Food Safety Best Practices Guide for the Growing and Handling of Mexican Papaya

First Edition

TEXAS EST. 1942 International Produce Association

UNITED FRESH PRODUCE ASSOCIATION

User's Note

These guidelines provide recommended food safety practices that are intended to minimize the microbiological hazards associated with fresh papaya from Mexico. This guide addresses areas identified by a papaya working group with diverse stakeholder input from Mexico and the United States, including the Mexican National Service of Agro-Alimentary Health, Safety, and Quality (SENASICA) and the U.S. Food And Drug Administration (FDA), as the systems-based practices and hazards likely to lead to product contamination. It does not address every known hazard, singular, or cumulative risk factors. It is expected that growers who export to the US are following the minimum food safety standards as laid out by the FDA's Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption (i.e. the Produce Safety Rule) as well as those required by the SENASICA. The information provided herein is offered in good faith and believed to be reliable, but is made without warranty, expressed or implied, as to merchantability, fitness for a particular purpose, or any other matter. These recommended guidelines were not designed to apply to any specific operation. It is the responsibility of the user of this document to verify that these guidelines are appropriate for its operation. The publishing trade associations, their members and contributors do not assume any responsibility for compliance with applicable laws and regulations. It is recommended that users consult with their own legal and technical advisers to be sure that their own procedures meet applicable requirements.

Throughout this document, the word "must" is used to designate practices, policies and procedures that are required by regulation or by general agreement within the Mexican papaya industry. The word "should" is used to designate best practice recommendations which operations should consider using, but are not required.

This magnifying glass symbol throughout the document indicates that additional research is needed on a particular topic.

TABLE OF CONTENTS

Do's and Don'ts

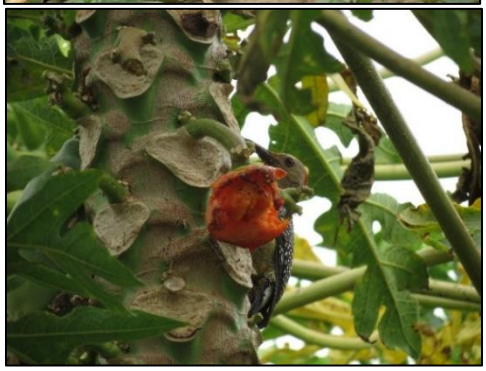
Do

- Follow Good Agricultural Practices and required FDA Produce Safety Rule and SENASICA regulations, recommendations, and guidance.
- Implement pest control methods and closely monitor papaya groves for bird and animal activity because they can cause contamination including, but not limited to papayas, soil, water, and equipment.
- Inspect the grove prior to harvest for evidence of animal activity or other potential contamination sources.
- Change gloves or wash hands after handling papaya that could be contaminated (e.g., culled, rotten, or fruit that has visible feces).
- Keep papayas as clean as possible before the first wash (e.g., minimize dirt and dust).
- Remove bruised or damaged fruit prior to the first wash.
- Keep wash water as clean as possible (by frequent water changes, filtration to remove debris, etc.).
- Use effective levels of antimicrobials in all wash water tanks and other washing steps.
- Monitor antimicrobial levels and pH (if the antimicrobial effectiveness is highly pH dependent) in all wash water often.
- Clean and sanitize food contact equipment and tools daily, or more often if needed.
- Properly clean equipment by removing soil and other organic material before sanitizing the equipment.
- Train workers on all applicable norms, as well as those laid out in this document, to understand the specifics of papaya safety.

Don't

- Don't harvest fruit that is visibly contaminated with feces, decayed/damaged, or extremely dirty.
- Don't handle or harvest additional fruit immediately after handling fruit with visible evidence of fecal contamination or likely to have been impacted by a contaminated source (e.g., untreated surface water known or likely to harbor readily measurable levels of human pathogens).
- Don't put decayed/ extremely dirty fruit in the wash tanks. They prevent optimal action by antimicrobials and may even completely eliminate their effectiveness.
- Don't expect wash water antimicrobials will 'sanitize' or otherwise destroy all pathogenic bacteria present on the fruit.
- Don't use recirculated water unless it's been treated with antimicrobials at levels sufficient to prevent cross-contamination of pathogens within and between lots.
- Don't re-wash fruit if antimicrobial levels decrease below the critical limit. Discard fruit back to the last time antimicrobials were verified to exceed the critical limit.
- Don't attempt to clean or reclean fruit if it is reasonable to expect they are contaminated – they must be discarded.
- Don't re-direct suspect lots including those known to have included visibly contaminated fruit, or fruit washed in water with insufficient antimicrobials, into local or other non-US markets.
- Don't allow sick workers to handle fruit or food contact surfaces during preharvest, harvest, or postharvest operations.

Pre-harvest Practices



Birds can be vectors for pathogens such as Salmonella*. Take measures to limit their presence in papaya groves.*

DO Limit Animals and Pests in the Groves

1. Mature fruit should be harvested as soon as possible before ripening onset so it does not become an attractant and food source for pests.
2. Groves should not be planted below taller tree shade, nor should harvest tools or equipment be placed beneath canopy shade for risk of contamination from bird droppings or other animal activity.
3. Measures should be taken to reduce snail presence, such as the use of a lime mixture (e.g. with paint or boiled nopal), dry lime, or copper sulfate granules at the base of papaya trees, because snails can attract other animals that can transmit pathogens to papayas.
4. Avoid standing water in the fields which can serve as an attractant to animals and pests.
5. Consider removing some leaves of the papaya tree to reduce shade and humidity in the grove.
6. Sorghum, sugar cane, or other green traps may be used to prevent insects, with the added benefit of reducing dust presence from surrounding roads that can transfer contaminants.
7. Fences may be built surrounding groves to further prevent larger wild animal intrusion.
8. Because rotten, damaged, or visibly contaminated fruit can serve as an attractant for bugs or animals in the grove, papaya growers should limit this by doing one or more of the following (listed in order of preference):
    i. Remove such fruit from the grove;
    ii. Treat the fruit (e.g., with lime powder) after removal from the tree so that it does not attract animals or pests; or
    iii. Move fruit to a separate area of the grove where harvest activities are no longer expected to occur.

