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Effect of Low Temperature Storage on Ripening and Quality of Mango (*Mangifera indica* L.)

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The mango (*Mangifera indica* L.) is climacteric fruit that ripens quite rapidly after harvest and special postharvest techniques required to prolong its shelf life. The study was initiated to assess effect of low temperature storage on postharvest ripening and quality of mango fruits. The fruits were harvested at mature-green stage and stored in cold storage at 10°C up to 21 days. The fruits were subjected to ripening assessment and quality analysis in 7th, 14th and 21st days. The quality analysis was done two times: immediately after removal from cold room and after ripening in subsequent seven days in ambient conditions. Physiological processes were progressively increased with storage time for mangoes stored in the cold room. The physiological weight loss was higher for fruits stored under cold storage condition for longer time. Low temperature storage reduced quality parameters such as peel color, TSS and pH. Juice content and flesh to seed ratio were higher for cold stored fruits as compared to mangoes stored at ambient temperature. Mango stored in low temperature was failed to reach full color stage and maximum TSS value. Chilling injury was observed and it was progressive with storage duration. Further investigation might be needed for determining the critical temperature of chilling injury for different mango varieties.

Key words: Low temperature, storage, mango fruits, quality, chilling injury.

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INTRODUCTION

The mango (*Mangifera indica* L.), a member of the Anacardiaceae family, is a tropical evergreen fruit tree native to south Asia from where it was distributed to the world (Mukbrjee, 1997). It is the most popular tropical fruit in the world both in the fresh and the processed forms. It has been described as king of fruits and an important component of human diet in many countries in subtropics and tropics. The fruit has attractive color, delicious taste and excellent nutritional properties (Rice *et al.,* 1991).

Much of mango fruits in Ethiopia are being produced by smallholders in home gardens mainly for home consumption; there are also few commercial farms producing for local markets and export (Seifu, 2003, Lemma, 2010). Among fruits cultivated by smallholders in Ethiopia, mango is preceded only by banana both in its area coverage and production. According to CSA (2015) about 1.2 million Ethiopian smallholder farmers have engaged on mango production and produced 90,561.4 tons in 12,860.5 hectares of land in 2014/15 cropping season. Most mango trees in the hands of farmers are developed from seedling of unknown origin, which are too tall for management and harvesting; and the overall yield

and fruit quality is poor (Edossa *et al.,* 2006). So far four improved varieties have been officially registered for production in the country (MoA, 2013).

Postharvest loss of perishable commodities is estimated to be as high as 20 to 50 percent in developing countries (Alemu, 2014). Compared to several temperate fruits, tropical and subtropical fruits such as mango present greater problems in storage and transportation because of their perishable nature (Mitra and Baldawn, 1997; Amare and Kebede, 2008). Mangoes are classified as climacteric fruit and ripen quite rapidly after harvest (Mitra, 1997). In Ethiopia, where there is great potential for production and export of mango, postharvest loss was estimated to be over 26% (Kader, 2009). It is not possible to improve the quality of produce after harvest, but it is possible to slow down the rate of undesirable changes (Kays, 1991; Wills *et al*., 1998).

At ambient temperatures, shelf life of mango fruit is too short to fully ripe. Many techniques have been used to prolong the shelf life of fruits (Waskar *et al.,* 1999). Temperature control is commonly used to reduce metabolism of fruits and vegetables and delay ripening. Pre-cooling to 10-13^{o}C is beneficial during hot weather or when shipping delayed (Hidalgo *et al.,* 1997). Refrigeration is a widely used technology to delay the ripening or postharvest deterioration of fresh horticultural commodities. Chilling injury is one of postharvest storage disorders that occur at low temperatures storage below a specific point and different threshold temperatures for chilling sensitivity have been reported for different mango varieties (Chaplin *et al.,* 1991).

There is limited information and experience in the post harvest handling of mangoes in general and application of low temperature in particular in Ethiopia. Therefore, the study was initiated with the aim to assess effect cold temperature storage on postharvest ripening and quality of mango.

