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Effect of low temperature storage on chilling injury and storage life of commercial cultivars of mango (*Mangifera indica* L)

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Abstract
An experiment was conducted to study the effect of low temperature storage on chilling injury and storage life of different commercial cultivars of mango (*Mangifera indica* L.) *viz.*, Banganpalli, Dashehari, Peddarasam, Chinnarasam and Totapari stored at 8 ºC ± 1 ºC at Fruit Research Station, Sangareddy, Medak, Telangana. The experimental design is completely randomized design with factorial concept with four replications per treatment. Various physical parameters like Physiological loss in weight, fruit firmness, chilling injury and shelf life were estimated. Significantly lowest chilling injury was recorded in mango cv Totapari. The ripening was delayed when compared with that of varieties where the chilling injury was maximum. Maximum number of days (52 days) was recorded in mango cv Totapari for reaching the chilling injury score of 1.5. The chilling injury in mango cv Totapari and Peddarasm were observed from 25th day onwards while in other varieties it was observed from 15th day onwards.

Keywords: chilling injury, low temperature, physiological changes, and storage life

Introduction
Mango (*Mangifera indica* L.) is one of the most popular fruits and commonly known as 'King of fruits' in Asian countries. Because of its delicious taste and pleasant flavour, it is ranked as one of the choicest fruits in the National and International market. Mango is a climacteric fruit and hence, ripe and deteriorate very fast when stored at ambient temperature, which leads to reduction in shelf life. Therefore, low-temperature storage is necessary to slow down the metabolic processes and decay development but, when this fruit is stored at temperature below 13 ºC, it develops chilling injury (CI) which further limits its shelf life during low-temperature storage and subsequently lead to rapid spoilage. The chilling injury symptoms in mango manifest as discoloration and pitting of the peel, sunken lesions, lenticels spotting, shriveling, uneven ripening, poor colour, off-flavour development and increased susceptibility to decay resulting in the reduction of market value of the fruit (Nunez *et at.*, 2007) [17].
In India, post-harvest losses of fruits and vegetables are estimated to be 30-35 per cent which amount to losses to the extent of Rs.3000 crores (Mitbander, 1990) [15]. Post-harvest losses can be minimized by adopting proper post-harvest handling practices and better understanding of bio-chemical control of fruit ripening. Post-harvest life of fruits and vegetables can be extended by low temperature storage, modified atmosphere packaging and by biochemical treatments.
Mangoes are reported to ripen satisfactorily (with acceptable eating quality) between 21º C and 24 ºC (Medlicott *et al.*, 1990) [14]. About 12-13 ºC is generally considered optimum for mango storage (Kader, 1992; Medlicott *et al*., 1990) [10, 14]. However, for long distance transport through sea, storage of mangoes below 12-13 ºC is necessary.
Previous reports have established that fruits at the pre-climacteric stage are generally more sensitive than those at post-climacteric stage to chilling injury in avocado (Kosiya-Chinda and Young, 1984) [11], tomato (Moline, 1976), and mango (Cheema *et al.*, 1950) [4]. Induction of chilling tolerance by chemical or physical treatments, or by exposure to other stresses such as high and low temperature stress is becoming a great potential approach for protecting harvested fruit from chilling injury, and enhancement of membrane integrity by regulating plasma membrane proteins and lipids (Li *et al.*, 2012; Zhang and Tian, 2010) [13], improvement of antioxidant system and suppression of reactive oxygen species (Chen and Yang, 2012) [5], and maintenance of high ATP content and energy charge (Chen & Yang, 2012) [5] are considered as the mechanisms being involved in the acquisition of chilling tolerance. In view of the scanty literature on the chilling injury of mango cultivars, the present experiment was

undertaken to study the effect of low temperature on prolonging the storage life.

Material and Methods

The experiment was carried out during 2014-15 at Fruit Research Station, Sangareddy, Medak. There were five treatments (varieties) replicated four times with 50 fruits per each replication. The mango cultivars used were Banganpalli, Totapari, Dashehari, Chinnarasam and Peddarasam, procured from the Fruit Research Station, Sangareddy. The experimental design followed was CRD with factorial concept. The fruits were harvested at 3/4th mature stage. Data were recorded at 5 days interval. The fruits were stored at a temperature of 8 ^{o}C $\pm$ 1 ^{o}C. Physical parameters *viz.*, Physiological loss in weight (PLW), Fruit firmness, Chilling injury and Colour score were recorded. Chilling injury score was given on five point hedonic scale as per Gonzalez-Aguiar *et al*. (2003) [6].

Results and Discussion

The following objects were observed in different commercial mango varieties.

a) Chilling injury (%)

The treated fruits differed significantly with lowest chilling injury (1.18) recorded in mango cv. Totapari (Table.1) while the highest (2.10) was recorded in cv. Chinnarasam. Mango cvs. Banganapalli (1.90) and Dashehari (1.99) were at par.

