Pak. J. Bot., 42(4): 2503-2512, 2010.

A NEW MANGO HYBRID SHOWS BETTER SHELF LIFE AND FRUIT QUALITY

ISHTIAQ AHMAD RAJWANA[1], AMAN ULLAH MALIK[2]*, AHMAD SATTAR KHAN[2], BASHARAT ALI SALEEM[2] AND SAEED AHMAD MALIK[3]

[1]*University College of Agriculture, Bahauddin Zakariya University, Multan, Pakistan.*
[2]*Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.*
[3]*Institute of Pure and Applied Biology, Bahauddin Zakariya University, Multan, Pakistan.*
**Corresponding author email: malikaman1@yahoo.com*

Abstract

Mango cultivars are mostly the result of selections from open pollinated chance seedlings of indigenous/introduced germplasm. Development of mango hybrid remains a major focus to boost local industry. Pakistan, being an important mango producing country developed a hybrid 'Faiz Kareem' by making a cross between two commercial mango cultivars i.e., Anwar Ratole X Chaunsa. These studies were carried out to compare the fruit ripening behaviour and quality of this new promising mango hybrid cultivar Faiz Kareem with its parents under ambient (28±2°C; 65-70% RH) conditions. Mature fruits of three cultivars were harvested randomly from a commercial orchard in district Multan, Punjab. During ripening, data on various physico-chemical characteristics including physiological fruit weight loss percentage, fruit softness, visual peel colour, titratable acidity, total soluble solids, sugars, vitamin C, and total carotenoids were recorded daily up to 7 days. Under ambient conditions all the cultivars took 7 days to ripe however, Faiz Kareem expressed better firmness, which indicates its potential for extended shelf life. Highest levels of total sugars (25.88%), total soluble solids (26.75°Brix) and total carotenoids (69.99µg g^{-1}) were observed in Chaunsa while lowest in Faiz Kareem (23.71%, 25.54°Brix and 24.60 µg g^{-1}, respectively) which can be an advantage for extended storage and for sugar conscious consumers. Taste panel studies also showed clear preference for hybrid cultivar Faiz Kareem followed by Chaunsa and Anwar Ratole. Results of the study will help to understand the potential of Faiz Kareem for domestic and export markets.

Introduction

Mangoes are in increasing commercial importance all over the world. Reputed as fruit par excellence, mango has assumed a leading position among commercial fruits (Singh, 2004), and is a valued source of income for producing countries. Pakistan is among the leading mango exporter of the world and earned about US$ 32.4 million during 2005 (Maqbool *et al.,* 2007). Conversely, its esteem among the consumer is experiencing new challenges from fruits like apple, lychee, strawberry, grapes, peaches, cherry and melons etc., which also compete due to same harvesting time particularly in Pakistan. Worldwide use of selected cultivars from Florida has not changed substantially, although most South East Asian and African countries have their own, in some cases ancient, selected cultivars. Breeding programmes in some countries particularly Australia, Israel, South Africa and Brazil have resulted in interesting cultivars some of which have been planted in commercial orchards. The situation regarding cultivars planted in other countries has, however, not experienced much change (Saúco, 2004). Despite the large scale planting of the attractively coloured Floridan cultivars, some changes are occurring in favour of plain green skinned but better tasting cultivars (COLEAP, 2001). United States is the largest mango importer of the world and US

market has started to differentiate mangoes at the consumer level according to skin colour (red, green or yellow) and most likely other markets will adopt this practice in the same fashion as has long been used for marketing apples (Campbell, 1995). This situation demands search for new mango varieties which can better suit the dynamic production environments, satisfy ever changing consumer preferences and provide vital diversity to avoid diseases like mango sudden death syndrome (Kazmi *et al.,* 2007).

