patulin in the fruit since some may have diffused into apparently healthy tissue
- Apple washing with ozone solution is reported to contribute substantially to the control of patulin

The code of practice recommends following the GAPs (Good Agricultural Practices) and GMPs (Good Manufacturing Practices) to reduce patulin contaminations.

Among the GMPs it is worth mentioning the following:

- Prior to processing fruit should be sorted carefully to remove any visually moldy fruit (check randomly and routinely for internal mold by cutting some fruits…) and washed thoroughly, using potable or suitably treated water

Juices presses and other equipment should be clean and sanitized, washed down with pressured water hoses, sanitized by application of suitable sanitizers, followed by a further rinse with potable cold water (suggested cleaning frequency once per day).

The topic of patulin limits in final juices is treated in the Commission Regulation EC No. 1881/2006 “Setting maximum levels for certain contaminants in foodstuffs”.

The maximum level of patulin for fruit juices, concentrated fruit juices as reconstituted and fruit nectars is set to 50µg/kg and to 10µg/kg for infant fruit juices.

According to industrial apple processors, the final juice patulin level can be kept under allowable limits using high pressure water rinsing, brushing, and filtering of transport water as well as with manual sorting. These methods apply particularly when the rotten part of the fruit is soft and located on the external surface, while they are not successful when the defect is internal.

For this latter problem a new generation of optical sorters based on chlorophyll luminescence have been utilized in recent years. In fact, chlorophyll tends to disappear on internally rotten fruits and this parameter can be detected by a camera which then sends a signal to an automatic reject system.

The maximum level of patulin for fruit juices, concentrated fruit juices as reconstituted and fruit nectars is set to 50µg/kg and to 10µg/kg for infant fruit juices.
4.2) Alicyclobacillus (ACB)

The topic of Alicyclobacillus is treated in the Best Practice Guideline from the AIJN. Below is a summary:

Alicyclobacillus is an acid tolerant thermophilic microorganism which is very heat resistant as a spore. The presence of ACB causes flavor spoilage but it is not known to cause a safety hazard.

Soil contamination is the primary source of ACB entry in the production chain.

Fruit washing and cleaning is critical to remove soil and dirt thus controlling Alicyclobacillus.

Sanitizers can be utilized to control ACB in water:
- Ozone
- Hydrogen Peroxide
- Chlorine dioxide
- Hypochlorite (Na, Ca)
- Peracetic acid
- UV
- Filtration
- Heat treatment

A testing regime and specification for all water used in the plant should be established based on risk.

Evaporator condensate can contain high concentration of ACB and should be tested on a routine basis.

4.3) Pesticides

It has been reported in scientific literature that ozone treated water can contribute to the reduction of pesticides and fungicides present on fruits and vegetables.

4.4) Heavy Metals

Fruit washing could reduce heavy metals from the surface of the fruits. No data are currently available on this topic.
Specific Applications

5) Fruit Washing and sanitation systems

5.1) Apple puree

5.2) Apples for clear and cloudy juice

5.3) Tropical Fruits

5.4) Berries

5.5) Banana

5.6) Orange

5.7) Carrots

5.1) Apple puree line

Apples destined for the production of apple puree are normally conveyed to the production facility in bins weighting 400 to 600 kg. Fruits are normally quite clean. Typically no storage of the fresh fruit is foreseen but rather a direct processing. Standard processing capacities for a single line range from 1 to 30 t/h. The receiving flume should be designed with a large enough capacity to store at least two or three bins. The simplest approach foresees the following equipment:

- Bin dumper
- Receiving flume with water recirculation
- Air blowing system into the flume for increased turbulence
- Water pumping and filtering group
- Roller conveyor to separate fruits from water
- Sorting table
- Optical sorter (optional)
- Pressurized nozzles for potable water washing during fruit rotation
A high-end approach consists of several loops of water from the dirtiest to the cleanest. Water sanitization systems with chlorine or other media can be utilized on the first flume water.
5.2) Apples for clear and cloudy juice

Apples are normally received in trucks with a capacity up to 30 tons and can carry all grades of dirt (sometimes extreme). Apples are normally stored in silos prior to processing to guarantee a constant feed to the processing line even when the trucks are not allowed to the facility (nights or weekends). Processing capacities can be as high as 140 t/h. Reception and transport of apples can happen with water or under dry conditions.

Within the wet storage and reception systems, silos can be of different types with regard to depth and geometry:

- Deep silo under ground level
- Flat silo at ground level
- Deep silo above ground level with indirect filling via distribution conveyor

![Example of a segmented deep silo with transport water lines](image)

Deep silos are normally segmented with each segment carrying one water feed line. They have a small inclination (1-1.5 %) so that apples “swim”. The silo capacity is generally quite large (e.g. 1 day of production).

