



3180 Imjin Road Suite 157 Marina, CA 93933

# **National Mango Board**

## **Fresh-Cut Existing Equipment Technology Literature Search**

Prepared By:

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Nathalia Tello  
Research Manager  
National Mango Board

January 12, 2024

Dear Nathalia,

The following report is designed to provide you with our work regarding our literature search and report on fresh cut existing equipment technology.

### 1. Problem:

Currently the shelf-life of Mango is a limiting factor on the consumption of fresh cut mango. Equipment technologies to extend the shelf life of fresh cut mango are instrumental in increasing the overall consumption. This search will identify relevant literature, evaluate the sources, identify products research themes, debates, deficiencies, knowledge gaps, contradictory research, the presence of puzzling anomalies, etc.

As Vandercook and Brandenburg (2023) stated, the importance of processing equipment is paramount as proper peeling and subdermal removal are VITAL to the shelf-life extension of fresh cut mango. Removing the stem side of the ends of fresh cut mango is also vital. Anywhere fibers/channels are present must be removed to completely stop browning.

Fresh cut mango does not require additional anti-browning solutions if the peel and subdermal layer are removed.

Clean cuts with a sharp knife is the best method

Subdermal removal

Peelers increased localized browning

The stem side, in particular, requires more trimming of side fibers and pore removal  
Flesh removal of oversized pores and fibers

Packaging and packaging equipment is also vital in order to minimize browning, and senescence as well as extending shelf life.

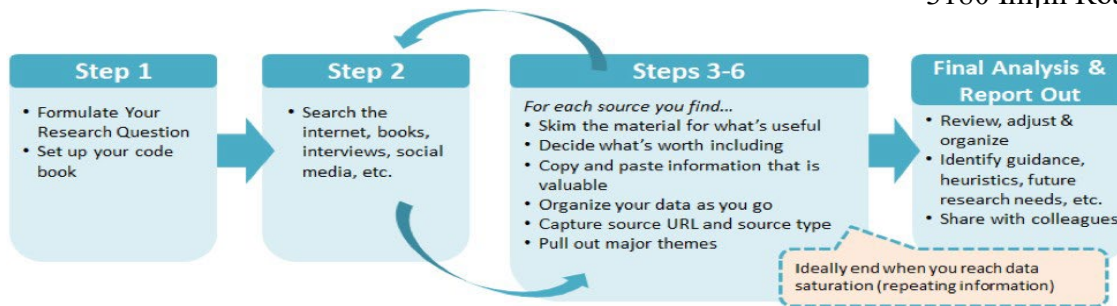
### 2. Methodology:

Our literature search and interviews will follow the six basic steps of literature research as outlined by (Pare & Kisiou, 2017).

- Formulate your research question: What fresh-cut existing equipment technology exists and what is missing?
- Search the literature
- Screen for the material you want to include
- Assess the quality of what you are including
- Extract the data
- Analyze the data



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### 3. Executive Summary:

- In order to optimize the quality of fresh cut mango, even before we get to the mechanical processing operations and equipment, there are a number of postharvest steps and treatments required to ensure that the whole fruit is in an optimal state.
- If the whole mango is not in its optimal state, then even with the best fresh cut equipment and packaging, quality will not be optimized.
- Proper peeling and subdermal removal are VITAL to the shelf-life extension of fresh cut mango.
- There is a wide selection of existing processing, packaging equipment available, and packaging to choose from.
- It is critical to understand your process, distribution channel and retail outlet in order to choose the optimal equipment and packaging.
  - The most important steps of the process include:
    - Proper application of pre treatments including 1-MCP, Firming, and Anti-browning
    - Washing in sanitized water
    - Peeling and slicing
    - Modified Atmosphere Packaging
- Sustainable packaging should also be a part of the design process.

### 4. Detail:

Liang Ma et al. (2017) state that fresh-cut fruits and vegetables, with the advantages of health, convenience, high nutrition, and flavor while still maintaining freshness, have gained great popularity among customers worldwide. This has led to a global trend of increased consumption and research investment of fresh-cut fruits and vegetables in recent years.

However, fresh-cut produce deteriorates faster than the unprocessed raw materials mainly due to the damages caused by minimally processing methods (peeling, slicing, dicing, shredding, etc.). These processing operations usually shorten the shelf life of fresh-cut fruits and vegetables by a series of typical symptoms, such as tissue softening, cut surface browning, decreased nutritional value, presence of off-flavor and microbiological spoilage during storage.

This highlights the need for proper and optimal postharvest handling, processing, and packaging in order to optimize quality and shelf life.



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#### 4.1. PROCESS

In their 'Fresh-cut Mango Best Management Practices Manual' Brecht et. (2023) detailed the processing steps for fresh cut mangos.

##### 4.1.1. Process Map

## PROCESS MAP FOR FRESH-CUT MANGOS

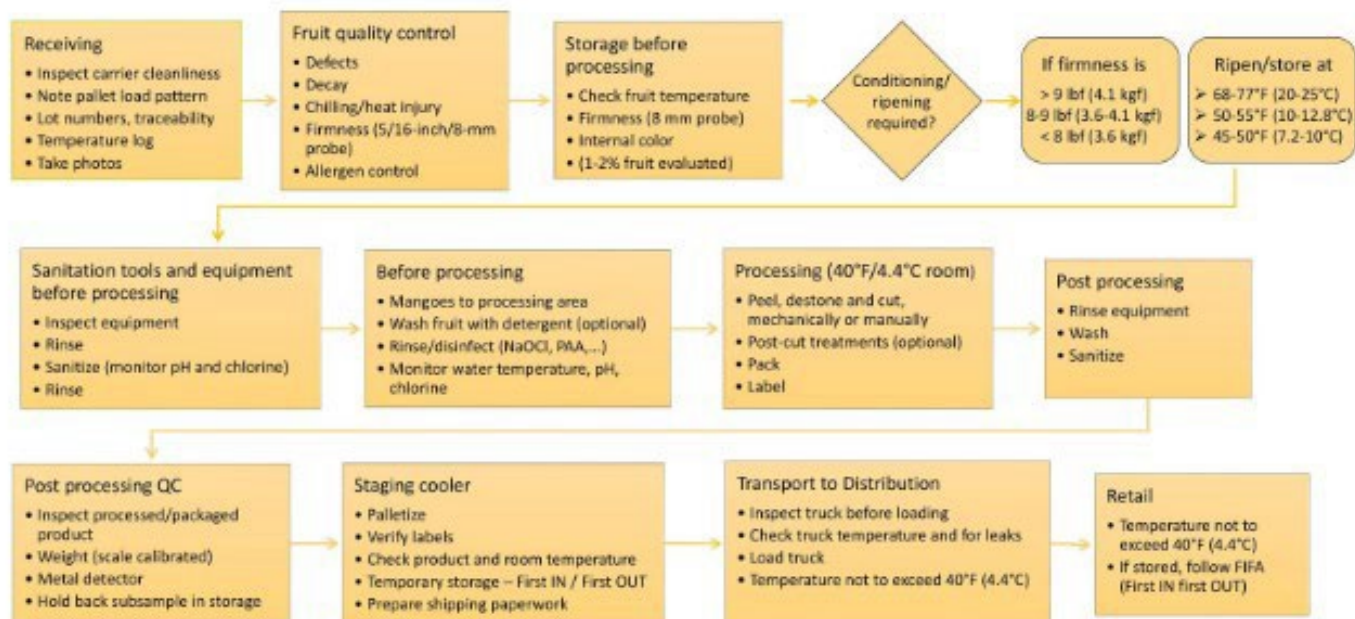


Figure 1. Process map for fresh-cut mangos.

Credit: UF/IFAS

Salinas-Roca et al. (2017) added that the requirements and processing conditions needed to get high-quality fresh-cut mango with fresh-like attributes include pre-treatments, which are applied to whole fruit, and have a considerable impact on the microbiological and sensorial quality of mango as well as the fruit metabolism.