Development of mango hybrids that are efficient in nutrient utilization, provide better return of high eminence products and are able to endure adverse environmental conditions, which are also the principal aims of modern fruit breeding (Khan, 2004). Resistance to insect pests and diseases, adapted to the needs of growers and consumers is also enviable for the sustainability of new cultivars. Many mango varieties are available in Pakistan and endeavours are under way to develop newer ones (Elahi & Khan, 1973). In mango breeding, hand pollination is remarkably difficult (Mukherjee *et al.,* 1968), however an amateur gardener, Malik Abdul Qadir Rajwana (Multan district of Punjab province) made a successful effort to develop a hybrid 'Faiz Kareem' by making a cross between Anwar Ratole X Chaunsa (Ahmad *et al*., 2007b). Chaunsa also called as Samar Bahist Chaunsa is the leading commercial cultivar of Pakistan both in domestic and international markets. Its fruit is canary yellow to raw sienna when fully ripe. It has got excellent quality and delightful aroma with a good fruit size. Yet erratic bearing and spongy fruit tissues are its biggest problems. Likewise, Anwar Ratole is another choicest cultivar of Pakistan. It has small to medium sized fruits with good flavor, pleasant aroma and good keeping quality. Shy bearing and small size of fruit has brought this tremendous variety at the verge of extinction. It is therefore, desirable that the quality traits of these two high priced cultivars should be gathered together with some additional characteristics and reduced problems. Review of literature suggests that mango cultivars differ in flavour (Berardini *et al.,* 2005), nutritional characteristics (Ahmad *et al*., 2007a) and storage behaviour (Elahi & Khan, 1973; Kim *et al*., 2007). High market losses, inadequate information on postharvest physiology and biochemistry of cultivars are the limiting factors in international mango trade (Medlicott & Thompson, 1985). Aims of the present studies were to compare the fruit ripening behaviour and postharvest quality characteristics of a new promising mango hybrid cv. Faiz Kareem with its parents under ambient (28±2°C; 65-70%RH) conditions. Results of the study will help to understand the potential of Faiz Kareem for domestic and export markets.

Materials and Method

Physiologically mature, hard green mango fruits (Pre-climacteric stage, n=120) of each cultivar (i.e., Faiz Kareem, Anwar Ratole and Chaunsa) were harvested from a commercial orchard located in Multan district (30^{o} 12′ N, 071^{o} 26′**)** of Punjab province, Pakistan. For practical comparison, fruits were selected randomly from several healthy trees of uniform age avoiding misshapen, bruised and diseased ones. Fruits after harvesting, were washed with tap water (pH 7), air dried, packed in corrugated, perforated open top card board boxes, transported and stored (28±1°C; RH 65-70%) at Postharvest Research Laboratory, Institute of Horticultural Sciences (IHS), University of Agriculture, Faisalabad, within 12 hours of harvest. The fruits were divided into two groups viz., 10 fruits in triplicate were taken as treatment unit for physical studies (non-destructive) while rest of the fruits were kept for biochemical analysis (destructive) using five fruits daily with three replications for each cultivar up to complete ripening.

Physical analysis: The fruits were assessed for physiological weight loss, textural softness and peel colour (visual). For physical analysis, means of ten fruits samples were taken with three replications.

Physiological weight loss: Fruit weight was recorded gravimetrically using standard top loaded balance and physiological weight loss (PWL) was calculated according to the equation:

$$PWL\ (\%) = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Visual peel colour: Peel colour development was scored visually (Malik & Singh, 2005) with some modifications: 0=100% Green & 0% Yellow; 1=75% Green & 25%Yellow; 2= 50% Green & 50% Yellow; 3= 25% Green & 75% Yellow; 4= 0% Green & 100% Yellow.

Fruit softness: Subjective (non-destructive) fruit softness (SFT) was recorded by finger pressure (Malik and Singh, 2005) with some modifications using the scale: 1= Hard; 2= Sprung; 3= Slightly soft; 4= Eating soft; 5= Over ripe

Bio-chemical analysis: Longitudinal slices of fruit pulp were used to extract juice with the help of standard commercial juicer. The juice was extracted from each sample and homogenized to study the biochemical parameters. Five fruits in three replications were used for biochemical analysis daily.

Total soluble solids: Digital Refractometer (RX 5000, Atago, Japan) was used for the determination of total soluble solids (TSS). A drop of juice was placed on the prism of refractometer, the lid was closed and TSS (°Brix) was noted directly from the digital scale at room temperature (30°C±1).

