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HOT WATER TREATMENT AFFECTS RIPENING QUALITY AND STORAGE LIFE OF MANGO (*Mangifera indica* L.)

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Keeping in view hot water treatmetn (HWT) protocols of importing cv. Sindhri countries like Iran and China, research trials were conducted in collaboration with industry in which mangoes cv. Sindhri were subjected to HWT at 45°C–75min. and 48°C–60min. along with control (wash only) to determine its effect on fruits ripening behaviour, shelf life and quality. A fruit coating, 'Fresh Seal P' (2%) was also applied in combination with HWT at 48°C–60min. After HWT application, fruits were ripened (without storage) at ambient temperature or were stored at 13±2°C and 85±5% RH. Stored fruits were removed after 7, 14 and 21 days and were ripened at ambient temperature (24±1°C, 68-70% RH). HWT effects on physical and biochemical characteristics were evaluated. Fruit subjected to HWT at 45°C–75min. and naturally ripened (without storage), showed non-significant difference for various quality parameters as compared to control (wash only) while maintaining the shelf life of fruits (six days). Application of HWT at 48°C–60min. decreased the ripening period i.e. three days. While, non-significant differences among treatments during storage showed that HWT does not affect the post-storage quality of fruit. Among different treatments, fruit subjected to HWT at 45°C–75min. produced better results as compared to HWT at 48°C-60min. TC contents were found highest in washed only fruits (62.78µg/g) followed by HWT at 45°C–75min. (59.39µg/g). Fruits subjected to higher temperature during HWT developed more yellow and uniform colour. Rest of the treatment results were non-significant.
Keywords: Hot water treatment, mango, shelf life, quality, total carotenoids.

INTRODUCTION

Non-chemical quarantine treatments in mango industry are increasingly becoming important. Recently, wide international interest in heat treatment technology for quality maintenance and disease control has been reflected in a range of literature (Aveno and Orden, 2004). Apart from quarantine insect pest, such treatments allow mango shipments out of areas where fruit flies are endemic (Mitchman and McDonald, 1993). Mango industry in Pakistan is facing problem of fruit fly and various importing countries are imposing restrictions like hot water treatment for specific duration for disinfestation of this pest. Among different heat treatments, use of hot water as a disinfestation treatment, has been widely adopted because of its efficacy (Jacobi *et al.*, 1995) and low cost. In 2005, protocols signed by Pakistan with Iran and China for export of mango requires Hot Water Treatment (HWT) (Iran: 45°C–75 minutes; China: 48°C–60 minutes) but effects of such treatment on mango shelf life and quality are yet to be tested. Previous studies on HWT show that the effects depend upon a number of factors including maturity stage, cultivar, HWT temperature and duration etc. Spalding and Reeder (1972) reported that 80% of mango fruit treated with hot water at 55°C for 5 minutes had injuries. Spalding *et al.* (1988) reported that the quality of 'Tommy Atkins' and 'Keitt' mangoes was not affected when fruits were treated with hot water at 46°C for 90 minutes and then stored for 3 days at 13°C and subsequently ripened at 24°C. But, Becerra (1989) reported fruit injury in 'Tommy Atkin' mangoes treated with hot water at 46.1°C for 90 minutes.

Among commercial mango cultivars in Pakistan, cv. Sindhri has great potential for export. Export of produce to nearby coutries through land routes provide a better alternative of enormous frieght charges. However, this tranport method requires extended storage period of mango fruits. So, specific protocols need to be developed for extending shelf life and maintaining fruit quality of mangoes. No information is yet available about commercial mango cv. of Pakistan on these aspects. Keeping in view the industry demands, these research investigations were undertaken to evaluate effects of HWT protocols, as required by Iran and China, on fruit's shelf life and storage and to determine the effect of 'Frehs Seal' in combination with HWT on physical, bio-chemical and organoleptic chracteristics of mango cv. Sindhri.