They go on to state that minimal processing is defined as the treatment to achieve minimal changes in final product quality characteristics as well as during storage and distribution. Fresh-cut mango processing includes three basic mechanical operations: peeling, cutting, and seed removal.

Therefore, we can see that in order to optimize the quality of fresh cut mango, even before we get to the mechanical processing operations and equipment, there are a number of postharvest steps and treatments required to ensure that the whole fruit is in an optimal state.



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*Therefore, we can see that in order to optimize the quality of fresh cut mango, even before we get to the mechanical processing operations and equipment, there are a number of postharvest steps and treatments required to ensure that the whole fruit is in an optimal state.*

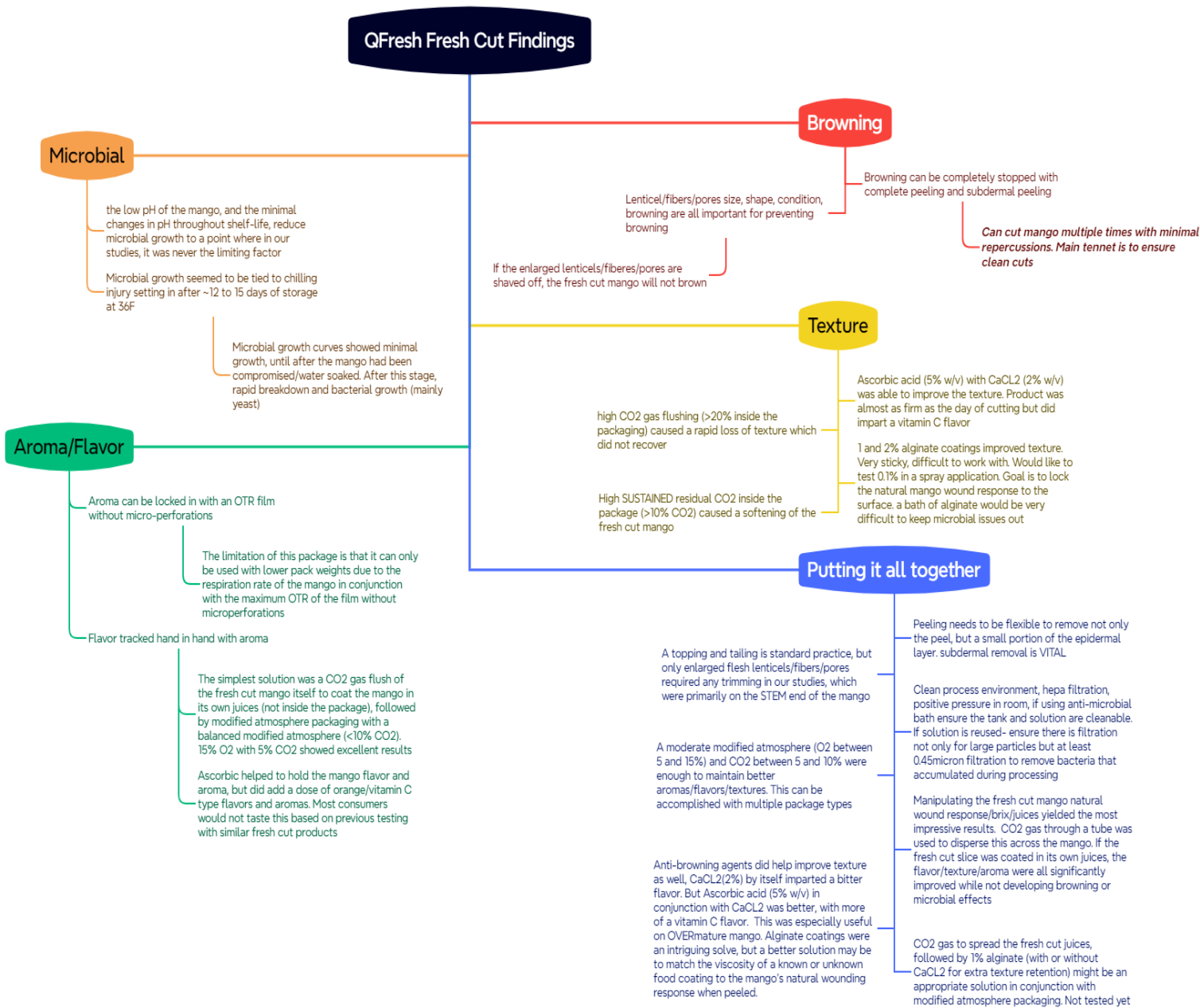
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#### **4.1.2. Qfresh Findings**

To better understand all the facets required to optimize fresh-cut mango, Vandercook and Brandenburg (2023) performed a mapping exercise and literature search. We can see from this document the importance of the post-harvest steps prior to mechanical processing and packaging.



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## 4.2. Literature Review

Literature Review Based on the mapping process, Vandercook and Brandenburg (2023) performed a literature review. Based upon the literature review, we generated the following table summarizing the main findings from available literature.

Literature Review	
Browning	Peeling — Subdermal Peel — Most studies chose an absolute subdermal peel depth to use
	Anti-browning dips and sprays — <ul style="list-style-type: none"> <li>Ascorbic Acid (2 to 5% w/v) — Naturally present in Mango, Antioxidant, synergistic to polyphenols, Heat sensitive</li> <li>Chlorine wash — Sugar Lixiviation a potential mode of action</li> <li>Alginate dip — Surface drying and modification of atmosphere</li> </ul>
	20% or more browning considered unacceptable
Microbial	Light — <ul style="list-style-type: none"> <li>405 ± 5 nm LED in storage — Reduces Salmonella, Listeria, E. Coli</li> <li>Pulsed light, 20 full spectrum pulse 80 J/cm — Reduce Psychrotroph, Y&amp;M</li> </ul>
	Sanitizers — <ul style="list-style-type: none"> <li>PAA, 50 to 100ppm</li> <li>Free chlorine- 200 to 300ppm on whole mango prior to cut — fresh cut mixed results for washing</li> </ul>
	2-5%O <sub>2</sub> and 10%CO <sub>2</sub> show micro inhibition at temp abuse storage condition
Texture	Softening caused by enzymatic activity and decompartmentalization between enzyme and substrate
	>10% CO <sub>2</sub> found to cause softening repeatedly. Time/Dose dependent
	Hydrolysis of pectic acids in cell walls
	Melatonin in one study was found to improve softening, slow RR, slow ripening and color loss on WHOLE mango
	CaCL <sub>2</sub> (2% w/v). by itself improves texture but imparts off odor
Aroma/Flavor	Low temperature= lower aroma
	pH stays steady throughout studies under multiple pack conditions
	low pH of product along with washing outside of mango prior to cutting caused low micro in most studies
	Brix increases slightly throughout studies
Modified atmospheres	2% O <sub>2</sub> along with 10% CO <sub>2</sub> seems to be what the researchers have settled on
	Superficially high O <sub>2</sub> environments (>21% to 100%) extremely negative results on multiple attributes
	Anaerobic compensation point is around 2% O <sub>2</sub> . Some studies showed positive results down to 0.5% O <sub>2</sub> though under certain conditions



#### 4.3. PRE-MECHANICAL PROCESSING STEPS:

##### 4.3.1. Post Harvest treatments

We can see from these documents the importance of the post-harvest steps prior to mechanical processing and packaging. These include:

- Postharvest Handling
- Washing
- Treatments & Coatings
  - 1-MCP
  - Firming
  - Anti-browning
- Storage Temperature

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*Li et al. (2020) demonstrated that 1-MCP was beneficial for maintaining quality. 1-MCP treatment retarded the decline of firmness, weight, total soluble solid and titratable acidity,*

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##### 4.3.2. Application of 1-MCP

In discussing 1-MCP, Li et al. (2020) demonstrated that 1-MCP was beneficial for maintaining quality. 1-MCP treatment retarded the decline of firmness, weight, total soluble solid and titratable acidity, which served as significant parameters for assessing fruit quality in the process of storage. Li et al. (2020) detail that the Mango fruit were separated into two halves at random, enclosed in a plastic container, and treated with 1-MCP, which was prepared from a commercial powder dissolved in sterile distilled water, and the final concentration was 1  $\mu\text{L/L}$  equal volume of sterile water which was used as the control. 1-MCP was dissolved in sterile distilled water at a final concentration of 1  $\mu\text{L/L}$ . The fruit were treated with 1-MCP for 24 h at 25°C and subsequently stored at 25°C and were then collected every two days, frozen in liquid nitrogen, and stored at -80°C until analysis. Three replicates per analysis were used for all measurements.

