Article

Handling of 'Kent' mango destined for the market as a fruit to eat

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Abstract

The increase in demand for ready-to-eat ripe mango opens up an interesting possibility for mango producers in Mexico due to the geographical proximity of production sites to U.S. markets. The key aspects in the production of ripe mango to eat are: maturity at harvest, requirement or not of hydrothermal quarantine treatment (HQT), temperature and duration of refrigerated transport, as well as handling during commercialization. The work was carried out in an area with and without the presence of fruit flies, as well as with and without requirement of HQT (Nayarit and northern Sinaloa, respectively). States of maturity at harvest (mature and ¾ fruit), refrigeration temperatures (12, 15, 18 and 22 °C), with or without HQT were evaluated. The variables analyzed were weight loss, pulp color, pulp firmness, total soluble solids (TSS), titratable acidity and °Bx/acidity ratio. It was found that the degree of maturity at harvest was not so impactful in most of the variables, while the temperature of transport had a significant impact on most of them. At lower temperatures, greater firmness, lower weight loss and slow development of TSS, as well as longer shelf life. The temperature of 12 °C showed measurements similar to 15 and 18 °C at consumption in all the variables evaluated, in addition to being the temperature with the highest shelf life. HQT led to up to two days less shelf life compared to fruits without HQT.

Keywords: *Mangifera indica* L., state of maturity, transport temperature.

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Introduction

The quality of freshly cut fruit is a factor of growing popularity in the supply of foods. Mango (*Mangifera indica* L.) is one of the most important tropical fruits in the world, ranking fifth in total world production among fruit crops, with good commercialization potential as a freshly cut product (Dea *et al*., 2010) and is one of the favorite fruits in the U.S. market. During the last three years, 120 million boxes have been imported, mainly from Mexico (65%), Peru (10%), Ecuador (9%), Brazil (7.1%), Guatemala (4.6%) and Haiti (2.3%) (USDA-FAS, 2018). The most demanded varieties for export are ‘Tommy Atkins’, ‘Ataulfo’, ‘Kent’, ‘Keitt’ and ‘Haden’ (SAGARPA, 2018).

Recently the demand for ready-to-eat ripe mango has increased. The key aspects in the production of ready-to-eat ripe mango are considered to be the following: a) maturity at harvest; b) requirement or not of hydrothermal quarantine treatment (HQT); c) temperature and duration of refrigerated transport; and d) handling in the wholesaler warehouse and during commercialization in supermarkets. The increase in demand for ready-to-eat ripe mango represents an important export window for mango producers in Mexico due to the geographical proximity of production sites to U.S. markets. Most production sites are located within a maximum of five days of ground travel to reach the farthest of destination markets in the United States of America.

Because the mango is host to the Mexican fruit fly [(*Anasthrepha ludens* (Loew) and *A. oblique* (Macquart)], the export of this fruit is regulated by international standards, so compliance with hydrothermal treatment is mandatory if exported to countries such as the United States, Japan, Chile, New Zealand and Australia (Luna-Esquivel *et al*., 2006). The hydrothermal treatment for mangoes, approved by the United States Department of Agriculture (USDA) and the Animal and Plant Health Inspection Service (APHIS), consists of the immersion of fruits in water at 46.1 °C for 65 to 110 min. However, it can be modified depending on the shape and size of the fruit, and it must be: a) 110 min for round mangoes >701 g; b) 90 min for round mangoes from 500 to 700 g; c) 75 min for round mangoes and less than 499 g, as well as for flat long mangoes from 375 to 570 g; and d) 65 min for flat long mangoes less than 375 g (USDA-APHIS, 2010).

It is known that heat treatments can extend the storage capacity and commercialization of the fruit by inhibiting the ripening process or inducing resistance to cold damage (Lurie, 1998; Fallik, 2004). However, it has also been pointed out that hydrothermal treatment affects fruit quality characteristics (Woolf and Lay-Lee, 1997; Yahia and Campos, 2000). The objective of this research was to study the effect of the degree of maturity at harvest and the temperature of transport on the quality and storage potential of ‘Kent’ mango fruits with export quality with or without HQT.

