AGREEMENT INIFAP-NATIONAL MANGO BOARD

DETERMINATION OF RIPENING DEGREE AT HARVEST, SHIPPING TEMPERATURE AND DAYS OF SHIPMENT IN RIPE AND READY TO EAT MANGO

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CONTENT

Executive summary ……3
Background …… 4
Objectives ..…… 5
Methodology…… 5
Detailed description of methodology…….. 7
Analyzed variables…...……..……..... 7
Results and Discussion …… 8
Dry matter Content ……..……..…… 8
Ataulfo ……..…… 10
Weight loss ……..…… 10
External appearance…..……..…… 11
Skin color ……..…… 11
Pulp firmness …..……..... 12
Pulp color …..…….. 13
Total soluble solids …….. 14
Ataulfo external fruit appearance …… 16
Tommy Atkins……..…… 17
Weight loss ……..…… 17
External appearance..……..…… 18
Pulp firmness …..……..... 18
Pulp color…….…….. 19
Total soluble solids …….. 20
Tommy Atkins external fruit appearance ……..……..…… 21
Kent with or without QHWT……..……22
Weight loss ……..…… 22
External appearance..……..…… 24
Pulp firmness …..……..... 24
Pulp color…….…….. 25
Total soluble solids …….. 26
External fruit appearance of Kent with QHWT ……..…… 29

External fruit appearance of Kent without QHWT ….…….. 30
Keitt with or without QHWT……..……31
Weight loss ……..…… 31
External appearance..……..…… 32
Pulp firmness …..……..... 32
Pulp color……..…….. 33
Total soluble solids …….. 34
External fruit appearance of Keitt with QHWT ……..…… 37
External fruit appearance of Keitt without QHWT …..……... 38
Conclusions ……..…… 40
References …..…..……..…..…… 41

EXECUTIVE SUMMARY

Recently, demand for ripe and ready to eat mango has increased, offering an interesting possibility for mango producers in Mexico because of geographic closeness of the production sites with the USA markets. Most of the production sites are located within a maximum shipping time of five days by land to the furthest market in the USA. It is considered that the key aspects in producing ripe and ready to eat mango are as follows: 1. Ripening stage at harvest; 2. Requirement of quarantine hot water treatment (QHWT); 3. Temperature and length of refrigerated shipping, and 4. Handling in wholesale warehouse and during commercialization in retail supermarkets.

The study was conducted in the mango zone with presence of fruit fly and mandatory Quarantine Hot Water Treatment (Nayarit and Southern Sinaloa) in 'Ataulfo', 'Tommy Atkins', 'Kent' and 'Keitt' varieties, as well as in the mango zone free of fruit fly without QHWT (North of Sinaloa) in 'Kent' and 'Keitt'. Two factors were considered: I. Two levels of fruit ripening at harvest: a) Ripe (rounded form with full cheeks and raised shoulders, pulp color ranging from stage 2 to 3, and a total soluble solid content > 7.3 °Bx); b) ¾ (higher ripening degree with skin turning color and total soluble solid content > 9.0 °Bx) and; II. Four levels of shipping temperature: a) 53.6 ± 1.5°F; b) 59.0 ± 1.5°F; c) 64.4 ± 1.5°F; and d) 71.6 ± 3°F. In all cases, the relative humidity was 85 ± 10 %. Sampling was done at the beginning and at the end of the shipping simulation period (5 days), and at consumption time. The variables were dry matter, weight loss, external appearance, skin color, pulp firmness, pulp color, total soluble solids (°Bx), tritatable acidity, and ratio °Bx/Acidity. We used a factorial design with 20 replications (fruit) for weight loss and 8 for all the other variables. Any variety was analyzed independently.

Results showed that ripening degree was one of the main factors in the handling of ripe and ready to eat mango (RRTEM), since the more mature mango showed the highest quality index (QI), and acceptability by consumers. Ripening degree affected pulp firmness, pulp color, total soluble solids (°Bx), and the ratio of °Bx/Acidity. The shipping temperature significantly influenced most of the variables, especially at the end of shipping simulation. The lower the temperature, the lower the weight loss, higher pulp firmness, and less development of pulp color and total soluble solids. This factor is very important for retailers to plan their orders volume of RRTEM according to their needs. The suggested ripening degree at harvest is ¾ and the shipping temperatures are 59.0 ± 1.5 and 64.4 ± 1.5°F. QHWT decreased two days the shelf life of 'Kent' and 'Keitt' fruit when compared without QHWT. Differences were detected among varieties, especially for shelf life.

BACKGROUND

Mango is one of the favorite fruits in the USA market, where consumption has doubled in the past 10 years. During the last three years (2010-2012) on 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 exported varieties for the USA market are Tommy Atkins, Ataulfo, Kent and Keitt compromising 35, 30, 15 and 10% respectively of the exported volume (EMEX, A.C., 2014).

Recently, demand for RRTEM has increased, offering and interesting possibility for mango producers in Mexico because of geographic closeness of the production sites with the USA markets. Most of the production sites are located within a maximum shipping time of five days by land to the furthest market in the USA. It is considered that the key aspects in producing ripe and ready to eat mango are as follows: 1. Ripening stage at harvest; 2. Requirement of quarantine hot water treatment (QHWT); 3. Temperature and length of refrigerated shipping, and 4. Handling in wholesale depot and during commercialization in retail supermarkets.

In a preliminary essay to determine the optimal degree of ripening at harvest, as well as the shipping conditions of RRTEM in Ataulfo, Tommy Atkins, and Kent varieties (Osuna, 2015), it was found that the ripening degree affected weight loss, firmness, pulp color, soluble solids content, tritatable acidity and the relation between °Bx/Acidity but did not affect external appearance. Further, ripe fruit was more susceptible to handling with easy softening and some with over ripening and/or fermentation. It was also observed the ripening degree of ¾ was the fruit with the best organoleptic characteristics, and a longer shelf life. Moreover, ¾ fruit after three days of refrigeration reached up to seven days of shelf life, enough to reach to the furthest USA market.

OBJECTIVES

- To determine the optimum ripening degree at harvest for ripe and ready to eat mango.
- To define the optimum ripening degree for mangos requiring QHWT, as well as, for those harvested in zones free of fruit fly that do not require QHWT.
- To delimit shipping temperature and temporary storage warehouse or grocery wholesaler which maintain and offer the maximum quality at consumption.

METHODOLOGY

a. VARIETIES: Ataulfo, Tommy Atkins, Kent y Keitt.

Variety	Origin	Harvest date	Hot water treatment	QHWT (Time)	Packinghouse
Ataulfo	Santiago, Nay.	May 16, 16	May 17, 16	75 + 10’	NATURAMEX
Tommy	Santiago, Nay.	June 7, 16	June 8, 16	90 + 10’	ALEX
Kent	Navarrete, Nay.	June 27, 16	June, 16	90 + 10’	ALEX
Keitt	Escuinapa, Sin.	Aug 4, 16	Aug 4, 16	90 + 10’	DIAZTECA
Kent	Los Mochis, Sin.	July 26, 16	Without QHWT		DANIELLA
Keitt	Los Mochis, Sin.	Aug 15, 16	Without QHWT		DANIELLA

a. PACKINGHOUSES:

1. In the zone with fruit fly and QHWT requirement (Nayarit and southern Sinaloa).
2. In the zone without fruit fly or QHWT requirement (North of Sinaloa).

b. RIPENING DEGREE AT HARVEST:

1. Ripe fruit (rounded form with full cheeks and raised shoulders, a pulp color ranging from 2 to 3 and a total soluble solid content > 7.3 °Bx).
2. ¾ Fruit (higher ripening degree with skin turning color and total soluble solid content > 9.0 °C)

c. SHIPPING TEMPERATURE:

1. Refrigeration (53.6 ± 1.5°F; 90 ± 5% RH)
2. Refrigeration (59.0 ± 1.5°F; 90 ± 5% RH)
3. Refrigeration (64.4 ± 1.5°F; 90 ± 5% RH)
4. Market simulation (71.6 ± 3.0°F; 75 ± 10% RH)

d. TREATMENTS

Treatment	Ripening Degree	Shipping temperature	Shipping days
1	**Ripe**	**53.6 ± 1.5°F**	**5**
2	**Ripe**	**59.0 ± 1.5°F**	**5**
3	**Ripe**	**64.4 ± 1.5°F**	**5**
4	**Ripe**	**71.6 ± 3.0°F**	**5**
5	**¾**	**53.6 ± 1.5°F**	**5**
6	**¾**	**59.0 ± 1.5°F**	**5**
7	**¾**	**64.4 ± 1.5°F**	**5**
8	**¾**	**71.6 ± 3.0°F**	**5**

e. FRUIT STORAGE: Five days under refrigeration in the mentioned temperatures + Market simulation (71.6 ± 3.0°F; 75 ± 10% RH) until consumption stage (colorful fruits and pulp firmness from 1 to 3 pounds).

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

g. VARIABLES TO MEASURE: Dry matter, weight loss, external appearance, skin color, pulp firmness, pulp color, total soluble solids (°Bx), tritatable acidity, and ratio °Bx/Acidity.

A factorial design was used, with 20 replications for weight loss and eight for all the other variables. Each variety was analyzed independently.

Detailed description of the methodology

For each variety, 50 fruits were chosen per treatment, which were collected after washing and already classified for QHWT for 75 or 90 min. Then, the fruits were classified according to the ripening degree, considering ripe and ¾ fruit with excellent external appearance and free of mechanical damage, pests and / or diseases. Once separated by ripening degree and size, the fruits underwent the QHWT according to the USDA-APHIS protocol. After this treatment, the fruits were stored for five days under refrigeration at the temperatures mentioned above + marketing simulation (71.6 ± 3.0°F; 75 ± 10% RH) until consumption stage, which varied from 10 to 14 days depending on the variety. Samples were taken at the beginning, at the end of the refrigeration period and at the consumption stage.

