Final Research Report

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Demonstrating MAP Feasibility for Mango Export

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Demonstrating Modified Atmosphere Packaging (MAP) Feasibility for Mango Export

Co-Principal Investigators:

Dr. Jeffrey K. Brecht and Dr. Steven A. Sargent, University of Florida, Horticultural Sciences Dept., Gainesville, FL

Collaborators:

Dr. Nara C. Ristow, Post-doc., University of Florida, **Dr. Sergio Tonetto de Freitas, Embrapa Semiarido**, Petrolina, Brazil;
Dr. Jorge A. Osuna Garcia, INIFAP, Nayarit, Mexico;
Mr. Rich MacLeod, TransFresh Corp., Salinas, CA;
Dr. Shehbaz Singh, Apio, Inc., Guadalupe, CA

Abstract/summary of the research

This preliminary research project was conducted to demonstrate the feasibility of incorporating modified atmosphere packaging (MAP) technology with optimum O_2 and CO_2 into existing mango handling systems. This has the potential to better maintain the quality of fully mature mangos for the extended transit periods required for export from South America to consumers in the USA. Since MAP slows the onset and progression of fruit ripening it can allow shipment of fully mature mangos at higher temperatures than are currently being used. Thus, MAP can allow avoidance of low temperatures that cause chilling injury while at the same time preventing arrival problems due to soft, ripe or decayed fruit after extended shipping times at non-chilling temperatures. The result is better quality mangos in the U.S. market.

Ataulfo, Tommy Atkins and Kent mangos were packaged in either Apio Breatheway MAP bags or NOW Plastics perforated bags (control) at a commercial mango packinghouse in Narayit, Mexico. Each bag held approximately 4 kg of fruit and was placed within a standard mango shipping carton. The mangos were maintained in better quality in the MAP bags than in the perforated (control) bags in separate commercial truck shipments and temporary storage (8-13 °C) from Mexico to Florida plus additional storage (12.5 °C) in Florida totaling 3 weeks to simulate long-distance shipping from South America. Mangos in the same packaging treatments held in Mexico for 3 weeks at 12.5 °C showed similar results. This research also demonstrated in the Ataulfo shipment that MAP can prevent development of *corte negro* in mangos. We believe that these results warrant scaling up the tests in commercial shipments from South America using mangos of different harvest maturities/ripeness stages.

Introduction

Modified atmosphere packaging (MAP) is a low-tech application of controlled atmosphere (CA) storage, which has been researched extensively with mangos for more than 50 years. The way MAP works is by balancing the O_2 and CO_2 permeability of a sealed package with the respiration rate of the enclosed product, which consumes O_2 and releases CO_2. When properly designed, the MAP develops an atmosphere of reduced O_2 and elevated CO_2 that adds to the effect of refrigerated storage temperatures to further slow the metabolic processes that lead to ripening and quality

deterioration. The optimum O_2 + CO_2 atmospheres for different mango varieties are well known and in our own research we have determined how mango fruit maturity/ripeness affects their response to CA. Our previous research has indicated that the optimum MA for mature mangos is 2-4% O_2 + 10-15% CO_2. However, while CA systems are available for marine containers, CA is quite expensive and the availability of CA-equipped containers is nowhere near enough to handle mango export volumes. Using MAP for mangos has until recently been hampered by the lack of availability of proper package materials to achieve optimum atmospheres for mangos. However, we identified two MAP providers, TransFresh (Tectrol) and Apio (Breatheway), who have jointly developed a pallet-scale MAP system that is being used commercially for blueberries exported from Argentina to the USA. They provided a similar MAP designed specifically for mangos for use in this research project.

Mango quality is strictly dependent on the maturity of the fruit at harvest. Mangos that are harvested too early (immature physiological state) are more sensitive to hot water injury and chilling injury (CI) and may suffer losses and wastage due to failure to ripen or development of poor sensory quality when ripe, while those fruit harvested at too late a stage of maturity have reduced shelf life from over-ripening and increased susceptibility to mechanical damage (i.e., bruising) and disease (Brecht et al., 2010; Sivakumar et al., 2011).

