Understanding the Role of the Physiological Maturity and Shipping Conditions on Mango Arrival Quality

Manuel Báez, Gayle M. Crisosto, Rosalba Contreras, Katherine Wilkins, and Carlos H. Crisosto

Centro de Investigación en Alimentación y Desarrollo, A.C. Unidad Culiacán
Laboratorio de Fisiología y Calidad Poscosecha
Carretera a Eldorado Km. 5.5, Culiacán, Sinaloa, México
manuel.baez@ciad.edu.mx

Department of Plant Sciences
Davis, CA 95616
University of California, Davis
chcrisosto@ucdavis.edu

CONCLUSIONS

- Maturity stage and shipping temperature limits transportation distance because mangos will arrive with firmness ≤ 5 pounds, thus, these soft mangos can be physically damaged during handling at receiving and/or shorten shelf life. In general, mangos harvested at NMB 3 or higher and transported at temperatures above 8°C will arrive with firmness below 5 pounds after 24-30 days of transit.
- The surface damage measured during these storage studies developed fast (within 10 days) during storage suggesting that these symptoms were not related to storage temperature and/or maturity at harvest.
- Maturity and storage temperature affected the onset and intensity of internal damage and this relationship is specific to cultivar and maturity. In general, low maturity and low temperature trigger early onset and intensity of symptoms.
- Harvested mangos consume oxygen (O_2) and produce carbon dioxide. During this 30 day period, mangos under medium and very high venting did not modify O_2 concentrations in the container.
- O_2 was reduced to concentrations ≤ 5.0% in the no venting treatment predicting potential 'off flavor' development.
- The trained panel detected 'off flavor' in fruit from all no venting treatment combinations (cultivars, maturity, temperature) except for 'Tommy Atkins' harvested at NMB 3&4 held at 8°C. The onset and intensity of 'off flavor' perception varies according to cultivars, maturity, and temperature. For example, 'Keitt' mangos only developed 'off flavor' by 20 days on mangos harvested at NMB 3&4 and stored at 12.5ºC with no venting.
- In our studies, all mango cultivars lost water in the same way; weight loss was mainly dependent on temperature and venting treatments. In general, weight loss followed a plateau shaped curve; weight loss was rapid reaching high values by 20 days and showing a steady low increase during the last 10 days in storage.
- High rates of weight loss (~4.0%) were measured on mangos at the end of the storage period, regardless of cultivar when stored at 10 and 12.5°C with the very high venting treatment.

- A significant influence of maturity stage on weight loss was detected only at 20 days, any potential effect disappeared later during storage. In general, mangos at NMB 3&4 lost more water than mangos at NMB 2.
- Avoid no venting and very high venting settings is recommended for mangos.
- Mango temperature was steady during two tested trips, keeping very close to the set temperature.
- Relative humidity was steady during two tested trips, it increased from ~35% to 85% immediately at the beginning of the trip (low temperature) and stayed at this high level during the entire trip until the container was opened.
- As mango temperature variability in the pallets and in the containers was not detected, container loading protocols to improve air flow for specific containers do not need to be developed. However, an educational program on the successful current loading and transportation protocol should be continued.
- Current shipping conditions do not protect mangos to successfully reach long distance markets. To avoid cold temperature damage during transportation and assure consumer quality, high quality hot water treated (HWT) mangos should be transported at ≥10-12.5°C. However, mango softening may become a problem during handling at destination. Therefore, we propose to develop the ideal controlled atmosphere (CA) recipe for mature and over-mature HWT mangos, then, validate the protocol using commercial shipments from cooperators.

Keywords: *container environmental conditions, cultivar, Da-meter, chilling injury, shipping temperature, off flavor, air exchange, arrival consumer quality.*

Acknowledgments. We would like to thank Agroproducto Diazteca S.A. De C.V. (Mazatlan, Sinaloa) for their mango fruit donations and good advice during the development of this study.

This study was a follow up of our previous work supported by the National Mango Board (NMB) that will generate new knowledge that will keep assuring the successful development of the 'ready to eat' mango program in the USA. During this season's work, we demonstrated the ability to successfully measure flesh color nondestructively on mangos prior to and after harvesting. As flesh color is the best indicator of mango physiological maturity, this new and unique near infrared (NIR) nondestructive technology will allow us to remove maturity variability in the fruit population that interferes with understanding the role of maturity on postharvest quality. Improving understanding of the physiological basis of the role of maturity and postharvest fruit quality will help to understand losses during postharvest life and marketing. This nondestructive sensor can be used reliably to segregate mangos according to harvest physiological maturity to study the role of maturity on mango quality, postharvest life limitations (chilling injury) and storage requirements. In addition to this information, we will be able to describe the dynamics of orchard maturity changes that can be useful to understand orchard manipulations.

ORCHARD MATURITY EFFECT ON ARRIVAL CONSUMER QUALITY AND POSTHARVEST LIFE (COLD STORAGE DISORDERS).

‘Tommy Atkins’, ‘Kent’ and ‘Ataulfo’ mangos grown in Mexico (with hot water treatment) were segregated according to mango maturity (flesh color) into one to three maturity stages (NMB 2, 3 and 4) within the commercial sampled population (Figure 1) using the Da-meter. Three maturity stages were found in ‘Tommy Atkins’ and only two stages in ‘Kent’, and ‘Ataulfo’. Mangos at two or three maturity stages were stored at three storage temperatures (8.0°C, 10.0°C and 12.5°C) which were selected according to new chilling injury temperature-cultivar information (NMB, 2014).

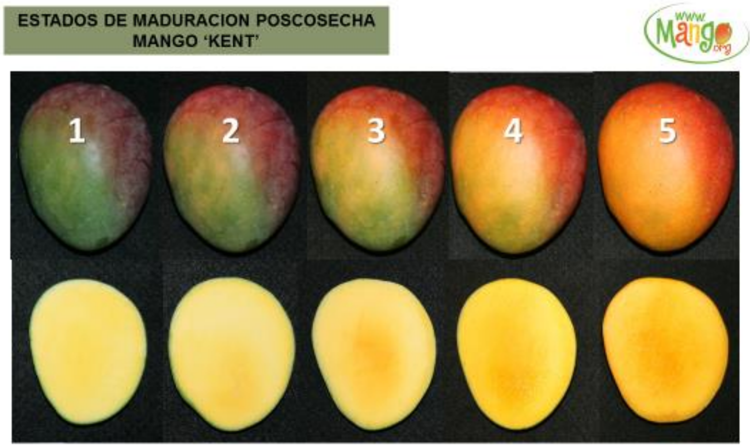


Figure 1. National Mango Board (NMB) mango maturity index based on skin and flesh color for Ataulfo, Tommy Atkins, and Kent cultivars according to Baez, 2016.

Ripe mango quality was evaluated after 10, 17, and 30 days cold storage followed by exposure to 20ºC until fruit reached the 'ready to eat stage' (~2-4 pounds). Visual defects, skin and flesh color, SSC, TA, DM, firmness, 'off flavor', physiological disorders, and chilling injury symptoms were evaluated.

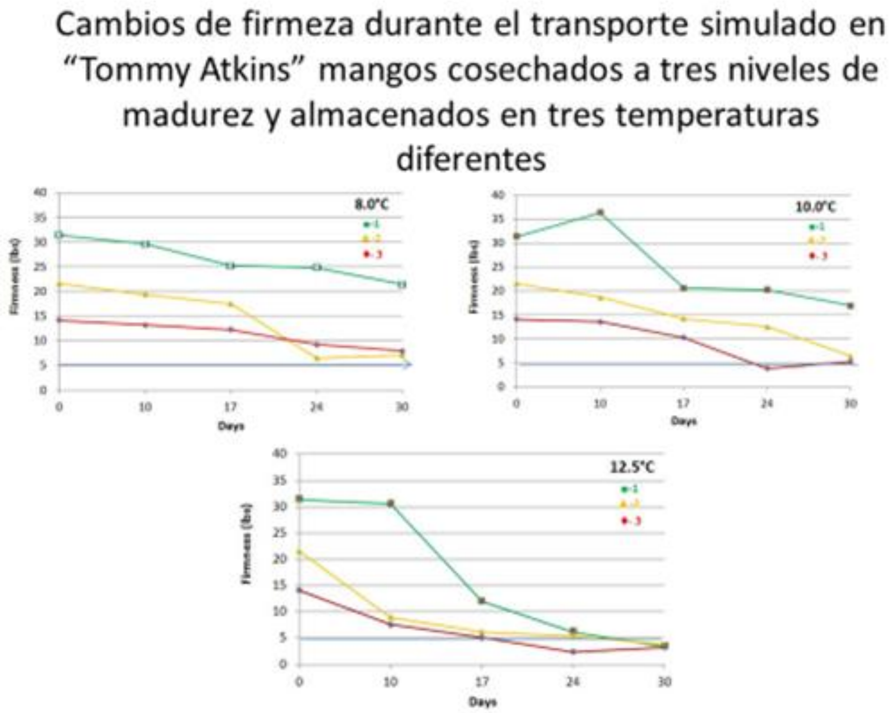
	
Surface and external damage observed in mangos during storage.	Internal damage observed in mangos during storage.

Figure 2. Surface and internal mango damage.

