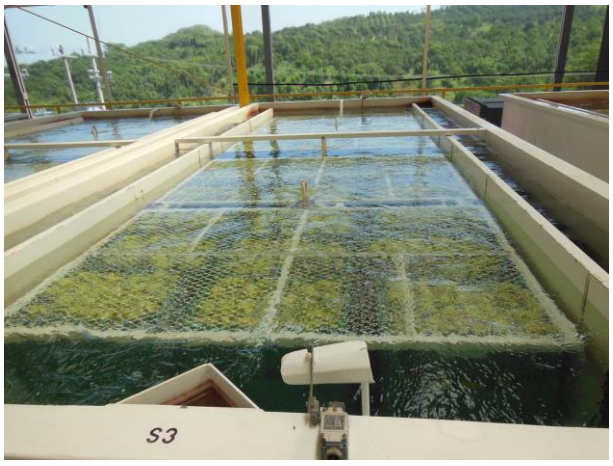
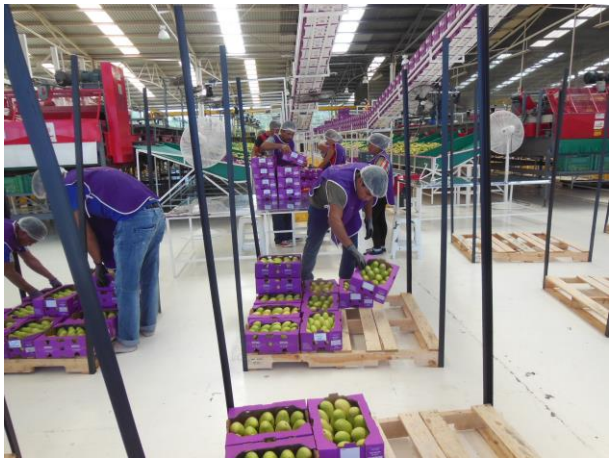
AGREEMENT INIFAP-NATIONAL MANGO BOARD

DIAGNOSIS OF THE EXPORT MANGO CHAIN FROM HARVEST TO REFRIGERATED SHIPPING

(February 2018 – March 2019)





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SUMMARY

The United States imports mango from Brazil, Peru, Ecuador, Haiti, Guatemala, and Mexico with an approximate volume of 120 million boxes, which implies diverse management and, therefore, different levels in the initial quality, shelf life and quality at consumption. The objectives of this study were to make a diagnosis of the practices that are carried out from harvest to the refrigerated shipment, including all the practices done in the packinghouse. As well as, to develop a protocol on the best recognized practices in the packinghouse to deliver a mango of excellent and consistent quality. A survey was designed including all operations from harvest to loading the truck or container for shipment to the United States. This survey was applied to 19 partners of EMEX, A.C. in Mexico, four packers in Guatemala, one in Ecuador and one in Peru. The survey (which consisted of 67 questions), was conducted in electronic format with specific questions and multiple-choice answers, through the Internet and when necessary, a few were made face-to-face. It was found that the relevant points that most impact on the initial quality, shelf life and quality at consumption of fresh mango fruit are the following: 1. Flowering and harvest, 2. Placement of the boxes during harvest, 3. Washing of fruit in orchard to prevent latex injury, 4. Washing of fruit in the packinghouse, 5. The quarantine hot water treatment (QHWT) and the hydrocooling, 6. The rest after QHWT and hydrocooling, and 7. Cooling temperatures in cold room and / or refrigerated shipping. For each of them, recommendations and suggestions are given, which are reflected in the Manual on the best practices of exporting mango from harvest to trailer or ship container.

BACKGROWN

The United States imports mango from Brazil, Peru, Ecuador, Haiti, Guatemala, and Mexico with an approximate volume of 120 million boxes. Mexico is the main exporter with 65% of the traded volume (USDA-FAS, 2018).

This diversity of mango exporting countries causes different degrees of fruit quality and even happens for exporters in Mexico. In Mexico, the packers are organized through the association of mango packers for export (EMEX A.C., 2018) with 64 packers nationwide. Although they are grouped and administered by their own regulations, most packers carry out different activities for packing the exporting mango, which affects the initial quality, shelf life and quality at consumption.

There are different harvest criteria, influenced by market demand and competition between growers and packers. After harvesting, there are different mechanisms for moving fruit from orchard to the packinghouse. There are from double-wheeled trucks with a capacity of 250 to 300 boxes, up to a trailer with a capacity of 1000 boxes. Of course, the moving times vary from a few hours to 2-3 days. In most cases, the fruit arrives at the packinghouse on the same day of harvest; it is washed and the next day is subjected to QHWT, hydrocooled and packed.

However, in fruit washing there are also many differences, some people use washing by immersion or by sprinkling recycled water from a tank. There are those who use detergents or disinfectants and the times of water use of the water varies a lot. There are those who change the water after washing some 600 boxes, but some people wash up to 3000 boxes with the same water.

In relation to the QHWT, all of them follow the USDA-APHIS (2010) rule in the lower limits (115 ° F), but there are differences in the upper limits, which can vary up to 3 °F. Regarding hydrocooling, there are packinghouses that do not have hydrocooled tanks, but those that have it vary in hydrocooling times from 10 to 40 minutes with or without disinfectants. Then comes the selection process and packaging, there are those who have automatic sorters by size and color, and those who do it manually.

All these differences cause different degrees of quality, which have not been systematized or quantified. Thus, the objectives of this study were to make a diagnosis of the practices that are carried out from harvest to the refrigerated shipment, including all the practices done in the packinghouse. As well as, to develop a protocol on the best recognized practices in the packinghouse to deliver a mango of excellent and consistent quality.

HYPOTHESIS

- The diagnosis will allow us to observe deviations and propose solutions to improve the handling of exporting mango.
- The Manual on the best practices of exporting mango from harvest to trailer or ship container will allow packers and growers to harvest the fruit in its optimal quality state, to prevent contamination risks, to maintain the quality during packing and shipping, as well as, to satisfy consumer demands and increase mango consumption.

METHODOLOGY

A survey was designed including all operations from harvest to loading the truck or container for shipment to the United States (Annex 1). This survey was applied to 19 partners of EMEX, A.C. in Mexico, four packers in Guatemala, one in Ecuador and one in Peru. The survey (which consisted of 67 questions), was conducted in electronic format with specific questions and multiple-choice answers, through the Internet and when necessary, a few of them were made face-to-face. Once the surveys were obtained, the information was analyzed using descriptive statistics using measures of central tendency (mean, mode), dispersion measures (maximum, minimum, coefficient of variation) and description of data by relative frequency histograms. It is expected that the analysis of the information will provide data to detect deviations and the comparisons will help to establish recommended practices in order to improve the whole chain.

RELEVANT RESULTS

The questionnaire applied to the packers consisted of 67 questions. The order considered was chronological from flowering to harvesting, packing and placed in a refrigerated truck for shipment to the wholesaler in the United States. Then, in that same order, the relevant points that affect the initial quality, shelf life and quality at consumption of fresh mango fruit are highlighted.

1. Flowering and harvesting:

One of the most relevant and striking aspects of mango cultivation is the decision of harvesting time. Although 80% of packers answered they used to record and monitor the flowering process in their orchards, 100% stated that their main criterion for harvesting is the aspect of size and color of the fruit. That is there is no specific monitoring of the flowering, fruit set and fruit development process and only 16% take into account the number of days after flowering (DAF) as harvest criteria.

It is fully recognized that maturity at harvest determines the quality at consumption of mango fruit. Those fruit harvested immature (unripe or low), never will reach the attributes of quality (color, taste, smell) required by the consumer. Several harvest indices are visually recognized, such as size, shape and color of the fruit. Also, shoulder development, formation of the cavity at the base of the peduncle, increase in size of lenticels, and cheek filling, among others. Unfortunately, recognizing these characteristics requires years of experience and not everyone can have them, so it is essential to sample with objective measurements of pulp color, acidity or total soluble solids content (°Bx), which, although destructive, they help to determine the optimum moment of harvest. In addition, the technique of Heat Units Accumulation (HU) generated by INIFAP in Nayarit indicates that the optimum harvest time is 1,600 HU for Tommy Atkins and Ataulfo, 1,800 HU for Kent and 2,100 to 2,200 HU for Keitt (Osuna, 2019). This technology is quite simple, economical and easy to use. It consists of placing a temperature and relative humidity recording device (Hobo Pro V2 Onset Corp), before the start of flowering and programmed to capture data every 30 minutes.

The start of HU accumulation in a given flowering flush begins at full flowering (when most panicles of a flush are in anthesis, that is, they show at least 50% of the flowers open) [Figure 1]. The survey states that up to three flowering flushes can be presented (64%), so there will be up to three 'zero moments' or start of HU accumulation. If the flowering process is monitored, it will be observed that the first flush is about 8 to 15% of the tree canopy; the second, which is the main one, represents 60 to 70% of the tree canopy and the third, when present, it signifies 15-20% of the tree canopy. The accounting of HU is done through the software HOBOware (Onset Computer Corp), which allows us to export the registered data to an Excel sheet and the accumulated HU are calculated with a base temperature of 10 °C (Osuna et al., 2007) . The use of this technology allows us to harvest higher caliber fruit, to increase the yield up to 2 ton / ha, to improve shelf life and to have fruit with higher content of °Bx at consumption, satisfying consumer demands.

Figure 1. Tree and panicles in full flowering stage, start of 'zero moment' and begin accounting HU accumulation.

Recently, in Ataulfo mango, a non-destructive technique has been investigated to determine the optimum harvesting time. With the use of the F-750 spectrometer (portable equipment that uses near infrared spectroscopy) and taking as indicator the skin color, it is possible to determine with an $R^2 > 0.90$ the ideal moment of harvest in fruits of this variety (Figure 2).