Analyzed variables

Dry matter. Five g of pulp were sliced with a potato peeler for sampling. The slices were taken from the middle part of the fruit after removing the skin. The slices were dehydrated in glass petri dishes in a microwave oven during 4 to 7 minutes up to reaching 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). Twenty individual fruits were weighed periodically during all of the evaluation period. The weight difference and its relation to the initial weight was expressed as weight loss percentage.

Firmness. It was measured 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).

A completely randomized design with factorial arrangement was used. Twenty replications were used for weight loss, and eight for the other variables. Each variety was analyzed independently.

RESULTS AND DISCUSSION

Dry matter content (%).

Table 1 shows the results of the dry matter (DM) content of the different varieties in both ripening degrees. In the first instance, it is possible to observe the values obtained here exceed the quality standards proposed by the Australian Mango Industry Association (AMIA, 2016) that handle a range of 13 to 15 % DM for their varieties. On the other hand, these values are much higher than those set by González-Moscoso (2014), who proposed a Minimum Quality Index (MQI). The values for 'Ataulfo' were ≤ 16.9, for 'Tommy Atkins' ≥ 13.0 and for 'Kent' ≤ 15.0, while those found in this trial had DM contents from 18.2 to 21.6 % for 'Ataulfo', 16.6 to 18.1 % for 'Tommy Atkins' and 24.2 to 27.8 % for 'Kent'. These data confirm the degree of ripeness at harvest is one of the fundamental factors in the handling of RRTEM and that as this is increased, the MQI is greater and consequently, its possible acceptance by the consumer is potentially higher.

Table 1. Dry matter content (%) of the different varieties grown in Mexico and harvested at different ripening degree. RRTEM 2016.

	Dry matter content (%)		
	Sampling stage		
Variety	Ripening degree	At harvest	At the end refrigeration
Ataulfo	Ripe	18.2	20.2
	3/4	21.6	20.2
Tommy	Ripe	16.6	17.1
	3/4	18.1	19.3
Kent	Ripe	24.2	25.2
	3/4	26.2	25.4
Kent Mochis	Ripe	26.8	25.2
	3/4	27.8	24.2
Keitt	Ripe	18.2	19.2
	3/4	19.2	19.0
Keitt-2 Daniella	Ripe	20.6	21.6
	3/4	22.0	20.8

Next, the results of the effect of ripening degree and shipping temperature on the main variables of each of the varieties included in this test are discussed.

1. Ataulfo

Table 2 shows the analysis of variance of the factors ripening degree and shipping temperature on the main quality variables in 'Ataulfo'. Significant differences were observed for all the variables in at least one of the samples because of the effect of both factors. For ripening degree, all the variables were significant, except for firmness and the effect of temperature was not significant for external appearance and skin color.

Table 2. Analysis of variance for ripening degree and shipping temperature on main quality variables of Ataulfo with QHWT. RRTEM 2016.

Factor	V A R I A B L E S						
	Weight loss (%)	External appearance	Skin color A	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	*	*	*	NS	*	*	*
Temperature	*	NS	NS	*	*	*	*

Weight loss

For weight loss, it was observed the ripe fruits had greater loss at the end of the shipping simulation (5 days of refrigeration) and at consumption (Figure 1A). For shipping temperature in the sampling carried out at the end of shipping temperature (Figure 1B), it was detected that any of the refrigeration temperatures (53.6 to 64.4°F) significantly decreased the weight loss compared to the control at 71.6°F.

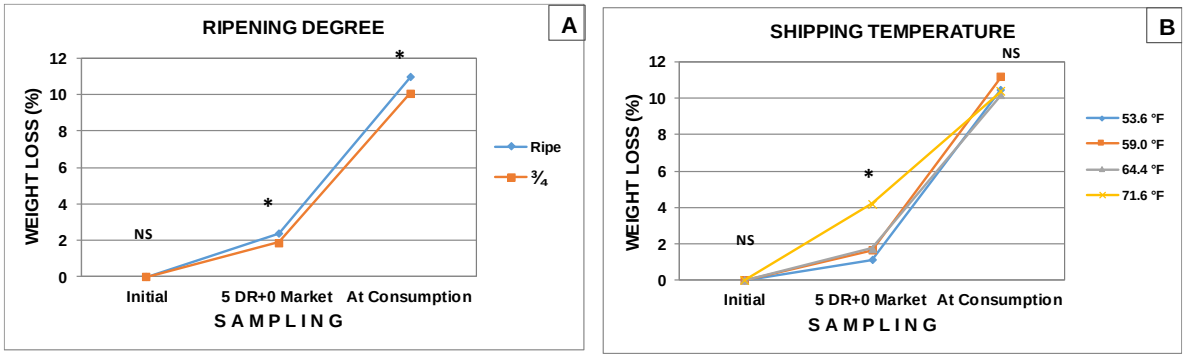

Figure 1. Effect of ripening degree (A) and shipping temperature (B) on weight loss (%) in Ataulfo fruit. RRTEM 2016.

External appearance

With regards to the external appearance of the fruits (data not shown), this was affected by ripening degree at the beginning and at the end of the shipping simulation, while the shipping temperatures only affected at consumption time, but in both cases the values were within the acceptance range for export fruits.

Skin color

Regarding skin color, for ripening degree, significant differences were detected at the beginning and at the end of the simulation, but at consumption time the fruits reached similar values (Figure 2A). Ripe fruits showed more negative values (indicating a more intense green color) than fruits at ¾ as they had a higher degree of maturity. Regarding the effect of shipping temperature (Figure 2B), only significant differences were detected at the end of it, where any of them maintained the most intense green color of the fruits and only the control showed a light green, a sign of greater degree of maturity.

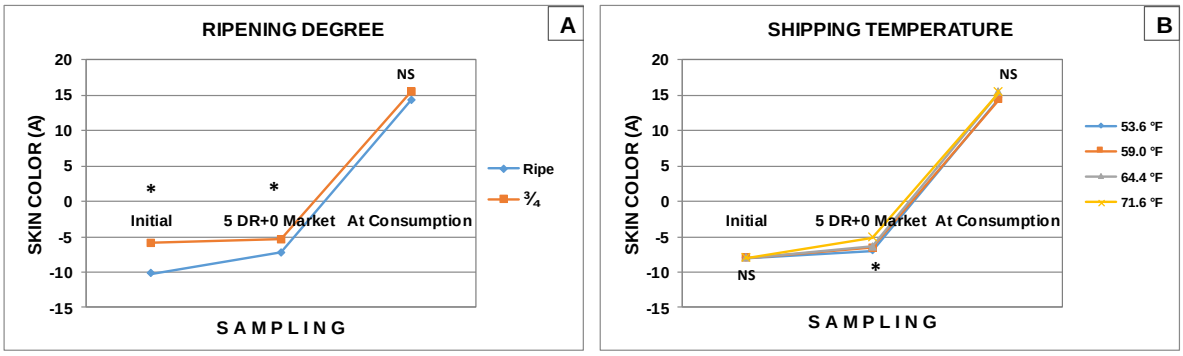

Figure 2. Effect of ripening degree (A) and shipping temperature (B) on skin color A in Ataulfo fruit. RRTEM 2016.

Pulp firmness

Regarding pulp firmness, significant differences were detected for both factors. The ripe fruits were firmer than the ¾ fruits (Figure 3A) in the initial sampling and at the end of the refrigeration transfer, while the effect of the refrigeration was evident and significant at the end of the shipping temperature since any of the fruits showed more intense green color than the controls at 71.6°F (Figure 3B). A correlation between temperature and firmness was observed; at lower temperature, greater firmness. Any of the refrigeration temperatures at the end of five days of shipping simulation maintained between 90 and 100% of the initial firmness, while fruits stored at 71.6°F decreased by almost 50 % its initial value, which was reflected in more or less shelf life.

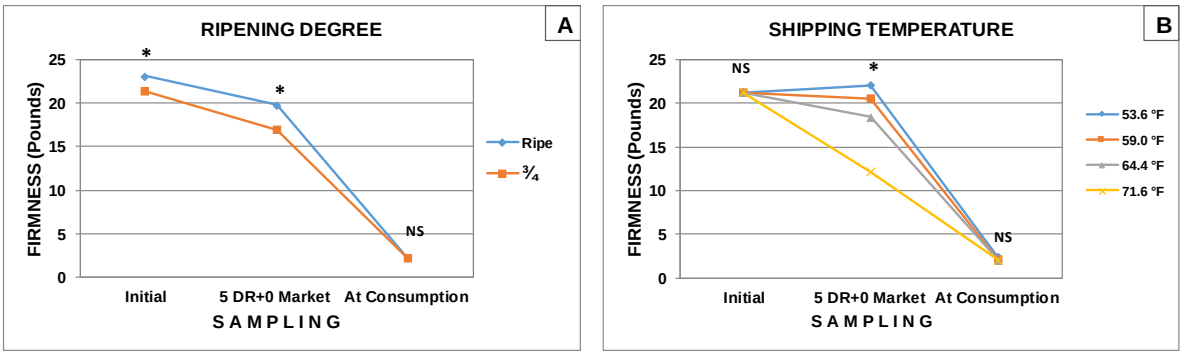

Figure 3. Effect of ripening degree (A) and shipping temperature on pulp firmness (Pounds) in Ataulfo fruit. RRTEM 2016.