MATERIALS AND METHODS

Mango fruits cv. Sindhri were sourced from *Nawazabad Farm*, *Tando Allah Yar, Sindh* (Pakistan) on 15th July, 2005. Mature green mango fruits (TSS 7.0°Brix), were harvested alongwith 4-5cm stalk and transported carefully from field to the packing shed, using plastic containers. Fruits with injuries, disease/insects symptoms and those which had soft

nose were separated. The pedicels were cut back and fruits were graded according to size and packed in plastic containers. Fruit were then transported to Karachi (5 hours transport distance) in a non-reefer Mazda truck. The processing work including hot water treatment (HWT), was done at *Quest Pack Pakistan Pvt Ltd, Karachi*. Before processing, fruits were once again checked for quality and uniformity, and those undesired were removed. Fruit were processed as; T_1) Wash only, T_2) HWT: 45°C – 75 minutes, T_3) HWT: 48°C – 60 minutes, T_4) HWT: 48°C – 60 minutes + 2% FreshSeal P (BASF Corporation, New Jersy, USA). Each treatment constituted three replications. During HWT, fruit core temperature was confirmed by using digital thermometer with an electronic probe. After processing, fruit in each trial were packed in corrugated cardboard boxes. Just after treatment, one lot of treatments, constituting three boxes per treatment, were transported by air from Karachi to *Postharvest Lab, Institute of Horticultural Sciences*, *University of Agriculture, Faisalabad* (experiment 1). Fruit were ripened at 24°C±2°C and 68-70% RH and various physico-chemical tests were performed. While other lot of fruit, constituting nine boxes per treatment, was stored at a commercial facility (13±2°C and 85% RH) in Karachi. After storage of 7, 14 and 21 days, fruit samples were air trasported to Postharvest Lab., Faisalabad, for quality testing (experiment 2). Observational data (fruit colour) were also recorded during storage.

During the study of HWT effect, different sensory and laboratory observations were made. Fruit softness and peel colour development was monitored daily. Fruit softening was based on subjective assesment of whether the mango yielded to thumb pressure (1 = very had to 5 = over ripe). Eating soft fruits were given 4 score. Peel colour development was assesed using rating scale of 1 to 5 (1 = 100%, 2 = 75% green, 3 = 50% green, 4 = 25% green and 5 = 100% yellow) (Miller and McDonald, 1991).

Blemished fruits were marked at optimum eatable ripening stage while end-consumer interest in fruit's organoleptic properties (aroma, flvaour, pulp, taste and texture) was observed using Hedonic scale. Fruits were presented to a 10 member taste panel. The panelists assessed fruit samples and rated for general acceptibility (1 – dislike extremely to 9 – like extremely) (Jacobi *et al.*, 1995). During laboratory tests, total titrable acidity (TTA), total carotenoids (TC), total soluble solids (TSS), ascorbic acid contents and total sugars, including reducing and non-reducing (NRS) were also estimated.

For first experiment, completely randomized design was used while the second experiment was laid out with factorial arrangement. The experimental data was subjected to analysis of variance (ANOVA) using Genstat Release 8.2 (Lawes Agricultural trust, Rothmsted Experimental Station, UK). Within the analysis of variance, effects of different treatments and their interaction were assessed. Least significant differences (Fisher's protected LSD) was calculated following significant F test (p=0.05). All assumptions of analysis were checked to ensure validity.

RESULTS AND DISCUSSION

Experiment 1: Effect of hot water treatment on ripening quality of mango fruit

Time period acquired by different treatments to reach eating soft stage was found to be significantly different. Fruits treated with hot water at 48°C–60min. (T_3) took minimum time period (3 days) to reach optimum eatable ripening quality while fruits which were given the same treatment along with application of 'FreshSeal P' (T_4) reach the same stage in relatively longer time period (5 days) which revealed that peel coating delayed the ripening process. Washed only fruits (T_1) and those subjected to HWT at 45°C–75min. (T_2) took maximum and equal time period (6 days) to reach optimum eatable ripening stage. In this way, HWT at 45°C–75min. was found better without significant impact on ripening process of fruits.

