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Postharvest Ripening and Shelf Life of Mango (*Mangifera indica* L.) Fruit as Influenced by 1-Methylcyclopropene and Polyethylene Packaging

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Abstract

*The mango (**Mangifera indica** L.) is a climacteric and highly perishable fruit that requires specialized postharvest handling to extend its storage life. The study was undertaken at Melkassa Agricultural Research Center (MARC) to evaluate the influence of 1-Methylcyclopropene (1-MCP) and polyethylene packaging (PP) on postharvest storage of mango. Fruits of two mango cultivars namely 'Apple' and 'Kent' were harvested at green-mature stage and were treated with gaseous 1-MCP (100 or 500 nLL^{-1}) in closed plastic containers for 18 hours and then individual fruits were either packaged with perforated polyethylene bags or kept without packaging. They were stored up to 21 days under ambient condition at temperature of 25.7 ±2.6^{o}C and relative humidify of 66.1±11.8%. Treatments were laid out in factorial arrangement in RCBD with three replications. The physiological weight loss (PWL), peel color change, firmness, juice content, total soluble solids (TSS) and titratable acidity (TA) were significantly ($p<0.01$) affected by 1-MCP treatment and polyethylene packaging throughout the storage periods. The 1-MCP treated and packaged fruits showed better performance in all physiological ripening qualities as compared to 1-MCP untreated and non-packaged fruits. The 1-MCP treatment and polyethylene packaging significantly reduced PWL. These treatments maintained better mango fruit quality in terms of firmness, juice content and TSS of mangoes. Thus, the result clearly showed that 1-MCP treatment and polyethylene packaging at ambient condition can extend storage life and maintain quality of mango fruits for about nine and six days, respectively. Therefore, 1-MCP treatment and polyethylene packaging can be used separately or together to extend storage life and maintain quality of mango fruits for remarkable days. Therefore, 1-MCP and PP can be used singly or combined to extend the shelf life and maintain quality of mango fruit for weeks on ambient storage condition.*

Key words: Mango Fruits, 1-Methylecyclopropene, Polyethylene Packaging, Quality, Storage Period

Introduction

The mango (*Mangifera indica* L.) is a tropical evergreen fruit tree commercially grown in many countries and popular both in the fresh and the processed forms (Mukherjee, 1997, Mitra and Bildwin, 1997). It is one of the most popular fruits of the world, because of its attractive color, delicious taste and excellent nutritional properties (Rice *et al.*, 1990). Among fruits cultivated in different Regional States of Ethiopia, mango is preceded only by banana; and the first in Gambela and Southern Ethiopia Regions (Edossa *et al.,* 2006). In 2008, the total area of production under small holders and production was estimated about 6.1 thousand hectares and 0.44 million metric ton, respectively (CSA, 2008).

Mangoes are classified as climacteric fruit and ripen quite rapidly after harvest (Mitra, 1997). Mango is very delicate and perishable fruit, highly susceptible to post harvest disease, extreme temperature and physical injuries (Kays, 1991). The general perishable nature of the fruit, sensitivity to low storage temperatures and disease problems limit transport distances of fresh fruits from production farms to markets (Mitra and Bildwin, 1997). The postharvest loss of some tropical fruits in the state farms and peasant sectors in Ethiopia was up to 49.2 %, due to handling (Kader, 2009).

The development of technologies to extend postharvest life would require approaches aimed at inhibiting ethylene action which is known to involve in the induction of ripening or retarding process have already been initiated before harvest (Lizada, 1991). The 1-Methylcycloprorene (1-MCP) is known to regulate both respiration and ethylene effects in many fruits which are known to be climacteric (Sisler and Serek, 2003). This product has been recognized as an ethylene action inhibitor that could block ethylene perception, preventing adverse ethylene responses in plant tissues for extended periods (Feng *et al.,* 2000). Mango is among the crops registered for 1-MCP treatment (Watkins, 2006). Modified Atmosphere Packaging (MAP), on the other hand, has been reported to affect postharvest quality of mango (Silva *et al.* 2004; Alye, 2005). According to Alye (2005) packaged fruits showed reduced physiological weight loss, higher pH, lower titratable acids and higher total sugar content than non-packed mango fruits.

Nowadays, 1-MCP is widely used through out the world. However, in Ethiopia, there is limited information and experience in the post harvest handling of mangoes in general and the use of 1-MCP, in particular, as postharvest treatment to extend the shelf life of mangoes. So far, there are no experiments conducted to assess the influence of 1-MCP on mango cultivars growing in Ethiopia. Therefore, the present study was initiated with the aim to evaluate separate or combined effect of 1-MCP and polyethylene packaging on postharvest ripening, shelf life and quality of mango fruits.

Materials and Methods

Experimental site

The experiment was carried out at Melkassa Agricultural Research Center (MARC) which is located at latitude 8°4' N and longitude 39°21' E and 115 km Southeast of Addis Ababa. The experiment site is situated at an altitude of 1550 masl and it is characterized by mean annual rainfall of 763 mm of which about 70% precipitates from June to September. Mean maximum and minimum temperature are 28.4°C and 14.0°C, respectively (MARC, 2007).

Treatments and experimental design

The experiment was conducted between July and August 2009. Two mango cultivars ('Apple' and 'Kent') were used to investigate the effect of 1-Methylcyclopropene (1-MCP) and polyethylene packaging (PP). A randomized complete block design (RCBD) with three replications was used and the treatments were arranged in a factorial scheme. The experiment followed 3*2*2 factorial arrangement, with three levels of 1-MCP (100, 500 nLL^{-1} and a control/without 1-MCP); two levels of PP (packaged and non-packaged) and two mango varieties ('Apple' and 'Kent').

