POSTHARVEST CHILLING SENSITIVITY OF MABROUKA, MESK AND KEITT MANGO CULTIVARS GROWN IN EGYPT

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ABSTRACT

Fruits of Mabrouka (early-season), Mesk (mid-season), and Keitt (late-season) Mango [*Mangifera indica* L.] cultivars, were harvested at mature-green stage, and stored at 10°C or 20°C and 90% RH. Storage temperature of 10°C was used as a minimum safe temperature and storage period was variable. The time-temperature for incipient visible symptoms of chilling injury development (pitting and necrosis) during or after cold storage was investigated. Also, the use of hot water treatment (53°C for 5 min) or imazalil dip (150 ppm / 5 min) was examined. Fruit physical and chemical parameters were determined initially before storage and followed periodically at weekly intervals throughout the storage period at 10°C and 20°C treatments. Weekly periods of holding at 10°C were followed with a subsequent ripening at room temperature of 20°C for three and six days intervals. Mesk fruits were more tolerant to chilling injury at 10°C than fruits of Mabrouka and Keitt. Hot water treatment alleviated chilling injury symptoms and reduced decay, while imazalil dip reduced fruit postharvest decay. Results indicated that prolonged storage period and warm temperature increased fruit weight loss and decreased fruit firmness. SSC, reducing sugars, total sugars, non-reducing sugars and carotene increased. However, starch, acidity, vitamin C, chlorophyll *a* & *b*, total chlorophyll and crude fiber decreased.

INTRODUCTION

The mango (*Mangifera indica* L.) is considered one of the choicest fruits of the world, because of its delicious taste and excellent nutritional values. The world fruit trade is expanding but mango sales are restricted by improper handling and inadequate transport facilities (Mitra, 1997). The high cost of mangoes in importing countries is due primarily to airfreight charges, but air transport does have the advantage of speed over sea transport. Sea transport is less expensive and enables transport of larger volumes, and thus would aid in the expansion of mango export industries. However, sea shipment does not guarantee good quality fruit on arrival nor sufficiently long shelf life for successful marketing. Sea transport generally involves the use of low temperature storage in an attempt to prolong storage life. In practice, the minimum temperature for storage of most tropical fruits is determined by their susceptibility to chilling injury. Many variations were reported for the mango optimum storage temperature which may be a cultivar effect or related to the stage of harvest maturity and ripeness of the mangoes when placed in storage (Medlicott et al., 1990). The final quality of ripe mango depends on the interaction between the postharvest environmental factors and the inherent characteristics of the fruit. These interactions must be understood to achieve optimal fruit quality (Chaplin, 1989).

Accordingly, the present study was carried out on Mabrouka, Mesk and Keitt mango cultivars to investigate the postharvest behavior of such cultivars during shipping in a shipment simulation trial of sea-export conditions, and to examine the potential of hot water treatment or Imazalil dip as supplementary methods for maintaining postharvest fruit quality.

MATERIALS AND METHODS

The present study was carried out during 1998 and 1999 seasons on three mango cultivars (*Mangifera indica* L.) grown in Egypt: Mabrouka (early), Mesk (moderate) and Keitt (late). Fruits were harvested from trees grown in two private orchards (PICO farm 'Om-Saber' near Badr station and Hegazi farm on the desert road near Cairo) at mature green stage on mid-September, 18th of September and 19th of October for Mabrouka, Mesk and Keitt cultivars, respectively, in 1998 season, and on the 16th of August, 7th of September and on the 22 of October for Mabrouka, Mesk and Keitt cultivars, respectively, in 1999 season. Fruits were free of obvious mechanical damage and defects and approximately homogenous in size and color. Sorted fruits were quickly washed with regular tap water, then air dried with the aid of an electric fan. Fruits of each of the three mango cultivars were divided into three lots, the first one was stored at 10°C and 90% RH, the second one held at room temperature of 20°C and 90% RH and the last one was divided into three groups to examine the potential of hot water treatment (53°C/5min), Imazalil dip (150 ppm/5min) and control treatment. Each of the last three groups was divided again into two equal groups, the first group was stored at 10°C and 90% RH and the second one was held at room temperature of 20°C and 90% RH. First and second lot were observed and analyzed but the third one was observed only to examine the changes of postharvest quality. Fruits were packed in open carton boxes. Each box contained about 9 fruits for Mabrouka and Mesk cultivars and about 6 fruits of Keitt cultivar. The total number of boxes was 27 for each mango cultivar. Fruit parameters of the three mango cultivars were determined initially before storage and followed periodically at weekly intervals throughout the storage period at 10°C and 20°C treatments. On the other hand, weekly period of holding at 10°C was followed periodically with a subsequent ripening at room temperature of 20°C for three and six days intervals. The time-temperature for incipient visible symptoms of chilling injury development (pitting and necrosis) during or after cold storage was recorded. Regarding the pomological characteristics shown in Table (1), the average weight in grams of the whole fruit, peel, pulp, and seed was recorded, and the percent of the weight of peel, pulp and seeds in respect to the whole fruit was also recorded. The average fruit dimensions in centimeters were measured by a caliper according to Campbell (1992). The percent of pulp moisture content was calculated according to Ranganna (1977). For the determination of physical parameters, five mango fruits were labeled in each 10°C and 20°C treatments for each cultivar, and the initial weight of each labeled fruit was recorded. Subsequent periodical weight determination at weekly intervals was carried out throughout the storage period. The percentage of weight loss for each fruit was calculated in relation to its original weight. Flesh firmness was determined by using the Effegi firmness tester with an eight mm plunger (Effegi, 48011 Alfonsine, Italy), and was expressed as pounds /square inch. Regarding the chemical parameters. the SSC % of fruit juice was measured by using a hand refractometer. according to Chen and Mellenthin (1981). Sugars were extracted according to Loomis and Shull (1937) then determined according to Malik and Singh (1980). and expressed as grams per 100 gm fresh weight of fruit flesh. Starch was determined according to A.O.A.C. (1950) and expressed as grams per 100 gm dry weight of fruit flesh. Acidity was determined by titration according to Chen and Mellenthin (1981). The titratable acidity was expressed as grams of citric acid per 100 ml of mango juice. The pH was measured in the fruit juice by using pH meter (OAKTON pH Tester 1. Model 35624-00). Ascorbic acid (V.C) was determined according to A.O.A.C. (1980), and expressed as milligrams ascorbic acid per 100 ml fruit juice. Pigments were extracted according to Moran and Porath (1980). For determination of peel and pulp pigments content the method of Grodzinksy and Grodzinsky (1973) was followed. Chlorophyll *a* & *b*. total chlorophyll and carotene contents were expressed as mg per 100 gm fresh weight. Percentages of the crude fiber were determined according to Ranganna (1977). According to the obtained results and indications from the first and second seasons (1998 and 1999) a third observational season was needed. Therefore. an observational study for the third season (2000) was carried out. The experimental design was a randomized complete block design with three replicates and all data obtained were statistically analyzed according to Snedecor and Cochran (1972).