Materials and methods

The fruits of the ‘Kent’ variety used in the present work were obtained from two areas. For the area with the presence of the fruit fly and with requirement of HQT, the fruits were acquired from the ALEX packing plant, located in Valle Lerma, municipality of Santiago Ixcuintla, Nayarit, while for the fruit fly-free area and without requirement of HQT, the fruits came from the DANIELLA packing plant, located in the city of Los Mochis, Sinaloa. The fruits were harvested during the 2017 season, obtaining a total of 50 fruits per treatment.

The fruits had an excellent external appearance and were free of mechanical damage, pests and diseases. Once classified, the fruits were washed and in the case of the area with the presence of the fruit fly, they were subjected to hydrothermal quarantine treatment of 90 min according to the USDA-APHIS protocol. For all fruits, the following factors were considered: 1) maturity at harvest: a) mature fruit (round shape with full cheeks and raised shoulders, pulp color 2 to 3 and content of total soluble solids >7.3 °Bx) and b) fruit ¾ (with higher degree of maturity, peel color turning, pulp color ≥3 and total soluble solids content >9 °Bx), as well as 2) transport temperatures: a) 12 ±1 °C; 90 ±5% RH; b) 15 ±1 °C; 90 ±5% RH; c) 18 ±1 °C; 90 ±5% RH; and d) commercialization simulation (22 ±2 °C; 75 ±10% RH), until consumption maturity.

The fruits with or without HQT were stored for five days in refrigeration to simulate the land transport to the furthest of the U.S. markets. A completely randomized design with factorial arrangement (2 x 4) was used with 20 repetitions for weight loss and eight repetitions for the rest of the variables in fruit (Table 1). Samplings were carried out at the beginning, at the end of refrigerated storage and at consumption maturity.

Table 1. Treatments generated by the factorial (2 x 4).

No.	Degree of maturity	Transport temperature (°C)	Transport time (days)
1	Mature	12 ±1	5
2	Mature	15 ±1	5
3	Mature	18 ±1	5
4	Mature	22 ±1	5
5	¾	12 ±1	5
6	¾	15 ±1	5
7	¾	18 ±1	5
8	¾	22 ±1	5

Variables analyzed

Weight loss. By means of a digital analytical balance (Acculab VI-4800) with approximation of 0.1 g (Ohaus Corp. Florham Park, NJ). Twenty fruits were weighed periodically from the beginning to the end of the experiment. The difference in weight with respect to the initial weight was expressed as a percentage of weight loss. Pulp color. It was measured with a portable Konica Minolta colorimeter model CR-400 (Konica Minolta Sensing Americas, Inc., Ramsey, NJ, USA) with standard C illumination, reporting the hue angle.

Firmness. A Chatillon penetrometer Model DFE-050 (Ametek Instruments, Largo, FL), adapted with a cylindrical punch of 8 mm in diameter, was used, the data were expressed in Newtons (N). Total soluble solids (TSS). They were measured with a digital refractometer with an ATAGO temperature compensator model PAL-1 calibrated with distilled water (AOAC, 1984). Titratable acidity. It was determined with a Metrohm 801 Stirrer semiautomatic titrator according to the method of the AOAC (1984). Five grams of previously homogenized pulp were used, employing phenolphthalein as an indicator and titrating with NaOH 0.1 N. Acidity was reported in % citric acid. °Bx/acidity ratio. It results from the division of TSS by acidity, desirable ≥32.

Results and discussion

Weight loss

For fruits with HQT, it was observed that the degree of maturity at harvest did not affect weight loss since no significant differences were detected for any of the samplings (Figure 1A). In contrast, the effect of temperature was significant at the end of the transport and even remained until consumption maturity (Figure 1B). At the end of the transport simulation, the fruits stored at 12 and 15 °C showed less weight loss than those stored at 18 and 22 °C, a trend that remained until consumption maturity. Based on the above, it is confirmed that refrigeration reduces weight loss by decreasing the rate of respiration (Kader, 1992).

