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RESPIRATION RATE, PHYSICO-CHEMICAL FRUIT QUALITY AND CONSUMER ACCEPTABILITY FOR FAJRI MANGO UNDER DIFFERENT STORAGE TEMPERATURES

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Fajri is a commercial yet scientifically an unexplored mango cv. of Pakistan. Due to large fruit size and being mid to late season in fruit maturity, it has tremendous potential for export. The storage life and quality of mango cv. 'Fajri' at low temperature has not been standardized. Present study was aimed to investigate the effect of low temperature storage on fruit quality and shelflife of mango cv. 'Fajri'. Fruits were harvested at commercial maturity and stored at 10, 12 or 14 ± 1°C with 80-85% RH for 21 days. After storage, the rate of respiration in the fruit stored at 12 and 14°C remained 1-2 times higher than fruit kept at 10°C. Storage of fruit at 14°C resulted in significantly higher fruit skin shriveling, fruit softening and disease incidence severity as compared to at 10 and 12°C. The fruit stored at 10 and 12°C showed statistically similar behaviour regarding fruit peel colour, fruit softness, disease incidence, disease severity, skin shriveling, acidity, SSC: TA ratio, total and reducing sugars contents. However, no chilling injury of fruit was observed at any storage temperatures. The extent of yellow peel colour and disease incidence was significantly higher at 14°C compared to fruit stored at 10 and 12°C. In conclusion, the fruit of cv. 'Fajri' exhibited extended (21 days) storage life with better fruit quality at 10 and 12°C compared to 4-5 days of under ambient conditions (32 ± 1°C; 55-60% RH). Study emphasized the need to further investigate and develop the strategies for disease management and post-storage peel colour development for better consumer acceptability.

Keywords: Storage temperature, *Mangifera indica*, fruit quality, respiration, shelf life

INTRODUCTION

Mango is fifth major fruit crop of the world with over 35.12 million tons annual production. Pakistan, being one of the major producer [ranking as fifth largest producer in the world with 1.78 million tons production (FAOSTAT, 2010) and sixth largest exporter with 0.073 million tons export (FAOSTAT, 2009)], needs to explore new opportunities for international mango fruit trade. Concomitantly, attempts are now being made to target the high end European and Far East markets for higher foreign exchange earnings together with traditional Gulf markets. During the last few years, Pakistan got access to many markets including European Union, Afghanistan, Iran and China. Moreover, the markets of United States of America, Singapore, Sri Lanka, Malaysia, Jordan and Lebanon have also been opened for export of Pakistani mangoes (Mirza, 2011).

In order to meet the diverse market demands in different countries, there is need to explore the export potential of wide range of local commercial cultivars. In the past, Pakistani mango export has been revolving around few cultivars including 'Sindhri', 'Samar Bahisht Chaunsa' with a new inclusion of 'Kala Chaunsa' and 'Sufaid Chaunsa' during the recent years. While, 'Fajri', 'Dusehri', 'Langra', 'Anwar Ratole', 'Sonehra', etc. have been used for domestic consumption thereby neglecting their potential for exports.

'Fajri' is one of the promising mango cultivar of Pakistan with large fruit size (456 g avg. wt), medium-thick skin having light yellow colour, obliquely oval shape, slightly rounded base, slightly prominent beak, very good fruit quality and ripens mid to late season (Jilani *et al*., 2010; Raza, 2011). Plant growth environment (Anwar *et al*., 2011; Saeed *et al*., 2011) and fruit storage conditions affect mango (Ullah *et al*., 2012). Presently, very limited information is available regarding the impact of low temperature storage on the postharvest quality and shelf life of mango cv. 'Fajri', which prompted us to investigate the low temperature storage potential of this cultivar for its extended storage life with better quality. Hence, the present study was conducted to investigate the effect of low temperature storage on the storage life and fruit quality of 'Fajri' mango.

MATERIALS AND METHODS

***Fruit sampling, transport and storage*:** Uniform sized, healthy fruit of cv. 'Fajri' were sourced from a commercial

mango orchard located at Lodhran District of Punjab Province (29.32°N; 71.38°E), Pakistan. Fruit (with 4-6 cm long intact pedicels) harvested at commercial maturity were de-sapped in 0.5% lime solution followed by washing with tap water and finally treated with 0.5 mL L^{-1} Sportak® (Prochloraz). Afterwards, the fruit were air dried, packed in corrugated card board boxes and transported to Postharvest Research and Training Centre (PRTC), Institute of Horticultural Sciences (IHS), University of Agriculture, Faisalabad, Pakistan in a reefer van (at 20ºC). Fruit were stored at 10, 12 or 14ºC with 80-85% RH for 21 days followed by ripening at ambient conditions (32 ± 1ºC and 60-65% RH). Lay out of experiment was under Completely Randomized Design and seven fruit were used per treatment unit for each parameter replicated thrice.