The international trade of fresh mangoes is limited due to the fruit's highly perishable nature and its susceptibility to CI when stored below 13 °C. More mature mangos have better sensory quality potential and are less sensitive to hot water and chilling injuries. Brecht et al. (2000) showed that the APHIS hot water quarantine treatment (USDA-APHIS, 2007) and other time-temperature combinations reduced the susceptibility of 'Tommy Atkins' and 'Keitt' mangoes to CI. Bender et al. (2000) showed that 'Tommy Atkins' and 'Keitt' could be shipped for 2 to 3 weeks in CA at 8 °C for tree-ripe fruit or 12 °C for mature-green fruit without developing CI.

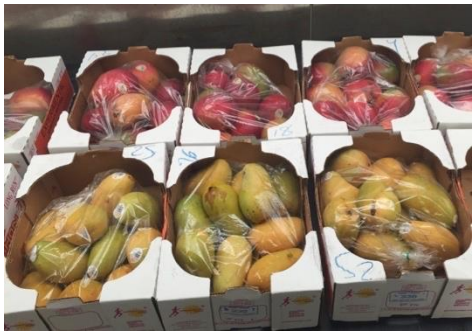
In international commerce, most mangoes are picked just at or even before the onset of ripening and shipped by ocean in refrigerated marine containers with transit times on the order of 2 to 3 weeks (Bender et al., 2000). The long shipping distances from mango growing regions in South America to the export markets in the United States (U.S) result in such long transit periods. This leads exporters to harvest mangos earlier and ship them at low temperatures (commonly 7 to 9 °C) to avoid arrival problems related to over-ripening, bruising, and decay. However, this practice can result in mangos with poor flavor in the marketplace.

The great challenge is to minimize the qualitative and quantitative losses during the supply chain of the mangos, ensuring adequate ripening, and the MA/MAP/CA can be used to maintain and extend the quality of mangos after harvest. Therefore, the successful control of respiration using MAP can result in a fruit of high organoleptic quality. However, control of these processes is dependent on temperature control along the whole fruit transit.

The objective of this research was to demonstrate the feasibility of incorporating MAP technology with optimum O_2 and CO_2 into existing mango handling systems to better maintain the quality of fully mature mangos for the extended transit periods required for export from South America to consumers in the USA to improve the quality of mangos available to consumers. We used 12.5 °C for the storage portion of these tests, but we know that higher maturity mangos can tolerate lower temperatures.

Materials & Methods

Fruit preparation. Ataulfo, Tommy Atkins and Kent mangos were obtained from a commercial packinghouse in Nayarit, Mexico on the same day when those fruits were being prepared for export. A sub-set of fruit was cut to determine the harvest maturity, using the 1 to 5 scale based on internal flesh color development as described in the "Mango Maturity & Ripeness Guide" provided by the National Mango Board (available at http://www.mango.org). The test fruit were pre-sized, received the quarantine hot water treatment, were hydrocooled, and were sized, graded, packed and forced-air cooled along with the other export fruit. Samples of packed fruit were collected and packaged in either Apio Breatheway MAP bags or NOW Plastics perforated bags (control). Each bag held approximately 4 kg (8 to 10 fruit) and the fruit were returned to the standard mango shipping carton after being placed in the bag (Fig. 1).



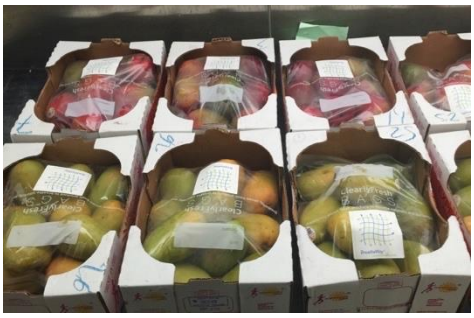


Fig. 1. Ataulfo mangos in control perforated bags (left) and MAP bags (right).