In cvs. Banganapalli, Dashehari and Chinnasrasam, the chilling injury has started on 15th day itself while, the chilling injury in mango cv. Totapari and peddarasam has started from 25th day onwards. However, in Totapuri, the maximum chilling injury of (2.58) was observed on 80th day where as in Peddarasam, the maximum chilling injury (3.55) was recorded on 70th day of storage period itself.

Pic 1: Effects of low temperature storage on chilling injury of commercial varieties of mango at 25th Day

Pic 2: Effects of low temperature storage on chilling injury of commercial varieties of mango at 55th Day.

Similar results on low temperature storage on chilling injury of mango was previously reported by Abou-Aziz *et al*. (1965), Jo-Feng and Pull (1990), Pratt and Workman (1962), in Papaya by Chen and paull (1986). Other reports indicated that temperatures below 13 ^{o}C for a period of 10 days produce chilling injury symptoms in fully ripened Kent mangoes (Saucedo Veloz *et al.*, 1977) [20]. In the present investigation, the least chilling injury symptoms were obtained in the mango cv Totapari and highest chilling injury in mango cv chinnarasam. The difference in the chilling injury symptoms may be attributed to the thickness of the skin and pulp firmness.

b) Colour score (%)

The lowest colour score (1.22) was recorded in mango cv. Chinnarasam but on par with the cvs. Banganapalli (1.33), Dashehari (1.26) while the highest colour score (1.66) was recorded in Peddarasam (Table 2). On all the days of storage, the colour increased significantly from 25th day (1.11) to 55th day (1.72). The interaction effect on colour score among different mango cultivars and storage period was not significant.

In the present study, irrespective of the mango cultivar, the colour score of mango has not reached 2.0 (i.e 50 per cent green and 50 per cent yellow) clearly indicating that the low

temperature has retarded the ripening process (Gonzalez *et al*., 1990) [6].

c) Fruit firmness (Kg.cm^{-2})

The treated fruits differed significantly and the lowest firmness (4.48) was recorded in mango cv. Peddarasam while the highest firmness (15.17) was recorded in mango cv. Totapari (Table 3). However, cv. Dashehari (6.21) was on par with Chinnarasam (6.47). On all the days of storage, the firmness increased significantly from 25th day (11.88) to 55th day (5.18). The interaction effect on colour score among different mango cultivars and storage periods was not significant.

In the present investigation, there is a progressive decrease in the fruit firmness irrespective of the mango cultivar indicating, the slow ripening process. Further, the slow ripening process even at low temperatures has resulted in the decrease of the fruit firmness in the present investigation. Similar results were also reported in guava by Wills *et al.* (1983) [24]. Highest firmness was observed in mango cv. Totapari which is incidentally having firm pulp.

d) Physiological loss in weight (PLW) (%)

The lowest PLW (3.54) was recorded in mango cv. Peddarasam while the highest (6.48) in Dashehari. The cvs. Banganpalli (5.45) was on a par with cv. Chinnarasam (5.39). There were significant differences in PLW among different commercial varieties of mango (Table 4). during all the days of storage with the PLW increased significantly from day 5 (1.22) to 55th day (7.02). The interaction effect on PLW among different cultivars and storage periods indicated that the lowest and the highest PLW (0.85 and 8.88 % respectively) was recorded with the mango cv. Dashehari on 5th and 55th days respectively.

In the present study, even at low temperatures, the substances that are used up in the degradative reactions provide energy for the process that make the fruit to acquire edibility and might have resulted in fruit loses a part of its original weight during the process of storage (Haard and Salunkhe, 1975) [7]. Similar increase in the PLW was also recorded in mango (Prasanna Lakshmi (2005) [18] and guava (Waskar *et al*., 1999).

Table 1: Effects of low temperature storage on chilling injury index (skin scald) of commercial varieties of mango at different storage periods.

Treatments	Days of storage														
	15	20	25	30	35	40	45	50	55	Mean	60	65	70	75	80
T_1- Banganpalli	0.50	1.00	1.08	1.12	1.45	1.70	1.74	2.60	3.62	1.90^{c}	-	-	-	-	-
T_2 – Dashehari	0.50	1.00	1.26	1.42	1.60	1.67	2.00	2.44	3.52	1.99^{c}	-	-	-	-	-
T_3- Chinnarasam	0.50	1.00	1.31	1.52	1.70	1.51	2.27	2.72	3.71	2.10^{d}	-	-	-	-	-
T_4 – Peddarasam	0.00	0.50	1.17	1.28	1.33	1.96	1.86	2.01	2.20	1.69^{b}	2.33	3.44	3.55	-	-
T_5- Totapari	0.00	0.00	0.60	1.00	1.12	1.18	1.23	1.41	1.70	1.18^{a}	1.80	2.21	2.34	2.40	2.58
Mean			1.08^{a}	1.27^{b}	1.44^{c}	1.60^{c}	1.82^{d}	2.23^{e}	2.95^{f}						
	F-Test	SEM	CD												
For Treatments (T)	**	0.042	0.120												
For Days (D)	**	0.050	0.124												
For D X T	**	0.113	0.318												