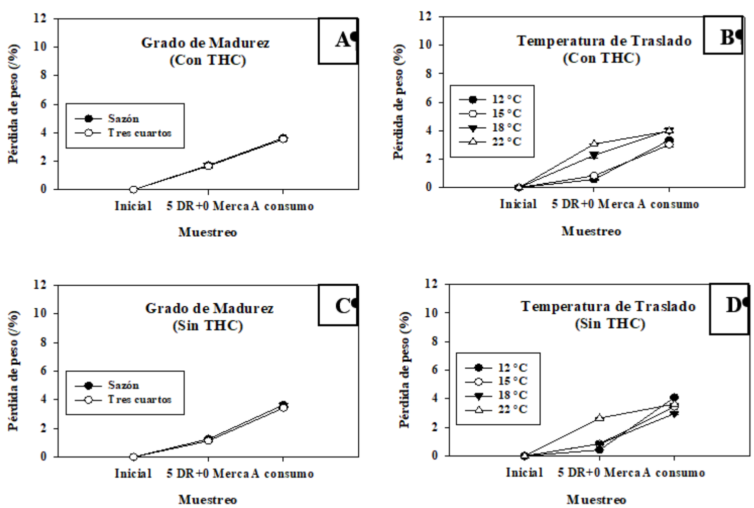

Figure 1. Effect of the degree of maturity (A and C) and the transport temperature (B and D) on weight loss in 'Kent' mango fruits. Each point represents the mean of twenty observations ± the standard error.

Regarding the fruits without HQT, the same trend was observed as in the fruits with HQT for the factor degree of maturity at harvest, as no significant differences were detected for any of the samplings (Figure 1C). However, the effect of transport temperature was significant, as in fruits with HQT, fruits stored at 22 °C lost more weight than those stored at any refrigeration temperature, although, at consumption, differences were only detected between 12 and 18 °C (Figure 1D).

Sripong *et al*. (2015) observed that the application of a hydrothermal treatment at 55 °C for 5 min combined with UV-C irradiation in 'Chok-Anan' mango fruits caused a progressive increase in weight loss in the fruits during the twelve days of storage. On the contrary, Osuna *et al*. (2007) point out that the accumulated weight loss in fruits of the 'Keitt' variety without hydrothermal treatment was statistically greater than that observed in fruits with hydrothermal treatment.

On the other hand, Pérez *et al*. (2005) studied the effect of the application of edible wax in mangoes of the 'Tommy Atkins' variety with hydrothermal treatment on the cuticular characteristics of the fruit during commercial storage and reported that, although the wax content contributes to waterproofing the fruits, the morphology and structure of these vary, favoring the loss of water. Whereas Jacobi *et al*. (2000) applied a hydrothermal treatment to 'Kensington' mango fruits stored at 21 °C, observing that the treated fruit had an increase in weight loss compared to the untreated fruit, concluding that the application of hydrothermal treatment accelerated the ripening of the fruit.

Other studies such as Luna-Esquivel *et al*. (2006); Henríquez *et al*. (2005), finding no statistically significant difference on weight loss in mango fruits of the 'Ataulfo' variety and tomato, respectively, without and with hydrothermal treatment, attributed this behavior as a consequence of the loss of water vapor through the lenticels during the transpiration process.

Pulp color

In fruits with HQT, no significant differences were detected for the factor degree of maturity (Figure 2A) but for transport temperatures, where the fruits stored at 12 °C showed less color development than those stored at 22 °C (Figure 2B). In contrast, for fruits without HQT, significant differences were detected for both factors in the sampling at the end of the transport. The mature fruits had a lower intensity of pulp color than the ¾ fruits (Figure 2C) and regarding transport temperature, the effect of refrigeration was clearly evident, since any of the fruits kept under this condition developed more slowly the color of the pulp, without detecting significant differences at consumption (Figure 2D).