One variant of this design is to fill the silo with flume water prior to fruit tipping. On this design a tight slide-gate valve keeps the water inside during filling. This type of silos can guarantee a gentler treatment of fruits avoiding damage during the truck tipping and allow to achieve a more even distribution of fruits inside the silo. As a downside, they are more expensive, consume more water and need a large water buffer.
Flat silos are cheaper than deep silos and generate less damage to fruits but also provide less capacity.

When deep silos above ground level are used, apples are discharged on a hopper and then conveyed to silos above the ground with a belt elevator. This solution has the advantage that non-compliant batches can be separated before entering the silos, but it is more expensive.
Example of deep silos above ground level with conveyor distribution

From the silos to the juice extraction area, apples are conveyed through flume systems. Two pumps are normally involved in this operation: a feed pump and a return pump.

Water is filtered with rotary filters and then buffered into tanks. Flume water should be changed a minimum of once per day (depending on dirt load, fruit healthiness, etc.)

Example of water filtering and buffering unit.
Apples coming from the silos together with flume water arrive at a grid for water separation and then to a washing and sorting system. At this stage apples are washed by fresh water by mean of spray balls. This water is then collected in the sump and refreshes the flume circuit.

*Elevation view of a complete apple receiving, transport and washing line*

When no water is utilized for receiving and transport, we talk about dry reception systems. In this case trucks dump into dry reception hoppers. Despite a lower investment in civil works, these systems have the disadvantage of no product buffer, no pre-washing and no possibility to prevent dirt and debris entering the facility.

*Examples of dry reception systems without silos*
5.3) Tropical fruits

5.3.1) Mango

Typically mango is collected in transport water then goes through a washing and sorting table where it is sprinkled with potable water.

Example of mango bins dumper

Then it goes through a brusher and finally a steam blancher that has the function of deeply cleaning the fruit as well as softening peeled to facilitate destoning process.
Mango washing system

Blancher section
5.3.2) Banana for puree

Banana pre-washing and sanitation system

Banana receiving, washing and peeling system
Harvesting, pre-washing, ripening

Bunches of banana are visually selected, cut at the stem and gently laid on the ground. Once harvest has been completed, the fruit is manually transferred to bins (300 to 500kg) and transported to the facility. At this stage, it is advisable to perform a cleaning and sanitation of the fruit prior to the storage in the ripening rooms.

Unloading, receiving and washing section

Once ripening is completed, fruit is dumped into a washing tank and subsequently is conveyed by and elevator where potable water is sprayed for the final washing. The transport water could be added with hypochlorite for proper sanitization.

Sorting belt conveyor

Finally, bananas are conveyed to the sorting belt where any damaged banana are manually removed as well as foreign materials.

Peeling table

Bananas are manually peeled with established movements. Particular attention should be utilized to avoid cross contamination from peels to the banana flash by keeping the transport belt for the whole bananas, peeled bananas and skins as separate as possible.
5.4) Citrus Fruits

The technology behind receiving, sorting and washing citrus fruits destined to the juice industry may be used for every single type of citrus: oranges, lemons, clementine, grapefruit...etc. The main differences among them are based on how the receiving/unload system is managed (silos, dry receiving system) or which is the final product profile (NFC, concentrate, unpasteurized juice).

Basically, the flow chart for the juice industry could be reduced to two main applications:

**Large and medium producers**

![Diagram of large and medium producers](image1)

**Small size processors**

![Diagram of small size processors](image2)
Receiving

First of all, the receiving system is designed according to the capacity and strategy of every specific industry. For the citrus industry the following can be found:

- **Dry receiving system with silos**: the residence time is critical as it could affect quality parameters and yield. They are recommended to absorb delivery fluctuations.

- **Dry receiving system without silos**: normally adapted to medium size processors.

- **In-water receiving system**: it is not a common solution due to the problems related with the water treatment and management. It represents a difficult citrical point to manage because of the high water microbiological load and the potential contamination of the raw material. Sometimes, water is just used to push into the feeding conveyors or elevators the fruits that remain clogged at the receiving system (soft fruits or non-rounded shape lemons).

- **Dumper bins, tilting or rotating forklifts unloading the fruit into a hopper**: adapted to small size processors.
Note to small processors:
Due to the quick growth of premium juices processed by HPP or non-heat treated (chilled storage) a recommendation for these small processors is to bring the cold chain to the fruit receiving and storage step. Different processor experiences suggest that keeping the fruit at 4-5 °C until the last minute, just before the juice extraction, will definitely improve the organoleptic profile of the juice as well as slow down all the enzymatic and non-enzymatic reactions (Pectin methyl esterase or oil oxidation).