Compared with the fruit of the control group, the treatment with 1-MCP dramatically delayed the colour change of both the pulp and peel and suppressed climacteric peaks of ethylene generation and respiration speed.

They conclude that the treatment with 1-MCP dramatically retarded softening and slowed both senescence and corruption of mango fruit through protecting membrane structures from peroxidation. Additionally, ethylene production was inhibited and the respiration rate reduced in fruit treated with 1-MCP.



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#### 4.3.3. Washing:

##### 4.3.3.1. Fruit washing prior to and during processing

Brecht, Plotto, Gozalbo, and Goodrich (2023) state that before processing, fruit should be washed, perhaps multiple times, to minimize potential contamination from the fruit peel.

- Fruit should go through a cleaning line using brushes to wash any soil from the fruit surface. A fruit cleaner is recommended in the first wash, followed by one or multiple rinse steps containing antimicrobial chemicals.
- Washing and rinsing the fruit should be done in a room separate from the processing room.
- Mangos used for fresh-cut processing are usually washed at the packinghouse, but they **should be washed again** and rinsed with water containing antimicrobial (listed below)s immediately prior to processing.
- The microbial load on the fruit surface can be considerably reduced with a final rinse of water containing one of the following:
  - Chlorine (100 ppm, not to exceed 200 ppm; pH adjusted to 6.5 to 7.0),
  - Peroxyacetic acid (80–100 ppm; pH 3.2),
  - Acidified sodium chlorite (200 ppm; pH 2.5 to 2.9)
  - Sodium hypochlorite (NaOCl—bleach)
  - Calcium hypochlorite (CaCl<sub>2</sub>O<sub>2</sub>)



Figure 2. Mangos being washed with disinfecting solution. Credit: J. K. Brecht, UF/IFAS



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- Once sanitized, fruit should only be handled with clean gloves and carried from one room to another (if applicable) in sanitized containers.
- Bins and other containers should never be cleaned on the floor or direct soil, where splashes could recontaminate the container.

#### **4.3.3.2. Washing Equipment:**

There are a number of companies who have developed equipment specifically designed for washing and treating Mango.

When determining the optimal equipment to buy the following parameters should be taken into account to ensure that the equipment meets your needs:

- Sanitary equipment design
- Ease of cleaning
- Footprint
- Throughput
- Manual vs automatic
- Sanitizer addition and monitoring
- Agitation method

##### **4.3.3.2.1. PND [PND srl - Fruit Washing Machines](#)**

The PREP-WASH prewash tank is a specific tool for washing fresh fruits. In the first part of the tank, a stream of water pushes the fruit onto a modular flighted conveyor belt that allows the fruits (including non-non-floating fruits) to be treated in water. The product is moved by the bubbling motion. The prewash tank is equipped with a recirculation pump and a filtering system for water. It is also possible to adjust the conveyor belt speed. It is also designed for easy post-process sanitization thanks to the openings on both sides of the tank and the easily removable side rails.

Optional extras:

- Double filter
- Sprinkler system on outfeed lifting belt
- Blower system on outfeed lifting belt
- Complete system of conductivity and dosage control



Figure 3. Prewash tank Credit [Pnd Srl - PREP-WASH](#)

#### 4.3.3.2.2. SWC ABL Industrial Fruit Washing Systems

The Industrial Fruit Washing Machine can be used for all fruits. ABL Industrial Fruit Washing systems are stainless steel AISI 316 washing tunnels that realize a homogeneous washing of the fruits on the whole surface in the phase prior to peeling with a roller system that advances and rotates the fruit and rain spray system, making the cleaning more precise and thorough.

Moreover, ABL fruit washers have brushing which further sanitize the fruit and can be removed in case they are not necessary. The fruit can remain immersed in the washing liquid for a duration editable using a convenient knob, while the rotating filter and the water recycling tank allow it to keep it clean. ABL Industrial Fruit Washing Machines have a convenient sliding opening and cap closing system, which allows to wash the pipes and avoid the creation of bacteria.



Figure 4. Prewash tank Credit [SWC Industrial Fruit Washing Systems | ABL \(ablcavezzo.com\)](#)



#### 4.3.4. Dips coatings and treatments

##### 4.3.4.1. Alginate

In discussing dips, coatings, and treatments Vandercook and Brandenburg (2023) indicated that Alginate coatings at 1% were very promising, but have some commercial challenges in terms of viscosity, reusability and cleanliness in a tank application, but a spray application may work. The alginate coats the surface of the mango, locking in flavor/texture/aroma through 14 days of shelf-life and beyond. More research is required to find the right percentage of alginate, the right viscosity, and exactly what other treatments may work in conjunction. There is limited research in this area, but other treatments were indicated to potentially counteract the alginate coating.

##### 4.3.4.2. $\text{CaCl}_2$

$\text{CaCl}_2$  seemed to help quality by preventing browning, but also imparted bitter off flavors which most consumers would detect. Literature showed no need for modified atmosphere in conjunction, but we saw no problem using it along with MAP and saw a slightly improved outcome.

Literature: Combined effect of pulsed light, edible coating and malic acid dipping to improve fresh-cut mango safety and quality by B. Salinas-Roca, R. Soliva-Fortuny, J. Weltri-Chanes, O. Martín-Belloso [Combined effect of pulsed light, edible coating and malic acid dipping to improve fresh-cut mango safety and quality - ScienceDirect](#)

##### 4.3.4.3. Ascorbic acid (Vandercook and Brandenburg (2023))

Ascorbic acids with or without  $\text{CaCl}_2$  provided mixed results.

- Ascorbic acids are known to prevent browning in a lot of fresh-cut fruits.  $\text{CaCl}_2$  is typically used in conjunction to prevent tissue softening of the fruit.
- In one test, there was MORE bacterial growth than in control samples using ascorbic acid with  $\text{CaCl}_2$ . They do a good job of preserving color (although they do darken the samples, it happens uniformly across the mango), preserving texture, preventing browning.
- They do impart a flavor and aroma, which are not off putting but do change the natural mango flavors and aromas. It is posited that the viscosity ascorbic acid of was not high enough, penetrating the fresh cut mango and causing water soak and premature breakdown, leading to bacterial growth. They seem like a marginally effective solution that could add more problems. This testing with was performed at 5% w/v ascorbic acid with 2% w/v  $\text{CaCl}_2$ .

##### 4.3.4.4. Washing of fresh cut slices

- Vandercook and Brandenburg (2023) found that washing the fresh cut mango may or may not improve outcomes. The mango has a natural wounding response once cut, this wounding response is a sticky substance of mainly enzymes and sugars that help to seal off the cut surface of the mango. If this is washed away, other treatments (products like Apeel, washing, ascorbic acids, etc.) are beneficial to seal the outer coat of the mango and prevent dehydration and texture loss.





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#### 4.3.4.5. Antimicrobial strips

- Vandercook and Brandenburg (2023) tested using anti-microbial strips, which imparted chlorine dioxide gas (50ppm) into the package, triggered by the relative humidity increasing in the package. However, this scalded the sensitive surfaces of the fresh cut mango. The dosage would need changing for retesting. Another test using a false bottom in the tray with moisture absorption dried out the fresh cut mango excessively, in addition to scalding from the chlorine dioxide gas.