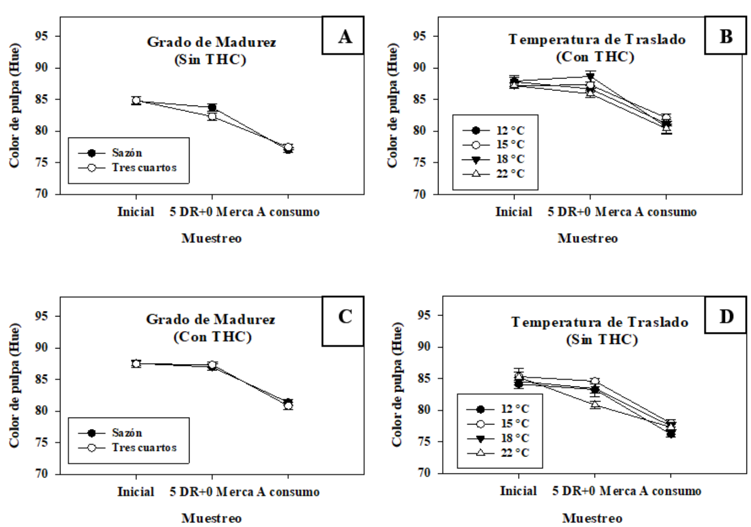

Figure 2. Effect of the degree of maturity (A, C) and the transport temperature (B, D) on pulp color in 'Kent' mango fruits. Each point represents the mean of eight observations ± the standard error.

Kim *et al*. (2007) reported that there were no significant differences in the color values of 'Tommy Atkins' mango fruits treated with hydrothermal treatment and the control. On the other hand, Osuna *et al*. (2007) point out that, in fruits of the 'Keitt' variety without HQT and application of 1-MCP (1-Methylcyclopropene), the evolution of the pulp color was significantly affected, while in fruits with HQT and application of 1-MCP, there were no alterations in pulp color.

Firmness

Fruits with HQT showed no significant differences for degree of maturity in any of the samplings (Figure 3A). In contrast, temperature was only significant at the end of the transport simulation (Figure 3B), where a direct correlation between temperature and firmness was observed. The higher the temperature, the greater the loss of firmness. While for fruits without HQT, significant differences were observed at the end of the transport simulation for both factors under study. The mature fruits were firmer than the ¾ fruits (Figure 3C), while for the transport temperatures, the differences were much more marked. The fruits transported at 12 or 15 °C practically maintained the same initial firmness at the end of the transport, while those stored at 18 and 22 °C lost more than 50% of the initial firmness (Figure 3 D).

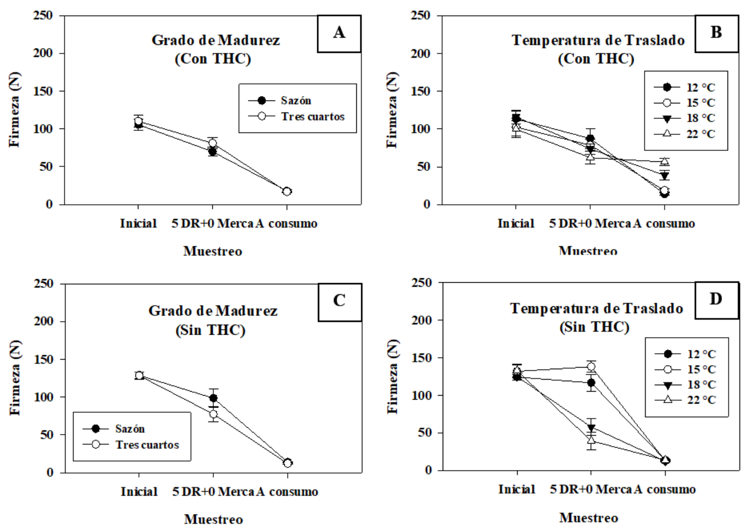

Figure 3. Effect of the degree of maturity (A and C) and the transport temperature (B and D) on pulp firmness in 'Kent' mango fruits. Each point represents the mean of eight observations ± the standard error.

Dea *et al*. (2010) observed that storage at low temperatures in 'Kent' mango fruits allowed maintaining the firmness, since refrigeration temperatures imply a decrease in respiration and in the fluidity of cell membranes, as well as in damage to membrane proteins, which increases the rigidity of the membrane. On the other hand, Osuna *et al*. (2007) indicated that 'Keitt' fruits without HQT maintained the firmness of the fruit in the presence of 1-MCP, while with HQT and 1-MCP, the firmness decreased significantly.