DO Limit the Amount of Dust and Dirt on Papayas

1. If dust is an issue:
    i. Roads where trailers are used to transport papayas should be wetted to control dust.
    ii. Biodegradable coatings and spray-on microfiber mulches are available to temporarily “seal” road.
    iii. If possible, transportation trailers should be covered to prevent dust settling on the papayas.
        i. These tarps should be cleaned and sanitized before storage.
        ii. When not in use, material used to cover the trailers must be dry-cleaned and stored in a manner to prevent contamination.

Pre-Harvest Contamination Sources

Papayas can be contaminated with *Salmonella* by birds, reptiles, domesticated (cattle, goats) and wild animals, amphibians, and other pests in the groves. Washing in the packing operation does not effectively remove contamination from the fruit surfaces. Instead, the water may simply spread contamination to more fruit (see Figure 1, page 17). Minimizing initial microbial contamination in the papaya groves is essential to food safety in the production of fresh papaya.

The presence of birds and other pests must be reduced as much as possible, and groves must be inspected routinely for their level of presence, locations or flocking, and activity. Preventive measures may include the use of barriers or other deterrents, minimizing wildlife attractants (such as snails or rotten/discarded fruit) and opportunities for harborage, and/or redirecting wildlife to non-sensitive areas. If animal intrusion is detected, measures must be taken to remove or prevent the harvest of any potentially contaminated papaya.

To the extent possible, papayas should be kept as clean as possible prior to and during harvest. Although papayas will be washed, the dirtier they are, the less effective washing is. Antimicrobials in the water do not work if excessive dirt and debris are in the water. The amount of dust in the groves can be dependent on season, weather, plantation age, or proximity to ground; in general, the months when there are higher amounts of dust due to dry weather may require additional steps to prevent dust deposition on fruit.

Pre-harvest Agricultural Water

DO NOT Use Water of Unknown Microbiological Quality

1. Water that will contact the fruit (during irrigation, application of pesticides, etc.) must be as microbiologically clean as possible and free from sources of contamination.
2. Only use water from sources that have been tested to show that levels of pathogens and/or indicator organisms are low.
3. Maintain the microbial quality of the water during distribution through well maintained, closed systems (e.g., do not store it in an open pond/ reservoir where it can become contaminated).
4. If microbiologically clean water is not available, growers should treat water when used for applications where water will directly contact the fruit.
    i. Effectiveness of the treatment in reducing indicator organisms to acceptable levels should be verified through scientifically valid dosing and periodic microbial testing.
    ii. Indicator organisms must be selected and shown by scientifically valid methods to reflect the tolerance level of diverse *Salmonella* subtypes.

DO Consider the Risk if Water Application Methods Result in Contact with Fruit

1. Drip irrigation is the recommended method because water does not contact the fruit, thereby reducing food safety risk as well as plant pathogen disease pressure.
    i. Drip tape should be maintained to prevent leaks and repaired or replaced if there is a large rupture(s), as water pressure can increase risk that the leaking water will contact the fruit.
2. Surface water (i.e. from rivers, ponds, reservoirs, etc.) may be used with irrigation methods in which water does not contact the fruit.
    i. If untreated surface water contacts the fruit (e.g. through leaking drip tape), the papaya must be discarded.
3. Water used for insecticides, fungicides, or other application methods in which water directly contacts the fruit must come from water sources that have been verified as acceptable through microbiological testing (i.e. potable, free of pathogenic organisms, total and fecal coliforms, as provided in the modification of NOM127-SSA1-1994).
    i. In addition to being of better microbial quality, this water has less dirt and other organic material which may react with the agrochemicals.
4. If surface water must be used for agrochemical or other direct contact application method, growers should treat the water with antimicrobials at a concentration that is effective at reducing the microbiological levels.
    i. Always check the label to determine whether the agrochemical formulation is compatible with antimicrobials, especially strong oxidizers, strong acids, and strong alkaline agents.

DO Use Valid Water Testing Methods

1. The method must accurately evaluate the water.
    i. Testing for generic *E. coli* should use a method recognized by FDA (**See "Water Testing Resources" on pg. 9)**.
    ii. Testing for coliforms should use a valid method.
2. See **Table 1** for microbiological limits for pre-harvest water, dependent on its origin and use.

Table 1: Water Use by Source

Water Source		Irrigation	Sprays	Hand washing	Wash water	Microbial limits[3]	Testing frequency
Surface[1]	Untreated	Yes, if used in drip tape with no contact with fruit	No	No	No	Coliforms: <100 CFU/ 100 mL *E. coli:* <10 CFU/ 100 mL	Monthly
	Self-Treated	Yes[4]	Yes[4]	No[5]	No[4,5]	(Tested *after* treatment) Fecal Coliforms: <1.1 MPN/ 100 ml *E. coli:* < 1.1 MPN/ 100 mL	Every 3 months
Well[2]		Yes	Yes[4]	Yes	Yes	Fecal Coliforms: <1.1 MPN/ 100 mL *E. coli:* < 1.1 MPN/ 100 mL	Every 3 months
Water Treatment Plant		Yes	Yes	Yes	Yes	Fecal Coliforms: <1.1 MPN/ 100 mL *E. coli:* < 1.1 MPN/ 100 mL	Annual (or by the government if municipal)

[1]Water from a municipal source, well, or other source that is held in an open reservoir/ pond is considered surface water.

