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DIFFERENTIAL RESPONSE OF MANGO FRUIT TO POSTHARVEST APPLICATIONS OF MODIFIED ATMOSPHERE PACKAGING (MAP) AND 1-Methylcyclopropene (1- MCP)

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ABSTRACT

The response of mango fruit *Mangifera indica* cv. Ewais to postharvest applications of modified atmosphere packaging, MAP, and 1-methylcyclopropene, 1-MCP, were tested using nine laser-micro-perforated films of different micro-perforation levels, and hence different transmission (permeation) levels were specially prepared by two USA companies for this study. 1-MCP was applied at 0, 1.0 or 5.0-ppm for 48 hours at 23-24°C. Fruits were stored at 13°C for 10 or 20 days and ripened for 2 days at 25°C. The response was evaluated using sensory attributes, L*, a* and b* color of the peel and flesh, flesh firmness, flesh texture and TSS and titratable acidity percentages. The TSS./acid ratio was also calculated. All MAP treatments extended storage life to more than 20 days as compared to at most 10 days for non-packaged fruits. Films of T5 and T10 were judged to have provided the best MAP environment and resulted in full-flavored fruits after 20 days at 13°C plus 2 days at 25°C. The films of these 2 treatments significantly maintained fruit appearance and fruit firmness, delayed the development of the yellow-orange color in the peel and delayed the increase in TSS%. By comparison, 1.0-ppm 1-MCP had no significant effect on the storage life, while at 5.0-ppm it produced few inconsistent significant effects in a direction of enhanced ripening. The differential response of Ewais mango to MAP and 1-MCP is suggested to be due to their mode of action.

Keywords: Mango fruit, cv, Ewais, micro-perforated, gas transmission, O_2-TR, CO_2-TR and water vapor transmission WVTR, MAP, 1-MCP, 1-MCP traps, storage.

INTRODUCTION

Postharvest handling and storage life are important components in fresh produce processing. The technological needs and challenges to extend the shelf life of perishable commodities are immense as they undergo fast and active metabolic changes that gradually and ultimately result in tissue aging and senescence.

Postharvest changes in climacteric fresh produce, such as mango proceed orderly and simultaneously, and these changes include: fruit softening due to loss of flesh firmness; loss of the peel green color due to loss of the green pigments, chlorophyll, in some cultivars; development of the yellow color in the peel and yellow-orange color in the flesh due to the formation of caroteniods, xanthophylls and anthocyanin pigments; development of specific flavor due to the hydrolysis of stored products such as starch into simple sugars and the disappearance of the phenolic compounds; and the development of aroma due to the formation of volatile

and non-volatile aroma compounds (Samson, 1986; Nakasone and Paull, 1999).

An increase in ethylene production and a climacteric rise in respiration rate trigger the above-indicated changes (Nakasone and Paull, 1999; Kader, 2002). Treating these produce with ethylene would enhance their ripening. Furthermore, compounds that reduce ethylene levels in the storage environment by surface adsorption (such as activated charcoal) or by its oxidation (such as potassium permanganate, $KmnO_4$, ozone, O_3, and titanium oxide, TiO_2) would positively impact the postharvest keeping quality of most perishable produce (Reid, 2002).

Storage of numerous perishable produce in modified atmosphere, MA, was effective in reducing the undesirable effects of ethylene, lowering their metabolic activities and extending their shelf life (Yahia, 1997, 1998; Kader, 2002). This is achieved by reducing O_2 level and increasing that of CO_2 in the storage environment compared to their percentage in the air (21.3% and 0.03%, respectively). This is usually combined with lowering the storage temperature to the lowest possible level without inducing freezing or chilling injury and by increasing the level of relative humidity, RH. The physiological needs of the stored produce define the optimum levels of each of these gases while the produce tolerance to high CO_2 and low O_2 levels define their limits. These principals have been tested and reported on numerous mango cultivars such as Amelie (Kane and Marcellien, 1979), Alphonso (Kapur *et. al.*, 1962), Carlotã, Haden, Jasmin and Sao Quirino (Bleinroth *et. al.*, 1977) and Rad (Noomhorm and Tiasuwan, 1995). Optimum conditions suggested by these studies were 5-10% CO_2, 4-6% O_2 and 90-94% RH. Temperature was in the range of 5.5-13°C, depending on the cultivar. Wide variations were reported on the effect of MA on shelf life as it varied from 30 days (at 8°C) for Haden, 35 days (at 8.3-10°C) for Alphonso and 49 days (at 5.5-7.2°C) for Raspuri.

The desirable effects of MA could be achieved by placing the fruits in a bag made of special film and is referred to as modified atmosphere packaging, MAP. The film should be selected to have the desired gas transmission, O_2-TR, CO_2-TR and water vapor transmission WVTR, for O_2, CO_2 and H_2O, respectively, to maintain the desired modified environment of O_2%, CO_2% and RH% to minimize the postharvest changes that lead to fruit deterioration (Schlimme and Rooney, 1994) . However, the desirable packaging film should maintain the levels of these gases within the proper needs and tolerance limits of packaged fruits since too low O_2 level would lead to anaerobic respiration and off taste (Kader, 1986 and 2002; Beaudry, 2000) and too high CO_2 would cause numerous undesirable effects such as discoloration, off odor and off taste (Kader, 1986 and 2002; Watkins, 2000). Unfortunately, such film was not available to match the physiological needs of multi-fruit packages of mango. Low O2 levels was considered as a limiting factor to the expanded use of MAP (Beaudry, 2000). However, perforating the film could increase its transmission (permeation) capacity. The size of the perforations could be micro (not visible to the naked eyes) or macro (visible to the naked eye). Laser-micro-perforation is the newest available technology and it allows precision in controlling perforation size and hence more

accurate regulation of the film transmission quality. This has not been tested on mango fruits.