Pulp color

The evolution of pulp color followed a pattern very similar to firmness. Ripe fruits had lower color intensity at the beginning and at the end of the shipping simulation, but no significant differences were detected at consumption (Figure 4A). With regards to the effect of shipping temperature (Figure 4B), at the end of it the most evident and significant result was observed, since the fruits with refrigeration showed less intensity of pulp color than those maintained at 71.6 °F. The fruit stored at 53.6°F presented the lowest development of pulp color, evidencing the tendency that at lower temperature, less intensity of pulp color.

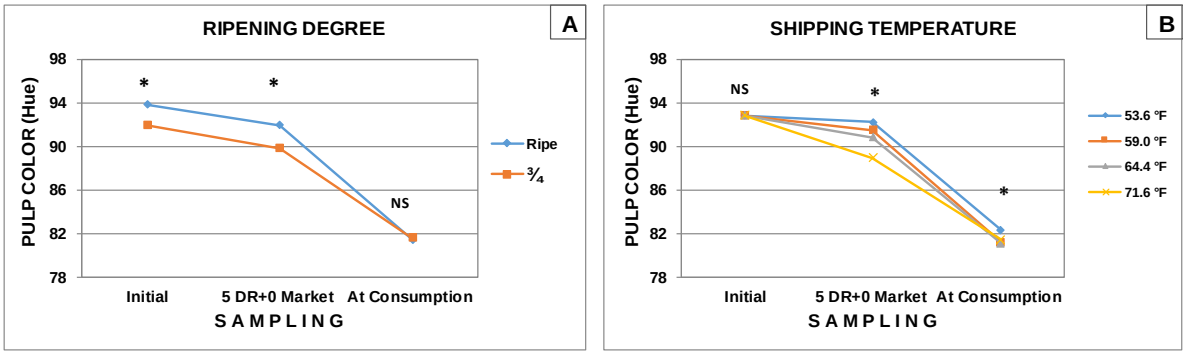

Figure 4. Effect of ripening degree (A) and shipping temperature on pulp color (Hue) in Ataulfo fruit. RRTEM 2016.

Total soluble solids (TSS)

A similar trend was observed regarding the development of TSS content. Ripe fruits had lower sweetness at the beginning and at the end of the shipping simulation than ¾ fruits, but differences at consumption were no longer detected (Figure 5A). Refrigeration temperatures influenced considerably at the end of the shipping simulation (Figure 5B), where it was evidenced that, at lower temperature, less development of TSS.

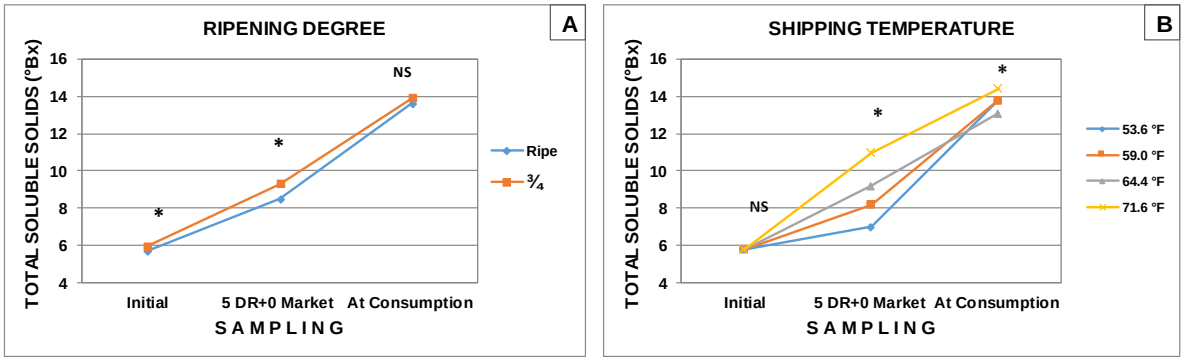

Figure 5. Effect of ripening degree (A) and shipping temperature on TSS content (°Bx) in Ataulfo fruit. RRTEM 2016.

It is evident the shipping temperature is another important factor to consider in the handling of MMLPC, since as it is observed in the Figure 6 for ripe fruit and for fruits ¾, at higher temperature, shorter shelf life. Fruits at 71.6°F reached maturity of consumption at 11 days of harvest, while those maintained at 64.4°F required 13 days (5+8) and those stored at 59.0 and 53.6°F required 14 days (5+9). The foregoing is a determining factor for the Importers to plan their needs of RRTEM.

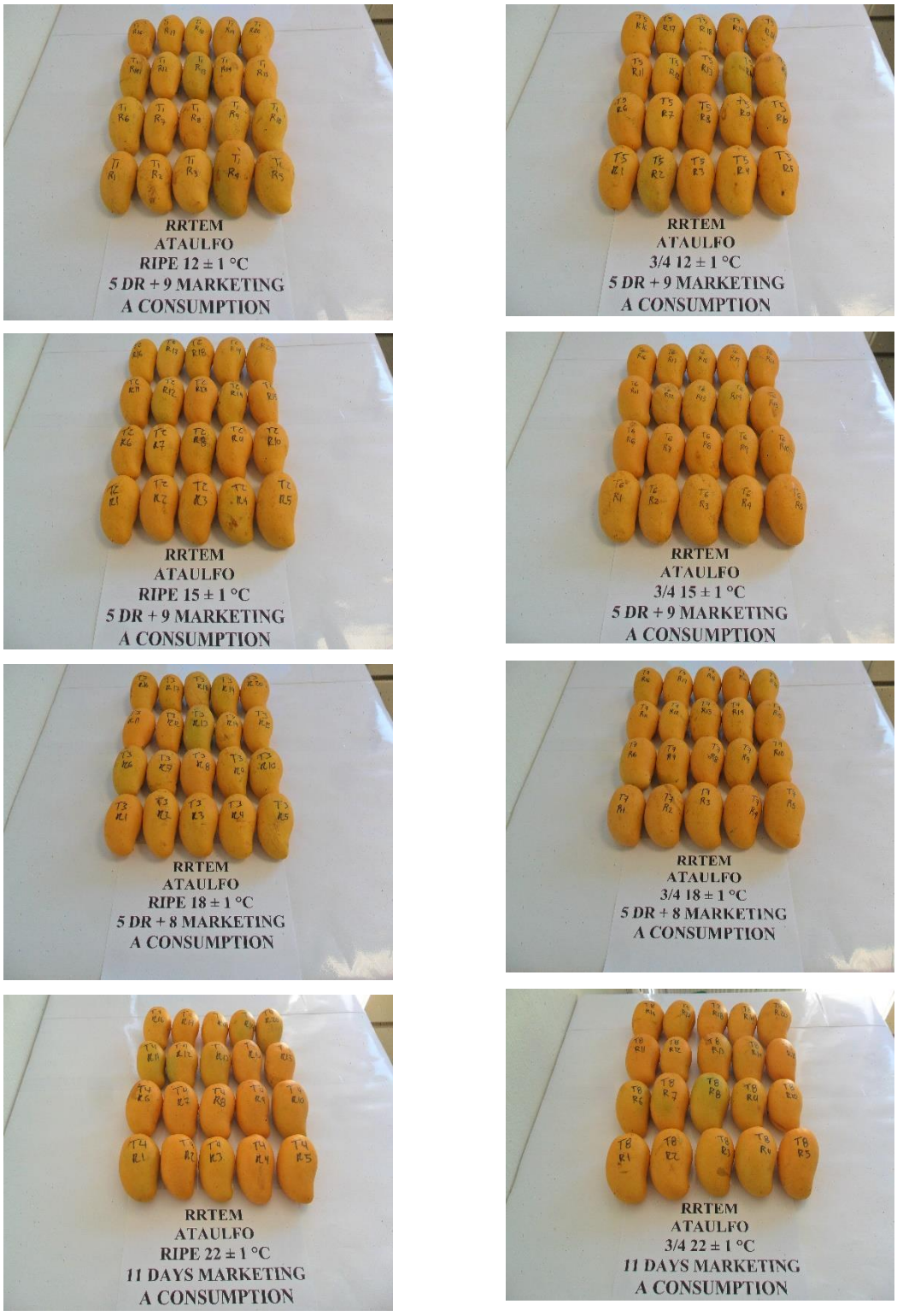

Figure 6. External appearance of Ataulfo fruit at consumption stage with a with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

2. Tommy Atkins

Table 3 shows the analysis of variance for ripening degree and shipping temperature on the main quality variables in 'Tommy Atkins'. Significant differences were observed due to ripening degree in firmness, pulp color, SST and °Bx / acidity ratio, while for shipping temperature the significant differences were detected for weight loss, external appearance, firmness and °Bx ratio / acidity, but not for pulp color or TSS.

Table 3. Analysis of variance for ripening degree and shipping temperature on main quality variables of Tommy Atkins with QHWT. RRTEM 2016.

Factor	VARIABLES					
	Weight loss (%)	External appearance	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	NS	NS	*	*	*	*
Temperature	*	*	*	NS	NS	*

Weight loss

In Figure 7A it is observed that ripening degree did not affect weight loss, since no significant differences were detected for any of the samplings. In contrast, the effect of temperature was significant at the end of the shipping and even remained until consumption stage (Figure 7B). At the end of the shipping simulation, any of the refrigeration temperatures showed less weight loss than the control at 71.6°F, confirming that cooling reduces weight loss by decreasing the respiration rate (Kader, 1992). At consumption, the difference was only very marked between the control (12 days of shelf life) and the temperature of 53.6°F (15 days of shelf life), which is recommended to extend shelf life and avoid chilling injury (Osuna, 2015).