On the other hand, Liu *et al*. (2015) point out that hydrothermal treatment by intermittent heating helped to maintain firmness in peppers stored at 4 °C for 6 and 13 days. Likewise, Ummarat *et al*. (2011) reported that, when applying hot water treatments on banana fruits, they found that it favored a greater retention of firmness after storing the fruits at low temperatures. In addition, Ghasemnezhad *et al*. (2008) mention that, when applying hydrothermal treatment on mandarin *cv* Satsuma, they found that it gave greater retention in firmness. For practical purposes, the difference in firmness maintenance due to the colder or milder transport temperature can be used by the packer and distributor to manipulate the temperature according to their needs for ready-to-eat ripe fruit stock.

Total soluble solids (TSS)

The TSS content (°Bx) showed a behavior similar to that of the pulp color. In fruits with HQT, no significant differences were detected for the factor degree of maturity (Figure 4A) but for transport temperatures, where the fruits stored at 22 and 18 °C showed higher TSS content than those stored at 12 or 15 °C (Figure 4B). In contrast, for fruits without HQT, significant differences were detected for both factors.

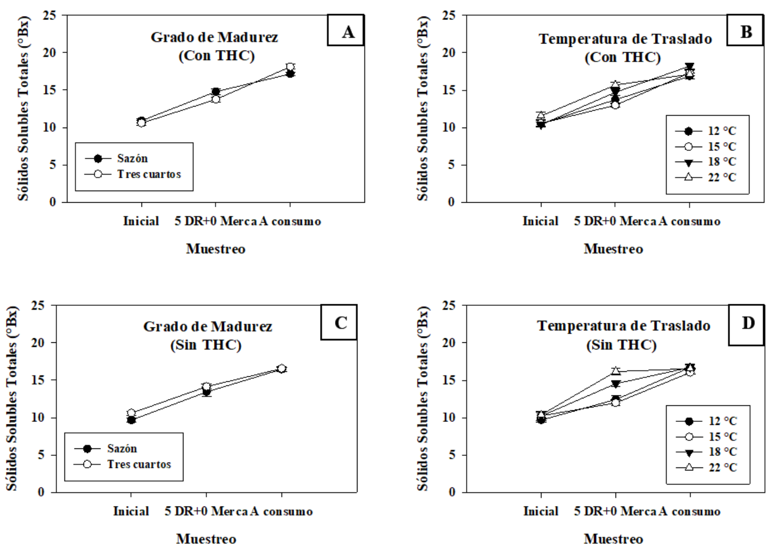

Figure 4. Effect of the degree of maturity (A and C) and the transport temperature (B and D) on the content of total soluble solids in 'Kent' mango fruits. Each point represents the mean of eight observations ± the standard error.

The mature fruits had a lower TSS content than the ¾ fruits (Figure 4C) and regarding transport temperature, the effect of refrigeration on the sampling carried out at the end of the transport was clearly evident, since the fruits kept at 12 and 15 °C developed the TSS content more slowly than those kept at 18 and 22 °C, with no significant differences detected at consumption (Figure 4D). Djioua *et al*. (2009) indicated that, in 'Keitt' mango fruits treated with hydrothermal treatment at 50 °C for 30 min, it induced a decrease in TSS content up to six days of storage, but after nine days, the final TSS value was higher than at the start of the experiment. While Luna-Esquivel *et al*. (2006) mention that hydrothermal treatment and storage at low temperatures reduced the final concentration of TSS in 'Ataulfo' mango fruits, compared to fruits without hydrothermal treatment.

By contrast, Kim *et al*. (2009) observed that, in 'Tommy Atkins' mango fruits, the application of hydrothermal treatment at 46.1 °C for 70, 90 and 110 min had no effect on the TSS content after four days of storage. Likewise, Paull and Shen (2000) point out that there were no significant effects of hydrothermal treatment on the TSS content in mango, grapefruit, orange and tomato fruits. On the other hand, Sripong *et al*. (2015) observed that the application of hydrothermal treatment combined with UV-C irradiation in ‘Chok-Anan’ mango fruits increased the concentration of TSS. Also, Osuna *et al*. (2007) claim that the increase in the total TSS content in fruits of the ‘Keitt’ variety was mainly due to the effect of hydrothermal treatment.