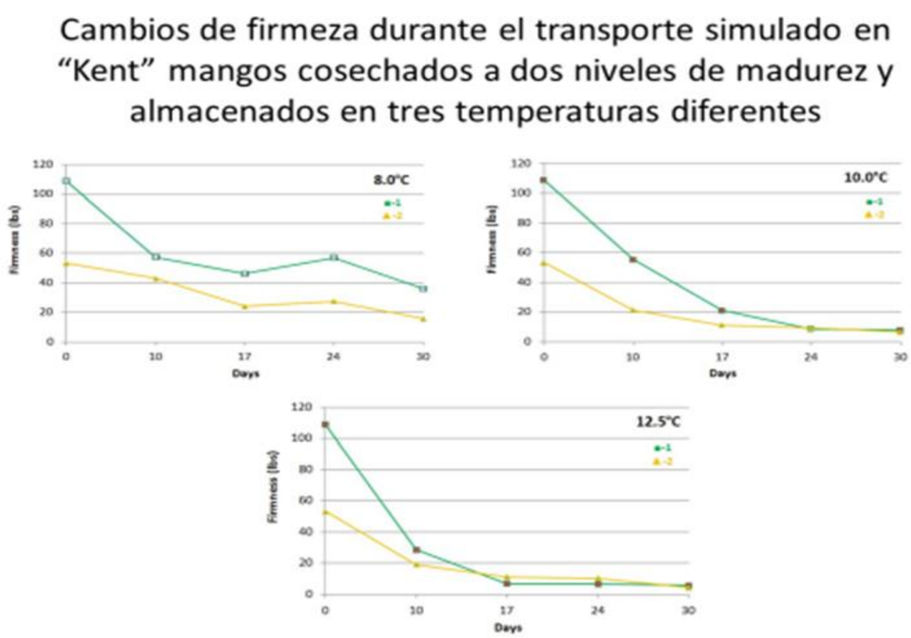
Table 1. Surface damage observed in 'Kent' mangos harvested at two maturities during 30 days storage at 8, 10, and 12.5°C.

Storage (Days)	Surface Damage (%)					
	8°C		10°C		12.5°C	
	NMB 2	NMB 3&4	NMB 2	NMB 3&4	NMB 2	NMB 3&4
0	0.0	0.0	0.0	0.0	0.0	0.0
10	43.0	50.0	50.0	50.0	50.0	50.0
17	50.0	50.0	50.0	50.0	50.0	50.0
24	50.0	50.0	50.0	50.0	50.0	50.0
30	50.0	50.0	50.0	50.0	50.0	50.0

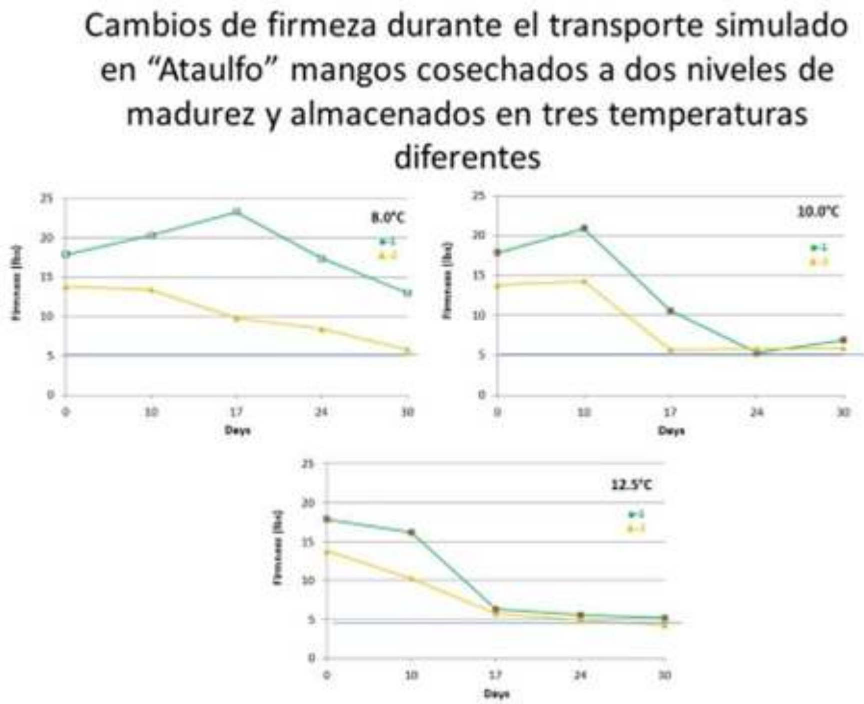
The surface damage measured during these storage studies developed fast and was observed immediately after 10 days. In fact, these symptoms (Figure 2) may have developed earlier during storage. These symptoms were not related to storage temperature and/or maturity at harvest as they reached ~50% levels across temperatures and maturity stages by 10 days after storage (Table 1). These symptoms appear to be a consequence of hot water treatment (HWT).



Firmness changes in ‘Tommy Atkins’ mangos harvested at three maturity levels and stored at three temperatures. M1=NMB 1, M2=NMB 2, and M3=NMB 3.



Firmness changes in ‘Kent’ mangos harvested at two maturity levels and stored at three temperatures. M1=NMB 2 and M2=NMB 3.



Firmness changes in 'Ataulfo' mangos harvested at two maturity levels and stored at three temperatures. M1=NMB 2 and M2=NMB 3.

Figure 3. Firmness changes in mangos harvested at different maturity levels and stored at three temperatures.

Table 2. Number of days for 'Ataulfo' and 'Tommy Atkins' mangos harvested at different maturity stages and stored at three temperatures to reach firmness ≤ 5 pounds.

Cultivar	NMB Maturity Stage	Storage Temperature		
		12.5°C	**10.0°C**	**8.0°C**
Ataulfo	NMB 2	17 days	24 days	Not observed within this period
	NMB 3	17 days	24 days	30 days
Tommy Atkins	NMB 1	28 days	Not observed within this period	Not observed within this period
	NMB 2	19 days	30 days	30 days
	NMB 3	17 days	24 days	30 days

The rate of softening was related to maturity and storage temperature depending on the cultivar. We used the firmness ≤ 5 pounds as a minimum firmness tolerance based on our previous bruising test. Mangos softer than 5 pounds may be subjected to mechanical damage during receiving-retail handling. Using this ≤ 5 pounds threshold, ‘Tommy Atkins’ mangos at NMB 1 did not soften to ≤ 5 pounds when stored at 10 or 8ºC within this storage period, while those stored at 12.5ºC reached this threshold after 28 days (Table 2). The time to reach this firmness threshold varied for ‘Tommy Atkins’ mangos at NMB 2 and 3 from 19 days to 30 days based on maturity stage and temperature (Figure 3).

‘Kent’ and ‘Ataulfo’ had similar softening rates affected by maturity and storage temperature (Figure 3). These mangos harvested at NMB 2 and 3 softened below the 5 pounds threshold at the same time; 17 days at 12.5ºC and 24 days at 10ºC. While it took more than 30 days at 8ºC storage for ‘Ataulfo’ mangos to reach the 5 pounds threshold (Table 2).

Maturity and storage temperature affected the onset and intensity of internal damage (Fig. 2). ‘Ataulfo’ mangos harvested at low maturity, NMB 2, showed the first internal symptoms of damage by 17 days when stored at either 8 or 10ºC, and by 24 days when stored at 12.5ºC (Table 3). ‘Ataulfo’ mangos harvested at NMB 3 behaved the same as those harvested at NMB 2, showing high damage, when stored at 8ºC. However, internal damage symptoms were not observed on ‘Ataulfo’ mangos harvested at NMB 3 and stored at 10 and 12.5ºC during the 24 days of the evaluation (Table 3). Evaluation at 30 days was not carried out because of random decay in the samples.

Table 3. Internal damage on ripe ‘Ataulfo’ mangos harvested at two maturity stages after 24 days storage at three temperatures.

Storage (Days)	**Internal Damage (%)**					
	8°C		**10°C**		**12.5°C**	
	NMB 2	NMB 3&4	NMB 2	NMB 3&4	NMB 2	NMB 3&4
0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0
17	16.7	20.0	33.3	0.0	0.0	0.0
24	75.0	88.0	100.0	0.0	33.0	0.0

Table 4. Internal damage on ripe 'Tommy Atkins' mangos harvested at three maturity stages after 30 days storage at three temperatures.

Storage (Days)	**Internal Damage (%)**								
	8°C			**10°C**			**12.5°C**		
	NMB 1	NMB 2	NMB 3	NMB 1	NMB2	NMB 3	NMB 1	NMB 2	NMB 3
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	27.0	0.0	0.0	38.0	0.0	0.0	20.0	0.0	0.0
24	38.0	11.0	17.0	36.0	6.0	11.0	25.0	20.0	14.0
30	46.0	23.0	38.0	50.0	19.0	17.0	50.0	33.0	14.0

In 'Tommy Atkins' mangos, the first symptoms of internal damage (~30%) became visible by 17 days across storage temperatures only on mangos harvested at NMB 1 (Table 4). By 24 days, 'Tommy Atkins' mangos harvested at NMB 2 and 3 behaved similarly, reaching damage levels that varied from 6.0 to 20%, while those harvested at NMB 1 had ~30% internal damage across storage temperatures. By 30 days, 'Tommy Atkins' mangos harvested at NMB 1 had approximately 50% damage across storage temperatures, while internal damage was lower for mangos harvested at NMB 2 and 3 when stored at 10 and 12.5ºC. Mangos harvested at NMB 1 had the highest internal damage symptoms compared to NMB 2&3.

Table 5. Internal storage damage of ripe Mexican ‘Kent’ mangos harvested at two physiological maturities and held at three simulated transportation storage temperatures for 30 days.