Fruit softness and peel colour changes were recorded on daily bases untill fruit reached eatable ripening stage (Table 1). As far as development in fruit softness is concerned, all the treatments produced non-significant results, whereas fruit peel colour development was significantly different among treatments. Highest peel colour score was noticed in T_3 (4.67) followed by T_2 (4.11) while washed only fruits (T_1) produced least peel colour score (3.94). As evident from results, HWT at higher temperature enhanced peel colour development when the fruit ripened (Jacobi and Wong, 1991; Muirhead, 1976 ; Quimio and Quimio, 1974). Fruits which were subjected to HWT at 48°C – 60min. with 'FreshSeal P' application (T_4) produced significantly lower peel colour score (3.92) than T_3 which might be due to creation of a physical barrier against gas exchange from fruit surface, that may have reduced oxygen intake which is necessary for the biodegradation of chlorophyll *a* (Fonseca *et al.*, 2004).

Table 1. Physical observations and organoleptic tests of naturally ripened fruit after hot water treatments (Experiment 1).

Treatment	Peel colour (score)	Fruit softness (score)	Pulp colour (score)	Taste (score)	Flavour (score)	Texture (score)	Aroma (score)
T_1	3.94b	4.00a	7.47a	7.73a	6.73a	7.20a	5.31a
T_2	4.11b	4.00a	7.21b	7.77a	6.53a	6.65b	5.30a
T_3	4.67a	4.08a	7.11b	6.34c	6.40a	6.05c	5.15a
T_4	3.92b	4.08a	6.87c	7.55b	6.43a	6.17c	5.30a
LSD (*p>0.05*)	*0.5522*	*NS*	*0.2216*	*0.0962*	*NS*	*0.2377*	*NS*

NS: Non-significant (values by the same letter are not significantly different)

Table 2. Bio-chemical analysis of naturally ripened fruit after hot water treatments (Experiment 1).

Treatment	TTA (%)	Ascorbic Acid (mg/100g)	TSS (Brix)	Total carotenoids (µg/g)	Sugars (%)			TSS/ Acidity ratio
					Total	Reducing	NRS	
T_1	0.23b	47.06b	20.84a	72.52a	15.29a	3.75a	10.97a	91.99a
T_2	0.24b	65.54a	20.05b	69.71ab	14.44b	3.53b	10.36b	84.73b
T_3	0.28a	65.54a	18.99c	66.18bc	14.04c	3.47bc	10.04c	68.53c
T_4	0.27a	65.51a	19.05c	63.20c	14.14c	3.44c	10.17c	69.77c
LSD (*p>0.05*)	*0.0171*	*4.503*	*0.1165*	*6.133*	*0.2441*	*0.0875*	*0.1956*	*5.091*

