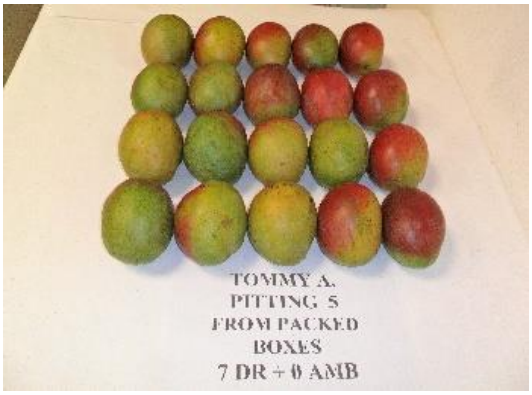
AGREEMENT INIFAP-NMB

DIAGNOSIS FOR IDENTIFICATION AND QUANTIFICATION OF 'PITTING' INJURY IN FRUIT OF TOMMY ATKINS MANGO GROWN IN MEXICO



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ABSTRACT

In several 'Tommy Atkins' growing regions, 'Pitting' or lenticel damage have been observed at different levels. However, most of the packers do not have a clear understanding if the damage comes from the orchards or it appears in some step during the packing process. In addition, there is no clear cause of this disorder, which is observed at a higher degree in 'Tommy Atkins' fruit. Because of that, this project has the following objectives: a) To diagnose the presence of 'Pitting' in 'Tommy Atkins' fruit grown in Mexico; b) To determine if 'Pitting' is associated to a field factor or to any step during the packing process, and c) Based on results, to find a strategy to control 'pitting' in 'Tommy Atkins' fruit. During the season 2013 and 2014 (March to July) four or five samplings were done at 3-4 week interval. For each sampling 50 fruit were collected completely randomized at the following steps during the packing process: a) Arrival at the packinghouse, b) After washing, c) After quarantine hot water treatment, d) After hydrocooling, e) After brushing y f) From packed boxes. Then fruit were immediately taken to the postharvest lab located at INIFAP-Santiago Ixcuintla Experimental Station where they were submitted to refrigeration (12 ± 1 °C; 90 ± 5 % HR) for seven days + market simulation (22 ± 2 °C; 75 ± 10 % RH) until ready to eat stage. Sampling was done at the beginning and at the end of the refrigerated period and at consumption stage. The variables to measure were pitting injury, dry matter, weight loss, skin color, firmness, pulp color, total soluble solids, tritatable acidity, ratio °Bx/Acidity and nutrient content (N, Ca and B). In both years a completely randomized design with 20 replications for weight loss and eight replications for all the other variables was used.

In 2013 the presence of 'Pitting' in Tommy Atkins fruit was with very low frequency and light intensity for fruit harvested in Jalisco and Nayarit. The damage was associated with some step during the packing process. 'Pitting' was absent from fruit harvested in Oaxaca and Sinaloa. In 2014 'Pitting' was present in all the harvested states. Jalisco (1.4), Michoacan 1 (0.65), and Michoacan 2 (0.53) had the highest 'Pitting' presence, which was correlated with higher nitrogen content, lower calcium content, as well as relatively higher boron content in the skin. 'Pitting' presence was correlated with higher nitrogen content, lower calcium content, as well as no differences in boron content for the pulp. 'Pitting' presence was correlated with higher nitrogen content in stone only for fruit collected in Michoacan 2 but not for those collected in Jalisco or Michoacan 1. With relation to calcium content, fruit harvested in Michoacan 1 or 2 had lower calcium content in stone, as well no differences in boron content. Since the presence of 'Pitting' was very low, these experiments helped us to make quality comparison among Tommy Atkins fruit harvested from different origins. In 2013 the fruit harvested from Sinaloa were the best because they did not show any 'Pitting' symptoms, they had the lowest WL, the highest TSS content and the lowest acidity. In 2014 the fruit harvested in Nayarit showed the best quality characteristics for all the evaluated variables except pulp color intensity.

BACKGROUND

Mango is one of the favorite fruits in the US market, where consumption has doubled in the past 10 years. During the last three years (2009-2011) on average 71.7 million 10-pound boxes have been imported; mainly from Mexico (65.1 %), Peru (9.7 %), Ecuador (9.4 %), Brazil (7.4 %), Guatemala (4.6 %), and Haiti (2.5 %) [USDA-FAS, 2012]. However, most of the time the quality of mango fruit at the consumer level is compromised, since exporter countries face several challenges in delivering high quality fruit (Brecht *et al*., 2009). In addition to traditional problems, a new disorder called 'pitting' has been recently observed. In this disorder, there is a development of some sunken pits on fruit peel, which distract consumers. According to Sharma and Singh (2009) this disorder is caused by a nutrient deficiency. Studies were conducted in five indigenous cultivars such as 'Alphonso', 'Amrapali', 'Dashehari', 'Mallika' and 'Neelum', and five exotic mango cultivars such as 'Edward', 'Irwin', 'Rosari', 'Sensation' and 'Tommy Atkins' with the aim to observe the fruit pitting incidence and degree, and to investigate its probable causes. Results indicated that nearly 13% of the mango fruit was affected by fruit pitting with variable degree and magnitude. All indigenous cultivars had higher incidence of fruit pitting than exotic cultivars. 'Dashehari' had the highest incidence of fruit pitting (30.3%), followed by 'Amrapali' (28.6%), and 'Rosari' the least (3.4%). The study indicated that the incidence of fruit pitting in mangos was nearly 13% with a significant variability among the cultivars. Although the concentrations of most of the major nutrients such as N, P, K, Mg, and minor nutrients such as Cu, Mn, Fe, Zn, did not differ significantly. However, the pitted fruit had lower Ca (1.53%) and B (22 $mgkg^{-1}$) concentrations than normal fruit (2.47% and 38 mgkg−1, respectively), indicating that deficiency of Ca and B probably is the cause for fruit pitting in mangos.

In a similar assay Sharma and Srivastav (2009) studied the incidence of pitting, along with intercepted light and net CO_2 assimilation. Leaf nutrient concentrations were also determined in branches bearing normal and pitted fruit. The incidence of pitting was lowest (6.3%) in fruit at the top of the tree, followed by fruit 1.0 m (13.6%) or 0.5 m (20.0%) above the crotch. 'Dashehari' mango had the highest incidence of fruit pitting (21.8%), and 'Tommy Atkins' had the lowest incidence (9.1%). The concentrations of leaf calcium (Ca) [1.17% (w/v) *vs*. 2.08% (w/v)], and boron (B) (28 µg g^{-1} *vs*. 45 µg g^{-1}) were lower in branches bearing pitted fruit than in those bearing normal fruit,

respectively. Results suggest that pitting is related to low light levels, and to low concentrations of Ca and B.