The second part of this study deals with blocking the stimulatory action of ethylene on fruit ripening and senescence. These effects of ethylene when applied as a gas, or as a liquid preparation that releases ethylene gas upon its breakdown (Ethephone™, Ethrel™) have been used commercially in enhancing fruit ripening and mechanical harvesting (Reid, 2002). On the other hand, regulating the stimulatory-action of ethylene is highly desirable to extend the shelf life of perishable produce and facilitate their storage and transport. In this regard, storage under low temperature has been identified as the most important factor to delay fruit ripening, extend shelf life and reduce spoilage (Hardenberg *et al* 1986; Thomposon *et. al.*, 2002). Low temperature acts by reducing the metabolic rate and endogenous ethylene formation. Inhibitors of ethylene synthesis such as cobalt ions, silver ions, as silverthiosulfate, STS, and aminoethoxyvinylglycine, AVG; ReTain™ (Yang, 1987; Reid, 2002) also were useful in retarding postharvest senescence of perishable produce. Most recently, the role of 1-mthylcyclopropene, 1-MCP, as an inhibitor of ethylene-action that reduces the undesirable postharvest effects of ethylene has been illustrated on climacteric fruits such as apple (Fan and Mattheis, 1999; Fan *et. al.*, 1999; Watkins *et. al.*, 2000), apricot (Fan *et. al.*, 2000), avocado (Feng *et. al.*, 2000; Hofman *et. al.*, 2001), mango (Jiang and Joyce, 1999; Hofman *et. al.*, 2001), Kiwifruit (Kim *et. al.*, 2001) and tomato (Sisler *et. al.*, 1996 and 1999; Sisler and Serek, 1997; Wills and Ku, 2002). Postharvest treatment with 1-MCP, also, positively impacted the keeping quality of Strawberry (Titan *et. al.*,2000; Jiang *et. al.*, 2001), broccoli (Ku and Wills, 1999; Fan and Mattheis, 2000a), carrot and lettuce (Fan and Mattheis, 2000b) and cut flowers (Reid *et. al.*, 2002).

The effects of postharvest application of MAP and 1-MCP on mango fruits were never compared and the use of laser-micro-perforated films for MAP has never been tested on mango. Therefore, this study was initiated to test the keeping quality of Ewais mango fruits in response to postharvest applications of these two technologies using the following approach:

1. Nine (9) different film treatments. The films were specially prepared by 2 USA film companies using different laser-micro-perforations levels and were of different sizes to accommodate different number of fruits per pack.
2. Two (2) different 1-MCP treatments.

MATERIALS AND METHODS

Fruits of Ewais cv were harvested on August and September 2002, from a commercial orchard located in Al-Fayoum. Harvested fruits were transferred in refrigerated trucks for overnight cooling at 13°C, at the Horticulture Research Institute at Giza. Magngo fruits were washed clean using tap water, no additional chlorine was added during washing to avoid any possible effect of chlorine on ripening. The fruits were allowed to dry out as a single layer on clean tables, sorted for uniformity in size and external color.

Film packaging treatments. Nine (9) different Laser-micro-perforated films were used in this study. The films were provided courtesy of Dr. William R. Romig and Mr. Al Topolski, EPL Technologies, Inc., Oswego, Illinois, USA and Ms. Elizabeth Marston, West Wind, 18 Wilson Road, Windham, NH 03087 USA. The fruits of each replicate (whose numbers are indicated below) were carefully placed in each bag (film) and sealed by rolling the free end and was either taped or tied with a rubber band, Packaged fruits of each replicate were placed in a well-ventilated carton box and stacked with adequate ventilation at 13°C. Control fruits were similarly handled although they were not packaged in any film. The following ten treatments were tested:

T1 Control (no film packaging).
T2 Packaged in EPL Technologies' film 702-I.
T3 Packaged in EPL Technologies' film 702-J.
T4 Packaged in EPL Technologies' film 702-K.
T5 Packaged in West Wind's film A-38.
T6 Packaged in West Wind's film B-50.
T7 Packaged in EPL Technologies' film 1X.
T8 Packaged in EPL Technologies' film 2X.
T9 Packaged in EPL Technologies' film 3X.
T10 Packaged in EPL Technologies' film 4X.

1-MCP treatments. A 0.14% concentrated preparations of 1-MCP was provided courtesy of Dr. Harlow Warner of Agro Fresh, Philadelphia, PA USA. The following three (3) treatments were tested:

T1 Control (no 1-MCP treatment). However, fruits were handled similar to those treated with 1-MCP.
T2 Treated with 1.0-ppm 1-MCP for 48-hours at 25°C.
T3 Treated with 5.0-ppm 1-MCP for 48 hours at 25°C.

Three replicates were used for each evaluation date. These fruits had an average of 250-g each. Twelve fruits per replicate were used in all controls and treatments except in T2, T3 and T4 where 5 fruits/replicate were used and for T7, T8, T9 and T10 where 8 fruits/replicate were used. Fruits were then stored at 13°C for 10 or 20 days after which they were transferred for 2 days at 25°C. Samples were evaluated at 0, 10 and 20 days as well as before the termination of each test as indicated in the Tables of Results.

Quality attributes evaluated.

1. Sensory evaluated attributes: fruit appearance, fruit firmness, aroma, peel and flesh color and fruit decay.
2. L*, a* and b* color of the peel and flesh.
3. Flesh firmness and flesh texture.
4. TSS% and titratable acidity%. TSS/acid ratio was also calculated.

Methods of evaluations.

- Fruit general appearance was evaluated visually on a scale 1 to 9 with 1 = fruit exhibiting excessive defects and 9 = free of defects.
- Aroma was evaluated on a scale 1 to 5 with 1= no aroma and 5 = rich typical mango aroma.

- Peel (skin) color was evaluate visually on a scale 1 to 5m with 1 = dark green and 5 = fully colored.
- Peel color was also evaluated objectively by Hunter Instrument DP-9000, which measures L*, a* and b*. The L*, measures color lightness (L* values are always positive where higher values are lighter), a* measures color chromaticity that indicates color direction (a* values may be negative or positive with +a* is the red direction and –a* is the green direction) and b* is the second chromaticity measure on the L*, a* and b* scale. It indicates color direction with +b* is the yellow direction and –b* is the blue direction.
- Flesh color was evaluated visually on cut fruits on a scale 1 to 5 with 1 = white, 2 = slightly yellow, 3 = moderately yellow, 4 = dark yellow and 5 = full yellow/orange (ripe).
- Flesh color was also evaluated objectively by Hunter Instrument DP-9000 to measure the L*, a* and b*.
- Flesh texture was measured on the bare flesh to 3 and 5 mm depth using Texture Instrument.
- Fruit firmness was evaluated on the whole fruit (with peels intact) using a sensory scale of 1 to 5 with 1 = soft and 5 = hard and very firm.
- Flesh firmness was measured, on the bare flesh, at the center of 2 sides of each fruit using a stationary penetrometer. Data are presented in $Kg.cm^{-2}$.
- Total Soluble solids was measured in the juice of a composite sample of the flesh of the fruits of each replicate using a hand-held refractometer. Data are reported as TSS percentage.
- Titratable acidity was measured in the juice of a composite sample of the flesh of the fruits of each replicate by titration against diluted calibrated alkali solution of known Normality. Data are reported as titratable acidity percentage.