Experimental procedures

Sample Preparation

The fruits were harvested at mature-green stage and carried out with care to minimize mechanical injuries. Fruits were collected in plastic box and were placed under shade, for about two hours, until transported to the horticulture laboratory of MARC. Uniform fruits with similar size and color were selected and hand washed with tap water to remove field heat, clear dust particles and to reduce microbial population that might be present on the fruit surface.

Treating With 1-MCP

Fruits were labeled and then grouped into three lots and each lot was kept in three large plastic containers, with a tight lid and with capacity of 330 liters, for 1-MCP treatment. The fruits were treated according to the procedures described by Fan *et al*. (1999). The formulated 1-MCP (Lupo Fresh™, Vankor Ltd., China) was uniformly distributed by shaking the solution. Then, the button was pressed to spray the solution in the free space for fumigation for 6 seconds and 30 seconds to have 100 nLL^{-1} and 500 nLL^{-1} 1-MCP concentrations, respectively. The plastic containers were closed tightly immediately after 1-MCP application and kept for 18 hours at ambient conditions.

Packaging

A low-density perforated PP with the thickness of 7.5 µm (Ethiopia plastic S.C.) was used to package individual mango fruits. Up on removal from sealed containers, about 50% of mango fruits were packaged and the other half were left without packaging.

Data collection

Samples of two mango fruits were randomly taken at a time from each treatment for physiological and physico-chemical quality assessment. Data collection started at sixth date of storage and then in every three days interval. The following data were collected.

Physiological weight loss of fruit

Weight of sample fruits were measured and recorded using precision scale (Sartorius GMBH Gottingen, Germany, model LS200). Physiological weight loss (PWL) was determined using the formula: Weight loss (%) = [(Initial weight – Final weight) / Initial weight] x 100

Peel color

Ripening of fruits were visually assessed by skin color and scored by experienced sensory panelists, based on specific cultivar color, using a 1 to 6 scale which represent six ripening stages of mango fruits as described by Silva *et al*. (2004). The six ripening stages were represented as 1 = totally green; 2 = <25 % color change; 3 = 25-50 % color change; 4 = >50 % but <100 % color change; 5 = 100 % color change; and 6 = color with many black spots. A color chart was used to support the visual or sensory observation.

Firmness

Firmness of mango fruits from different treatments was assessed using a texture analyzer (TA.XT.Plus, Stable Micro Systems Ltd., UK). Whole mango fruits were measured for maximum penetrating force using 4 mm diameter stainless cylinder probe rig attachment at a cross-head speed of 0.5 mm per second for a maximum penetration distance of 10 mm. The force required to penetrate were automatically recorded by software installed.

Juice content

Juice content of mango fruits was determined according to the procedure described by Lacey, *et al.* (2001). Weight of sample fruits were measured and recorded using precision scale and then the flesh part of the sample fruits were extracted and their weight were recorded. Percentage of juice content was determined by the formula:

Juice content (%) = (Flesh weight / Fruit weight) x100

Fruit marketability

The descriptive quality attributes were determined subjectively by observing the surface appearance characteristics such as smoothness or shininess, shriveling or dehydration, and the level of visible mould growth. Shiny mango fruits without shriveling, rotting and free of black spots were considered as marketable fruits and calculated as follows:

$$\text{Percentage marketability} = \frac{\text{Number of marketable fruits}}{\text{Total number of fruits}} \times 100$$

Total soluble solids

Mango juice was extracted from the sample fruits and blended using juice blender (New Harteford, Waring Commercial, USA). Total soluble solids (TSS) of mango juice was measured by a portable hand Refractometer (Miscor, Japan) with a range of 0 to 30^{o} Birx and resolutions of 0.2. The ^{o}Brix reading was used to determine TSS by placing 1 to 2 drops of clear juice on the prism of the Refractometer. Between samples reading, the prism of the Refractometer was washed with distilled water and dried with a tissue paper.

Titratable acidity

Mango juice was extracted from the sample fruits and blended using juice blender (New Hharteford, Waring Commercial, USA). Titratable acidity (TA) was determined according to procedures described by Nielsen (2003) using digital titration instrument (Jencons Digitrate, UK). Mango juice (10 ml) was diluted with 20 ml distilled water and then five drops of phenolphthalein were added as an indicator. It was titrated with 0.1N NaOH until the indicator changed pink and then the titrate volume of NaOH was recorded. The TA, expressed as citric acid (with equivalent weight of 64.04) using the following formula.

$$\%\ \text{Acid} = \frac{(\text{ml NaOH}) \times (\text{N of the base in mol/liter}) \times (\text{Eq. wt. of acid})}{(\text{Sample volume in ml}) \times 10}$$

Statistical analysis

Analysis of variance (ANOVA) was performed to determine differences between the treatments with factorial arrangement in RCBD (Gomez and Gomez, 1984). The results were analyzed with Statistical Analysis System (SAS) soft ware version 8 (SAS 2002). Comparisons of the treatment means was done by the least significant difference (LSD) test at 5% significance level. Data on interaction of treatment factors is only presented when significant and left for insignificant combinations.