Other authors mention an anomaly similar to pitting but they call it lenticel damage. Magwaza (2008) analyzed the incidence of lenticel damage and its relationship to fruit moisture and fruit nutrient concentration. Results showed that the intensity of lenticel damage was significantly higher in the orchard that received additional nitrogen. However, it was not possible to formulate nitrogen-lenticel damage correlations. The study failed to prove the case for a direct relationship between the disorder and nitrogen, as there were no significant or consistent correlations with nitrogen content. An interesting relationship was nevertheless observed between lenticel damage and the time of harvest before and after rainfall. The results indicated that both 'Tommy Atkins' and 'Keitt' fruit become more susceptible to lenticel damage when harvested a day after rainfall and this gradually reduces afterwards. Thus, the hypothesis that lenticelar injury may be correlated to rain presence is stated.

Otherwise, Simão de Assis et al. (2009) reports that fruit for the EU market, which does not receive the hot water treatment, is affected mainly by red spotting, and fruit for the US market by black spotting. It is suggested that black lenticel spotting occurs principally through physical processes involving the entry of water into the lenticels and the subsequent collapse and discoloration of sub-lenticellular cells. In contrast, red lenticel spotting is a physiological process involving anthocyanin production in response to low temperature in which water entry to the lenticels plays a role.

In addition, Rymbai et al. (2012) revealed that lenticel discoloration is due to several factors including cultivar differences, movement of air and water through lenticel and membrane damage and liberation of phenolics, as a consequence of inadequate pre- and post-harvest handling.

Problem to solve

In several 'Tommy Atkins' growing regions, 'pitting' or lenticel damage have been observed at different levels. However, most of the packers do not have a clear understanding if the damage comes from the orchards or it appears in some step during the packing process. In addition, there is no clear cause of this disorder, which is observed at a higher degree in 'Tommy Atkins' fruit. Because of that, this project has the following objectives

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OBJECTIVES

- To diagnose the presence of 'pitting' in 'Tommy Atkins' fruit grown in Mexico.
- To determine if 'pitting' is associated to a field factor or to any step during the packing process.
- Based on results, to find a strategy to control 'pitting' in 'Tommy Atkins' fruit.

METHODOLOGY 2013 SEASON

a. **VARIETY:** Tommy Atkins.
b. **HARVEST DATE:** From March to June, 2013 at four-week interval.

Pitting	Origin	Harvest Date	QHWT Date	Packinghouse
1	Chahuites, Oaxaca	23/March/2013	26-27/March/2013	ALEX
2	Cihuatlán, Jalisco	26/May/2013	29 -30/May/2013	ALEX
3	18 de Marzo, Nayarit	16/June/2013	18 -19/June/2013	ALEX
4	Culiacan, Sinaloa	01/July/2013	03 -04/July/2013	ALEX

c. **SAMPLING STEPS:** Collect a 50 fruit sample (completely randomized) in the following steps: a) Arrival at the packinghouse, b) After washing, c) After hot water treatment, d) After hydrocooling, e) After brushing y f) From packed boxes.
d. **STORAGE:** Simulation of refrigerated shipment (Seven days at 12 ± 1 °C; 90 ± 5 % RH) + Market simulation (22 ± 2 °C; 75 ± 10 %RH) until consumption stage.
e. **SAMPLING:** Initial, at the end of refrigerated period and then at consumption stage.
f. **VARIABLES TO MEASURE:** Pitting injury, dry matter, weight loss, skin color, firmness, pulp color, total soluble solids, titratable acidity, ratio °Bx/Acidity and nutrient content (N, Ca and B).

Detailed description of methodology

During the season 2013 (March through July) four samplings at four-week interval were done. For each sampling 50 fruit were collected (completely randomized) in the following steps: a) Arrival at the packinghouse, b) After washing, c) After hot water treatment, d) After hydrocooling, e) After brushing y f) From packed boxes. Then fruit were immediately taken to the postharvest lab located at INIFAP-Santiago Ixcuintla

Experimental Station where they were submitted to refrigeration (12 ± 1 °C; 90 ± 5 % HR) for seven days + market simulation (22 ± 2 °C; 75 ± 10 % RH) until ready to eat stage. Sampling was done at the beginning and at the end of the refrigerated period and at consumption stage. The variables to measure were pitting injury, dry matter, weight loss, skin color, firmness, pulp color, total soluble solids, tritatable acidity, ratio °Bx/Acidity and nutrient content (N, Ca and B).

'Pitting' injury based on a visual scale.

0 = no damage (< 5% skin affectation)

1 = Slight (6 to 15 % skin affectation)

2 = Moderate (16 to 25 % skin affectation)

3 = Severe (> 25 % skin affectation)

Dry matter. It was determined by cutting longitudinally 5 g of pulp in thin slices using a potato peeler. The slices were taken from the middle of the fleshy portion to ensure uniformity. Slices were placed in glass Petri dishes and dried in a microwave oven for 4-7 min until constant weight (Brecht *et al*., 2011).

Weight loss. By using an analytical digital balance (Acculab VI-4800) with accuracy of 0.1 g (Ohaus Corp. Florham Park, NJ). Twenty fruit were weighed periodically throughout the evaluation period. The difference in weight with respect to initial weight was expressed as percentage weight loss.

Peel color. By a portable colorimeter CR-10 (Konica Minolta), reporting as L a b.

Firmness. Firmness was measured using a DFE-050 Chatillon penetrometer (Ametek Instruments, Largo, FL) with a 10 mm diameter head. A portion of the skin of approximately 5 mm was removed to expose the pulp and the probe inserted about 4 mm depth at a speed of 180 mm·min-^{1}. Measurements were taken at two opposite sites. Data were expressed in Newtons (N).

Pulp color. By a portable colorimeter CR-10 (Konica Minolta), reporting as Hue values.

Total soluble solids (TSS). By a digital refractometer with temperature compensator, ATAGO model PAL-1 calibrated with distilled water (AOAC, 1984).

Titratable acidity. It was determined in 3 to 5 g of homogenized sample using phenolphthalein as an indicator with NaOH 0.1 N. Acidity was reported as % of citric acid.

Ratio ºBx/Acidity. This variable is the result of dividing total soluble solids between acidity. Desirable values at consumption time are ≥ 30.

Nutrient content. Healthy and damaged fruit will be analyzed for N, Ca and B content.

A completely randomized design with 20 replications for weight loss and eight replications for all the other variables was used.

METHODOLOGY 2014 SEASON

It was done similarly to the 2013 season with the following origins and harvesting dates:

Pitting	Origin	Harvest Date	QHWT Date	Packinghouse
1	Nva. Italia, Michoacan	20/April/2014	21/April/2014	ALEX
2	Nva. Italia, Michoacan	12/May/2014	13/May/2014	ALEX
3	Cihuatlan, Jalisco	02/June/2014	03/June/2014	ALEX
4	Tecuala, Nayarit	16/June/2014	17/June/2014	ALEX
5	Culiacan, Sinaloa	07/July/2014	08/July/2014	ALEX

RESULTS AND DISCUSSION

I.SEASON 2013.

Table 1 contains the general mean of analyzed variables for origin and harvesting date in the 2013 'Pitting' experiment. Practically there was no presence of fruit with 'Pitting' symptoms since in Oaxaca and Sinaloa the anomaly was absent, while in Jalisco and Nayarit it showed values close to 0.1. That is, almost with no injury. With respect to weight loss (WL), significant differences were detected among origins and harvesting dates; fruit harvested in Jalisco had the highest WL with 2.4 % while those harvested in Sinaloa had the lowest values with only 1.8 % WL. In relation to fruit firmness, fruit harvested in Oaxaca were superior than those harvested in the other origins. The fruit with the best quality characteristics were those harvested in Sinaloa. They showed the highest pulp color intensity, the highest TSS content, the lowest acidity, and the best ratio °Bx/Acidity.