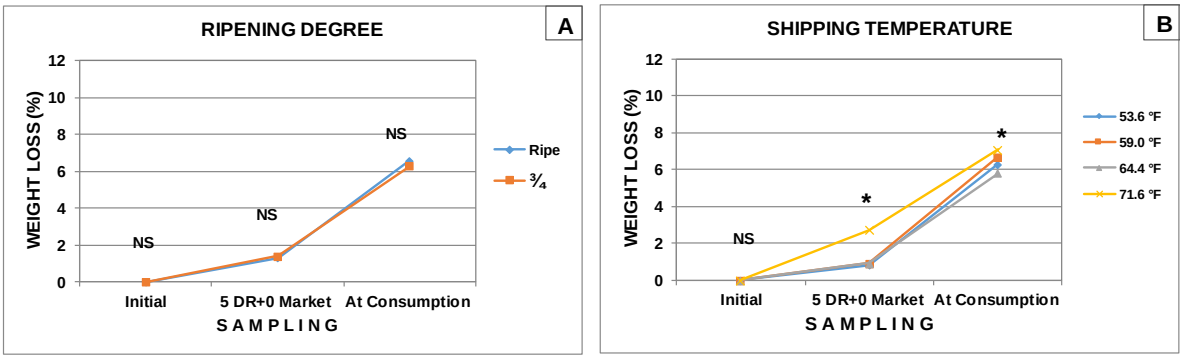

Figure 7. Effect of ripening degree (A) and shipping temperature on weight loss (%) in Tommy Atkins fruit. RRTEM 2016.

External appearance

Regarding the external appearance of fruits (data not shown), no significant differences were detected for ripening degree in any of the samples. However, for shipping temperature only differences were detected at consumption sampling, where only fruits stored at 53.6°F presented a good appearance and those stored at 59.0, 64.4 and 71.6°F showed excellent external appearance.

Pulp firmness

Regarding pulp firmness, only significant differences were detected for ripening degree at the beginning of the experiment (Figure 8A). Ripe fruits were firmer than ¾ fruits. In contrast, the temperature was only significant at the end of the shipping simulation (Figure 8B), where fruits stored at 53.6 and 59.0°F maintained greater firmness than those stored at 64.4 and 71.6°F. For practical purposes, the difference in maintaining firmness due to cooler shipping temperature can be used by the packer and / or distributor to manipulate it according to their needs of RRETM.

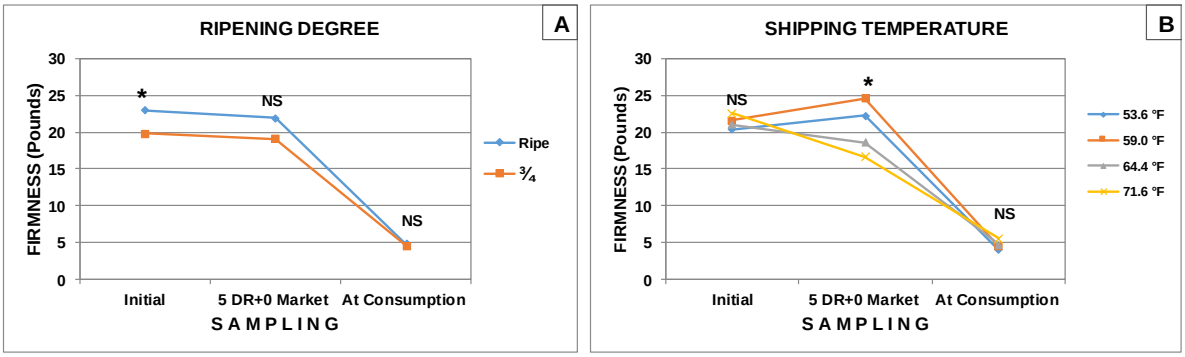

Figure 8. Effect of ripening degree (A) and shipping temperature on pulp firmness (Pounds) in Tommy Atkins fruit. RRTEM 2016.

Pulp color

Regarding to pulp color, only significant differences were detected for ripening degree (Figure 9A). The ¾ fruits showed a pulp color more intense than the ripe fruits from the beginning until consumption stage. In contrast, shipping temperatures did not show significant differences for any of the samplings (Figure 9B).

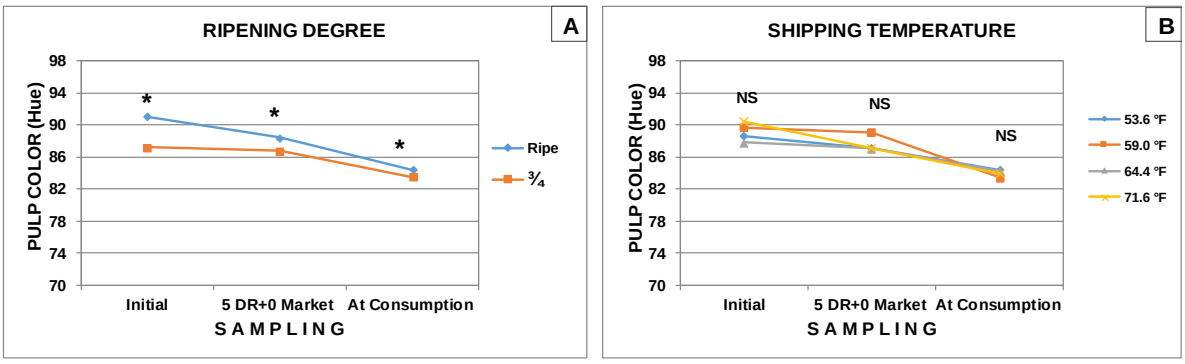

Figure 9. Effect of ripening degree (A) and shipping temperature on pulp color (Hue) in Tommy Atkins fruit. RRTEM 2016.

Total soluble solids (TSS)

TSS content (°Bx) showed a behavior similar to that of pulp color. Ripening degree significantly affected this variable, the ¾ fruits were statistically higher than ripe fruits (Figure 10 A), while shipping temperature did not significantly influence any of the samplings (Figure 10B).

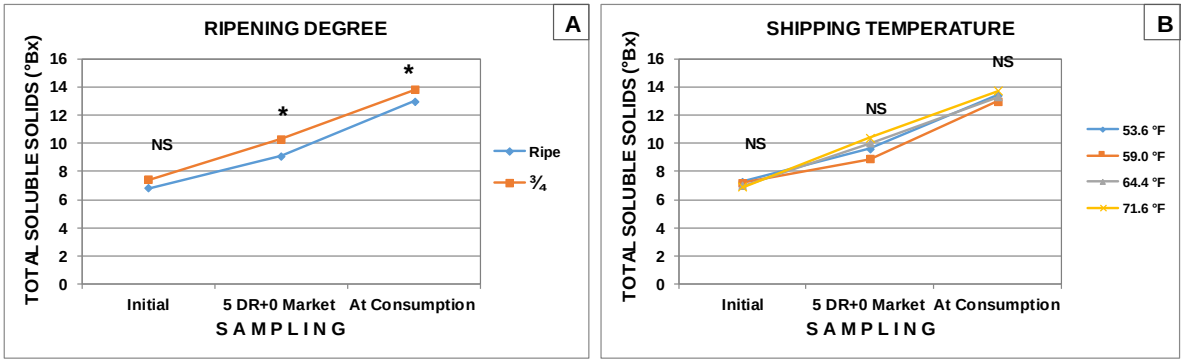

Figure 10. Effect of ripening degree (A) and shipping temperature on TSS content (°Bx) in Tommy Atkins fruit. RRTEM 2016.

It is evident that shipping temperature is another important factor to consider in the handling of RRETM since as it is observed in the Figure 11, for ripe fruit and for ¾ fruits, at higher temperature, shorter shelf life. Fruits for shipping simulation at 71.6°F reached consumption stage 12 days after harvest, while those maintained at 64.4°F required 13 days, those preserved at 59.0°F required 14 days and those maintained at 71.6°F required 15 days. The above is a determining factor for the importer to plan their needs according to time and shipping temperature.

Figure 11. External appearance of Tommy Atkins fruit at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

3. Kent with or without QHWT

Table 4 shows the analysis of variance for ripening degree and shipping temperature on the main quality variables for 'Kent' with or without QHWT. Under QHWT, no significant differences were detected for ripening degree in any of the variables, while for shipping temperature only the external appearance was not significant. In contrast, for 'Kent' without QHWT significant differences were detected by effect of ripening degree for all variables, except weight loss and °Bx / acidity ratio, while shipping temperature significantly influenced all variables except external appearance and °Bx / acidity ratio.

Table 4. Analysis of variance for ripening degree and shipping temperature on main quality variables of Kent with or without QHWT. RRTEM 2016.

Factor	KENT with QHWT					
	Weight loss (%)	External appearance	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	NS	NS	NS	NS	NS	NS
Temperature	*	NS	*	*	*	*
Factor	**KENT without QHWT**					
	Weight loss (%)	External appearance	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	NS	*	*	*	*	NS
Temperature	*	NS	*	*	*	NS

Weight loss

For 'Kent' with THC it was observed that the degree of maturity did not affect the weight loss since no significant differences were detected for any of the samples (Figure 12A). In contrast, the effect of temperature was significant at the end of the transfer and even remained until consumption maturity (Figure 12B). At the end of the transfer simulation, fruits stored at 53.6 and 59.0°F showed less weight loss than those stored at 64.4 and 71.6°F. This trend was maintained until consumption stage and again confirms that refrigeration reduces weight loss at decrease the speed of respiration (Kader, 1992).