#### 4.3.4.6. PND

**The Treatment Tank** DTU has been developed for the treatment of non-floating fruits: it helps to improve the quality of the fruit by using products that prolong its shelf-life. The peeled and/or cut product is loaded via hoppers or feeding belts and is immersed in the tank and sprayed. Depending on the customer's request and the type of product, it remains immersed between 30 seconds to 2 minutes. At the end of the process, the product can be optionally dried with the blower and discharged directly into a container or repositioned on a conveyor belt for further processing. The tank and the conveyor belts have been designed so that cleaning and maintenance can be carried out in a very short time reducing labor costs.

Available Options:

- Conductivity control system
- Dosing system



Figure 5. Treatment tank Credit [Pnd Srl - DTU Tubs](#)

#### 4.4. MECHANICAL PROCESSING STEPS:

There are a number of companies that supply equipment specifically designed for processing Mango. They range from fully automatic combination equipment that peels, destones, and cheeks in one unit to more modularized systems with each process step in a separate piece of equipment. The range from 40 mangos per minute down to single cut manual equipment.

##### 4.4.1. Peeling, Pitting And Cutting

Salinas-Roca et al. (2017) state that fresh-cut mango processing includes three basic mechanical operations:

- Peeling,



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- Cutting
- Seed removal.

As Brecht et al. (2023) add that this also can be referred to as:

- Peel
- Pit
- Slice

In discussing the importance of peeling, Vandercook and Brandenburg (2023) state that their research yielded peeling and subdermal removal are VITAL to the shelf-life extension of fresh cut mango. Removing the stem side of the ends of fresh cut mango is also vital. Anywhere fibers/channels are present must be removed to completely stop browning.

- Fresh cut mango **does not** require additional anti-browning solutions if the peel and subdermal layer are removed. The subdermal layer is clearly visible on the surface of the mango after peeling, and is only a couple millimeters deep.
  1. Clean cuts with a sharp knife is the best method
  2. Peelers increased localized browning.
  3. The stem side, in particular, requires more trimming.

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Peeling and subdermal removal are VITAL to the shelf-life extension of fresh cut mango. Removing the stem side of the ends of fresh cut mango is also vital.

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Pictures of subdermal layer with improper and proper peeling:

**Not enough subdermal removed:** fibers still visible, pitted portions on surface of mango





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**Properly peeled example:**





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Brecht et al. (2023) tell us that machines to peel, pit, and slice mangos are available commercially. Machines are usually modular, with washing, sanitizing, peeling, coring, and slicing subunits.

Because mangos have a prolate (elongated) and oblate (flattened on the narrow side) spherical shape, they usually need to be placed manually on a holder. Then each fruit is rotated against a sharp blade. The blade typically goes against the shape of the fruit via sensors, and the peeling depth can be adjusted, depending on manufacturers [approximately 2 mm (5/64-inch) depth should be sufficient. If the peel depth is not sufficient, the tissue underneath is prone to browning.

Then the pit is removed with two parallel blades. Some manufacturer systems remove the pit before peeling, others after peeling.

Mango ripeness must be such that it can sustain peeling and pitting forces without disintegrating. Generally this means using stage 2 (Semi-Firm) to stage 3 (Semi-Soft) fruit. Several manufacturers of fresh-cut fruit processing machinery claim to have machines that are capable of processing fairly ripe mangos. All manufacturers claim their machines process from 20 to 40 fruit per minute, depending on the machine capacity. Mango peeling, pitting and cutting machinery must be regularly adjusted and maintained according to the manufacturer's guidelines to operate optimally (Brecht, et al., 2023).

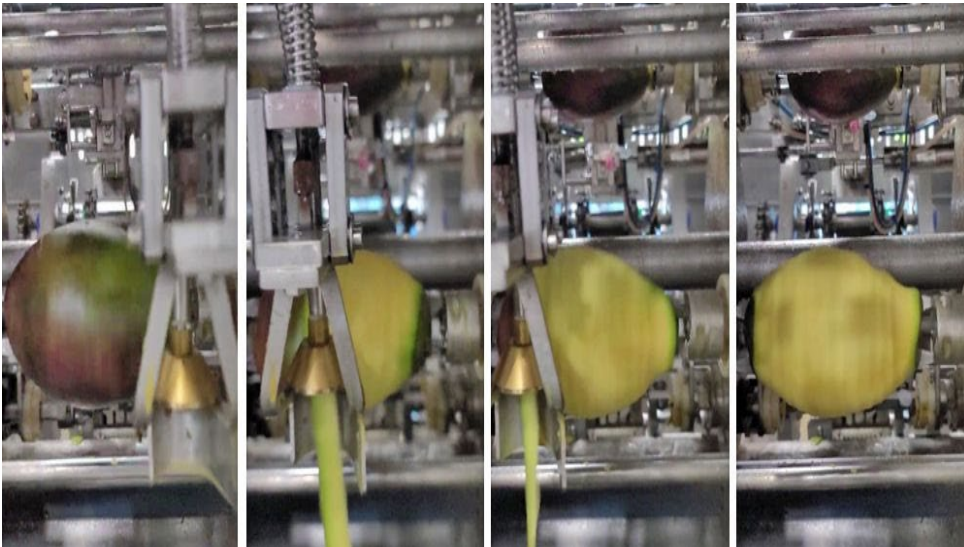


Figure 6. A machine being used to peel mangos.

Credit: Fresh Del Monte Produce, Inc.

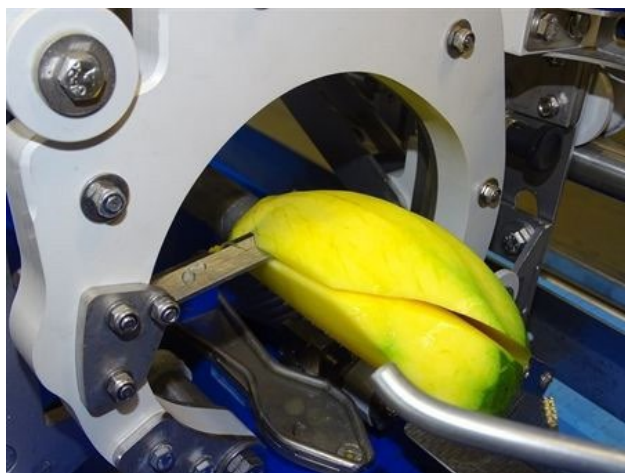


Figure 7. A machine being used to pit or de-cheek mangos after peeling. Credit: ZTI Smart Machines

While at the Fruit Logistica show in Berlin 2023 we met with three separate Mango equipment Manufacturers to discuss and view their processing equipment. The equipment ranges from large to small and from automatic to manual. All of the companies we interviewed and equipment we saw was very high quality, of sanitary design, professional and engaged. When determining which equipment is best for your operation it is a matter of which one meets your specific parameters versus the quality of one company over another.

Each has advantages and disadvantages;

<b>Mechanical Processing</b>	<b>PND</b>	<b>ZTI</b>	<b>ABL</b>	<b>Astra</b>
Advantages	High Speed, adjustable cut depth, sanitary design	Number of Sizes, Modular, unique holding method, adjustable cut, sanitary design	High Speed, programmed sequence of operations, variable cut depth	Inexpensive, small footprint
Disadvantages	Cap Cost, large footprint	Cap Cost, Large footprint	Cap cost Large Footprint	Low output, manual set cut depth



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Each are detailed below:

#### 4.4.1.1. ZTI:

##### **ZTI Mango Peeler and Cheeker**

The mango is a very tender fruit and so demands special care in processing. Conventional peeling methods fail to provide the desired result, as the fruit is often damaged. So, the Mango Peeler-de-Cheeker 40 holds the fruit not on the outside, by the fruit, but by the stone. The starting point - longer shelf-life

The fruit is peeled naturally, as if it were being peeled by hand. In other words, along the length of the fruit. The result of this peeling method is a nice authentic, smooth cut. After peeling the mango 'cheeks' are sliced with two sharp, rotating blades. This unique processing method increases the shelf-life of your product.