Statistical analysis. A completely randomized design was employed for each harvest date. Since the data for the two harvest dates (August and September, 2002) exhibited similar patterns and trends, the analysis was run on the combined data. The treatment means were compared using the method of L.S.D. at the 5% level of significance (Snedecor and Cochran, 1989).

RESULTS AND DISCUSSION

Response to Modified Atmosphere Packaging (MAP)

At day 1, the fruits were fully mature with dark green peel color, light yellow flesh color and were very firm (hard) as evidenced by sensory evaluation (Table 1). At that stage, sensory evaluation indicated lack of aroma (Table 1). The bare flesh was equally hard as it recorded 9.0 $Kg.cm^{-2}$ when measured by the penetrometer and had good texture when measured by the Texture Instrument (Table 3). These fruits exhibited 11.9% TSS, 3.0% titratable acidity and 4.0 TSS/acidity ratio (Table 3).

After 10 days at 13°C, non-packaged fruits exhibited inferior general appearance (sensory evaluation, Table 1). In addition, the green color of the peel disappeared and the yellow color became dominant and the fruit had high aroma (Table 1). Quantitative measurements (Tables 2 and 3) indicated that the fruit had soft flesh, soft texture, high TSS, low acidity and high TSS/acid ratio, all of which are indices of fruit ripening. This is supported by the following comparable changes in the peel and flesh color as measured by L*, a* and b*.

- L* of the peel increased to 58.62 from 44.29 at day-1 (indicating lighter color). This is due to the loss of the dark green color. In the meantime, L* of the flesh decreased to 60.10 from 77.64 (indicating darker color). This is due to the development of more pigmentation with ripening. These measurements are in line with the sensory evaluation.
- a* of the peel increased to –8.29 from –15.57 at day 1 (indicating changes into yellow from green) while a* of the flesh increased to +14.29 from 1.80 at day 1 (indicating a change to dark orange from very light yellow). These values are, also, in line with the sensory evaluation.
- b* values increased in the peels as well as in the flesh due to the formation of yellow pigments. This is parallel with the sensory evaluation.

The data in Tables 1-3 on sensory evaluations, changes in L* , a* and b* values, loss in firmness, loss in texture, increase in TSS, reduction in titratable acidity, increase in the ratio of TSS to acidity and loss in fruit appearance indicate that non-packaged fruits have passed the optimum ripening stage and became overripe after 10 days of storage at 13°C.

By comparison, after 10 days of storage at 13°C, all packaged fruits exhibited delayed ripening. This is evidenced by the sensory evaluation (good appearance, lack of aroma, firmer fruits and green peel color, Table 1). However, flesh color became darker orange. This, while indicating some progressive ripening, suggests that MAP environment was more inhibitory on the breakdown of peel green color, i.e., chlorophyll pigments, than on the development of flesh orange color. Quantitative color analysis of L*, a* and b* supports the findings and conclusion that MAP delayed ripening (Table 2). Also, most packaging treatments reduced the magnitude of increase in TSS%, reduction in acidity% and rise in TSS to acidity ratio (Table 3). However, these treatments showed no effect on the complete loss of flesh texture and some only very slightly delayed flesh softening (Table 3).

After 20 days at 13°C, fruits of the control, T1, were not included in the evaluation as they became extremely aged and non-edible while packaged fruits, T2-T10, continued to be firm with good appearance (Table 1). In the meantime, peel color (by sensory evaluation), L*, a* and b* of the peel and flesh (Table 2) as well as other quality indices of TSS, acidity and TSS/acidity ratio (Table 3) showed minimum changes from that after 10 days. Similarly, flesh texture was 0.0 in all samples (same as after 10 days) and flesh firmness became 0.0 for all samples (Table 3).

Table 1: The effects of modified atmosphere packaging, MAP, on sensory evaluations of mango fruit cv. Ewais.

Film Treatment	Quality attribute: General appearance	Aroma	Fruit Firmness	Peel Color	Flesh Color	Decay
			Day 1			
None	9.0	1.0	5.0	1.0	2.5	1.0
			After 10 days at 13°C			
T1 None	4.3	3.0	1.5	3.5	4.6	1.0
T2 MAP 702-I	9.0	1.0	5.0	1.0	3.0	1.0
T3 MAP 702-J	9.0	1.0	3.7	1.0	3.3	1.0
T4 MAP 702-K	9.0	1.0	3.3	1.0	4.5	1.0
T5 MAP A-38	9.0	2.0	5.0	1.0	3.5	1.0
T6 MAP B-50	9.0	2.0	4.8	1.0	3.3	1.0
T7 MAP 1X	9.0	1.0	5.0	1.0	3.5	1.0
T8 MAP 2X	9.0	1.0	4.7	1.0	3.5	1.0
T9 MAP 3X	9.0	1.0	4.2	1.0	3.5	1.0
T10 MAP 4X	9.0	1.0	4.8	1.0	3.7	1.0
L.S.D at 5%	NS	NS	1.3	NS	0.5	NS
			After 20 days at 13°C			
T1 None	1.0	NA	NA	NA	NA	NA
T2 MAP 702-I	9.0	2.7	2.9	1.0	4.6	1.0
T3 MAP 702-J	9.0	1.0	4.8	1.0	3.0	1.0
T4 MAP 702-K	9.0	2.2	3.6	1.0	3.3	1.0
T5 MAP A-38	9.0	1.1	3.6	1.0	4.5	1.0
T6 MAP B-50	7.0	1.6	3.7	1.0	3.5	1.0
T7 MAP 1X	7.0	1.7	3.2	1.0	3.3	1.0
T8 MAP 2X	7.0	1.8	4.7	1.0	3.5	1.0
T9 MAP 3X	7.0	1.0	2.3	1.0	3.5	1.0
T10 MAP 4X	7.0	2.3	4.5	1.0	3.7	1.0
L.S.D at 5%	NS	0.9	1.3	NS	0.5	NS

NA: No fruits were available as all fruits of the control samples exhibited excessive deterioration and were not fit for any usage or evaluation

Scale:

General appearance: 9 = fruit exhibited fresh look and free of defectives; 1 = fruit exhibited excessive defectives.