Results and Discussion

Physiological weight loss

Physiological Weight Loss (PWL) of mango fruits were affected significantly by both 1-MCP treatment and polyethylene packaging throughout the storage periods. Interaction effects were non-significant ($p>0.05$) for PWL of mango fruits. The 1-MCP affected mango fruits significantly ($p<0.01$) in reducing PWL (Table 1). Mango fruits treated with 1-MCP showed lower percentage PWL as compared to the fruits stored without 1-MCP treatment. The maximum PWL (9.98%) were recorded for 1-MCP untreated fruits on 21st days while PWL for mangoes treated with 100 nL.L^{-1} and 500 nL.L^{-1} 1-MCP were 6.54% and 5.42%, respectively. This reduction in PWL is most probably because of the property of 1-MCP that blocks the action of ethylene which has a direct relation with respiration and fruit ripening (Sisler and Serek, 2003). The result is in line with observations of Silva *et al.* (2004) who reported that mango fruits treated with 1-MCP showed reduced weight loss as compared to non-treated control in two mango cultivars. However, non-significant difference ($p>0.05$) was observed between 100 nL.L^{-1} and 500 nL.L^{-1} 1-MCP concentration treatments which might indicate that its effectiveness in blocking the receptors of ethylene at low concentration as stated by Sisler and Serek (1997).

The PP also showed significant difference ($p<0.01$) in reducing PWL throughout the storage periods. Packaged fruits were with lower PWL as compared to the non-packaged fruits (Table 1). Higher PWL were recorded on 18th day of storage for non-packaged mango fruits with maximum value, 12.34%. On the same date of storage, PWL for packaged mangoes were only 3.93%. Higher relative humidity and modified atmosphere created within the package were possible causes for significant reduction of PWL for packaged mango fruits. Wills *et al.* (1998) stated that faster air movement around fruits may result in higher water loss. The result agrees with reports of many researchers (Cocozza *et al*., 2004; Silva *et al*.; 2004, Alye, 2005). Such effect of MAP is possibly through depletion of oxygen and release of carbon dioxide in the sealed plastic packaging free space (Be-Yehoshua *et al.,* 1985) when the fruits are ripening.

Generally, PWL increased with storage time throughout the storage period. The minimum weight losses were recorded at the beginning of each storage period while the maximum values were towards the end of storage (Table 1). This phenomenon was also reported by Zeweter (2008).

Table 1. Physiological weight loss (%) of mango fruits as affected by 1-MCP and polyethylene packaging (PP)

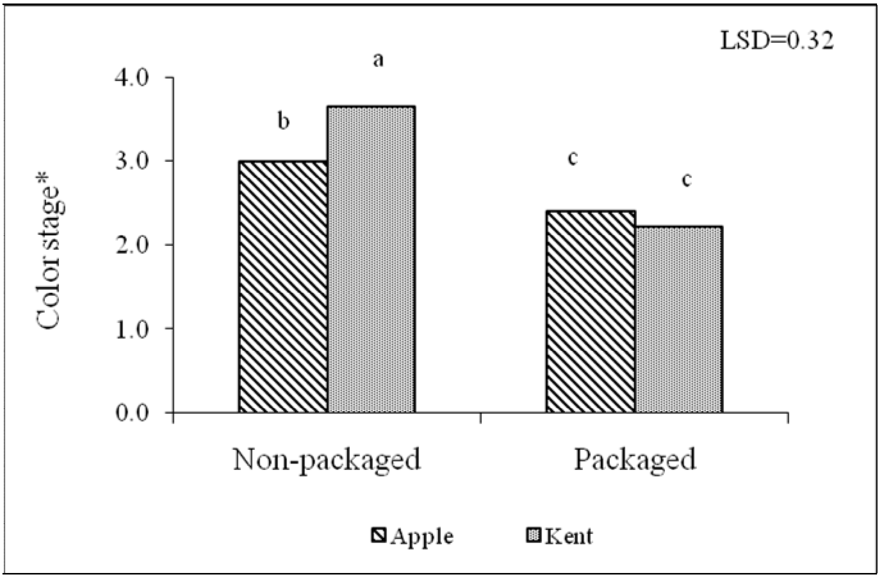
Treatments		Storage period on days					
		6	9	12	15	18	21
1-MCP(nLL^{-1})	0	2.84^{a}	6.29^{a}	7.60^{a}	8.96^{a}	9.74^{a}	9.98
	100	1.81^{b}	4.49^{b}	6.02^{b}	6.96^{b}	7.40^{b}	6.54
	500	1.81^{b}	4.14^{b}	5.78^{b}	6.8^{b}	7.27^{b}	5.42
	LSD*	0.59	0.92	0.90	1.36	0.69	4.73
PP	kaged	1.58^{b}	2.24^{b}	2.62^{b}	3.38^{b}	3.93^{b}	7.31
	kaged	4.73^{a}	7.72^{a}	10.31^{a}	11.77^{a}	12.34^{a}	-
	LSD*	0.48	0.75	0.74	1.11	0.56	3.86 -
Cultivars	Apple'	3.38	5.06	6.25	7.50	7.70	9.197
	'Kent'	2.93	4.89	6.68	7.65	8.58	5.437
	LSD*	0.48	0.75	0.74	1.11	0.56	
SE		0.49	1.18	1.14	2.59	2.59	13.56
CV (%)		12.16	11.83	9.55	11.23	10.12	18.33

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different.