[2]Must be established through microbiological testing to be not contaminated by external sources (e.g. surface water or sources of fecal contamination)

[3]Using an FDA recognized test method (See pg. 9). Results expressed in MPN (most probable number) or CFU (colony forming units) are considered equivalent.

[4]The Ministry of Health of Mexico requires water for use in chemical foliar application, product washing and human use to be "potable, free of pathogenic organisms, total and fecal coliforms, as provided in the modification of NOM127-SSA1-1994". (https://www.gob.mx/cms/uploads/attachment/file/475353/Anexo_T_cnico_1_compressed.pdf)

[5]In certain situations where water has undergone validated treatment to meet potable water standards required by SENASICA, self-treated surface water may be acceptable for use in post-harvest.

Agricultural Water Considerations

Agricultural water used for irrigation and crop protection can contaminate papayas depending on the water source and the way the water is used. Water originating from open sources such as a pond, river, a shallow hand-dug well, or a constructed canal has the highest risk of microbial contamination by animals or other environmental hazards. Growers must be familiar with the surrounding hazards specific to their region and environment and ensure that any subsequent mitigation adequately controls the hazards most likely to occur.

Well water can be of higher microbiological quality due to natural physical, chemical, and biological processes, only if the well is protected from outside sources of contamination through proper construction and maintenance. Depth of the well may also impact quality, with deeper wells generally of higher quality than shallow. Well water should be pumped directly to its point of use, as opposed to a reservoir or canal, to avoid additional sources of contamination. If you must store water in an open reservoir, it should be considered surface water.

Irrigation methods in which water does not directly contact the fruit (e.g. drip tape), are recommended over those that do (e.g. overhead sprinklers). To prevent water from leaking or spraying during drip irrigation, take care not to damage drip tape while walking or using heavy equipment in the groves. Inspect for animal damage due to nest building of juveniles. Flood irrigation may be acceptable depending on the height of the tree and risk of incidental contact with the fruit. If the grove floor is flooded from an uncontrolled source, including nonpoint source environmental runoff, take extra precautions to not place harvest totes on the soil or vegetated grove floor or raised berms.

Due to the tropical nature of the growing regions, insecticides and fungicides are a necessity for growers of papaya in Mexico. Because these products are sprayed directly on the fruit, water used for mixing and application should be strictly managed and of adequate microbial quality. If water is treated to meet the microbiological standards, the treatment methods must be validated and verified. Note that any agrochemical used in the production of papaya must follow all applicable regulations.

Water Treatment Resources

Several water treatment options exist, both chemical (chlorine, chlorine dioxide, PAA, etc.) and physical (filtration, UV, etc.). The cleaner and clearer the water, the more effective treatment will be. For example, dirty water will clog filters, UV treatment will not be uniform, and effective chlorine levels will be difficult to maintain. Additional research on agricultural water treatment is a critical need for the food industry.

Water Testing Resources

- SENASICA Official Mexican Standard NOM-127-SSA1-1994: http://www.salud.gob.mx/unidades/cdi/nom/m127ssa14.html
- FDA Water testing methods: https://www.fda.gov/files/food/published/Equivalent-Testing-Methodologies-for-Agricultural-Water-%28PDF%29.pdf
- FDA Water testing methods (in Spanish): https://www.fda.gov/media/114167/download
- https://agwater.arizona.edu/onlinecalc/default.aspx
- https://ucfoodsafety.ucdavis.edu/pre-post-harvest/produce-preharvest/agricultural-water

Harvest Practices

Inspect groves immediately prior to harvest for evidence of animal or pest activity.

DO Inspect the Grove Prior to Harvest

1. Immediately prior to harvest, groves must be inspected for evidence of animal/pest activity (e.g. feces, damaged fruit, etc.) or other evidence suggesting reasonable likelihood of contamination of the fruit.

DO NOT Harvest Contaminated or Dropped Papayas

1. If animal intrusion is detected, measures must be taken to remove or prevent the harvest of any potentially contaminated product.
2. Inspect groves for papaya that are visibly contaminated with animal excreta and do not harvest them. Papayas contacted by any fecal material must not be harvested. Other papaya that is immediately surrounding the visually contaminated papaya should be assessed to determine whether they are also reasonably likely to be contaminated and if so, should not be harvested.
3. Papaya that have fallen from the plant to the ground (i.e., "drops") must not be harvested. They should be handled so they do not attract animals/ pests, as noted above.
4. Damaged, soft or decayed papaya should not be harvested and packed, because they are more susceptible to pathogen growth. They should be handled so they do not attract animals/ pests, as noted above.
5. Care must be taken when removing dropped, damaged, or contaminated fruit from the grove so as to prevent cross-contamination of harvested papaya.
    i. If harvest workers touch visibly contaminated fruit, they must discard the fruit and wash their hands or change gloves prior to returning to harvest.