Figure 2. Determination of maturity in 'Ataulfo' mango through spectrometry.

2. Placement of boxes during harvest:

Even though most of the packers stated that when they harvest they use plastic boxes. They say these boxes are placed in the shade and without touching the ground directly, however, the evidence of photographs (Figure 3) shows the opposite. The disadvantage of placing fruits in the sun is that due to heating the fruit reach more than 40 °C, causing increased respiration and ethylene production, which can be so severe. It is thought that, for every hour of the fruit exposed to the sun, fruit have one less day of shelf life. On the other hand, the direct contact of the boxes with the soil can increase the probability of microbiological contamination.

Figure 3. Placement of mango boxes during harvest.

3. Fruit washing in the orchard to prevent latex injury:

Only a small percentage of packers surveyed said they washed the fruit in the orchard, specifically 40% in the case of 'Ataulfo'. Results of research carried out in Nayarit indicated that the latex exuded during the first 30 seconds is the most corrosive and for the latex with the longest exposure time (from 10 min to 4 h), significant differences were detected among varieties, with 'Ataulfo' being the most sensitive, 'Haden' and 'Tommy Atkins' moderately susceptible and 'Kent' the most tolerant. To prevent latex injury in 'Ataulfo', the fruit should be washed with water + liquid washing detergent (1 l / 1,000 l of water) preferably immediately after harvest or after two hours, because afterwards the damage is irreversible. The rest of the varieties can tolerate up to six hours in contact with the latex without irreversible damage (Osuna et al., 2000). There are other options to prevent and reduce latex injury: sodium chloride (5.0%) and calcium hydroxide (0.5 and 1.0%) for 5 min; alum (0.5 and 1.0%); use of Agral®, Cold Power®, Mango Wash® detergents; sodium hydroxide (2.0%); cut with peduncle > 5 cm length and remove peduncle after 24 h; desapping for 20 min up to 4 h; Lemon (0.5%); Sodium bicarbonate (1.0%): Tween 80; Ether Sodium lauryl sulfonate or sodium hypochlorite (0.1%) or dry decolorized; Commercial or enzymatic detergent (0.1%); Sodium carboxymethyl cellulose and sodium lauryl sulfate; wax coating based on polyethylene; DC Tron (100-1000 µL / L) [Osuna, 2018].

Figure 4. Details of application of washing dishes detergent.

4. Fruit washing in the packinghouse:

With regard to the fruit washing in the packinghouse, most washes the fruit by sprinkling with recycled water + detergent + disinfectant from tanks with a maximum capacity of 2,000 l. The majority of packers have only one washing line, which means that more than 59% of them wash between 1,200 and 1,800 field boxes of fruit during a single washing cycle. This causes the potential for microbiological contamination to be very high, so work was established to determine the effectiveness of chlorine as a disinfectant, possible damage to fruit at high concentrations and determine the effectiveness of chlorine in long-term wash water. It was found that chlorine at 20 ppm was effective to eliminate total coliforms and total aerobic bacteria without affecting fruit quality even at initial doses of 200 ppm. The initial concentration of chlorine at 200 ppm is reduced to only 10 ppm at the end of a wash cycle of 600 boxes (which is normally the capacity of the truck that transports fruit from the orchard to the packinghouse). In addition, the chlorine in water from prolonged use washing could be used for up to three cycles (carrying 200 ppm at each cycle start), although it is advisable to change the water at the end of each washing cycle of 600 boxes (Osuna et al., 2019).

Figure 5. Details of fruit washing in the packinghouse.

Table 1. Effectiveness of chloride as a disinfectant.

	Initial	
Treatment	**Total Aerobia Bacteria**	**Total Coliforms**
Control	10^3	+
10 ppm	10^2	-
20 ppm	-	-
30 ppm	-	-
40 ppm	-	-
50 ppm	-	-
NOM-127-SSA	< 200 Col/ml	-

Table 2. Determination of chlorine injury.

	Initial	
Treatment	**Total Aerobia Bacteria**	**Total Coliforms**
Control	10^3	+
50 ppm	-	-
100 ppm	-	-
150 ppm	-	-
200 ppm	-	-
NOM-127-SSA	< 200 Col/ml	-

Even though 60% of the packers said they washed the field boxes after each use, a high percentage declared washing them only at the beginning of the cycle. This is a critical factor for contamination of the just harvested fruit, because from mid to late season the boxes are so dirty that they are not only a potential source but also a real source of contamination, since they present microbial loads of 10^6 total aerobic bacteria. If the field boxes are washed and disinfected after each use, this contamination problem would be greatly reduced.

Figure 6. Field boxes with potential of microbiological contamination (A, B) and illustration of box washing before returning to the field.

The answer to the question of whether high chlorine concentrations affected fruit quality characteristics, is shown in Figure 7. It was observed that even at 200 ppm, none of the quality characteristics was affected, since no significant differences were detected among treatments for none of the variables. This shows that initial concentrations of 200 ppm of chlorine do not affect the quality of the fruit, which was the fear of the packers. In addition, the Figure 8 illustrates the drop of the chlorine concentration in washing water. Other alternatives of disinfectants in process water in packinghouses, in addition to sodium hypochlorite at 200 ppm, are peroxyacetic acid (80 ppm) or chlorine dioxide at 5 ppm, although the latter was not as stable (Amalaradjou, 2017). However, Castro del Campo (2015) stated that chlorine dioxide eliminated *Salmonella sp* at 5 ppm and that it was equal to sodium hypochlorite at 200 ppm. She also stated that copper (at 8.5 and 12.5 ppm) controlled *E. coli* in QHWT tanks. In addition, Ozone at 2 ppm is another alternative

to control *Salmonella sp* (Danyluk, 2018) although at 4 ppm ozone can be toxic for workers.