Table 2: Effects of low temperature storage on colour score (scale) of commercial varieties of Mango at different storage periods

Treatments	Days of storage												
	25	30	35	40	45	50	55	Mean	60	65	70	75	80
T_1- Banganpalli	1.13	1.21	1.25	1.26	1.33	1.41	1.72	1.33^{a}	-	-	-	-	-
T_2 – Dashehari	1.02	1.05	1.07	1.15	1.30	1.53	1.72	1.26^{a}	-	-	-	-	-
T_3- Chinnarasam	1.05	1.16	1.13	1.21	1.21	1.30	1.50	1.22^{a}	-	-	-	-	-
T_4 – Peddarasam	1.37	1.51	1.26	1.72	1.77	1.81	1.84	1.66^{c}	2.14	2.50	3.03	-	-
T_5- Totapari	1.00	1.45	1.45	1.51	1.63	1.72	1.85	1.51^{b}	2.05	2.05	2.20	2.40	2.55
Means	1.11^{a}	1.27^{ab}	1.30^{ab}	1.37^{b}	1.45^{b}	1.55^{b}	1.72^{c}						
	F-Test	SEM	CD										
For Treatments (T)	**	0.064	0.181										
For Days (D)	**	0.076	0.214										
For T X D	NS	0.171	-										

Table 3: Effect of low temperature storage on firmness of commercial varieties of mango at different storage periods

Treatments	25 day	30 day	35 day	40 day	45 day	50 day	55 day	Means	60 day	65 day	70 day	75 day	80 day
T_1- Banganpalli	9.67	8.92	8.00	7.97	7.57	7.30	5.62	7.86^{c}	-	-	-	-	-
T_2 – Dashehari	12.50	9.52	6.37	4.92	4.47	3.77	1.95	6.21^{b}	-	-	-	-	-
T_3- Chinnarasam	11.25	9.65	7.00	5.62	4.35	4.35	3.07	6.47^{b}	-	-	-	-	-
T_4 - Peddarasam	5.42	5.67	5.05	4.82	4.55	3.50	2.37	4.48^{a}	2.35	2.00	1.88	-	-
T_5- Totapari	17.05	16.25	16.07	16.05	14.25	13.65	12.90	15.17^{d}	11.53	11.00	10.75	9.25	8.55
Means	11.18^{a}	10.00^{ab}	8.50^{b}	7.88^{b}	7.04^{b}	6.51^{bc}	5.18^{c}						
	F-Test		SEM		CD								
For Treatments	**		0.482		1.352								
For Days	**		0.570		1.600								
For T X D	NS		1.276		-								

Table 4: Effects of low temperature storage on physiological loss of weight (%) of commercial verities of mango at different storage periods.

Treatments	5 day	10 day	15 day	20 day	25 day	30 day	35 day	40 day	45 day	50 day	55 day	Means	60 day	65 day	70 day	75 day	80 day
T_1- Banganpalli	0.92	3.26	3.30	4.45	5.58	6.74	6.88	7.03	7.23	7.17	7.36	5.45^{c}	-	-	-	-	-
T_2 - Dashehari	0.85	2.70	3.75	5.36	6.64	8.45	8.53	8.65	8.83	8.61	8.88	6.48^{d}	-	-	-	-	-
T_3- Chinnarasam	1.33	1.96	3.45	5.49	6.31	6.78	6.47	6.72	7.01	6.84	7.00	5.39^{c}	-	-	-	-	-
T_4 - Peddarasam	1.63	2.49	4.47	2.76	3.51	3.49	3.61	3.72	3.90	4.64	4.69	3.54^{a}	5.23	5.93	6.44	-	-
T_5- Totapari	1.38	1.27	2.33	3.06	3.68	4.39	4.89	5.04	5.15	6.51	7.18	4.08^{b}	7.25	7.83	7.53	8.32	8.68
Means	1.22^{a}	2.34^{b}	3.47^{c}	4.22^{c}	5.14^{cd}	5.97^{d}	6.07^{d}	6.23^{d}	6.42^{d}	6.75^{d}	7.02^{e}						
	F-Test		SEM		CD												
For Treatments	**		0.216		0.605												
For Days	**		0.321		0.898												
For T X D	**		0.719		2.008												

Conclusion

Significantly lowest chilling injury was recorded in mango cv Totapari followed by Peddarasam. Significantly highest chilling injury was recorded in the mango cv Chinnarasam. Irrespective of the variety, storage at low temperature has significantly delayed the ripening process. However, in the mango cultivars where the chilling injury was recorded minimum, the ripening was delayed when compared with that of varieties where the chilling injury was maximum. The various physic-chemical parameters indicated reduced chilling injury symptoms in mango cv. Totapari.

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