Vitamin C: For the estimation of ascorbic acid in the pulp, the method described by Rusk (1961) was used. For this purpose extracted juice from each sample was filtered through Whatman® filter paper. Filtered aliquot 10 mL was taken in 100 mL round bottom flask, then volume was made up to the mark by adding 0.4% oxalic acid. Out of 100 mL aliquot, 5 mL was taken in a beaker and titrated against freshly prepared dye 2, 6-dichlorophenol indophenol till light pink end point which persisted for 10-15 seconds. For the preparation of dye, 42 mg baking soda ($NaHCO_3$) and 52 mg 2, 6-dichlorophenol indophenol were taken in a 200 mL volumetric flask and volume was made up to the mark by adding distilled water. Ascorbic acid was calculated by using the following formula:

$$\text{Ascorbic acid (mg 100 mL}^{-1}) = \frac{R_1 \times V \times 100}{R \times W \times V_1}$$

where
R_1= mL dye used in titration of aliquot
R = mL of dye used in titration of 1mL standard ascorbic acid solution prepared by adding 1mL of 0.1% ascorbic acid + 1.5 mL of 0.4% oxalic acid
V_1= mL of juice used
V = volume of aliquot made by addition of 0.4% oxalic acid
W = mL of aliquot used for titration

Titratable acidity: Titratable acidity (TA) was determined as stated by Hortwitz (1960). Fruit juice 10 mL was taken from each sample in a beaker, diluted (1:4) with distilled water and titrated against N/10 NaOH solution after adding 2-3 drops of phenolphthalein ($C_{20}H_{14}O_4$) as indicator. The results were expressed as % citric acid. Calculations were made by the formula:

$$\text{Titratable acidity (\%)} = \frac{\text{N/10 NaOH used x 0.0064 x 100}}{\text{Volume of sample used}}$$

Sugars: To estimate the sugars in juice of each sample, the method as described by Hortwitz (1960) was followed. Ten mL of juice was taken in 250 mL flask in which 100 mL distilled water, 25 mL lead acetate solution (430 g 1000 mL^{-1}) and 10 mL of 20% potassium oxalate solution was added. Volume was made up to the mark with distilled water and contents were filtered. Then the filtrate was used for the estimation of sugars as follows.

Reducing sugars: The above mentioned filtrate was taken in burette and titrated against 10 mL Fehling's solution using 2-3 drops of Methylene blue with continuous boiling till brick red end point appeared. Reducing sugars (RS) were calculated by:

$$\text{\% Reducing sugars} = 6.25\ (X/Y)$$

where
X = mL of standard sugar solution used against 10 mL Fehling's solution
Y = mL of sample aliquot used against 10 mL Fehling's solution

Total sugars: For estimation of total sugars, 25 mL of aliquot already prepared for reducing sugars was taken in a 100 mL volumetric flask in which 20 mL distilled water and 5 mL concentrated HCl was added and solution was kept overnight for converting the non-reducing sugars into reducing sugars. Then it was neutralized with 50% concentrated NaOH solution and volume was made to 100 mL with distilled water. The solution was taken in burette and titrated against 10 mL Fehling's solution to brick red end point using Methylene blue as an indicator. Total sugars were calculated by the following formula:

$$\text{\% Total sugars} = 25 \text{ x } (X/Z)$$

where
X = mL of standard sugar solution used against 10 mL Fehling's solution
Z = mL of sample aliquot used against 10 mL Fehling's solution

Non reducing sugars: Non-reducing sugars (NRS) for juice were estimated with the formula:

$$\text{NRS} = (\text{Total sugars\% - Reducing sugars \%}) \text{ x } 0.95$$

Preparation of standard invert sugar solution: 23.75 g pure sucrose was dissolved in about 120 mL water in a 250 mL volumetric flask, added 9 mL concentrated hydrochloric acid and kept for 8 days at room temperature. Volume was made up to the mark adding distilled water. (When inversion was completed, rotation in a 200 mm tube = 11.80°± 0.05°S). Transferred 200 mL of the solution into a 2 L volumetric flask, added 200 mL water during shaking and added 71.4 mL of Sodium hydroxide solution (40 g L^{-1}) containing 4 g benzoic acid. Further 1 L water was added, mixed and checked with indicator paper that the solution was approximately of pH 3. pH was adjusted if necessary and made up to the 2 L mark. This produced a stable 1% m/v stock solution of invert sugar which was diluted 1:4 to give a 0.25% standard solution when required. Fresh solutions were prepared as per requirement, since neutral or alkaline solutions of sugar do not keep well (Ronald & Sawyer, 1981).