***Data collection*:** Data regarding respiration rate, physical (peel colour, textural softness, shriveling and disease development), organoleptic (taste, flavour, pulp colour, texture and aroma) and biochemical [soluble solid contents (SSC), titratable acidity (TA), SSC: TA ratio, ascorbic acid, sugars and total carotenoid contents] fruit quality attributes were collected. Assessments regarding physical fruit quality attributes were made both after removals from the storage and at fully ripen stage (eating soft). Respiration rate was recorded daily during post-storage fruit ripening. However, organoleptic and biochemical fruit quality attributes were determined at fully ripen stage (eating soft).

***Respiration rate*:** Rate of respiration was determined as CO_2 produced using a digital CO_2 Gas Analyzer (MI-70, VAISALA, Finland) and was expressed as mmol CO_2 kg^{-1} h^{-1} (Hameed *et al*., 2010).

***Physical fruit quality*:** Fruit peel colour development was scored visually as reported earlier by Malik and Singh (2005), using the scale: 1 = 100% green and 0% yellow, 2 = 75% green and 25% yellow, 3 = 50% green and 50% yellow, 4 = 25% green and 75% yellow, 5 = 0% green and 100% yellow. Similarly, fruit textural softness was recorded by thumb pressure described by Anwar and Malik (2007), rated from 1 to 5 score **(**1 = hard, 2 = sprung, 3 = slightly soft, 4 = eating soft and 5 = ripe). Fruit skin shriveling was scored manually as described earlier by Malik and Singh (2005), where 1 = nil, 2 = <10%, 3 = 10-25%, 4 = 25-50%, 5 = 50% and disease incidence and disease severity were assessed by using different scales earlier reported by Akhtar and Alam (2002), where 1 = none, 2 = traces (after care full observation), 3 = slight, 4 = moderate, 5 = severe. Organoleptic evaluation was done by a panel of ten judges using a nine point hedonic scale where 1 = dislike extremely and 9 = like extremely (Peryam and Pilgrim, 1957).

***Biochemical fruit quality*:** SSC (ºBrix) of fruit juice was determined by digital refractometer (RX 5000, ATAGO, Japan). TA (%) was determined using the titration method as described by (Rajwana *et al*., 2010). For the determination of ascorbic acid contents, the method of Saleem *et al*. (2007), was used and was expressed as mg 100 g^{-1} FW. Determination of reducing (RS), non-reducing (NRS) and total sugars (TS) in the mango juice were done by using the method outlined by Khan *et al*. (2009), and were expressed in percentage (%). Total carotenoids were determined by using the method of Lalel *et al*. (2003), with a modification of using silica sand instead of quartz sand and were expressed as µg g^{-1} FW.

***Statistical analysis*:** The collected data were subjected to analysis of variance (ANOVA) using Statistix 8.1 software and treatment means were compared using Least Significant Difference (LSD) test at 5% level of significance ($P \leq 0.05$). To ensure the validity of the statistical analysis, all the assumption were checked.

RESULTS

***Respiration rate*:** Low temperature storage significantly ($P \leq 0.05$) influenced the respiration rate during fruit ripening. Respiration rate of low temperature stored fruit increased as fruit ripening period progressed (Fig. 1). Fruit removed from all the storage temperatures exhibited their respiratory peaks on day-5 of fruit ripening (Fig. 1). Fruit stored at 10°C showed 1-fold and 1.5-fold less respiration rate during ripening period as compared to the fruit stored at 12 and 14°C, respectively.

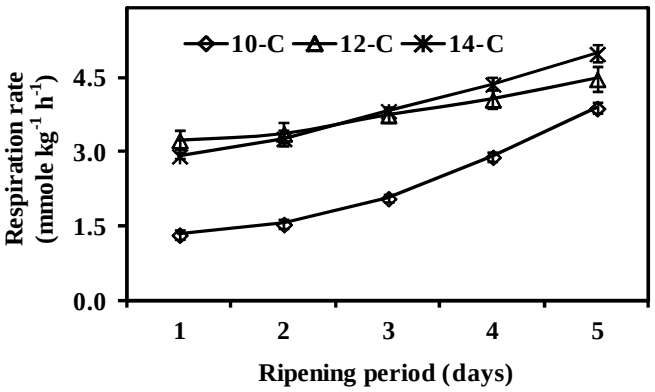

Figure 1. Effect of storage temperature on respiration rate of mango cv. 'Fajri' fruit during ripening. Vertical bars indicate ± SE of means; n = 3 replicates.