Aroma: 5 = rich typical mango aroma; 1 = no aroma.

Firmness: 5 = Very firm (hard); 1 = soft.

Peel color: 5 = yellow, 4= 3/4 yellow; 3 = 1/2 yellow; 2 = 1/4 yellow; 1 = green.

Flesh color: 5 = dark orange; 4 = yellow/orange; 3 = yellow; 2 = light yellow; 1 = white.

Decay: 5 = excessive; 1 = none.

Table 2: The effects of modified atmosphere packaging, MAP, on Peel and flesh color of mango fruit cv. Ewais.

Film Treatment	Peel Color			Flesh Color		
	L*	a*	b*	L*	a*	b*
			Day 1			
None	44.29	-15.57	26.63	77.64	1.80	61.94
			After 10 days at 13°C			
T1 None	58.82	-8.29	34.19	60.10	14.29	82.94
T2 MAP 702-I	45.90	-15.34	24.90	74.48	4.40	74.61
T3 MAP 702-J	44.92	-14.19	24.22	71.73	6.57	78.42
T4 MAP 702-K	43.01	-14.65	25.45	57.65	15.71	83.64
T5 MAP A-38	44.62	-15.33	28.00	67.51	9.01	81.66
T6 MAP B-50	43.55	-14.86	26.14	68.59	8.27	79.97
T7 MAP 1X	43.22	-14.54	23.53	72.32	4.20	76.42
T8 MAP 2X	46.75	-15.27	25.54	72.39	5.35	76.19
T9 MAP 3X	44.30	-15.57	25.03	63.57	11.46	81.85
T10 MAP 4X	44.27	-15.58	23.95	67.49	9.42	80.09
L.S.D at 5%	NS	1.38	4.69	9.09	6.94	NS
			After 20 days at 13°C			
T1 None	NA	NA	NA	NA	NA	NA
T2 MAP 702-I	42.97	-11.17	27.28	67.17	14.33	70.81
T3 MAP 702-J	43.04	-13.10	24.87	69.83	7.27	66.98
T4 MAP 702-K	44.32	-10.95	25.85	57.70	16.70	72.24
T5 MAP A-38	47.00	-12.37	25.69	64.68	10.11	73.24
T6 MAP B-50	44.49	-12.47	25.24	65.70	7.63	74.42
T7 MAP 1X	42.62	-13.11	21.58	64.65	13.06	77.63
T8 MAP 2X	43.14	-12.61	23.53	69.06	8.22	72.55
T9 MAP 3X	43.71	-12.63	23.02	66.96	9.89	77.46
T10 MAP 4X	42.80	-11.60	24.09	65.57	11.80	78.63
L.S.D at 5%	NS	NS	NS	NS	NS	NS

NA: No fruits were available as all fruits of the control samples exhibited excessive deterioration and were not fit for any usage or evaluation.

At this stage (after 20 days at 13°C), some fruits from each treatment were ripened for 2 days at 25°C and sensory evaluation of taste was conducted by experienced panel. Fruits of T5 and T10 exhibited full flavor and high aroma and were closely followed by fruits of T6 while fruits of other MAP treatments failed to develop good flavor. Thus while most MAP treatments significantly delayed the ripening indices, only film treatments of T5 and T10 resulted in full-flavored fruit. This suggests that among all films tested, these two treatments, T5 and T10, provided best modified atmosphere of low O_2 and high CO_2. This conclusion is based on the fact that flavor is affected by O_2 and CO_2 levels (Kader *et. al.*, 1989; Mattheis and Fellman, 2000) due to their effect on the changes in TSS and acidity as well

as other flavor compounds. Although the level of micro-perforations is proprietary information of the manufacturer, we know that the film of T5 has fewer micro-perforations than that of T6 (same supplier) and the film of T10 has the highest level of micro-perforations among other film treatments of the same other supplier. Thus these two levels of micro-perorations provided best effective permeability and best combined O_2 and CO_2 for MAP for 2.500 to 3.000 Kgs mango fruits. As compared to non-packaged fruits, these two packaging treatments significantly affected the following quality attributes:

1. Maintaining fruit appearance and fruit firmness.
2. Delaying development of the yellow and orange color in the peel.
3. Delaying the increase in TSS%.
4. Extending shelf life at 13°C to at least 20 days as compared to at most 10 days for the non-packaged fruits.

Table 3: The effects of modified atmosphere packaging, MAP, on flesh firmness, total soluble solids, titratable acidity and TSS/acid ratio for mango cv. Ewais.

Film Treatment	Flesh Firmness $Kg.cm^{-2}$	Total Soluble Solids (TSS) %	Titratable Acidity %	TSS/Acid Ratio
		Day 1		
None	9.0	11.9	3.0	4.0
		After 10 days at 13°C		
T1 None	0.0	22.4	0.92	24.3
T2 MAP 702-I	3.9	17.4	0.55	31.6
T3 MAP 702-J	2.3	18.5	1.44	12.8
T4 MAP 702-K	0.0	19.9	0.66	30.2
T5 MAP A-38	0.1	16.4	1.41	11.6
T6 MAP B-50	0.2	16.5	1.88	8.8
T7 MAP 1X	0.2	15.9	1.60	10.0
T8 MAP 2X	0.3	17.1	1.92	8.9
T9 MAP 3X	0.0	18.7	1.48	12.6
T10 MAP 4X	0.2	17.2	1.24	14.0
L.S.D at 5%	0.5	1.0	0.83	-
		After 20 days at 13°C		
T1 None	NA	NA	NA	NA
T2 MAP 702-I	0.0	15.2	0.39	39.0
T3 MAP 702-J	0.0	14.0	0.96	14.6
T4 MAP 702-K	0.0	18.3	0.53	34.5
T5 MAP A-38	0.0	20.2	1.29	15.7
T6 MAP B-50	0.0	18.3	1.18	15.5
T7 MAP 1X	0.0	21.1	1.09	19.4
T8 MAP 2X	0.0	19.2	1.94	9.9
T9 MAP 3X	0.0	20.2	1.53	13.3
T10 MAP 4X	0.0	18.4	1.00	18.4
L.S.D at 5%	NS	3.8	0.62	-

NA: No fruits were available as all fruits of the control samples exhibited excessive deterioration and were not fit for any usage or evaluation.