Shipping. The test fruit were placed on commercial truck shipments on the day of packing in Mexico and sent to a mango importer in Texas with one shipment per variety. A HOBO temperature datalogger (Onset Corp.) was placed in each test shipment. After arrival in Texas, the fruit were temporarily held in the importer's cold storage until a truck shipment to Florida could be identified. The mangos were then shipped to the University of Florida in Gainesville.

Storage. In Florida, the fruit were held in a 12.5 °C cold storage room until a total of 3 weeks storage and transport had been accrued. This was to simulate long-distance shipping from South America to the U.S. After 3 weeks, the fruit were transferred to 20 °C for ripening. Evaluations were conducted after 2 weeks and 3 weeks of transport/storage, and after 3 weeks plus 3 days ripening at 20 °C. Identical sets of packaged fruit of each variety were held in cold storage at 12.5 °C at the INIFAP laboratory in Nayarit and those fruit were evaluated at the same time as the fruit in Florida.

Quality evaluation.
Epidermal color and flesh color were evaluated objectively using a Minolta Chromameter with an 8-mm aperture and converted from L*a*b* scale to L*c*h* color system (Lightness, chroma, and hue angle, respectively). Measurements were made for each fruit, with one measurement taken on the green side (to avoid the red "blush") on the mangoes 'Tommy Atkins' and 'Kent' and, one measurement was taken on the equatorial region on the mango 'Ataulfo'. After that, the mangoes were cut longitudinally along the sides of the seed, obtaining two parallel halves, and the flesh color measurements were taken on one of those parts of each fruit.

Firmness was measured using an Effe-gi type penetrometer with an 8-mm Magness-Taylor probe. Results were measure as lbs-force required for the probe to penetrate the tissue and were converted to Newtons (N). For each fruit, two measurements were taken on whole fruit at the equatorial region after removing the epidermis.

Chilling injury (CI) was evaluated in terms of visual symptom development, softening and decay according to methods we have used in our previous research (Nunes et al., 2007). The visual CI symptoms (lenticel darkening, skin pitting, scalding, uneven ripening) were evaluated for each individual mango using a visual rating scale where: 1 = severe, >50% of the fruit's surface showing damage; 2 = moderate, 25–50% chilling damage; 3 = slight, up to 25% pitting and/or scalding; 4 = trace (small pits), 2–5% of the total fruit surface damaged; 5 = no visible symptoms of injury.

Fruit shriveling was assessed using a visual rating scale in which 1 = extremely shriveled, wrinkled and dry, not acceptable under normal conditions; 2 = severe shriveling, definitely, objectionable; 3 = moderate, shriveling evident, becoming objectionable; 4 = slight, minor signs of shriveling, not objectionable; 5 = none, field fresh, no signs of shriveling.

Decay severity of each mango was assessed using a modified visual rating scale from Horsfall and Barratt (1945) in which 1 = 76–100% decay, severe to extreme decay (the mango is either partially or completely rotten); 2 = 51–75% decay, moderate to severe decay; 3 = 26–50% decay, slight to moderate decay (spots with decay and some mycelium growth); 4 = 1–25% decay, probable decay (brownish/grayish sunken minor spots); 5 = 0%, no decay.

Pulp browning of each fruit was assessed using scale in which: 1 = 76–100% affected area; 2 = 51–75% affected area; 3 = 26–50% affected area; 4 = 1–25% affected area; 5 = 0% affected area. The mangoes were cut along the sides of the seed, obtaining two parallel parts and then evaluated the percentage of internal browning of each fruit.

Bruises, scars and cuts of each individual mango were accessed using a scale in which: 1 = severe injury; 2 = moderate injury; 3 = slight injury, 4 = no scars or cuts.