***Physical fruit quality*:** Significant impact of different storage temperatures was noted on various physical fruit quality attributes (including peel colour, textural softness, skin shriveling and disease development) of 'Fajri' fruit after 21 days of storage followed by ripening at 32±1°C (Table 1, Fig. 2). The peel colour development during ripening in 'Fajri' fruit stored at 10 or 12°C remained very poor as compared to fruit stored at 14°C (Table 1). Fruit stored at 10 or 12°C were more firm than at 14°C after removal from the

cold storage (Table 1). However, on day-5 of fruit ripening fruit stored at 10°C exhibited lowest fruit softness score compared to those stored at 12 and 14°C (Table 1). Fruit stored at different storage temperatures exhibited significant ($P \leq 0.05$) difference with respect to skin shriveling (Table 1). Rate of fruit skin shriveling was highest for fruit kept at 14°C both after removal from cold storage as well as during fruit ripening in contrast to fruit stored at 10 or 12°C. Similarly, disease incidence and disease severity were significantly reduced in the fruit stored at 10°C compared to all other treatments (Fig. 2).

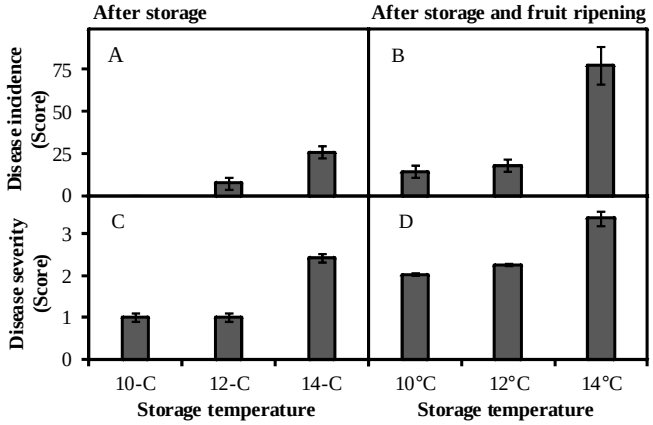

Figure 2. Effect of storage temperature on disease incidence and disease severity after storage (A and C), and after storage & ripening (B and D) of mango cv. 'Fajri' fruit respectively. Vertical bars indicate ± SE of means; n = 3 replicates.

After removal from storage the fruit stored at 10°C did not exhibit any disease incidence, whereas fruit kept at 12 and 14°C showed 7-fold and 26-fold higher disease incidence compared to fruit stored at 10°C respectively. After 5 days of ripening at ambient conditions, fruit stored at 14°C showed 6-fold and 5-fold higher disease incidence compared to fruit stored at 10 and12°C, respectively (Fig. 2A, 2B). During fruit ripening period, fruit kept at 14°C exhibited 2.4-fold and 1.1-fold higher disease severity than fruit stored at 10°C (Fig. 2C, 2D).

Fruit stored at 14°C exhibited significantly ($P \leq 0.05$) better fruit taste and aroma after ripening compared to 10 or 12°C stored fruits (Table 2). However, fruit texture score was higher for fruit stored at 12°C than all other temperatures (Table 2). Data regarding fruit flavour and pulp colour of ripe fruit did not show any significant ($P \leq 0.05$) difference with respect to various storage temperatures (Table 2).

***Biochemical fruit quality*:** Biochemical fruit quality attributes including SSC, TA, SSC: TA ratio, AA and sugar contents were significantly ($P \leq 0.05$) affected by the storage temperatures (Table 3, Fig. 3). At ripe stage, fruit stored at 10°C showed 1.1-fold higher SSC as compared to fruit stored at 12 or 14°C (Fig. 3A). The fruit stored at lower temperature (10°C) had 1.3-fold and 2.7-fold higher TA in contrast to 12 and 14°C, respectively (Fig. 3). SSC: TA ratio was significantly higher in fruits stored at 14°C compared to 10 or 12°C (Fig. 3). The level of ascorbic acid in fruit juice improved with increase in the storage temperature. Maximum amount of ascorbic acid (32.3 mg 100 g^{-1} FW) was recorded in the fruit kept at 14°C than all other temperatures (Table 3). Maximum level of reducing sugars (5.26%) and total sugars (17.44%) were observed in the fruit stored at 10°C as compared to all other storage temperature

