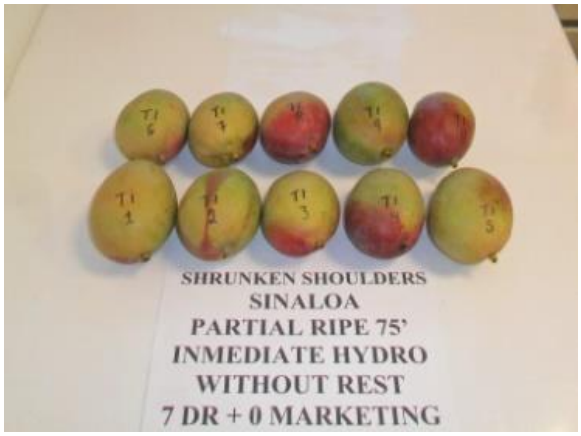
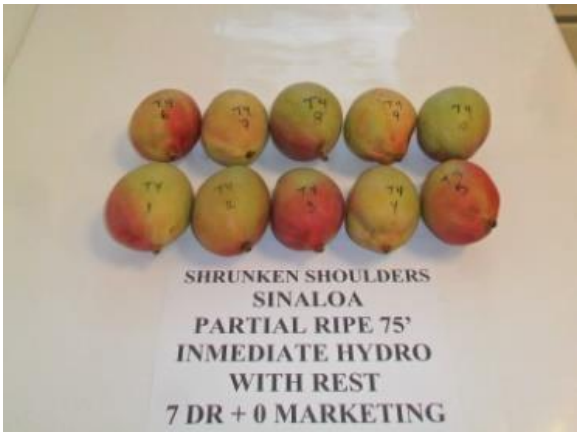
AGREEMENT INIFAP-NATIONAL MANGO BOARD

DETERMINING THE CAUSE OF SHRUNKEN SHOULDERS IN 'TOMMY ATKINS' FRUIT GROWN IN DIVERSE ENVIRONMENTS IN MEXICO





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CONTENT

EXECUTIVE SUMMARY

In 'Tommy Atkins' it is common to find a high percentage of fruits with 'shrunken shoulders' or 'sucking', which is correlated, among others, with the following factors: 1. Ripening degree at harvest 2. Quarantine hot water treatment (QHWT) 3. Hydrocooling 4. Rest after hydrocooling and 5. Nutritional status of the orchard. The objectives were the following: a. Check if ripening degree at harvest is a determining factor for the presence of 'shrunken shoulders' in fruits of 'Tommy Atkins' b. Determine if the time of normal QHWT or with additional time influences the presence of ' shrunken shoulders' in 'Tommy Atkins' fruits c. To establish if the method of hydrocooling is fundamental to revert and/or reduce the potential damage of the QHWT on the presence of 'shrunken shoulders', as well as d. To prove if the rest is beneficial or harmful in the incidence of 'shrunken shoulders' in 'Tommy Atkins' fruits.

The study was carried out during the 2016 season with fruits of 'Tommy Atkins' harvested in Guerrero, Nayarit and Sinaloa, as well as during the 2017 season with fruits of 'Tommy Atkins' harvested in Jalisco, Nayarit and Sinaloa. The factors under study were: a. Origin b. Ripening degree at harvest (partial ripe and ripe) c. Time of QHWT (75 or 90 min) d. Hydrocooling (immediate, after 30 min and without) and e. Rest (without or rest for 24 h). Once the treatments were applied, the fruits were stored for seven days in refrigeration (12 ± 1 °C, 95 ± 5% RH) and then in marketing simulation (22 ± 2 °C, 75 ± 10% RH) until consumption stage. Samplings were done at the beginning and at the end of the refrigerated storage and at consumption stage. The variables measured were fruit temperature, dry matter, percentage of shrunken shoulders, weight loss, firmness, pulp color, content of total soluble solids and acidity. A completely randomized design with a factorial arrangement was used, taking 10 replications for weight loss and shrunken shoulders, as well as five replications for the rest of the variables.

It was found that the presence of 'Tommy Atkins' fruits with shrunken shoulders for the 2016 season was minimal (<1.0%). Significant factors were origin and rest after hydrocooling. The fruits harvested in Nayarit presented the highest percentage of shrunken shoulders, while the fruits without rest showed the least presence. However, the results of 2017 showed a presence of almost 30% of fruits with shrunken shoulders. The fruits of 'Tommy Atkins' harvested in Jalisco did not show the damage. However, the fruits 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 fruits of 'Tommy Atkins' with shrunken shoulders were ripening degree at harvest and rest. Fruits harvested partial ripe showed a higher percentage of shrunken shoulders in all the samplings. At the beginning, the partial ripe fruits showed 18.1% of fruits with shrunken shoulders, in comparison to only 3.9% of the ripen fruits. At the end of refrigeration, partial ripe fruits increased the presence of shrunken shoulders to 25.3%, while ripen fruits showed only 8.9% of fruits with shrunken shoulders. At consumption stage, the partial ripe fruits accumulated 25.6% of fruits with shrunken shoulders, while ripe fruits accumulated only 11.4%. Growers and packers will have to take into account the ripening

degree at harvest of 'Tommy Atkins' fruits, since the fruits harvested low and/or partial ripe will present a high percentage of this anomaly. The other factor that significantly influenced the presence of fruits with shrunken shoulders was the rest, mainly in the initial sampling, since the fruits with rest of 24 h showed three times more fruits with sunken shoulders (16.1%) than those without rest (5.8%). This information confirms that the practice of rest is not as beneficial as most packers think, since at the end of the rest only the fruits that show this anomaly are detected, but it does not prevent its appearance. If the packing process is done continuously, the presence of fruits with shrunken shoulders will be less. On the other hand, QHWT times were very influenced by ripening degree at harvest. Those subjected to 75 min showed a higher percentage of shrunken shoulders than those subjected to 90 min. The QHWT for 75 min was applied to fruits with weight less than 500 g and these were the ones with the highest percentage of partial ripe fruits. Hydrocooling did not affect the presence of 'Tommy Atkins' fruits with shrunken shoulders, since in the initial sampling no significant differences were detected among immediate hydrocooling, after 30 min or without hydrocooling. However, both at the end of refrigeration and consumption stage, the trend was to have a higher percentage of fruits with shrunk shoulders in immediate hydrocooling, followed by hydrocooling after 30 min or without hydrocooling. Apparently, there is a contradiction in the effect of this factor, although it is worth noting that the fruits with immediate hydrocooling had an additional 10 min of QHWT and those of hydrocooling after 30 min only had the regulatory time of 75 or 90 min of QHWT. The nutritional diagnosis in the fruit is a precedent that indicates that tree nutrition is related to the presence of shrunken shoulders. If the orchard has an unbalanced fertilization, the possibility of occurrence of this anomaly is greater. In summary, to reduce or minimize the presence of fruits with shrunken shoulders, it is recommended to harvest ripe fruits, as well as, to avoid the rest of 24 or 48 h (if economically viable), traditionally carried out by the packers.