RESULTS AND DISCUSSION

1- Mango storage and the postharvest treatments with hot water or imazalil during the observational study of 1998, 1999 and 2000 seasons:

Concerning Mabrouka fruits stored at 10°C, the incipient of visible symptoms of chilling injury (CI) were observed after 7 days of storage at 10°C and were more severe when these fruits were transferred at 20°C for 3 days to ripen. Furthermore, the observational study of season 2000 revealed that 13°C was not a safe holding temperature. Mabrouka fruits stored at 20°C for 14 days showed the best appearance and eating quality. Mesk fruits stored at 10°C showed no obvious CI symptoms after 21 days of storage, but CI appeared after 28 days. The subsequent ripening for 6 days at 20°C after 14 days of storage at 10°C gave the best appearance and eating quality. For Mesk fruits stored at 20°C, the best appearance and eating quality were obtained after 14 days. Regarding Keitt fruits stored at 10°C, the incipient of CI symptoms were observed after 14 days of holding in the cold store, while CI symptoms were noticed before that for the fruits which ripened for 3 days at 20°C after 7 days of holding at 10°C. Furthermore, the observational study of season 2000 revealed that 13°C was a safe holding temperature for mature Keitt fruits. Keitt fruits stored at 20°C for 14 days showed the best marketing appearance and eating quality. The incipient of visible symptoms of CI was indicated by the development of pitting on the peel and with the discoloration of those pitted areas (necrosis), which became more severe with the progress of storage period. Mabrouka and Keitt Fruits which treated with hot water (53°C/5 min) and held at 10°C showed less CI symptoms. Also, the hot water treatment generally reduced the decay development during ripening of Mesk and Keitt fruits while this was not evident in Mabrouka. Furthermore, imazalil treatment (150 ppm/5 min) gave a good control for the postharvest decay in Mabrouka and Keitt while this was not clear in case of Mesk. There are many variations in the susceptibility to chilling injury among mango cultivars as reported by Farooqui et al. (1985). In addition, Graham (1990) illustrated that there are 2 likely causes of chilling sensitivity which lead to chilling injury. The first involves physical changes in certain membrane lipids, particularly phosphatidylglycerols, which result in changes in membrane properties and eventual disorganization of cellular compartmentation. The second cause is due to the impairment of the catalytic function of certain key enzymes of metabolism. of which phosphoenol pyruvate carboxylase is an example. Mango tolerance to chilling temperatures may increase after prestorage heat treatment Saucedo-Veloz et al., 1995). On the other hand, hot water treatment dip (50-55°C for 3-10 min) is an important natural strategy against mango postharvest pathological disorders (decay) as reported by Roy and Joshi (1988). Moreover, McGuire (1993) reported that imazalil in combination with hot water reduced anthracnose typically greater that due to the effect of heat alone.

2- Physical and chemical parameters as affected by cultivar, storage temperature and storage period in 1998 and 1999 seasons:

2.1- Crude fiber:

During ripening of mature green Mabrouka, Mesk and Keitt fruits the crude fiber contents declined in both seasons as shown in Table (2). The findings of the present study agreed with those reported by El-Zoghbi (1994).