Table 1. Effect of storage temperature on peel colour, fruit softness and shriveling of mango cv. 'Fajri' fruit

Storage temperature	Peel colour (score)		Fruit softness (score)		Shriveling (score)	
	After storage	Storage & ripening	After storage	Storage & ripening	After storage	Storage & ripening
10°C	1.00 b	1.17 b	2.17 b	3.87 b	1.00 b	1.23 b
12°C	1.07 b	1.23 b	2.27 b	4.03 a	1.00 b	1.30 b
14°C	1.53 a	4.27 a	2.57 a	4.13 a	1.43 a	1.90 a
LSD ($P \leq 0.05$)	0.2209	0.3263	0.2825	0.1153	0.2664	0.3883

Means not sharing similar letters are significantly different ($P \leq 0.05$); NS = non-significant.

Table 2. Effect of low temperature storage (21 days) on organoleptic attributes of mango cv. 'Fajri' after storage and fruit ripening

Storage Temperature	Taste (Score)	Flavour (Score)	Pulp colour (Score)	Texture (Score)	Aroma (Score)
10°C	6.57 b	6.60	8.47	5.10 b	8.13 b
12°C	6.83 b	6.30	8.53	5.47 a	8.10 b
14°C	7.40 a	6.67	8.83	4.90 b	8.70 a
LSD ($P \leq 0.05$)	0.498	NS	NS	0.203	0.48

Means not sharing similar letters are significantly different ($P \leq 0.05$); NS = non-significant.

Table 3. Effect of storage temperature on bio-chemical characteristics of mango cv. 'Fajri' after storage and fruit ripening

Storage temperature	Ascorbic acid (mg 100 g^{-1} FW)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)	Total carotenoids (µg g^{-1} FW)
10°C	25.80 b	5.26 a	11.58	17.44 a	35.31
12°C	30.11 a	4.77 b	11.29	16.65 b	29.19
14°C	32.26 a	2.49 c	12.73	15.90 b	28.10
LSD ($P \leq 0.05$)	2.226	0.4419	NS	1.120	NS

Means not sharing similar letters are significantly different ($P \leq 0.05$); NS = non-significant.

(Table 3). However, levels of non-reducing sugars and total carotenoids were not affected by different storage temperatures (Table 3). Fruit stored at 10ºC exhibited highest total carotenoids (35.3 µg g^{-1} FW) about 15% and 18% higher in fruit juice in contrast to fruit stored at 12 and 14°C, respectively (Table 3).

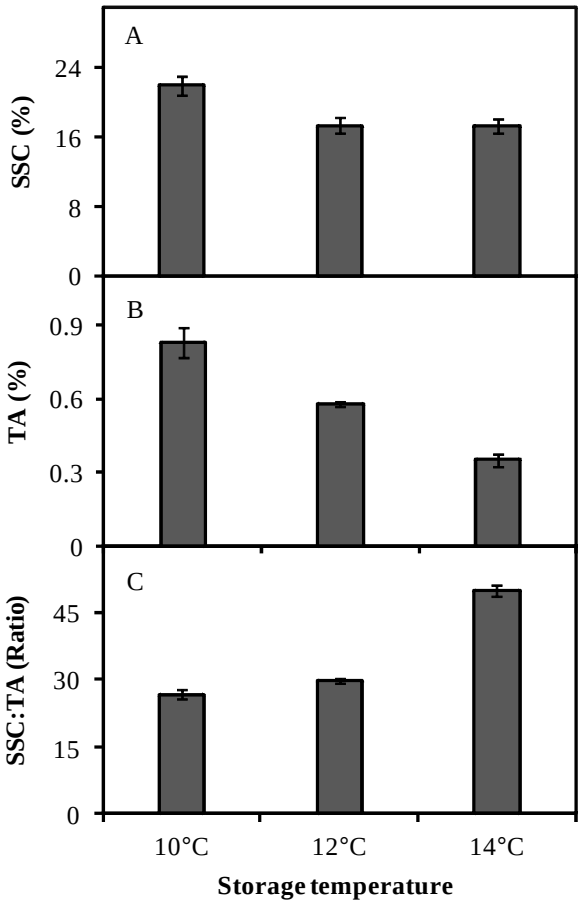

Figure 3. Effect of storage temperature on soluble solid contents (SSC) (A), titratable acidity (TA) (B) and SSC: TA ratio of mango cv. 'Fajri' fruit after ripening. Vertical bars indicate ± SE of means; n = 3 replicates.