*Least significant different at 5% level

Peel Color

Peel color change of mango fruits was significantly affected ($p<0.01$) by both 1-MCP treatment and polyethylene packaging throughout the storage periods. There was also significant interaction effect between PP and cultivars ($p<0.05$) on 6th storage day (Figure 1). 'Kent' was with higher color stage for non-packaged mango fruits while its packaged fruits were with lower peel color change (Figure 2). This might indicate that color change in 'Kent' mango responds fast under polyethylene packaging. Silva *et al.* (2004) reported that mango cultivars varied in their response to some postharvest treatments.



*1 = totally green; 2 = <25 % color change; 3 = 25-50 % color change; 4 = >50 % but <100 % color change; 5 = 100 % color change; and 6 = color with wide (many) black spot

Figure 1. The interaction effect between polyethylene packaging and mango cultivars for color change of mangoes

The 1-MCP treatment showed significant difference ($p<0.01$) throughout the storage periods with regard to peel color change. Treatment with 1-MCP resulted in better color maintenance for all cultivars (Table 2). Mangoes without 1-MCP treatment reached around 100% color change on 9th day of storage while 1-MCP treated mango fruits reached this full color change at 18th day of storage. On the 18th day, 1-MCP non-treated mangoes peel showed many black spots where as the 1-MCP treated mangoes attained full color change with good appearance. Silva *et al.* (2004) reported that 1-MCP treatment effectively maintained the external appearance and reduced rate of color change for both cultivars they tested.

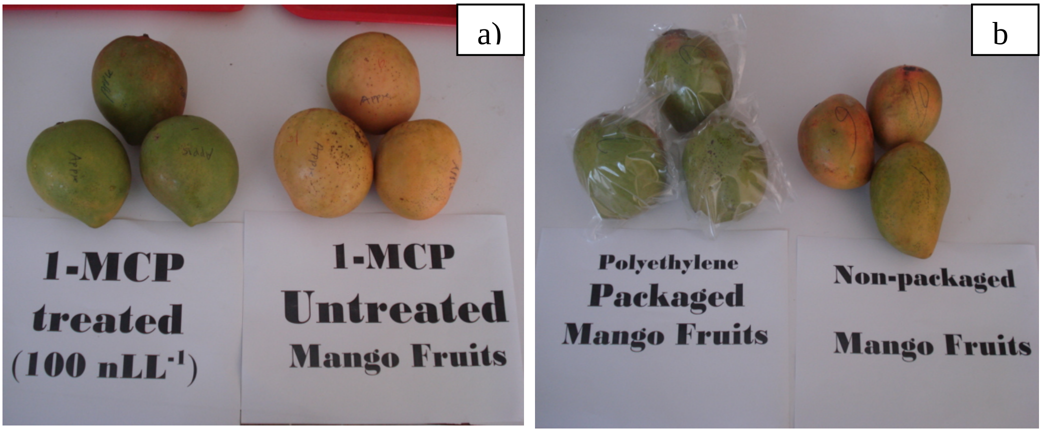


Figure 2. Color difference observed on 9th day of storage for 'Apple' mango fruits subjected to 1-MCP treatment (a) and polyethylene packaging (b)

The PP significantly affected ($p<0.01$) color change of mango fruits throughout storage periods. Packaged mangoes showed delay in color development than those of non-packaged ones (Table 2). Full color change was observed on 12th day of storage for non-packaged fruits and 18th day for packaged mangoes. The non-packaged fruits have access to O_2 to increase in concentration of ethylene which may enhanced respiration (Wills *et al.,* 1998). They showed rapid change in color from green to yellow, faster than the polyethylene packaged fruits. The observed delay in color change of packaged mango fruits as compared to non-packaged fruits might be due to retarded respiration as a result of modified atmosphere (O_2 depletion and CO_2 accumulation) in the packaging materials (Be-Yehoshua *et al.,* 1985). In line with the present result, a report of Cocozza *et al*. (2004) also show that MAP delayed skin color changes in 'Tommy Atkins' mangoes.

Table 2. Peel color change of mango fruits subjected to 1-MCP treatment and polyethylene packaging (PP)

Treatments		Storage period on days					
		6	9	12	15	18	21
1-MCP (nLL-1)	0	3.97[a]	4.63[a]	5.43[a]	5.76[a]	5.88[a]	6.21[a]
	100	2.27[b]	3.35[b]	3.91[b]	4.24[b]	5.53[b]	6.01[b]
	500	2.20[b]	3.11[b]	3.91[b]	4.20[b]	5.58[b]	5.93[b]
	LSD**	0.37	0.33	0.26	0.16	0.21	0.19
PP	Packaged	2.31[b]	3.35[b]	4.00[b]	4.85[b]	5.30[b]	6.22
	Unpackaged	3.32[a]	4.04[a]	4.84[a]	5.42[a]	5.99[a]	-
	LSD**	0.30	0.27	0.21	0.13	0.08	-
Cultivars	'Apple'	2.70	3.66	4.42	5.08	5.56	6.31[a]
	'Kent'	2.93	3.73	4.42	5.18	5.60	6.13[b]
	LSD**	0.30	0.27	0.21	0.13	0.08	0.15
SE		0.19	0.15	0.09	0.03	0.012	0.02
CV (%)		8.62	10.72	7.14	11.34	2.00	2.37

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different

* 1 = totally green; 2 = <25 % color change; 3 = 25-50 % color change; 4 = >50 % but <100 % color change; 5 = 100 % color change; and 6 = color with wide
(many) black spots

**Least significant different at 5% level

Firmness

The 1-MCP treatment, polyethylene packaging and cultivars significantly affected ($p<0.01$) firmness of mango fruits throughout the storage periods. Interaction effects were non-significant ($p>0.05$) for firmness of mango fruits. Mango fruits treated with 1-MCP required more force to penetrate as compared to untreated once (Table 3). This indicates that the 1-MCP has inhibition action on ethylene and hence delayed ripening process. As noted by Mattheis *et al* (2003), 1-MCP binds irreversibly to ethylene receptors and ripening of treated fruit will be delayed until new binding site is synthesized which could explain results observed in this study. However, the two 1-MCP treatment levels showed non-significant difference for fruit firmness, showing that 1-MCP effectively block the ripening action of ethylene at low concentrations. Silva *et al.* (2004) also stated that 1-MCP was effective at lower concentrations such as 100 nLL^{-1}.