NRS: Non-reducing sugars
TTA: Total titrable acidity

Significant differences were observed among different treatments regarding bio-chemical analysis (Table 2). Highest amount of total titrable acidity (TTA) was measured in T_4 (0.28%) followed by T_3 (0.27%) which was statistically at par with T_4 showing the non-significant effect of 'FreshSeal P' on TTA contents. Washed only fruits (T_1) depicted least amount of TTA (0.23%) which was statistically at par with that of fruit, subjected to HWT at 45°C–75min. (T_2). These results confirmed the earlier findings of Mahajan *et al.* (2005) who observed the lowest acidity levels upon ripening in chlorine washed and hot water dipped fruits which were stored in cardboard boxes. Ascorbic acid contents were found statistically significant among treatments. Washed only fruit (T_1) showed least amount of ascorbic acid (47.06mg/100g) while treated fruit in T_2, T_3 and T_4 did not show considerable variation. Impact of water temperature and dipping time during HWT had a significant effect on TSS, total sugars (including reducing and non-reducing sugars) and TSS/Acidity ratio. Washed only fruit (T_1), had maximum TSS and sugar contents followed by fruit subjected to HWT at 45°C–75min. (T_2). Fruit subjected to HWT at 48°C–60min., with or without 'FreshSeal P' application, showed least development of TSS and sugar contents, while their values were statistically at par with each other. Sugar production during ripening is due to hydrolysis of starch granules in the chloroplast which continues until ripening (Medlicott *et al.*, 1986; Selvaraj *et al.*, 1989). HWT seems to hinder this normal metabolic process of starch hydrolysis which results in low sugar production in HWT fruits. Statistically significant differences were also observed among treatments regarding total carotenoid (TC) contents. Washed only fruits (T_1) produced highest TC contents (72.52µg/g). Increase in temperature during HWT was found directly related to decrease in TC contents in fruits. Fruits subjected to HWT at 45°C–75min. (T_2) produced higher TC contents (69.71µg/g) as compared to T_3 in which fruits were given HWT at 48°C–60min. (66.18µg/g). 'FreshSeal P' application with HWT at 48°C–60min. (T_4) resulted in least development of TC contents (63.20µg/g) which might be due to physical barrier of this peel coating that slowed down the metabolic processes in fruits as earlier discussed by Fonseca *et al.* (2004).

The organoleptic quality evaluation of ripened fruit showed that fruit pulp colour, prefered by the penalists, ranked maximum score for T_1 (4.47 score) that was more clean, uniform and attractive as compared to hot water treated fruits. Highest taste scores were given to T_1 (7.73) and T_2 (7.77) which were statistically at par with each other. Changes in fruit texture seemed to be influenced by water temperature and dipping time.

Non-significant differences were recorded regarding aroma and flavour (table 1).

Experiment 2: Effect of hot water treatment on storage life and quality of mango fruit

Treatments, stored for 7, 14 and 21 days of storage periods, were further subjected to ambient temperature (24±1°C and 68-70% RH) for ripening. Non-significant differences were observed among treatments regarding development of fruit softness but, significant differences were found at various storage periods ($p \leq 0.05$). An increasing trend in development of fruit softness was observed (Fig. 1a). Fruit peel colour development was found to be significantly different among treatments and storage periods (Table 3). Highest peel colour score was found in T_3 (3.66) followed by T_2 (3.48). Treatments subjected to higher temperature during HWT developed more yellow and uniform colour during storage, as earlier stated by Muirhead (1976). These results also coincide with the earlier findings of Jacobi and Wong (1991) who concluded that HWT at higher temperature (52°C – 20 minutes) enhanced peel colour when the fruit were ripened. Moreover, among treatments at different storage periods, T_4 produced significantly lower peel colour score (3.11) than T_3. Results revealed non-significant differences for percentage of blemsihed fruits among treatments while bruised fruits showed pronounced symptoms of skin injury due to hot water treatment.

The reason of slow and lower peel colour development may be due to 'FreshSeal P' coating on fruits which created a physical barrier against the gas exchange and thus reduced oxygen intake which is necessary for the biodegradation of chlorophyll *a* (Fonseca *et al.*, 2004). Significant difference among storage periods for development of fruit peel colour were observed ($p \leq 0.05$). Fruit stored for 21 days produced highest peel colour score (3.78) followed by 14 days stored fruit (3.30). Minimum colour score was observed in fruit stored for 7 days. Interaction between treatments and storage periods also proved to be significant during the study of fruit peel colour development.

Significant differences in TC contents were analyzed among treatments (Fig. 2). Highest TC contents were observed in T_1 (62.78µg/g) while T_4 produced lowest amount (47.21µg/g). T_2 (59.39µg/g) was statistically at par with T_1. With the increase in storage period, significantly increasing trend in TC contents was observed. Highest amount was determined in 21 days stored fruits (68.62µg/g) while 7 days stored fruits had the least contents of TC (36.34µg/g). Same results were stated earlier by Yahia and Pedro-Campos (2000) who revealed that HWT at 46°C–60min. increased the carotene content after 21 days of storage at 10°C. Amount of TC determined after 14 days and 21 days of storage, was statistically at par with each other. Significant interaction was also found among treatments and storage periods (Fig. 2).