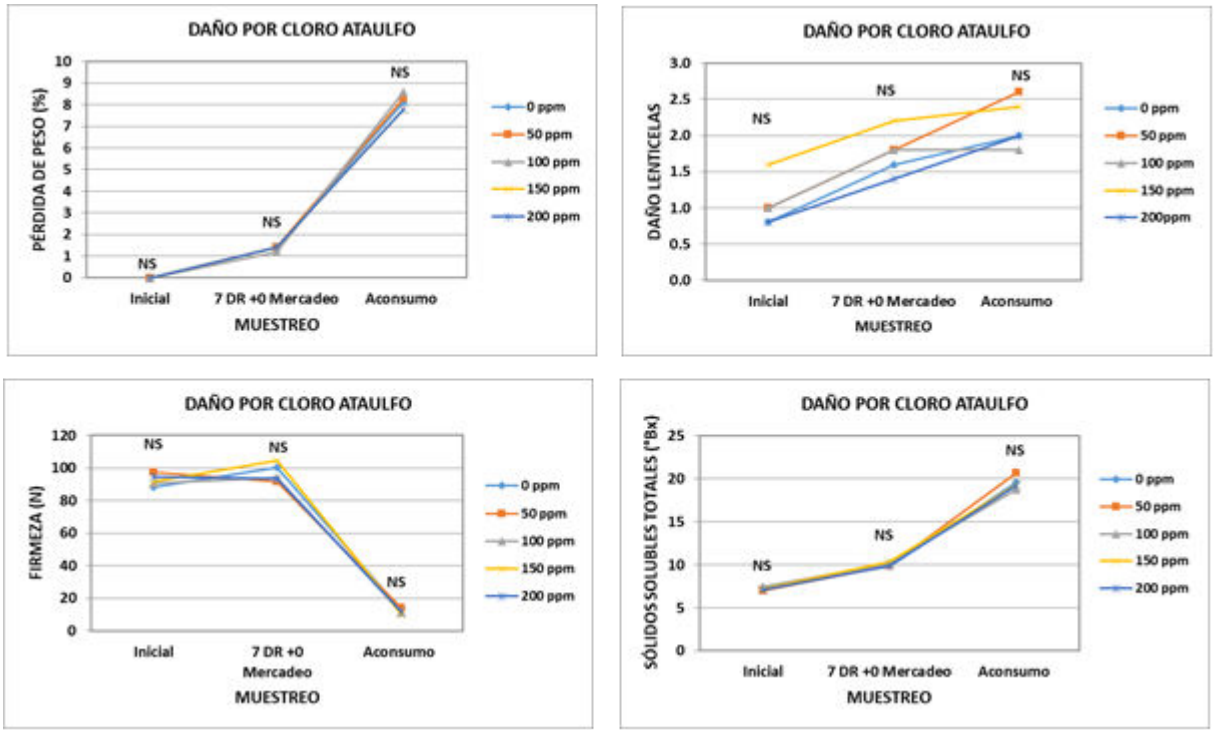


Figure 7. Illustration of chlorine injury even at 200 ppm. NS = Non Significant

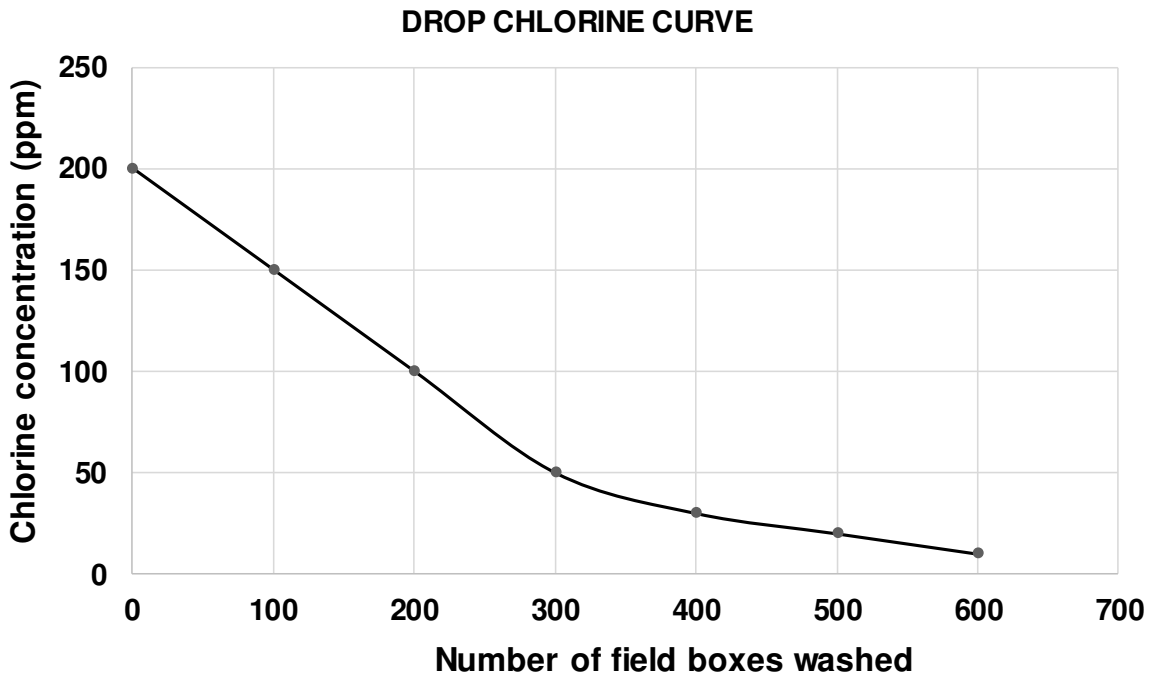


Figure 8. Chlorine effectiveness in washing water of prolonged use

5. The Quarantine Hot Water Treatment (QHWT) and Hydrocooling:

The USA requires quarantine hot water treatment (QHWT) for fruit fly control, which consists of treating the fruits with hot water (46.1 °C or 115 °F) for 65 to 110 min depending on the type and weight of the fruit (USDA-APHIS, 2010). Recently in a study funded by the National Mango Board (NMB), Osuna et al. (2015) showed that, if the QHWT is applied according to the protocol, no damage is observed because of this in fruit of the Tommy Atkins variety. However, 64% of Packers indicated that they use start ramps from 119.5 to 117.5 °F and only 32% said they use 117.4 to 116.0 °F. The results reported by Osuna et al. (2015) indicated that the most important factor that influenced external damage and fruit quality during QHWT was the treatment temperature (set point). The recommended set point between 115.5 and 116.5 °F showed only light damage while those treated at 117.0 °F showed moderate damage. Therefore, if the QHWT

is applied according to the recommendation and protocol, only light external damages will be observed while maintaining quality and shelf life.

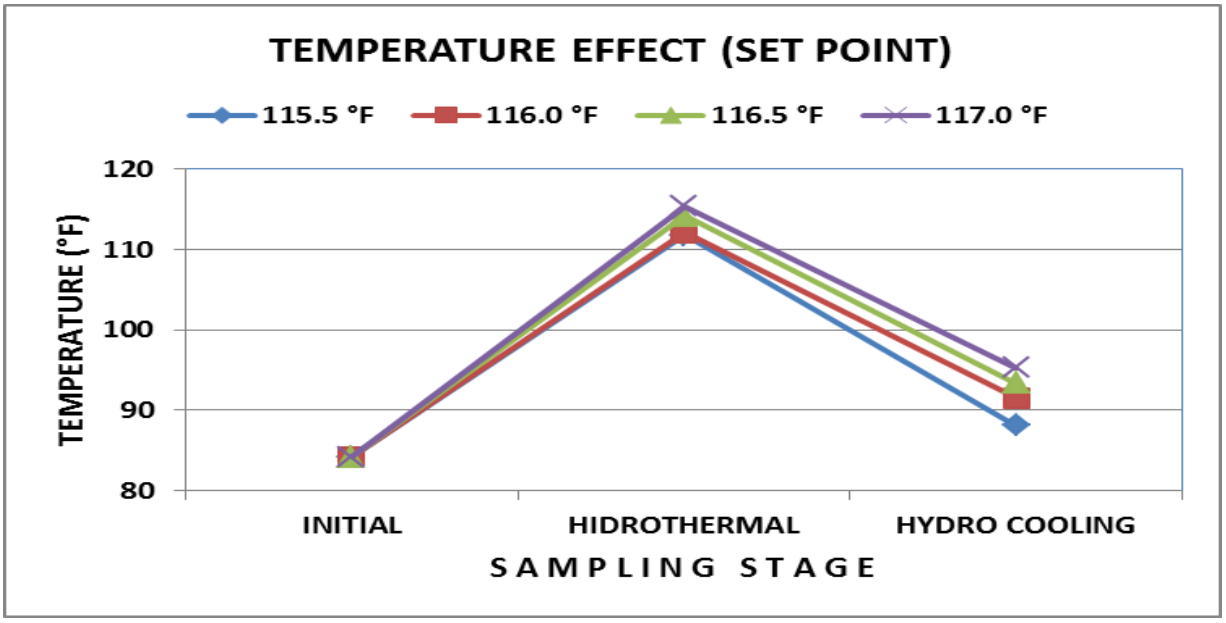


Figure 9. Effect of temperature (Set Point) on the Initial temperature, after hot water treatment and after hydrocooling in Tommy Atkins fruit submitted to QHWT.

During the packing process, the fruit goes through several stages where it is susceptible to contamination, especially in the hot water treatment where disinfectants are not applied (although 84% of the packers stated that they chlorinate the water at 5-10 ppm to keep it potable), since temperatures higher than 115 °F deactivate them. It is speculated that the growth of some pathogenic microorganisms and the consequent damage to the fruits could be due to deficiencies in the chemical and microbiological quality of the treatment water for the QHWT and hydrocooling. To verify the above, two types of tests were established: a) Complete cycle in Packer 1 with 'Ataulfo' and b) 'Scanning' in Packer 2 and 3 with 'Tommy Atkins' and 'Kent', respectively. For a complete cycle (considered from the beginning until the end of a QHWT or hydrocooling process), a same QHWT tank and a hydrocooling tank were sampled at the beginning (first

basket or cage containing 182 field boxes), in the middle (7 baskets) and at the end of the cycle (14 baskets). Water samples were taken for physical-chemical analysis of QHWT and hydrocooling water, as well as total coliforms. For 'scanning' it was considered practically the same, but in tanks with different level of use. The results showed that, with regard to water quality, the variable most affected was turbidity (Figure 10), which increased its value and surpassed the Standard as a longer use was made, which favors bacterial growth.

Figure 10. Illustration of turbidity of processing water for exporting mango packinghouses.

In hot water treatment tanks it is suggested to change water to no more than 14 baskets per cycle, with each basket containing 180 boxes of approximately 20 kg of fruit (Osuna et al., 2018). Thirty two percent of the packers said to make changes of the hot water tanks every 2-3 days and another 32% every 6-7 days. However, depending on the time of the season this can be a lot or a little, so it is suggested that the water change be made based on the number of baskets and not on the days of use. In addition, the water of prolonged use in hot water treatment tanks showed the presence of total coliforms and total aerobic bacteria

that indicate risk of contamination. However, maintaining a chlorination level of 20 to 50 ppm in hydrocooling tanks controls the presence of pathogenic microorganisms, such as *Salmonella* and *E. coli* (Table 4, Figure 11).

Table 3. Presence/Absence of total c*oliforms* in processing water in exporting mango packinghouses.

	Initial (1)	Middle (7)	End of cycle (14)
Treatment	***Total coliforms***	***Total coliforms***	***Total coliforms***
Source	-	-	-
Washing	+	+	+
QHWT	+	+	+
Hydrocooling	-	-	-
NOM-127-SSA	-	-	-

+ Presence - Absence

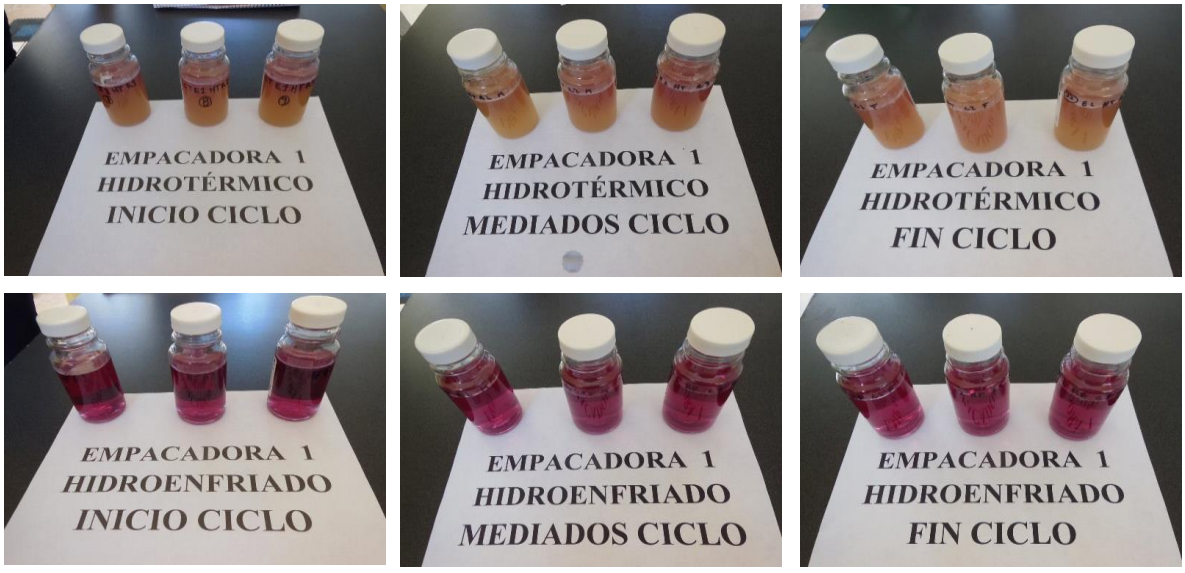


Figure 11. Illustration of sampling results for Presence/Absence *total coliformes* in processing water of exporting mango packinghouses.
Yellow (+) Purple (-).