Mango odor was assessed in all Apio Breatheway MAP bags using a scale where: 1 = unripe odor; 2 = normal ripe odor; 3 = off odor. The odor was assessed when the bags were opened to determine if there were indications of degree of ripeness, or disorders, such as fermentation or decay.

Sensory evaluation was conducted by a small, expert panel of four persons for 'Ataulfo' and 'Tommy Atkins' and five for 'Kent' consisting of experienced personnel from the Postharvest Laboratory group. Mangos from each treatment were cut in half, longitudinally, with one half used for physical and compositional analysis. The other half was cut into slices that were placed in a lidded 50-mL clamshell container, which was closed for 3 minutes to allow for headspace accumulation. Panelists then opened the lids and rated the samples for aroma descriptors followed by tasting. The tasting descriptors were aroma, taste, yellow color, maturity, and overall acceptance using a 9-point hedonic scale, where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely.

Compositional analyses. Replicate composite pulp samples from each treatment were centrifuged and the supernatant frozen at -20 °C and later used for measurements of soluble solids content (Brix), pH, and total titratable acidity.

Atmosphere measurement. The CO_2 and O_2 concentrations in each sealed Apio Breatheway MAP bag were quantified with a Bridge CO_2/O_2 gas analyzer (model 900141; Bridge Analyzers; O_2 Sensor

EGA & MAP CO_2 20% Max). The calibrated analyzer was verified to be within ±4% accuracy of authentic CO_2 and O_2 gas standards. Package atmospheres were measured upon arrival at the University of Florida and daily during storage at 12.5 °C until completing 3 weeks. Hypodermic needles connected to the analyzer inlet and outlet were inserted through opposite sides of each bag. A piece of adhesive tape was used to close each sampling hole in the bag following measurement.

Experimental design and statistical analysis. The experiments were conducted using a completely randomized design with fruit numbers as described above. Statistical analysis was done using SAS for PC (SAS Institute Inc., Cary, N.C.) with data subjected to analysis of variance (PROC ANOVA) and LSD values calculated for $P = 0.05$. Statistical analysis was done separately for each mango cultivar.

Results and Discussion

During the test set up in the Nayarit packinghouse, 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos were handled at temperatures that varied from 23 to 28 °C. During shipment in refrigerated trucks, the temperature within the pallets with the mangoes remained between 8-10 °C for 'Ataulfo', 9-11 °C for 'Tommy Atkins', and 9-13 °C for 'Kent' fruit.

The average initial maturity of the mangos was Stage 3.0 for Ataulfo, Stage 2.5 for Tommy Atkins, and Stage 3.1 for Kent. The corresponding Brix readings were 11.4, 9.6 and 8.6 degrees, respectively.

Upon arrival at the University of Florida, the atmospheres in the MAP bags were:
Ataulfo, 2.0% O_2 + 14.6% CO_2, Tommy Atkins, 3.6% O_2 + 6.4% CO_2, and Kent, 4.9% O_2 + 10.9% CO_2.

After 2 weeks, the atmospheres were:
Ataulfo, 4.6% O_2 + 15.7% CO_2, Tommy Atkins, 10.6% O_2 + 7.3% CO_2, and Kent, 5.3% O_2 + 11.3% CO_2.

After 3 weeks, the atmospheres were:
Ataulfo, 4.7% O_2 + 13.1% CO_2, Tommy Atkins, 3.6% O_2 + 11.4% CO_2, and Kent, 8.9% O_2 + 9.0% CO_2.

After 3 weeks of simulated long distance shipping, representing the "arrival condition" in this simulation, the indicators of ripening showed that MAP slowed fruit ripening (**Table 1**). For Ataulfo, the maturity score remained almost unchanged in MAP while declining in Air; however, the maturity scores were unaffected by MAP in Tommy Atkins and Kent. Fruit firmness was maintained at higher levels in MAP for fruit of all three varieties. Soluble solids (Brix) was unaffected by MAP for Ataulfo, but was kept lower in MAP for Tommy Atkins and Kent. Titratable acidity (TA) was maintained at higher levels in MAP for all three varieties.