2.2- Fruit weight loss:

Data presented in Tables (3&5) showed that the percentages of weight loss in Mabrouka, Mesk and Keitt cultivars generally increased significantly with the increasing of storage temperature and with the progress of storage period at the same temperature. There were significant differences between the percentages of weight loss at the storage temperatures of 10°C and 20°C at RH of 90%. So, the weight loss percentage was temperature and storage period dependent. The weight loss from harvested horticultural crops is mainly due to the water loss, which is known as transpiration, while some weight loss is due to loss of carbon in respiration but this is only a minor part of the total. The high storage temperature causes a high respiration rate which leads to a fruit weight loss (Hardenburg et al., 1990). Furthermore, (Dietz et al.. 1988) found that the weight loss of mango fruits is significantly correlated with the total number of lenticels per fruit but not significantly correlated with the cuticular thickness.

2.3- Fruit firmness:

The fruits of Mabrouka, Mesk and Keitt stored at 20°C were consistently softer than those at 10°C. Softening under each of the storage conditions advanced further with the progress of storage period at the same temperature degree. The data also showed that the Keitt mesocarp was firmer and also remained firm longer during ripening than those of Mabrouka and Mesk as shown in Tables (3&5).Generally, the statistical analysis clearly indicated that there were significant differences between the firmness values at the storage temperatures of 10°C and 20°C, also, there were significant differences within the same storage temperature as the storage period advanced. The enzyme activity increased in parallel with increase in tissue softness during ripening (Ali et al., 1995). Polygalacturonase has been implicated as the primary enzyme mediation the softening or the decrease in firmness during the ripening process, as reported by Roe and Bruemmer (1981).

2.4- Soluble solids content (SSC):

According to the data presented in Tables (3&5) there were significant effects of storage temperatures at 10 and 20°C with the progress

Table (1): Pomological characteristics of Mabrouka, Mesk and Keitt mango Cultivars in 1998 and 1999 seasons.

Cultivar	Fruit wt. (gm)		Fruit dimensions (cm)						Peel				Seed				Pulp				Moisture content (%)	
			Length		Diameter		Thickness		Wt. (gm)		%		Wt. (gm)		%		Wt. (gm)		%			
	1998	1999	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99	98	99	1998	1999
Mabrouka	444.93	526.16	12.78	14	8.5	9.03	7.86	8.23	45.73	83.5	10.28	15.87	43.1	51.83	9.69	9.85	356.1	390.83	80.03	74.28	83.79	86.38
Mesk	454.93	333.73	13.17	11.57	8.33	7.5	7.9	6.97	60.53	52.67	13.31	15.78	67.17	54.7	14.76	16.39	327.23	226.36	71.93	67.83	80.31	82.53
Keitt	749.43	746.1	13.77	14.31	10.08	10.41	9.47	9.24	86.5	67.73	11.54	9.08	53.9	40.63	7.19	5.44	609.03	637.74	81.27	85.48	74.52	75.90

Table (2): Means of crude fibers contents (%) of Mabrouka, Mesk and Keitt mango fruits at mature green and ripe stages in 1998 and 1999 seasons.

	% Crude fiber					
	1998			1999		
Ripening stage \ Cultivar	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
Mature green	0.45	0.52	0.54	0.54	0.51	0.52
Ripe	0.39	0.41	0.43	0.41	0.43	0.47
L.S.D. 0.05						
Treat.	0.1			0.067		
Cv.	0.123			0.082		
Treat. x Cv.	0.172			0.115		

Table (3): Means of fruit parameters as affected by cultivar, treatment, and their interaction in 1998 season.

Fruit Parameter	Weight loss (%)			Firmness (Lb/in²)			SSC (%)			Reducing sugars (%)			Total sugars (%)		
Cv. / *Treat.	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
T1	0	0	0	15.42	16.22	23.28	8.47	9.93	8.73	5.32	5.55	8.07	5.64	9.11	8.93
T2	1.68	3.05	2.12	7.11	13.35	21.6	13.6	12.87	10	7.51	7.05	10.05	10.33	9.49	10.52
T3	2.96	4.04	2.59	2.64	2.7	4.06	15.93	19	17.9	6.8	7.18	12.3	13.58	17.57	15.69
T4				1.66	2.88	8.2	14.47	18.13	14.2	7.09	9.85	8.82	12.3	18.74	11.15
T5				0.5	1.3	3.79	15.2	18.4	18.67	6.32	7.79	10.76	12.97	17.64	17.31
T6	3.42	5.68	3.41	9.69	8.98	18.54	13.33	16.2	10.4	8.94	5.15	8.65	12.67	12	10.5
T7	6.15	7.36	4.63	0.58	0.9	0.95	13.73	20.4	19	4.49	9.54	13.81	12.62	18.77	18.35
T8				1.76	1.3	2.02	15.47	19.6	16.6	8.58	9.47	10.84	13.19	19.75	15.06
T9				0.66	0.85	1.01	15.4	20.2	18.8	7.45	12.07	10.48	13.53	17	17.7
T10	5.46	8.42	4.64	1.7	2.14	16.34	16	19.8	11.93	7.25	9.1	9.39	11.57	17.26	13.58
T11	8.45	10.11	6.82	0.5	0.62	0.73	14	18.13	18.8	5.28	10.43	8.12	13.15	18.49	17.38
T12					0.78			18.93			8.51			15.43	
T13					0.68			18.67			11.46			17.34	
T14		10.23			1.12			19.93			8.92			17.77	
T15		13.01			0.63			17.8			9.78			16.38	
L.S.D. 0.05															
Treat.	0.146			1.551			0.674			0.342			0.804		
Cv.	0.096			0.81			0.352			0.179			0.42		
Treat. x Cv.	0.25			2.689			1.168			0.593			1.708		
Mesk treat.	0.298			1.565			1.433			0.568			1.847		

