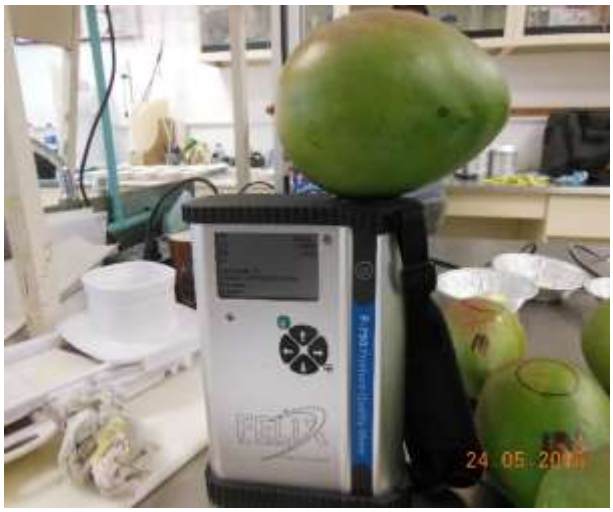
DRY MATTER ACCUMULATION DURING GROWTH, DEVELOPMENT, AND RIPENING OF MANGO FRUIT FROM ATAULFO, TOMMY ATKINS, KENT, AND KEITT VARIETIES GROWN IN NAYARIT AND SOUTHERN SINALOA
EXECUTIVE REPORT 2020-2021





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OBJECTIVES

- To investigate the behavior of DM accumulation during the growth and development of mango fruit from ‘Ataulfo’, ‘Tommy Atkins’, ‘Kent’, and ‘Keitt’ varieties.
- To evaluate the impact of DM content at harvest with the fruit quality at consumption.
- To correlate HU accumulation with fruit DM content to get the maximum quality at consumption.
- To validate the spectrometer F-751 to determine DM content of different mango varieties using a unique Model.

ACHIEVEMENTS

Season 2020

Assays were established in commercial orchards of ‘Ataulfo’, ‘Tommy Atkins’ and ‘Keitt’ in Nayarit, as well as ‘Ataulfo’, ‘Tommy Atkins’, ‘Kent’ and ‘Keitt’ in southern Sinaloa. In each orchard, temperature and relative humidity sensors / recorders were installed in the canopy of a representative tree of the selected orchards. The HOBOS were installed during early January to follow up on flowering, mooring and fruit development from full bloom to optimum harvest maturity. HOBOS were programmed to record temperature and RH every 30 min. The HU accumulation was calculated using the base temperature of 10 °C (50 °F) (Guzmán-Estrada et al., 1996; Ruiz-Corral et al., 1999; Pérez de Azkue and Puche, 2003). In each orchard, 10 representative trees were selected, in which at least 40 panicles were marked (10 in each cardinal point) when full blooming (at least 60% of the canopy). Once the fruit was set, they were individually labeled to follow up the DM accumulation every three weeks starting 50 days after full blooming until harvest at three different ripening stages. An F-751 spectrometer (Felix instruments, Camas, WA, USA) was used to non-destructively measure the development and accumulation of DM. At the same time during harvest, DM was corroborated in a universal natural convection oven, allowing the samples to dry for 72 hours at 60 °C.

The length and diameter of the fruit was measured every three weeks with a digital Vernier. In addition, DM content during their growth and development, as well as weight, size and initial quality at harvest, at the end of the refrigerated transfer simulation (seven days at 53.6 ± 1.8 °F; 90 ± 5 % RH) and at consumption (after 7-12 days of marketing simulation at 71.6 ± 3.6 °F; 75 ± 10 % RH). The analyzed variables were DM, weight loss, skin color, external appearance, pulp firmness, pulp color, total soluble solids content, acidity, and ratio Brix/acidity.

Results are presented independently according to variety following the next sequence: a) Growth and development; b) Comparison of DM between the F-751 vs the conventional oven, and c) Comparison of quality among the three harvesting stages. 'Ataulfo' and 'Tommy Atkins' were harvested at 1500, 1600 and 1700 HU; 'Kent' at 1650, 1800 and 1950 HU, while 'Keitt' at 2000, 2200 and 2400 HU.