Storage (Days)	Internal Damage (%)					
	8°C		10°C		12.5°C	
	NMB 2	NMB 3&4	NMB 2	NMB 3&4	NMB 2	NMB 3&4
0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0
17	7.0	0.0	0.0	0.0	0.0	0.0
24	17.0	8.0	21.0	13.0	30.0	13.0
30	17.0	29.0	30.0	30.0	29.0	10.0

In ‘Kent’ mangos, internal damage (Fig. 2) developed by 24 days of storage showing a low incidence, except for NMB 2 at 12.5°C (Table 5). By 30 days, damage was still low and it showed no clear differences between maturity stages and storage temperatures.

MATURITY AND ENVIRONMENTAL CONTAINER REQUIREMENTS (AIR EXCHANGE AND TEMPERATURE).

Hot water treated mangos harvested in Mexico (‘Tommy Atkins’, ‘Kent’, ‘Keitt’ and ‘Ataulfo’) were used for testing the maturity as previously described by the NMB (Stage 1, 2, 3, and 4, (Fig 1) and environmental shipping conditions on arrival quality.

Air exchanges during the simulated shipments were designed for no air exchange (0 ft^3/min), medium air exchange (30 ft^3/min), and very high air exchange (60 ft^3/min). Fruit immediately at arrival to Coast Tropical in San Francisco were shipped to UC Davis Postharvest Laboratory where they were exposed to these different environmental shipping conditions for further market life potential evaluations.

In these four cultivars, we used six combinations of relative humidity and air exchanges combined with two or three maturity stages and three fruit-storage temperature (8.0ºC, 10.0ºC, & 12.5ºC) conditions. The three fruit storage temperatures per cultivar were selected based on recent chilling injury damage work supported by the NMB. Fruit quality was evaluated on ripe mangos after 10, 17, 24, and 30 days cold storage followed by exposure to 20ºC until fruit reached the ‘ready to eat stage’ (~2-4 pounds). Our trained panel measured perception of ‘off flavor’.

Table 6. Maturity and environmental shipping conditions (relative humidity, temperature and container air exchange conditions) for 'Keitt', 'Kent', 'Ataulfo', and 'Tommy Atkins' during simulated shipments under the presence of ethylene (500ppb).

	Container Venting	**NMB 2**	**NMB 3&4**
	Air Exchange (container volume/hour)		
1	No venting	40% RH	40% RH
2	Medium (1.0 time per hour)	40% RH	40% RH
3	Very High (2.0 times per hour)	40% RH	40% RH
4	No venting	90% RH	90% RH
5	Medium (1.0 time per hour)	90% RH	90% RH
6	Very High (2.0 times per hour)	90% RH	90% RH

Container Venting: air exchange treatments in a ~2,000 ft^3 container volume with fresh air consisted of: No air exchange (0 ft^3/min), Medium air exchange (30 ft^3/min=1.0 time container volume exchange per hour), and Very High air exchange (60 ft^3/min=2.0 times container volume exchange per hour).

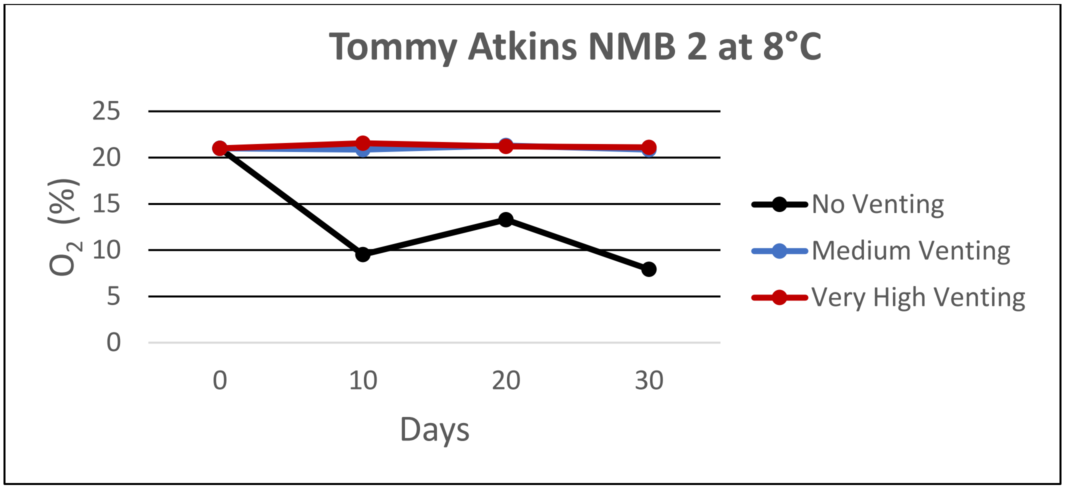
Container Atmosphere Oxygen Concentration Depletion

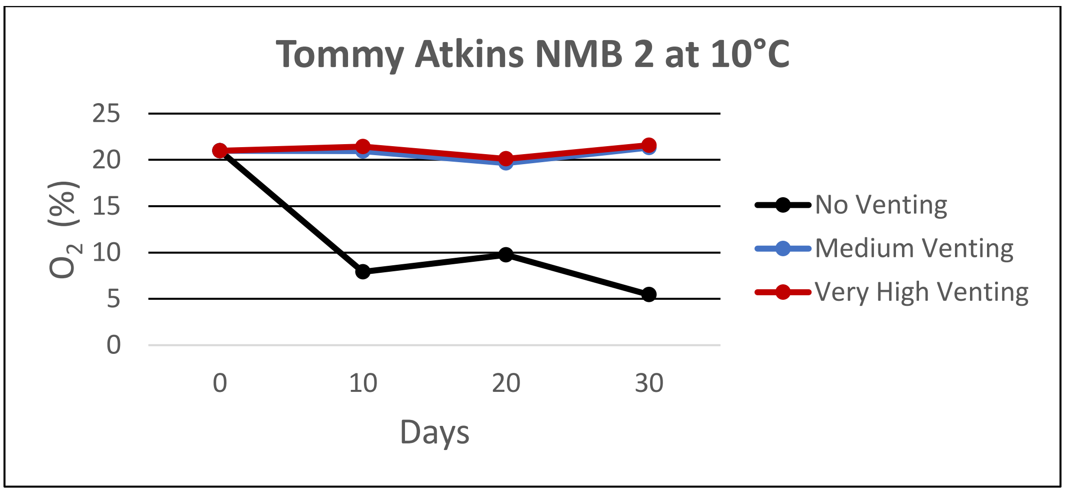
Harvested mangos consume oxygen (O_2) and produce carbon dioxide. During this 30 day period, mangos under medium and very high venting (air exchanges) did not modify O_2 concentration in the container. However, O_2 was reduced to concentrations ≤ 5.0% in the no venting treatment. This 5.0% O_2 threshold (in fruit) indicates when mango fruit will start anaerobic respiration and develop 'off flavor' which was developed in previous studies. In this work, we report the time to reach the 5.0% O_2 in the container atmosphere which varied according to cultivar, maturity and temperature. In general, 'Tommy Atkins' had the highest rate of O_2 consumption and 'Keitt' the lowest rate.

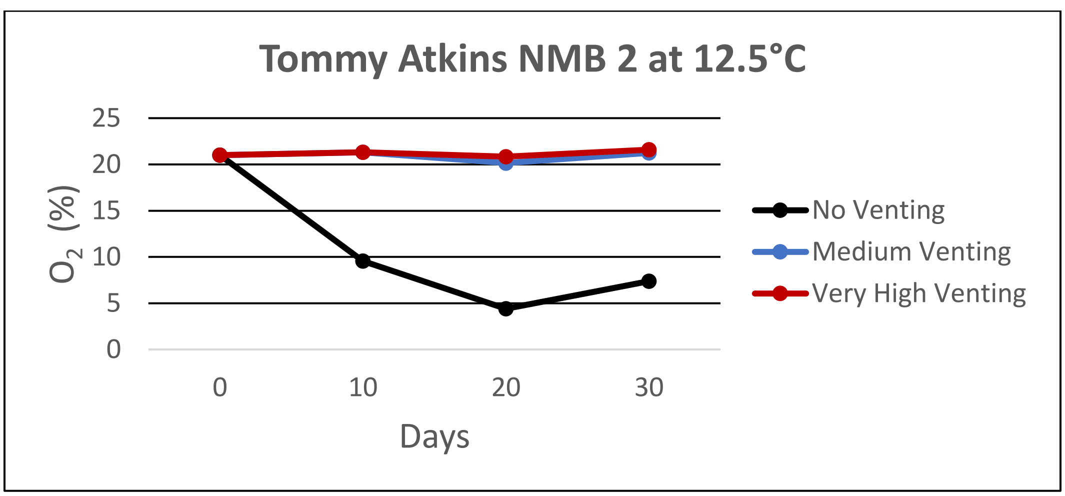
'Tommy Atkins' mangos reached O_2 concentrations below 10% by 10 days across all temperature-maturity combinations with the no venting treatment. After that O_2 concentrations decreased to near 5.0% during the rest of the study.