Sorting step
Sorting is as important as all the other steps of the processing line. Final quality of the juice is highly affected by the degree of sorting done. And there are two main reasons why:

Microbiological:
Damaged, rotten fruits or mold infected fruits need to be removed because they cause an increase of the initial microbiological load. Quality may be highly affected due to a non-fresh fruit flavour or micro by-products coming from the spoiled fruits when mixed with good fruits at the extraction step.

Foreign objects:
Fruits are, in many cases, directly come from the orchards so wood and metal pieces such as harvesting tools or stones are well known foreign materials. It mainly occurs while running directly from trucks or bins but also from silos.

Such foreign material could end at the extractors causing a significant damage that in many cases stops the machine from working. In other cases, the machine remains lightly damaged (cup cutters, alignment…) affecting at the performance of the machine and finally to the quality and yield of the juice (e.g. more oil content at final juice).

Some examples about accepted and rejected fruits
Washing

When the fruit needs to be processed, it is important to remove all contamination, both organic and non-organic, that might affect the final product’s shelf life and quality.

Fruit peel could contain pesticides, dust, bird feces and a large amount of micro. It is understood that post-harvest waxes present at the peel surface may reduce water rinsing effectiveness.

Pesticides used in citriculture, both pre- and post-harvest, are not systemic and do not penetrate in the edible part of the fruit. Besides, they have a very low mobility and tend to place themselves in the outer part of the peel surface of the fruit. They usually dissolve in the waxes of the peel.

Therefore, the use of a detergent in fruit washing operations ensures the fruit used for juice extraction be free from microbiological as well as from physical-chemical contamination.

Residues of natural citrus oil present at the fruit surface, out of the oil glands, due to transportation and handling, are oxidized and have to be removed. The use of a detergent ensures the removal of the oil residues with no effect on the oil inside the glands so the oil recovery system yield is not affected.

For small juice producers with a premium final product and without an oil recovery system, they need to remove the oil as much as possible from the peel at the washing step in order to avoid that some essential oil enters into the final juice during the juice extraction. Normally, small processors use an extractor with a standard configuration according to the average fruit that are supposed to process but, due to logistic difficulties or difficulties with the raw material availability during the season, the configuration cannot be perfectly suitable for all the fruit size or varieties. When extractor configuration and fruit do not match, the juice could contain some traces of essential oil that evolves during the product’s shelf life releasing an off-flavour that could reduce the freshness of the juice.
The following scheme shows a washing system used by the citrus industry:

**Brush/Washer Machine**

- **Injector**
- **Bottom valve**
- **Concentrate detergent pump**: approx. 1 L detergent per 12 TONNES of fruit (optional)
- **Pre-washing manifold with recirculated water**: approx. 100-300 L per TONNE of fruit
- **Manifold for detergent application solution** (9%) = approx. 2.78 L solution per TONNE of fruit
- **Sprior on both side long all pipe**
- **Typical manifold section**
- **Final rinsing with two manifold with fresh water**: approx. 100-300 L per TONNE of fruit
- **Manual centralized Lubrication**
- **Water recycling and filtering system**: (optional)
- **Water filter holes DIA. 1 mm**: (optional)
- **Waste water**
- **Fruit inlet**
- **Fruit outlet**

Total product residence time approx. 30/40 second max

20 second for detergent reaction
The rotating brushes cause the rotation of the fruit. In addition, the non-regular shape of the brushes increases the contact area and maximize the exposure to sprays and brushes.

The residence time of the detergent has been determined as critical as it needs some time to react with the organic and inorganic material at the fruit surface.
Detergent importance: industrial trials

The following data can be used as a reference of the efficiency of using a detergent to wash citrus fruits.

A test (JBT & Miguel Hernandez University) was carried out in different citrus processing facilities across Spain in order to collect results from different scenarios. The differences were based on fruit origin/handling and water hardness as follow:

Conduction of the tests:

4 plants were selected to run the tests:

a) In Murcia: where water is hard and lightly salty.

b) In Andalusia: similar to Murcia region but normally with more availability of water.

c) Zaragoza and Lerida: light-medium water hardness and high availability.

The fruit varies also between the plants situated in the South and North. The two plants located in the South were closer to the orchards than the northern plants.

The detergent used for the tests was an Alkali/Surfactant solution known as FC-400 cleaner (for general cleaning of fruits and vegetables).