Due to the Coronavirus contingency and climatic conditions, sampling done for growth and development varied according varieties and locations. In 'Ataulfo' at Nayarit two samplings previous harvest and three at harvest were done, while for 'Ataulfo' in Sinaloa only a previous sampling and the three harvesting stages at 1500, 1600, and 1700 HU were done. For 'Tommy Atkins' was very similar to 'Ataulfo', in Nayarit were two samplings before harvest and the three harvesting stages while at Sinaloa only one sample before harvest and the three harvesting stages at 1500, 1600, and 1700 HU were done. For 'Keitt' in Nayarit, three samples were done before harvest and only two at 2000 and 2200 HU since the cooperate grower harvested before the last sampling at 2400 HU. In contrast, at Sinaloa state two samplings before harvest were done while we did at three different harvesting stages (2000, 2200, and 2400 HU). Finally, in the 'Kent' variety, two samplings were done before harvest and the three at different harvesting stages (1650, 1800, and 1950 HU) only in Sinaloa state since due to climatic conditions it was not possible to follow up this variety in Nayarit state.

With respect to follow up the growth and development during the growing of the fruit, it was found that is not necessary to monitor it continuously during the full season since sampling just a few days before harvest any of the varieties showed a similar trend: the higher the HU accumulation, the higher the length, diameter and DM content. On the other

hand, respect to the validation of the F-751 to determine DM in a non-destructive way and comparison with the conventional oven, the spectrometer overestimated the DM content in ‘Ataulfo’ fruit, but underestimated it in ‘Tommy Atkins’, ‘Kent’, and ‘Keitt’ while R^2 values were lower than 0.70, indicating that the F-751 required some adjustments to use it as a trusty device to measure the fruit DM content still in the tree. We continue working with the Felix team to improve the predictive capacity of the device and a new App was developed using the methodology of the Artificial Neural Networks. This App will be validated during the 2021 season. Finally, with respect to fruit quality of different varieties, it was found that there was a direct relationship between accumulated HU and quality. Fruit harvested with higher accumulated HU had higher skin and pulp color intensity, higher total soluble solids, less acidity, and overall, a higher ratio Bx/Acidity.

Season 2021

During this period, it was possible to establish the assays in commercial orchards in ‘Ataulfo’, ‘Tommy Atkins’, ‘Kent’, and ‘Keitt at Nayarit and Sinaloa, starting with the Hobos installation at early January to follow up on flowering, mooring and fruit development from full bloom to optimum harvest maturity. HOBOS were programmed to record temperature and RH every 30 min. The HU accumulation was calculated using the base temperature of 10 °C (50 °F) (Guzmán-Estrada et al., 1996; Ruiz-Corral et al., 1999; Pérez de Azkue and Puche, 2003). In each orchard, six representative trees were selected, in which at least 40 panicles were marked (10 in each cardinal point) when full blooming (at least 60% of the canopy). Once the fruit was set, they were individually labeled to follow up the DM accumulation before harvest and at harvest at two different ripening stages (Green mature and Fully Ripe). An F-751 spectrometer (Felix instruments, Camas, WA, USA) was used to non-destructively measure the development and accumulation of DM. At the same time during harvest, DM was corroborated in a universal natural convection oven, allowing the samples to dry for 72 hours at 60 °C. In addition, DM, weight loss, skin color, external appearance, pulp firmness, pulp color, total soluble solids content, acidity, and ratio Brix/acidity were measured at harvest, at the end of the refrigerated transfer simulation (seven days at 53.6 ± 1.8 °F; 90 ± 5 % RH) and at consumption (after 7-12 days of

marketing simulation at 71.6 ± 3.6 °F; 75 ± 10 % RH). Harvests were done from June 10 until July 28.

Results are presented in a similar way tan season 2020, independently by variety and considering the next sequence: a) Growth and development; b) Comparison of DM between the F-751 vs the conventional oven, and c) Comparison of quality among the two harvesting stages. ‘Ataulfo’ and ‘Tommy Atkins’ were harvested at 1600 and 1750 HU; ‘Kent’ at 1800 and 1950 HU, while ‘Keitt’ at 2200 and 2400 HU. The lower HU value was consider for green mature fruit while the higher value was for fully ripe fruit. In all cases, sampling was done before harvest and at the two mentioned ripening stages.