DISCUSSION

Reduced respiration rate during ripening in the fruit stored at 10°C as compared to 12 and 14°C (Fig. 1) revealed the significant impact of storage conditions on physiological processes of 'Fajri' mangoes even after storage. Significantly higher rate of respiration (Fig. 1) in the fruit stored at 14°C showed the increased rate of physiological processes than fruit stored at 10 or 12°C as described earlier by Yamashita *et al*. (1997).

As the skin colour development was lower in fruit stored at 10°C than those kept at 12 or 14°C; it is obvious that the storage at low temperature slows down the process of fruit ripening in mangoes (Govender *et al*., 2005). Overall, poor post storage peel colour development in cv. 'Fajri' mangoes stored at 10 or 12°C indicated the sensitivity of physiological phenomena of its peel colour development towards the low temperature storage possibly due to less antioxidant enzyme activity (Arafat, 2005). Better fruit firmness at low storage temperature might be due to inhibition of ripening related changes (Kader, 2008). Thus, low temperature handling provides opportunity for better shelf life of 'Fajri' mango compared to higher temperature. Similar reports have been made by various researchers in the past regarding the relationship between fruit firmness and storage temperature (Pathak, 2007). Moreover, significantly higher skin shriveling and disease development at ripe stage in the fruit stored at 14°C compared to 10 or 12°C also confirmed the relationship of temperature with the fruit physiology and pathogenic activities (Nunes and Emond, 2007) thereby discouraging the storage/transportation of 'Fajri' mango at 14°C. Due to similar level of disease incidence and skin shriveling at 10 or 12°C, the storage of 'Fajri' mango at 10°C seems to be relatively more advantageous compared to 12°C.

Organoleptic evaluation presented better taste and aroma in the fruit stored at 14°C; however, significantly poor texture discouraged the storage of this cultivar (Table 2). As per mean ratings of judges panel, the fruit stored at 10°C or 12°C had acceptable organoleptic attributes (>6.0 score) thus highlighting the commercial importance of these two temperatures.

Significantly higher SSC at ripe stage was recorded in the fruit stored at 10°C, compared to 12 or 14°C. These results indicated the relationship of storage temperature with post-storage ripening behaviour (Fig. 3A). Generally, SSC considered higher at higher storage temperature due to increased rate of respiration and accelerated metabolic process compared to lower temperature storage (Pal and Roy, 1988). But in the current study, higher SSC was observed during ripening in the fruit stored at lower temperature (10°C) despite of lower rates of respiration (Fig. 1) and sugar conversion during storage compared to fruit kept at higher temperatures (12 and 14°C). It might be due to rapid sugar conversion rate during ripening under similar conditions (Table 3), thus resulting in higher SSC at 10°C (Tefera *et al*., 2008). Higher TA in the fruit stored at 10°C compared to 12 or 14°C (Fig. 3B) seemed to be the impact of temperature as observed earlier by various researchers (Seyoum, 2002). Hot water phytosanitory treatment (Jabbar *et al*., 2011) and chemical applications (Huang *et al*., 2012) are also used for mangoes. As the low temperature storage slows down the ripening process (Kader, 2008), that is why the fruit stored at 10°C had higher percentage of TA than the fruit stored at 12 or 14°C. Moreover, significantly higher SSC: TA ratio in the fruits stored at 14°C may be due to decrease in TA (Sankat *et al*., 1994). Lowest ascorbic acid contents were recorded in fruits stored at 10°C compared to 12 or 14°C (which remained at par) (Table 3), thereby indicating the similar results as recorded earlier by Rathore *et al*. (2007). Reduced ascorbic acid contents at lower storage temperature (10°C) could be due to conversion of organic acid into sugars since this fruit has better SSC and total sugars (Kader, 2008) (Table 3). Non-significant differences among the pulp total carotenoid contents (Table 3) indicate that low temperature does not influence the process of *β*-carotene synthesis in 'Fajri' mangoes.

***Conclusion*:** Significantly higher disease development and skin shriveling; higher respiration rate and lesser firmness at 14°C limit the storage of 'Fajri' mango at 14°C for commercial purpose, thereby highlighting the potential of 10 or 12°C. Results of the studies have expressed the potential of cv. Fajri under low temperature storage for extended shelflife and better fruit qualities, however further comprehensive studies are desired to explore the optimum storage temperature for this cultivar with special emphasis on post storage disease management and fruit skin colour development.

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