The scheme below shows the procedures and application:

<table>
<thead>
<tr>
<th>CONDITIONS</th>
<th>STEPS</th>
<th>EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water from final rinsing</td>
<td>Preliminary washing</td>
<td>Brushes / nozzles. Water discharge</td>
</tr>
<tr>
<td>Detergent 3% in water. Ambient temperature. 100 liters of solution are applied to 36,000 kg fruit 1 liter of detergent per 12 Tm of fruit</td>
<td>Washing with FC 400 solution.</td>
<td>Brushes / nozzles. Foam formation.</td>
</tr>
<tr>
<td>Potable water. Sufficient water pressure</td>
<td>Final rinsing with plentiful water</td>
<td>Brushes / nozzles. High pressure water.</td>
</tr>
</tbody>
</table>
Analysis and methodology:

The parameters analyzed to assess the efficiency of the detergent and of the washing process were:

- Total plate count of the juice.
- Pesticide residues in the juice: by chromatography.
- Sodium residues in the juice: by atomic absorption

The samples analyzed were:

- Juice from fruit washed with water only.
- Juice from fruit washed with detergent.
- Juice from unwashed fruit, as reference or blank.

The total number of samples analyzed was 3 per test per plant, i.e. 12 per plant and 36 in total.

Results:

**Microbiology:**

<table>
<thead>
<tr>
<th></th>
<th>Juice from unwashed fruit.</th>
<th>Juice from fruit washed with water.</th>
<th>Juice from fruit washed with detergent</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPC u.f.c./ml. Juice</td>
<td>$30 - 85 \times 10^3$</td>
<td>130 – 280</td>
<td>10 – 25</td>
</tr>
</tbody>
</table>
**Pesticides:**

<table>
<thead>
<tr>
<th>% reduction of the pesticide content.</th>
<th>Juice from unwashed fruit.</th>
<th>Juice from fruit washed with water.</th>
<th>Juice from fruit washed with detergent</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBZ</td>
<td>0 %, Reference</td>
<td>&lt; 10 %</td>
<td>Up to 85 %</td>
</tr>
<tr>
<td>Imazalil</td>
<td>0 %, Reference</td>
<td>&lt; 10 %</td>
<td>Up to 85 %</td>
</tr>
<tr>
<td>Ortophenilphenol</td>
<td>0 %, Reference</td>
<td>&lt; 10 %</td>
<td>Up to 85 %</td>
</tr>
</tbody>
</table>

**Residual Sodium**

The aim of this analysis was to determine the possible residues of the detergent in order to optimized flow and distribution of rinsing water.

The sodium content in all the juices was 5 – 12 ppm.

**Conclusions of the detergent efficiency in washing citrus fruits:**

1- The results of the trials above did not show significant differences between the different locations or scenarios of the citrus processors where the detergent was used. Efficiency was not affected by fruit or water quality.

2- A clear reduction of the microbiological contamination levels as a result of the application of the detergent was detected.

3- An important reduction of the pesticide residues in the juice was confirmed. The optimum reaction time for this specific detergent was established at 15–20”

4- The use of a brush washer that ensures an effective application of the detergent is critical. Also very fine spray nozzles, irregular shape brushes that allow the application of the detergent over the entire fruit surface and a sufficient rinsing section.

5- The combination of brush washer, sufficient detergent residence time and effective spay nozzles ensures an adequate sanitation and washing process.
5.6) Carrots for puree and juice

5.7.1) Cold washing system

**Unloading and receiving section**
Carrots can be fed to the facility in trucks, boxes or storage bins. The above scheme refers to the delivery on trucks. Carrots are dumped into a belt conveyor providing some buffering capacity and constantly feeding the processing line.

**Washing tank**
Carrots are delivered to a washing tank with air injection on the bottom producing turbulence that helps removing sand and impurities.

**Stone separator**
Stones are removed by sedimentation inside the conical tank and then extracted with a screw conveyor.

**Cylindrical washing machine**
Carrots are transported to a cylindrical washing machine that continuously rotates the vegetable for a few minutes while spraying water on them.
**Brushing machine**

A gently scrub to brush away any dirt that might be present on the vegetable.

**Washing tank**

An additional cleaning can be done in conjunction with chemical sanitizers diluted in potable water.

**Sorting table**

Carrots are transported to a sorting table to manually remove damaged or decomposed carrots while clean water is sprayed in carrots as a final wash treatment prior to the process.

**Filtering and sand removal unit**

A filtering unit must be considered to remove the large amount of sand, mud, and other foreign materials that are normally harvested together with carrots.

5.7.2) **Steam pressure washing system**

The above scheme is similar to the cold washing system but it includes a batch steam peeler followed by washer brusher. The steam peeler is loaded with a fixed amount of fruit then the inlet valves closes and the body turns while high pressure steam is injected inside. Typical working conditions are pressure up to 15bars and holding times up to 40seconds.
References


Bilek, S.E., & Turantas F. (2013). Decontamination efficiency of high power ultrasound in the fruit and vegetable industry, a review. International Journal of Food Microbiology, 166 (1), 155-162.


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