At day 1, texture was 40.79 for 3 mm and 95.69 for 5 mm. At days 10 and 20, texture was 0.00 for all samples.

Our results are in agreement with those reported by (Kader, 1986, 1997 and 2002; Kader *et. al.*, 1989; Beaudry, 2000; Mattheis and Fellman, 2000; Watkins, 2000). In this study, the limiting factors to further extension in storage life were loss of flesh firmness and loss of fruit texture.

Response to 1-Methylcyclopropene (1-MCP)

At day 1, the fruits were fully mature as evidenced by sensory evaluation with dark green peel color, very firm (hard), light yellow-orange flesh color and lack of aroma (Table 4) which are supported by L*, a* and b* quantitative measurements (Table 5). These fruits exhibited high flesh firmness of 8.3 $Kg.cm^{-2}$, low TSS of 11.7%, high titratable acidity of 2.73% and low TSS/Acidity ratio of 4.3% (Table 6).

Table 4: The effects of 1-methylcyclopropene, 1-MCP, on sensory evaluations of mango fruit cv. Ewais.

1-MCP treatment	*Quality attribute*					
	General Appearance	Aroma	Fruit Firmness	Peel Color	Flesh Color	Decay
			Day 1			
None	9.0	1.0	5.0	1.2	2.5	1.0
			After 10 days at 13°C			
T1 0-ppm	8.7	2.1	1.0	2.3	4.7	1.0
T2 1-ppm	8.3	2.0	1.0	1.5	4.3	1.0
T3 5-ppm	8.3	2.2	1.0	2.3	4.6	1.0
L.S.D at 5%	NS	NS	NS	NS	NS	NS
			After 10 days at 13°C + 2 days at 25°C			
T1 0-ppm	5.4	3.0	1.0	2.5	4.9	1.0
T2 1-ppm	5.4	2.0	1.0	3.0	4.7	1.0
T3 5-ppm	5.0	2.6	1.0	2.7	4.7	1.0
L.S.D at 5%	NS	NS	NS	NS	NS	NS

Scale:
General appearance: 9 = fruit exhibited fresh look and free of defectives; 1 = fruit exhibited excessive defectives.
Aroma: 5 = rich typical mango aroma; 1 = no aroma.
Firmness: 5 = Very firm (hard); 1 = soft.
Peel color: 5 = yellow, 4= 3/4 yellow; 3 = 1/2 yellow; 2 = 1/4 yellow; 1 = green.
Flesh color: 5 = dark orange; 4 = yellow/orange; 3 = yellow; 2 = light yellow; 1 = white.
Decay: 5 = excessive; 1 = none.

After 10 days at 13°C, all fruits whether untreated (T1) or treated with 1.0-ppm or 5.0-ppm 1-MCP (T2 and T3, respectively) exhibited comparable changes indicating lack of an effect of 1-MCP treatment and that all fruits

progressed into ripening with no significant effect of 1-MCP treatment. Sensory evaluated quality attributes (Table 4) illustrate that all fruits had comparable good general appearance, no decay, comparable loss of some of the green color in the peel and development of approximately 1/4 yellow, development of orange-dark orange color in the flesh and loss of firmness. Peel and flesh L*, a* and b* indicate that:

- L* showed minimum comparable changes in the peel of all samples between that of day 1 and 'after 10 days' at 13°C (Table 5), which is in line with the sensory evaluation (Table 4). However, L* values of the flesh exhibited higher magnitude changes, although comparable for all samples, during this storage period. This is also in line with the sensory evaluation and supports the findings of the lack of an effect of 1-MCP treatment.
- a* values of the peel and flesh of untreated fruits and those treated with 1.0-ppm 1-MCP were comparable indicating that treatment with 1.0-ppm 1-MCP for 48-hours had no effect on the changes in a* values of either the peel or the flesh. However, 5.0-ppm 1-MCP significantly increased a* of the peel, which may suggest an enhanced ripening.
- b* increased in each of the peel and flesh 'after 10-days' at 13°C. The results of the peel and flesh samples were comparable for untreated fruits and for fruits treated with 1.0-ppm 1-MCP. Fruits treated with 5.0-ppm 1-MCP exhibited significantly higher b* values in the flesh than untreated fruits.

Table 5: The effects of 1-methylcyclopropene, 1-MCP, on peel and flesh color of mango fruit cv. Ewais.

1-MCP treatment	Peel			Flesh		
	L*	a*	b*	L*	a*	b*
			Day 1			
None	47.57	-15.77	27.37	70.17	4.47	64.93
			After 10 days at 13°C			
T1 0-ppm	50.97	-9.83	35.37	59.33	12.27	77.53
T2 1-ppm	50.77	-8.50	37.63	65.73	12.67	77.33
T3 5-ppm	50.83	-11.60	36.43	60.43	14.00	81.87
L.S.D at 5%	NS	1.52	NS	NS	NS	2.34
			After 10 days at 13°C + 2 days at 25°C			
T1 0-ppm	49.60	-6.77	39.40	56.87	15.23	79.27
T2 1-ppm	48.63	-4.27	38.73	60.90	16.07	76.37
T3 5-ppm	51.43	-5.90	40.53	60.40	15.63	81.30
L.S.D at 5%	NS	NS	NS	NS	NS	NS

Thus, quantitative measurements 'after 10-days' of storage at 13°C (Table 6) illustrated that all samples completely lost their flesh texture and flesh firmness, which indicate that 1-MCP had no effect. However, since the

response was measured after 10 days, the kinetics of the response is not known. This is also true for all other indices. By comparison, TSS increased during this storage from 11.7% at day 1 to 17.3% with no significant differences between untreated and 1-MCP treated samples. Contrary to that, titratable acidity decreased in all samples from 2.73% at day 1 to 0.70%. The magnitude of decrease was highest in the samples treated with 5.0-ppm and was significantly different from that of the untreated fruits. The increase in TSS and decrease in titratable acidity caused the TSS/Acid ratio to increase from 4.3 at day 1 to 20.3. The increase in this ratio is almost 5 times the initial value of day 1 and represents the highest change in magnitude of any quality attribute measured.