Fruit Parameter	Non-reducing sugars (%)			Starch (%)			Acidity (%)			pH		
Cv. / *Treat.	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
T1	0.32	3.56	0.86	3.97	3.84	3.58	2.42	3.01	1.16	2.9	3.33	3.5
T2	2.82	2.44	0.46	2.71	2.37	3.11	1.97	2.73	1.2	3.17	3.03	3.3
T3	6.78	10.39	3.39	2.63	2.35	3.29	0.85	0.97	0.85	3.8	3.53	3.3
T4	5.21	8.89	2.33	2.44	2.76	3.41	1.49	1.51	0.93	3.17	3.33	3.5
T5	6.64	9.85	6.54	2.16	2.13	1.65	0.46	0.59	0.85	4.1	4.1	3.47
T6	3.73	6.86	1.84	2.58	3.47	3.83	1.84	2.04	1.08	3.13	3.57	3.3
T7	7.53	9.23	4.53	1.84	1.8	1.93	0.25	0.28	0.34	4.8	4.5	4.17
T8	4.62	10.28	4.21	2.51	2.91	2.75	1.43	1.11	0.82	3.1	3.67	3.6
T9	6.09	4.93	7.22	2.83	1.91	2.19	1.08	0.63	0.69	3.5	3.7	3.8
T10	4.32	8.17	4.18	2.48	2.75	3.25	1.7	1.57	1.11	3.23	3.37	3.3
T11	7.87	8.05	9.26	1.96	2.13	2.83	0.26	0.24	0.34	4.9	4.8	4.6
T12		6.92			3.01			0.84			4.07	
T13		5.89			2.48			0.4			4.4	
T14		8.85			2.85			1.11			5.77	
T15		6.6			2.17			0.14			7.17	
L.S.D. 0.05												
Treat.	0.813			0.387			0.206			0.092		
Cv.	0.424			0.282			0.107			0.048		
Treat. x Cv.	1.41			0.669			0.357			0.154		
Mesk treat.	1.727			0.816			0.316			0.231		

*Treatments: T1 (Initial)// T2 (7d. @ 10 °C) // T3 (7d. @ 20 °C)// T4 (7d. @ 10°C + 3d. @ 20°C)// T5 (7d. @ 10°C + 6d. @ 20°C)// T6 (14d. @ 10 °C)// T7 (14d. @ 20 °C)// T8 (14d. @ 10°C + 3d. @ 20°C)// T9 (14d. @ 10°C + 6d. @ 20°C)// T10 (21d. @ 10 °C)// T11 (21d. @ 20 °C)// T12 (21d. @ 10°C + 3d. @ 20°C)// T13 (21d. @ 10°C + 6d. @ 20°C)// T14 (28d. @ 10 °C)// T15 (28d. @ 20 °C)

Table (4): Means of fruit parameters as affected by cultivar, treatment, and their interaction in 1998 season.