The PP also resulted in significant difference ($p<0.01$) throughout the storage periods for fruit firmness. Packaged mango fruits needed higher force to penetrate indicating that they were firmer than non-packaged ones. For instance, force required to penetrate fruits from PP fruits on day 15 of storage was 15.52 N but only 10.96 N was required to penetrate fruits from non-packaged (Table 3). The effect of polyethylene bag in delaying loss of firmness could be due to modified atmosphere created within the packaging free space which may show influence to reduced rate of respiration (Zagory and Kader, 1988). Similar effect of polyethylene packaging was observed on banana fruits (Zeweter, 2008). In line with the present result, Cocozza *et* *al*. (2004) also reported that the application of 100 nL.L^{-1} and 500 nL.L^{-1} 1-MCP associated to MA maintained fruits firmness by 25% than the control.

In most of storage periods, significant differences (p<0.01) were observed with regard to firmness among mango cultivars. 'Apple' mango was firmer than 'Kent' (Table 3**)**. The observed difference between the mango varieties indicate that cultivars might differ in firmness genetically. This could be due to variation in physiological and physical characteristics among cultivars such as skin thickness. Jiang and Joyce (2000) described that positive effects of packaging in delaying ripening and maintain harvested product quality vary with plant genetic, physiological and morphological characteristics.

Generally, the force needed to penetrate the fruits decreased with storage time indicated that firmness of mangoes decreases ripening (Table 3). The steady reduction in fruit firmness during storage period is a natural process of ripening of almost all fleshy fruits as a result of biochemical changes of the cellular structure (Brady, 1987). That could be the reason for the observed reduction in firmness of mango fruits subjected to all treatments during storage time.

Table 3. Force (N) required to penetrate mango fruits treated by 1-MCP and polyethylene packaging (PP)

Treatments		Storage period on days					
		6	9	12	15	18	21
1-MCP (nLL-1)	0	14.79^{b}	15.14^{b}	13.98^{b}	11.75^{b}	10.39^{b}	8.45^{b}
	100	20.09^{a}	20.20^{a}	16.47^{a}	15.60^{a}	15.39^{a}	14.23^{a}
	500	21.49^{a}	21.64^{a}	17.92^{a}	16.03^{a}	15.67^{a}	15.92^{a}
	LSD*	2.18	1.95	1.79	1.58	1.21	4.75
PP	Packaged	21.66^{a}	21.58^{a}	18.16^{a}	16.41^{a}	15.90^{a}	12.86
	Unpackaged	15.92^{b}	16.41^{b}	14.09^{b}	12.52^{b}	12.41^{b}	-
	LSD*	1.78	1.59	1.46	1.29	3.33	-
Cultivars	'Apple'	22.23^{a}	22.12^{a}	17.23^{a}	15.95^{a}	15.19	15.14^{a}
	'Kent'	15.35^{b}	15.86^{b}	15.02^{b}	12.97^{b}	13.81	10.59^{b}
	LSD*	1.78	1.59	1.46	1.29	3.33	3.88
SE		0.66	0.53	0.44	0.35	1.89	1.36
CV (%)		7.74	6.14	7.15	5.93	8.00	8.73

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different. *Least significant difference at 5% level

Juice Content

Juice content of mango fruits was significantly affected (p<0.01) by 1-MCP treatment, polyethylene packaging and cultivars throughout the storage periods. There was also significant interaction between PP and the cultivars on 15th day storage period (p<0.01) for juice content of mango fruits. Figure 3 shows the positive effect of packaging in keeping higher juice content of mango fruits in general and interaction between PP and mango cultivars on some storage days in particular. For non-packaged mangoes, 'Apple' mango showed higher juice content than 'Kent' but packaged 'Kent' mango fruits had higher juice content as compared to that of 'Apple'. As described above, ‘Kent’ responded better for packaging as compared to ‘Apple’ mango. Positive effects of 1-MCP in delaying ripening vary with plant genetic, physiological and morphological characteristics (Sisler and Seker, 1997).