Table 6: The effects of 1-methylcyclopropene, 1-MCP, on flesh firmness, total soluble solids, titratable acidity and TSS/acid ratio for mango cv. Ewais.

1-MCP treatment	Flesh Firmness $Kg.cm^{-2}$	Total Soluble Solids (TSS) %	Titratable Acidity %	TSS/Acid Ratio
		Day 1		
None	8.3	11.7	2.73	4.3
		After 10 days at 13°C		
T1 0-ppm	0.0	18.9	0.93	20.3
T2 1-ppm	0.0	17.3	0.80	21.6
T3 5-ppm	0.0	17.8	0.70	25.4
L.S.D at 5%	NS	NS	0.18	-
		After 10 days at 13°C + 2 days at 25 °C		
T1 0-ppm	0.0	20.5	0.57	36.0
T2 1-ppm	0.0	19.3	0.43	44.9
T3 5-ppm	0.0	19.8	0.53	37.4
L.S.D at 5%	NS	0.38	NS	-

At day 1, flesh texture was 67.49 and 100.70 for 3 and 5 mm depth, respectively. At days 10 and 10+2, flesh texture for all samples was = 0.0 for 3 and 5 mm depth.

This indicates that treatment with 1.0-ppm 1-MCP for 48 hours had no effect on the loss in flesh texture and flesh firmness, increase in TSS, loss in titratable acidity and the increase in TSS/acidity ratio 'after 10 days' of storage at 13°C. However, treatment with 5.0-ppm 1-MCP significantly increased the loss in titratable acidity than untreated fruit, otherwise it had no significant effect on other indices.

After 10-days at 13°C plus 2-days at 25°C, sensory evaluation of quality attributes (Table 4) indicated that all fruits continued to ripe exhibiting loss in fruit firmness, increase in aroma, flesh color and peel color, and substantial deterioration in fruit appearance, although no decay was observed. Fruit response, untreated or 1-MCP treated, was comparable

which is in line with previous findings and indicates a complete lack of response to 1-MCP treatment.

There was no significant effect of 1-MCP treatments on L*, a* or b* of either the peel or the flesh (Table 5). Each of flesh texture and flesh firmness was already at its minimum during the previous evaluation. However, each index was evaluated again (Table 6) and verified. In the meantime, TSS slightly increased (only 5.0-ppm increased TSS significantly) and titratable acidity slightly decreased and that effect was not significantly different from that of the untreated fruits. This differential response of these two indices resulted in increasing TSS/Acid ratio.

These observations are in line with those noted 'after 10 days', namely, that 1.0-ppm 1-MCP (the maximum recommended and approved application) did not affect the keeping quality of treated mango fruits, while at 5.0-ppm (not approved by the USA Food and Drug Administration) it had mostly no effect or it inconsistently affected few indices in a direction toward enhancing fruit ripening. These results are not in agreement with the reported effects of 1-MCP in enhancing the post-harvest keeping quality of perishable commodities. For example, treatment with 1-MCP is reported to retard softening and extend shelf life of numerous fruits (indicated previously). It acts by blocking the action of ethylene (Blankenship, 2001). Its inhibitory effect on ethylene action is independent of any effect it may exert in inhibiting ethylene synthesis. This is based on the theory that 1-MCP binds itself to the ethylene active sites which are present on proteins in the cells. These sites and proteins are referred to as '1-MCP traps'. For 1-MCP to become effective in blocking the action of ethylene, the following conditions must be met:

1. 1-MCP must reach inside the cells. In this study 1-MCP was applied at room temperature to facilitate its penetration and was applied for 48 hours to allow adequate time for 1-MCP to penetrate. The observed lack of effect of 1-MCP is supported by the finding that when 1-MCP was applied to cut mango, i.e., the integrity of the peel as a possible barrier to 1-MCP penetration was removed, the chemical was effective (Vilas-Boas and Kader, 2001).
2. 1-MCP must be in quantity adequate to saturate all ethylene-active sites. In this regard, two concentrations of 1-MCP (1.0 and 5.0-ppm) were tested. The highest concentration, 5.0-ppm, is much higher than the maximum 1.0-ppm that is recommenced and allowed (Warner, 2002, personal communication).
3. The phenomenon to be tested must be known to respond to ethylene. This is the case with mango fruits. Mango is a climacteric fruit in which endogenous ethylene plays a role, like all climacteric fruits, in its ripening and it can be ripen by gassing with ethylene.

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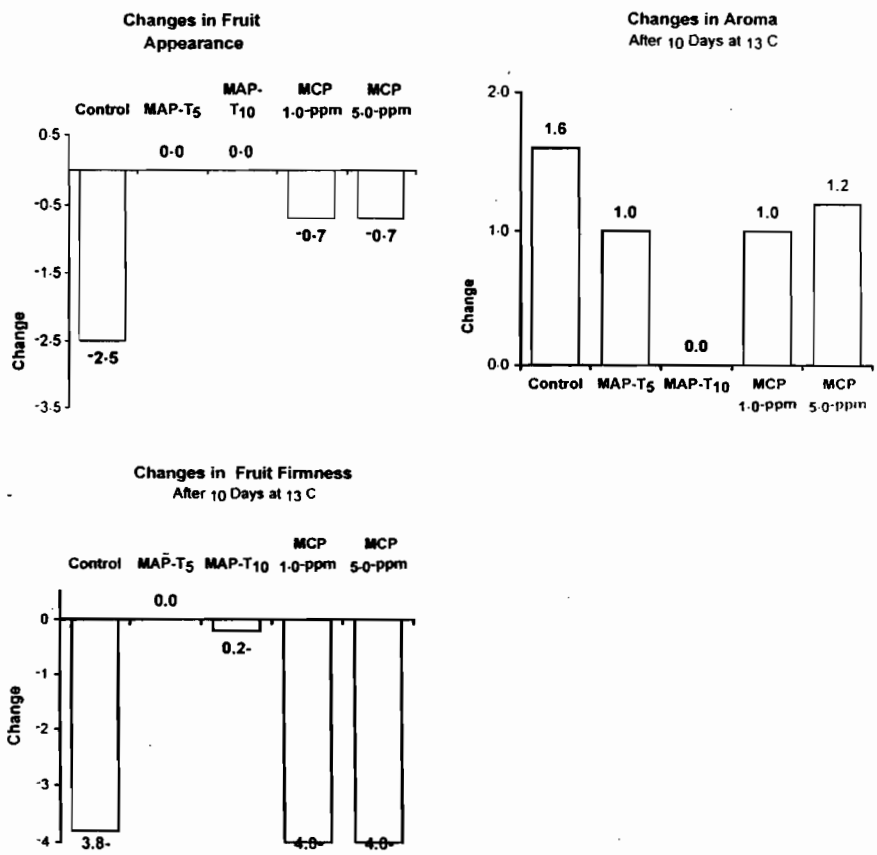

Figure 1: Changes in fruit general appearance, fruit aroma and fruit firmness (by sensory evaluation) after storage for 10 days at 13° C.