Do not harvest fruit if it is visibly contaminated with animal excreta

DO Limit Cross-Contamination via Harvest Equipment and Tools

1. Any food-contact tools used in the field including knives, reusable gloves, and reusable protective aprons/clothing must be on a cleaning and sanitation schedule so that contamination is not transferred between papayas.
    i. Gloves should be changed at least once per shift and in accordance with GAPs (e.g., after use of the restroom, eating, etc.).
        a. While in the process of harvesting, harvesters should avoid touching contaminated papayas or fruit that has been on the ground. If papayas have

evidence of fecal material, gloves should be changed after handling those papayas, and after handling fruit that has been on the ground.

ii. Knives and other tools used for harvesting should be regularly cleaned and then sanitized throughout the day by dipping in an antimicrobial solution.
   a. Tools that are damaged should be immediately repaired or replaced.
   b. Tools should not be placed on the ground, or must be cleaned and sanitized after touching the ground.
   c. Antimicrobial dip for harvest tools should be monitored for adequate concentration of active antimicrobial at least hourly.
   d. Tools should be placed in dip stations at every break.
   e. Thorough cleaning and sanitizing should occur after each shift, and tools should be stored to limit contamination.

iii. Protective aprons/ outerwear must be changed if contaminated (e.g., with feces). If not disposable, they should be washed through an owner-controlled program and changed at least daily.

2. If ladders are used in the field, they should be transported separately from harvested fruit, ensuring the feet of the ladder and residual soil do not contact the papayas.
   i. When using ladders, employees should be trained to not place their hands on the rungs of ladders where they step, but instead only on the sides of the ladders, both when carrying ladders as well as when climbing them.
   ii. Consider adding a grip on the side of the ladder for facilitating carrying within the grove.

DO Limit Cross-Contamination during Transportation of Harvested Fruit

1. Trailers, crates, and wheelbarrows must be properly handled in the field and must be cleaned and sanitized at least daily or in between use so that contamination is not transferred between papayas.
   i. Harvest containers (crates, wheelbarrows, etc.) must be stored in manner to prevent contamination before use (i.e. not under trees where there may be bird droppings).
   ii. Harvest crates and totes must not be placed on drip tape during harvest.
   iii. Harvest crates should not be stacked on one another if they have been placed on ground.
      i. If this is unavoidable, consider using inexpensive, single-use slip-sheets under the harvest totes.
   iv. While waiting for transport to the packinghouse, already-harvested papaya must be stored to protect from potential contamination (e.g., not under trees).

Consider using inexpensive, single-use slip-sheets under the harvest totes to minimize the transfer of soil contamination from the bottoms of crates to papayas when stacked for transport

2. Any material (e.g. paper) used for lining of crates/wheelbarrows, or used to protect fruit or during transportation to the packinghouse, must be single-use only.

3. Workers should not stand in harvest trailers unless proper controls are in place to prevent contamination from their shoes (e.g. wearing disposable protective boot coverings when in truck).

Harvest Considerations

Even if papayas are not contaminated via pre-harvest sources (water, animals, etc.), contamination may still occur indirectly through cross-contamination. For example, because shoes come into direct contact with soil in the grove that is likely to be contaminated with feces or other contamination sources, they can be a common source of cross-contamination.

Any food contact tools or surfaces (crates, wheelbarrows, trailers, etc.) used in the groves must be cleaned and sanitized prior to use. However, grower should also consider where those tools and surfaces are stored or placed immediately prior to being used. In particular, do they come into contact with the ground or uncontrolled sources of water? If so, care must be taken to prevent those surfaces from later coming into contact with the fruit. For example, a crate that had been placed on the ground should not be stacked onto another full crate of papaya.

Also consider a harvester who climbs a harvest ladder and placing their hands onto the ladder steps, rather than the sides. As they climb down, their hands will contact the same steps that their shoes have touched. If the harvest employee then immediately handles harvested papaya, contamination from their shoes may be transferred to the papaya (see Figure 1).

Points of cross-contamination within a harvest environment may not be obvious. Growers should closely analyze the movement of equipment, tools, and employees and consider where points of contact could transfer potential contamination.

Post-Harvest Handling

DO Limit the Presence of Animals/ Birds/ Pests in the Packing operation

1. If the packing operation is relatively open to the environment, netting or other barriers should be used to prevent animal activity.

DO Limit Cross Contamination During Papaya Cleaning/ Washing

1. **<u>Papayas should be as clean as possible when entering the packing operation.</u>**
2. If sponges or wash mitts are used to wipe papaya, they must be changed out at least once per shift, or sooner if the sponge becomes visibly dirty or otherwise contaminated.
    i. Sponges and wash mitts *cannot* be washed, sanitized and reused for multiple shifts or days. They must be discarded after use.

Sponges should be discarded and replaced if they are visibly dirty or are reasonably likely to lead to cross-contamination of papayas.

3. During use, sponges should be dipped in the papaya wash water with adequate antimicrobial control (see Table 2), or a separate antimicrobial solution (e.g. 80 ppm PAA; 50-150 ppm free chlorine) for a few seconds between **each** papaya to reduce the potential for cross-contamination between fruit. Employees should wear protective gloves and avoid direct inhalation of the antimicrobial solution over prolonged periods.
4. Base-stabilizing sponges or similar fruit contact mounts should also be periodically squeezed to remove excess liquids and dipped in an antimicrobial solution at least every two hours.
5. *As research on spray bars continues, and as cost is evaluated, the use of single-pass or treated recirculated water in spray bars may be lower risk than the use of sponges.*

Post-Harvest Washing and Water Use

DO NOT Use Water of Poor Microbiological Quality to Wash Papayas

1. Untreated surface water must not be used in packinghouses or other postharvest contact. Water that will contact papayas or food contact surfaces (including hands/ gloves) must meet the microbial requirement of no detectable generic *E. coli* in 100 ml water. **Refer to Table 1.**
2. If water is stored in tanks, cisterns, or closed reservoirs prior to use in the packinghouse, the storage unit must be monitored and maintained to not serve as a source of contamination.
    i. Stored water should contain 3-5 ppm free chlorine, either by addition from the papaya operation, or as a result of treatment by a water treatment facility.
    ii. Storage units should be cleaned and sanitized a minimum of every six months.