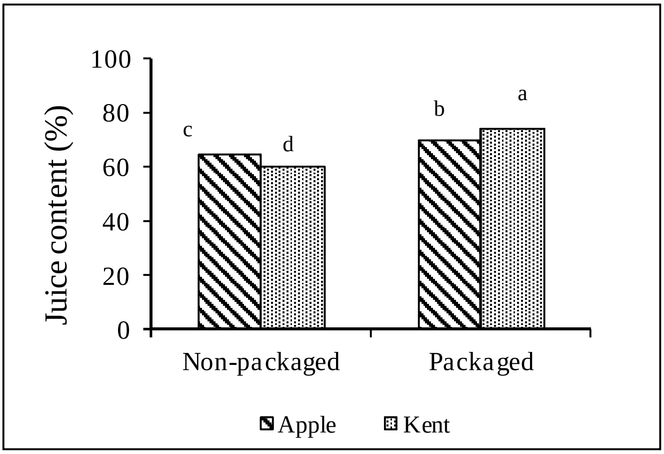


Figure 3. The interaction effect between polyethylene packaging and cultivars for mango for juice content

The 1-MCP treatment resulted in significant differences ($p<0.01$) for juice content of mangoes throughout the storage periods. The 1-MCP treated maintained higher juice content as compared to 1-MCP-untreated ones (Table 4). Zagory and Kader (1988) reported that 1-MCP has a negative effect on ethylene actions and hence delays respiration loss. Juice content of mango fruits decreased throughout the storage periods due to PWL increases with storage time.

Table 4. Percentage juice content of mango fruits treated by 1-MCP and polyethylene packaging (PP)

Treatments		Storage period on days					
		6	9	12	15	18	21
1-MCP (nLL-1)	0	70.9[b]	66.86[c]	67.82[b]	60.84[b]	60.42[b]	59.37[b]
	100	76.2[a]	71.16[b]	70.69[ab]	68.45[a]	64.65[ab]	71.90[a]
	500	77.19[a]	74.44[a]	74.47[a]	70.68[a]	68.81[a]	73.59[a]
	LSD*	2.16	2.86	3.81	5.01	5.57	9.85
PP	Packaged	76.89[a]	74.26[a]	74.35[a]	71.49[a]	69.45[a]	68.28
	Unpackaged	72.71[b]	67.38[b]	67.64[b]	61.82[b]	59.80[b]	-
	LSD*	1.76	2.33	3.11	4.09	4.55	-
Cultivars	'Apple'	74.43	69.67	71.16	66.58	64.07	69.47
	'Kent'	75.17	71.96	7.0.82	66.73	65.18	67.10
	LSD*	1.76	2.33	3.11	4.09	4.55	8.04
SE		6.53	5.43	4.28	5.05	4.39	5.67
CV (%)		3.41	4. 77	6.34	8.88	10.19	11.21

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different.
*Least significant different at 5% level

Fruit Marketability

Marketability of mango fruits was significantly affected ($p<0.01$) by both 1-MCP treatment and polyethylene packaging throughout the storage periods. There was also significant interaction effect between 1-MCP and PP for marketability of mango fruits from 9th to 18th storage days. As displayed in Figure 4, generally packaging showed increase percentage marketable fruits both for 1-MCP-treated and untreated mango fruits. However, the rate of increase was significantly higher for untreated ones. This may show that 1-MCP-treated fruits already attain higher percentage even without packaging. However, marketability further maintained by using packaging together with 1-MCP treatment rather than applying each of the postharvest treatments alone (Zeweter, 2008).

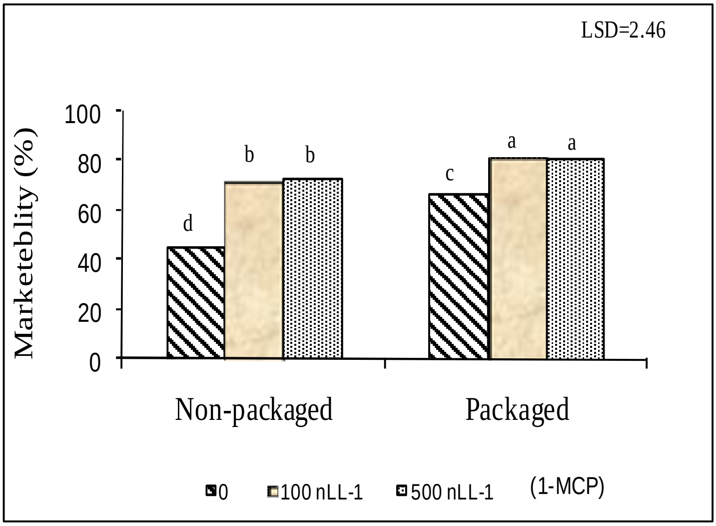


Figure 4. Interaction effect among postharvest treatment for marketability of mango fruits

Both 1-MCP treatment and PP showed significant differences ($p<0.01$) for all cultivars on percentage marketable fruits (Table 5). At the early days of storage, it was observed that percentage marketable fruit was almost similar to mangoes subjected to all treatments. But in the later storage periods, 1-MCP treated fruits resulted in higher marketable fruits. The 1-MCP, which has a competitive effect with ethylene for receptors, (Feng *et al.,* 2000) might decreased rate of respiration and hence slowed down senescence.

The PP showed a greater effect in keeping higher percentage of marketable mango fruits during storage. Ben-Yenoshua *et al.* (1985) reported that sealing individual climacteric fruit in low-density polyethylene bag delayed ripening and softening, and hence improved marketability. The low relative humidity around non-packaged fruits could be the main cause for rapid deterioration of the fruits due to moisture loss, which result in shriveled and brownish fruits. Moreover, the effect of polyethylene could partially be due to the possible difference in air composition around the fruits that might suppress respiration.