Titratable acidity

In fruits with HQT, no significant differences were detected for the factor degree of maturity (Figure 5A) but for transport temperatures, where the fruits stored at 22 °C had the highest percentage of citric acid during the beginning. However, at consumption, the fruits stored at 15 and 18 °C showed a higher percentage of citric acid than those stored at 22 °C (Figure 5B), which indicates that these temperatures delayed the ripening process. In contrast, fruits without HQT presented statistical differences with respect to those of HQT for the factor degree of maturity at the end of the transport (Figure 5C).

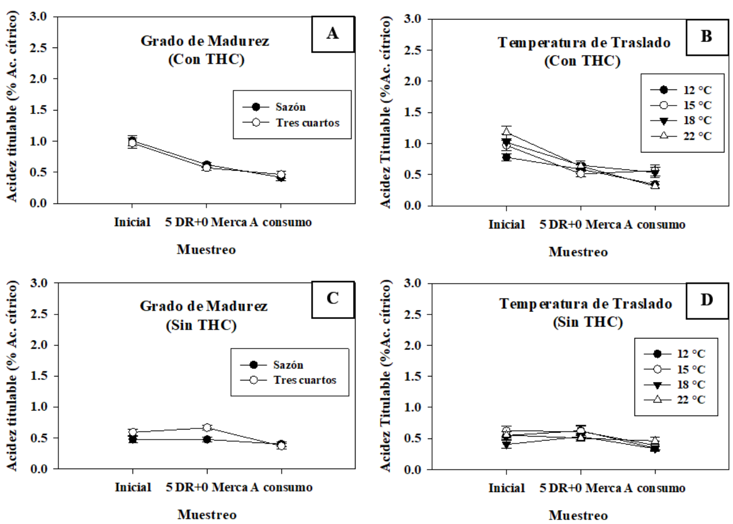

Figure 5. Effect of the degree of maturity (A and C) and the transport temperature (B and D) on the titratable acidity in ‘Kent’ mango fruits. Each point represents the mean of eight observations ± the standard error.

While for the factor transport temperatures, there was only a significant difference at the beginning, where the fruits stored at 15°C had the highest percentage of acidity (Figure 5D). Baloch and Bibi (2012) reported that mango fruits stored at 20 °C showed a decrease in titratable acidity, attributing it to the conversion of acids to sugars with the ripening process and whose conversion rate increased with temperature. Also, Dea *et al*. (2010) claim that, in ‘Kent’ mango fruits, titratable acidity decreased as the storage time elapsed, which could be attributed to the use of organic acids in various physiological processes and mainly as substrates in respiration.

In another study, it was observed that, in ‘Keitt’ mango fruits with HQT, the titratable acidity remained constant, to which they concluded that this parameter was not affected by the treatment (Djioua *et al*., 2009).

On the other hand, Luna-Esquivel *et al*. (2006) studied hydrothermal treatment in 'Ataulfo' mango fruits stored at 10 and 13 °C, where they observed that fruits with hydrothermal treatment and stored at 10 °C obtained the lowest titratable acidity values compared to fruits without hydrothermal treatment; they attributed this to the fact that hydrothermal treatment caused an acceleration in the ripening process, considerably decreasing the acidity in the mango, because the citric, malic and ascorbic acids are used as substrates of respiratory activity in the fruit.

°Bx/acidity ratio

For the factor degree of maturity at harvest, no significant differences were detected for fruits with HQT (Figure 6A). In contrast, no significant differences were detected for temperatures at the end of the transport (Figure 6B), but very noticeable at the time of consumption. The fruits stored under commercialization simulation (22 ±2 °C) showed the highest °Bx/acidity ratio, although they were statistically equal to those initially stored at 12 °C and later to commercialization simulation, indicating that this transport refrigeration temperature did not interfere so that the fruits reached a good quality at consumption as they did not exhibit cold damage.