With regard to fruits of 'Kent' without QHWT, the same tendency was observed as in 'Kent' fruits with QHWT for ripening degree where no significant differences were detected for any of the samples (Figure 12C). However, the shipping temperature effect was significant, but different from 'Kent' fruits with QHWT. Fruits stored at 71.6°F lost more weight than those stored at any refrigeration temperature, although at consumption only differences between 53.6 and 64.4°F were detected (Figure 12D).

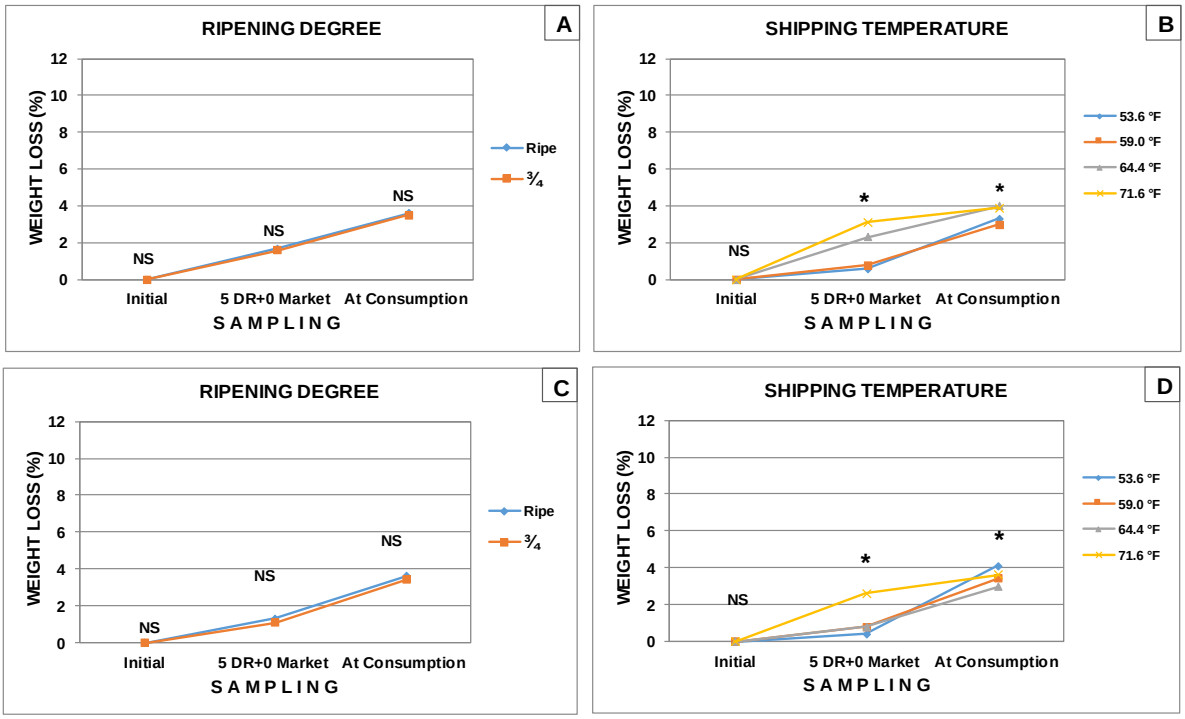

Figure 12. Effect of ripening degree (A, C) and shipping temperature (B, D) on weight loss (%) in Kent fruit with or without QHWT. RRTEM 2016.

External appearance

Regarding the external appearance of fruits (data not shown), no significant differences were detected for ripening degree or for shipping temperature in any of the samples. Nevertheless, all the fruits showed an external appearance from good to excellent according to the Standard.

Pulp firmness

Regarding to pulp firmness, 'Kent' fruits with QHWT did not show significant differences for ripening degree in any of the samples (Figure 13A). In contrast, the temperature was only significant at the end of shipping simulation (Figure 13B), where a direct correlation between temperature and firmness was observed. The higher the temperature, the greater the loss of firmness. In contrast, for 'Kent' fruits without QHWT, significant differences were observed at the end of shipping simulation for both factors. Ripe fruits had more firmness than the ¾ fruits (Figure 13 C), while for shipping temperatures the differences were much more marked. Fruits transported at 53.6 or 59.0°F practically maintained the same initial firmness at the end of shipping while those stored at 64.4 and 71.6°F lost more than 50% of the initial firmness (Figure 13 D).

For practical purposes, this difference in maintaining firmness due to the cooler shipping temperature can be used by the packer and / or distributor to plan their needs of RRETM according to time and shipping temperature.

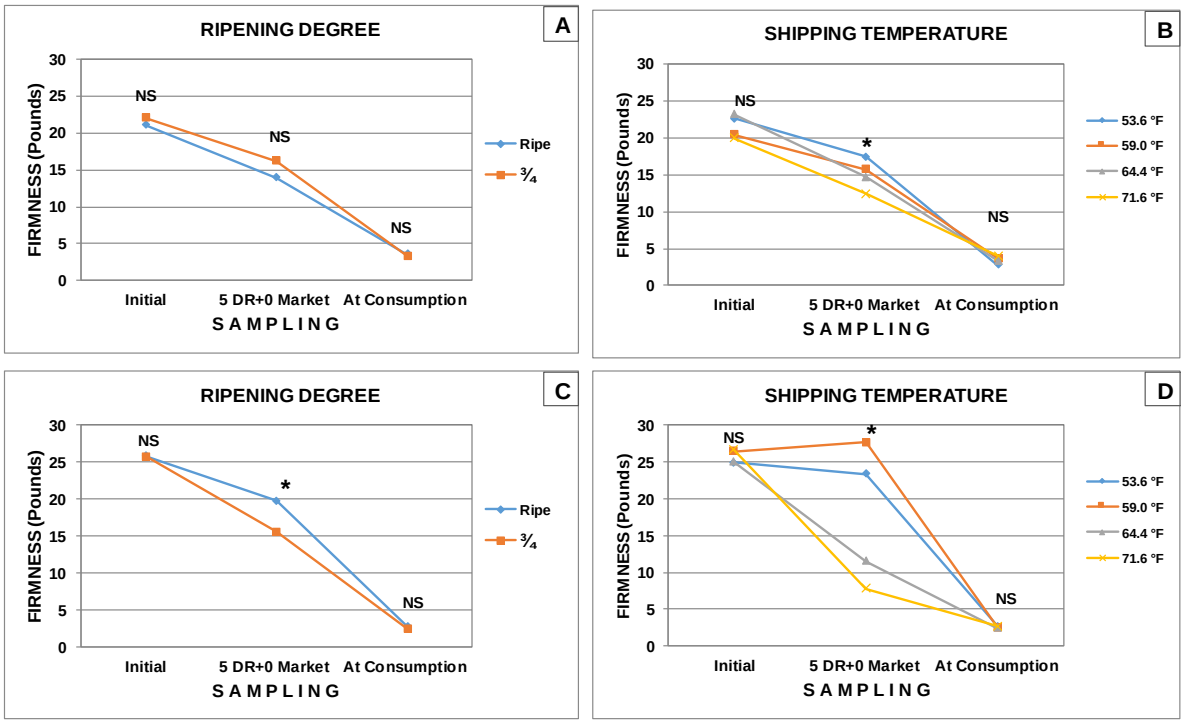

Figure 13. Effect of ripening degree (A, C) and shipping temperature (B, D) on pulp firmness (Pounds) in Kent fruit with or without QHWT. RRTEM 2016.

Pulp color

Regarding to pulp color in fruits of 'Kent' with QHWT, no significant differences were detected for ripening degree (Figure 14A), but for shipping temperatures fruits stored at 53.6°F showed less color development than those stored at 71.6 F (Figure 14B). In contrast, for 'Kent' fruits without QHWT, significant differences were detected for both factors at the end of shipping. Ripe fruits had lower pulp color intensity than ¾ fruits (Figure 14C). The effect of refrigeration was evident, since all the fruits maintained under this condition developed slowly the pulp color. No significant differences were detected at consumption stage (Figure 14D).

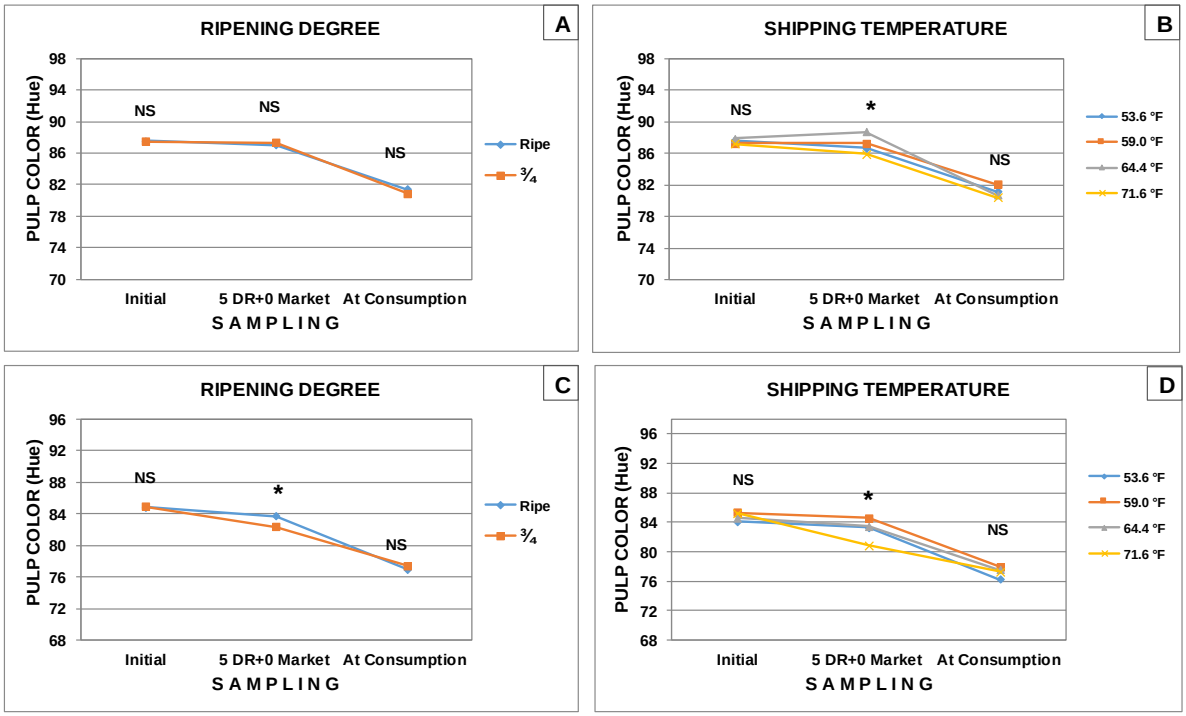

Figure 14. Effect of ripening degree (A, C) and shipping temperature (B, D) on pulp color (Hue) in Kent fruit with or without QHWT. RRTEM 2016.