Figure 8. Credit ZTI: [Mango Peeler-de-Cheeker 40 - Fruit processing machines | ZTI - Smart Machines](#)



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The ZTI Mango Peeler-de-Cheeker 20 is the economical and compact version of the Mango Peeler-de-Cheeker 40. The biggest differences can be found in the method of inserting the fruit and the step-by-step movement of the main transport. The original Mango Peeler-de-Cheeker 40 processes 40 mangos per minute. The reduced version peels and destones 20 mangos per minute.

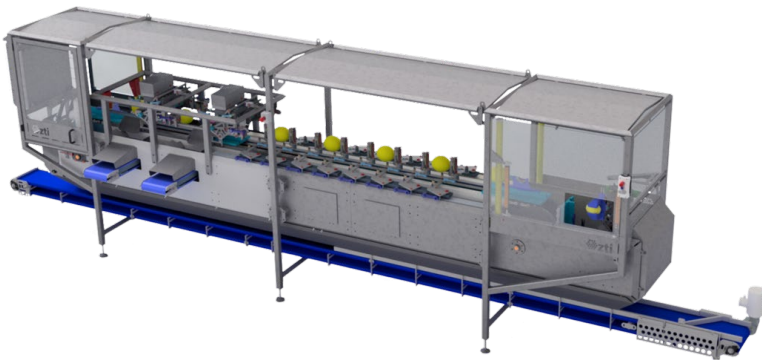


Figure 9. Credit ZTI: [Mango Peeler-de-Cheeker 20 - Fruit processing machines | ZTI - Smart Machines](#)

#### **ZTI Mango Peeler:**

The mango is a very tender fruit and so demands special care in processing. Our Mango Peeler holds the fruit by the stone during the peeling process, cutting the fruit lengthways. This leaves the pulp intact. The result is better than for a hand-peeled mango.



Figure 10. Credit ZTI: [Mango | ZTI - Smart Machines](#)

Mango Cutter



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#### **Mango Cutter:**

The ZTI Mango Cutter cuts peeled or unpeeled fruit with minimal external force. The machine is suitable for cutting peeled mango halves in dices. It is also possible to cut rectangles (fingers). The external force that is exerted on the fruit is kept to a minimum due to the cutting action of the rotating blades. No pressure is exerted on the fruit, so it retains more of its juice. Once the fruit has been cut into pieces, the tray is carefully transferred to a conveyor belt. In this way, the cubes of fruit are subject to as little processing damage as possible and are ready to be weighed and packed.



Figure 11. Credit ZTI: [Mango | ZTI - Smart Machines](#)

#### **4.4.1.2. ABL:**

Mango peeling and processing equipment <https://www.ablcavezzo.com/>

##### **ABL OP30**

The OP30 is a semi-automatic fruit processing machine that can be used to process mango, kiwi, or citrus, including orange and grapefruit. The machine can be used to peel one fruit variety at a time or even two separate fruits since it's equipped with two peeling heads. The speed is 24 fruit per minute when processing mangoes, increased to 30 when peeling citrus or kiwi. Fruits are positioned manually into the feeding cups by one operator. Two self-centering hands will center and transfer the fruit between two mandrels, these will put the fruits in rotation to allow their peeling. The ABL patented peeling head will gently perform the peeling following the fruit shape according to its dimension with the possibility to adjust the peeling depth also with the machine in function. MNG24 Automatic destoning machine for mangoes, with manual fruit feeding and direct transfer to the lower and upper cutting stations, following a programmed sequence of operations. The machine is equipped to perform an incision between pulp and stone, by means of blades properly shaped to follow the fruit profile, ensuring a high-quality standard of the final product, keeping the physical and organoleptic properties (like structure, color, taste and consistency), unchanged during the complete process. The machine performs an output up to 24





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mangoes/minute. MNG24 Mango Destoner can be connected to the OP30KM peeling machine and to the TKM Mango Cutting Machine.



Figure 12. Credit: [OP30](https://www.op30.com/) | [ABL \(ablcavezzo.com\)](https://www.ablcavezzo.com/)

#### **ABL MNG24** Mango Destoner

The MNG24 Mango Destoner can be used to process mangos. This automatic mango destoner uses manual fruit feeding and direct transfer to the lower and upper cutting stations, following a programmed sequence of operations. The machine is equipped to perform an incision between pulp and stone, using blades properly shaped to follow the fruit profile and ensuring a high-quality standard of the final product. This keeps the physical and organoleptic properties (like structure, color, taste and consistency) unchanged during the complete process. The machine performs an output up to 24 mangoes per minute. MNG24 can be connected to the Industrial Citrus Peeler OP30 peeling machine for mango and to the TKM Mango Cutting Machine, by means of the fruit collecting belt suitable for manual inspection from the operator.



Figure 13. Credit: [MNG24 Mango Destoner | ABL \(ablcavezzo.com\)](#)

#### **ABL TKM Mango Cutting Machine**

The Cutter TK can be used to process kiwi, while the TKM version the machine can be used to process mango. The industrial kiwi cutter allows for the production of kiwi slices to a predefined selected thickness as well as wedge cut/chunk. On its TKM version for mango the machine will perform chunk cutting as well as spear-cut style.



Figure 14. Credit: [TKM Mango Cutting Machine | ABL \(ablcavezzo.com\)](#)



#### 4.4.1.3. PND

##### Mango Peeling and Processing Equipment

The PLM model peeling machines are dedicated to mango and kiwi peeling. They are machines entirely built in stainless steel and materials compliant with food standards. PLMs can be configured with 4, 6 or 8 peeling heads depending on the customer's production capacity. The PLM machines are able to peel any diversity of fruit shape and size as they are equipped with a peeling system designed to obtain the maximum product yield. All the machines are electrically powered by speed-adjustable motors and by pneumatic systems which are also easily adjustable to obtain the maximum in terms of quality. The fruit is loaded into the machine manually by simply inserting the fruit into the appropriate slots. PLM machines are easy to maintain and sanitize; all consumable spare parts and all routine maintenance components are always available in a short time.

##### Relevant features:

- Peeling ability on any type of fruit ripening;
- Adjustable peel thickness;
- Production speed regulation;
- Variation of production speed and fruit rotation by inverter;
- Adjustment of the peeling finish quality;
- Simple and fast maintenance, sanitation and adjustment of the machine;
- Electrical panel built according to EEC/IP 65 standards.



Figure 15. Credit: [Pnd Srl - PL4M | PL6M | PL8M Kiwi Peelers](#)



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The **PND SS2/SS8** universal segmenting and coring machine has been designed for the coring and cutting of various fruit and vegetables.

It is a semi-automatic machine, which allows the cutting of mango into different shapes (slices, wedges, sticks) and dimensions thanks to the possibility of replacing cutters and plungers.

The operator only needs to load the product. The automatic mechanism is equipped with plungers that push the product through the cutters performing the desired cut.

The product will be collected on the included conveyor belt.

**Advantages:**

- High cutting quality
- Very robust machine structure
- Compact size
- SHAPES

**STICK:**

- 8×8 mm
- 10×10 mm
- 12×12 mm
- 15×15 mm
- 20×20 mm

**SLICES:**

- Thickness from 4 mm to 12 mm
- Max diameter fruit: 85 mm
- Max. Length fruit: 100 mm

**SEGMENT:**

- From 2 to 16 wedges with or without coring
- Max diameter fruit: 110 mm
- Max. Length fruit: 120 mm



Figure 16. Credit: [Pnd Srl - SS2 | SS8 Cutters](#)

#### 4.4.1.4. Astra Inc.

Mango Peeling and Processing equipment <https://en.e-astra.co.jp/>

This equipment is designed mor for a manual operation.