6. Rest after QHWT and hydrocooling

According to the surveys, a high percentage (76%) of the packers usually makes the rest of the fruit (12 to 24 h) after the hydrocooling. Also, 20% of packers said they do not have hydrocooling; however, they do rest after the QHWT. In addition, a very particular case was found in which a packer (for the specific case of 'Tommy Atkins') performed up to 48 h of rest before submitting to QHWT. The packers argue that giving 24 to 48 h of rest before sorting and packing is very useful to visually detect fruits with shrunken shoulders. However, under our own experience, this can be a harmful practice, since the rest only increases the percentage of fruit with damage because they are left for 24 to 48 h under packinghouse conditions (at temperatures greater than 30 °C), increasing the speed of physiological processes of respiration and ethylene production, which accelerate ripening and deterioration of the fruits. In this regard, Osuna (2018) stated that in an experiment conducted during 2016-2017 in 'Tommy Atkins' it was

found that the presence of fruit with shrunken shoulders for the 2016 season was minimal (<1.0%). Significant factors were origin and rest after hydrocooling. The fruit harvested in Nayarit had the highest percentage of shrunken shoulders, while the fruits without rest showed the least presence of this anomaly. However, the results of 2017 showed a presence of almost 30% of fruit with shrunken shoulders. 'Tommy Atkins' fruit harvested in Jalisco did not manifest the damage. However, the fruit of Nayarit and Sinaloa accumulated 27.1 and 28.3% of the presence of shrunken shoulders, respectively. The factors that most influenced the presence of fruit with shrunken shoulders were the ripening degree at harvest and rest. With regard to rest, it was observed that this significantly impacted the presence of fruit with shrunken shoulders, primarily at the initial sampling, since the fruit with rest of 24 h showed three times more fruit with shrunken shoulders (16.1%) than those without rest (5.8%) [Figure 12]. This shows that resting after hydrocooling does not diminish the presence of shrunken shoulders. It only allows us to identify the fruit with this anomaly. Due to the above, the suggestion for the packers is that they do not continue with their practice of submitting the fruits to rest, but that they should follow the continuous process for the packing.

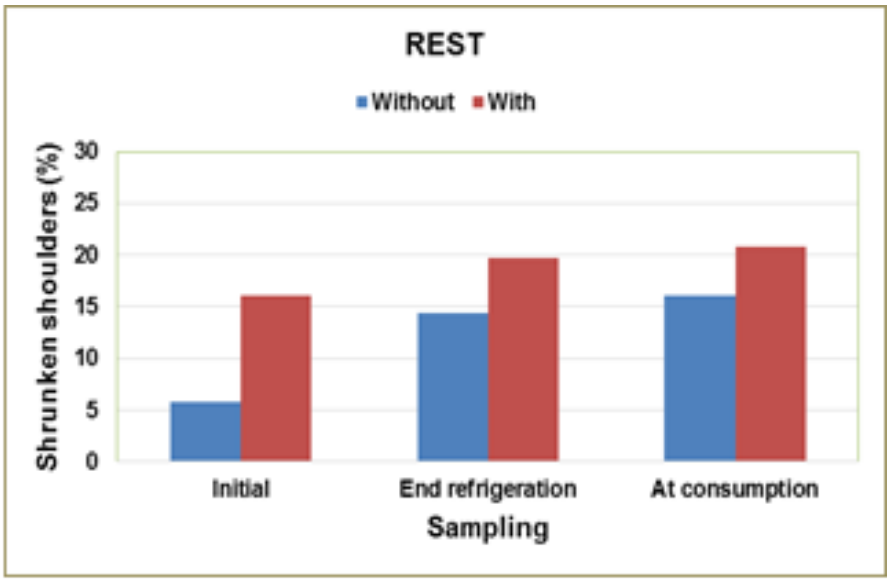


Figure 12. Effect of rest on the presence of shrunken shoulders in 'Tommy Aktins' fruit.

7. Refrigeration temperatures during store in cold room or shipping

One hundred percent of the packers surveyed said they had a cold room, and 68% of them keep their fruit at least 9 h in cold storage before loading the trailer or container, which positively influenced the shelf life of the mango fruit. Unfortunately, serious faults were found was in the temperatures used for cold room and / or refrigerated container since 52% use temperatures ≤ 10 °C. Results obtained by Osuna (2015), mentions that significant differences were detected for cold injury among varieties. 'Ataulfo' and 'Kent' were more susceptible than 'Tommy Atkins' and 'Keitt'. The external damage was greater than the internal damage. The most important factors were temperature and storage time. At lower temperatures, more damage; the longer the storage time, the greater the damage. 'Ataulfo' and 'Kent' showed external damage from a week of storage at 7.5 and 10.0 °C while 'Tommy Atkins' and 'Keitt' showed moderate to severe damage only at 7.5° C and up to three weeks of storage (Figure 13). The internal damage was very low and was reflected mainly in the pulp color. At lower temperatures, less intensity of pulp color. Also, the longer the storage time, the lower the intensity of pulp color. A very clear effect of temperature and storage time on firmness was observed in all varieties. The lower the temperature, the greater the firmness, while the longer the storage time, the lower the firmness. Regarding total soluble solids, it was observed that at lower storage temperature, the content of the total soluble solids decreased. For practical purposes, 'Ataulfo' and 'Kent' should be shipped only at 12.5 °C while 'Tommy Atkins' and 'Keitt' can tolerate up to 10 °C. None of the varieties should be sent at 7.5 °C.

Figure 13. External an internal cold injury due to temperatures ≤ 10 °C.