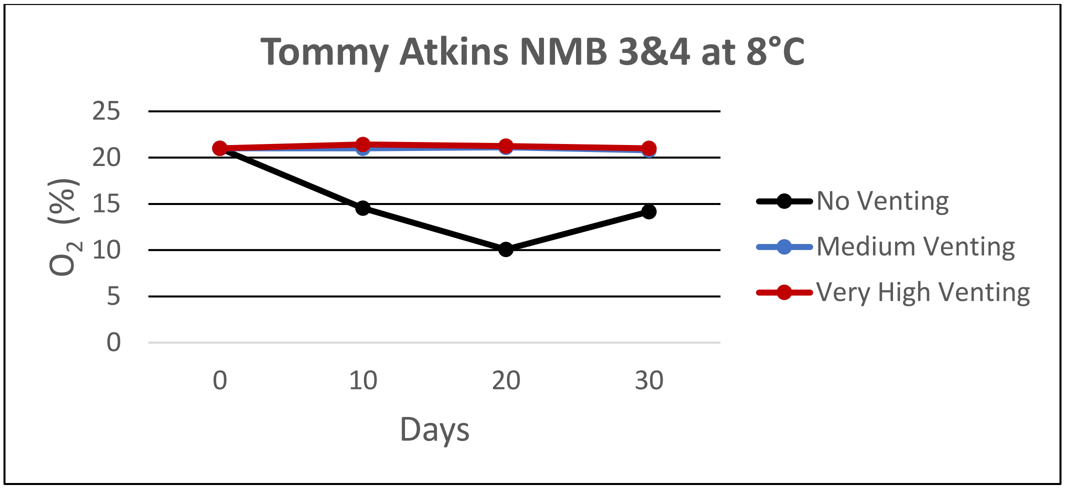
'Ataulfo' mangos harvested at NMB 2 reached the 5% O_2 threshold by 20 days when stored at 12.5ºC and by 30 days when stored at 8.0ºC with no venting. In 'Kent' harvested at NMB 2, O_2 reached 5.0% by 30 days at the two storage temperatures, while the more advanced maturity mangos (NMB 3&4) reached 5.0% O_2 by 20 days with no venting. This difference in oxygen consumption may be related to the rate of respiration and/or maturity variability within the fruit samples.

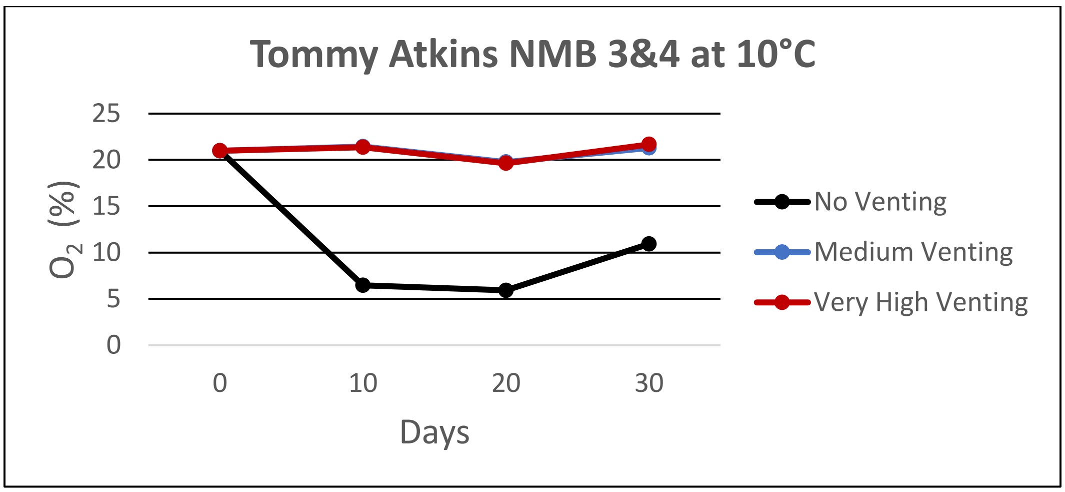
'Keitt' mangos were less susceptible to no venting than the other cultivars tested. Oxygen level was only depleted down to the 5.0% on 'Keitt' harvested at NMB 2 by 30 days when stored at 12.5ºC. Oxygen level was not strongly modified in the other treatment combinations with no venting.

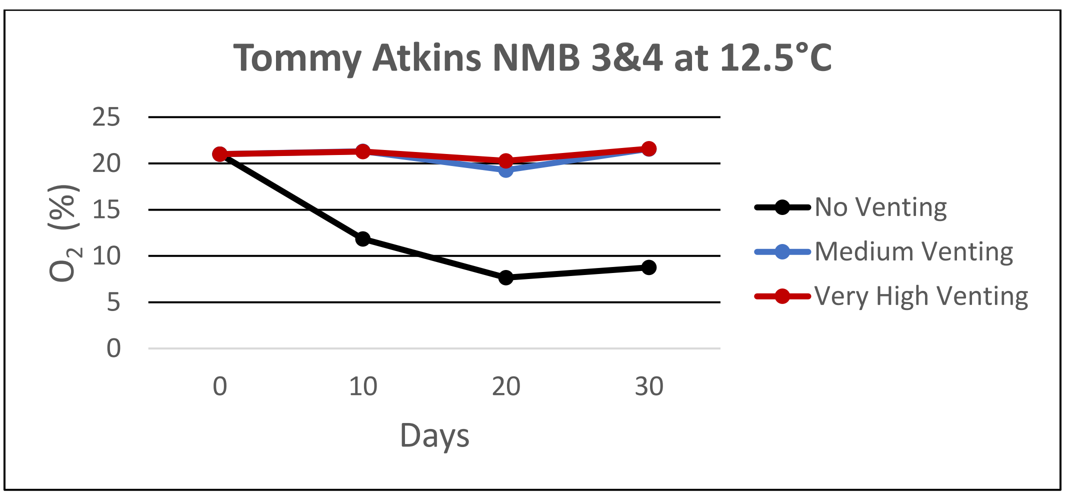

Tommy Atkins NMB 2 at 8°C
O2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

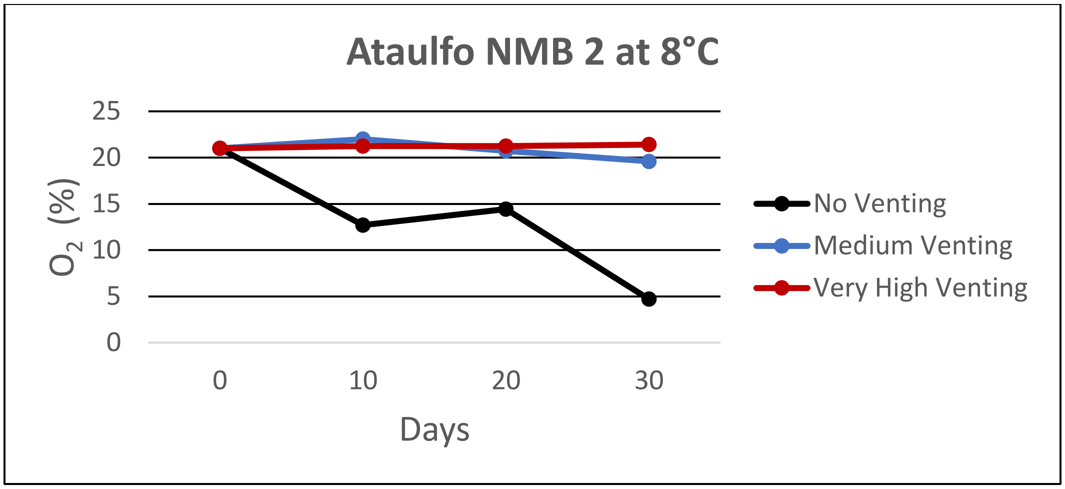

Tommy Atkins NMB 2 at 10°C
O2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

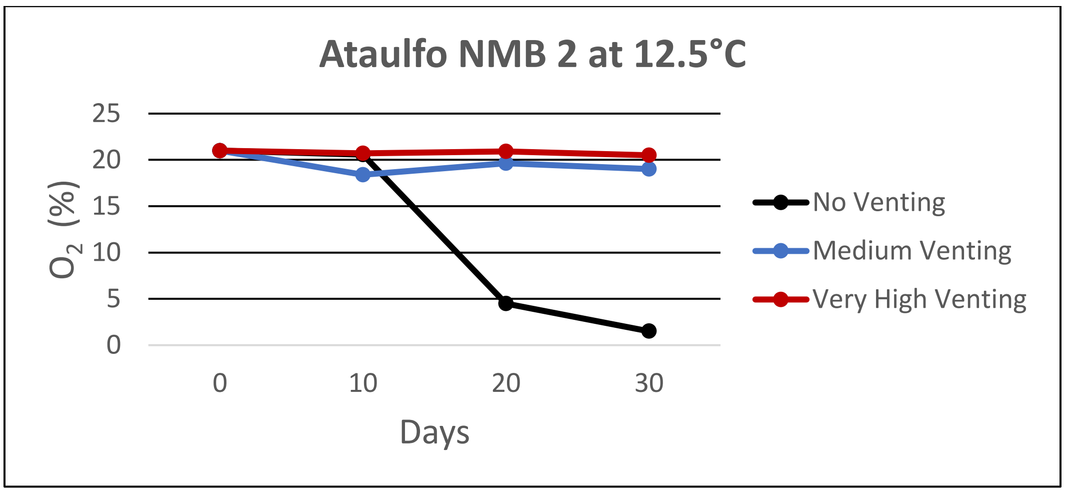

Tommy Atkins NMB 2 at 12.5°C
O2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