BACKGROUND

Mango is one of the favorite fruit in the USA market, where consumption has doubled in the past 10 years. During the last three years (2010-2012) on the average, 76.3 million 10-pound boxes have been imported; mainly from Mexico (67.0%), Peru (10.0%), Ecuador (9.0%), Brazil (7.1%), Guatemala (4.6%), and Haiti (2.3%) [USDA-FAS, 2012].

Mexico is one of the top mango exporters to the USA providing 67% of the total exported by producing countries, which represents around 60 million boxes per year (USDA-FAS, 2012). The main varieties exported for the US market are Tommy Atkins, Ataulfo, Kent and Keitt accounting 35, 30, 15 and 10% respectively of the exported volume (EMEX, A.C., 2014).

In 'Tommy Atkins', a high percentage of fruit with 'shrunken shoulders' is frequently found (Figure 1), which is correlated to the following factors:

1. Ripening stage at harvest
2. Quarantine Hot Water Treatment (QHWT)
3. Hydrocooling
4. Rest after hydrocooling
5. Nutrimental status of the orchard

Fig. 1. Example of fruit with 'shrunken shoulders'

Taken from Brecht *et al*. (2011)

Regarding the effect of ripening stage at harvest on the presence of 'shrunken shoulders', packers comment that under their experience fruit partially ripe is more susceptible to present this problem. Although, during the last seasons this anomaly has been present in ripe fruit harvested in certain growth areas. Bretch *at al.* (2011) stated that this disorder can be present in unripe mango submitted to QHWT, or that has exceeded time or recommended temperature.

Treatment with hot water to control fruit fly larvae (QHWT) must be done in strict compliance to the protocol indicated by the USDA-APHIS (2010). Water temperature must be of 46.1 °C (115 °F) and timing varies according to shape and weight of the fruit (table 1). If the QHWT is applied according to protocol, only slight external damage will be observed maintaining quality and shelf life (Osuna, 2015).

Table 1. QHWT protocol by the USDA-APHIS (2010)

Fruit shape	Fruit weight (g)	QHWT time (min)
Round[1]	≤ 500	75
	501-700	90
	701-900	110
Flat[2]	≤ 375	65
	376-570	75

[1] Round varieties: Tommy Atkins, Kent, Keitt, and Haden

[2] Flat varieties: Ataulfo, Manila, Francis

Hydrocooling after QHWT is allowed by the USDA-APHIS (2010) under two modalities:

1. Hydrocooling immediately after the QHWT adding 10 additional min to the treatment time, or

2. Hydrocooling after a 30-minute stay at packinghouse temperature (normally above 30 °C), without changing treatment time.

In both cases it is required that hydrocooling temperatures not be under 21.1 °C (70 °F) and the hydrocooling time be long enough to reach a pulp temperature between 27 and 29 °C (80 to 85 °F), which is achieved with at least 30 min treatment.

Hydrocooling immediately after QHWT is recommended, because it reduces pulp temperature faster than just leaving the fruit at room temperature, which in turn prevents some of the possible injury caused by the hot water treatment of the QHWT (Brecht *et al*., 2011). In places where the infrastructure needed for hydrocooling is not available, fruit is cooled at packinghouse temperature, which reduces pulp temperature much more slowly causing the possible damage by the QHWT, which cannot be reverted and the fruit enters a much faster ripening process because of the increase in respiration and ethylene production.

Concerning the rest period after QHWT and/or hydrocooling, packers argue that waiting for 24 to 48 hours before classification and packing is very useful to detect fruit with shrunken shoulders. However, under my own experience, this can be a harmful practice that is increasing the percentage of damaged fruit, since letting fruit remain hot for 24 to 48 h at packinghouse conditions (higher than 30 °C), increases the speed of physiological processes, such as respiration and ethylene production, which in turn accelerates the ripening and deterioration processes.

Finally, it seems that nutrimental conditions influence the quality and potential of postharvest life, as well as, the presence or absence of shrunken shoulders. Growers debate that there are certain zones where this anomaly is frequently seen and that can be due to the nutrimental status of the orchard. Fruit with a low content of calcium and potassium and high in nitrogen are potentially in higher risk of presenting this anomaly (Romero-Gomezcaña *et al.,* 2006).

OBJECTIVES

- To prove if the ripeness stage at harvest is a determining factor to the presence of ‘shrunken shoulders’ in ‘Tommy Atkins’ fruit.
- To determine if a normal QHWT time or a lengthened period influences the presence of ‘shrunken shoulders’ in ‘Tommy Atkins’ fruit.
- To establish if the cooling method is fundamental in reverting and/or reducing potential damage by the QHWT on the presence of ‘shrunken shoulders’ in ‘Tommy Atkins’ fruit.
- To prove if a rest period is useful or harmful in the incidence of ‘shrunken shoulders’ in ‘Tommy Atkins’ fruit.
- To diagnose if the concentrations of nitrogen, potassium, phosphorus and calcium in fruits of 'Tommy Atkins', with and without incidence of 'shrunken shoulders', are related to this anomaly.

METHODOLOGY

a. VARIETY: Tommy Atkins.

b. PRODUCTION ZONES: Guerrero, Jalisco, Nayarit, and Sinaloa.

c. RIPENING STAGE AT HARVEST:

1. Low or partial ripe fruit (neither flat shaped without filled cheeks nor risen shoulders, with a pulp color ranging from 1 to 2 (according to EMEX A.C. chart) and a total soluble solid content <7.3 °Bx).
2. Ripe fruit (rounded form with full cheeks and raised shoulders, a pulp color ranging from 2 to 3 (according to EMEX A.C. chart) and a total soluble solid content >7.3 °Bx).

d. EXPOSITION TIME TO QHWT:

1. 75 min.

2. 90 min.

e. HYDROCOOLING:

1. Immediately for 30 min (with 10 additional min of QHWT)
2. With 30 min of wait after the QHWT without additional time.
3. Without hydrocooling.

f. REST TIME AFTER HYDROCOOLING

1. Without rest.
2. Rest for 24 h.

g. TREATMENTS

Treat.	Ripening degree	QHWT time (min)	Hydrocooling	Rest
1	Partial ripe	75	Immediate	Without
2	Partial ripe	75	After 30 min	Without
3	Partial ripe	75	Without	Without
4	Partial ripe	75	Immediate	With
5	Partial ripe	75	After 30 min	With
6	Partial ripe	75	Without	With
7	Partial ripe	90	Immediate	Without
8	Partial ripe	90	After 30 min	Without
9	Partial ripe	90	Without	Without
10	Partial ripe	90	Immediate	With
11	Partial ripe	90	After 30 min	With
12	Partial ripe	90	Without	With
13	Ripe	75	Immediate	Without
14	Ripe	75	After 30 min	Without
15	Ripe	75	Without	Without
16	Ripe	75	Immediate	With
17	Ripe	75	After 30 min	With
18	Ripe	75	Without	With
19	Ripe	90	Immediate	Without
20	Ripe	90	After 30 min	Without
21	Ripe	90	Without	Without
22	Ripe	90	Immediate	With
23	Ripe	90	After 30 min	With
24	Ripe	90	Without	With

h. **STORAGE:** Simulation of refrigerated shipment (7 days at 12 ± 1°C; 90 ± 5 % RH) + Market simulation (22 ± 2°C; 75 ± 10% RH) until consumption stage.

i. **SAMPLING**: Initial, at the end of refrigerated period and then at consumption stage.