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### Three types available to meet your needs

The all-around basic model "KA-750PM", economically designed pineapple peeler "KA-720P", and "KA-730M" specialized in mangoes. You can choose the one that best suits your work and budget.

#### Our customers

- **720% productivity** at an East Asia pineapple factory
- **Peeling in front of the customers** at Taiwanese supermarkets
- **50% labor fee saved** at a central kitchen in the USA
- Japanese factories with **strict hygiene control**
- **30% less waste** at a processing factory in India



Figure 17. Credit: <https://en.e-astra.co.jp/>

#### Astra Fruit Peeling Machine KA-750PM

Can peel: Pineapple, Mango and Melon KA-750PM uses its large steel blade to peel fruits vertically. With minimal edible flesh removed in the process, product yield is increased +20% than traditional hand peeling.



Figure 18. Credit: <https://en.e-astra.co.jp/>

### Astra Mango Peeling Machine KA-730M

Can peel: Choose one from Mango/ Melon

KA-730M is the affordable priced, smaller version of KA-750PM, specially manufactured for mangoes. Possible to peel all small to large mangoes with the same speed of KA-750PM. Recommended if you don't peel pineapples.



Figure 19. Credit: <https://en.e-astra.co.jp/>

### 4.5. Manual Peeling

Brecht et al. (2023) state that in spite of improving processing speed, machines still require a certain amount of labor. Some plants prefer processing mangos manually. In this case, the processing line has workstations where the same person peels, splits the fruit along both sides of the pit, cuts and packs, or lines have workstations with specialized tasks—peeling, cutting, packing.

Most fresh-cut processors peel and de-pit the mangos manually, using knives to peel the fruit and either a knife or a de-pitting instrument with two, parallel blades to remove the pit. Complete removal of the peel tissue is critical because any remaining sub-epidermal tissue is prone to browning during fresh-cut mango shelf life.

	Manual Peeling
Pro's	Low cost, accurate, sharp knives,
Con's	Low output, people intensive, safety, training, potential large footprint

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Figure 20. Mangos being peeled by hand.  
Credit: Elena Branca, USDA/ARS



Figure 21. De-pitting and slicing of mangos by hand with a specialized instrument.  
Credit: Fresh Del Monte Produce, Inc.





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## 4.6. PACKAGING AND PACKAGING EQUIPMENT

### 4.6.1. Whole Mango prior to processing:

Modified Atmosphere Packaging, MAP, can be used on both the whole Mango as well as the fresh cut mango to increase the overall quality and shelf-life of fresh-cut Mango.

MAP used on the whole mango is often in the form of a case liner, which can be micro-perforated or utilizing a MAP technology such as Breatheway (BW) MAP. This type of packaging technology can be used to maintain the quality of the Mango during shipment.

#### Hazel Breatheway

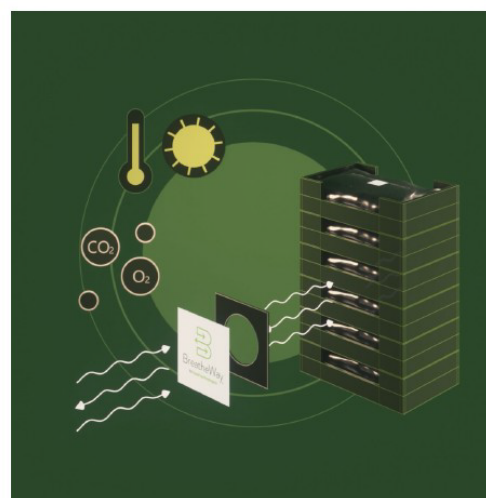
### Overview

#### What it does

Provides fresh produce with beneficial atmospheric gas ratios. The Hazel Breatheway's SMART membrane solution regulate the in- and out-flow of  $O_2$  and  $CO_2$  within packaging. This process ensures that gas ranges stay within optimal ranges through longer, riskier supply chains thereby improving quality, extending shelf life and reducing retail shrink/waste.

#### How Hazel Breatheway works

1. Hazel Breatheway envelops box or pallet of produce, creating an air-tight seal.
2. Breathable packaging of optimally balanced  $O_2$  and  $CO_2$  is formed within the packaging – adjusting to each crop's unique "respiration" rate.
3. Adjusts during temperature fluctuations - When the temperature increases outside the membrane, internal  $CO_2$  levels also rise. Breatheway's SMART membrane releases a specific amount of excess  $CO_2$  to ensure gas ratios are maintained within optimal ranges.



#### Crop compatibility



Figure 22. Credit: [Hazel Breatheway® from Hazel Technologies](#)

Shahzad et al. (2003) state from their BW MAP study that the results suggest that BW MAP protects fruit from stress as expressed by lenticel discoloration and may also protect from chilling injury in some cases.

Specifically Mango in BW MAP treatments, retained their firmness compared to the non-MAP control fruit by slowing ripening related fruit softening.

Fruit sensory quality panelists on day 4 rated the BW treatments as sweeter, less acidic, and with an overall higher eating quality and on day 10 treatment BW was rated as sweeter and juicier than the control treatment.



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### Fresh cut mango

As stated by Vandercook and Brandenburg (2023), modified atmosphere packaging improves shelf-life outcomes but is not a complete solve for fresh cut mango:

High CO<sub>2</sub> gas flushing (30%) in the package led to tissue softening earlier in shelf-life than controls. It is possible that a lower gas flush may be beneficial (10 to 15% initial but was not tested by Qfresh). Mango is not tolerant of sustained CO<sub>2</sub> >10%, so therefore is nominally beneficial. No other studies tested this concentration.

### Gases

Using food grade CO<sub>2</sub> gas from a food grade cylinder directly onto the fresh cut mango surface, followed by packing showed very promising results. It had the best texture, aroma and flavor retention of any minimal solution. It did not brown or develop microbial issues. It worked well in packaging targeting 5 to 15% residual O<sub>2</sub> and 5-10% CO<sub>2</sub> environments. Vandercook and Brandenburg (2023)

The mode of action seems to be 2-fold:

Using CO<sub>2</sub> gas directly onto the fresh cut mango with some pressure pushed the fresh cut juice around the surface. This coats the cut mango in its' own wounding response/juices evenly on the cut surfaces helping to lock in flavors/aromas/textures and prevent bacteria growth.

The next step might be to then add a coating over the top, which matches the chemistry and viscosity of the natural mango juice.

High CO<sub>2</sub> for short periods of time has a bacteriostatic effect. This is localized to where the CO<sub>2</sub> gas is used, and best of all the texture was improved. Previous studies showed PROLONGED CO<sub>2</sub> exposure caused negative texture effects. But short burst CO<sub>2</sub> gas caused extremely positive effects that lasted.

A High CO<sub>2</sub> gas application could be accomplished with air knives and a dewatering belt in a commercial setting. While mangos do not tolerate prolonged CO<sub>2</sub> in a package, they tolerated a quick flush very well. A key component of this may be the gas velocity though, as in our testing it was high enough to disperse the surface juice. It was also viscous enough that juice stayed on the fresh cut mango. N<sub>2</sub> gas and air drying had negative effects for both texture loss and microbial growth when tested side by side, so it was the CO<sub>2</sub> gas also promoting positive outcomes. Vandercook and Brandenburg (2023)

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*Moderate atmospheres (<10% CO<sub>2</sub> is most important) to improve texture, flavor and aroma but only through about 8-10 days post cutting.*

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#### 4.6.2. MAP

Moderate atmospheres (<10% CO<sub>2</sub> is most important) to improve texture, flavor and aroma but only through about 8-10 days post cutting.

Low residual O<sub>2</sub> (<5%) had mixed results in our testing. Fresh cut mango does not seem to have a high tolerance to low O<sub>2</sub> and can develop ethanol off flavors and aromas.