Regarding TTA, non-significant differences among treatments were found while storage periods produced significant results ($p \leq 0.05$). Decreasing trend was observed in amount of TTA with the increase in storage period. After 21 days of storage, TTA level decreased from 0.72% (7 days) to 0.29%. In treatments stored for 7 days, TTA was found highest (0.75%) followed by samples stored for 14 days (0.44%). Treatments with 21 days of storage period produced minimum amount of TTA (0.29%). The decrease in acidity during storage could be attributed to the use of organic acid as respiratory substrate (Ulrich, 1974). Non-significant differences ($p > 0.05$) for sugars (total, reducing and NRS), TSS, ascorbic acid content and TSS/TTA ratio were found among treatments (Table 4) and their interaction with storage periods.

During estimation of sugar contents, significantly decreasing trend in reducing sugars and increasing trend in production of NRS was observed with increase in storage period (Fig. 1b). Reducing sugars, in fruits stored for 7 days, was found highest (4.74%)

Table 3. Post-storage effect of hot water treatments on fruit peel colour development (Experiment 2).

Storage Periods	7 days	14 days	21 days	*Mean*
T_1	2.69	3.52	3.03	*3.08*^{b}
T_2	2.93	3.43	4.10	*3.48*^{a}
T_3	3.27	3.51	4.21	*3.66*^{a}
T_4	2.778	2.76	3.78	*3.11*^{b}
Mean	*2.92*^{c}	*3.30*^{b}	*3.78*^{a}	
LSD ($p \leq 0.05$)	Treatment = 0.362 Storage periods = 0.313 Treatment x Storage periods = 0.627			

Table 4. Post-storage effect of hot water treatments on bio-chemical properties of mango fruit (Experiment 2).

Treatments	Sugars (%)			TSS (Brix)	Ascorbic acid (mg/100g)	TSS/Acidity ratio
	Total	Reducing	NRS			
T_1	14.01	3.91	9.60	20.06	54.77	50.82
T_2	14.15	3.79	9.84	20.03	54.61	48.85
T_3	14.15	3.78	9.85	19.08	60.07	49.38
T_4	13.57	3.76	9.32	18.46	56.86	40.38
LSD (p>0.05)	*1.393*	*0.325*	*1.200*	*1.583*	*11.99*	*9.53*

Note: Non-significant resuls were found among given parameters.

and with the passage of time its concentration decreased and was minimum (3.32%) in 21 days stored fruit. Minimum amount of NRS was found in 7 days stored fruit (8.73%) followed by fruit stored for 14 days (10.07%) while 21 days stored fruit produced highest amount of NRS (10.16%). Concentration of NRS in 14 days stored fruit was found statistically at par with 21 days stored fruit. Treatments and storage period interaction produced non-significant results (p>0.05) for total, reducing and non-reducing sugars.

Significantly decreasing trend in ascorbic acid concentration was found among storage periods (Fig. 1c). Its amount in samples stored for 7 days was found maximum (68.39mg/100g) and with the passage of storage days, ascorbic acid concentration decreased. In samples stored for 21 days, its value was found minimum (44.03mg/100g). Significantly increasing trend in ratio for TSS/TTA was also observed at different storage periods (Fig. 1d). In 7 days stored fruits, its ratio was minimum (27.41) while maximum (69.29) in fruits stored for 21 days.