Lane and eynon titration: Fehling solutions (A and B) were prepared by the following method:

Fehling's A:- Dissolved 69.3 g Copper sulphate pentahydrate ($CuSO_4.5H_2O$) in distilled water using 1 L volumetric flask and making the volume.

Fehling's B:- Dissolved 100 g Sodium hydroxide and 345 g Sodium potassium tartrate ($KNaC_4O_6.4H_2O$) in distilled water using 1 L volumetric flask and making up to volume mark.

Total carotenoids: Two grams of ripe fruit pulp with 0.05 g of magnesium carbonate was ground and extracted two times with a 20 mL of acetone: n-hexane (75:60, v/v). The pool extract was washed with a 40 mL of 10% NaCl and 2 x 40 mL of distilled water to remove acetone. The hexane extract was measured for its absorbance at 436 nm using spectrophotometer model 6405 UV/VIS (Jenway Ltd., Essex, England). Total carotenoids were expressed as μg g^{-1} of β-carotene equivalent from a standard curve of β-carotene (Lalel *et al.,* 2003).

Organoleptic evaluation: A Panel of 25 judges was made for organoleptic analysis after nine point's hedonic scale as reported by Larmond (1987) and fruit characteristics such as peel and flesh colour, taste, flavor, texture and aroma were recorded.

Statistical analysis: Analysis of variance (ANOVA) was preformed according to completely randomized design (CRD) along with factorial arrangements by using MSTATC (MSTATC, Michigan, USA). Tukey's Least Significant Difference (LSD) was used to test significant difference at 95% confidence level of each variable.

Results and Discussion

All the cultivars used in this study ripened in 7 days after harvest. By this time, fruits had softened, peel colour turned yellow to orange from green. The attained physico-chemical changes during the ambient storage ripening (28 ± 2°C; 65-70% RH) are given in Table 1.

Table 1. Physico-chemical analysis of Faiz Kareem, Anwar Ratole and Chaunsa ripened under ambient temperature (28±1°C RH 65-70%).

Cultivars	DAH	TA (%)	VC (mg 100mL^{-1})	TSS (°Brix)	TS (%)	RS (%)	NRS (%)	TC (µg g^{-1})	VPC	SFT	PWL (%)
Faiz Kareem	1	1.43b	108.0a	7.13	7.30i	2.27ef	4.78j	19.08	1.20jk	1.00h	0.00m
	2	1.24bc	71.68bc	8.24	7.71i	2.46def	5.04j	20.14	1.33ij	1.03h	1.73fg
	3	1.04c	35.34efgh	9.35	7.95i	2.54def	5.13j	29.24	1.70gh	1.22h	1.11l
	4	1.04c	31.02fgh	15.72	11.13efgh	2.19f	8.49ghi	22.23	2.00fg	1.70g	1.84def
	5	0.71d	25.08gh	19.49	15.25d	4.22a	10.48efg	17.71	2.70d	2.55e	1.90cde
	6	0.53de	31.68fgh	20.09	15.12d	3.50b	11.03efg	18.52	3.20bc	3.22d	1.49hi
	7	0.39de	24.33gh	25.54	23.71ab	4.69a	18.07c	24.06	3.97a	3.85bc	1.29jk
Anwar Ratole	1	1.90a	82.92a	12.62	8.91h	2.66cde	6.33gh	33.99	1.0j	1.04jk	0.00h
	2	1.90a	64.10b	17.49	9.47h	2.68cde	6.79g	42.72	1.07ij	1.22i	1.93d
	3	1.80a	45.27c	17.30	8.63h	2.89bc	5.74h	25.27	1.53h	1.82g	1.90d
	4	1.82a	24.88de	19.0	11.92fg	2.69cde	8.96f	37.39	1.83g	2.26f	1.99c
	5	0.55bc	17.71de	25.20	12.69f	3.30a	9.39f	42.42	2.33e	3.44d	2.02c
	6	0.46cd	14.38de	26.37	22.47c	2.85bcd	19.67c	36.43	2.75d	3.78c	1.54f
	7	0.42de	12.87e	26.47	26.45a	2.94b	23.5a	32.31	2.90c	4.11b	1.42g
Chaunsa	1	0.60b	65.52b	11.24	11.47g	2.63de	8.84f	40.92	1.00j	1.00k	0.00h
	2	0.50bcd	44.69c	18.08	12.28fg	2.69cde	9.59f	43.41	1.13i	1.15ij	1.44g
	3	0.41def	23.86de	21.86	14.98e	2.63de	12.35e	38.44	1.60h	1.63h	2.09b
	4	0.31efg	28.91d	22.50	15.21e	2.69cde	12.52e	51.11	2.10f	2.74e	1.52f
	5	0.29fg	27.57de	23.95	18.29d	2.18g	16.11d	69.99	2.75d	3.83c	2.29a
	6	0.30efg	20.49de	26.75	24.41b	2.46ef	21.95b	60.58	3.20b	4.04b	2.27a
	7	0.27g	17.57de	26.72	25.88a	2.27fg	23.61a	49.07	3.33a	4.26a	1.77e
	LSD $_{(p\leq0.05)}$	**0.32**	**26.01**	**NS**	**3.01**	**0.62**	**2.72**	**NS**	**0.30**	**0.29**	**0.14**