VARIABLES MEASURED:

Fruit temperature. With a digital pen type thermometer, model JR1 before and after QHWT, at the end of hydrocooling, and at the end of the rest period.

Dry matter. Using a potato peeler 5 g of pulp was sliced. The slices were taken from the middle part of the fruit after removing the skin. The slices were placed in glass petri dishes and dehydrated in a microwave oven during 4 to 7 minutes up to reaching to a constant weight (Brecht *et al.*, 2011).

Weight loss. By means of portable digital scale with a 2000 g capacity and an approximation of 0.1 g (Ohaus corp Florham Park, NJ). Ten individual fruits were weighed periodically during all the evaluation period. The weight difference and its relation to the initial weight were expressed as weight loss percentage.

Percentage of fruit with shrunken shoulders: Sampling within the same population of fruit used for weight loss, and it was quantified as percentage of the total fruit.

Firmness. Using a DFE-050 Chatillon penetrometer (Ametek Instruments, Largo, FL) with an 8 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}. Data was expressed in pounds.

Pulp color. Using a Konica Minolta CR 400 portable colorimeter reporting hue values.

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

Fruit nutrimental composition. The nutrimental composition (Nitrogen, potassium, phosphorus, and calcium) were compared in skin and pulp, from fruit with or without shrunken shoulders.

A Factorial design was used, with 10 replications for weight loss and shrunken shoulders, three for fruit temperature and five for all the other variables.

RESULTS AND DISCUSSION

Fruit temperature

Figure 1 shows the 'Tommy Atkins' fruit temperatures of the three origins (Jalisco, Nayarit and Sinaloa) before and after the QHWT, as well as after the hydrocooling variants (immediate, after 30 min or without hydrocooling). The trends were practically the same in the fruits of the three regions. The initial fruit temperature was around 82°F, observing the norm, which indicates that to initiate the QHWT; the pulp temperature must be higher than 70°F (USDA, 2010). The duration of the QHWT (at least 115.0°F), was critical for the fruit temperature being higher; the longer the QHWT, the higher the fruit temperature. This is one of the factors that can affect the postharvest quality and shelf life of 'Tommy Atkins' fruits; however, it is a mandatory quarantine requirement for anyone who exports mangos to the United States from areas reported with fruit fly presence. The duration varies with the size of the fruit. For 'Tommy Atkins', 75 min are required for fruits less than 500 g and 90 min for fruits with weights between 501 and 700 g (USDA, 2010). On the other hand, the impact of the hydrocooling variant on the fruit temperature was very clear. It would be assumed that the immediate hydrocooling should be the one that would decrease the temperature the most; however, in the fruits of Nayarit and Sinaloa the fruit temperature with immediate hydrocooling was higher than that of the fruits with hydrocooling at the end of 30 min of rest at the packinghouse environment (usually >86°F). This is because, as a rule, fruits with immediate hydrocooling receive an additional 10 min of QHWT. On the other hand, the fruits that did not receive hydrocooling maintained a temperature of 104 to 107°F, which

certainly will not decrease rapidly since the ambient temperature is higher than 86°F. This situation influences the fruit to accelerate their respiration and ethylene production, which consequently shortens their shelf life.

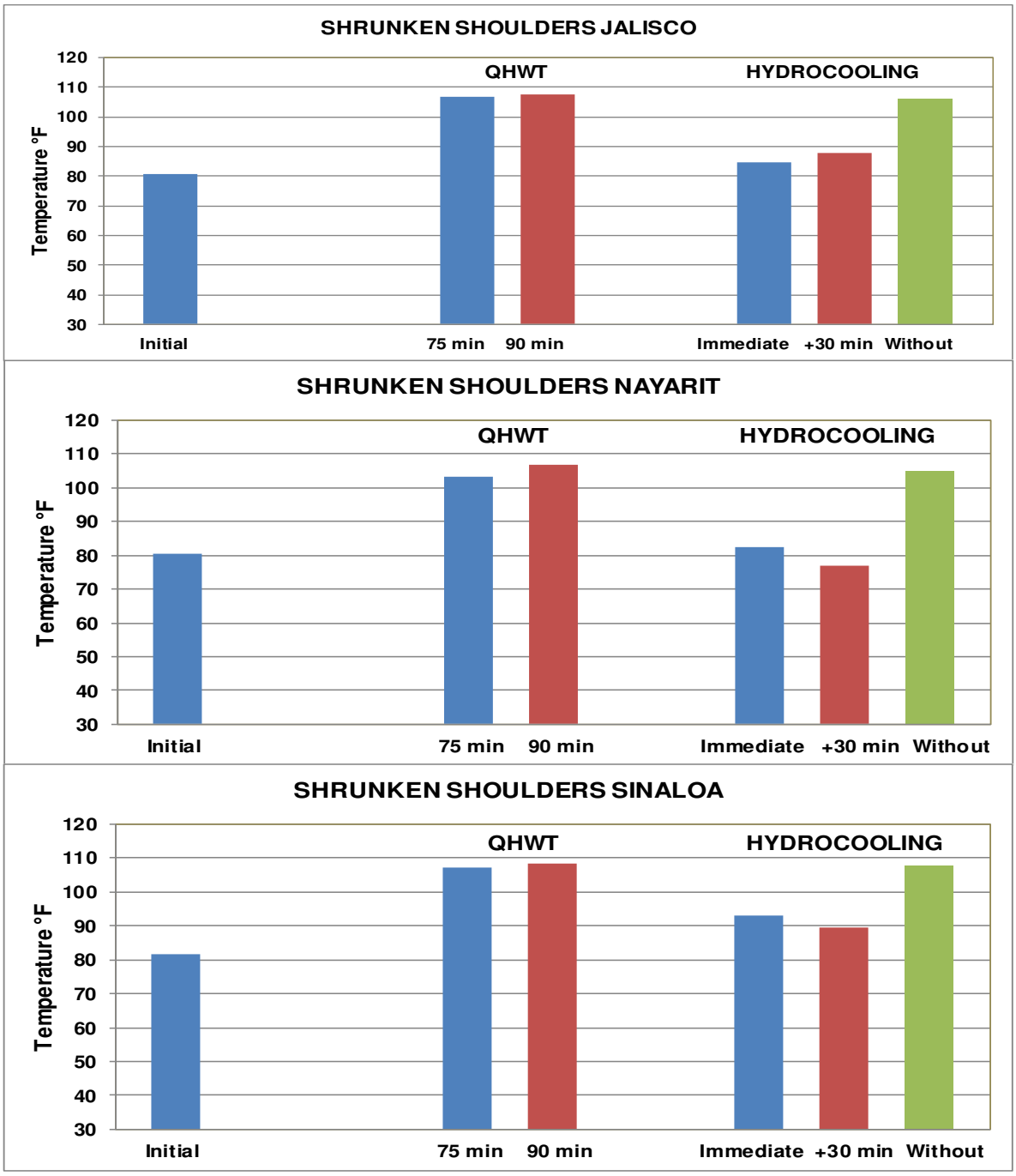

Figure 1. Effect of hydrothermal time and hydrocooling on Tommy Atkins

fruit temperature. 2017.