Table 1. General mean of analyzed variables in the 'Pitting' experiment during the four harvest dates and origins. 2013 Season.

Harvesting Date	Variables 2013					
	Pitting	WL (%)	Firmness (lbf)	Hue	TSS (°Bx)	Acidity (% citric a)
March (Oaxaca)	0.000 b	2.2 b	35.3 a	80.9 b	10.3 b	0.57 a
May (Jalisco)	0.104 a	2.4 a	31.9 b	81.2 b	9.9 c	0.63 a
June (Nayarit)	0.139 a	2.2 b	33.2 b	83.3 a	10.6 a	0.46 b
July (Sinaloa)	0.000 b	1.8 c	32.6 b	78.8 c	10.8 a	0.41 b

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

Pitting Scale: 0 = No damage 1 = Light (6-15 %) 2 = Moderate (16-25 %) 3 = Severe (> 25 %)

In Table 2 it is illustrated the treatment effect on the presence of 'Pitting' in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). Fruit harvested in Oaxaca and Sinaloa did not show any 'Pitting' symptoms in none of the sampling steps, whereas fruit harvested in Jalisco and Nayarit showed only slight 'Pitting' symptoms. In both cases the fruit damage appeared after the handling during the packing processes. Thus, there are strong evidences to state that 'Pitting' doesn´t come from the orchard.

Table 2. Effect of treatment on the presence of 'Pitting' in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	0.0 a	0.0 a	0.000 a	0.000 a	0.00 a	0.0 a	0.0 a	0.0 a
2. After washing	0.0 a	0.0 a	0.125 a	0.000 a	0.25 a	0.0 a	0.0 a	0.0 a
3. After QHWT	0.0 a	0.0 a	0.000 a	0.125 a	0.50 a	0.0 a	0.0 a	0.0 a
4. After hydrocooling	0.0 a	0.0 a	0.375 a	0.250 a	0.00 a	0.0 a	0.0 a	0.0 a
5. After brushing	0.0 a	0.0 a	0.375 a	0.375 a	0.25 a	0.0 a	0.0 a	0.0 a
6. From packed boxes	0.0 a	0.0 a	0.250 a	0.000 a	0.00 a	0.0 a	0.0 a	0.0 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

Scale values: 0 = No damage 1 = Light (6-15 %) 2 = Moderate (16-25 %) 3 = Severe (> 25 %)

In Table 3 it is illustrated the treatment effect on the weight loss (WL) in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). In general it was observed that fruit WL values are according to those registered in similar experiments. It was noticed that fruit collect at arrival, after brushing, and from packed boxes had the lowest WL values. Fruit collected at arrival didn't have QHWT and those collected after brushing or from packed boxes did have QHWT but they were waxed. So, one of the benefits of waxing is to decrease the water loss.

Table 3. Effect of treatment on the weight loss (WL) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	1.6 c	5.2 b	1.6 c	6.1 c	1.7 b	5.7 a	1.2 bc	4.8 b
2. After washing	1.7 b	6.0 a	1.6 c	6.3 a	1.6 b	5.6 a	1.3 b	4.8 b
3. After QHWT	1.7 b	6.2 a	2.4 a	7.8 a	2.0 a	6.0 a	1.5 a	5.2 a
4. After hydrocooling	1.9 a	6.3 a	2.0 b	7.1 b	1.7 b	6.0 a	1.1 c	5.0 ab
5. After brushing	0.7 d	4.7 b	0.3 d	5.0 d	0.4 d	4.2 b	0.3 d	3.3 d
6. From packed boxes	0.6 d	5.0 b	0.4 d	5.2 d	0.7 c	4.2 b	0.4 d	3.8 c

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 4 it is illustrated the treatment effect on pulp firmness (lbf) in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). Firmness values observed at the end of shipping simulation were acceptable since they were around 40.0 lbf. However, it was observed that in all the cases significant differences were detected among treatments (except for Nayarit), the firmness values were around or less than 40.0 lbf, but data were inconsistent. In Oaxaca the lowest value (41.0 lbf) was for fruit collected after the QHWT; in Jalisco, the lowest firmness value (37.2 lbf) was for fruit collected after washing. For Sinaloa, the lowest firmness value (32.7 lbf) was shown by fruit collected after brushing.

Table 4. Effect of treatment on the pulp firmness (pounds) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	49.8 ab	4.5 a	46.1 ab	2.5 a	46.0 a	4.3 a	47.9 a	3.7 ab
2. After washing	50.4 ab	3.2 a	37.2 b	3.3 a	44.9 a	4.2 ab	45.4 a	4.1 a
3. After QHWT	41.0 b	3.3 a	45.9 ab	3.2 a	45.3 a	2.9 c	48.2 a	2.6 b
4. After hydrocooling	54.9 a	4.2 a	46.7 ab	2.6 a	49.5 a	3.1 abc	49.4 a	3.1 ab
5. After brushing	53.5 a	3.8 a	48.0 ab	2.8 a	46.0 a	3.0 bc	32.7 b	2.6 b
6. From packed boxes	52.9 a	4.0 a	50.8 a	2.9 a	47.8 a	3.8 abc	43.8 ab	3.5 ab

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 5 it is illustrated the treatment effect on pulp color (Hue) in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). Fruit with higher pulp color intensity will show lower values of hue, whereas the opposite occur with fruit with lower pulp color intensity since they present lower values of hue. No significant differences among treatments were detected for fruit harvested in Oaxaca and Sinaloa. However, fruit harvested in Jalisco and Nayarit showed significant differences among treatments. In Jalisco the higher pulp color intensity (82.6) was shown for fruit collected after washing, while for Nayarit were the fruit collected after QHWT (85.9). With respect to pulp color intensity at consumption stage, significant differences were detected among treatment for all the origins except Sinaloa. For fruit harvested in Oaxaca, the highest pulp color intensity was shown for fruit collected after washing and after hydrocooling with a value of 77.0. For fruit harvested in Jalisco, those collected after brushing had the highest pulp color intensity with a value of 62.2. For fruit harvested in Nayarit, those collected after washing had the highest color intensity with a value of 68.7.