With relation to growth and development, differences were found among varieties. For ‘Ataulfo’ in fruit length, the fruit harvested in Nayarit were bigger than those harvested in Sinaloa, however, no significant differences were observed for fruit diameter. On the other hand, DM content was higher for fruit harvested in Sinaloa, whereas no significant differences were detected between ripening stages. In addition, no significant differences were found for TSS (°Bx) neither between locations nor ripening degree. With respect to ‘Tommy Atkins’, no significant differences were detected neither locations nor ripening degree except that for DM content fruit harvested in Sinaloa showed higher values. In relation to ‘Kent’, significant differences were detected between locations for length and diameter. The fruit harvested in Nayarit were bigger than those harvested in Sinaloa. In contrast, the values of DM and TSS were higher for fruit harvested in Sinaloa. With respect to ‘Keitt’, no significant differences were detected between locations neither ripening degree for any of the measured variables.

With respect to the comparison of DM content measured nondestructively with the F-751 versus the conventional oven, in the general Model the four varieties and the two ripening degrees were considered. A very acceptable average value of 15.6% was found for the spectrometer while the oven had 15.2% DM, only 0.4 points difference and $R^2 = 0.4227$. That indicated the adjustments made to the Model were good enough and confirmed that the F-751 is a viable tool to determine nondestructively the fruit DM content of any of the four varieties using the unique Model generated using the Artificial Neural Networks methodology. In the case of varietal effect, ‘Ataulfo’ average values for the F-751 were

15.9% while for the oven were 15.6% with an R^2 = 0.6466, while for ‘Tommy Atkins’ the DM detected with the F-751 was 15.1% while for the oven was 14.9%, only 0.2 percentage points but with a relative low R^2 = 0.3824. With respect to ‘Kent’, the difference between methods was a little higher, 16.0% for the spectrometer and 15.5% for the oven with an R^2 = 0.3971. In addition, ‘Keitt’ had a difference even higher with an average DM value of 15.5% for the F-751 and 14.9% for the oven with an R^2 = 0.3631. In summary, the adjustment made to the model and spectrometer was effective, since the unique Model was able to predict acceptably the fruit DM content of all varieties with only 0.3 to 0.6 percentage points compared to the traditional oven method.

Comparison of fruit quality between harvesting stages

According to the data got the last season, it was found a direct correlation between accumulated HU and quality. Fruit harvested with more HU had higher intensity of skin or pulp color, higher TSS content, less acidity and, overall, higher ratio Bx/Acidity. For this season, we only considered two ripening stages. ‘Ataulfo’ and ‘Tommy Atkins’ at 1600 HU represented green mature fruit while those harvested at 1750 HU were classified as fully ripe fruit (¾). For ‘Kent’ those fruit harvested at 1800 HU represented green mature fruit while those harvested at 1950 HU were classified as fully ripe fruit (¾). With respect to ‘Keitt), fruit harvested at 2200 HU represented green mature fruit while those harvested at 2400 HU were classified as fully ripe fruit (¾). Maybe for this reason the differences among variables between both ripening degrees was not so remarkable in the four varieties since the previous season we considered three ripening stages (minimum acceptable, green mature, and fully ripe).

For example, for skin color in ‘Ataulfo’ harvested in Nayarit, no significant differences were detected for any of the samplings while for fruit harvested in Sinaloa, statistical differences were found for the sampling at harvest. Fruit harvested at 1750 had lower green skin color (-5.4) whereas those harvested at 1600 HU showed average values of -11.2.

With relation to weight loss, practically no significant differences were detected for any of the varieties between ripening degrees except for the sampling at consumption where green mature fruit had higher weight loss than fully ripe fruit (12% for green mature and 10% for fully ripe).

In relation to pulp firmness, a similar situation was observed for all varieties, except ‘Kent’, where at harvest green mature fruit were firmer than fully ripe fruit.