Dry matter content (%).

Table 2 shows the results of dry matter (DM) content of 'Tommy Atkins' fruits for different origins and ripening degrees during 2016 and 2017. It was observed that DM values ranged from 15.0% (partial ripe) up to 20.4% (ripe), which are higher than the quality standards proposed by the Australian Mango Industry Association (AMIA, 2016) that handle a range of 13 to 15% DM for their varieties. In addition, these values are higher than those set by González-Moscoso (2014), who pointed out in her proposal of Minimum Quality Index (MQI) that values for 'Tommy Atkins' are ≥13.0. For 2016, the fruits of Nayarit presented the highest DM content, and the greatest difference between partial ripe and ripe fruits was detected in the fruits of Guerrero, although in all cases the partial ripe and ripe fruits were well defined. For 2017, the fruits of Sinaloa presented the highest DM content at harvest; the greatest difference between partial ripe and ripe fruits was detected in the fruits of Jalisco. In general, DM values were higher in 2016 compared to 2017.

Table 2. Dry matter content (%) of 'Tommy Atkins' fruit harvested in three origins and two ripening degree. Shrunken shoulders 2016 and 2017.

Origin 2016	Dry matter content (%)		
	Sampling stage		
	Ripening degree	At harvest	At the end of refrigeration
GUERRERO	Partial ripe	16.5	16.4
	Ripe	19.8	18.4
NAYARIT	Partial ripe	19.3	18.8
	Ripe	19.6	20.6
SINALOA	Partial ripe	17.3	16.2
	Ripe	17.9	17.0
Origin 2017	Dry matter content (%)		
	Sampling stage		
	Ripening degree	At harvest	At the end of refrigeration
JALISCO	Partial ripe	15.7	15.6
	Ripe	17.5	16.2
NAYARIT	Partial ripe	15.0	20.4
	Ripe	16.0	20.0
SINALOA	Partial ripe	18.0	19.4
	Ripe	18.0	19.8

Next, we discuss the results of the origin effect, ripening degree, hydrothermal and hydrocooling time, as well as rest, on the presence of shrunken shoulders and main quality variables in 'Tommy Atkins' fruits. Only the results of

2017 are included since in 2016 the presence of fruits with shrunken shoulders was very low (<1.0 %).

Shrunken shoulders

Figure 2 illustrates the effect of each of the factors in the presence of shrunken shoulders. Regarding the origin, the fruits harvested in Jalisco did not present this anomaly, while those of Nayarit and Sinaloa accumulated 27.1 and 28.3%, respectively. Regarding the effect of ripening degree, significant differences were detected from the beginning until consumption stage. Partial ripe fruit showed 18.1, 25.3 and 25.6% respectively, while ripe showed only 3.9, 8.9 and 11.4% of fruits with shrunken shoulders. The above shows that there were from 2.2 to 4.6 times more fruits with shrunken shoulders in partial ripe fruits compared to ripe fruits. Thus, it is recommended to harvest only ripened fruits. Regarding the effect of the hydrothermal treatment, the fruits with 75 min showed 1.8 to 2.3 times more fruits with shrunken shoulders than those of 90 min. However, this situation may be due to the fact that the 75-min treatment is for fruits of less than 500 g and it was in these that there was a greater amount of partial ripe fruits. Without a doubt, the factor that most affected the presence of shrunken shoulders at the beginning was the rest. Those fruits that were subjected to rest for 24 h showed 2.8 times more fruits with shrunken shoulders than those that did not undergo rest. With this it is verified that the rest after hydrocooling does not diminish the presence of shrunken shoulders; it only allows identifying the fruits with this anomaly. Therefore, the suggestion for packers is they do not continue with their practice of submitting the fruits to rest, but to do the continuous process for packing (if economically viable). No significant differences were detected for the hydrocooling factor.

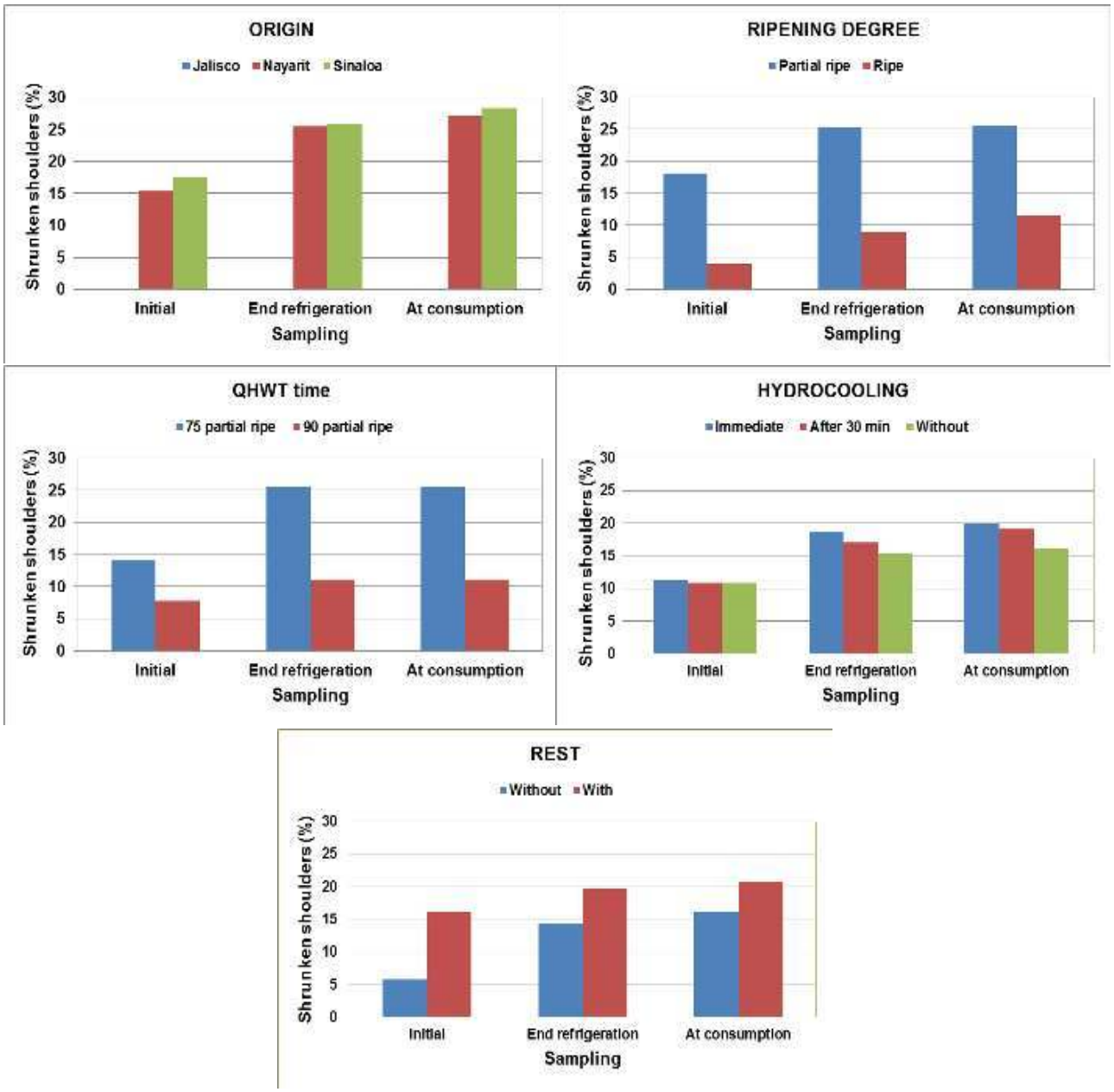

Figure 2. Effect of origin, ripening degree, QHWT time, hydrocooling and rest on the presence of shrunken shoulders in Tommy Atkins fruits. 2017.