Table 5. Effect of treatment on the pulp color intensity (Hue) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	82.9 a	77.2 ab	87.6 a	64.6 cd	87.8 ab	69.5 ab	84.5 a	61.2 a
2. After washing	82.5 a	77.0 b	82.6 b	67.4 bc	89.1 a	68.7 b	83.1 a	64.1 a
3. After QHWT	80.9 a	77.8 ab	86.7 ab	73.5 a	85.9 b	71.8 ab	84.3 a	64.1 a
4. After hydrocooling	82.5 a	77.0 b	85.3 ab	69.9 ab	88.4 ab	72.2 a	85.1 a	65.4 a
5. After brushing	81.0 a	77.8 ab	88.6 a	62.2 d	87.9 ab	73.1 a	84.3 a	67.2 a
6. From packed boxes	81.4 a	78.7 a	89.4 a	66.5 bcd	87.4 ab	72.5 a	84.4 a	65.8 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 6 it is illustrated the treatment effect on total soluble solids content (°Bx) in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). No significant differences among treatments were detected at consumption stage for fruit harvested in Oaxaca (12.2-13.6 °Bx) or Nayarit (12.5-13.7 °Bx). However, significant differences among treatments were detected at consumption stage for fruit harvested in Jalisco and Sinaloa. In Jalisco the lowest values were observed on fruit collected after the QHWT with only 11.5 °Bx, whereas the highest TSS content was found in fruit collected at arrival with 13.7 °Bx. In Sinaloa the lowest values were observed on fruit collected from packed boxes with only 12.6 °Bx, whereas the highest TSS content was found in fruit collected after hydrocooling with 14.4 °Bx.

Table 6. Effect of treatment on the total soluble solid content (°Bx) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	9.3 b	13.6 a	8.7 b	13.7 a	10.2 ab	12.5 a	10.2 b	13.0 b
2. After washing	10.0 ab	13.2 a	10.5 a	13.5 a	9.5 b	13.5 a	10.8 ab	13.6 ab
3. After QHWT	11.0 a	12.9 a	9.5 ab	11.5 b	11.1 a	13.6 a	11.3 ab	13.4 ab
4. After hydrocooling	9.6 b	12.2 a	10.1 ab	12.2 ab	10.6 a	13.0 a	10.9 ab	14.4 a
5. After brushing	9.9 ab	12.5 a	9.4 ab	12.4 ab	10.5 a	13.7 a	11.9 a	13.1 b
6. From packed boxes	9.7 b	12.6 a	9.7 ab	12.3 ab	10.2 ab	12.8 a	10.3 ab	12.6 b

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 7 it is illustrated the treatment effect on tritatable acidity (% of citric acid) in Tommy Atkins fruit during the 2013 season at the end of shipping simulation (a) or at consumption time (b). No significant differences among treatments were detected for acidity in any of the harvested dates at the end of the shipping simulation. However, significant differences among treatments were detected at consumption stage for fruit harvested in Oaxaca and Jalisco. In Oaxaca the lowest value (0.09) was found in fruit collected after QHWT while the highest value (0.25) was observed from packed boxes. With respect to Jalisco, the lowest value (0.09) was found in fruit collected after hydrocooling, while the highest value (0.18) was also observed from packed boxes.

Table 7. Effect of treatment on the tritatable acidity (% of citric acid) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2013 Season.

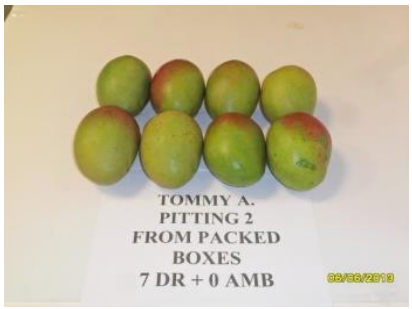
TREATMENT	TOMMY ATKINS, 2013							
	March (Oaxaca)		May (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b
1. Arrival	0.96 a	0.19 ab	0.93 a	0.12 b	0.72 a	0.16 a	0.50 a	0.18 a
2. After washing	0.96 a	0.12 b	0.80 a	0.11 b	0.84 a	0.14 a	0.66 a	0.15 a
3. After QHWT	0.84 a	0.11 b	0.86 a	0.11 b	0.49 a	0.09 a	0.52 a	0.17 a
4. After hydrocooling	0.83 a	0.12 b	0.81 a	0.09 b	0.55 a	0.10 a	0.55 a	0.17 a
5. After brushing	0.68 a	0.24 a	0.99 a	0.09 b	0.59 a	0.18 a	0.55 a	0.15 a
6. From packed boxes	0.84 a	0.25 a	0.90 a	0.18 a	0.78 a	0.12 a	0.61 a	0.22 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

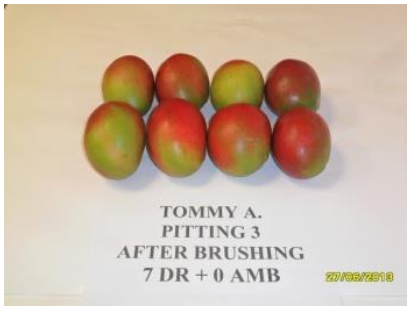
PHOTO GALLERY 2013 SEASON.

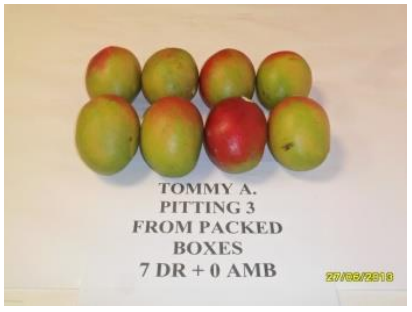
a. OAXACA

b. JALISCO



c. NAYARIT





d. SINALOA

II. 2014 SEASON.

Table 8 contains the general mean of analyzed variables for origin and harvesting date in the 2014 'Pitting' experiment. This season the presence of 'Pitting' was relatively higher than the previous year. Significant differences were detected among harvesting dates and origins. Jalisco had the highest presence of 'Pitting' with a value of 1.4, which means a light to moderated occurrence. Michoacan 1 and 2 had a little less 'Pitting' presence with values of 0.65 and 0.53, respectively, close to light occurrence. The lowest incidence of 'Pitting' was observed in Nayarit and Sinaloa, both with a value of 0.17, very close to absent. With respect to weight loss (WL), significant differences were detected among origins and harvesting dates; fruit harvested in Sinaloa had the highest WL with 2.4 % while those harvested in Nayarit had the lowest values with only 1.4 % WL. In relation to fruit firmness, fruit harvested in Nayarit were superior to those harvested in the other origins. The fruit with the best quality characteristics (except for pulp color intensity) were those harvested in Nayarit.

Table 8. General mean of analyzed variables in the 'Pitting' experiment during the five harvest dates and origins. 2014 Season.

Harvesting Date	Variables 2014					
	Pitting	WL (%)	Firmness (lbf)	Hue	TSS (°Bx)	Acidity (% citric a)
April (Michoacan)	0.650 b	1.9 b	33.0 b	75.9 d	10.4 c	0.54 b
May (Michoacan)	0.530 b	1.9 b	29.2 cd	81.0 c	10.5 c	0.43 c
June (Jalisco)	1.400 a	2.0 b	29.1 d	90.5 a	09.6 d	0.63 a
June (Nayarit)	0.170 c	1.4 c	34.7 a	90.7 a	11.6 a	0.48 bc
July (Sinaloa)	0.170 c	2.4 a	30.9 c	87.5 b	10.9 b	0.42 c

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

Pitting Scale: 0 = No damage 1 = Light (6-15 %) 2 = Moderate (16-25 %) 3 = Severe (> 25 %)

In Table 9 it is illustrated the treatment effect on the presence of 'Pitting' in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). Only Jalisco and Michoacan 1 and 2 had presence of 'Pitting' at the arrival step. Thus, in those states there is the possibility of having 'Pitting' on the orchards. Fruit with 'Pitting' symptoms had higher nitrogen content, lower calcium content and practically no differences in boron content. Fruit harvested in Jalisco, Michoacan 1 and 2, showed the higher presence of 'Pitting' at consumption stage, but the collected steps were not consistent. Fruit harvested in Jalisco had the highest 'Pitting' incidence in fruit collected after hydrocooling, while Michoacan 1 showed the higher incidence in fruit collected after washing, and in Michoacan 2 the higher incidence was in fruit collected after brushing. Nayarit and Sinaloa had a low 'Pitting' occurrence.