DO Maintain the Cleanliness of Wash Water Systems

1. The immersion tanks must be cleaned and sanitized, and the water changed daily or more often as needed. See "Cleaning and Sanitation of Equipment and Tools" on pg. 20 for more information.
2. Turbidity should be monitored (see Table 2).
    i. If water is monitored using a turbidity meter, individual operations should determine turbidity levels (NTU) that correlate with decreased antimicrobial effectiveness in the water, indicating water should be changed or refreshed with new water.
    ii. If water is monitored visually, refer to the photo on this page to identify the recommended turbidity level that would trigger a change.
    iii. The first immersion tank is where the most dirt/debris is sloughed off the fruit, so water used in that tank may need to be changed more frequently than water used in subsequent processes.
    iv. Smaller immersion tanks may need to be changed more frequently than larger tanks due to the more rapid buildup of soil and organic material. A minimum tank size of 1500L is recommended.

Water should be changed when there is visible buildup of dirt and organic material and/or when consistent antimicrobial levels can no longer be maintained.

Antimicrobial use is still required in spray systems so that a hostile environment on equipment is maintained that limits cross contamination, biofilm formation, and the establishment of environmental pathogens.

DO Always Use Antimicrobials in Recirculated Wash Water Systems

1. Antimicrobials must be maintained in immersion tank water and any other reused/recirculated water at all times (See Table 2). This is extremely important.
2. Operations should maintain antimicrobial levels at an operational limit that exceeds the levels required to prevent cross contamination (the critical

limits). Operational limits should be higher than critical limits to ensure that fluctuations in antimicrobial levels do not result in potentially unsafe conditions (Zhou et al., 2014).

3. **If antimicrobial levels drop below the critical limit, all affected papaya (going back to the last record of when the antimicrobial concentration was within acceptable limits) must be discarded. Affected fruit *cannot* be re-washed and considered safe.**

Table 2: Antimicrobial monitoring parameters for recirculated wash water systems

	Operational limit	*Critical Limit*	*pH*[1]	*Monitoring method*	*Monitoring frequency*	*Turbidity (Water change frequency)*
Free Chlorine	125-200 ppm	100 ppm	6.0-7.0	*Preferred:* Free chlorine in-line sensor, Titration or Calibrated probe *Alternative:* Test strip	*For titration or probe:* Beginning of shift (or immediately after water change), then every 30 min *For test strip:* Every 30 min	If NTU ≥300, 30% or more of fresh water should be added to tank
PAA	40-80 ppm	30 ppm	<8	*Preferred:* PAA in-line sensor or Titration, or calibrated probe *Alternative:* Test strip	Every 30 min	If NTU ≥600, 30% or more of fresh water should be added to tank

[1] pH should be monitored at the same frequency as antimicrobial concentration

DO Monitor Temperature of Water Supplies Used in Postharvest Applications

1. Water temperature and pulp temperature of incoming fruit should be monitored. It is recommended that water temperature in dump tanks to be maintained at least 5°C warmer than the pulp temperature of the papaya to limit infiltration of water.
    a. If papaya pulp temperature is too warm (e.g. due to prolonged exposure to sunlight), they may be stored under a shaded structure (not trees) to cool before washing).

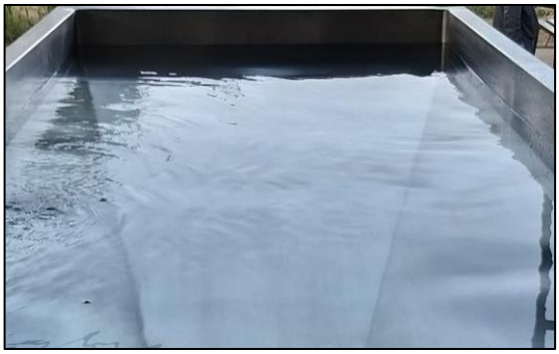
To reduce risk of infiltration, papaya must not be submerged in wash water for more than 2 minutes.

2. Papaya should not be immersed in wash tanks for more than 2 minutes or submerged more than 30 cm to minimize potential for infiltration. These recommendations assume that the antimicrobial levels in the water are being maintained and monitored.

DO Monitor Antimicrobial Levels

It is critical that antimicrobial levels be maintained. Levels can fluctuate substantially based on dirt, debris, and other factors, so levels must be monitored frequently to ensure that levels are close to the operational limit, and do not drop below the critical limit.

Best Practice

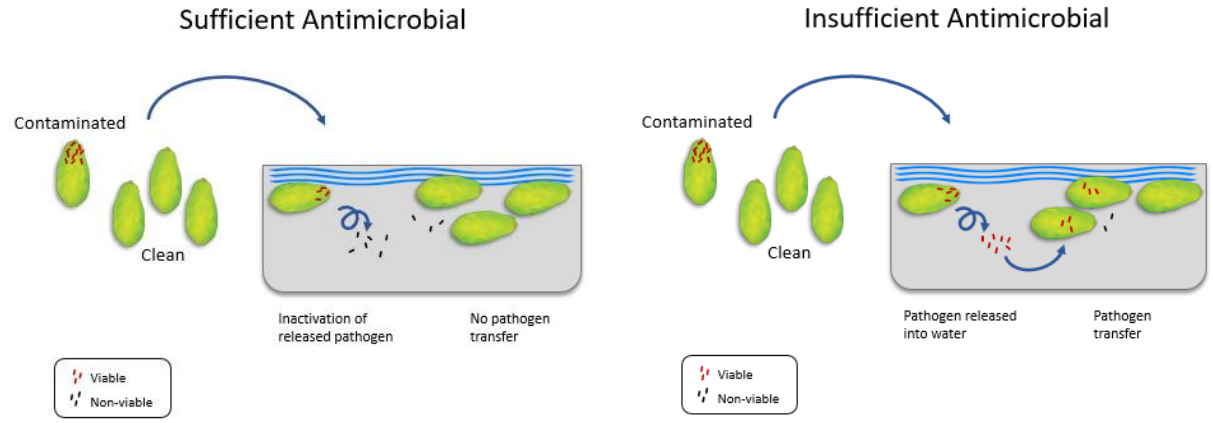


Antimicrobial levels are most effectively maintained in clean wash water.