Organopletic qualitities of different treatments were scored to be non-significantly different by panelists (Table 5). Earlier findings of Ram *et al.* (1983) concluded same remarks for the effect of HWT on cv. Dashehari that HWT induced ripening without impairing taste and flavour of fruit. Significant differences were observed among storage periods for taste, flavour and aroma (Fig. 3) while no significant change in pulp colour and texture was observed with respect to change in storage periods. Interaction of treatments and storage period also produced statistically non-significant results (p≤0.05) among all organoleptic characteristics. In this way, it is clear that HWT do not negatively effect end-consumer preferences. Although, negative effects of HWT on fruit have been reported (Joyce *et al.*, 1993), but all these effects were more pronounced on mangoes which were harvested at immature green stage (Jacobi and Wong, 1992; Jacobi *et al.*, 2001).

CONCLUSION

For quality evaluation during natural ripeinng, fruit subjected to HWT at 45°C–75min. yielded non-significantly different results as compared to control (wash only) revealing the fact that HWT at this temperature not only keep the fruit quality undisturbed but also maintains better shelf life of fruits while application of HWT at 48°C–60min. slightly decreased the ripening period. While, non-significant differences among treatments during storage showed that HWT does not effect the storage potential and post-storage quality of mango fruit cv. Sindhri but further research on this aspect is still imperative to test commerical cv. of Pakistan for impact of hot water treatment on postharvest physiology of mango fruit.

Table 5. Post-storage effect of hot water treatments on organoleptic evaluation (score) of various treatments (Experiment 2).

Treatments	Aroma	Flavour	Pulp	Taste	Texture
T_1	5.23	5.67	5.98	5.73	5.83
T_2	5.82	5.63	5.96	5.39	5.58
T_3	5.53	5.68	6.41	5.64	6.08
T_4	5.31	5.88	6.41	6.08	6.06
LSD (*p>0.05*)	*0.828*	*0.694*	*0.523*	*0.694*	*0.672*

Note: Non-significant resuls were found among given parameters.