Table 9. Effect of treatment on the presence of 'Pitting' in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	0.0 b	0.38 d	0.00 b	0.63 b	0.38 b	1.13 b	0.00 b	0.00 c	0.0 b	0.0 a
2. After washing	0.0 b	2.75 a	0.00 b	0.50 b	1.38 ab	2.25 a	0.00 b	0.00 c	0.0 b	0.0 a
3. After QHWT	1.1 a	2.38 ab	0.13 ab	1.38 ab	2.25 a	2.38 a	0.75 a	0.00 c	0.88 a	0.5 a
4. After hydroc.	0.3 b	2.25 ab	0.38 a	2.13 a	0.88 b	2.87 a	0.00 b	1.00 a	0.25 ab	0.5 a
5. After brushing	0.0 b	0.63 cd	0.25 ab	2.25 a	0.88 b	2.38 a	0.13 b	0.38 bc	0.38 ab	0.4 a
6. Packed boxes	0.0 b	1.50 cd	0.00 b	1.75 a	1.38 ab	2.63 a	0.13 b	0.63 ab	0.00 b	0.1 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

Scale values: 0 = No damage 1 = Light (6-15 %) 2 = Moderate (16-25 %) 3 = Severe (> 25 %)

In Table 10 it is illustrated the treatment effect on the weight loss (WL) in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). In general it was observed that fruit WL values are according to those registered in similar experiments. Significant differences were detected among treatments in all the harvested dates and origins. In Michoacan 1 the highest WL was for fruit collected from packed boxes with 5.5 % while the lowest WL was found for fruit collected after brushing with 4.4 %. In Michoacan 2 the highest WL was for fruit collected after QHWT with 6.0 % while the lowest WL was found for fruit collected after brushing with 3.8 %. In Jalisco the highest WL was for fruit collected after washing with 6.0 % while the lowest WL was found for fruit collected at arrival with 4.9 %. In Nayarit the highest WL was for fruit collected after QHWT with 4.3 % while the lowest WL was found for fruit collected from packed boxes with 2.6 %. In Sinaloa the highest WL was for fruit collected after QHWT with 7.1 % while the lowest WL was found for fruit collected after brushing with 5.7 %.

Table 10. Effect of treatment on the weight loss (WL) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	0.9 a	4.5 cd	0.8 c	4.8 c	0.7 b	4.9 c	0.9 a	3.7 b	1.1 c	5.8 b
2. After washing	0. 8 a	5.1 ab	1.0 b	5.3 b	1.1 a	6.2 a	0.7 ab	3.8 b	1.2 bc	5.9 b
3. After QHWT	0.7 a	4.9 bc	1.5 a	6.0 a	0.80 b	6.0 a	0.8 ab	4.3 a	1.6 a	7.1 a
4. After hydroc.	0.7 a	5.0 b	1.1 b	5.6 ab	0.7 b	6.1 a	0.7 bc	3.5 bc	1.3 b	7.0 a
5. After brushing	0.7 a	4.4 d	0.5 d	3.8 d	0.5 b	5.2 bc	0.6 cd	3.2 c	0.7 d	5.7 b
6. Packed boxes	0.8 a	5.5 a	0.4 d	4.1 d	0.6 b	5.7 ab	0.5 d	2.6 d	0.8 d	6.8 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 11 it is illustrated the treatment effect on pulp firmness (lbf) in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). Firmness values observed at the end of shipping simulation were acceptable since they were around 40.0 lbf. However, it was observed that in all the cases significant differences were detected among treatments (except for Michoacan 1 and 2), the firmness values were around or less than 40.0 lbf, but data were inconsistent. In Jalisco the lowest value (36.0 lbf) was for fruit collected after washing; in Nayarit, the lowest firmness value (40.2 lbf) was for fruit collected at arrival. For Sinaloa, the lowest firmness value (36.9 lbf) was shown by fruit collected after QHWT.

Table 11. Effect of treatment on the pulp firmness (pounds) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	46.1 a	6.4 a	42.6 a	4.3 a	41.5 ab	4.1 a	40.2 b	8.0 ab	44.1 ab	3.8 a
2. After washing	44.4 a	3.9 a	41.4 a	3.3 ab	36.0 b	4.1 a	48.6 ab	8.7 a	48.8 a	3.8 a
3. After QHWT	44.6 a	4.8 a	42.3 a	3.9 a	40.2 ab	3.8 ab	56.1 a	5.7 bc	36.9 b	2.5 b
4. After hydroc.	47.1 a	2.8 a	40.6 a	4.0 a	40.6 ab	3.5 ab	52.3 a	6.8 abc	44.9 ab	3.1 ab
5. After brushing	46.9 a	3.1 a	39.9 a	3.7 ab	43.2 ab	3.1 b	48.1 ab	4.9 c	41.3 ab	2.9 ab
6. Packed boxes	48.1 a	3.5 a	38.2 a	2.7 b	44.5 a	4.4 a	45.7 ab	4.3 c	47.2 a	2.7 ab

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 12 it is illustrated the treatment effect on pulp color (Hue) in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). Fruit with higher pulp color intensity will show lower values of hue, whereas the opposite occur with fruit with lower pulp color intensity since they present lower values of hue. No significant differences among treatments at consumption stage were detected for fruit harvested in Michoacan 1, Jalisco, and Nayarit. However, fruit harvested in Michoacan 2 and Sinaloa showed significant differences among treatments. In Michoacan 2 the higher pulp color intensity (83.2) was shown for fruit collected at arrival, while for Sinaloa were the fruit collected also at arrival (82.0).

Table 12. Effect of treatment on the pulp color intensity (Hue) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	74.0 b	69.1 a	74.5 ab	83.2 b	90.0 a	86.6 a	91.9 ab	85.3 a	88.6 ab	82.0 b
2. After washing	76.7 ab	69.5 a	80.9 a	84.7 a	89.9 b	86.4 a	93.3 a	85.2 a	89.3 ab	84.0 a
3. After QHWT	78.0 ab	69.6 a	78.3 ab	85.3 a	92.9 ab	86.8 a	94.3 a	86.3 a	87.5 b	84.4 a
4. After hydroc.	78.3 ab	69.0 a	73.4 ab	85.3 a	92.4 ab	86.4 a	94.1 a	85.6 a	89.2 ab	84.4 a
5. After brushing	77.1 ab	64.7 a	66.6 b	85.4 a	94.4 a	86.7 a	92.3 ab	85.8 a	87.7 b	84.2 a
6. Packed boxes	81.8 a	68.3 a	77.0 ab	85.1 a	93.6 a	87.3 a	89.8 b	84.6 a	90.1 a	84.0 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 13 it is illustrated the treatment effect on total soluble solids content (°Bx) in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). No significant differences among treatments were detected at consumption stage for fruit harvested in Michoacan 1 (13.2-14.4 °Bx), Michoacan 2 (13.6-14.8 °Bx), or Jalisco (11.6-12.5 °Bx). However, significant differences among treatments were detected at consumption stage for fruit harvested in Nayarit and Sinaloa. In Nayarit the lowest values were observed on fruit collected after brushing with 14.6 °Bx, whereas the highest TSS content was found in fruit collected after washing with 16.9 °Bx. In Sinaloa the lowest values were observed on fruit collected after brushing with only 13.0 °Bx, whereas the highest TSS content was found in fruit collected at arrival with 15.1 °Bx.