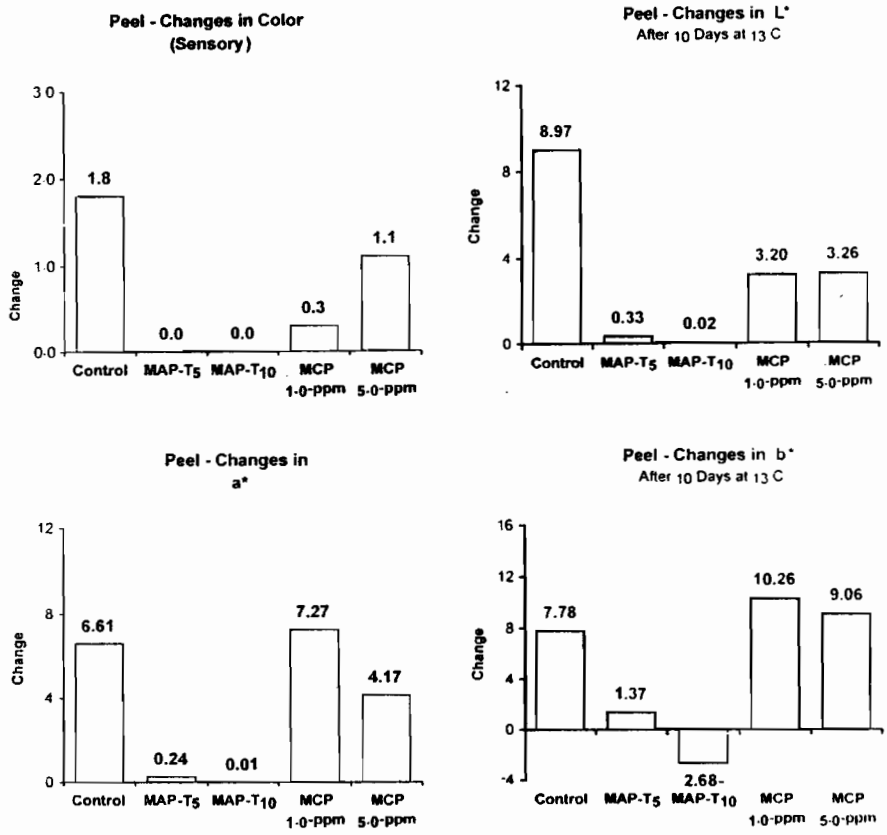

Figure 2: Changes peel color (by sensory evaluation) and in L*, a" and b" (by Hunter Instrument) after storage for 10 days at 13° C.

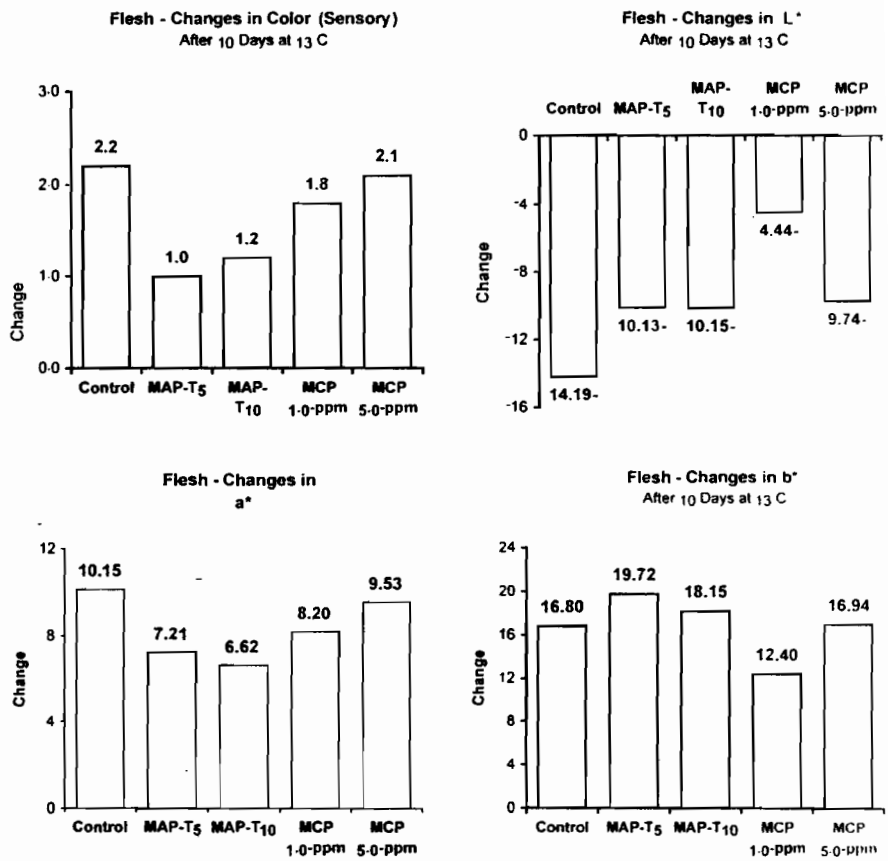

Figure 3: Changes flesh color (by sensory evaluation) and in L*, a" and b" (by Hunter Instrument) after storage for 10 days at 13° C.