Table 5. Marketability of mango fruits (%) as affected by 1-MCP and polyethylene packaging (PP)

Treatments		Storage period (days)					
		6	9	12	15	18	21
1-MCP (nLL-1)	0	97.75[b]	83.50[b]	72.00[b]	58.16[b]	40.33[a]	29.50[b]
	100	100.00[a]	94.83[a]	88.75[a]	82.91[a]	75.83[a]	70.29[a]
	500	100.00[a]	95.83[a]	92.33[a]	88.41[a]	83.66[a]	79.45[a]
	LSD*	1.18	3.33	5.32	7.03	9.05	11.09
PP	Packaged	100.00[a]	94.33[a]	88.38[a]	82.11[a]	73.77[a]	67.63[a]
	Unpackaged	97.88[b]	88.44[b]	80.33[b]	70.88[b]	59.44[b]	51.87[b]
	LSD*	0.96	2.72	4.35	5.74	7.39	9.05
Cultivars	'Apple'	99.00	90.61	83.72	75.27	65.16	57.52
	'Kent'	99.77	92.16	85.00	77.72	68.05	61.98
	LSD*	0.96	2.72	4.35	5.74	7.39	9.05
SE		1.95	15.50	39.60	69.08	114.42	171.74
CV (%)		1.40	4.30	7.45	10.86	16.05	21.93

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different.
*Least significant difference at 5% level

Total Soluble Solids

Total soluble solids (TSS) of mango fruits was significantly affected ($p<0.01$) by 1-MCP treatment, polyethylene packaging and cultivars throughout the storage periods. There was also significant interaction effect ($p<0.05$), for TSS, between the packaging and mango cultivars on some storage days. Packaging affected non-significantly for 'Apple' mango while it showed significant effect on 'Kent' mango (Figure 5). This may indicate that packaging was more effective to 'Kent' than 'Apple' mango for delaying fruit ripening.

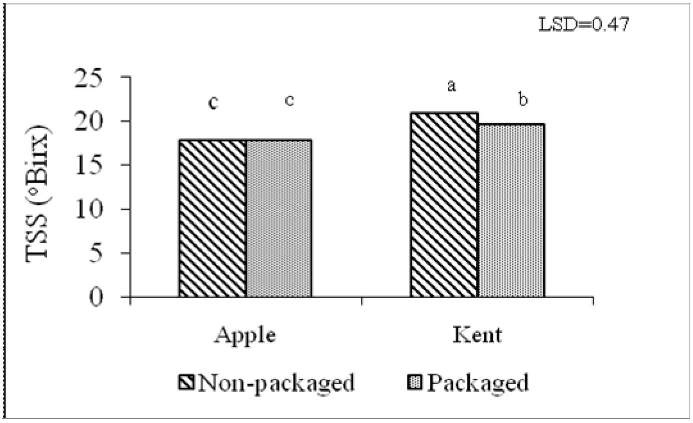


Figure 5. Interaction effect between polyethylene packaging and cultivars for mango total soluble solids

The 1-MCP treatment significantly affected TSS value ($p<0.01$) of throughout the storage period. Mango fruits that treated with 1-MCP showed lower TSS as compared to untreated mangoes (Table 6**)**. This indicated that fruit ripening process had retarded by 1-MCP action. Jiang and Joyce (2000) stated effect of 1-MCP could be associated with an apparent delay in the onset of elevated ethylene evolution and respiration. This result is in agreement with the report of Zeweter (2008) in which 1-MCP treatment for banana fruits delayed the increase of TSS as well as onset of several physiological responses related to ripening that could extend the shelf life of the fruits with better quality maintenance. Mango is a climacteric fruit having a tendency to have increased soluble solid concentration until a maximum is reached at full ripe stage and showed slight reduction towards senescence stage (Durigan *et al*., 2004). This fact was observed in the present investigation as demonstrated in Table 6.
The maximum TSS value which indicate the full ripeness of fruits reached on 12^{th} day and 21^{st} day for 1-MCP untreated and treated mangoes, respectively. The result clearly showed that 1-MCP treatment delayed ripening period of mango fruits by about 9 days as compared to untreated fruits.

The PP was also resulted in significant difference ($p<0.01$) for TSS of mango fruits. Packaged fruits also maintained at lower TSS values as compared to non-packaged fruits (Table 6**)**. Thus, packaging retarded ripening process. Non-packaged fruits reached the highest TSS values (20.47) on 12^{th} day of storage; whereas polyethylene packaged fruits reached maximum TSS value (18.70) on 18^{th} days (Table 6). The result indicated that PP delayed the ripening period of mango fruits at least by 6 days. Alye (2005) also obtained similar result. Inline with the current investigation, Zagory and Kader (1988) also reported that the role of MAP was primarily to reduce respiration rate of fruit and vegetables. Reduced respiration also retards softening and slowdown various compositional changes such as TSS, which are associated with ripening. The observed fast increment in TSS of fruits stored without packaging may indicate higher respiration rate and ripening. Brady (1987) stated that higher respiration result in fast ripening rate and then quality deterioration with the onset of senescence.

There was significant difference ($p<0.01$) for TSS of the mango varieties fruits**;** and ‘Kent’ mango showed the highest TSS during most of storage periods. As described earlier, this difference among mango cultivars indicate mango cultivars varied in sweetness might be due to difference in genetic and physiological characteristics.