Table 13. Effect of treatment on the total soluble solid content (°Bx) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	10.2 a	13.9 a	9.7 ab	14.7 a	9.7 a	11.7 a	11.6 a	16.6 a	9.3 d	15.1 a
2. After washing	10.2 a	14.4 a	8.4 b	14.7 a	9.4 ab	12.1 a	9.3 b	16.9 a	9.7 cd	14.9 a
3. After QHWT	7.7 c	13.6 a	9.1 ab	14.7 a	9.1 ab	11.7 a	10.7 ab	15.8 ab	11.3 a	14.3 a
4. After hydroc.	8.8 b	14.2 a	9.7 ab	13.9 a	8.6 abc	11.6 a	9.2 b	15.1 ab	9.9 bcd	14.5 a
5. After brushing	9.7 ab	13.2 a	10.5 a	13.6 a	7.9 c	12.0 a	10.7 ab	14.6 b	10.9 ab	13.0 b
6. Packed boxes	10.1 a	13.4 a	10.7 a	14.8 a	8.3 c	12.5 a	12.4 a	15.2 ab	10.7 abc	14.4 a

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

In Table 14 it is illustrated the treatment effect on tritatable acidity (% of citric acid) in Tommy Atkins fruit during the 2014 season at the end of shipping simulation (a) or at consumption time (b). No significant differences among treatments were detected for acidity at the end of the shipping simulation for Michoacan 1 an2, and Nayarit. However, significant differences among treatments were detected at consumption stage for fruit harvested in Jalisco and Sinaloa. In Jalisco the lowest value (0.15) was found in fruit collected after QHWT while the highest value (0.41) was observed at arrival. With respect to Sinaloa, the lowest value (0.10) was found in fruit collected from packed boxes, while the highest value (0.18) was also observed from fruit collected after washing.

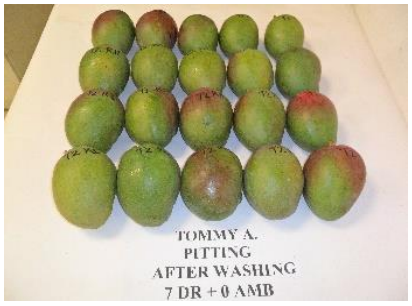
Table 14. Effect of treatment on the tritatable acidity (% of citric acid) in Tommy Atkins fruit at the end of shipping simulation (a) o at consumption (b). 2014 Season.

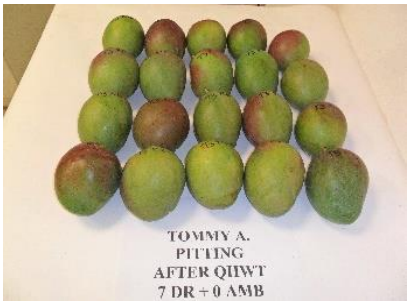
TREATMENT	TOMMY ATKINS, 2014									
	April (Michoacan)		May (Michoacan)		June (Jalisco)		June (Nayarit)		July (Sinaloa)	
	a	b	a	b	a	b	a	b	a	b
1. Arrival	0.88 a	0.14 a	0.69 a	0.16 a	0.74 b	0.41 a	0.65 a	0.45 a	0.69 a	0.26 ab
2. After washing	0.76 a	0.11 a	0.70 a	0.12 a	0.73 b	0.27 bc	0.48 a	0.21 a	0.75 a	0.28 a
3. After QHWT	0.61 ab	0.16 a	0.51 abc	0.13 a	1.10 ab	0.15 c	0.67 a	0.28 a	0.66 a	0.11 c
4. After hydroc.	0.58 ab	0.11 a	0.35 c	0.13 a	0.95 ab	0.28 b	0.48 a	0.22 a	0.63 a	0.13 bc
5. After brushing	0.48 b	0.08 a	0.45 bc	0.16 a	0.81 b	0.27 bc	0.38 a	0.18 a	0.56 a	0.13 bc
6. Packed boxes	0.81 a	0.13 a	0.63 ab	0.14 a	1.21 a	0.22 bc	0.62 a	0.40 a	0.80 a	0.10 c

Means with the same letter within columns are statistically equal (Duncan P ≤ 0.05)

PHOTO GALLERY 2014 SEASON.

a. MICHOACÁN 1.



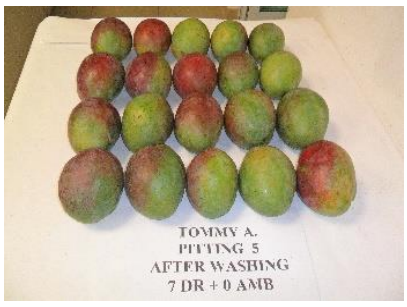


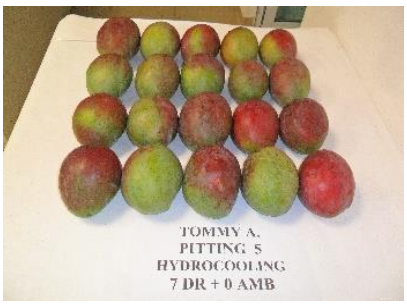
b. MICHOACÁN 2.

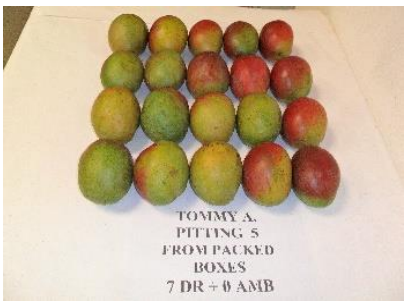
c. JALISCO.

d. NAYARIT.

e. SINALOA.







With respect to nutrient content and its relationship with presence of ‘Pitting’, in the Figure 1 it is illustrated the nitrogen, calcium, and boron content in the skin of Tommy Atkins fruit with or without ‘Pitting’. Fruit with higher incidence of ‘Pitting’ were those harvested Jalisco (1.4), Michoacan 1 (0.65), and Michoacan 2 (0.53), which was correlated with higher nitrogen content, lower calcium content, as well as relatively higher boron content.