DAH= Days after Harvest; TA=Titratable Acidity; VC=Vit.C; TSS= Total Soluble Solids; TS= Total Sugars; RS= Reducing Sugars; NRS= Non-Reducing Sugars; TC= Total Carotenoids; VPC= Visual Peel Colour; SFT= Fruit Softness; PWL= Physiological Weight Loss.

Means with similar letters in the tables are statistically non-significant ($p\leq0.05$).

Physical characteristics: In the present study all the cultivars exhibited higher PWL on 4th and 5th day of ripening and significantly higher value (2.29%) was recorded in cv. Chaunsa as compared to Anwar Ratole (2.02%) and Faiz Kareem (1.90%). In another study on cv. Alphonso, Yashoda *et al.,* (2006) observed 10% PWL which may be attributed to cultivar difference or ripening conditions. The main ripening trends in mangoes are similar to those reported for most other climacteric fruits (Hulme, 1971; Medlicott & Thompson, 1985; Aina 1990; Singha *et al.,* 1991). Physiological weight loss during ripening occurs due to respiration, transpiration and other biological factors. Mango fruit reaches to respiration peak of ripening on about 3rd and 4th day after harvesting and storage at ambient temperature (Naryana *et al.,* 1996). Mean values for softness were statistically significant between cultivars during ripening (Table 1). Higher softness values were observed in Chaunsa (4.26) followed by Anwar Ratole (4.11) and Faiz Kareem (3.97). Shelflife of fruit is dependent on textural firmness which is due to cell wall modification resulting in structural changes in starch and non-starch polysaccharides (Yashoda *et al.,* 2006). Lower softening in hybrid cultivar Faiz Kareem under ambient ripening conditions express better shelf life potential as compared to its parents. Change in colour is another pre-requisite for the ripening of fruit and is due to chlorophyll degradation leading to unveiling of previously present pigments and accumulation of carotenoids such as β-carotene, esters, xanthophylls and lycopene in plastids (Tucker & Grierson, 1987). Visual colour data for the study revealed higher values for Faiz Kareem (3.97) and was statistically significant followed by Chaunsa and Anwar Ratole which is very important feature from consumer perspective.

Bio-chemical characteristics: Titratable Acidity (TA) and Vit. C in all the cultivars decreased with progressive peel colour development and concurrent increase in sugars which continues till ripening and was statistically significant between cultivars. At harvest, highest acidity (1.90%) was observed in Anwar Ratole followed by Faiz Kareem (1.43%) and Chaunsa (0.60%). However, Anwar Ratole experienced a sharp decrease in TA from 4th to 5th day and it came at par with Faiz Kareem yet, higher than Chaunsa at complete ripening (Table 1). TA in ripe pulp of Florida grown mangoes ranged between 0.4% and 0.24% (Beyer *et al.,* 1979). In another study (Elahi & Khan, 1973) TA was found in the range of 2.96 to 0.03%, while working with four mango varieties from Pakistan viz. Malda, Anwar Ratole, Katha and Dusehri. The comparable values found in this study ranged between 1.90 and 0.27%. The relationship for TSS between the cultivars was statistically non-significant however, an increasing trend in TSS up to ripening was observed in all the cultivars. Yellowness of the fruit is accompanied by a progressive sweetness of the fruit pulp due to the formation of sugars resulting probably from starch hydrolysis (Aina, 1990). In our study highest value for total sugar (TS) was observed in Anwar Ratole (26.45%) which was statistically at par with Chaunsa (25.88%) at ripe stage (7th day) followed by Faiz Kareem (23.71%). Non reducing sugars remained higher than reducing sugars in all cultivars throughout the ripening process at ambient temperature and the relationship was statistically significant.