MATERIALS AND METHODS

Experimental Sites

The experiment was carried out at Rose Ethiopia Ltd. and Melkassa Agricultural Research Center (MARC). Rose Ethiopia Ltd. that located at Ziway and it was the place where mango fruits stored in cool storage facility while MARC was where quality analysis was undertaken. Agro-ecological characteristics of the location are described in Table 1.

Treatments and Experimental Design

The experiment was conducted in the year 2009. Two varieties namely ‘Apple’ and ‘Kent’ were used to investigate the effect of low temperature shortage on mango fruits. A randomized complete block design (RCBD) was used with three replications. The experiment followed 4*2 factorial arrangement in which ‘4’ represents four levels storage duration (0, 1, 2 and 3 weeks storage in cold room) where as ‘2’ represents two mango varieties (‘Apple’ and ‘Kent’).

Experimental Procedures

Sample preparation

Fruits of the mango cultivars were obtained from research plot at MARC. The fruits were harvested at mature-green stage and it was carried out manually with care to minimize mechanical injuries. Fruits were collected in plastic boxes and placed under shade, for about 20-30 minutes, until transported to the horticulture laboratory of MARC. Uniform fruits with similar size and color were selected and hand washed using tap water to remove field heat, clear dust particles and to reduce microbial population that might be present on the fruit surface.

Storage

Washed and air-dried mangoes were packaged by low-density perforated polyethylene bags with the thickness of 7.5 µm; 75% of mango fruits from both varieties were kept in cold room (adjusted to 10^{o}C) for 7 to 21 days and the remaining 25% of the fruits kept under ambient temperature as control. The treatments were randomly assigned by lottery method within each block. Then the fruits were stored in the cold room with 10^{o}C temperature up to 21 days. Fruits had removed from cold room after every seven days for ripening and quality analysis. Half amount mango fruits were subjected to quality analysis immediately after removal from cold room while the remaining half amount were analyzed after subsequent seven days storage under ambient conditions (25.7^{o}C average temperature and 66.1% relative humidity).

Data Collection

Samples of three mango fruits were randomly taken at a time from each treatment for physiological and physico-chemical quality assessment. Data were collected on 1st, 7th, 14th, and 21st day of storage. It was collected for physiological weight loss (PWL), skin color, firmness, total soluble solids (TSS), titratible acids (TA), power of hydrogen (pH), sugar to acid ratio (SAR), juice content (JC), flesh to seed ratio (FSR), fruit marketability, chilling injury (CI) and sensory evaluation.

Table 1. Brief description of the study areas

No	Locations	Altitude	Geographic Coordinates	Average Temprature		Annual rainfall
				Minimum	Maximum	
1	Rose Ethiopia Ltd. (Ziway)	1643m	7°56'N; 38°43'E	12.5°C	26.2°C	775 mm
2	Melkassa Agricultural Research Center	1550m	8°24'N; 39°21'E	14°C	28.4°C	763 mm

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) software version 9.0 (SAS, 2004). Comparisons of the treatment means were done by the least significant difference (LSD) test at 5% significance level.

RESULT AND DISCUSSION

Mango Fruits Immediately after Removal from Cold Storage

There was significant quality differences ($p<0.01$) among mango fruits stored for various duration in cold room. Mango fruits stored for seven days showed significantly lower PWL as compared to fruits stored for 14 and 21 days. The PWL for mango fruits that stored under cold storage for 7 days was 0.74% and respective values on 14th and 21st days were 1.25% and 2.15% (Table 2). The fruits showed higher marketability and non-significant differences were observed among treatments. Progressive increment was observed for PWL with storage time. As it is showed in the table, quality parameters such as peel color, TSS and pH also progressively increased with storage time for mangoes stored in cold room. This indicates that physico-chemical changes and limited ripening process of mango fruits was still in its progress with storage time, even during cold storage periods. The result was agreed with that of Gutiérrez *et al.* (1997). They stated that ripening processes were still in progress for mangoes stored in refrigerator above chilling temperature. Medlicott *et al.* (1990) reported similar result as development of peel and pulp color, soluble solids concentration, pH, and softening in 'Amelie', 'Tommy Atkins', and 'Keitt' mangos occurred progressively during storage for up to 21 days at 12C.