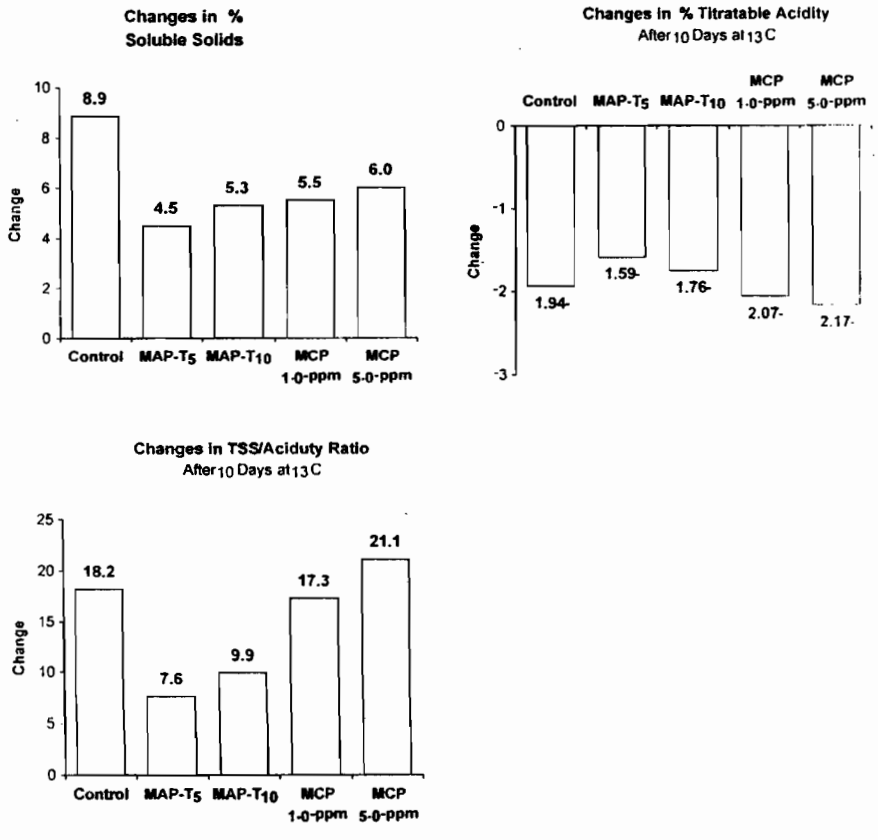

Figure 4: Changes in total soluble solids (TSS), titratable acidity ant TSS/acid ratio after storage for 10 days at 13° C.

Differential Response of Ewais Mango to MAP and 1-MCP

The observed lack of mango fruit response to 1-MCP presents a sharp contrast to the effect of MAP which was highly effective in delaying post-harvest fruit ripening and in extending fruit life (as illustrated in Figures 1, 2, 3 and 4). This differential response of Ewais mango to post-harvest applications of MAP and 1-MCP is, most likely, related to their mode of action. The effect of 1-MCP is not dependent on its effect on reducing ethylene production since it is also effective in the presence of applied exogenous ethylene. To be effective, 1-MCP must be able to penetrate the cells, reach to the ethylene active sites and binds itself firmly on those sites. Any factor that may interfere with any of these processes would render it ineffective. It is proposed that Ewais mango fruit contain compound(s) that interfered with the ability of 1-MCP to bind itself firmly on the ethylene active sites and/or cause the rapid destruction of 1-MCP or could be attributed to the reduction of 1-MCP penetration due to the peel since 1-MCP was effective on fresh cut mango as indicated by (Vilas-Boas and Kader, 2001).

By comparison, the positive impact of MAP on extending post-harvest life of perishable produce may be due to its effect on reducing respiration rate, ethylene synthesis, fruit response to ethylene and retarding chlorophyll degradation (Kader, 1986, 1997 and 2002; Kader *et. al.,* 1989; Beaudry, 2000; Mattheis and Fellman, 2000; Watkins, 2000). These responses are feasible as long as the MAP O_2–TR, CO_2–TR and WVTR transmissions are within the physiological needs of packaged produce with respect to amount of produce packaged and the storage environment. Apparently, this was the case with the two films used in T5 and T10.

The findings indicate that MAP was effective in maintaining fruit quality and in extending the shelf life of mango, with T5 and T10 being the best in this regard. On the other hand, 1-MCP had no significant effect on mango storage life. The differential response of Ewais mango to MAP and 1-MCP is suggested to be due to their mode of action.

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الاستجابة المختلفة لثمار المانجو للتعبئة في جو هوائي معدل والمعاملة بـــ ١- مثيل سيكلوبروبان بعد الحصاد

راوية البسيونى ابراهيم البسيونى

قسم تداول الخضر – معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة

تمت دراسة استجابة ثمار المانجو صنف عويس للتعبئة في أجواء معدلة وذلك باستخدام ٩ أنواع من المغلفات المثقبة بالليزر ذات نفاذية مختلفة ، وكذلك للمعاملة بـ ١- مثيل سيكلوبروبان بتركيز ١ و ٥ جزء في المليون لمدة ٤٨ ساعة عند درجة حرارة من ٢٣م – ٢٤م. وقد تم تخزين ثمار جميع المعاملات بالإضافة للكنترول لمدة ١٠ أيام و ٢٠ يوما عند درجة حرارة ١٣م بالإضافة إلى يومين عند درجة ٢٥م ، كما تم تقييم الاستجابة باستعمال الصفات الحسية ولون الثمار واللحم والصلابة والقوام والمواد الصلبة الذائبة والحموضة ونسبة المواد الصلبة الذائبة إلى الحموضة. وقد أظهرت النتائج أن جميع عبوات الأجواء المعدلة أطالت فترة حياة الثمار لأكثر من ٢٠ يوما مقارنة بـ ١٠ أيام على الأكثر للثمار غير المعبأة ، وكانت معاملتي T5 و T10 هما الأفضل في توفير جو هوائي معدل كما تميزت ثمارهما بجودة نكهتها في نهاية فترة التخزين ، ووجود فروق معنوية لصالحهما من جهة الاحتفاظ بجودة الثمار وصلابتها ، وتأخير تكوين الصبغات الملونة في القشرة ، وتأخير الزيادة في نسبة المواد الصلبة الذائبة ، في حين لم يكن للمعاملة بـ ١- مثيل سيكلوبروبان بتركيز ١ جزء في المليون أي تأثير معنوي لإطالة فترة تخزين الثمار. هذا ويرجع الاختلاف في استجابة المانجو للتعبئة في أجواء معدلة وللمعاملة بـ ١- مثيل سيكلوبروبان إلى تباين طبيعة تأثيرهما.