Total soluble solids

The TSS (°Bx) showed a behavior similar to that of pulp color. In fruits of 'Kent' with QHWT, no significant differences were detected for ripening degree (Figure 15A), but for shipping temperatures fruits stored at 71.6 and 64.4°F showed higher TSS content than those stored at 53.6 or 59.0°F (Figure 15B). In contrast, for 'Kent' fruits without QHWT, significant differences were detected for both factors. Ripen fruits had lower TSS content than the ¾ fruits (Figure 15C). The effect of the refrigeration at the end of the shipping was evident, since fruits maintained at 53.6 and 59.0°F developed the TSS content more slowly than those maintained at 64.4 and 71.6°F, without detecting significant differences at consumption (Figure 15D).

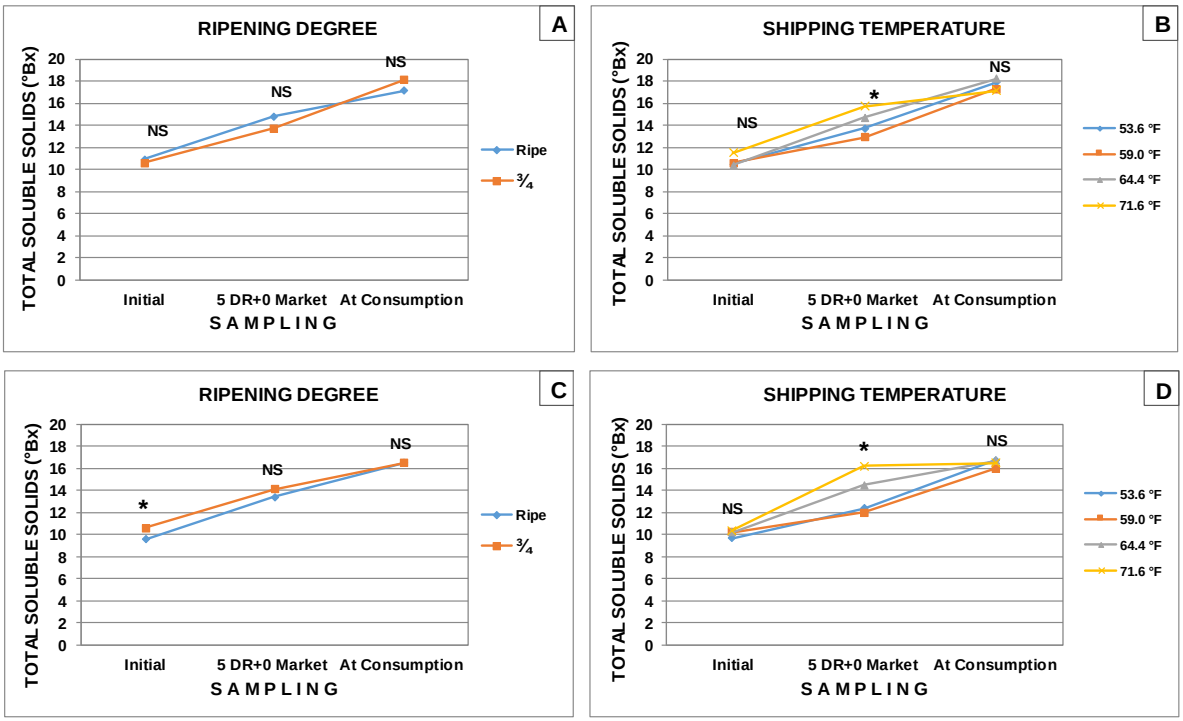

Figure 15. Effect of ripening degree (A, C) and shipping temperature (B, D) on TSS (°Bx) in Kent fruit with or without QHWT. RRTEM 2016.

It is evident shipping temperature is another important factor to consider in the handling of RRETM since as it is observed in Figure 16 for ripe and ¾ 'Kent' fruits, at higher temperature, shorter shelf life. Fruits maintained at 71.6°F reached maturity of consumption at seven days after harvest, while those kept at 64.4 and 59.0°F required nine days and those maintained at 53.6°F reached up to 10 days of shelf life.

In contrast, 'Kent' fruits without QHWT presented the same trend as those with QHWT, but had at least two additional days of shelf life. It corroborates the effect of QHWT, which accelerates the ripening process by increasing respiration and ethylene production (Luna et al., 2006; Yahia and Campos, 2000). Fruits in shipping simulation at 71.6°F reached consumption stage seven days after harvest, while those maintained at 64.4°F required nine days, those kept at 59.0°F gave 10 days and those preserved at 53.6°F showed 12 days of shelf life (Figure

17). The above is a determining factor for the importer to plan their needs of RRETM according to the shipping time and temperature.

Figure 16. External appearance of Kent fruit with QHWT at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

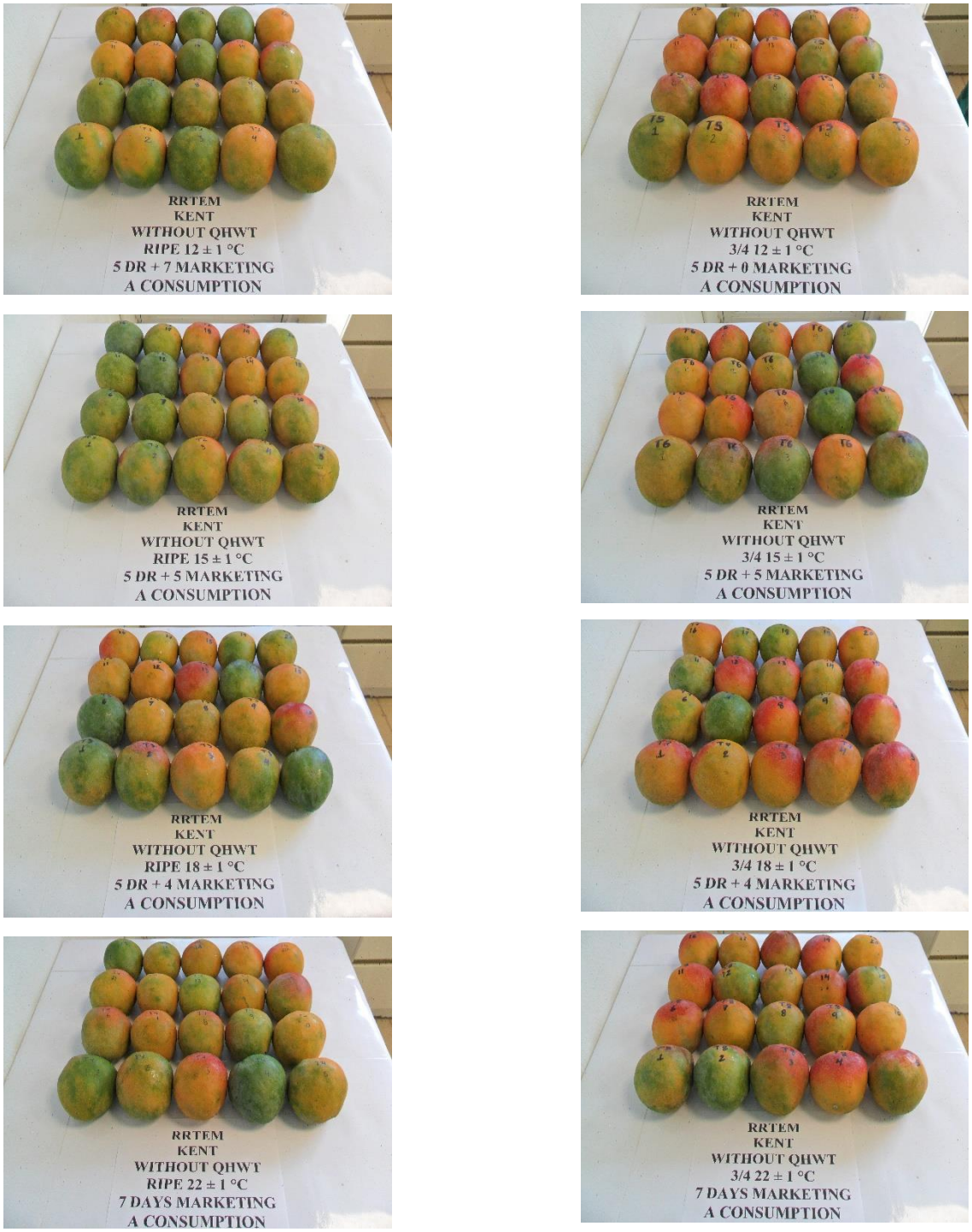

Figure 17. External appearance of Kent fruit without QHWT at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

4. Keitt with or without QHWT

Table 5 shows the analysis of variance of ripening degree and shipping temperature on the main quality variables in 'Keitt' with or without QHWT. Under QHWT, the ripening degree effect didn't affect significantly any of the variables, except for the TSS content, while for shipping temperatures only the ratio Bx / acidity was not significant. Regarding 'Keitt' without QHWT, a similar tendency was observed, only that ripening degree affected significantly firmness and pulp color, while shipping temperature significantly influenced all the variables except the relation Bx / acidity.