Fruit Parameter	V. C (mg / 100 ml Juice)			Peel chlorophyll a (mg / 100 g fresh wt.)			Peel chlorophyll b (mg / 100 g fresh wt.)			Peel total chlorophyll (mg / 100 g fresh wt.)			Peel carotene (mg / 100 g fresh wt.)			Pulp chlorophyll a (mg / 100 g fresh wt.)			Pulp chlorophyll b (mg / 100 g fresh wt.)			Pulp total chlorophyll (mg / 100 g fresh wt.)			Pulp carotene (mg / 100 g fresh wt.)		
Cv. / *Treat.	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
T1	2.61	51.2	60.18	1.95	4.95	0.92	0.95	2.37	0.21	5.24	16.01	10.79	2.73	9.19	8.8	0.36	0.29	0.32	0.26	0.38	0.71	1.25	1.19	2.01	1.12	3.59	0.86
T2	5.66	57.63	56.53	1.92	2.18	0.61	1.36	0.87	0.23	7.19	6.88	7.8	4.99	4.01	5.95	0.22	0.19	0.18	0.34	0.26	0.52	0.76	0.6	1.11	0.69	0.35	0.38
T3	1.35	21.75	35.64	0.74	0.62	0.53	0.35	0.27	0.05	2.41	2.75	6.77	4.3	7.23	5.82	0.26	0.53	0.13	0.14	0.58	0.05	0.8	1.84	0.44	2.66	2.77	0.67
T4	1.46	30.78	53.22	0.87	1.15	0.45	0.67	0.53	0.29	3.23	3.91	7.12	3.4	5.86	6.2	0.2	0.21	0.2	0.37	0.06	0.19	0.89	0.5	0.87	1.77	8.7	0.82
T5	1.43	37.71	31.82	0.31	1.17	0.58	0.73	0.61	0.11	1.45	4.22	5.91	6.87	5.42	7.64	0.17	0.18	0.18	0.17	0.2	0.5	0.81	0.64	1.05	2.81	3.45	1.53
T6	3.77	47.18	53.87	1.65	1.83	1.84	1.06	0.77	0.3	4.9	5.14	4.83	4.42	3.92	3.54	0.34	0.21	0.12	0.18	0.25	0.31	1.2	0.75	0.78	2.13	2.85	0.51
T7	1.23	22.8	21.77	0.32	0.36	0.09	0.56	0.35	0.01	1.44	1.53	1.04	8.77	14.31	8.66	0.2	0.37	0.04	023	0.4	0.33	0.79	1.14	0.52	3.23	3.98	3.12
T8	3.5	32.29	29.83	0.91	1.97	1.25	0.48	3.82	0.06	2.22	5.7	6.94	4.06	5.63	7.96	0.25	0.33	0.07	0.1	1.01	0.02	0.86	1.52	0.35	1.75	2.36	1.15
T9	1.43	30.88	7.93	0.28	0.68	0.7	0.34	0.64	0.1	1.19	2.03	2.89	6.35	4.14	3.07	0.2	0.23	0.15	0.29	0.55	0.14	0.85	1.16	0.61	2.21	3.29	1.86
T10	2.95	36.17	45.71	0.71	2.12	0.74	0.41	0.72	0.14	2.35	6.05	5.01	4.33	5.99	5.57	0.17	0.44	0.03	0.39	0.45	0.64	0.72	1.34	0.91	1.08	2.17	1.17
T11	1.43	38.99	5.54	0.23	0.46	0.17	0.32	0.63	0.22	0.98	1.58	1.05	8.11	7.21	5.02	0.22	0.24	0.11	0.31	0.2	0.24	0.9	1.83	0.58	3.56	8.6	2.23
T12		38.3			1.13			0.56			3.45			6.06			0.41			0.33			0.99			2.05	
T13		31.45			0.57			0.5			1.94			5.68			0.22			0.21			0.84			2.57	
T14		45.25			2.49			1.19			7.03			6.46			0.12			0.34			0.65			2.51	
T15		36.14			0.38			0.29			1.55			12.19			0.26			0.42			1.12			5.39	
L.S.D. 0.05																														
Treat.	2.912			0.479			0.528			0.99			0.898			0.117			0.281			0.391			0.326		
Cv.	1.52			0.25			0.275			0.517			0.469			0.061			0.146			0.204			0.17		
Treat. x Cv.	5.049			0.831			0.915			1.718			1.556			0.2			0.487			0.677			0.565		
Mesk treat.	7.678			0.935			0.899			0.854			0.77			0.225			0.53			0.828			0.405		

*Treatments: T1 (Initial)// T2 (7d. @ 10 °C) // T3 (7d. @ 20 °C)// T4 (7d. @ 10°C + 3d. @ 20°C)// T5 (7d. @ 10°C + 6d. @ 20°C)// T6 (14d. @ 10 °C)// T7 (14d. @ 20 °C)// T8 (14d. @ 10°C + 3d. @ 20°C)// T9 (14d. @ 10°C + 6d. @ 20°C)// T10 (21d. @ 10 °C)// T11 (21d. @ 20 °C)// T12 (21d. @ 10°C + 3d. @ 20°C)// T13 (21d. @ 10°C + 6d. @ 20°C)// T14 (28d. @ 10 °C)// T15 (28d. @ 20 °C)

Table (5): Means of fruit parameters as affected by cultivar, treatment, and their interaction in 1999 season.

Fruit Parameter	Weight loss (%)			Firmness (Lb/in²)			SSC (%)			Reducing sugars (%)			Total sugars (%)			Non-reducing sugars (%)			Starch (%)			Acidity (%)			pH		
Cv. / *Treat.	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
T1	0	0	0	14.87	15.17	21.24	7.53	10.8	10	6.17	4.33	9.44	6.79	8.71	10.81	0.68	4.18	1.37	2.67	2.69	3.44	2.7	3.14	0.66	3.17	3.2	4.07
T2	1.54	1.41	1.37	9.53	13.71	16.38	10.47	11.33	10.6	4.66	7.61	9.53	6.65	11.31	10.67	1.98	3.7	1.14	3.22	1.86	3.89	2.4	2.13	0.76	2.93	3.1	3.87
T3	3.54	3.48	2.34	1.2	1.35	6.07	13.07	18.13	14.07	5.62	8.94	12.65	11.54	18.72	14.21	5.91	9.77	1.4	2.33	1.75	3.15	0.88	0.75	0.7	3.53	3.8	3.83
T4				2.07	5.52	10.24	12.73	16.07	14.53	6.95	8.2	9.5	12.22	17.46	12.05	5.27	9.26	2.55	2.34	2.63	2.72	1.92	1.51	0.58	3.17	3.37	3.87
T5				1.42	6.38	5.63	13.8	17.33	15.8	7.45	10.71	11.21	15.51	15.7	14.12	8.07	4.99	2.91	2.85	2.34	2.66	1.06	0.84	0.36	3.47	3.77	4.1
T6	2.82	2.66	2.21	6.5	9.52	19.65	13.4	15.2	14	9.16	6.58	7.92	13.81	13.81	13.42	4.66	7.23	5.71	3.39	3.01	2.9	1.74	1.7	0.91	3.17	3.13	3.8
T7	6.92	6.21	4.24	0.71	0.78	2.06	13.67	17.4	16	6.84	11.41	9.68	14.18	15.64	14.93	7.35	4.23	5.25	2.4	2.06	1.34	0.26	0.21	0.28	4.77	4.47	4.5
T8				3.51	3.35	4.06	14.4	17.53	14.8	8.31	7.31	10.69	13.19	15.81	13.59	4.80	8.49	2.9	2.51	1.71	2.34	1.37	1.08	0.54	3.3	3.6	3.9
T9				0.92	1.56	2.73	13.93	18.8	16.4	7.86	11.58	9.53	13.69	16.52	14.4	6.63	4.95	4.87	2.65	2.83	2.35	0.79	0.45	0.35	3.63	4.2	4.2
T10	4.23	3.91	3.21	4.91	7.93	14.79	13.27	16.4	14.4	7.18	9.03	8.67	12.35	13.78	13.85	5.17	4.75	5.18	3.13	3.08	3.47	1.64	1.38	0.81	3.27	3.2	3.6
T11	9.93	8.39	6.31	0.5	0.57	0.58	11.93	17	18.2	4.2	10.49	10.16	11.28	16.62	19.21	7.08	6.13	9.05	1.57	2.01	2.11	0.17	0.28	0.17	4.9	4.4	4.8
T12					3.68			17			7.55			14.95			7.39			2.68			1.26			3.4	
T13					1.08			17			10.77			15.37			4.6			2.17			0.52			4	
T14		5.2			3.73			17.2			9.49			13.71			4.15			2.67			1.15			3.4	
T15		10.42			0.5			15.8			8.66			14.01			5.35			1.96			0.23			4.6	
L.S.D. 0.05																											
Treat.		0.072			2.745			0.536			0.42			0.673			0.783			0.54			0.141			0.058	
Cv.		0.047			1.433			0.28			0.219			0.351			0.409			0.282			0.073			0.03	
Treat. x Cv.		0.116			4.76			0.929			0.728			1.167			1.358			0.936			0.242			0.089	
Mesk treat.		0.158			3.469			1.078			0.736			1.341			1.56			0.766			0.234			0.091	