The lightness (L* value) and chroma (C* value) of the fruit peels were lower while the hue (h) was greater for fruit handled with MAP (**Table 2**). This corresponds to reduced loss of green color that normally accompanies mango ripening. The flesh lightness and hue decreased while chroma increased with storage, more so in Air than in MAP, indicating more darkening and more vivid and orange color in Air (**Table 3**). These results indicate that MAP inhibited ripening-associated color changes. Fruit from all of the treatments completed the normal ripening process when transferred to air at 20 °C.

Table 1. Indicators of fruit ripeness for MAP- and Air-stored Ataulfo, Tommy Atkins and Kent mangos after shipping and storage for a total of 3 weeks.

		Mat. Score	Firmness		SSC (Brix)	TA
		(1-5)	(lbs)	(N)	(%)	(%)
Ataulfo:	Air	3.9a[z]	4.7b	20.9b	19.6a	0.78b
	MAP	2.9b	7.9a	35.1a	19.4a	1.18a
Tommy Atkins:	Air	3.3a	4.4b	19.6b	14.4a	0.55b
	MAP	3.1a	6.1a	27.1a	13.5b	0.62a
Kent:	Air	4.2a	5.5b	24.4b	15.2a	0.30b
	MAP	4.0a	6.8a	30.2a	13.7b	0.60a

[z]Averages for treatment pairs followed by the same lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

Table 2: Effect of modified atmosphere packaging (MAP) on the peel color attributes lightness (L), chroma (C), and hue angle (H) for 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos.

Cultivar	Treatment	Storage period								
		2 weeks			3 weeks			3 weeks plus 3 days		
		L*	C*	h	L*	C*	h	L*	C*	h
Ataulfo										
	Air	68.4Ba[z]	53Ba	85.7Ab	77.9Aa	59.3Aa	82.4Ab	68.8Ba	57.2Aa	77.7Bb
	MAP	64.3Cb	46.9Bb	95.5Aa	73.7Ab	53.2Ab	93.8Aa	68.2Ba	53.2Ab	83.9 Ba
CV (%)								2.4	3.3	2.7
Average								70.2	53.8	86.5
Tommy Atkins										
	Air	60.2Ba	39Ca	73.7Ab	69.7Aa	45.2Aa	71.6Ab	62.5Ba	41.8Ba	72.7 Aa
	MAP	57.6Ba	35.3Bb	83.2Aa	66.4Ab	39.9Ab	82.1Aa	58.5Bb	38.7Ab	76.3 Aa
CV (%)								2.9	3.2	7.8
Average								62.5	40	76.6
Kent										
	Air	51.5Ca	32.2Ca	108.9Aa	54.3Ba	35.8Ba	95.9Bb	57.8Aa	41.4Aa	93.8Ba
	MAP	49.1Bb	28.1Bb	112.1Aa	40,2Bb	29.8Bb	107.9Aa	55.5Ab	37Ab	99.5Ba
CV (%)								2.5	5.1	5
Average								52.9	34	103

[z]Averages followed by the same uppercase letter in the row and lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

Table 3: Effect of modified atmosphere packaging (MAP) on the pulp color attributes lightness (L), chroma (C), and hue angle (H) for 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos.