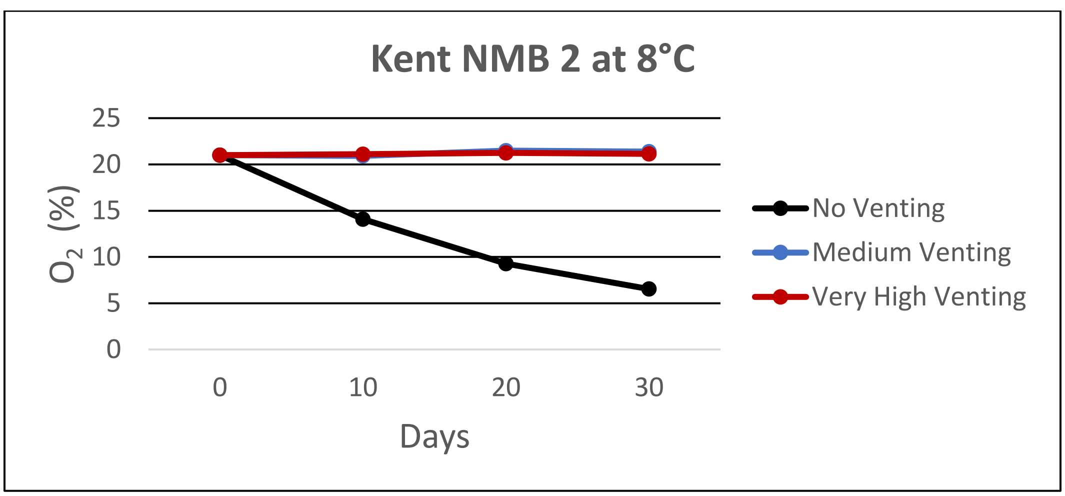

Tommy Atkins NMB 3&4 at 8°C
O_2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

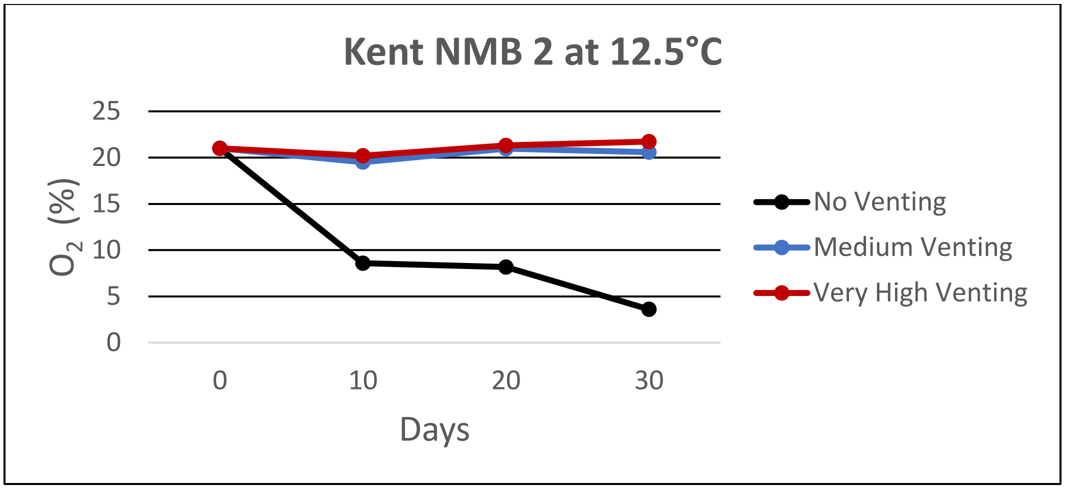

Tommy Atkins NMB 3&4 at 10°C
O_2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

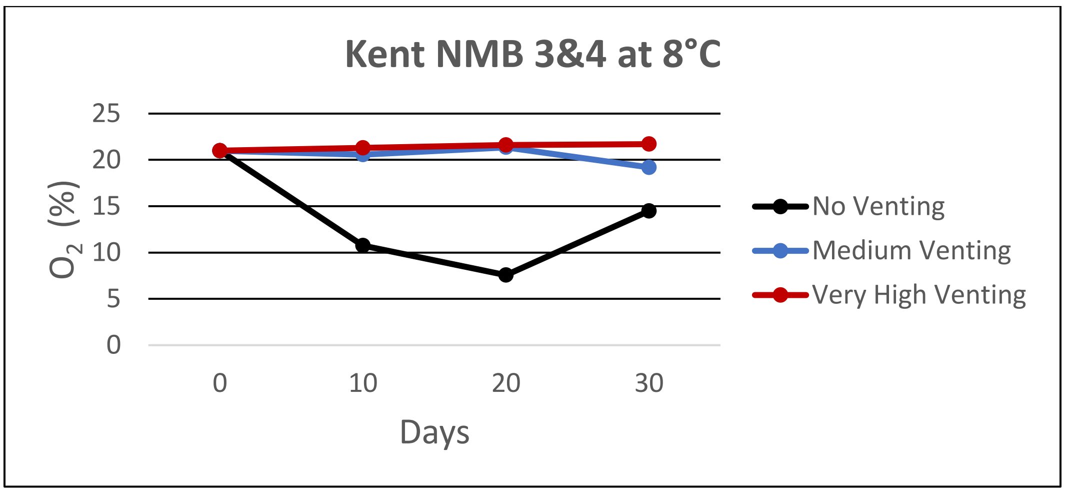

Tommy Atkins NMB 3&4 at 12.5°C
O_2 (%)
25
20
15
10
5
0
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