*Treatments: T1 (Initial)// T2 (7d. @ 10 °C) // T3 (7d. @ 20 °C)// T4 (7d. @ 10°C + 3d. @ 20°C)// T5 (7d. @ 10°C + 6d. @ 20°C)// T6 (14d. @ 10 °C)// T7 (14d. @ 20 °C)// T8 (14d. @ 10°C + 3d. @ 20°C)// T9 (14d. @ 10°C + 6d. @ 20°C)// T10 (21d. @ 10 °C)// T11 (21d. @ 20 °C)// T12 (21d. @ 10°C + 3d. @ 20°C)// T13 (21d. @ 10°C + 6d. @ 20°C)// T14 (28d. @ 10 °C)// T15 (28d. @ 20 °C)

of storage period on the percentages of SSC in the fruits of Mabrouka, Mesk and Keitt cultivars. The average SSC percentages increased gradually with fruit ripening. At the ripe stage, the Mesk fruits were the highest in SSC values (18.9%) followed by Keitt (17.5%) while Mabrouka showed the lowest values (13.7%). The gradual increase in the percentage of SSC with the increase of temperature and storage period could be due to the degradation of complex insoluble compounds, like starch, to simple soluble compounds like sugars (Joshi and Roy, 1988), and also other complex insoluble components which degrade to soluble forms.

2.5- Starch and sugars:

Data presented in Tables (3&5) revealed that percentages of starch in Mabrouka, Mesk and Keitt cultivars generally decreased with the increasing of storage temperature. There were significant differences between the percentages of starch at the storage temperatures of 10°C and 20°C. Also, the percentages of starch decreased significantly with the progress of storage period especially at higher temperatures. In Mabrouka fruits, the refrigerated storage prior to ripening reduced the rate of ripening followed by inhibition of starch hydrolysis, but this was not marked in Mesk and Keitt, which showed a general decline in starch contents as the fruits ripened at higher temperatures. On the other hand, the reducing sugars percentages increased with the increasing of storage temperature and with the progress of storage period with a significant difference between the percentages of storage temperatures of 10 and 20°C. Concerning the ripening treatments, it has been found that cold storage prior to ripening reduced the rate of ripening and inhibited the formation of reducing sugars in the case of Mabrouka and Keitt. while this was not marked in Mesk. Also, there were significant effects of storage temperatures at 10 and 20°C with duration of storage on the percentages of total sugars in the fruits of Mabrouka, Mesk and Keitt cultivars. The percentages of total sugars in the three cultivars showed a rise with the progress of storage period, but in Mabrouka and Mesk fruits this rise was followed by a decline at the end of storage period. Also, there was a general increasing trend in the total sugars percentages as the storage temperature increases. Concerning the ripening treatments, it has been found that refrigerated storage prior to ripening reduced the rate of ripening and also inhibited the formation of sugars. The data also showed that at the ripe stage, the Mesk fruits were the highest in total sugars percentage followed by Keitt while Mabrouka showed the lowest values. Furthermore, there was a significant effect of storage temperature on the percentages of non-reducing sugars in mango fruits of Mabrouka, Mesk and Keitt. The non-reducing sugars, in fruits of the three cultivars, increased with the increasing of storage temperature and with the progress of storage period, except in Mabrouka fruits the non-reducing sugars for the fruits stored at 20°C reached the maximum after 7 days, and then declined. In general, the obtained data also showed that non-reducing sugars increased in fruits of the three cultivars when stored at 20°C rather than at 10°C for the same period of storage. The refrigerated storage prior to ripening reduced the formation of non-reducing sugars in Mabrouka and Mesk, while this was not marked in Keitt. It has been recorded that mango fruit at the mature green stage contain some accumulated starch which is mobilized during ripening and this phenomenon is evident in the chloroplast where the starch granules become progressively smaller as ripening proceeds (Morga et al., 1979). The starch that has accumulated in the mature fruit is rapidly lost during ripening and the ripe fruit usually contains negligible levels of starch (Joshi and Roy. 1988). Starch hydrolysis in the ripening mango has been associated with amylase activity and the complete disappearance of starch may be attributed to an upsurge of amylase as ripening is completed (Fushs et al., 1980). As a consequence of starch hydrolysis, total sugars increase during ripening, with glucose, fructose and sucrose constituting most of the monosaccharides (Selvaraj et al., 1989). Furthermore, Medlicott and Thompson (1985) working on Keitt mangoes, arranged the principal sugars in mango fruits, in descending order, to sucrose, fructose and glucose.