Nutrient content

Literature mentions that the presence of shrunken shoulders in 'Tommy Atkins' may be related to low contents of Ca and K as well as high contents of N, for which it was decided to analyze the content of these nutrients in skin and fruit pulp with and without presence of this anomaly. As already mentioned, the fruits harvested in Jalisco did not present fruits with symptoms, but they did for those harvested in Nayarit and Sinaloa. Table 2A presents the results for N, P, K and Ca contents in the skin of the fruits harvested in Nayarit. No significant differences were detected for N and K but for P and Ca. For P significant differences were detected for damage and the interaction of damage X ripening degree, while for Ca significant differences were detected for the interaction of damage X ripening degree and damage X hydrothermal time.

Regarding the relationship of nutrient content in the pulp with shrunken shoulders (Table 2B), no significant differences were detected for N and P but for K and Ca. For K the fruits with damage showed lower content of this element for ripening degree, hydrothermal time and rest. For Ca, significant differences were detected for the interactions damage X ripening degree and damage X ripening degree X hydrothermal time X rest.

Table 2A. Content of nutrients in skin of 'Tommy' Atkins' fruit harvested in Nayarit. Shrunken Shoulders 2017.

Factor	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
Ripening degree	Without	With	Without	With	Without	With	Without	With
Partial ripe	0.58	0.55	0.066	0.070	0.629	0.553	0.265	0.259
Ripe	0.62	0.51	0.072	0.056	0.636	0.589	0.224	0.247
Hydrothermal	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
75 min.	0.56	0.50	0.066	0.056	0.599	0.569	0.291	0.273
90 min.	0.64	0.56	0.072	0.070	0.666	0.573	0.198	0.234
Rest	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
Without	0.62	0.53	0.680	0.068	0.641	0.557	0.241	0.248
With	0.58	0.52	0.710	0.058	0.624	0.585	0.247	0.258

Table 2B. Content of nutrients in pulp of 'Tommy' Atkins' fruit harvested in Nayarit. Shrunken Shoulders 2017.

Factor	Total N (%)		P (%)		K (%)		Ca (%)	
Ripening degree	With out	With	With out	With	With out	With	With out	With
Partial ripe	0.53	0.47	0.077	0.075	0.680	0.628	0.051	0.057
Ripe	0.49	0.37	0.056	0.058	0.631	0.569	0.041	0.043
Hydrothermal	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
75 min.	0.47	0.40	0.056	0.064	0.639	0.614	0.053	0.060
90 min.	0.54	0.44	0.076	0.068	0.672	0.584	0.039	0.039
Rest	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
Without	0.51	0.42	0.061	0.077	0.663	0.639	0.048	0.051
With	0.50	0.42	0.071	0.056	0.647	0.558	0.044	0.048

For fruits harvested in Sinaloa, results were obtained only for ripening degree and hydrothermal time. For the case of skin (Table 3A), significant differences were detected for P and Ca but not for N and K. In P, significant differences were detected for the interactions damage X ripening degree and damage X hydrothermal time, being practically the same for Ca in skin. On the other hand, in the pulp significant differences were detected for all the nutrients. For N, significant differences were detected for the interaction of ripening degree X hydrothermal time, while for P significant differences were detected for the interaction of damage X ripening degree; for K only, it was significant for the hydrothermal time and for Ca it was significant for the interactions damage X ripening degree and damage X hydrothermal time.

Table 3A. Content of nutrients in skin of 'Tommy' Atkins' fruit harvested in Sinaloa. Shrunken Shoulders 2017.

Factor	Total N (%)		P (%)		K (%)		Ca (%)	
Ripening degree	With out	With	With out	With	With out	With	With out	Con daño
Partial ripe	0.50	0.46	0.070	0.067	0.551	0.606	0.254	0.228
Ripe	0.48	0.61	0.064	0.066	0.480	0.598	0.188	0.288
Hydrothermal	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
75 min.	0.47	0.57	0.062	0.057	0.549	0.551	0.223	0.283
90 min.	0.51	0.50	0.072	0.076	0.482	0.654	0.219	0.233

Table 3B. Content of nutrients in pulp of 'Tommy' Atkins' fruit harvested in Sinaloa. Shrunken Shoulders 2017.

Factor	Total N (%)		P (%)		K (%)		Ca (%)	
Ripening degree	With out	With	With out	With	With out	With	With out	With
Partial ripe	0.41	0.37	0.086	0.088	0.740	0.753	0.085	0.084
Ripe	0.36	0.51	0.081	0.093	0.746	0.792	0.074	0.109
Hydrothermal	**Total N (%)**		**P (%)**		**K (%)**		**Ca (%)**	
75 min.	0.36	0.54	0.082	0.082	0.702	0.719	0.084	0.112
90 min.	0.41	0.33	0.085	0.099	0.784	0.826	0.076	0.082

The above diagnosis is a precedent that the nutrition in the 'Tommy Atkins' tree and its translocation in the fruit is related to shrunken shoulder injury. Similarly, it was observed that some nutrients may be at lower or higher concentration depending on the ripening degree, hydrothermal time, and with or without rest, which increases the risk of the problem, since it is determined that these factors are associated with the presence of shrunken shoulders in 'Tommy Atkins' fruits. Therefore, if the orchard does not have a balanced fertilization, it can increase the risk of shrunken shoulders in 'Tommy Atkins' fruits.

Possibly the orchard located in Jalisco has a better management in terms of balanced fertilization and therefore has not recorded incidence of damage to the

fruit. Probably, the identification of some nutritional indicators can help to determine the nutritional elements that require more attention when it comes to fertilize the orchard. Thus, it is necessary to validate and evaluate in detail, how it affects the component of the nutritional contribution to the tree, with evaluations that also include soil and foliar analyzes, which were not carried out in the present study, and which can provide knowledge on how much the tree's nutritional demands were met.

Weight loss

Figure 3 illustrates the effect of each of the factors on the 'Tommy Atkins' fruit weight loss. The only factor that significantly affected was the origin. The fruits of Nayarit lost more weight (9.5%) and the least loss were those of Sinaloa (7.1%). The fruits of Jalisco had an intermediate loss (7.8%), maybe because fruit harvested far away from Nayarit lost some weight, which was no taken in account.