Low temperature storage significantly retarded ripening process of mangoes. The experiment conducted at the same time under ambient temperature revealed that significantly higher (7.31%) PWL was observed for packaged mango fruits on 21st day as compared to PWL recorded at the low temperature storage in the current result (2.15%). The quality parameters were far less than their respective values of mangoes at ambient storage temperature (Lemma *et al.* 2012).This showed that cold storage reduces physiological processes such as respiration at low temperature storage. Purwanto *et al.* (2016) also stated that low temperature storage extended postharvest life of mango fruits.

Mango Fruits after Subsequent Ambient Condition Storage

Mango fruits stored in cold room showed significant difference among storage duration for most mango quality parameters considered when evaluated after subsequent seven days of ripening at ambient condition (Table 3). The PWL was higher for fruits stored under cold storage condition for longer time. Significantly highest PWL was recorded for mango fruits stored for 21 days (5.23%) and 14 days (4.71%) as compared to mangoes kept at cold room for seven days (3.28%). The PWL at ambient condition was 7.31%, indicating cold storage was better as compared to ambient storage condition to reduce PWL. Significant differences were observed for fruit marketability among duration in cold storage and it was lower when fruits kept for longer time.

Base on the result some quality defects observed due to the low temperature storage. Cold stored mangoes, after being allowed to ambient temperature storage for subsequent seven days, fail to reach full color stage of ripen fruit. Mangoes kept under ambient temperature for seven days as control showed better color appearance as compared to mangoes stored in cold storage. In Lizada (1991) it is mentioned that mangoes stored at low temperatures and subsequently ripened at room temperature failed to synthesize as much carotenoids as fruits kept continuously at room temperature. The TSS

Table 2. Effect of low temperature storage on unripe mango fruits that analyzed on the day removed from cold storage

Treatments		Quality parameters							
		PWL (%)	Color Stage	Firmness (N)	TSS (^{o}Brix)	TA	pH	SAR	Marketable (%)
Storage	W_1	0.74^{b}	1.16^{b}	47.67	12.10^{b}	2.54^{ab}	3.62^{b}	5.22^{b}	99.07^{a}
	W_2	1.25^{b}	1.08^{b}	51.13	12.32^{b}	3.19^{a}	3.45^{b}	5.43^{ab}	97.96^{ab}
	W_3	2.15^{a}	1.66^{a}	43.56	15.35^{a}	2.22^{b}	3.71^{a}	7.17^{a}	97.72^{b}
	LSD*	0.52	0.34	7.59	1.47	0.71	0.14	1.91	1.24
Cultivars	'Apple'	1.30	1.27	45.08	13.58	2.38	3.66^{a}	6.96^{a}	98.01
	'Kent'	1.47	1.33	49.83	12.93	2.92	3.54^{b}	4.92^{b}	98.48
	LSD*	0.42	0.28	6.20	1.20	0.58	0.11	1.56	1.01
SE		0.37	0.16	0.80	3.05	0.71	0.02	5.09	2.16
CV (%)		44.33	31.03	8.11	13.17	31.80	4.75	37.97	1.49

W1 = one week cold storage; W2 = two weeks cold storage; W3 = 3 weeks cold storage.

Note: Mean separation was done for each parameter independently and treatments with the same letters are not significantly different.

Table 3. Effect of low temperature storage on ripe mango fruits that analyzed after subsequent seven days storage at ambient condition