Table 5. Analysis of variance for ripening degree and shipping temperature on main quality variables of Keitt with or without QHWT. RRTEM 2016.

Factor	Keitt with QHWT					
	Weight loss (%)	External appearance	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	NS	NS	NS	NS	*	NS
Temperature	*	*	*	*	*	NS
Factor	**Keitt without QHWT**					
	Weight loss (%)	External appearance	Firmness (Pounds)	Pulp color (Hue)	TSS (°Bx)	Bx / Acidity
Ripening degree	NS	NS	*	*	NS	NS
Temperature	*	*	*	*	*	NS

Weight loss

For 'Keitt' with QHWR it was observed that ripening degree of maturity did not affect the weight loss since no significant differences were detected for any of the samplings (Figure 18A). In contrast, the effect of temperature was significant at the end of shipping simulation and even remained until consumption stage (Figure 18B). At the end of shipping simulation, fruits stored at 53.6, 59.0 and 64.4°F showed less weight loss than those stored at 71.6°F, a trend that remained until

consumption stage, and again it confirms that refrigeration reduces weight loss by reducing respiration rate (Kader, 1992).

Regarding 'Keitt' fruits without QHWT, the same tendency was observed as in fruits of 'Keitt' with QHWT for ripening since no significant differences were detected for any of the samples (Figure 18C). The shipping temperature effect was significant and similar to that observed in 'Keitt' fruits with QHWT at the end of the shipping simulation. Fruits stored at 71.6°F lost more weight than those stored at any refrigeration temperature, although at consumption the fruits stored at 53.6 and 59.0°F showed greater weight loss than those shipped at 64.4 and 71.6°F (Figure 18D).

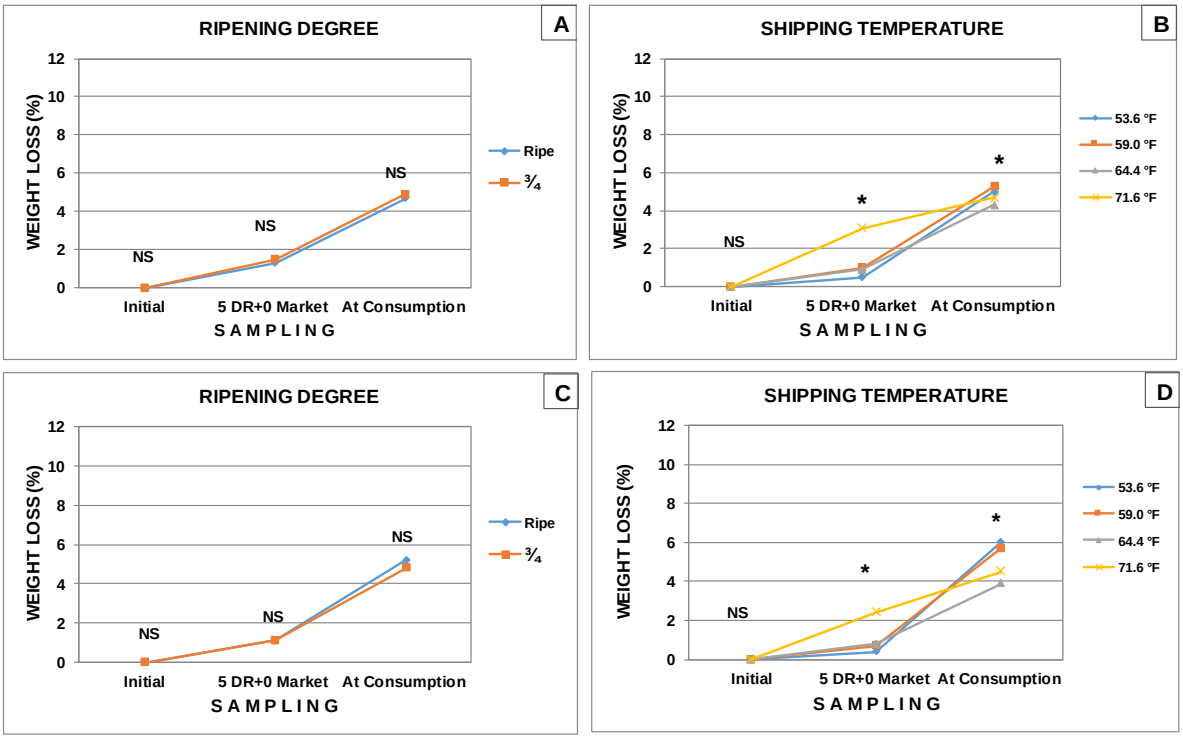

Figure 18. Effect of ripening degree (A, C) and shipping temperature (B, D) on weight loss (%) in Keitt fruit with or without QHWT. RRTEM 2016.

External appearance

Regarding the external appearance of fruits (data not shown), no significant differences were detected for ripening degree or for shipping temperature in any of the samples; nevertheless, all the fruits showed an external appearance of good to excellent according to the Standard.

Pulp firmness

Regarding pulp firmness, in fruits of 'Keitt' with QHWT no significant differences were detected for ripening degree in any of the samples (Figure 19A). In contrast, the temperature was only significant at the end of the shipping simulation (Figure 19B), where a direct correlation between temperature and weight loss was observed. The higher the temperature, the greater the loss of firmness. However, for fruits of 'Keitt' without QHWT, significant differences were observed at the end of shipping simulation for both factors. At the beginning, ripe fruits showed greater firmness than ¾ fruits (Figure 19 C), while for shipping temperatures, the differences were much more marked. The fruits shipped at 53.6, 59.0 or 64.4°F practically maintained the same initial firmness at the end of the shipping, while those stored at 71.6°F lost almost 50% of the initial firmness (Figure 19 D).

For practical purposes these differences in maintaining firmness due to cooler shipping temperatures can be used by the packer and/or distributor to plan their needs of RRETM.

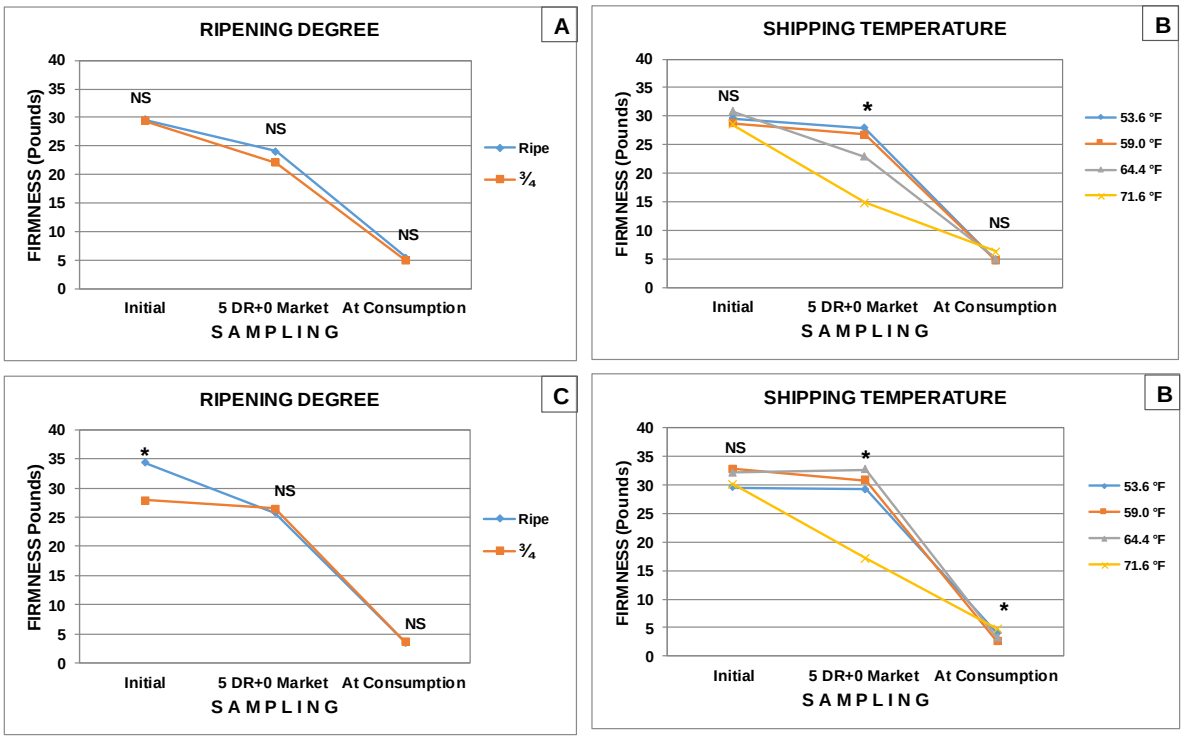

Figure 19. Effect of ripening degree (A, C) and shipping temperature (B, D) on pulp firmness (Pounds) in Keitt fruit with or without QHWT. RRTEM 2016.