With respect to pulp color, this was the variable of higher significance, where in general at consumption, fully ripe fruit were more colorful than green mature ones. The exception was for ‘Keitt’, fruit harvested in Sinaloa at 2200 HU at consumption showed higher pulp color intensity than those harvested at 2400 HU. The reason for this behavior (opposite to expected) may be because there were heavy rain between both harvest stages. It is known that when we have rain or irrigation very close to harvest, the TSS (°Bx) decrease and pulp color move back slightly. For this reason it is advisable to delay harvest for at least 24 h after a heavy rain or if you have irrigation, to stop it at least one week before harvest.

In relation to TSS content, no significant differences were detected between ripening stages in ‘Ataulfo’ or ‘Kent’, but for ‘Tommy Atkins’ and ‘Keitt’ fruit harvested at fully ripe stage were sweeter than those harvested at green mature stage.

With respect to acidity, significant differences were found for ‘Ataulfo’ fruit harvested in Nayarit being more acid those harvested at green mature stage. However, significant differences were found for ‘Tommy Atkins’ fruit for both ripening stages at the beginning and at the end of refrigeration. Fruit harvested at green mature stage were more acid than those harvested at fully ripe stage. In addition, no significant differences were detected for ‘Kent’ neither between locations nor ripening degrees. Finally, in ‘Keitt’ fruit an apparent contradiction was observed at consumption since fully ripe fruit were more acid than green mature. As commented previously, heavy rain between both harvesting stages caused a regression of maturity degree.

Finally, for the ratio Bx/Acidity, the expected differences were only observed for ‘Ataulfo’ fruit harvested in Nayarit, where fully ripe fruit harvested at 1750 HU showed better ratio than those harvested at 1600 HU. No significant differences for this variable for both ripening degrees were observed in ‘Tommy Atkins’ or ‘Kent’, whereas the results for ‘Keitt’ were opposite to expected because of heavy rain between harvest of both ripening stages.

CONCLUSIONS

- DM was proportional to the increase of accumulated HU at harvest.
- The higher the DM content, the fruit quality (skin and pulp color, TSS, acidity, and ratio Bx/Acidity) was positively influenced.
- With the modification to the unique Model using the Artificial Neural Networks methodology altogether with accumulated HU, it was possible to better predict nondestructively the optimum harvest time compared to the traditional method based on pulp color and TSS content destroying the fruit.

Presentations in support of the NMB extension program

2020

1. APEM. XIX International Congress of Peruvian Mango. November 5-6. Zoom conference. “Protocol for best practices in orchard and packinghouse for getting the best quality mango fruit”.
2. Workshop Course on the Best Practices for Exporting Mango. December 4. Taught to Cultivares team in face-to-face way with 9 h of duration.

2021

1. Workshop Course on the Best Practices for Exporting Mango. Guatemala. March 18. Zoom conference.
2. Workshop Course on the Best Practices for Exporting Mango. Tapachula, Chiapas. May 3 to 7. Zoom conference.
3. Workshop Course on the Best Practices for Exporting Mango. Tepic, Nayarit. Technological University. May 12. Zoom conference.
4. Workshop Course on the Best Practices for Exporting Mango. Ixtapa de la Concepción, Nayarit. Vegetales Nacionales Team. May 20. Zoom conference.
5. Expo Mango. “Harvest and Postharvest of Exporting Mango. Festival of Dominican mango. June 15. Zoom conference.
6. ASHS Annual Meeting. “Building a Unique Model for Exporting Mango Varieties Grown in Mexico”. Denver, CO. August 6. In Person.

7. APEM. “Determination of Ripening Degree at Harvest, Shipping Temperature and shipping days for Ready to Eat Mango. Peru. August 19. Zoom conference.

Field Demonstrations:

1. Validation of Techniques to Determine Optimum Harvest Time in Exporting Mango Varieties. Sauta, Nayarit. July 19, 2021.
2. Validation of Techniques to Determine Optimum Harvest Time in Exporting Mango Varieties. El Rosario, Sinaloa. July 28, 2021.