With respect to nutrient content and its relationship with presence of ‘Pitting’, in the Figure 2 it is illustrated the nitrogen, calcium, and boron content in the pulp of Tommy Atkins fruit with or without ‘Pitting’. Fruit with higher incidence of ‘Pitting’ were those harvested Jalisco (1.4), Michoacan 1 (0.65), and Michoacan 2 (0.53), which was correlated with higher nitrogen content, lower calcium content, as well as no differences in boron content.

Finally, with respect to nutrient content and its relationship with presence of ‘Pitting’, in the Figure 3 it is illustrated the nitrogen, calcium, and boron content in the stone of Tommy Atkins fruit with or without ‘Pitting’. Fruit with higher incidence of ‘Pitting’ were those harvested Jalisco (1.4), Michoacan 1 (0.65), and Michoacan 2 (0.53), which was correlated with higher nitrogen content only for fruit collected in Michoacan 2 but not for those collected in Jalisco or Michoacan 1. With relation to calcium content, fruit harvested in Michoacan 1 or 2 had lower calcium content, as well no differences in boron content.

Figure 1. Nitrogen, calcium, and boron content in the skin of Tommy Atkins fruit with or without 'Pitting. 2014 Season.

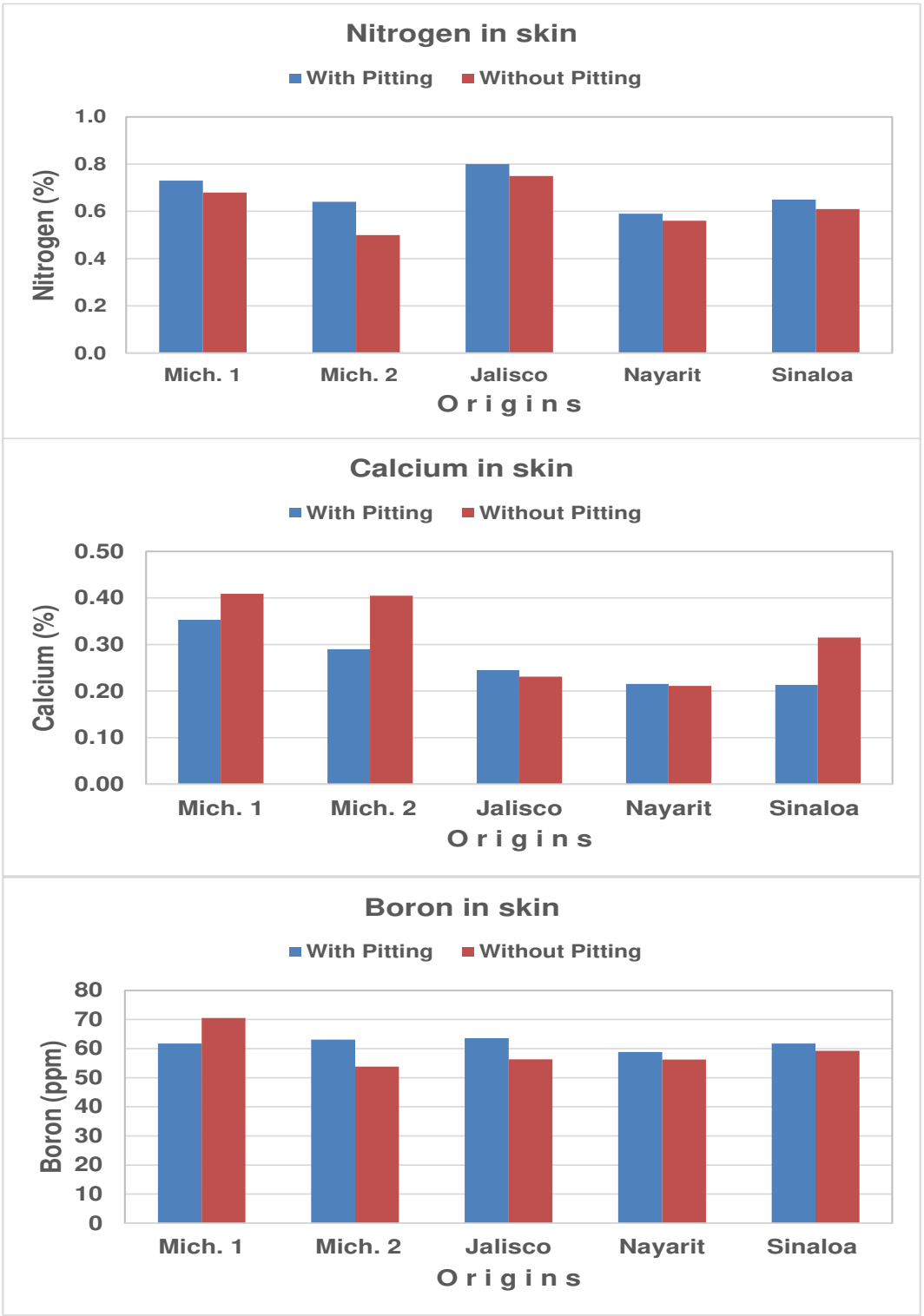


Figure 2. Nitrogen, calcium, and boron content in the pulp of Tommy Atkins fruit with or without 'Pitting. 2014 Season.