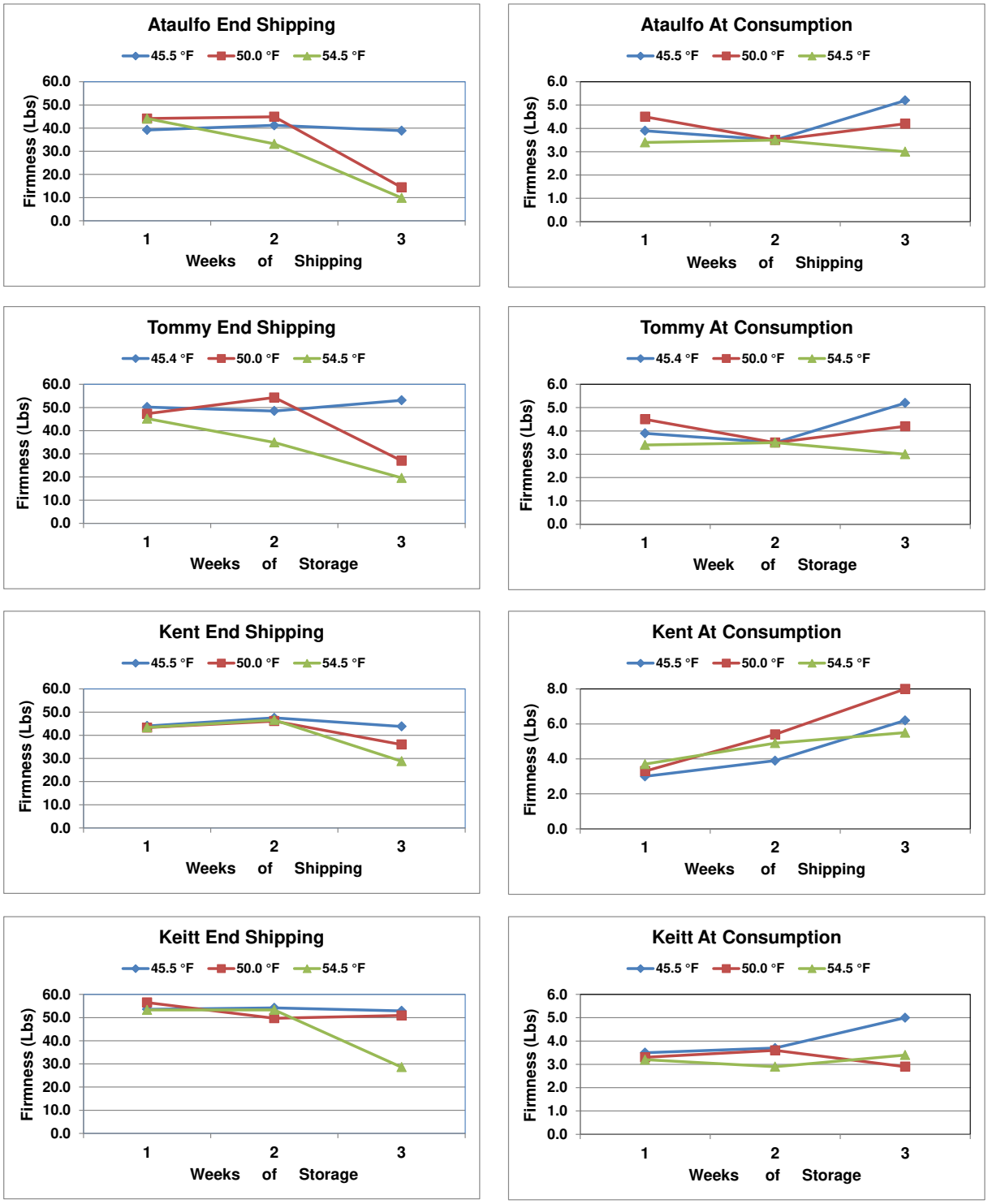
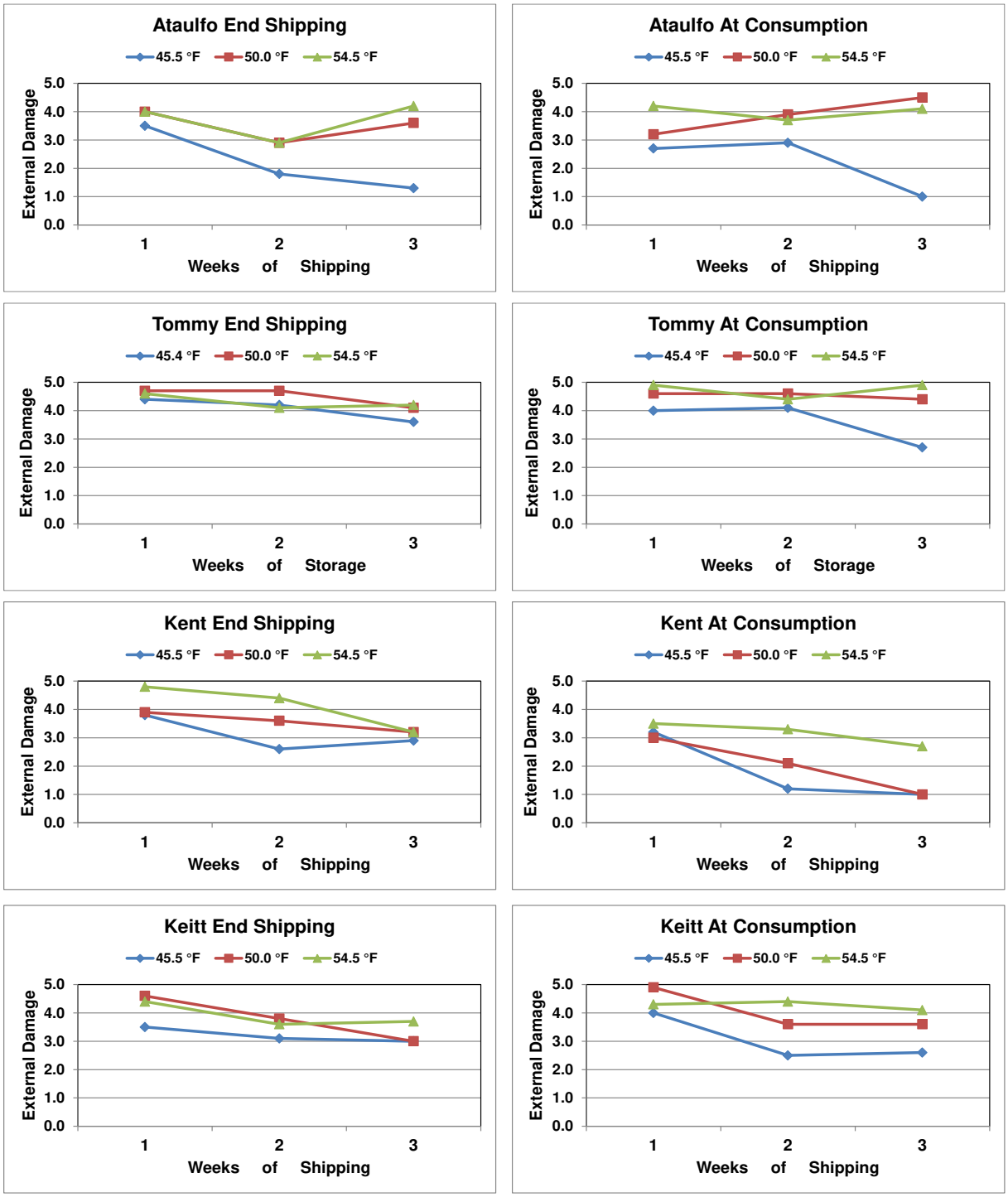


Figure 14. Effect of Temperature and Storage time on Pulp Firmness (Lbs) from mango fruit of Ataulfo, Tommy Atkins, Kent, and Keitt varieties at the end of shipping simulation or ready to eat stage.



Scale values: 1 = Severe 2 = Moderate 3 = Slight 4 = Traces 5 = No Damage

Figure 15. Effect of Temperature and Storage time on the External Damage of mango fruit from Ataulfo, Tommy Atkins, Kent, and Keitt varieties at the end of shipping simulation or ready to eat stage.

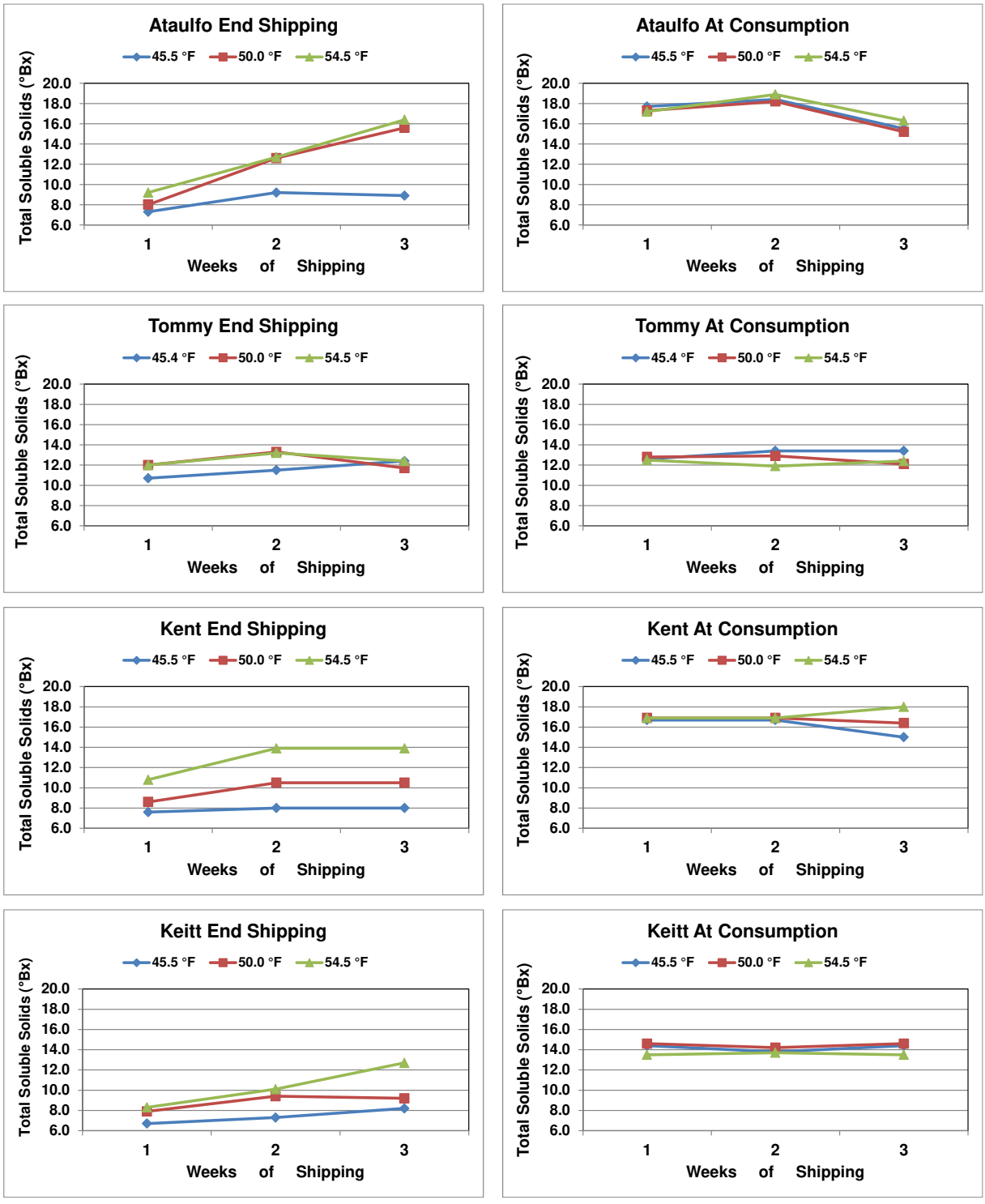


Figure 16. Effect of Temperature and Storage time on content of Total Soluble Solids (°Bx) of mango fruit from Ataulfo, Tommy Atkins, Kent, and Keitt varieties at the end of shipping simulation or ready to eat stage.

On the other hand, the demand for ripe and ready to eat (RRTEM) has recently increased, which opens an interesting possibility for mango producers in Mexico due to the geographic proximity of the production sites to the US markets. Most of the production sites are located within a maximum of five days of land transportation to reach the farthest of the destination markets in the USA. Osuna and González (2018) investigated the effect of the ripening degree and shipping temperature for the handling of RRTEM. It was found that the ripening degree at harvest is one of the fundamental factors in the handling of RRTEM and as it increases, the higher the Minimum Quality Index (MQI) and, therefore, its possible acceptance by the consumer. However, for this study the ripening degree was not so striking in most of the variables; there were significant differences at the beginning for skin color, firmness, pulp color and TSS, but they were no longer reflected in consumption. On the other hand, the shipping temperature factor had a significant impact on most of the variables, especially at the end of the shipping. At lower temperatures, less weight loss, greater firmness, less development of pulp color and TSS, as well as longer shelf life. This factor is decisive for the importer to plan their volumes of ripe and ready to eat mango. The shipping temperatures of 15 and 18 ° C would be recommended depending on the needs of the importer. The effect of ripening degree and shipping temperatures on quality and shelf life of RRTEM of Ataulfo variety is illustrated below (Figures 17 and 18).