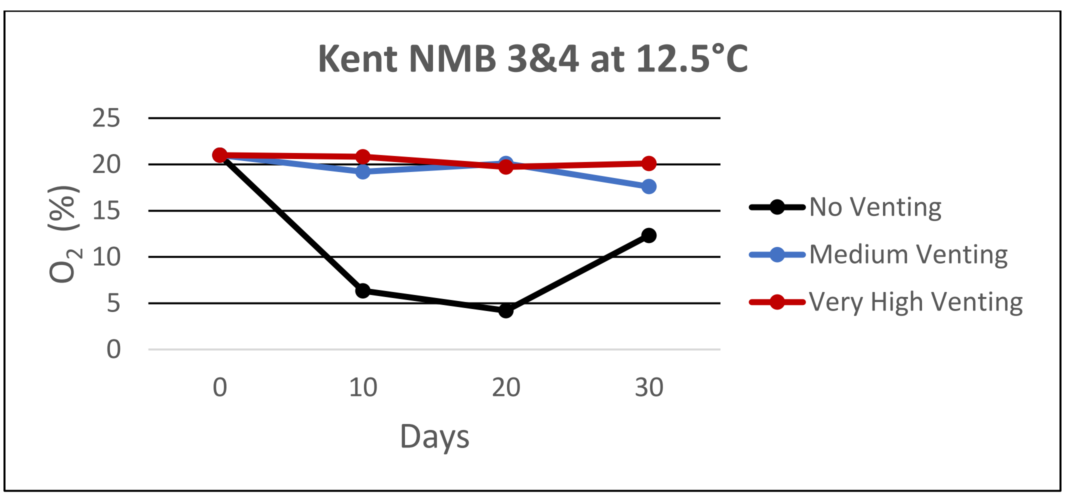

Ataulfo NMB 2 at 8°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

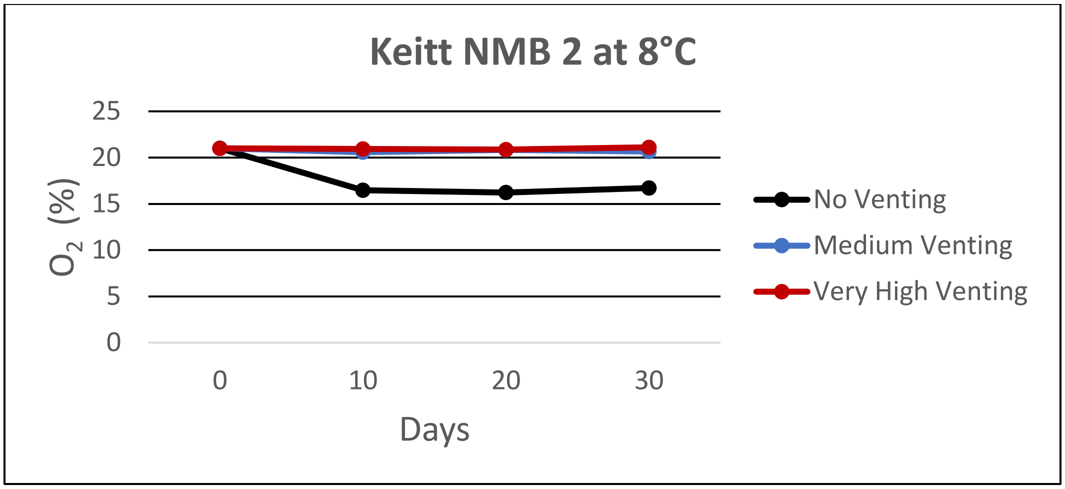

Ataulfo NMB 2 at 12.5°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

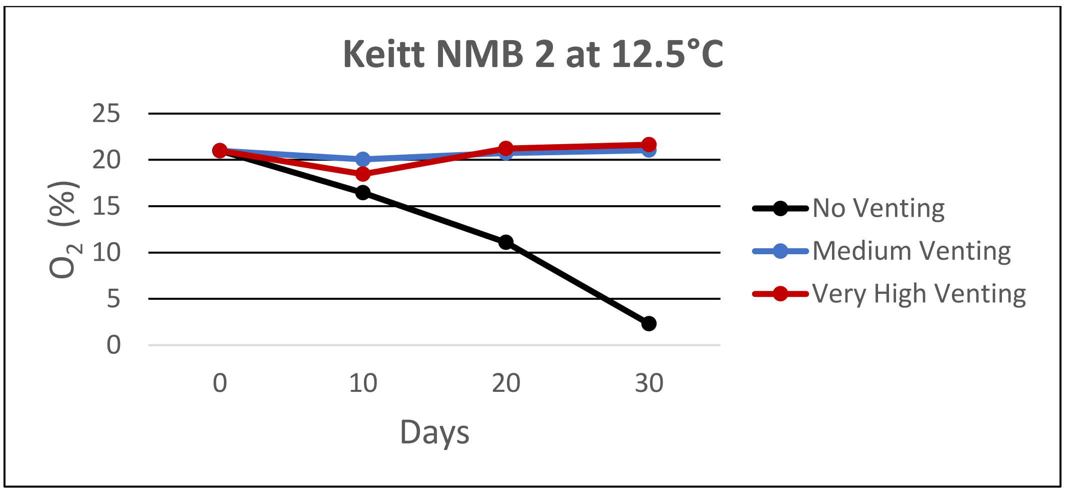

Kent NMB 2 at 8°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

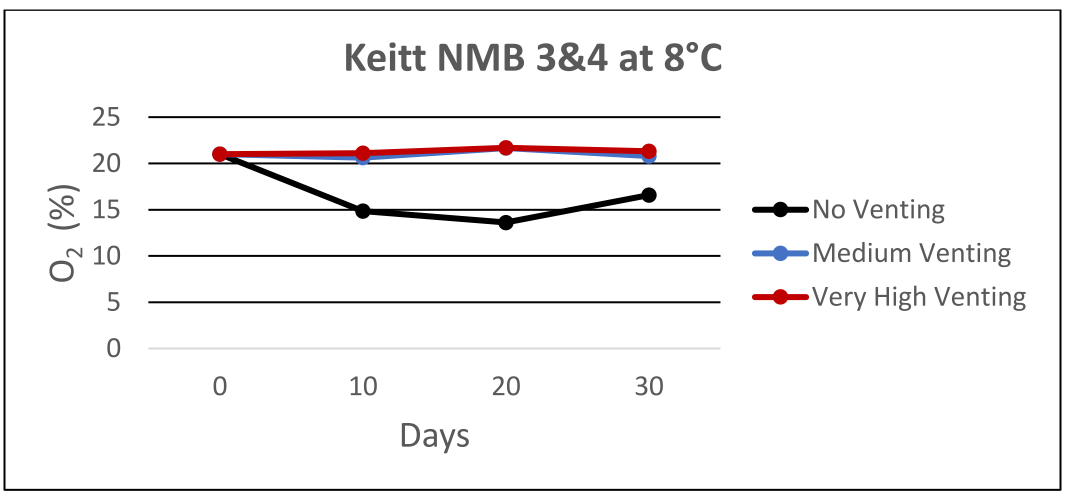

Kent NMB 2 at 12.5°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting


Kent NMB 3&4 at 8°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting


Kent NMB 3&4 at 12.5°C
25
20
15
10
5
0
O_2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting


Keitt NMB 2 at 8°C
25
20
15
10
5
0
O2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting


Keitt NMB 2 at 12.5°C
25
20
15
10
5
0
O2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting


Keitt NMB 3&4 at 8°C
25
20
15
10
5
0
O2 (%)
0
10
20
30
Days
No Venting
Medium Venting
Very High Venting

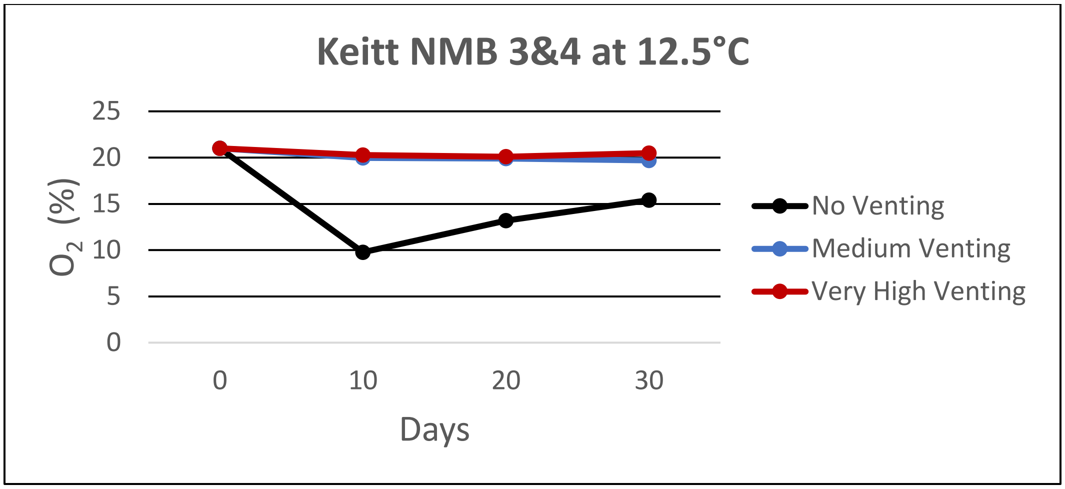


Figure 4. Oxygen concentrations measured inside containers during storage of four mango cultivars at different maturity stages under different venting and temperature conditions.

‘Off Flavor’ Perception

On Mexican mangos collected after arrival in California, the trained panel did not detect noticeable ‘off flavor’ in the medium and very high venting treatments. Although harvested mangos produce a measureable amount of ethanol-acetaldehyde (previous work) at harvest time, it does not interfere with mango flavor. Our harvest designation is not the real harvest as a few days passed and changes occurred from harvest in Sinaloa to arrival in Davis (shipping). For our work, we used as harvested fruit, fruit shipped from Mexico to San Francisco and immediately to Davis (shortest time from field to Davis).

‘Off flavor’ was detected in fruit from all no venting treatment combinations (cultivars, maturity, temperature) by 30 days (Figure 5) by the trained panel except for ‘Tommy Atkins’ harvested at NMB 3&4 held at 8°C. ‘Keitt’ mangos only developed ‘off flavor’ by 20 days on mangos harvested at NMB 3&4 and stored at 12.5ºC with no venting. ‘Ataulfo’ harvested at NMB 2 exhibited ‘off flavor’ at 10 days stored at 8°C and at 20 days at 12.5°C under no venting treatment. By 30 days for both storage temperatures very high levels of ‘off flavor’ were detected in the no venting treatment. In ‘Kent’, ‘off flavor’ developed early during storage on mangos harvested at the two maturity stages. Only on ‘Kent’ mangos harvested at the advanced maturity stage (NMB 3&4) did ‘off flavor’ development occur later during storage at 8.0ºC with no venting. ‘Off flavor’ in ‘Tommy Atkins’ mangos harvested at the NMB 2 developed rapidly after 20 days at all three storage temperatures with no venting. At 30 days, mangos stored at 10 and 12.5ºC had approximately 60% of the fruit exhibiting ‘off flavor’ and 40% on mangos stored at 8.0ºC. ‘Tommy Atkins’ mangos harvested at the more advanced maturity stage reached the same percentage of ‘off flavor’ as mangos harvested at NMB 2 at 30 days with no venting, except on mangos harvested at NMB 3&4 and stored at 8.0ºC which had no ‘off flavor’.