Scientific Articles or Abstracts

1. Scientific Article. Journal of Advances in Agriculture 12:61-69. “Novel Nondestructive Technique to Determine Optimum Harvesting Stage of ‘Ataúlfo’ Mango Fruit. 2021. Jorge A. Osuna-García, Jesús Daniel Olivares-Figueroa, Peter M.A. Toivonen, Ma. Hilda Pérez Barraza, Ricardo Goenaga and María J. Graciano-Cristóbal.

2. Abstract in the Annual Meeting of the American Society for Horticultural Science 2021. “Building a Unique Model for Exporting Mango Varieties Grown in Mexico”. Jorge A. Osuna-Garcia*, Brian Schultz, CID Bio-Science Inc., Eric Munoz, CID Bio-Science Inc. and Ricardo Goenaga, ARS-USDA.

Professional Assistance (Thesis)

1. **“**Acumulación de materia seca durante el crecimiento, desarrollo y maduración del fruto de mango de la variedad Ataulfo”. 2020. Técnico Superior Universitario en Procesos Alimentarios. Clarissa González Bañuelos. UT de la Costa.
2. **“**Acumulación de materia seca durante el crecimiento, desarrollo y maduración del fruto de mango de la variedad Tommy Atkins”. 2020. Técnico Superior Universitario en Procesos Alimentarios. Julia Esmeralda López Sánchez. UT de la Costa.
3. **“**Acumulación de materia seca durante el crecimiento, desarrollo y maduración del fruto de mango de la variedad Kent”. 2020. Técnico Superior Universitario en Procesos Alimentarios. María de Jesús Soto Ayala. UT de la Costa.

4. “Validación de técnicas para determinar momento óptimo de cosecha en la variedad Ataulfo para exportación cultivada en Nayarit”. 2021. Técnico Superior Universitario en Procesos Alimentarios. Litzy Méndez Bañuelos. UT de la Costa.
5. “Validación de técnicas para determinar momento óptimo de cosecha en la variedad Ataulfo para exportación cultivada en Nayarit”. 2021. Técnico Superior Universitario en Procesos Alimentarios. Stephanie Nicole Cruz Solís. UT de la Costa.

Generation of Technologies

1. “The Accumulated Heat Units and Dry Matter Content as Ripening Indicators for Harvest”. 2021. The technology consists of using altogether the Accumulated Heat Units technique starting at full blooming and using base temperature of 10 °C, as well as, the Dry Matter content attained nondestructively with a portable spectrometer (F-751®), getting more confidence than the traditional destructive method based on pulp color and total soluble solids content (°Bx).

ANEXXES

I. NAYARIT

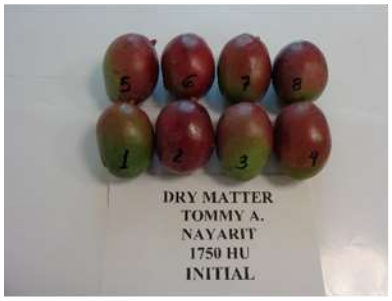
1. ATAULFO: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