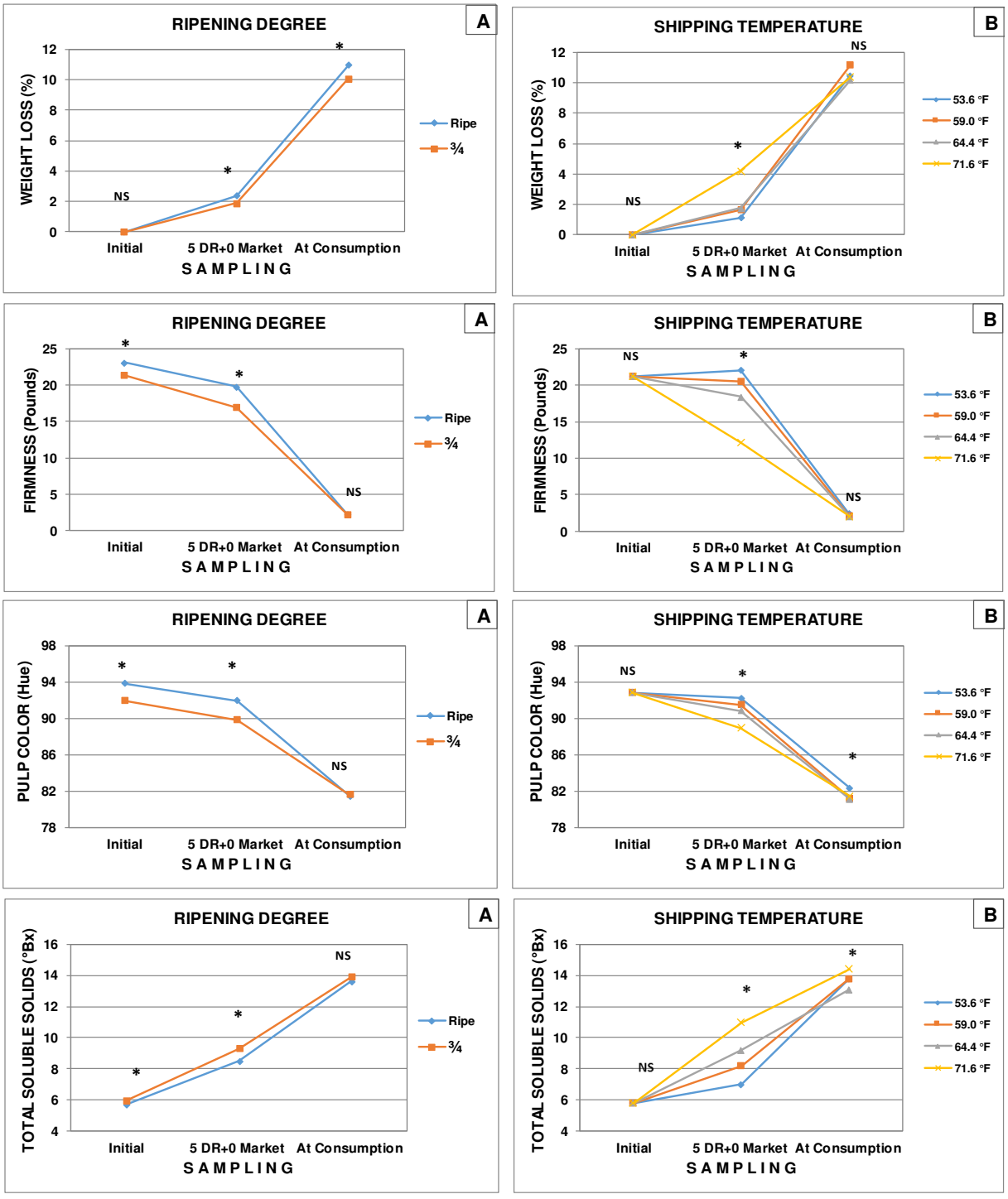


Figure 17. Effect of ripening degree and shipping temperature on quality and shelf life of Ataulfo mango at the beginning, at the end of shipping simulation or at consumption stage.

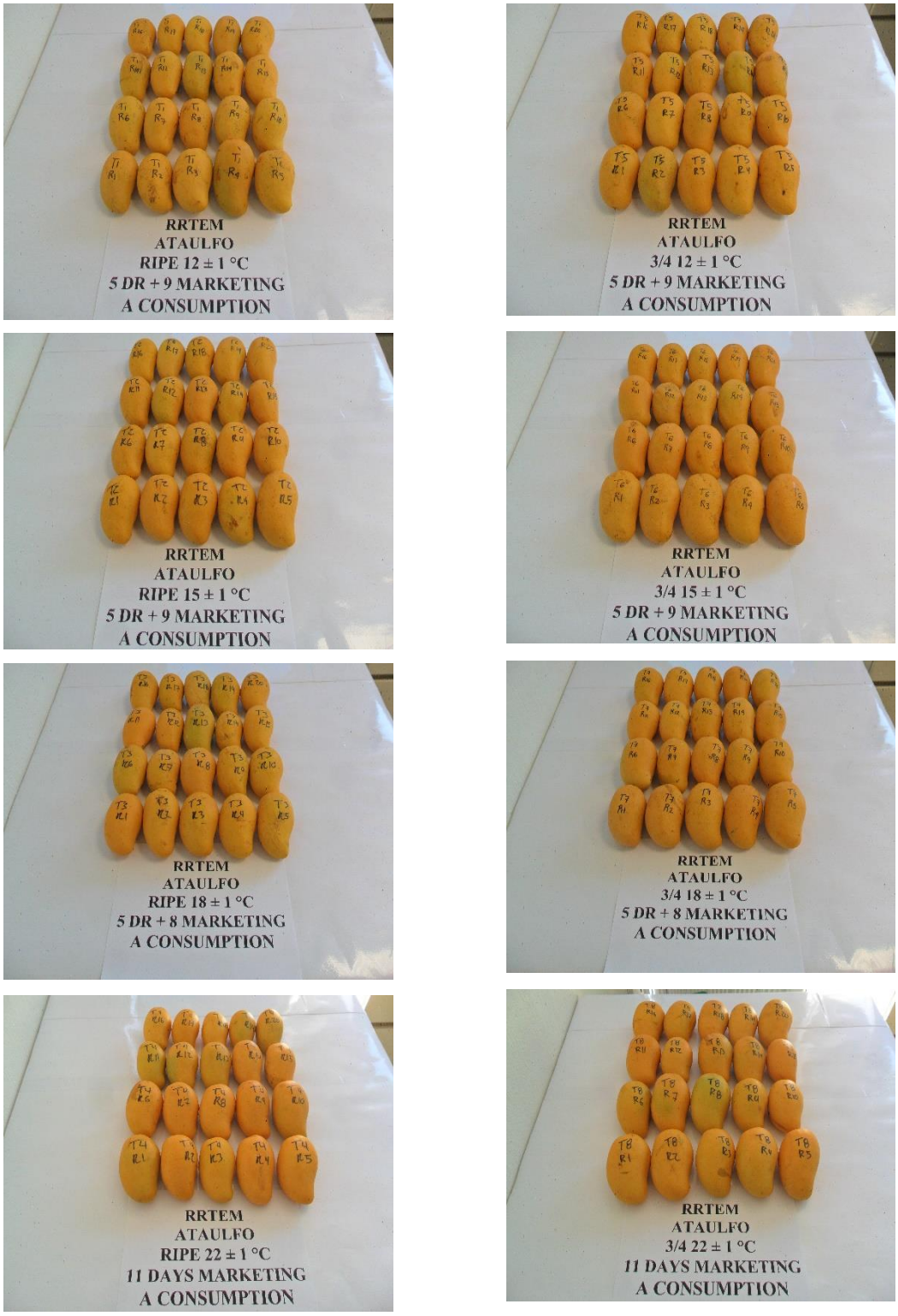


Figure 18. External appearance of Ataulfo fruit at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures.

Protocol of best practices to be performed to deliver mango with high and consistent quality

The most transcendental and impressive practice to have initial quality, good shelf life and excellent flavor, color and aroma at the time of consumption is to harvest the mango fruit in ripe stage (color 3, according to EMEX, AC), as well as a Total soluble solids content > 8.0 °Bx in Ataulfo, Haden, Keitt, Kent and Tommy Atkins varieties.

Once the fruit are harvested at the appropriate ripeness, they follow several steps in the orchard and packinghouse that are important to maintain quality, extend shelf life and ensure optimum consumption flavor:

1. Harvest When harvesting with a hook and bag, immediately pour away the fruit into empty plastic boxes placed in the shade of the tree canopy and preventing them from touching the ground to prevent microbiological contamination.

2. Manual harvest. When making manual harvest, it is practically impossible to avoid latex emission. Ataulfo should be washed immediately after harvest and within a maximum of 2 hours to avoid irreversible damage caused by latex. Floridian varieties can tolerate up to 6 hours in contact with latex without irreversible damage. The washing can be done with simple water or water + washing-dishes liquid detergent (1 l of detergent in 1,000 l of water).

3. Transportation from the orchard to the packinghouse. It should not take more than 36 hours for the fruit after harvest to reach the packinghouse. Avoid overfilling the boxes to prevent mechanical damage and compression when they are stowed. Likewise, the suspension of transport vehicles must be in good condition to avoid rubbing, bumps and bruising due to excessive sprouting of the fruit.