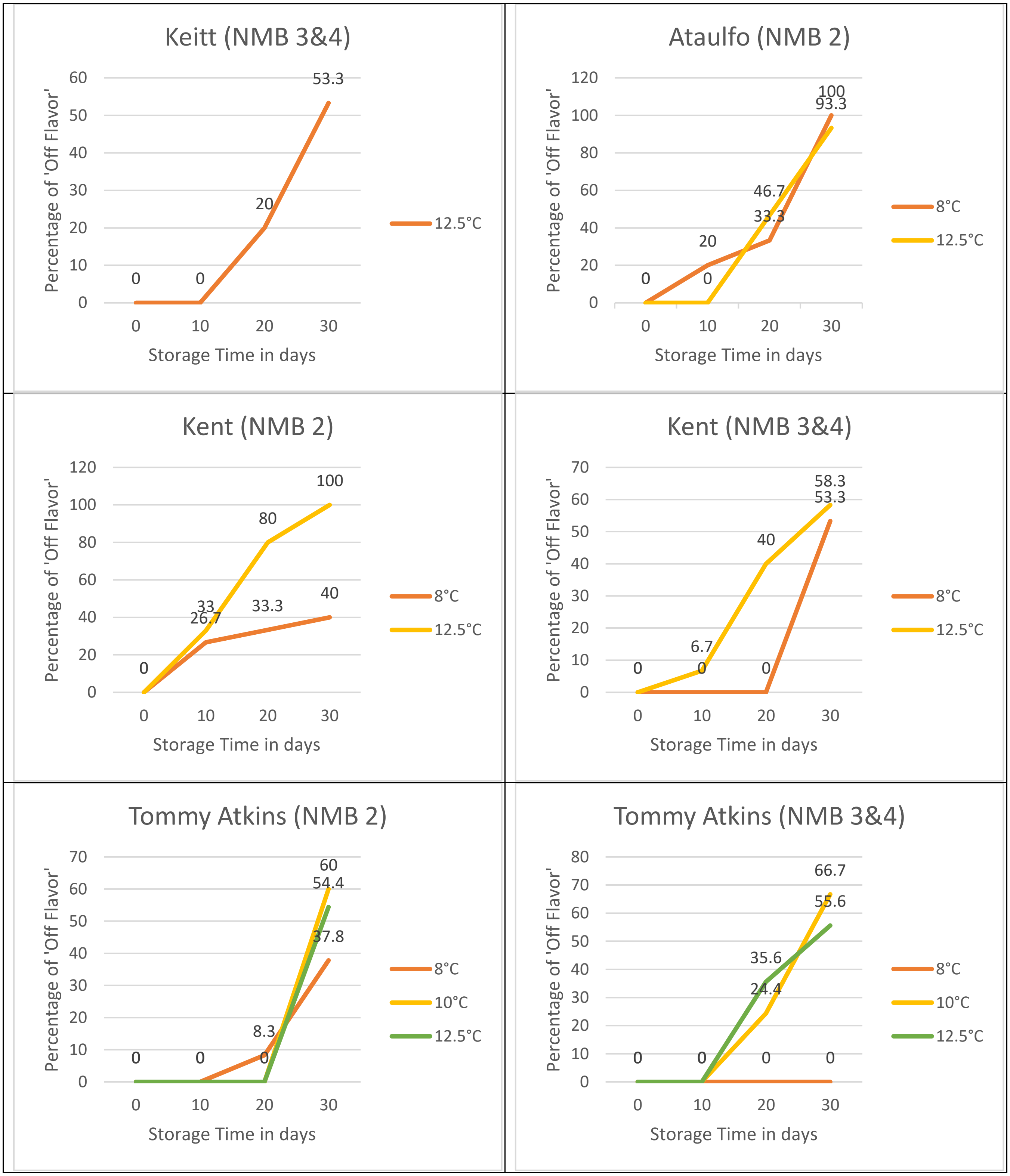


Figure 5. Percentage of 'off flavor' detected by a trained panel on mangos at different maturity stages stored under no venting and different temperature conditions. Only treatments expressing 'off flavor' are shown in this figure.

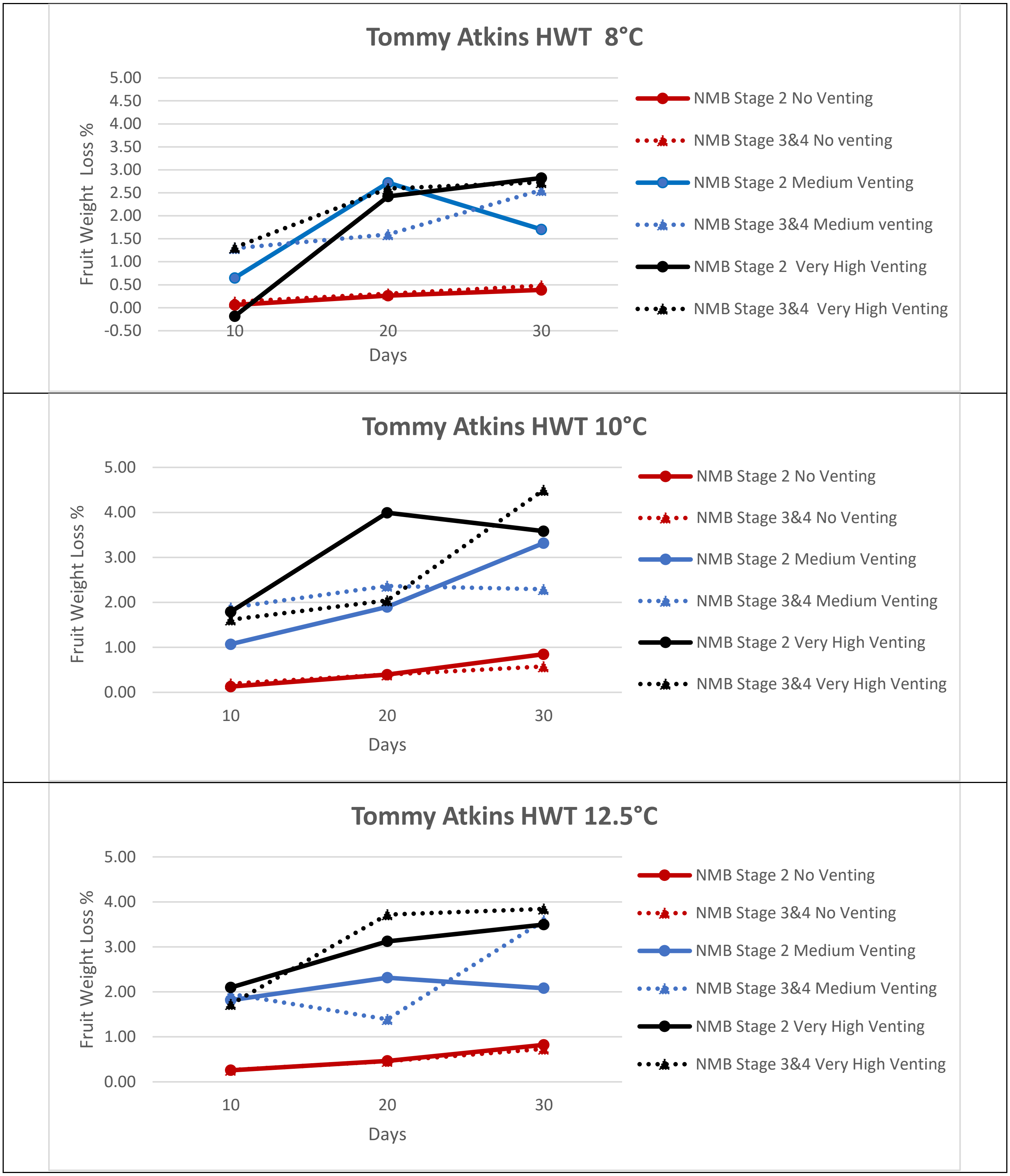


Figure 6. Weight loss on ‘Tommy Atkins’ mangos at two maturity stages stored under different venting and temperature conditions.

Weight Loss

Weight loss (WL) which is an indication of fruit water loss (dehydration); is an important quality trait as it indicates potential losses both in quantity (product weight-kilos) and cosmetic quality that can result in mango rejections (Figure 7). In similar fruit such as peaches, when fruit lose approximately 6-8% of their original weight shriveling symptoms are visible.

In our studies, all mango cultivars behaved the same way, WL was mainly dependent on temperature and venting treatments. Any potential of cultivar influence on WL was overridden by the strong temperature and venting effects. In general, WL followed a plateau shaped curve, WL was rapid reaching high values by 20 days and showing a steady low increase during the last 10 days in storage. High rates of WL (~4.0%) were measured on mangos at the end of the storage period, regardless of cultivar, when stored at 10 and 12.5°C with the very high venting.

In mangos stored at 8ºC for 30 days, very low WL (0.5%) was detected in the no venting treatment while 2.7% and 1.7% WL was measured in the very high and medium venting treatments, respectively. On mangos stored at 10ºC, WL reached approximately 0.7% in mangos under no venting, 2.7% WL for medium venting, and 4.0% WL for very high venting conditions. A similar situation occurred on mangos stored at 12.5ºC, WL reached approximately 0.8% in mangos under no venting, 2.8% WL for medium venting, and 4.0% WL for very high venting conditions. Although venting and temperature treatments had a great influence on WL, maturity also played a role at 20 days. We think that measurements at 30 days were compromised by decay and bruise development which interfered with natural weight loss. A significant influence of maturity on WL was detected only at 20 days, any potential effect disappeared later. In general, mangos at NMB 3&4 lost more water than mangos at NMB 2. For example, mangos stored at 8ºC under medium venting had a 1.0% differences (2.6 versus 1.6) between NMB 3&4 and NMB 2. While on mangos stored at 10ºC, there were differences of 2.0% and 0.6% WL on mangos under very high and medium venting conditions, respectively for these maturity stages. By the end of the storage period, there was approximately 1.0% WL differences according to maturity in mangos under the two venting treatments.

Figure 7. Mango dehydration symptoms due to water loss

SURVEY OF MANGO TEMPERATURE AND RELATIVE HUMIDITY (RH) VARIABILITY WITHIN THE CONTAINER AND IN A PALLET DURING SHIPMENT.

A survey of mango temperature variability within the container was carried out on ‘Kent’ mangos shipped from Peru to the USA led by Dr. Jeff Brecht (Center for Food Distribution & Retailing, Horticultural Sciences Department, University of Florida, Gainesville, FL). In cooperation with exporters from Peru, temperature variability during two shipments (Piura, Peru to Los Angeles and Piura to Newark) were evaluated during commercial shipment by placing pulp temperature and relative humidity data loggers inside mango boxes loaded in different positions in the container (Figure 8). Container temperature was set at 10.0ºC. In the two shipments, mango temperature was steady during the trip, keeping very close to the set temperature. The same situation occurred for the relative humidity, RH increased from ~35% to 85% immediately at the beginning of the trip (low temperature) and stayed at this high level during the entire trip until the container was opened (Figure 9).