Pulp color

Regarding to pulp color in 'Keitt' fruits with QHWT, no significant differences were detected for ripening degree (Figure 20A), but for shipping temperatures any of the fruits kept under refrigeration showed greater development color than those stored at 71.6°F (Figure 20B). In contrast, for fruits of 'Keitt' without QHWT, significant differences were detected for both factors. Ripe fruits had a lower intensity of pulp color than the ¾ fruits (Figure 20C) and, about the shipping temperature; the effect of the refrigeration was evident, since any of the fruits maintained under this condition developed slowly pulp color. No significant differences were detected in consumption (Figure 20D).

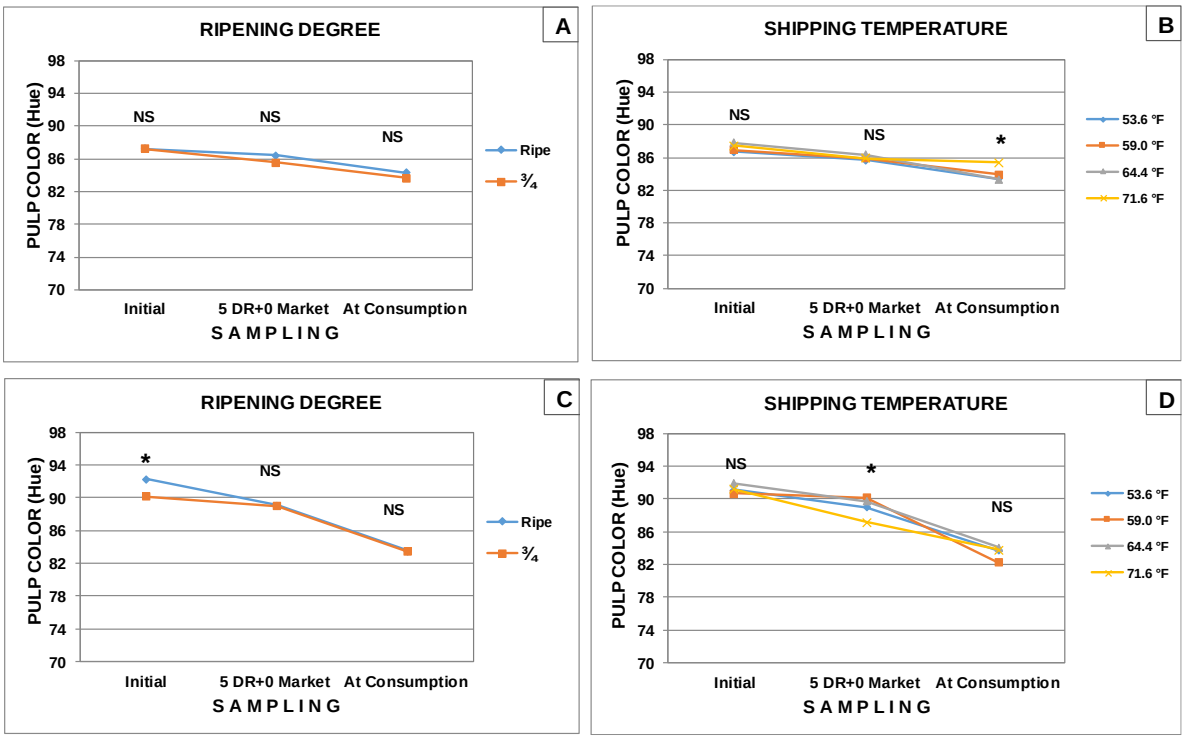

Figure 20. Effect of ripening degree (A, C) and shipping temperature (B, D) on pulp color (Hue) in Keitt fruit with or without QHWT. RRTEM 2016.

Total soluble solids (TSS)

The TSS content (°Bx) showed a behavior similar to that of pulp color. In fruits of 'Keitt' with QHWT, no significant differences were detected for ripening degree (Figure 21A), but for shipping temperatures fruits stored at 71.6 and 64.4°F showed higher TSS content than those stored at 53.6 or 59.0°F (Figure 21B). A similar trend was observed for 'Keitt' fruits without QHWT since no significant differences were detected for ripening degree (Figure 21C), and regarding shipping temperature, the effect of refrigeration was evident since the fruits maintained at 53.6 and 59.0°F developed more slowly the TSS content than those maintained at 64.4 and 71.6°F, without significant differences at consumption time (Figure 21D).

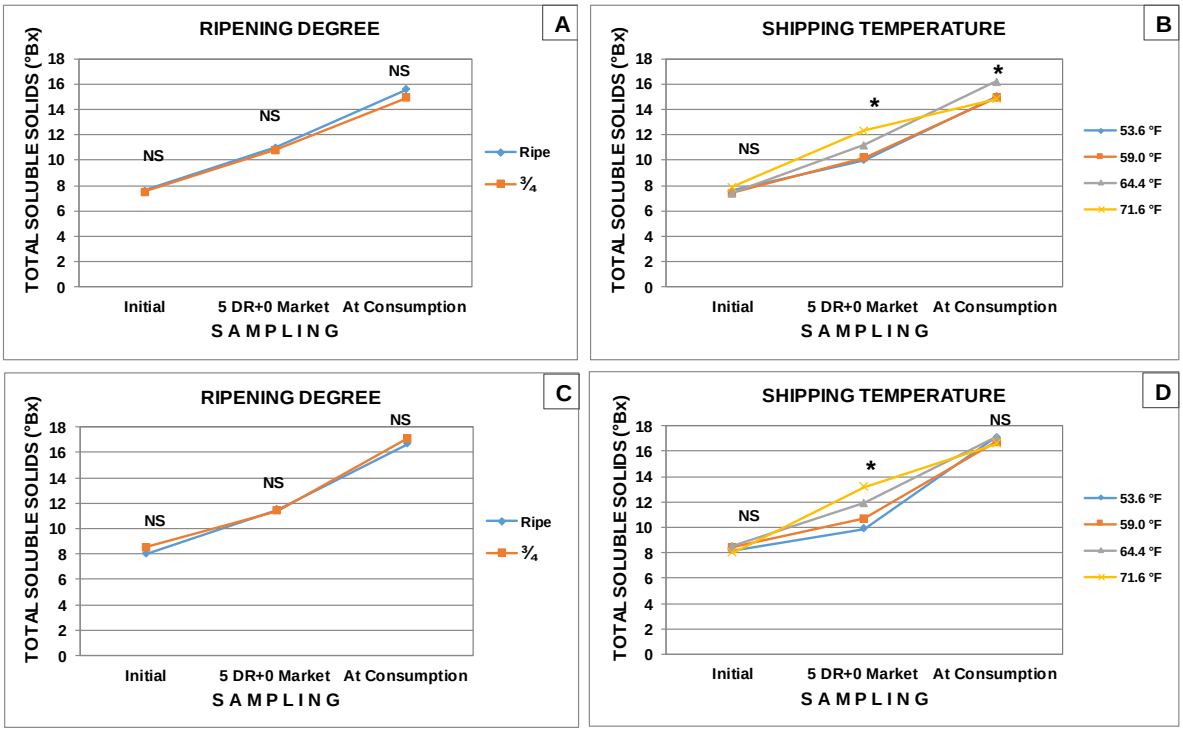

Figure 21. Effect of ripening degree (A, C) and shipping temperature (B, D) on TSS content (°Bx) in Keitt fruit with or without QHWT. RRTEM 2016.

It is evident that shipping temperature is another important factor to consider in the handling of RRETM since as it is observed in Figure 22 for ripe and ¾ 'Keitt' fruits, at higher temperature, shorter shelf life. Fruits in shipping simulation at 71.6 °F reached maturity of consumption at 8 days after harvest, while those maintained at 64.4°F required 11 days, those preserved at 59.0°F required 12 and those maintained at 53.6°F reached up to 13 days of shelf life.

In contrast, the 'Keitt' fruits without QHWT presented the same trend as those with QHWT but had at least two additional days of shelf life, which corroborates the effect of QHWT which accelerates the ripening process by increasing respiration and ethylene production (Luna et al., 2006; Yahia and

Campos, 2000). Fruits shipped 71.6°F reached maturity of consumption at nine days after harvest, while those maintained at 64.4°F required 11 days, those kept at 59.0°F gave 14 days and those preserved at 53.6°F showed 15 days of shelf life (Figure 23). The above is a determining factor for the importer to plan their needs of RRETM according to shipping time and temperature.

Figure 22. External appearance of Keitt fruit with QHWT at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

Figure 23. External appearance of Keitt fruit without QHWT at consumption stage with a ripe and ¾ ripening degree and shipped at different temperatures. RRTEM 2016.

CONCLUSIONS

- Ripening degree was one of the main factors in the handling of RRTEM, since the more mature mango showed the highest quality index (QI), and acceptability by consumers.
- Ripening degree affected pulp firmness, pulp color, total soluble solids (°Bx), and the ratio of °Bx/Acidity.
- Shipping temperature significantly influenced most of the variables, especially at the end of shipping simulation. The lower the temperature, the lower the weight loss, higher pulp firmness, and less development of pulp color and total soluble solids. This factor is very important for retailers to plan their orders volume of RRTEM according to their needs.
- The suggested ripening degree at harvest is ¾ and the shipping temperatures are 59.0 ± 1.5 and 64.4 ± 1.5°F.
- QHWT decreased two days the shelf life of ‘Kent’ and ‘Keitt’ fruit when compared without QHWT.
- Differences were detected among varieties, especially for shelf life. ‘Kent’ had a shelf life of 10 and 12 days with or without QHWT, respectively. ‘Keitt’ reached 13 to 15, ‘Ataulfo’ got 11 to 14, and ‘Tommy Atkins reached 12 to 14 days shelf life.

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