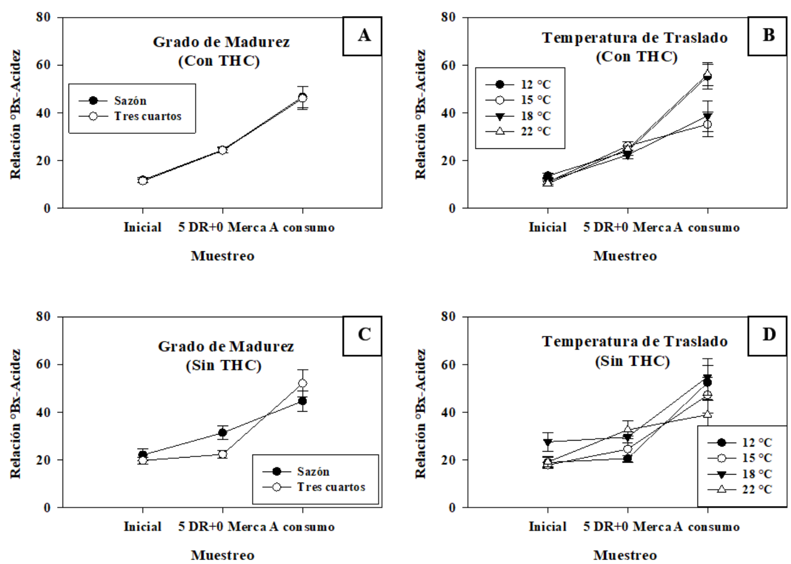

Figure 6. Effect of the degree of maturity (A and C) and the transport temperature (B and D) on the °Bx/acidity ratio in 'Kent' mango fruits. Each point represents the mean of eight observations ± the standard error.

In this regard, Brecht *et al*. (2015) state that the optimum ripening temperature of mango fruits is achieved at temperatures between 20 and 22 °C and this also coincides with what is cited by Osuna *et al*. (2019), who express that 'Kent' fruits showed cold damage from one week of storage at 7.5 and 10 °C, but not at 12 °C, even at three weeks of storage. In contrast, fruits without HQT showed differences in degree of maturity (Figure 6C). At the end of the transport, the mature fruits showed a higher °Bx/acidity ratio than the ¾ fruits; however, at consumption, these showed a higher ratio according to what was expected.

Regarding the effect of the transport temperature, at the end of this, the fruits stored at warmer temperatures (18 and 22 °C) showed a higher °Bx/acidity ratio (riper) than those stored at 12 and 15 °C (Figure 6D). However, at the time of consumption, the fruits with the greatest ratio were those stored at 12 and 18 °C. The °Bx/acidity ratio can be influenced by several factors. Siller-Cepeda *et al*. (2009) mention varietal differences, since, when evaluating 13 varieties of early, intermediate or late maturation, they found values as low as 23.3 in 'Osteen' and as high as 134.5 in 'Diplomático', while 'Kent' obtained a low ratio of only 23.6.

In addition, Méndez *et al*. (2010), when evaluating 13 varieties in the plain of Maracaibo, Venezuela, found values from 17.95 in 'Haden' to 55.14 in 'Carousel' and 'criollo de Mara', while 'Kent' had values of 30.7. On the other hand, García-Martínez *et al*. (2015) showed a consistent increase in the °Bx/acidity ratio during the first six days of ripening in response to three levels of fertilization, with the High and Normal levels presenting the highest levels (about 45) versus 40 of the Control treatment. Regarding storage temperature, Galviz *et al*. (2002) report that the 'Van Dyke' variety had the lowest values of °Bx/acidity at the temperature of 7.5 and 10 °C, while the fruits stored at 12 °C reached a value of 80 on day 30, while the controls stored at 18 °C reached a value of 60.85 at 15 days of storage.

Conclusions

The factor maturity at harvest did not significantly affect any of the variables evaluated. The transport temperature is a factor to consider in the handling of the ready-to-eat ripe mango. The fruits in simulation of transport at 22 °C reached maturity of consumption seven days after harvest, while those preserved at 18 °C required nine, those preserved at 15 °C reached ten days and those preserved at 12 °C showed up to twelve days of shelf life. On the other hand, at a lower temperature, less weight loss, greater firmness, less development of pulp color and TSS, as well as longer shelf life. Depending on their needs and times, the importer can schedule the transport temperatures at their convenience. In addition, consider that HQT decreased the shelf life by at least two days.

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