Cultivar	Treatment	Storage period								
		2 weeks			3 weeks			3 weeks plus 3 days		
		L*	C*	h	L*	C*	h	L*	C*	h
Ataulfo										
	C	75.5Ba[z]	64.5Ba	84.5Ab	80.5Ab	73.2Aa	81.6 Bb	71.4Ca	63.6Ba	81.6Bb
	MAP	77.6Ba	62.7Ba	86.3Aa	83.7Aa	72.5Aa	85.0 Aa	73.2Ca	61.5Ba	85.5Aa
CV (%)								2.6	3.7	1
Average								76.9	66.3	84
Tommy Atkins										
	C	70Ba	63.9Ba	83.3Ab	76Aa	67.4Aa	82.9 Ab	68.3Ba	63.4Ba	83.4Ab
	MAP	71.2Ba	63.3Ba	85.2Aa	77.7Aa	67.9Aa	85.2 Aa	69Ba	61.3Ba	85.2Aa
CV (%)								2.4	2.4	1.2
Average								72	64.5	84.2
Kent										
	C	75.1Aa	58Ba	88.5Aa	71.9Bb	57.9Ba	86.8 Ab	71.8Ba	69.7Aa	87.8Ab
	MAP	75.9Aa	59.5ABa	88.6Ba	73.9Ba	57Ba	88.9 Ba	70.9Ca	62.2Ab	91Aa
CV (%)								1.2	2.9	1.2
Average								73.3	60.7	88.6

[z]Averages followed by the same uppercase letter in the row and lowercase letter in the column do not differ by Tukey test ($p \square 0.05$)

The results for fruit firmness and maturity stage (**Table 4**) corroborate the flesh color results. 'Ataulfo' softening and flesh color development (i.e., maturity stage) were slower in MAP than in Air. Maturity stage also remained lower in MAP for 'Tommy Atkins' and 'Kent' but MAP did not affect fruit softening for those varieties. These results also show that fruit from all the treatments completed the normal ripening process when transferred to air at 20 °C.

Table 4. Effect of modified atmosphere packaging (MAP) on firmness (N) and maturity/ripeness scores (scale 1 to 5) for 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos.

Cultivar	Treatment	Storage period					
		2 weeks		3 weeks		3 weeks plus 3 days	
		Firmness (N)	Maturity Stage (1-5)	Firmness (N)	Maturity Stage (1-5)	Firmness (N)	Maturity Stage (1-5)
Ataulfo							
	Air	10.9 Ab	3.8 Ba	10.9 Ab	4.8 Aa	8.0 Ab	5 Ab
	MAP	28.2 Aa	3.3 Bb	20.6 Ba	3.8 Ab	18.8 Ba	4.1 Aa
CV (%)						25.6	7
Average						16.3	4.1
Tommy Atkins							
	Air	23.5 Aa	4.1 Aa	21.9 Aa	4.4 Aa	15.8 Aa	4.6 Aa
	MAP	25.5 Aa	3.7 Ab	24.8 Aa	3.7 Ab	12.1 Ba	4.1 Ab
CV (%)						33.8	6.3
Average						20.6	4.1
Kent							
	Air	69.1 Aa	2.9 Ca	38.5 Ba	3.5 Ba	16.5 Ca	4.4 Aa
	MAP	44.3 Ab	2.8 Ba	46.6 Aa	2.9 Aa	15.3 Ba	3.5 Ab
CV (%)						24	9.2
Average						38.4	3.3

[z]Averages followed by the same uppercase letter in the row and lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

Ataulfo and Kent fruit in MAP were maintained with lower SS and pH plus higher TA than Air-stored fruit throughout, all indicating that MAP slowed the fruit ripening (**Table 5**). However, there was little treatment effect on SS, pH, and TA for Tommy Atkins fruit.

Table 5. Effect of modified atmosphere packaging (MAP) on the soluble solids content (SS; °Brix), pH, and total titratable acidity (TA) expressed as % citric acid for 'Ataulfo', 'Tommy Atkins', and 'Kent' mangos.