Sustained high CO<sub>2</sub> environments (>10% CO<sub>2</sub> for 3+ days) causes tissue softening and water soaking.

Fresh cut mango is a good candidate for breathable films with or without micro-perforations.

Larger pack sizes (>5oz) tend to outpace the breathability of the film, requiring micro-perforations to ensure package does not reach <3% O<sub>2</sub>.

Smaller pack sizes are better candidates for breathable films, as these types of films let out excess CO<sub>2</sub>, and the respiration rate of the product does not outpace the breathability of the film.

#### 4.6.3. PACKAGE FILLING, CLOSING, AND SEALING

##### 4.6.3.1. Packaging types suitable for fresh cut mango:

There is a wide variety of packaging and packaging equipment available to use on fresh cut Mango.

Selecting the right equipment and package style and geometry is critical in maximizing the quality and shelf life of the product. Although all are applicable it is critical that one chooses the optimal choice for your specific product and circumstances.

Packages can include:

- Bags
- Stand up pouches
- Trays with lidding film
- Flow wrap packages over trays

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*There is a wide variety of packaging and packaging equipment available to use on fresh cut Mango. Selecting the right equipment and package style and geometry is critical in maximizing the quality and shelf life of the product.*

---

More specifically packaging supplier NNZ, stated that types suitable for fresh cut Mango may depending on the specific circumstances include:

- Fibre and PET trays covered with OPP flow wrap package
- Single ply OPP surface bags
- PE Bags
- Stand-alone Fibre trays
- Single, two ply and PE coated paper with fiber mesh windows
- Mesh fiber windows of various sizes as well as a side mesh configuration and cotton mesh window





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- Thermoformed fiber and paper trays
- Mesh rigid tray
- Microwave cook in and steam in packaging



Figure 23. Credit: Fibre and PET trays covered with PET lidding film [Thermofibre: Innovative Sustainable Packaging Company](#)

There are many options when looking for packaging companies. Some of the more common specifically serving the fresh produce industry include:

Emerald Packaging: [Home - Emerald Packaging \(empack.com\)](http://empack.com)

Printpack: [Enhancing and Preserving Lives with Printpack's Packaging Solutions - Printpack](#)

Amcor: [Global Packaging Solutions | Amcor](#)

Belmark: [Total Packaging Solutions to Build Your Brand | Belmark inc](#)

Destiny: [Destiny Packaging](#)

Schur Systems: [Bagging Equipment | Schur® Star USA | Manual, semi- or automatic filling \(schurstarusa.com\)](#)

NNZ: <https://www.nnz.com/>

It is important to note that there is no one perfect package and all packaging types have pros and cons. This is why it is critical to understand the specifics so that the best package can be chosen.



#### 4.6.3.2. Advantages and Disadvantages of Packaging Types



### Advantages and Disadvantages of Packaging Types

Package Type	Pros	Cons
<b>Bags</b>	Modified Atmosphere- Can perforate each product individually	Prone to Mechanical Damage
	Faster Run Rates	Poor Consumer Appeal
	Anti-Fog	Doesn't fit in produce racks, falls over, marketability worse than clams
	Less Expensive	
	Resealable	
<b>Clamshells</b>	Better Protection (less mechanical damage)	Lower Run Rates
	Reseal-able	No MAP unless lidded
	Better consumer acceptance	More Expensive than bags, less than lidded clams
	Fits well in Produce racks	No anti-fog (more water droplets on front package of produce rack)
<b>Lidded Clams</b>	MAP	Slower Run Rates
	Best Shelf-life (protection from mechanical damage unlike bag along with MAP)	Added cost for lidding film and hard lid on top of film. Most expensive option. Need special equipment to seal
	Has anti-fog on lidding film, resealable	Consumer Acceptance?





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#### 4.6.3.3. Conditions of Use

**Conditions of Use defined in the Regulations**

For food-contact substances (FCSs) cleared by a food additive regulation, any temperature restriction on intended use is generally specified by reference to the Conditions of Use as defined in Title 21 Code of Federal Regulations (C.F.R.) Section 176.170(c), Table 2, which are as follows:

- Condition of Use A, High temperature heat-sterilized (e.g., over 212° F)
- Condition of Use B, Boiling water sterilized
- Condition of Use C, Hot filled or pasteurized above 150° F
- Condition of Use D, Hot filled or pasteurized below 150° F
- Condition of Use E, Room temperature filled and stored (no thermal treatment in the container)
- Condition of Use F, Refrigerated storage (no thermal treatment in the container)
- Condition of Use G, Frozen storage (no thermal treatment in the container)
- Condition of Use H, Frozen or refrigerated storage: Ready-prepared foods intended to be reheated in container at time of use
- Then in April 2006, FDA expanded its list of Conditions of Use to include Conditions I (Irradiation) and J (Cooking at temperatures exceeding 250° F),

The graphic also features a color-coded bar at the bottom with four segments: green, blue, red, and yellow, corresponding to the conditions listed.

#### 4.6.3.4. Equipment

Equipment can include both **Horizontal and Vertical configurations**. There are pros and cons of each type of equipment. Equipment choice is dependent on a number of parameters including.

##### Vertical Form Fill and Seal (VFFS):

- Smaller floor footprint
- Generally higher run speeds/output
- Longer drop height, which could cause bruising Flexible bag
- Less physical protection
- Can be configured to run plastic or paper
- Multiple seal configurations depending on packaging substrate

There are multiple equipment supplies for VFFS equipment including but not limited to:

- Illapack: <https://www.ilapak.com/>



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- Hayssen: [Bag Sealing Machines for Packaging Lines | BW Flexible Systems | BW Flexible Systems](#)
- Triangle: [Vertical Form Fill Seal | Sanitary VFFS Baggers | Triangle Package Machinery](#)
- Viking Masek: [Vertical Packaging Machines | Vertical Form Fill Seal Machinery | VFFS Machines \(vikingmasek.com\)](#)
- Matrix: [Vertical Form Fill Seal Equipment - Vertical Form Fill Seal Baggers | VFFS Machines | Matrix \(matrixpm.com\)](#)
- WeighPack: [WeighPack | Automated Weighing & Packaging Machines](#)

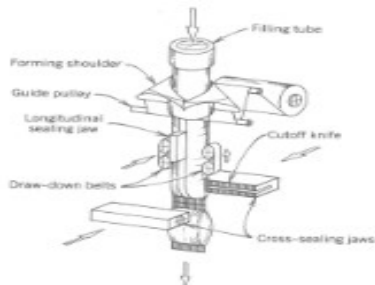
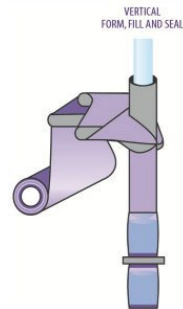


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## Vertical form fill & seal (VFFS)

- Film is mounted around a tube
- Seals at the back with a lap or fin seal usually
- Rapid
- Adaptable to a wide range of films
- Works well for foods that can fall (e.g. chopped lettuce)

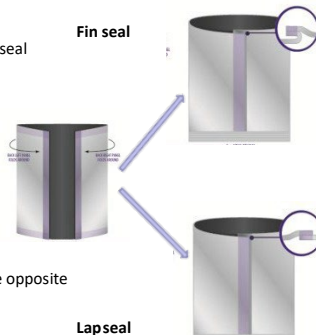


## Seal type for pillow packs

### ❖ Fin Seal

Inside surfaces of the film meet and seal against themselves.

Fin seal



### ❖ Lap Seal

Inside surface of the film seals to the opposite or outer surface of the film.

Lap seal



## Seal type

### ❖ Zipper

can be placed on roll stock, resulting in more flexibility during manufacturing, or can be atomically applied at forming of the bag.