1600 HU

1750 HU

2. TOMMY ATKINS: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

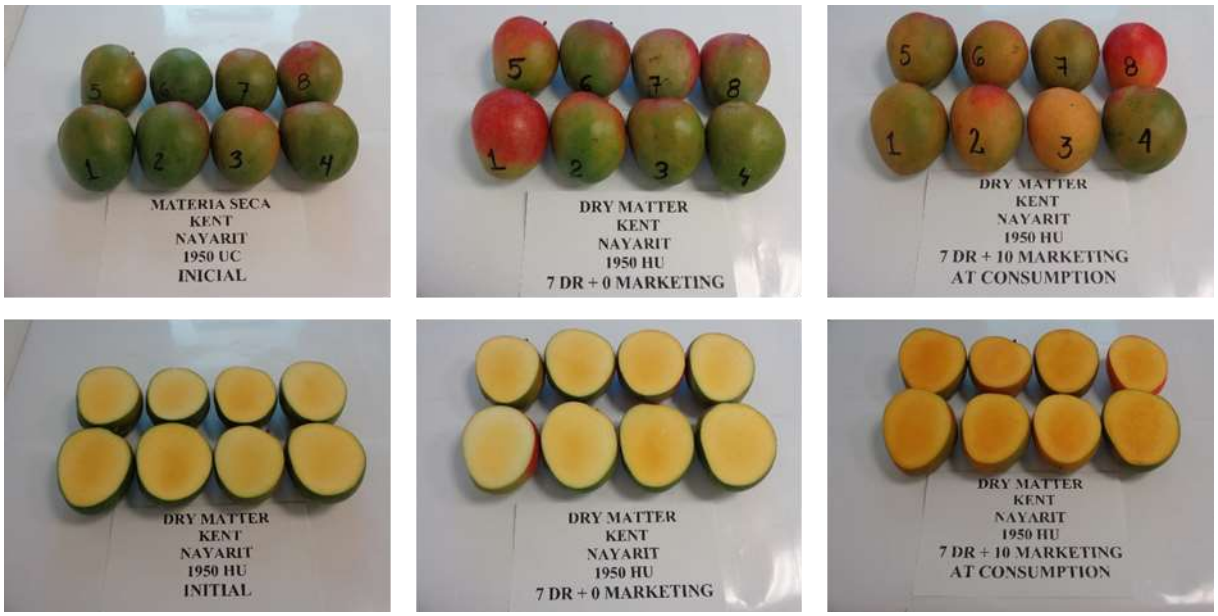
1600 HU



1750 HU

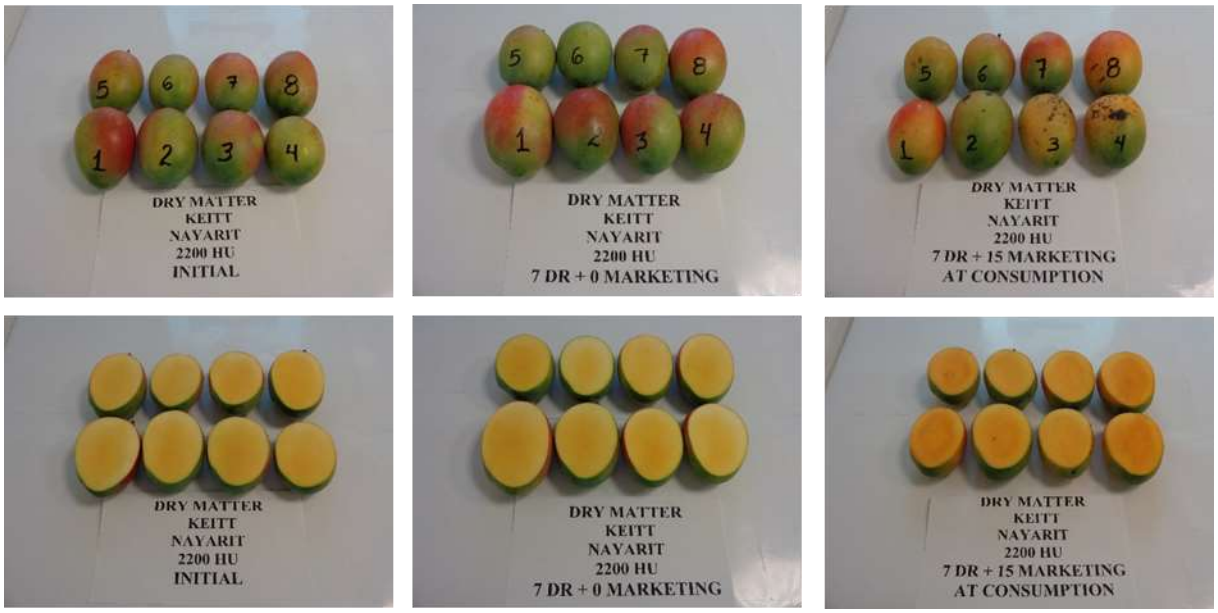
3. KENT: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