4. Operations in the packinghouse:

a. Reception, phytosanitary and quality tesst: Once in the packinghouse, trucks must remain in the shade and take no longer than 4 hours to unload them.

b. Washing: It should be performed as soon as possible, using chlorinated water with an initial chlorine concentration at 200 ppm and wash a maximum of 600 field

boxes to proceed to change the water in the washing tank and bring back to a chlorine concentration 200 ppm. It is very important to wash and disinfect the field boxes every time they return to the orchard. Otherwise, they are a significant source of microbiological contamination.

c. Quarantine Hot Water Treatment (QHWT). According to the Standard, the QHWT for fruit fly control consists of treating the fruit with hot water (115 °F) for 65 to 110 min depending on the type and weight of the fruit. It is very important to maintain the water temperature between 115.4 and 116.5 °F maximum, otherwise temperatures > 116.5 °F affect firmness and shelf life of the fruit. From a microbiological point of view, it is advisable to change the water in the QHWT tank every 14 baskets (from 180 to 200 boxes each).

d. Hydrocooling. Ideally, cool the fruit immediately after QHWT for at least 30 min in cold water at 21.1 °C (70.0 °F). To avoid microbiological contamination, hydrocooling water should be maintained with a free chlorine concentration of 20 to 50 ppm and should be changed when it becomes too cloudy (at least once a week). During the mango packing process there are three critical points: the washing tank, the hot water treatment tanks and the hydrocooling tanks. In addition, the lack of hygiene in transport boxes, bands and banks, can lead to microbial contamination of the fruit. Osuna et al. (2010), recommend the use of rapid microbiological tests as an excellent alternative to establish controls for hygiene monitoring of the entire packaging process.

e. Rest. The results are conclusive, resting after hydrocooling does not decrease the presence of sunken shoulders, especially in the Tommy Atkins variety; therefore, the suggestion for packers is that they avoid the practice of putting the fruit at rest and follow the packing process continuously.

f. Cooling temperature in cold room and/or shipping. Ataulfo should be handled from 11 to 13 °C (51.8 to 55.4 °F); Floridians varieties like Haden, Keitt, Kent and Tommy Atkins from 10 to 12 °C (50.0 to 53.6 °F). None of the varieties should be stored or shipped at temperatures < 10.0 ° C (< 50.0 ° F).

Following these recommendations, it is certain that mango of excellent and consistent quality will be delivered, fully satisfying consumer demands and thus increasing mango consumption in the US market.

CONCLUSIONS

- The survey was applied to 19 partners of EMEX, A.C. in Mexico, four packers in Guatemala, one in Ecuador and one in Peru.
- the relevant points that most impact on the initial quality, shelf life and quality at consumption of fresh mango fruit are the following: 1. Flowering and harvest, 2. Placement of the boxes during harvest, 3. Washing of fruit in orchard to prevent latex injury, 4. Washing of fruit in the packinghouse, 5. The quarantine hot water treatment (QHWT) and the hydrocooling, 6. The rest after QHWT and hydrocooling, and 7. Cooling temperatures in cold room and / or refrigerated shipping.
- A Manual suggesting the best practices of exporting mango from harvest to trailer or ship container was published.

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Annex 1. Format and summary results of the survey

1. **Do you usually record and monitor the flowering process in your orchards?**

   a) Yes (**80 %**) b. No (**20 %**)

2. **If the answer was positive, how many flowering flows occur in your orchards?**

   a. 1 (**8 %**) b. 2 (**32 %**) c. 3 (**24 %**)

   d. More than 3 (**16 %**) e. No answer (**20 %**)

3. **What varieties do you handle?**

   a) Ataulfo (**76 %**) b. Haden (**40 %**) c. Keitt (**64 %**) d. Kent (**76 %**)

   e. Tommy Atkins (**84 %**) f. Other [Which?] Nan Doc Mai, Manila Pink_(**4 %**)

4. What criteria do you use to start your harvest?

4a. Round varieties (Tommy, Kent, Keitt, Haden)

a. Appearance of the fruit [size, color] (**100 %**) b. Days of flowering to harvest ( ) c. Heat Units ( ) d. Pulp color: white-cream ( ); 50% yellow ( ); 100% yellow ( ) e. TSS [°Bx] ( ) f. Other [Which?] External appearance + DAF (**16 %**)

4b. Elongated Varieties (Ataulfo)

a. Appearance of the fruit [size, color] (**100 %**) b. Days of flowering to harvest ( ) c. Heat Units ( ) d. Pulp color: white-cream ( ); 50% yellow ( ); 100% yellow ( ) e. TSS [°Bx] ( ) f. Other [Which?] External appearance + DAF (**16 %**)

5. **How do you harvest?**

   a. With hook and bag (**88 %**) b. With scissors (**12 %**) c. With ladders ( ) d. Other [Which?] ( )

6. **What container do you use for harvest?**

   a. Plastic boxes (**100 %**) b. Plastic buckets ( ) c. Wooden box ( ) d. Other [Which?] ( )

7. Do you usually leave your harvested boxes under the shade of the tree?

a. Yes (**100 %**) No ( )

8. Are your boxes in contact with the ground during harvest?

a. Yes (**32 %**) No (**68 %**)

9. Do you wash the fruit immediately after harvest?

9a. Round Varieties (Tommy, Kent, Keitt, Haden)

a. Yes (**36 %**) No (**64 %**)

9b. Variedades elongadas (Ataulfo)

a. Si (**40 %**) No (**60 %**)

10. If your answer was positive, with what do you wash your fruit?

a. Only water (**10 %**) b. Water + disinfectant (**30 %**) Type and concentration

c. Water + detergent (**60 %**) Type and concentration

e. Water + lime ( ) Concentration _____ f. Other [Which?]_( )

11. Besides washing the fruit, What do you do to prevent latex injury?

11a. Round Varieties (Tommy, Kent, Keitt, Haden)

a. Cut with long peduncle (**8 %**) b. Desapp in the orchard (**32 %**)

c. nothing (**60 %**) d. Other [Which? _____

11b. Elongated varieties (Ataulfo)

a. Cut with long peduncle (8 %) b. Desapp in the orchard (32 %)

c. nothing (60 %) d. Other [Which? _____

12. Do you use a specialized and / or certified cutting crew?

a. Yes (**76 %**) b. No (**24 %**)

13. How do you pay for harvest of the fruit?

a. By day (**20 %**) b. By box (**80 %**) c. By volume ( )

d. Other [Which?]_____

14. In the orchard, do you use any prevention system to avoid contamination?

a. Yes (**96 %**) b. No (**4 %**) If positive, which? GAP's and RCRS

15. How do you transport your fruit to the packinghouse?

ANSWERS	(%)
ALL	**48.0**
TORTON AND TRAILER	**28.0**
DOUBLE WHEEL AND SEMITRAILER	**24.0**

16. Do you cover with sailcloth the vehicles where the mango boxes are shipped?

a. Yes (**92 %**) b. No (**8 %**)

17. How long does it take from the harvest of the mango until its arrival at the packinghouse?

a. Less than 6 h (**80 %**) b. Between 6 and 12 h (**16 %**) c. up to 24 h (**4 %**)
d. ≥ 48 h ( )

18. Is the packing waiting area shaded?

a. Yes (**60 %**) b. No (**40 %**)

19. How much time does it pass from arrival at the packinghouse to unloading?

a. Less than 1 h (**44 %**) b. 2 h (**32 %**) c. 3 h (**12 %**) d. ≥ 4 h (**12 %**)

20. Do you monitor for fruit fly?

a. Yes (**100 %**) b. No ( )

21. What is your simple size?

d. One fruit every 3 boxes ( ) b. One fruit every 4 boxes ( ) c. One fruit every 5 boxes ( ) d. One fruit every 6 boxes ( ) e. Other __According to the Norm__ (**100 %**)___

22. Do you have records for Traceability / Traceability?

a. Yes (**100 %**) b. No ( )

23. How is your tracking code?

ANSWERS	(%)
HARVEST FOLIO	**4.0**
INTERNAL REGISTES AND SOFTWARE	**4.0**
PACKING DATE/ORCHARD	**4.0**
NUMERIC	**4.0**
TICKETS	**4.0**
JULIAN CODE	**4.0**
LOT NUMBER	**12.0**
LOT, ORCHARD AND CERTIFICATE	**4.0**
FROM EMEX	**44.0**
ORCHARD AND LOT	**4.0**
ORCHARD, LOTE, LOCATION	**4.0**
PROVIDER. SUBPROVIDER, LOT NUMBER	**4.0**
MGO - CNV - AT - LM0009 - 321/320	**4.0**

24. What volume do you handle per day (boxes, trucks, tons)?

ANSWERS	(%)
9,000 – 10,000 boxes	**4.0**
NO ANSWER	**44.0**
2,500 boxes	**4.0**
44 Tons	**4.0**
3,500 boxes	**4.0**
12,000-15,000 boxes	**4.0**
8,000-10,000 boxes	**4.0**
3,000 boxes	**4.0**
1,500-2,000 boxes	**4.0**
6,000 boxes	**4.0**
10,0000 boxes	**4.0**
2,000 boxes	**8.0**
4 trucks	**4.0**
4,500 boxes	**4.0**

25. How many washing lines do you have?

a. 1 (**56 %**) b. 2 (**40 %**) c. 3 (**4 %**) d. ≥ 4 ( )

26. What do you use in your wash water?

a. Only water ( ) b. Water + detergent ( ) Type and concentration

c. Water + disinfectant (**88 %**) Type and concentration

d. Other _Water + detergent + Disinfectant_ (**12 %**)

27. Do you check the concentration of disinfectant?

a. Yes (**92 %**) b. No (**8 %**)

28. If positive, how often?

a. Daily (**92 %**) b. Every two days ( ) c. Every week ( )

d. Never (**8 %**)

29. Do you check temperature and pH of the washing water?

a. Yes (**48 %**) b. No (**32 %**) c. Only pH (**20 %**)