2.6- The titratable acidity:

The acidity percentages in Mabrouka, Mesk and Keitt cultivars generally decreased with the increasing of storage temperature and with the progress of storage period especially at higher temperatures as shown in Tables (3&5). Titratable acidity declines as the mango ripens (Medlicott and Thompson, 1985). Also, titratable acidity decreased with the increasing of storage temperature (Corrales-Garcia and Lakshminarayana, 1991). In Keitt mangoes citric and malic acids were the main organic acids, and a large decrease in citric acid and a small decrease in malic acid were responsible for the loss of acidity, while tartaric, ascorbic, oxalic and alpha-ketoglutaric acids were present in low concentrations (Medlicott and Thompson, 1985). The decline in levels of organic acids during fruit ripening, presumably due to their utilization as respiratory substrates in the respiration process (Ulrich, 1970).

2.7- pH values:

The pH values in Mabrouka, Mesk and Keitt cultivars generally increased with the increasing of storage temperature and with the progress of storage period especially at higher temperatures as illustrated in Tables (3&5). Ripening of mango fruits is generally associated with increasing pH values (Medlicott et al., 1990).

2.8- The ascorbic acid (Vitamin C):

There were significant effects of storage temperatures and storage time on the contents of ascorbic acid of the Mabrouka, Mesk and Keitt fruits. In general, the results illustrated that the ascorbic acid contents declined with the increasing of storage temperature and with the progress of storage period as shown in Tables (4&6). The loss in ascorbic acid content during storage could be attributed to the increase in ascorbate oxidase activity (Cardello and Cardello, 1998). In contrast, Vazquez-Salinas and Lakshminarayana (1985) reported that ascorbic acid content increased during storage.

2.9- Peel and pulp pigments content:

According to the data presented in Tables (4&6) the contents of peel chlorophyll a, b, and total chlorophyll in Mabrouka, Mesk and Keitt fruits declined with the increasing of storage temperature and with the progress of storage time. Regarding the subsequent ripening at room temperature after a period of holding at 10°C, the obtained data showed a general declining trend in the contents of peel chlorophyll "a" as the fruits ripened at higher temperatures. Peel carotene content in Mabrouka fruits generally increased with the increasing of storage temperature and with the progress of storage period. The obtained results also showed that carotene contents for Mesk fruits stored at 10°C did not increase with the progress of storage duration, while those contents increased slightly for the fruits stored at 20°C. In contrast, Keitt fruits stored at 10 and 20°C showed a slightly decline in carotene content as the storage period proceeds. The initial pulp chlorophyll levels for Mabrouka, Mesk and Keitt were in appreciable amounts while afterwards the chlorophyll diminished in the pulp and the changes were very inconsistent. On the other hand, the pulp carotene contents in Mabrouka fruits increased gradually with the increasing of storage temperature and with the progress of storage period. As for Mesk and Keitt fruits, the pulp carotene contents increased with the increasing of storage temperature and duration, and this increase was finally followed by a decline for the fruits stored at 20°C. During ripening of Tommy Atkins mangoes Medlicott *et al.* (1986) observed a rapid destruction of chlorophyll, with chlorophyll "a" preferentially degraded relative to chlorophyll "b", while the carotenoids level increases. A more rapid loss in chlorophyll "a" is typically observed in senescence (Simpson et al., 1976). Furthermore, the plastid thylakoid membrane systems in the peel are gradually broken down during ripening, while osmiophilic globules enlarge and increase in number. This loss of granal membrane integrity is associated with chlorophyll degradation, while the appearance of osmiophilic globules accompanies increases in carotenoid levels, indicating the transformation of the chloroplast to a chromoplast

Table (6): Means of fruit parameters as affected by cultivar, treatment, and their interaction in 1999 season.