1800 HU



1950 HU

4. KEITT: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.



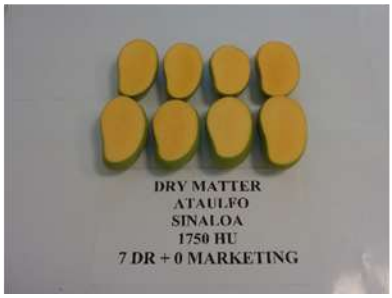
2200 HU

2400 HU

II. SINALOA

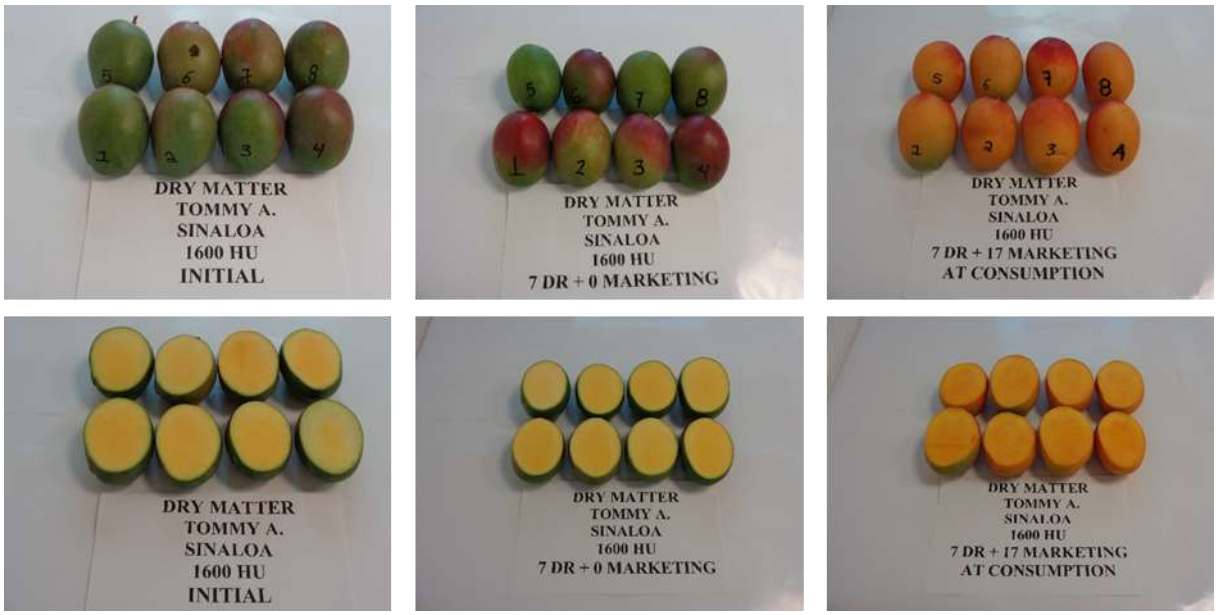
1. ATAULFO: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