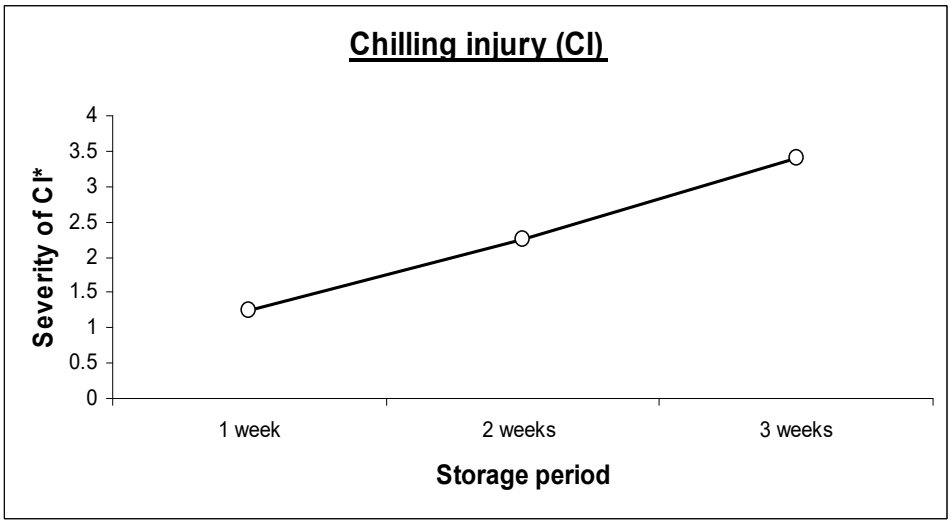
Treatments		Quality parameters									
		PWL (%)	Color stage	Firmness (N)	JC (%)	FSR	TSS (^{o}Brix)	TA	pH	SAR	Marketable (%)
Storage	$W_{0.7}$	2.22^{c}	5.50^{a}	17.3^{a}	44.95^{c}	4.74^{c}	19.41^{a}	1.58^{a}	4.36^{b}	12.62^{b}	98.41^{a}
	$W_{1.7}$	3.28^{b}	5.10^{b}	15.9^{ab}	68.61^{ab}	7.32^{ab}	18.99^{a}	1.03^{b}	4.67^{a}	18.68^{a}	90.66^{b}
	$W_{2.7}$	4.71^{a}	4.75^{bc}	19.1^{a}	70.83^{a}	7.81^{a}	17.56^{b}	0.84^{c}	4.66^{a}	21.89^{a}	85.00^{b}
	$W_{3.7}$	5.23^{a}	4.50^{c}	13.1^{b}	65.79^{b}	6.85^{b}	17.22^{b}	0.87^{bc}	4.62^{a}	22.81^{a}	76.08^{c}
	LSD*	0.69	0.36	0.33	3.83	0.61	1.08	0.15	0.11	4.67	7.13
Cultivars	'Apple'	4.11^{a}	5.07	1.71	63.24	6.65	18.34	1.09	4.54	19.66	86.37
	'Kent'	3.61^{b}	4.85	1.57	61.86	6.71	18.25	1.07	4.61	18.34	88.70
	LSD*	0.49	0.25	0.23	2.71	0.43	0.76	0.11	3.30	0.08	5.04
SE		0.69	0.18	0.16	21.18	0.53	1.69	0.03	0.02	31.39	73.31
CV (%)		21.56	8.72	24.46	7.35	10.95	7.10	17.50	3.13	29.48	9.78

$W_{0.7}$ = 7 days in ambient temperature; **$W_{1.7}$** = 7 days cold storage and 7 days subsequent storage at ambient temperature; **$W_{2.7}$** = 14 days cold storage and 7 days subsequent storage at ambient temperature; **$W_{3.7}$** = 21 days cold storage and 7 days subsequent storage at ambient temperature.

Note: Mean separation was done for each parameter independently and treatments with the same letters are not significantly different.

Table 4: Chilling injury on mango fruits stored in cold room

Treatments	CI	CI
Storage	$W_{0.7}$	-
	$W_{1.7}$	1.25^{c}
	$W_{2.7}$	2.25^{b}
	$W_{3.7}$	3.41^{a}
	LSD*	0.25
Cultivars	'Apple'	2.44^{a}
	'Kent'	2.16^{b}
	LSD*	0.20
SE		0.08
CV (%)		12.89



*1 = nil; 2 = slight (up to 5 % surface affected); 3 = moderate (6-25% surface affected); 4 = severe (26-50% surface affected); 5 = very severe (greater that 50% surface affected)

Figure 1. Chilling injury as increased with storage time

was also significantly higher ($p<0.01$) for control treatment and for those stored in cold room for seven days as compared to fruits stored in cold room for 14 days and 21 days. As it can be observed in Table 3, mango fruits stored in cold temperature storage failed to reach the maximum TSS value as compared to the control. Juice content and flesh to seed ratio were higher for cold stored fruits as compared to mangoes stored at ambient temperature. The result showed that the influence of cold storage to delay ripening process of mango fruits. Chaplin *et al.* (1991) reported that low temperature reduce metabolism of fruits and vegetables and delay ripening.