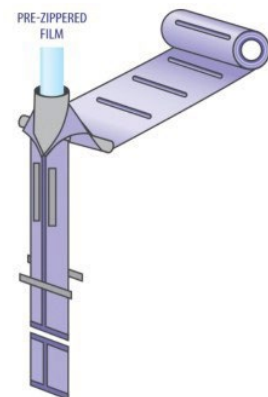




Figure 24. Ilapak: Packaging equipment <https://www.ilapak.com/>

#### Horizontal Form Fill and Seal Tray Sealer format:

- Larger floor footprint
- Generally lower run speeds/output
- Shorter drop height which should minimize bruising Tray with a lid
- Greater physical protection
- Can be configured to run plastic or fiber trays Polymer lidding film

There are multiple equipment supplies for VFFS equipment including but not limited to:

- Multivac: <https://us.multivac.com/en/>
- Reiser: [Reiser | Produce Packaging](#)
- Paxiom: [Vegetable Packaging Machines | Fresh Produce Solutions \(paxiom.com\)](#)
- Proseal: [Proseal | Tray Sealing Machines | Packaging Solutions](#)
- Platinum Packaging: [Packaging Machinery Manufacturer Company - Platinum Packaging Group \(platinumpkggroup.com\)](#)





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## Horizontal form fill & seal (HFFS)



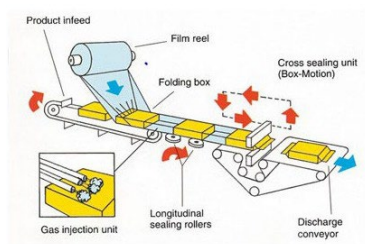
Figure 25. Credit: Multivac: Packaging equipment <https://us.multivac.com/en/>



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## Horizontal Form Fill and Seal Flow Wrap configuration

### Horizontal form fill & seal (HFFS)



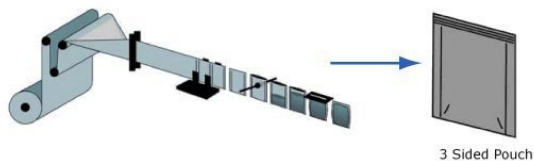
- Uses one film that is folded on itself
- Filled with product
- Sealed at back, front or both ends
- Fast and economical



## Horizontal Form Fill and Seal Flow Pouch Configuration

### Horizontal form fill & seal (HFFS)

Horizontal Form, Fill, and Seal



- Uses one film that is folded on itself
- Filled with product from top
- Sealed at back, front







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#### 4.7. SUSTAINABLE PACKAGING:

In today's environment, sustainable packaging options must be a part of the decision matrix to determine the optimal package.

As is discussed by the Sustainable Packaging Coalition there are certain criteria that must be met  
Sustainable Packaging Criteria

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**TABLE 23.3**

#### **Sustainable Packaging Criteria<sup>a</sup>**

- Is beneficial, safe and healthy for individuals and communities throughout its life cycle
- Meets market criteria for performance and cost
- Is sourced, manufactured, transported and recycled using renewable energy
- Optimizes the use of renewable or recycled source materials
- Is manufactured using clean production technologies and best practices
- Is made from materials healthy throughout the life cycle
- Is physically designed to optimize materials and energy
- Is effectively recovered and utilized in biological and/or industrial closed loop cycles

*Source:* Sustainable Packaging Coalition, 2011. [www.sustainablepackaging.org/](http://www.sustainablepackaging.org/)

<sup>a</sup> No ranking is implied by the SPC in the order of criteria.

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Figure 26. Credit: [Sustainable Packaging Coalition – For People + The Planet](#)

In addition, the total lifecycle of the packaging should be taken into account



## Advancing to a Circular Economy



Total Lifecycle  
Figure 27. Credit: Qfresh Lab

There are a number of ways to achieve sustainable objectives. Like choosing the optimal package and packaging equipment, there is no optimal answer and all options have pros and cons. It is therefore critical to evaluate all of the options and choose a technology(s) which best reaches your goals and meets the requirements of your mango product and situation.

### 4.7.1. Recycling and Recyclability:

- Despite the widespread use of plastic films, it is mainly the rigid plastic packaging materials that are recycled, with PET providing the greatest tonnage, followed by HDPE and PP.
- Sorting is the critical step in plastic packaging recovery, determining the purity and ultimately the value



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of the secondary raw materials

- Most sorting of plastics is still done manually at an MRF although there are large variations between and within countries.
- Chemical recycling (also known as solvolysis) is much more complicated and energy intensive than mechanical recycling. It involves breaking down the polymer chains by treatment with chemicals and two technologies are used commercially: methanolysis and glycolysis.

Companies who are leading the way in Post Consumer Recycled content:

Charter Next generation: [Home - CNG \(cnginc.com\)](http://cnginc.com)

[NOVA Chemicals and CNG Scale Up Use of Post-Consumer Resin | NOVA Chemicals](#)

Emerald Packaging: [Home - Emerald Packaging \(empack.com\)](http://empack.com)

#### 4.7.2. Composting

### TIPA Films:

Packaging that acts like plastic, with the same disposal as organic material



Figure 28. Credit: <https://tipa-corp.com/>

#### 4.7.2.1. Industrial vs. Home Composting

## What is the difference between industrial and home compostable?

If a plastic product is labeled “compostable,” can we add it to our home compost pile?

No. Unless the label indicates that the product is okay for home composting, you should not try to compost it at home. Plastic that is labeled as compostable is generally intended to be sent to an industrial or commercial composting facility which has higher temperatures and different breakdown conditions than those found in a typical homeowner's compost bin. If your community has a residential compost collection program, check with your local government or recycling company to find out if they will accept compostable plastic under this program.



## Assessing Biodegradability of Biobased Polymers

- Two key steps occur in the biodegradation of polymers. First, a **depolymerization** chain cleavage step (hydrolysis and/or oxidation may be responsible) converts the polymer chain into smaller oligo-meric fragments. The hydrolytic or oxidative processes may be promoted biotically (in biological pathways) and abiotically (in nonbiological pathways), with oxidation usually a slower process than hydrolysis.
- The second step (known as **mineralization**) occurs inside the cell, where oligomeric fragments are converted into biomass, minerals and salts, water and gases such as CO<sub>2</sub> and CH<sub>4</sub>. The biodegradation of plastics depends on both environmental factors (i.e., temperature, moisture, oxygen and pH) and the chemical structure of the polymer or copolymer.
- Complete biodegradation of the product is commonly measured through respirometric tests such as in ASTM D5338, which is equivalent to ISO 14852.
- It comes as a surprise to many people to learn that certain natural materials do not meet these standards, for example, a leaf will not naturally biodegrade within the time frame allowed by either D6400 or EN13432.

Robertson, Gordon L. Food Packaging. Available from: VitalSource Bookshelf, (3rd Edition). Taylor & Francis, 2016.



## Assessing Biodegradability of Biobased Polymers





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## 5. Conclusion and Next Steps:

The optimal quality of fresh cut mango is dependent on proper practices, equipment and technology from growing thru the use of the final package. Attention must be given to post-harvest handling, post-harvest treatments, processing, and packaging equipment as well as packaging technology.

There is an abundant choice of processing and packaging equipment; making the optimal choice directly dependent on knowing the entire distribution chain and requirements that the fresh cut mango will face.

Sustainable packaging and practices should be incorporated into the decision matrix. The technology and status of sustainable packaging technology is constantly evolving. As such it is important to stay on top of this evolution so that the most up to date technology and systems can be applied.

Thank you again for the opportunity to submit this report.

If you have any questions or require any additional details, please don't hesitate to contact us.

Best Regards,

**Jeff**

Jeffrey Brandenburg

Founder/Partner

The Qfresh Lab

**Eric**

Eric Vandercook

Partner/Lab Director

The Qfresh Lab



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 Book Editor(s): Muhammad Siddiq, Jeffrey K. Brecht, Jiwan S. Sidhu  
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Multivac: <https://us.multivac.com/en/>

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