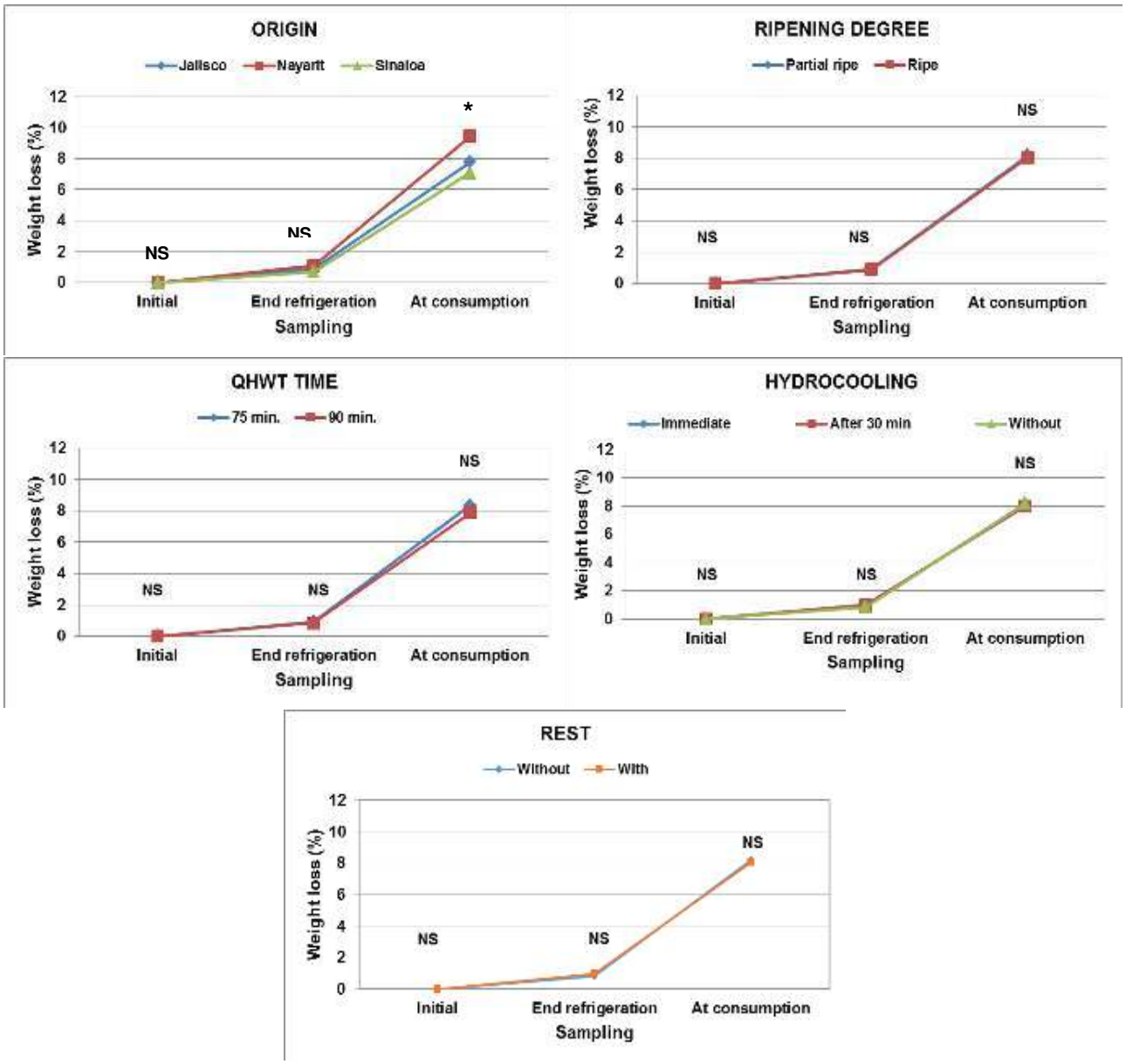

Figure 3. Effect of origin, ripening degree, QHWT time, hydrocooling and rest on the weight loss of Tommy Atkins fruits. 2017.

Pulp firmness

With respect to pulp firmness (Figure 4), only significant differences were detected for origin and ripening degree. At the beginning and at the end of refrigeration, the fruits of Sinaloa showed greater firmness (28.5 and 27.8 pounds), followed by those of Nayarit (25.5 and 23.7 pounds) and the least firm were those of Jalisco, perhaps because the shipping time from the orchard to packinghouse is smaller, although at consumption no significant differences were detected. For ripening degree, at the beginning and at the end of refrigeration, significant differences were detected. The partial ripe fruits were firmer than ripe fruits, which is according to expectations.