Chilling injury

Visual symptoms of chilling injury (CI) were observed on some mango fruits stored under low temperature storage. There was brown discoloration on the peel which was accompanied by pitting in some cases as a result of the occurrence of CI (Chaplin *et al.,* 1991). However, there were no fruits failed to ripen. This might indicates that the mango fruits were slightly to moderately injured at 10°C low temperature storage.

Significant difference ($p<0.0001$) were observed among treatments (Table 4). Fruits stored in cold room for 21 days showed the highest injury as compared to the fruits removed on 7th and 14th days. This showed that severity of CI increased as storage time extended (Figure 1). Mango fruits was affected by CI only slightly (1.25) when they kept under low temperature for seven days, in 14th day CI was moderate (2.25) and it was sever (3.41) in 21st day. This might indicate that under low temperature CI is progressive with storage duration. Wainwright and

Beurbage (1989) reported that the extent of injury being dependent upon the storage temperature and duration. 'Apple' mango was relatively severely injured during low temperature storage as compared to 'Kent'. Hidalgo *et al.* (1997) reported that critical temperatures for CI might vary among different mango varieties from 5-15^{o}C.

Sensory Evaluation

Sensory evaluation was undertaken to further explain the results of physiological and physico-chemical quality analysis that has already discussed in earlier sections. Higher scores were given by panelists for mango stored at ambient temperature during the first week as compared to mangoes stored under low temperature condition (data not shown). At the second week, fruits stored under low temperature were given better score for color and general acceptability. Similar score was given for the two mango varieties that were considered. The flavor of mango fruits stored under ambient condition were given better score than the fruits stored in cold room due to some off-flavor and poor appearance developed may be by chilling injury (Hidalgo *et al.,* 1997).

SUMMARY AND CONCLUSION

The mango (*Mangifera indica* L.) is a climacteric fruit and highly perishable fruit that requires specialized postharvest handling to extend its storage life. Many techniques have been used to prolong the shelf life of fruits. Temperature control has been commonly practiced to reduce metabolism of fruits and vegetables and delay ripening.

The present study was conducted to evaluate the influence of low temperature storage on postharvest ripening and quality of mango fruits. The research was carried out at Rose Ethiopia Ltd. and Melkassa Agricultural Research Center (MARC). A randomized complete block design (RCBD) with three replications was used and the treatments were arranged in a factorial scheme for four levels of low temperature storage durations and two mango varieties. Mango fruits were assessed for physiological weight loss (PWL), peel color, firmness, juice content (JC), flesh to seed ratio (FSR), total soluble solids (TSS), titratable acidity (TA), power of hydrogen (pH), sugar to acid ratio (SAR), chilling injury and sensory attributes.

Significant quality differences were observed among storage duration in cold room. Physiological processes were progressively increased with storage time for mangoes stored in the cold room. Quality parameters such as peel color, TSS and pH are progressively increased with storage time for mangoes stored in cold room. Even though limited amount of PWL was evident, cold storage showed significant influence in reducing PWL. The PWL was higher for fruits stored under cold storage condition for longer time. Chilling injury was observed and it was progressive with storage duration. Low temperature storage reduced PWL, maintained higher JC and FSR of mangoes even after subsequent ambient temperature storage for seven days after removing it from cold room. The result indicated that low temperature above chilling point could extend ripening period of mango fruits for more than two weeks with some quality defects.

Therefore, low temperature storage was found to be among essential postharvest treatments to delay ripening of mango fruits. Further investigation might be needed for determining the critical temperature of chilling injury for different mango cultivars.

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