1600 HU

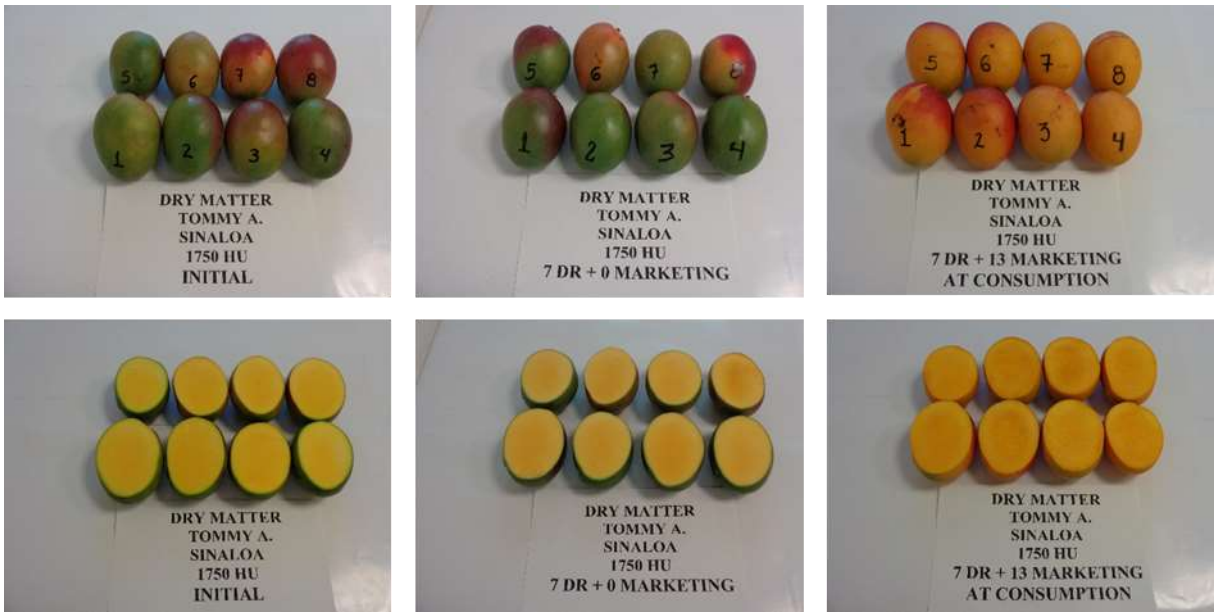


1750 HU

2. TOMMY ATKINS: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.



1600 HU



1750 HU

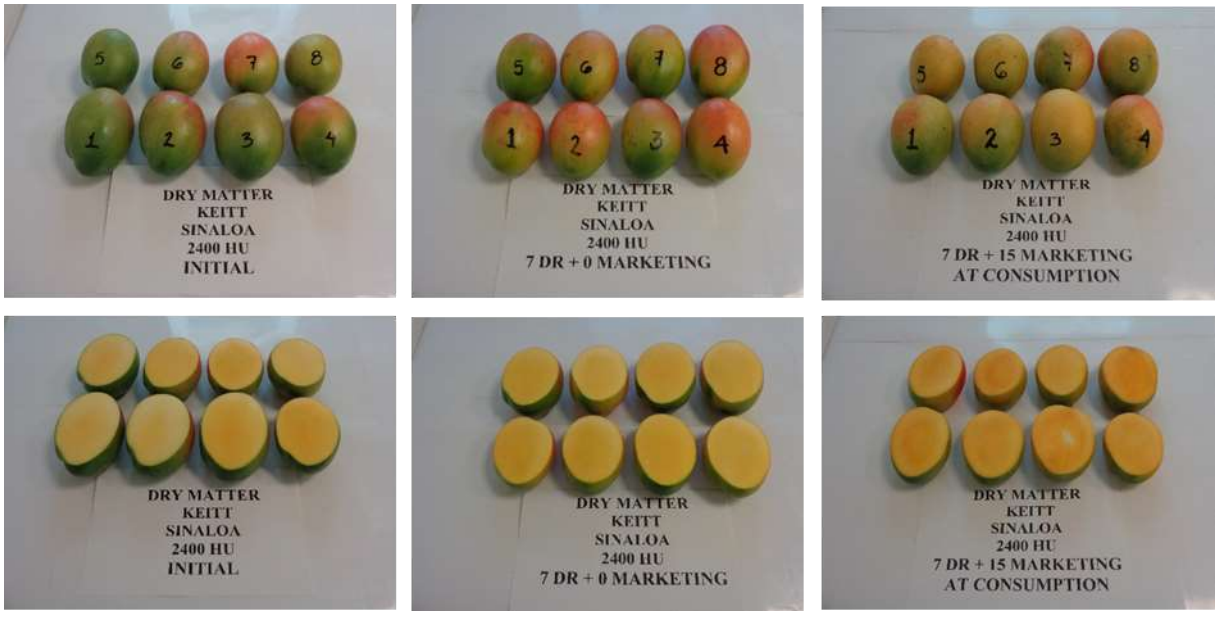
3. KENT: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

1800 HU

1950 HU

4. KEITT: EXTERNAL AND INTERNAL APPEARANCE OF FRUIT QUALITY AT HARVEST, AT THE END OF SEVEN DAYS OF REFRIGERATED SHIPPING AND AT CONSUMPTION ACCORDING TO DIFFERENT ACCUMULATED HEAT UNITS.

2200 HU



2400 HU