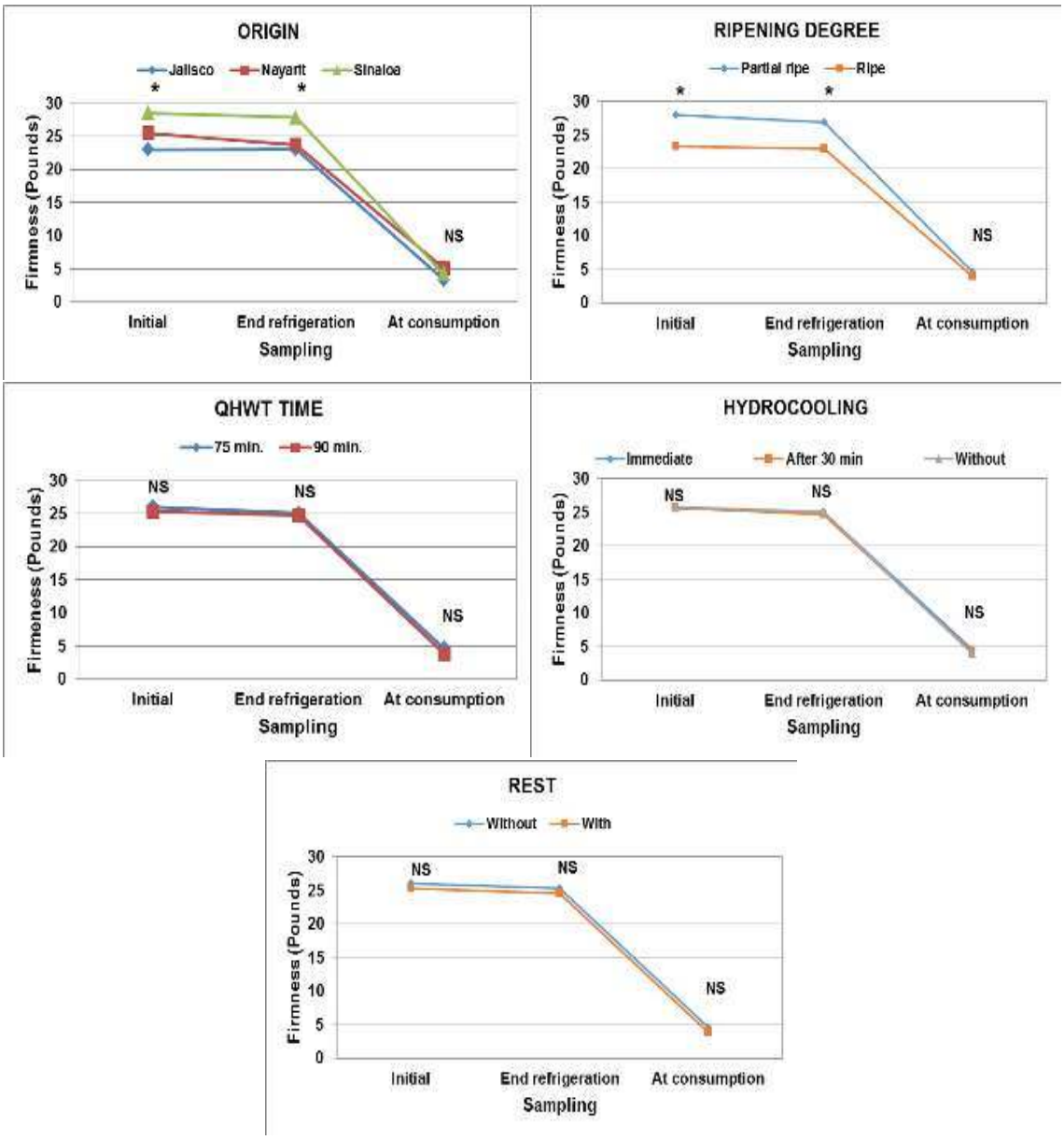

Figure 4. Effect of origin, ripening degree, QHWT time, hydrocooling and rest on pulp firmness (pounds) of Tommy Atkins fruits. 2017.

Pulp color

In relation to the influence of the factors on pulp color (Figure 5), all of them, except for the hydrocooling, were significant. The origin affected this variable significantly. The fruits of Jalisco showed a less intense pulp color at the end of refrigeration and consumption and those of Sinaloa exhibited the highest intensity of pulp color at harvest. Probably these differences are due to the ripening degree at harvest. On the other hand, according to the expected, ripening degree affected pulp color. The partial ripe fruits showed less intensity of color at the beginning and at the end of refrigeration; although at harvest no significant differences were detected. In relation to the QHWT time, significant differences were detected at the beginning and at the end of refrigeration. Fruits subjected to 75 min showed less pulp intensity than those subjected to 90 min. This may be because fruits subjected to 75 min correspond to those with weights less than 500 g and could have lower maturity, or could be because the shorter time of QHWT treatment could induce lower ethylene production than those treated by 90 min. No significant differences were detected in any of the samplings for hydrocooling. Finally, it is confirmed that rest increased pulp color (> ripening degree), since fruits presented a greater color intensity, possibly due to an increase in respiration and ethylene production. This has been discussed with the packers. It was confirmed that there was reason to suggest they do not practice the rest, since the presence of sunken shoulders is more easily detected, it may be because the maintenance or temperature increase. The rest is carried out inside the packinghouse and usually environmental temperatures are higher than 86°F, which causes a higher respiration and ethylene production.

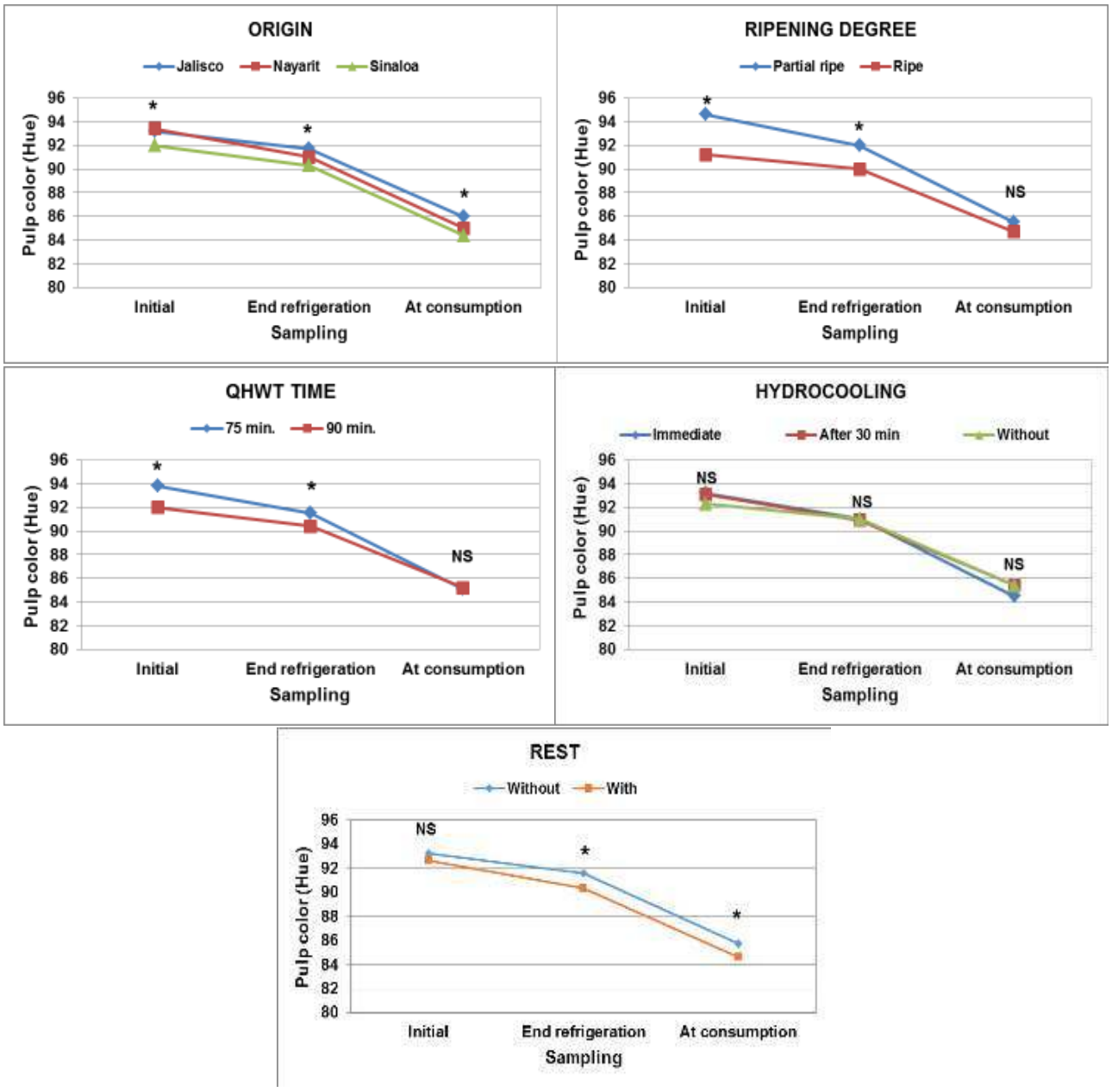

Figure 5. Effect of origin, ripening degree, QHWT time, hydrocooling and rest on pulp color (Hue) of Tommy Atkins fruits. 2017.