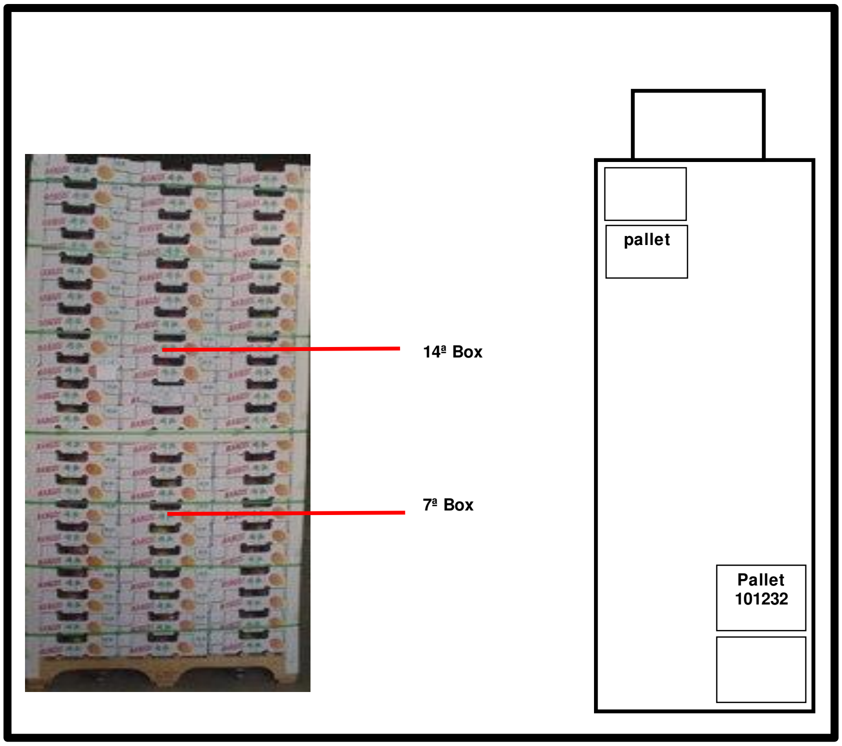
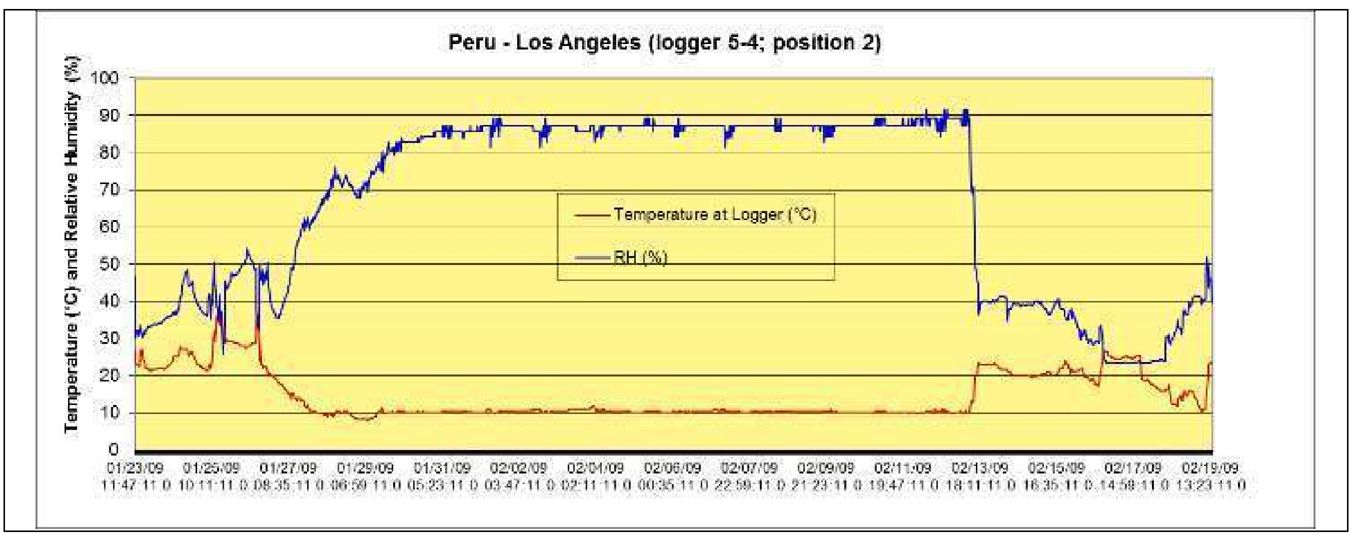
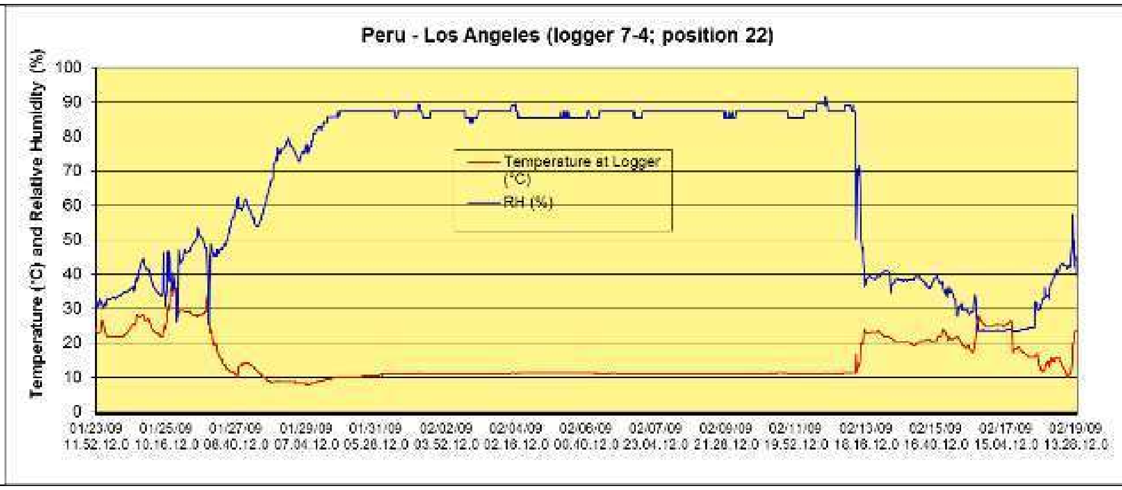
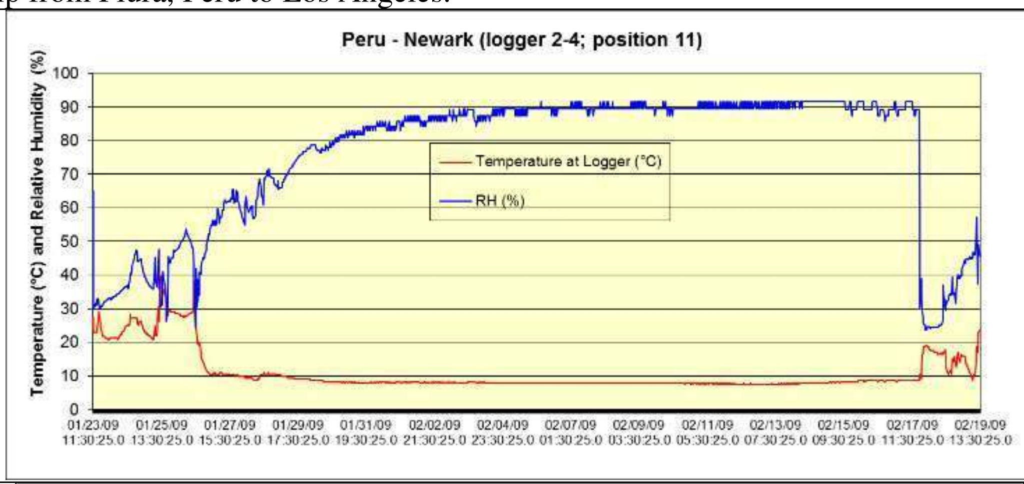


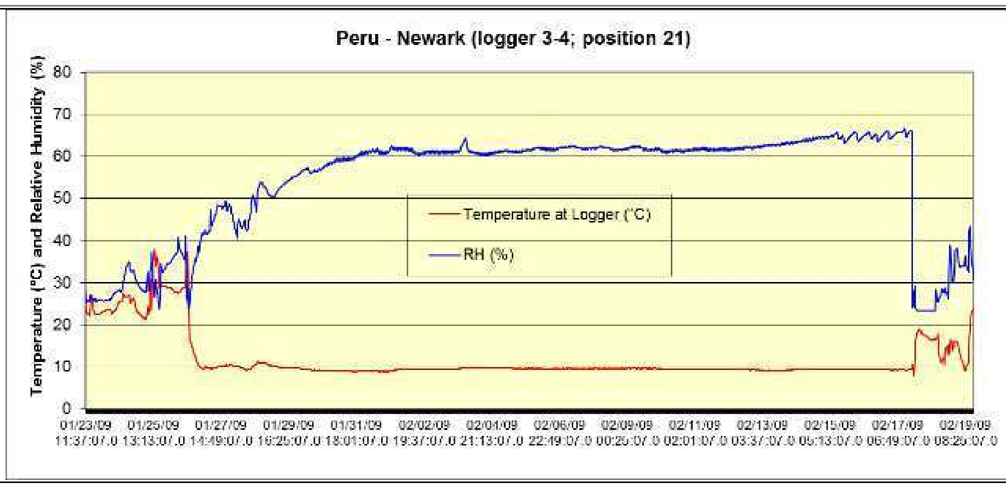
Figure 8. Temperature and relative humidity recorders placement within the container and in the pallet.





Mango temperature and RH measured at different positions within the container and in the pallet during a trip from Piura, Peru to Los Angeles.





Mango temperature and RH measured at different positions within the container and in the pallet during a trip from Piura, Peru to Newark.

Figure 9. Mango temperature and RH measured at different positions within the container and in the pallet during two trips from Piura, Peru to USA.