1. Packinghouses should use calibrated probes or titration procedures to verify antimicrobial concentration.
    i. Test strips provide only estimates and are not very reliable or accurate.
    ii. ORP does not correlate with antimicrobial levels at high doses when water has organic material/ debris in it.
2. Samples should *not* be taken close to where antimicrobials are dispensed, or they will measure higher than they actually are. Instead, samples should be taken from areas expected to have the lowest reading (e.g., worst case conditions, farthest from the antimicrobial injection site, etc.).
3. If using a chlorine-based antimicrobial, free chlorine must be measured, not total chlorine.
    i. Because levels of free chlorine fluctuate, ideally, levels should be monitored continuously.
    ii. If water quality maintenance is based on *manually* monitoring chlorine levels, then free chlorine and pH must be monitored at start-up and at least every 30 minutes thereafter, and recorded, unless the operation has data that indicate that levels are maintained for longer intervals (based on worst case conditions of product volume and condition).
    iii. When monitoring antimicrobial levels electronically, the monitoring should be verified with a chemical test that measures antimicrobial levels (and pH where applicable) at start-up and at a frequency sufficient to demonstrate accuracy of the electronic measurements and recorded.
4. If using PAA based antimicrobial, total ppm should be measured.
    i. Ideal levels should be monitored at least hourly and recorded, unless the operation has data that indicates the levels are maintained for longer intervals.
    ii. When monitoring antimicrobial levels electronically, the monitoring should be verified with a chemical test that measures antimicrobial levels (and pH where applicable) at start-up and at a frequency sufficient to demonstrate accuracy of the electronic measurements, and recorded.

Alternative

1. If an operation chooses to rely on test strips, only use them when target antimicrobial levels (the operational limit) are much higher than the critical limit. Additionally, the target concentration should fall somewhere in the middle of the test strip range (e.g. test strip range of 0-300 for a target concentration of 150ppm).
    a. Always be mindful of test strip expiration dating on the container.



Antimicrobials in wash water are not intended to decontaminate fruit. Instead, they are meant to prevent cross-contamination to clean fruit. By maintaining sufficient concentrations of antimicrobials in the water, bacteria that are released from contaminated fruit will be destroyed in the water and will be unable to transfer to clean fruit. However, contamination may remain on the original fruit. Modified from Gombas et al., (2017).

Figure 1: Cross-contamination potential via wash water

Antimicrobial Use in Wash Water

If antimicrobials are not added to wash water, the water will spread contamination from one papaya to others in the tank. Antimicrobials are used to reduce this risk, but they are most effective in clean (not dirty) water. Keeping antimicrobials effective and at the correct concentration is very challenging.

The recommendations in this guide were identified based on current industry practices in the papaya industry, preliminary data evaluating antimicrobial levels used with papayas, and research on commodities with similar washing steps. ***Recommendations may change as papaya-specific research becomes available.***

2-stage systems are most common in the Mexican papaya industry, however some packers may include a third stage tank or spray bar to apply fungicide treatment.

The purpose of using antimicrobials in wash water is to limit cross contamination between papayas that may have been contaminated in the field and other papayas in the immersion tank. To the extent possible, papayas should be as clean as possible prior to entering the first immersion tank. The effectiveness of antimicrobials in wash water is greatly reduced by organic material, so every effort should be made to reduce the level of dirt and debris.

Chlorine and peracetic acid (PAA) are the two most commonly used antimicrobials in immersion tanks. Note that antimicrobials in wash water are not “sanitizers” or “disinfectants” for the papaya and cannot be relied upon to render previously contaminated papaya safe. This is why you cannot “rewash” papayas after they have been exposed to water with insufficient levels of antimicrobials.

Different types of wash systems (*e.g.*, immersion tanks and spray bars) influence the types and levels of antimicrobials that are appropriate.

Although the risk of cross contamination in a single pass spray bar system is lower than in a dump tank or flume, antimicrobial use is still required so that a hostile environment on equipment is maintained that limits cross contamination, biofilm formation, and the establishment of environmental pathogens.

Internalization

Internalization of bacteria into the fruit has been demonstrated in certain commodities (e.g. tomatoes) submerged in water without an antimicrobial. **Water adequately treated with antimicrobial is the most effective method of controlling internalization of pathogens due to cross-contamination**.

Several factors influence the risk due to immersion:

1. Contamination of the papaya surface
2. Contamination of wash water
3. Amount of time the papaya is in the water
4. Depth of the papaya in the water
5. Temperature of the water compared to temperature of the fruit

Papaya packers should avoid fruit piling up in wash tanks so it’s not submerged for too long. A submersion time of 2 minutes or less is best. If possible, it is recommended that water temperature in dump tanks to be maintained 5°C warmer than the papaya pulp temperature. Temperature control of water, and the risk of internalization, does not apply to spray bar or other processes in which papayas are not submerged.

Wash water Monitoring

Monitoring general bacterial levels in wash water is not a useful method of verifying water quality or potential for cross contamination.