Mangoes are good source of Vitamin C. For three Pakistani mango varieties, Vit. C level decreased during ripening process and ranged between 12.87 and 24.33 mg $100mL^{-1}$ in ripe pulp. Similar Vit C levels have also previously been reported for most mango varieties (Pudmini & Prabha 1997). Reduction in Vit. C contents of the fruit during ripening may be attributed to the susceptibility of ascorbic acid to oxidative destruction particularly at high ambient storage temperature (Thomas & Oke, 1980).

Relationship between cultivars for total carotenoids was non-significant. TC increased during ripening and highest values were recorded for Chaunsa (69.99 µg g^{-1}) during 4th and 5th day which decreased in the subsequent days while lowest TC were recorded for hybrid cultivar Faiz Kareem (17.71 µg g^{-1}). Inherent variations in carotenoids composition are expected due to factors such as, stage of maturity, varietal differences, geographic or climatic effect and storage conditions. On the other hand, part of this incongruity is due to the analytical procedures employed (Mercandante & Rodriguez-Amaya, 1998). Development of yellow/orange peel color and subsequent prominence of carotenoids, the major colour pigment in ripe mango fruits is due to chlorophyll degradation (Hulme, 1971; Rathore *et al.,* 2007).

Organoleptic characteristics: Concomitant with changes in fruit colour and texture was the development of a characteristic pleasant flavour that may be due to the reduction in TA as well as an increase in extractable flavolans resulting from polymerization of tannins and other polyphenolic compounds, all of which contribute to fruit flavour (Hulme, 1971). Nine point hedonic scale taste panel scores revealed statistically significant results. Faiz Kareem was preferred in all parameters followed by Chaunsa and Anwar Ratole (Table 2). However, higher TSS/Acidity ratio was observed in cv. Chaunsa followed by Faiz Kareem and Anwar Ratole (Fig. 1). Acidity turnover during ripening is due to intermediary metabolism and it reflects taste and aroma by its sugar-acid ratio (Yashoda *et al.,* 2006).

Table 2. Organoleptic analysis of Faiz Kareem, Anwar Ratole and Chaunsa under ambient (28±1°C, 65-70 % RH) storage conditions.

Cultivars	Peel colour	Flesh colour	Taste	Flavour	Texture	Aroma
Faiz Kareem	6.70a	7.02a	6.97a	6.52a	6.77a	5.54a
Anwar Ratole	5.23b	5.28c	5.37b	5.48b	5.73c	4.96b
Chaunsa	6.25a	6.38b	6.63a	6.25a	6.28b	5.47a

Means with similar letters are statistically non-significant ($p<0.05$).