Fruit Parameter	V. C (mg / 100 ml Juice)			Peel chlorophyll a (mg / 100 g fresh wt.)			Peel chlorophyll b (mg / 100 g fresh wt.)			Peel total chlorophyll (mg / 100 g fresh wt.)			Peel carotene (mg / 100 g fresh wt.)			Pulp chlorophyll a (mg / 100 g fresh wt.)			Pulp chlorophyll b (mg / 100 g fresh wt.)			Pulp total chlorophyll (mg / 100 g fresh wt.)			Pulp carotene (mg / 100 g fresh wt.)		
Cv. / *Treat.	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt	Mabrouka	Mesk	Keitt
T1	7.76	62.9	40.4	2.17	3.87	0.84	1.47	1.51	0.75	6.9	14.63	11.18	4.85	9.33	10.87	0.29	0.28	0.2	0.36	0.46	0.33	1.4	1.12	1.21	1.46	1.29	1.13
T2	6.27	61.28	40.08	1.38	2.21	0.75	0.88	0.79	0.17	4.79	8.26	8.75	2.97	5.69	7.3	0.18	0.22	0.04	0.31	0.16	0.39	0.84	0.68	0.62	2.14	1.1	0.77
T3	2.09	23.84	23.48	0.46	2.02	0.74	0.27	0.71	0.13	1.82	7.5	8.63	9.05	7.91	9.85	0.21	0.24	0.1	0.04	0.78	0.04	0.75	1.33	0.4	3.08	3.39	1.14
T4	3.37	50.78	24.29	0.43	2.24	0.59	0.77	0.87	0.18	1.87	7.31	7.88	4.87	5.94	5.34	0.17	0.21	0.2[illegible]	0.3	0.43	0.64	0.76	1	1.44	2	3.41	1.22
T5	2.28	30.8	20.49	0.29	0.69	0.23	0.46	0.28	0.19	1.51	2.94	3.76	8.76	8.84	8	0.25	0.21	0.12	0.25	0.25	0.21	0.91	0.88	0.63	2.24	2.4	1.56
T6	4.83	63.7	43.17	1.56	2.64	1.6	1.19	1.14	0.65	3.84	8.76	5.45	2.75	6.83	3.46	0.33	0.2	0.1	0.34	0.14	0.2	0.93	0.46	0.58	1.49	0.42	0.76
T7	2.25	33.6	15.2	0.48	0.19	0.15	0.67	0.49	0.05	1.67	1.09	1.83	5.87	9.31	8.46	0.16	0.13	0.02	0.85	0.34	0.55	0.79	0.68	0.82	4.42	6.84	3.06
T8	2.17	47.54	26.33	0.85	1.12	0.64	0.38	0.75	0.23	2.96	3.31	3.32	3.93	4.4	6.39	0.24	0.28	0.04	0.33	0.5	0.04	0.81	1.11	0.27	1.32	2.04	1.33
T9	2.5	40	22	0.34	0.77	0.46	0.68	0.61	0.39	1.31	2.86	2.71	3.42	8.46	5.66	0.26	0.29	0.15	0.4	0.52	0.09	0.88	1.07	0.62	1.7	2.66	1.58
T10	3.08	56.72	46.5	0.55	2.77	0.72	0.44	1.3	0.12	2.12	6.55	4.65	3.82	4.49	5.19	0.18	0.35	0.11	0.23	0.18	0.25	0.69	0.72	0.72	1.45	0.6	0.68
T11	1.96	30.82	10	0.38	0.69	0.1	0.25	0.38	0.22	1.18	2.49	0.79	7.97	8.81	5.06	0.21	0.42	0.07	0.25	0.63	0.66	0.73	1.63	0.92	3.96	4.4	2.16
T12		56.42			1.91			1.07			6.61			7.46			0.26			0.21			0.71			1.1	
T13		45.08			0.87			0.63			2.39			4.85			0.27			0.23			0.81			2.31	
T14		62.03			1.55			1.15			4.7			4.24			0.32			0.28			1.2			1.4[illegible]	
T15		48.81			0.3			0.33			1.01			9.46			0.34			0.68			1.12			3.19	
L.S.D. 0.05																											
Treat.	2.918			0.522			0.565			1.174			1.06			0.092			0.225			0.3			0.266		
Cv.	1.524			0.272			0.295			0.613			0.553			0.048			0.117			0.156			0.139		
Treat. x Cv.	5.06			0.904			0.979			2.036			1.838			0.154			0.389			0.518			0.461		
Mesk treat.	6.559			0.845			0.783			0.883			0.96			0.201			0.404			0.707			0.388		

*Treatments: T1 (Initial)// T2 (7d. @ 10 °C) // T3 (7d. @ 20 °C)// T4 (7d. @ 10°C + 3d. @ 20°C)// T5 (7d. @ 10°C + 6d. @ 20°C)// T6 (14d. @ 10 °C)// T7 (14d. @ 20 °C)// T8 (14d. @ 10°C + 3d. @ 20°C)// T9 (14d. @ 10°C + 6d. @ 20°C)// T10 (21d. @ 10 °C)// T11 (21d. @ 20 °C)// T12 (21d. @ 10°C + 3d. @ 20°C)// T13 (21'd. @ 10°C + 6d. @ 20°C)// T14 (28d. @ 10 °C)// T15 (28d. @ 20 °C) containing red or yellow carotenoid pigments (Medlicott et al., 1986). The synthesis of carotenoids in mangoes involves mevalonic acid and geraniol as precursors via the same biosynthetic pathway of carotenogenesis established in other species (Mattoo et al., 1968).

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