Operations should establish and implement monitoring antimicrobial levels at an appropriate frequency to maintain sanitary conditions in consideration of product volume and product condition

Probes should be located, and/or water samples should be taken from areas expected to have the lowest reading (e.g., worst case conditions, farthest from the antimicrobial injection site, etc.).

Ideally, sensors would be placed on both the supply side and the return side to monitor the drop in effective dose (or pH) in closer to real-time to maintain process control.

Measuring devices must have sufficient precision to ensure levels are within established limits, and accuracy should be verified periodically to ensure that measurements, particularly those close to the established threshold, are reliable.

Chlorine "wheels" and test strips can provide directional information but generally do not have the precision or accuracy for chlorine measurements near the critical limits. In such operating ranges, facilities should use calibrated free chlorine probes or titration procedures to monitor or verify free chlorine levels. Test strips are not recommended.

If antimicrobial levels drop below the critical limit, all affected papaya (going back to the last record of when the antimicrobial concentration was within acceptable limits) must be discarded. Affected fruit *cannot* be re-washed and considered safe.

Papaya Packing

DO NOT Pack Wet Papayas

1. Wet papayas will spoil more quickly, and likely allow *Salmonella* to grow.
2. Papayas should be dried by air/ fans.
3. If cloths are used to dry papayas, they must be changed every two hours.
    i. Cloths must be washed and sanitized before re-use.

Papaya should be dry as possible prior to packing to avoid the potential for spoilage or growth of pathogens during storage.

DO NOT Re-Use or Improperly Store Packing Paper

1. Whether white paper or newspaper is used for packing, the material must be new, not previously used.
2. Materials used for packing must be single-use.
3. Packing material should be inspected upon arrival to ensure it is free from contamination and must be stored in a manner so as to prevent contamination or infestation by bugs or animals.

Sanitation

DO clean and sanitize all food contact equipment, surfaces, and tools daily

1. All food contact surfaces that must be cleaned and sanitized include, but are not limited to:
    i. Immersion tanks, conveyor belts, packing tables.
    ii. Edge of immersion tanks where papayas are set when cleaning with sponges/cloths.
    iii. Plastic trays or other equipment used to transport papaya through the packinghouse.
2. Prior to start-up, all equipment should be inspected for cleanliness to verify contamination did not occur overnight (e.g. via pests) and that the previous day's cleaning/sanitation was effective.

Cleaning and Sanitation of Equipment and Tools

Any food contact material can become a vehicle for cross contamination of papaya if not properly cleaned and sanitized, or otherwise managed.

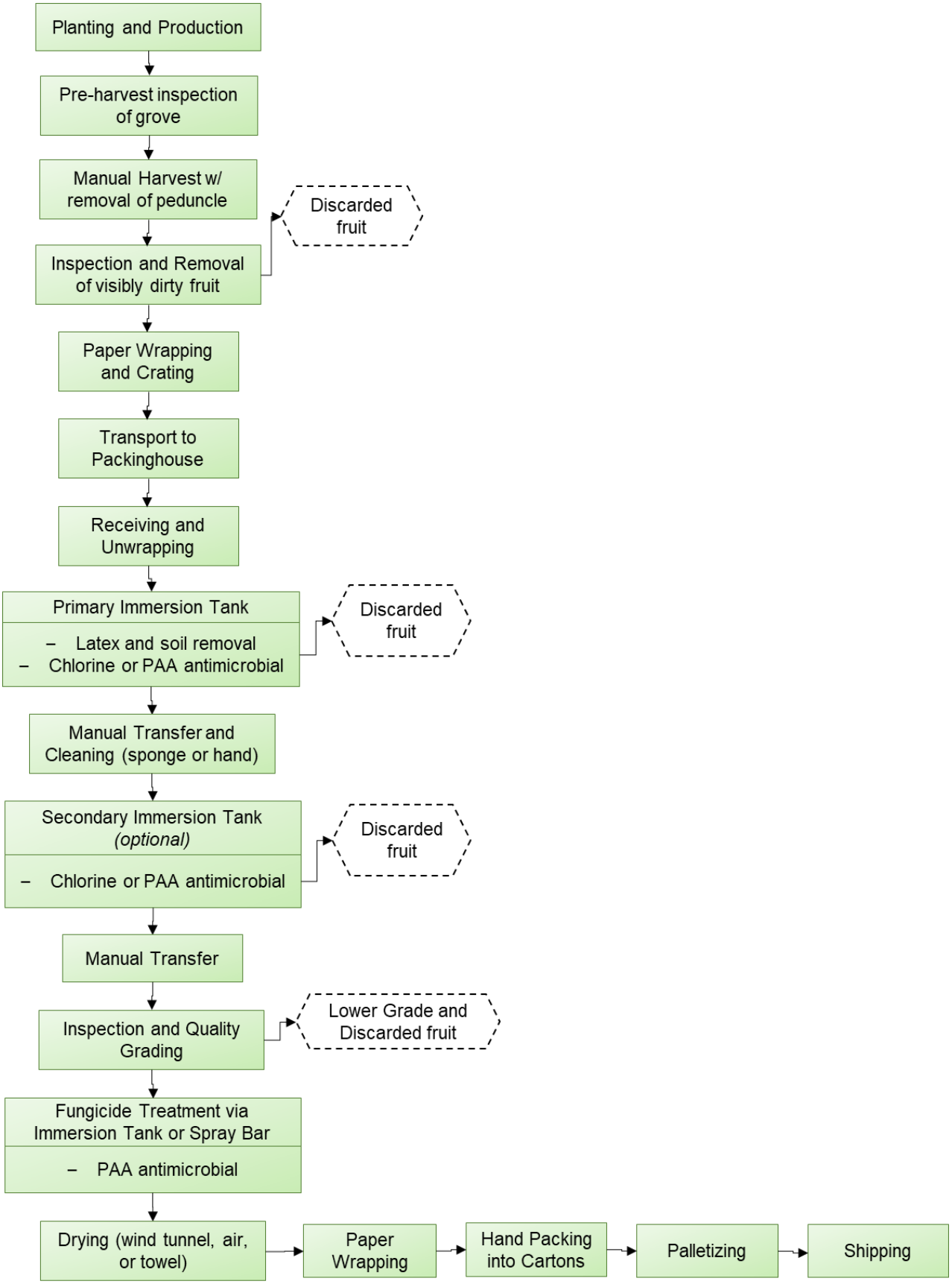
Cleaning and sanitation steps should include:

1. Dry Cleaning – removal of fruit, debris, packing material, other obvious waste material
2. Pre-Rinse with clean water– working from top to bottom
3. Chemical/Soap application- bottom to top, cover all surfaces, mix according to manufacturer's instruction
4. Manual scrubbing and cleaning – using dedicated sanitation tools/brushes not used elsewhere in the packinghouse
5. Rinse – top to bottom
6. Visual Inspection and Re-cleaning as necessary until visible dirt/ debris are gone.
7. Verify the removal of organic material using ATP swabs (e.g., 3 per shift in the areas most difficult to clean [corners, junctures, etc.])
8. Sanitize

Additional information on the difference between cleaning and sanitizing can be found at this link: Cleaning vs. Sanitizing (Cornell University Produce Safety Alliance, accessed on 3/13/20)

Appendix

Flowchart of Papaya Production



Water Treatment Monitoring Record *Template*

Name and address of farm:_____

Please see the food safety plan for overall water treatment procedures.

Date	Time	Water pH	Water Temperature	Turbidity	Sanitizer[1] (name & rate)	Corrective Action Needed (yes or no)[2]	Initials
10/14/20	*8:35 am*	*8.5*	*75° F*	*25 NTU*	*NaOCl 145 ppm*	*Yes - pH was too high, added citric acid; retested –pH 7.0*	*EAB*
10/14/20	*9:03 am*	*7.0*	*78° F*	*47 NTU*	*NaOCl 130 ppm*	*no*	*EAB*

[1]Refer to the product's label for specific use instructions.

[2]If antimicrobial levels drop below the critical limit, all affected papaya (going back to the last record of when the antimicrobial concentration was within acceptable limits) must be discarded. Affected fruit *cannot* be re-washed and considered safe

Reviewed by: _____ **Title:** _____ **Date:**_____

FSMA PSR reference § 112.50(b)(4) Confidential Record

Modified from Records Required by the FSMA Produce Safety Rule
K. Woods, D. Pahl, D. Stoeckel, B. Fick, G. Wall, and E.A. Bihn, 2019

https://producesafetyalliance.cornell.edu/sites/producesafetyalliance.cornell.edu/files/shared/documents/Records-Required-by-the-FSMA-PSR.pdf

References

- Gombas, D., Luo, Y., Brennan, J., Shergill, G., Petran, R., Walsh, R., Hau, H., Khurana, K., Zomorodi, B., Rosen, J., Varley, R., and Deng, K. 2017. Guidelines to Validate Control of Cross-Contamination during Washing of Fresh-**Cut Leafy Vegetables. Journal of Food Protection, 80 (2): 312**-330
- Secretaría de Salud. 1994. NORMA Oficial Mexicana NOM-127-SSA1-1994. http://www.salud.gob.mx/unidades/cdi/nom/m127ssa14.html. Accessed on 24 March 2020.
- Secretaría de Salud. 2017. PROYECTO de Norma Oficial Mexicana PROY-NOM-127-SSA1-2017, Agua para uso y consumo humano. Límites permisibles de la calidad del agua. http://dof.gob.mx/nota_detalle.php?codigo=5581179&fecha=06/12/2019. Accessed on 24 March 2020.
- Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria. 2018. TECHNICAL APPENDIX 1. GENERAL REQUIREMENTS FOR CERTIFICATION AND RECOGNITION OF CONTAMINATION RISK REDUCTION SYSTEMS, GOOD USE AND MANAGEMENT OF AGRICULTURAL PESTICIDES OR GOOD PRACTICES IN HARVESTING ACTIVITIES DURING THE PRIMARY PRODUCTION OF VEGETABLES. https://www.gob.mx/cms/uploads/attachment/file/475353/Anexo_T_cnico_1_compressed.pdf. Accessed on 24 March 2020.
- Zhou, B., Luo, Y., Nou, X., and Millner, P. 2014. Development of an Algorithm for Feed-Forward Chlorine Dosing of Lettuce Wash Operations and Correlation of Chlorine Profile with *Escherichia coli* O157:H7 Inactivation. Journal of Food Protection, 77 (4): 558-556.

Additional Resources

- Records Required by the FSMA Produce Safety Rule. 2019. Produce Safety Alliance. https://producesafetyalliance.cornell.edu/sites/producesafetyalliance.cornell.edu/files/shared/documents/Records-Required-by-the-FSMA-PSR.pdf. Accessed on 24 March 2020.
- Template Records in Word format. 2019 Produce Safety Alliance. https://producesafetyalliance.cornell.edu/sites/producesafetyalliance.cornell.edu/files/shared/documents/Templates.docx Accessed on 24 March 2020.
- Registros requeridos por la Norma de inocuidad de los productos agrícolas frescos de FSMA. 2019. Produce Safety Alliance. https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/9/3801/files/2019/06/Registros-Requeridos-por-la-Norma-de-inocuidad-de-FSMA.pdf. Accessed on 24 March 2020.