Total soluble solids

Regarding the TSS content (Figure 6), only the origin, ripening degree and rest significantly affected this variable. The fruits of Sinaloa had the highest TSS content at consumption time with 13.7 °Bx and were statistically superior to those of Jalisco (12.4 °Bx) and those of Nayarit (12.6 °Bx). Concerning the effect of ripening degree, as expected, ripe fruits had a higher TSS content at the beginning and at the end of refrigeration. However, no significant differences were detected at consumption. Regarding the rest, the fruits with 24 h of rest showed higher content of TSS (8.9 °Bx) at the beginning in comparison to the fruits without rest that only had 7.8 °Bx. This is probably because these fruits were at packinghouse temperature (± 90°F) for an additional 24 h, so the ripening process progressed rapidly and, in addition, it was still reflected at the end of refrigeration. For the above, it is confirmed that rest is not beneficial as it accelerates the ripening process and as it was seen in the figure of shrunken shoulders, it does not avoid the presence of this one, it only manifests it to discard. Therefore, rest is not suggested.

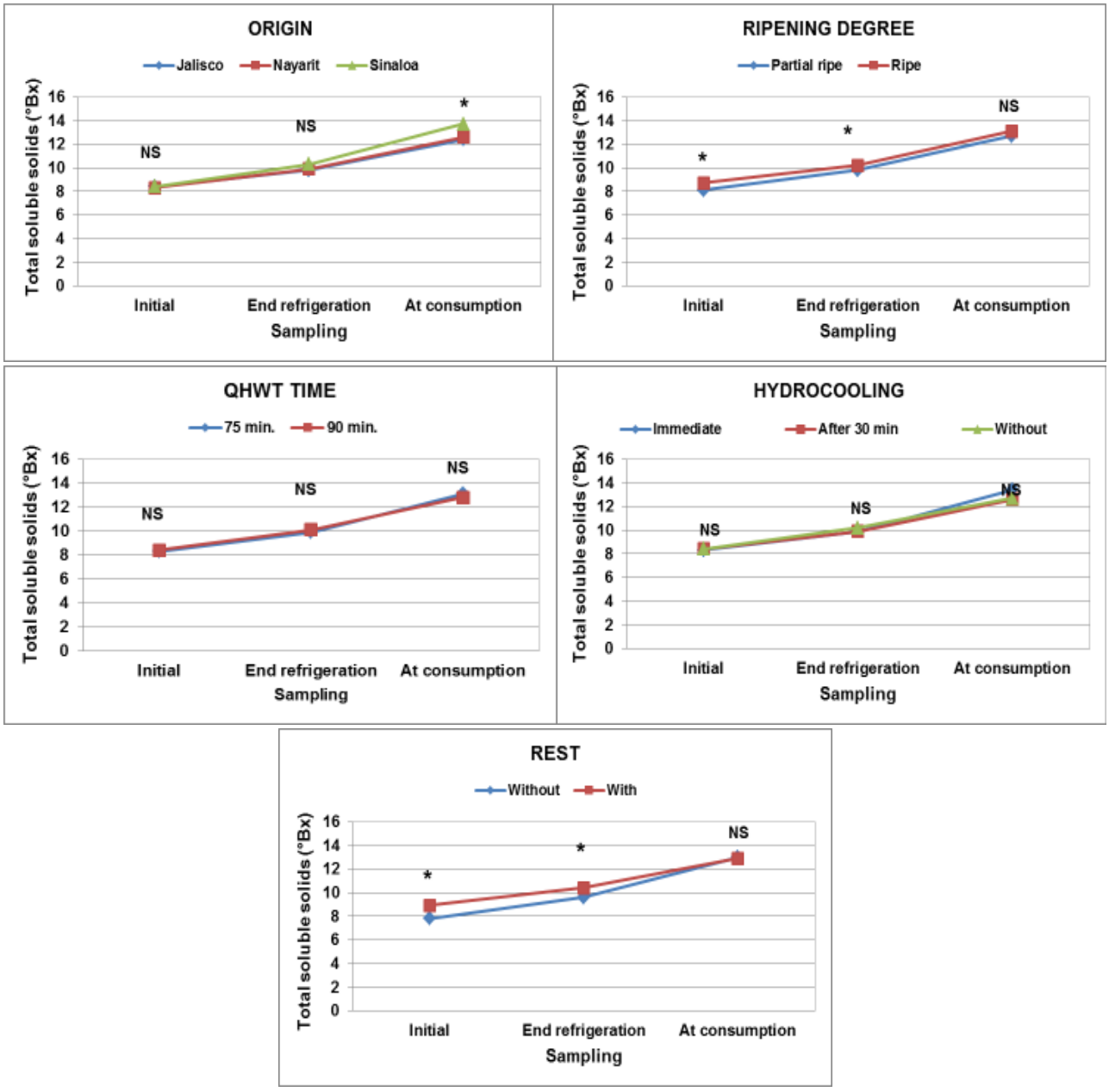

Figure 6. Effect of origin, ripening degree, QHWT time, hydrocooling and rest on TSS content (°Bx) of Tommy Atkins fruits. 2017.

CONCLUSIONS

- It was found that the presence of fruits of 'Tommy Atkins' with shrunken shoulders for the 2016 season was minimal (<1.0%). Significant factors were origin and rest after hydrocooling.
- The results of 2017 showed a presence of almost 30% of fruits with shrunken shoulders. The 'Tommy Atkins' fruits harvested in Jalisco did not show the damage. However, the fruits 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 fruits of 'Tommy Atkins' with shrunken shoulders were the ripening degree at harvest and rest. Fruits harvested partially ripe, at the initial sampling showed 18.1% of fruits with shrunken shoulders, in comparison to only 3.9% of the fruits harvested ripe.
- Growers and packers will have to take into account the ripening degree at harvest of 'Tommy Atkins' fruits, since the fruits harvested partial ripe will present a high percentage of this anomaly.
- The other factor that significantly influenced the presence of fruits with shrunken shoulders was the rest, mainly at the initial sampling, since the fruits with rest of 24 h showed three times more fruits with shrunken shoulders (16.1%) than those without rest (5.8%).
- On the other hand, the QHWT times were very influenced by ripening degree at harvest, since fruits subjected to 75 min showed a higher percentage of shrunken shoulders than those subjected to 90 min. QHWT for 75 min is applied to fruits weighing less than 500 g, and these were the ones with the highest percentage of partial ripe fruit.
- Hydrocooling did not affect the presence of 'Tommy Atkins' fruits with shrunken shoulders.
- The nutritional diagnosis in the fruit is a precedent that indicates that tree nutrition is related to the presence of shrunken shoulders. If the orchard has an unbalanced fertilization, the possibility of occurrence of this anomaly is greater.

- In summary, to reduce or minimize the presence of fruits with shrunken shoulders, it is recommended to harvest the fruit ripe or physiologically mature, as well as, to avoid the rest of 24 to 48 h traditionally carried out by the packers.

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Jalisco


SHRUNKEN SHOULDERS
PARTIAL RIPE 75'
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