Cultivar	Treatment	Storage period								
		2 weeks			3 weeks			3 weeks plus 3 days		
		SS	pH	TA	SS	pH	TA	SS	pH	TA
Ataulfo										
	Air	18.8Aa[z]	3.5Ca	1.6Aba	19.3Aa	3.8Ba	0.9Bb	19.2Aa	4.2Aa	0.5Cb
	MAP	15.6Ab	3.3Ab	2.2Aa	16.6Ab	3.3Ab	1.9Ba	17.0Ab	3.4Ab	1.6Ba
CV(%)								5.2	3.3	14.8
Average								17.7	3.6	1.4
Tommy Atkins										
	Air	15.7Aa	4.2Aa	0.4Aa	14.8Aa	3.9Bb	0.5Aa	14.3Ba	4.1ABb	0.4Aa
	MAP	14.7Aa	4.1Aa	0.4Aa	14.6Aa	4.1Aa	0.4Ab	14.9Aa	4.2Aa	0.35Ab
CV(%)								5.2	2.4	14.7
Average								14.8	4.1	0.4
Kent										
	Air	14.3Aa	3.8Bb	0.8Aa	15.0Aa	3.8Bb	0.9Aa	14.9Aa	4.4Aa	0.5Ba
	MAP	12.3Bb	4.3Aa	0.7Ab	13.5ABb	4.2Aa	0.7ABb	14.6Aa	4.4Aa	0.5Ba
CV(%)								5.6	2.9	9.6
Average								14.1	4.1	0.7

[z]Averages followed by the same uppercase letter in the row and lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

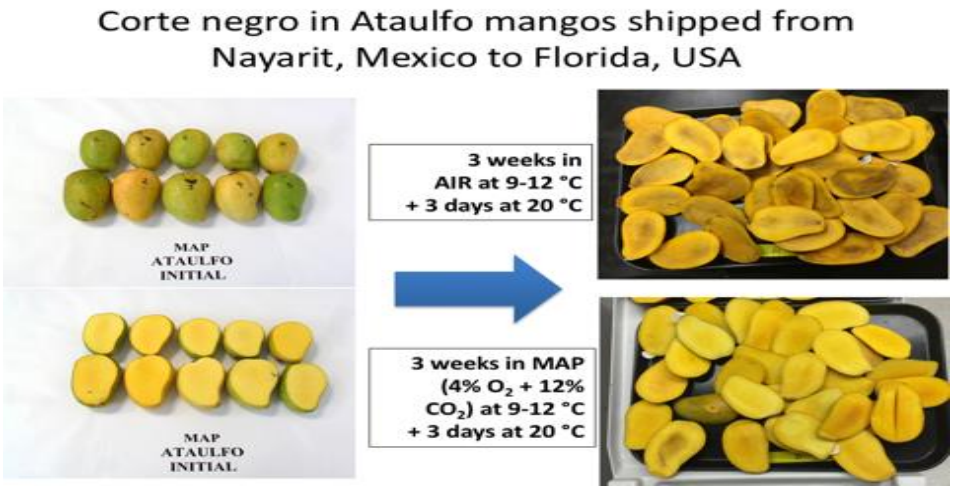
There was little or no evidence of CI, decay, or pulp browning in 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos during the simulated transport period except for pulp browning in 'Ataulfo' after 3 weeks plus 3 days at 20 °C (**Table 6**). In the latter case, the Air-control 'Ataulfo' fruit were almost all afflicted with "corte negro" (cutting black) with the darkening apparent on an average of about 25% of the cut surface of the flesh while the MAP fruit exhibited almost no symptoms of corte negro (**Fig. 2**).

Table 6. Effect of modified atmosphere packaging (MAP) on chilling injury (CI), decay, and pulp browning for 'Ataulfo', 'Tommy Atkins' and 'Kent' mangos.