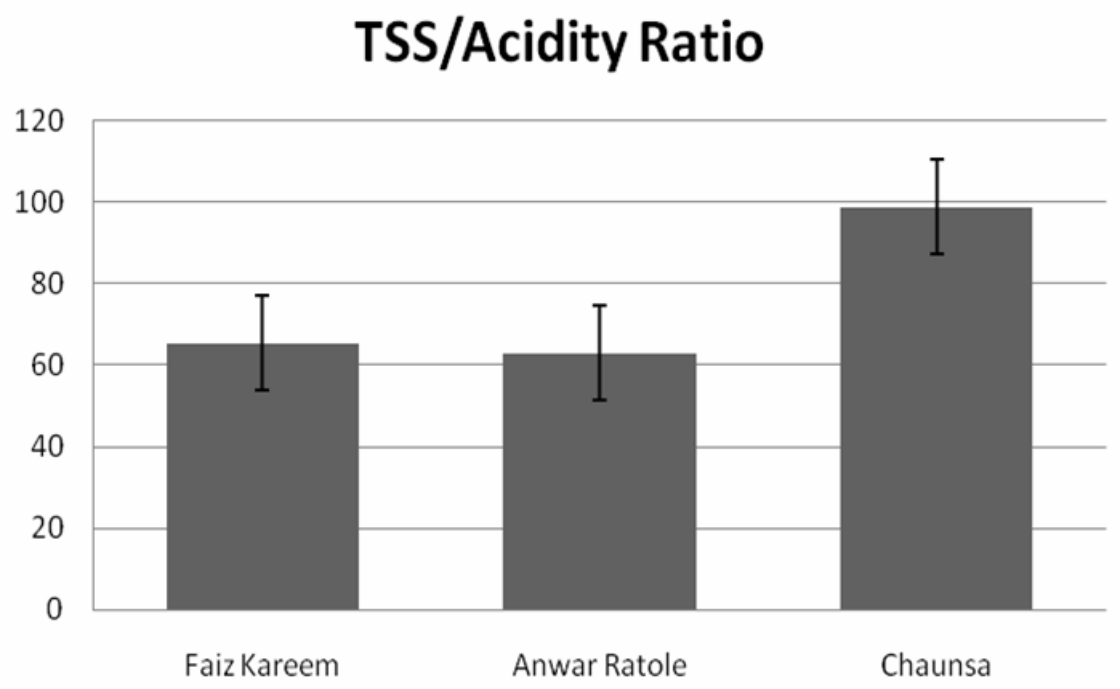

Fig. 1. TSS/Acidity Ratio of mango cvs. Faiz Kareem, Anwar Ratole and Chaunsa at ripening. *Bars showing standard error.

Acknowledgements

Authors are thankful to Late Professor Dr. Muhammad Ibrahim Chaudhary and Mr. Karim Yar Abbasi, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, for all their assistance to conduct this research. One of the authors I. A. Rajwana acknowledges the financial support provided by Higher Education Commission of Pakistan under Indigenous PhD scholarship scheme.

References

Ahmad, I., A.U. Malik, M. Amin and R. Anwar. 2007a. Comparative studies on the performance to two commercial mango cultivars under ambient ripening conditions. *Life Sci. Intl. J.,* 4: 463-467.

Ahmad, I., M. Rahman, N. Tabasuum, Y. Zafar, R. Anwar, A.U. Malik and S.A. Malik. 2007b. 'Faiz Kareem': A New Mango Cultivar. *In: Proc. first interl conference Mango and Date Palm: Culture and Export, June 20-23, 2005*. (Eds.): A.U. Malik, M.A. Pervaiz and K. Ziaf. Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan. 54.

Aina, J.O. 1990. Physico-chemical changes in African Mango (*Irvingia gabonensis*) during normal storage ripening. *Food Chem.,* 36: 205-212.

Berardini, N., R. Fezer, J. Conrad, U. Beifuss, R. Carle and A. Schieber. 2005. Screening of mango (*Mangifera indica* L.) cultivars for their contents of flavonol O- and xanthone C-Glycosides, anthocyanin, and pectin. *J. Agric. Food Chem*., 53: 1563-1570.

Beyer, M., A.C. Thomas and A.J. Tonder. 1979. Y-irrigation of sub-tropical fruits. I. Compositional tables of mango, papaya, strawberry and litchi fruits as edible ripe stage. *J. Agric. Food. Chem.,* 27: 37-42.

Campbell, C.W. 1995. Mangoes in the United States: A yearlong supply. *Proc. Fla. State Hort. Soc.,* 107: 303-334.

COLEAP. 2001. Mangoes key figures 1999. http;//www.coleap.org

Elahi, M. and N. Khan. 1973. Physicochemical changes in some Pakistani mango varieties during ripening. *J. Agr. Food. Chem.,* 21: 229-231.

Hortwitz, W. 1960. *Official and tentative methods of analysis*. *Association of the Official Agriculture Chemist.* Washington, D.C. Ed. 9: 320-341.

Hulme, A.C. 1971. *The biochemistry of fruits and their products*. (Vol. 2) Academic Press, London.

Kazmi, M.R., S.I. Farooq, F.S. Fateh, S. Hameed, F. Fahmeed, M. Ashraf and I. Ahmed. 2007. Identification of phytoplasma from mango trees showing sudden death phenomenon through molecular techniques. *Pak. J. Bot.,* 39: 2153-2157.