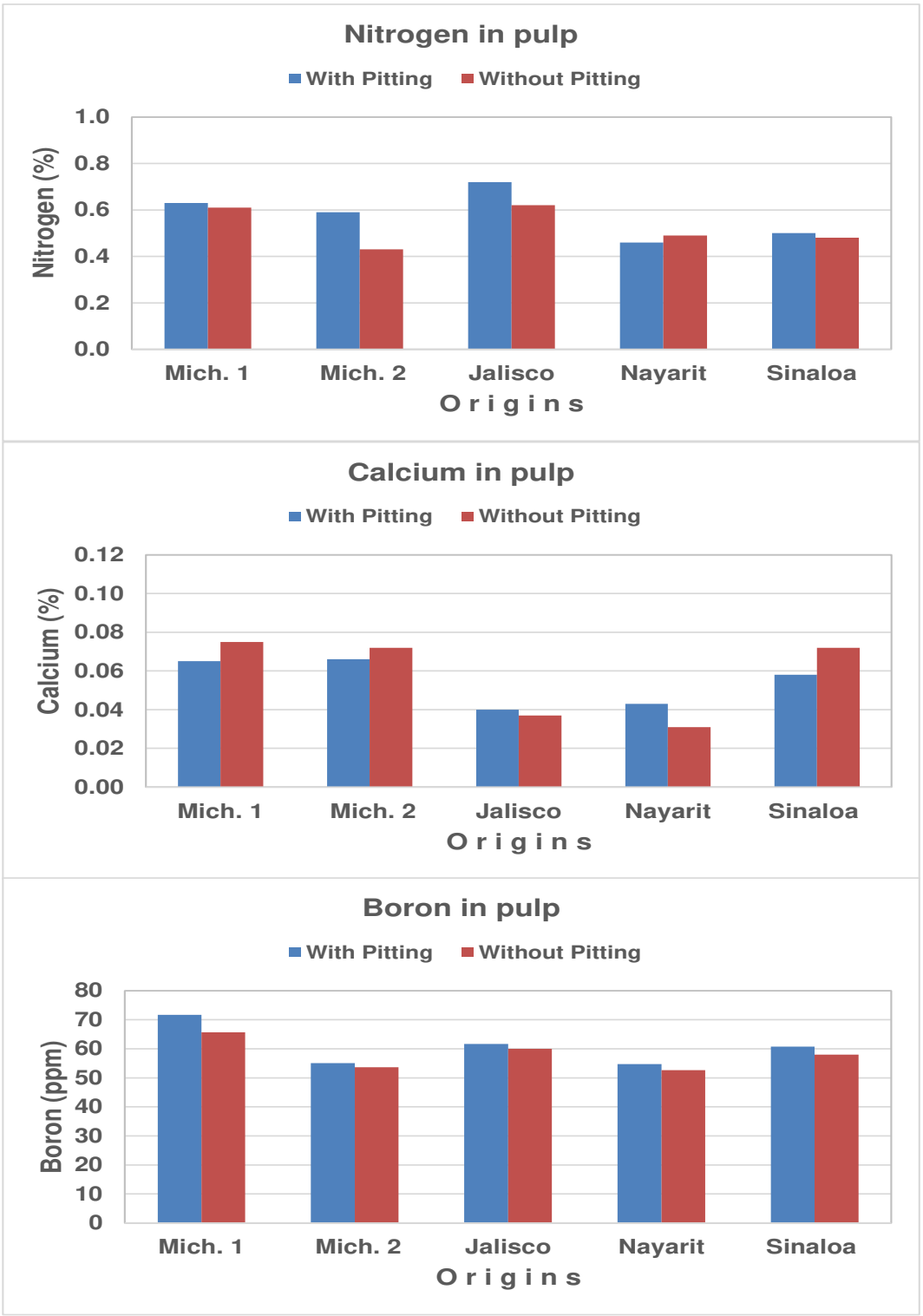
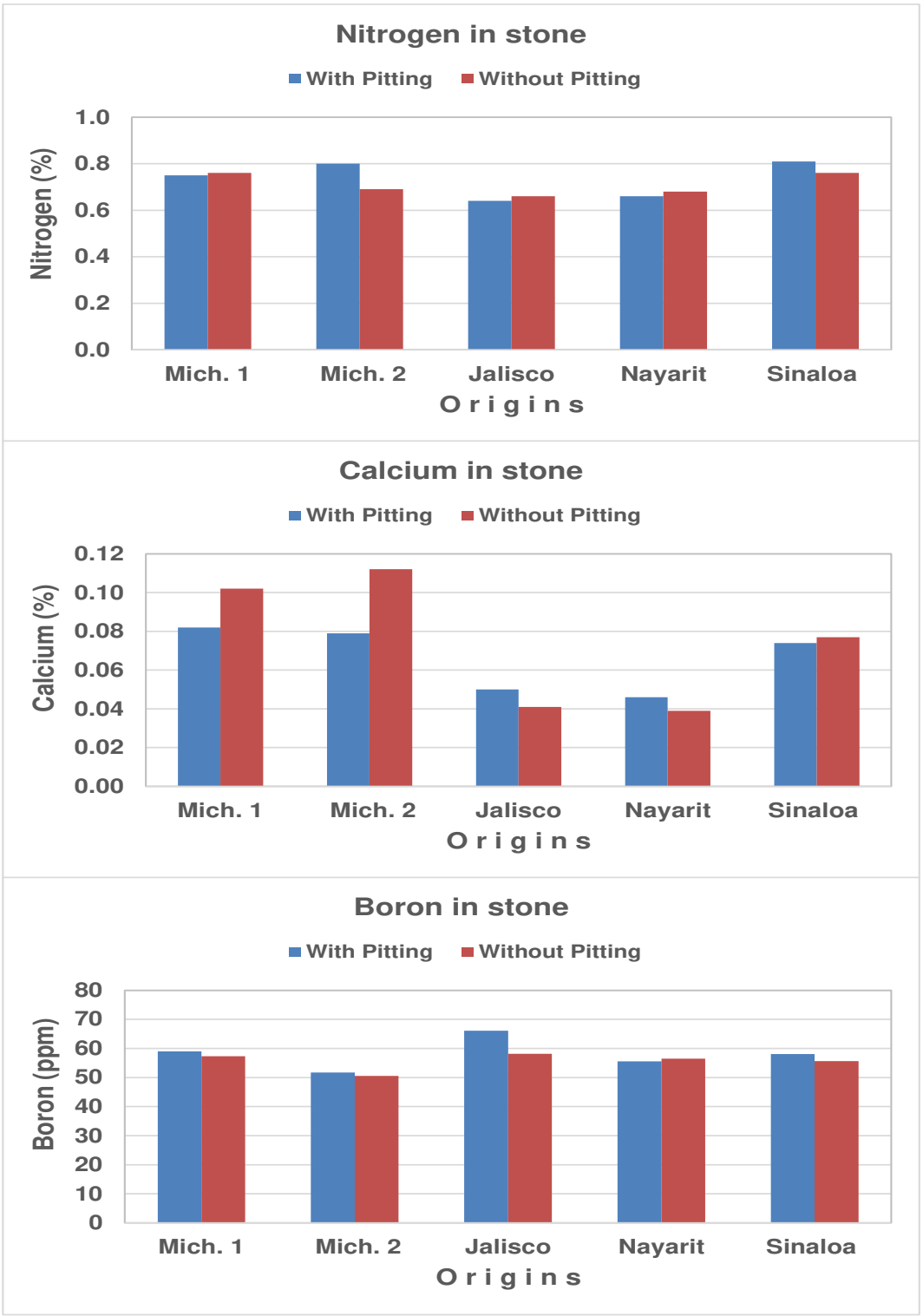


Figure 3. Nitrogen, calcium, and boron content in the stone of Tommy Atkins fruit with or without 'Pitting. 2014 Season.



CONCLUSIONS

- In 2013 the presence of 'Pitting' in Tommy Atkins fruit was with very low frequency and light intensity for fruit harvested in Jalisco and Nayarit. The damage was associated with some step during the packing process. 'Pitting' was absent from fruit harvested in Oaxaca and Sinaloa.

- In 2014 'Pitting' was present in all the harvested states. Jalisco (1.4), Michoacan 1 (0.65), and Michoacan 2 (0.53) had the highest 'Pitting' presence, which was correlated with higher nitrogen content, lower calcium content, as well as relatively higher boron content in the skin. 'Pitting' presence was correlated with higher nitrogen content, lower calcium content, as well as no differences in boron content for the pulp. 'Pitting' presence was correlated with higher nitrogen content in stone only for fruit collected in Michoacan 2 but not for those collected in Jalisco or Michoacan 1. With relation to calcium content, fruit harvested in Michoacan 1 or 2 had lower calcium content in stone, as well no differences in boron content.

- Since the presence of 'Pitting' was very low, these experiments helped us to make quality comparison among Tommy Atkins fruit harvested from different origins. In 2013 the fruit harvested from Sinaloa were the best because they did not show any 'Pitting' symptoms, they had the lowest WL, the highest TSS content and the lowest acidity. In 2014 the fruit harvested in Nayarit showed the best quality characteristics for all the evaluated variables except pulp color intensity.

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