Cultivar	Treatment	Storage period								
		2 weeks			3 weeks			3 weeks plus 3 days		
		(CI)	Decay	Pulp Browning	(CI)	Decay	Pulp Browning	(CI)	Decay	Pulp Browning
Ataulfo										
	Air	4.7Aa[z]	4.9Aa	5.0Aa	4.6Aa	4.9Aa	4.7Aa	4.7Aa	4.3Bb	3.6Bb
	MAP	4.7Aa	4.9Aa	5.0Aa	4.8Aa	4.9Aa	5.0Aa	4.6Aa	4.9Aa	4.9Aa
CV (%)								4.4	2.1	6.2
Average								4.7	4.8	4.7
Tommy Atkins										
	Air	4.8Aa	4.9Aa	5.0Aa	4.7Aa	4.5Aba	5.0Aa	4.7Aa	4.4Ba	5.0Aa
	MAP	4.9Aa	4.9Aa	5.0Aa	4.7Aa	4.7Aa	5.0Aa	4.6Aa	4.2Ba	5.0Aa
CV (%)								4.2	5.1	0.0
Average								4.7	4.6	5.0
Kent										
	Air	4.2Aa	5.0Aa	18.7Aa	3.7ABb	4.8Aa	5.0Aa	3.4Ba	4.7Aa	5.0Aa
	MAP	4.2Aa	4.7Aa	15.6Aa	4.4Aa	5.0Aa	5.0Aa	3.3Ba	4.9Aa	5.0Aa
CV (%)								11.3	4.6	0.0
Average								3.8	4.9	5.0

[z]Averages followed by the same uppercase letter in the row and lowercase letter in the column do not differ by Tukey test ($p \leq 0.05$)

Fig. 2. Corte negro in 'Ataulfo' mangos shipped from Nayarit, Mexico to Florida, USA after 3 weeks in Air or MAP at 9-12 °C plus 3 days in Air at 20 °C.



'Ataulfo' mango sensory analysis revealed significant differences for appearance (yellow color development), maturity, and overall acceptance and flavor among treatments (**Table 7**). The panelists indicated that 'Ataulfo' fruit from MAP had better appearance with better taste and overall acceptance. For 'Tommy Atkins' fruit, the panelists considered that the fruit from MAP had better aroma and appearance. 'Kent' fruit from MAP were judged by the panelists to have better taste than Air control fruit. For both the 'Tommy Atkins' and 'Kent' fruit, the scores for taste and overall acceptance were also substantially higher for MAP fruit, but unlike for 'Ataulfo' the differences were not statistically different.

Table 7. Sensory quality of Ataulfo, Tommy Atkins, and Kent mangos following shipping/storage at 9 to 12.5 °C for 21 days plus 3 days' shelf life at 20 °C.*

Cultivar	Treat-ment	Aroma[z]	Taste	Appearance (yellow color)	Overall Acceptance
Ataulfo	**Air**	4.73 a	3.09 b	1.23 b	3.87 b
	MAP	5.57 a	6.20 a	7.03 a	7.02 a
Tommy Atkins	**Air**	5.12 b	5.62 a	5.85 b	5.71 a
	MAP	8.02 a	7.10 a	7.45 a	7.14 a
Kent	**Air**	5.62 a	4.79 b	7.30 a	4.61 a
	MAP	5.77 a	7.30 a	8.25 a	7.10 a

*Values followed by the same letter in a column do not differ according to Tukey's Test ($P \leq 0.05$).
[z] 9-Point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely

Conclusions

- The test MAP developed and mostly maintained close to the target atmosphere range of 2-4% O_2 + 10-15% CO_2 for fully mature mangos. This will need to be fine-tuned for each mango variety in future testing.
- Fruit quality was better maintained by MAP than Air during 3 weeks simulated shipping plus 3 days shelf life due to slowing of ripening processes in MAP.
- The MAP almost eliminated *corte negro* symptoms in the one shipment (Ataulfo) in which it occurred.
- These results warrant scaling up the tests in commercial shipments from South America using mangos of different maturity/ripeness stages

Based on our preliminary testing, we propose to test the Tectrol/Breatheway MAP pallet-scale system in multiple commercial shipments from the exporting countries to Florida using several mango varieties at different maturity stages, with different packinghouse handling and cooling scenarios applied prior to covering the pallet with the MAP, and with and without ethylene scrubbers inside the MAP. In those tests, one pallet of mangos in a container would be handled in

MAP and the rest of the load would be handled normally. Quality of several cartons of fruit from a non-MAP (control) pallet and the MAP pallet in each shipment would be evaluated at the University of Florida, upon arrival and after ripening.