Table 6. Total soluble solids (°Brix) of mango fruits as affected by 1-MCP and polyethylene packaging (PP)

Treatments		Total soluble solids (°Brix)					
		6	9	12	15	18	21
1-MCP (nLL^{-1})							
	0	12.43^{a}	20.04^{a}	20.48^{a}	20.31^{a}	14.77^{c}	15.66^{c}
	100	11.59^{b}	17.00^{b}	18.27^{b}	18.65^{b}	19.99^{a}	20.02^{a}
	500	11.10^{b}	16.31^{b}	16.66^{b}	17.43^{b}	18.16^{b}	18.96^{b}
	LSD*	0.82	1.25	0.60	0.54	1.07	1.65
PP	Packaged	10.54^{b}	16.22^{b}	17.37^{b}	18.81^{b}	18.70^{b}	16.83
	Unpackaged	12.87^{a}	19.35^{a}	20.47^{a}	19.78^{a}	19.46^{a}	-
	LSD*	0.67	1.02	0.49	0.44	0.75	-
Cultivars	'Apple'	10.73^{b}	18.95^{a}	17.88^{b}	17.96^{b}	18.66^{b}	16.11^{b}
	'Kent'	12.68^{a}	16.61^{b}	20.38^{a}	19.83^{a}	19.27^{a}	17.55^{a}
	'TN185'	-	-	-	-	-	-
	LSD*	0.67	1.02	0.49	0.44	0.75	1.35
SE		0.95	2.20	0.50	0.42	0.96	1.65
CV (%)		8.34	8.34	3.72	3.37	5.28	7.65

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different.
*Least significant different at 5% level

Titratable Acidity

Titratable acidity (TA) of mango fruits was significantly affected ($p<0.01$) by 1-MCP treatment, polyethylene packaging and cultivars throughout the storage periods. Interaction effects were non-significant ($p>0.05$) for TA of mango fruits. Mango fruits subjected to 1-MCP treatment showed significantly higher TA content as compared to untreated mangoes. The highest TA value (1.89) was recorded for 1-MCP treated mango fruits, at 100 nLL^{-1} dose, on 6th storage day while the least TA value (0.71) was recorded for mango fruits without 1-MCP treatment on 18th day (Table 7). The concentrations of these acids are known to diminish during ripening (Medlicott *et al.,* 1988). The 1-MCP treated mango fruits maintained high TA as compared to the control throughout the storage periods. Kader (1992) stated that higher fruit acidity due to postharvest treatments that delay respiration could be result of reduced utilization rate of respiratory substrates (such as organic acids).

The PP also significantly affected ($p<0.01$) the changes in TA of mangoes during storage periods. Packaged fruits showed higher TA as compared to the non-packaged ones throughout the storage period (Table 7). For instance, TA value on 6th and 18th day for polyethylene packaged mangoes were 1.87 and 1.32; while TA values for non-packaged mango fruits on respective days were 1.37 and 0.99.

In general, the values of TA were highest at earlier stage of storage indicating that unripe fruits are more acidic than ripen ones; and hence ripening of mangoes resulted in fall of acidity. The result is in line with Cocozza *et al*. (2004) and Silva *et al.* (2004) reports.

Table 7. Titratable acidity (%) of mango fruits as affected by 1-MCP and polyethylene packaging (PP)

Treatments		Titratable acidity (%)					
		6	9	12	15	18	21
1-MCP (nLL^{-1})							
	0	1.34^{c}	0.86^{b}	0.59^{c}	0.88^{b}	0.71^{b}	1.06^{b}
	100	1.63^{b}	1.12^{a}	0.79^{b}	1.22^{a}	1.17^{a}	1.39^{ab}
	500	1.89^{a}	1.21^{a}	0.87^{a}	1.35^{a}	1.15^{a}	1.61^{a}
	LSD*	0.23	0.17	0.06	0.18	0.26	0.34
PP	Packaged	1.87^{a}	1.25^{a}	0.85^{a}	1.32^{a}	1.16^{a}	1.35
	Unpackaged	1.37^{b}	0.88^{b}	0.65^{b}	0.99^{b}	0.92^{b}	-
	LSD*	0.19	0.13	0.04	0.15	0.22	-
Cultivars	'Apple'	1.71	1.09	0.75	1.03^{b}	1.12	0.89^{b}
	'Kent'	1.52	1.03	0.75	1.27^{a}	1.01	1.82^{a}
	'TN185'	-	-	-	-	-	-
	LSD*	0.19	0.13	0.04	0.15	0.22	0.28
SE		0.07	0.04	0.01	0.05	0.08	0.07
CV (%)		7.12	5.83	4.45	6.33	8.01	7.93

Note: Mean separation was done for each treatment at every storage periods; and treatments with the same letters are not significantly different.
*Least significant different at 5% level

As a summery, both 1-MCP treatment and polyethylene packaging showed significant effect on mango fruits for all ripening and quality parameters considered. The 1-MCP treated and packaged fruits were resulted in lower PWL, firmer, better color maintenance, higher juice content and higher in percent marketable fruits for all cultivars tested. The result clearly showed that 1-MCP treatment extended ripening period by nine days under ambient storage condition of high temperature area like Melkassa. This improvement in ripening and quality of mango fruits was most probably because of the property of 1-MCP that blocks the action of ethylene which has a direct relation with respiration and fruit ripening. On other hand, polyethylene packaging retained fruit quality and extended ripening period of mango fruits by at least six days under ambient storage conditions. Such effect of MAP is possibly through depletion of oxygen and release of carbon dioxide in the sealed plastic packaging. Postharvest life and marketability further improved by using packaging along with 1-MCP treatment rather than applying each of the treatments alone. Further investigation may be needed on economic analysis, determining 1-MCP rate for different cultivars of mango and the effect of other packaging materials on postharvest life of mango.

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