Khan, M.D. 2004. Advances in mango hybridization. *In: Mangoes in Pakistan.* (Ed.): S. Ahmed. The Horticultural Foundation of Pakistan. pp. 50-54.

Kim, Y., J.K. Brecht and S.T. Talcott. 2007. Antioxidant phytochemical and fruit quality changes in mango (*Mangifera indica* L.) following hot water immersion and controlled atmosphere storage. *Food Chem*., 105: 1327- 1334.

Lalel, H.J.D., Z. Singh and S.C. Tan. 2003. Distribution of aroma volatile compounds in different parts of mango fruit. *J. Hort. Sci. Biotech.,* 78: 131-138.

Larmond, E. 1987. *Laboratory methods of sensory evaluation of food*. Research branch Canada. Deptt. Agri. Publication, p. 44.

Malik, A.U. and Z. Singh. 2005. Pre-storage application of polyamines improves shelflife and fruit quality of mango. *J. Hortl. Sci. Biotechnol.,* 80: 363-369.

Maqbool, M., A.U. Malik and A. Jabbar. 2007. Sap dynamics and its management in the commercial cultivars of Pakistan. *Pak. J. Bot*., 39: 1565-1574.

Medlicott, A.P. and A.K. Thompson. 1985. Analysis of sugars and organic acids in ripening mango fruits (*Mangifera indica* L. var. Keitt) by high performance liquid chromatography. *J. Sci. Food. Agric.,* 36: 561-566.

Mercandante, A.Z. and D.B. Rodriguez-Amaya. 1998. Effects of ripening, cultivar differences, and processing on the carotenoid composition of mango. *J. Agric. Food. Chem.,* 46: 128-130.

Mukherjee, S.K., R.N. Singh, P.K. Majumder and D.K. Sharma. 1968. Present position regarding breeding of mango in India. *Euphytica,* 17: 462-4677.

Narayana, C.K., R.K. Pal and S.K. Roy. 1996. Effect of pre-storage treatments and temperature regimes on shelf-life and respiratory behaviour of ripe Baneshan mango. *J. Food Sci. Tech. Mysore,* 33: 79-82.

Padmini, S. and T.N. Prabha. 1997. Biochemical changes during acetylene-induced ripening in mango (var. Alphonso). *Trop. Agic.,* (Trinidad) 74: 265-271.

Rathore, H.A., T. Masud, S. Sammi and A.H. Soomro. 2007. Effect of storage on physico-chemical composition and sensory properties of mango (*Mangifera indica* L.) variety Dosehri. *Pak. J. Nutr.,* 6: 143-148

Ronald, S. and K.R. Sawyer. 1981. Pearson's chemical analysis of foods. *Longman Scientific and Technical,* England. p. 211.

Rusk, J.A. 1961. *Chemical methods for analysis of fruits and vegetables*. Research Station Summerland, Canada Deptt. Agric., Publication No. 1154.

Saúco, V.G. 2004. Mango Production and World Market: Current Situation and Future Prospects. *Acta Hort.,* 645: 107-116.

Singh, D. 2004. Current mango varieties situation and future trends in India. *In: Mangoes in Pakistan.* (Ed.): S. Ahmad. The Horticultural Foundation of Pakistan. pp. 101-105.

Singha, S., T.A. Baugher, E.C. Townsend and M.C. de'Souza. 1991. Anthocyanin distribution in "Delicious" apples and the relationship between anthocyanin concentration and chromaticity values. *J. Amer. Soc. Hort. Sci.,* 116: 497-499.

Thomas, P. and M.S. Oke. 1980. Vitamin C content and distribution in mangoes during ripening. *J. Food. Technol.,* 15: 669-672.

Tucker, G.A. and D. Grierson. 1987. Fruit ripening. *In: The Biochemistry of plants.* (Ed.): D. Daries. Academic Press, New York. pp. 265-319.

Yashoda, H.M., N.K. Prabha and R.N. Tharanathan. 2006. Mango ripening: changes in cell wall constituents in relation to textural softening. *J. Sci. Food Agic.,* 86: 713-721.

(Received for publication 14 February 2009)