30. How is the washing of the fruit?

a. By immersion (**36 %**) b. By sprinkling (**60 %**) c. Other: Both (**4 %**)_

31. What capacity does your wash tank have?

a. 200 - 500 l (**12 %**) b. 600 – 1,000 l (**36 %**) c. 1,100 – 2,000 (**16 %**)

d. Higher than 2,000 l (**24 %**) e. Other (**12 %**)

32. How many fruit boxes do you wash per wash cycle?

a. 500 boxes (**16 %**) b. 1,200 boxes (**12 %**) c. 1,500 boxes (**20 %**)

d. ≥ 1,800 boxes (**36 %**) e. Continous flow (**16 %**)

33. How often do you wash your field boxes?

a. After each use (**60 %**) b. Once a week (**12 %**) c. Every 2 weeks (**4 %**)

d. Only at the beginning of the season (**24 %**) e. Never ( ) f. Other ( )

34. How do you separate fruit sizes for Quarantine Hot Water Treatment?

a. Manual ( ) b. Mechanical (**84 %**) c. Electronic (**8 %**)

d. Mechanical and manual (**8 %**)

35. How many hot water treatment tanks do you have?

ANSWERS	(%)
2 tanks	**12.0**
3 tanks	**12.0**
4 tanks	**12.0**
5 tanks	**8.0**
6 tanks	**20.0**
7 tanks	**4.0**
8 tanks	**8.0**
9 tanks	**4.0**
11 tanks	**4.0**
12 tanks	**12.0**
DOESN'T APPLY	**4.0**

36. What capacity of liters of water and/or mango boxes does each hot water treatment tank have?

ANSWERS	(%)
8,000 -10,000 L	**20.0**
11,000 - 15,000 L	**8.0**
16,000 - 20,000 L	**36.0**
21,000 - 25,000 L	**16.0**
26,000 - 30,000 L	**12.0**
≥ 30,000 L	**4.0**
DOESN'T APPLY	**4.0**

37. What are your set points and temperature ramps for QHWT?

RESPUESTAS	(%)
Max 119.5-117.5 °F : Min 115.9-115.0 °F	**64.0**
Max 117.4-116.0 °F : Min 115.9-115.0 °F	**32.0**
DOESN'T APPLY	**4.0**

38. Do you use disinfectants in the hot water treatment tanks?

a. Yes (**84 %**) b. No (**12 %**) c. Other (**4 %**)

39. If positive, what disinfectant do you use?

ANSWERS	(%)
Chloride	**52.0**
Calcium chloride	**16.0**
Sodium chloride	**8.0**
Ozone	**4.0**
Ácido peroxiacético	**4.0**
None	**12.0**
Other	**4.0**

40. How often do you check concentration?

a. Daily (**80 %**) b. Every week (**4 %**) c. Never (**12 %**)

d. Other (**4 %**)

41. How often or with how many baskets do you change the water of the QHWT tank?

ANSWERS	(%)
Daily	**8.0**
Every 2-3 Days	**32.0**
Every 4-5 Days	**8.0**
Every 6-7 Days	**32.0**
Every 10 treatments	**16.0**
Other	**4.0**

42. How many hydrocooling tanks do you have?

ANSWERS	(%)
1 tank	**16.0**
2 tanks	**32.0**
3 tanks	**8.0**
4 tanks	**4.0**
6 tanks	**4.0**
None	**36.0**

43. How much time do you perform the hydrocooling?

43a. Round varieties (Tommy, Kent, Keitt, Haden)

a. 10 min (**16 %**) b. 20 min (**12 %**) c. 30 min (**20 %**)

d. > 30 min ( ) e. Doesn't apply (**52 %**)

43b. Elongated varieties (Ataulfo)

b. 10 min (**16 %**) b. 20 min (**12 %**) c. 30 min (**20 %**)

d. > 30 min ( ) e. Doesn't apply (**52 %**)

44. Do you use disinfectants in hydrocooling tanks?

a. Yes (**52 %**) b. No (**44 %**) c. Other (**4 %**)

45. If positive, what disinfectant do you use?

RESPUESTAS	(%)
Calcium chloride (65%)	**4.0**
Sodium chloride (10%)	**8.0**
Chloride dioxide (5 ppm)	**4.0**
Chloride (200 ppm)	**16.0**
Chloride (10 ppm)	**20.0**

46. How often do you check concentration?

a. Daily (**52 %**) b. Every week ( ) f. Doesn't apply (**48 %**)

47. Do you perform the hydrocooling immediately after the QHWT?

a. Yes (**52 %**) b. No (**16 %**) c. Doesn´t apply (**32 %**)

48. How often or with how many baskets do you change the water of the hydrocooling tank?

ANSWERS	(%)
Every day	**4.0**
Every 2 days	**4.0**
Every 3 days	**8.0**
Every 4 days	**4.0**
Every 7 days	**24.0**
Every 8 days	**4.0**
Every 8 treatments	**4.0**
Every 2 weeks	**4.0**

49. Do you usually rest the fruit after the hydrocooling?

a. Yes (**76 %**) b. No (**4 %**) c. Doesn't apply (**20 %**)

50. If positive, for how long?

Ataulfo, Tommy Atkins, Kent, Keitt y Haden

a. < 12 ( ) b. 12 h (**24 %**) c. 24 h (**44 %**) d. 36 h ( ) e. 48 h ( )
f. ≥ 60 h ( ) g. Doesn't apply (**32 %**)

b.

51. How many packing lines do you have?

ANSWERS	(%)
1 Line	**16.0**
2 Lines	**28.0**
3 Lines	**20.0**
4 Lines	**20.0**
5 Lines	**4.0**
7 Lines	**8.0**
14 Lines	**4.0**

52. Do you have an automatic emptying machine?

a. Yes (**44 %**) b. No (**56 %**)

53. What type is your sorter machine?

a. Mechanical (**32 %**) b. Electronic (**32 %**) c. Manual (**8 %**)

d. Doesn't apply (**28 %**)

54. Do you use waxes?

a. Yes (**80 %**) b. No (**20 %**)

55. If positive, what type and concentration?

ANSWERS	(%)
NATURAL SHINE AND CARNAUBA PACE	**8.0**
SPA FRESH	**4.0**
ORGANIC WAX PRO WAX	**4.0**
CARNAUBA PACE	**16.0**
ALCOHOL, OIL AND WATER 10:10:80	**4.0**
CHAROL	**4.0**
CARNAUBA PACE, 505	**4.0**
CARNAUBA PACE AND ORGANIC	**4.0**
NATURAL SHINE	**4.0**
NATURAL SHINE, 505-OR	**4.0**
ECOWAX, 1L/TON	**4.0**

56. Does your sorter distinguish uniform sizes and send to individual banks?

a. Yes (**40 %**) b. No (**52 %**) c. Don't use sorter (**8 %**)

57. How big is your scaffold or pallet?

ANSWERS	(%)
40 X 44"	**16.0**
40X48"	**80.0**
43 X 57"	**4.0**

58. What sixe box do you use?

ANSWERS	(%)
6, 9, 20 and 48 LBS	**4.0**
8 LBS	**16.0**
9 LBS	**8.0**
8.5 LBS	**4.0**
10 LBS	**8.0**
3.3, 4, 6, 9, 20 and 48 LBS	**4.0**
Other	**4.0**
Doesn't apply	**52.0**

59. Do you have cold room?

a. Yes (**100 %**) b. No ( )

60. What cooling temperatures do you handle?

Round varieties (Tommy, Kent, Keitt, Haden) and Ataulfo

a. ≤ 8°C (**4 %**) b. 9-10°C (**48 %**) c. 11-13°C (**48 %**) d. ≥ 14°C ( )

e. Other _____

61. How long do you keep the pallets in the cold room before loading the trailer?

Round varieties (Tommy, Kent, Keitt, Haden) and Ataulfo

a. ≤ 3 h (**16 %**) b. 3-6 h (**16 %**) c. 9-12 h (**20 %**) d. ≥ 12 h (**48 %**)

62. Do you have forced air tunnels?

b. Yes (**60 %**) b. No (**40 %**)

63. If positive, how long does it cool the pallets?

ANSWERS	(%)
≤ 2 H, ≤ 8°C	**20.0**
2-4 H, 9-10°C	**16.0**
4-6 H, 11-13°C	**4.0**
> 6 H, ≥ 14°C	**4.0**
2-4 H, 11-13°C	**12.0**
> 6 H, 9-10°C	**4.0**

64. Do you check before loading the cleaning and temperature of the trailer box?

a. Yes (**100 %**) b. No ( )

65. What is the set point of the thermos king?

Round varieties (Tommy, Kent, Keitt, Haden) and Ataulfo

a. ≤ 8°C (**16 %**) b. 9-10°C (**52 %**) c. 11-13°C (**32 %**) d. ≥ 14°C ( )

e. Other _____

66. How much is the time of transportation from packing to wholesaler's warehouse in the USA?

ANSWERS	(%)
12 h	**4.0**
18 h	**8.0**
24 h	**20.0**
36 h	**8.0**
48 h	**24.0**
72 h	**8.0**
120 h	**4.0**
144 h	**4.0**
180 h	**4.0**
48 and 72 h	**4.0**
30 h	**4.0**
552 h	**4.0**
Other	**4.0**

67. Do you maintain homogeneous your work scheme from receiving to thermo King or do you use different handling according to the season?

ANSWERS	(%)
Doesn't apply	**36.0**
Homogeneous	**60.0**
Homogeneous except for KENT	**4.0**

PUBLICATIONS

Osuna-García J.A. 2019. Manual sobre las mejores prácticas de empacado del mango para exportación desde cosecha hasta tráiler o contenedor. Electronic publication only in Spanish (CD).