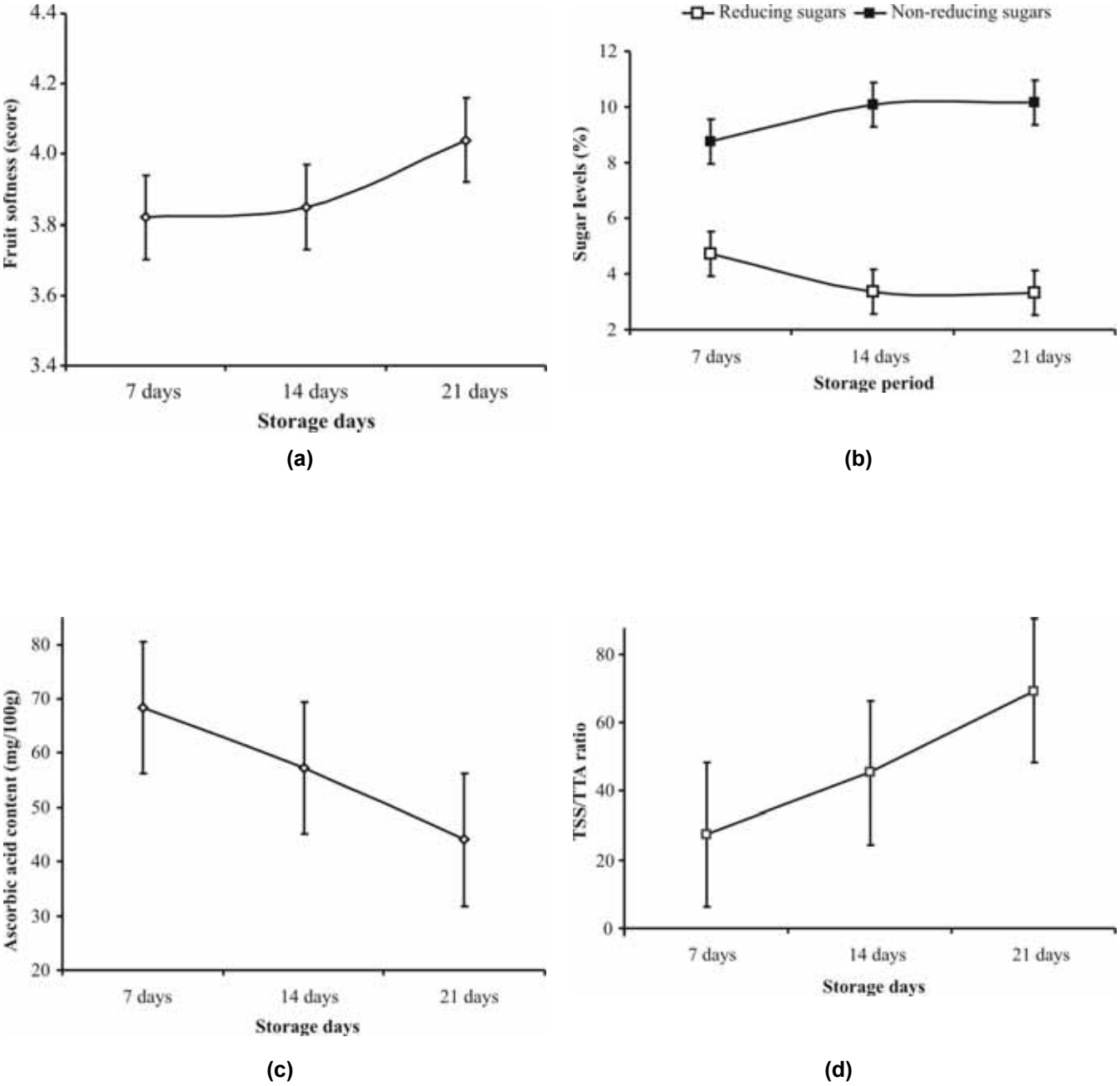

Figure 1. Variation in physico-chemical attributes of fruit at three storage intervals. Vertical bars depict standard deviations at a) 0.12, b) 12.22, c) 19.62 and d) 0.80

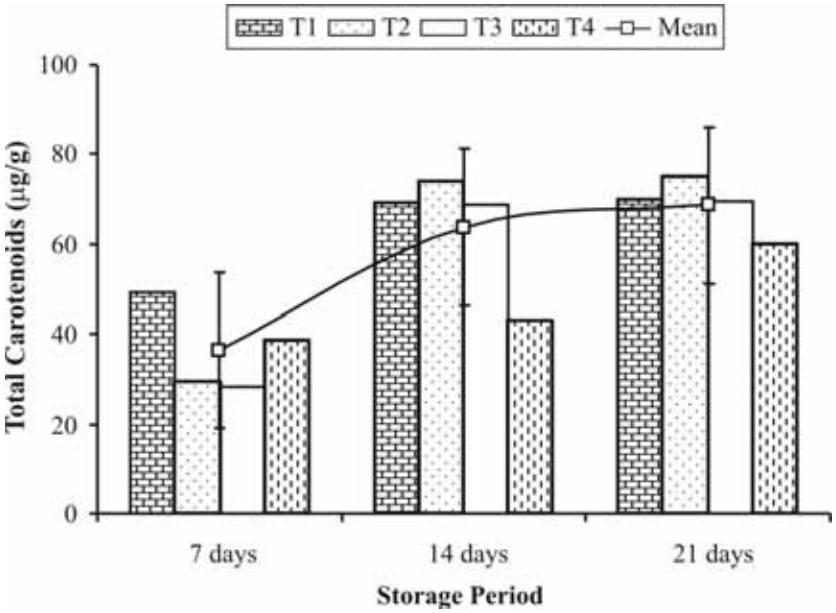

Figure 2. TC contents at various storage intervals untill eatable ripening stage within a) treatments (LSD=10.62); b) storage periods (LSD=9.20) and c) significant interaction between treatments and stoage periods (LSD=18.39). Vertical bars show standar deviation at 17.42

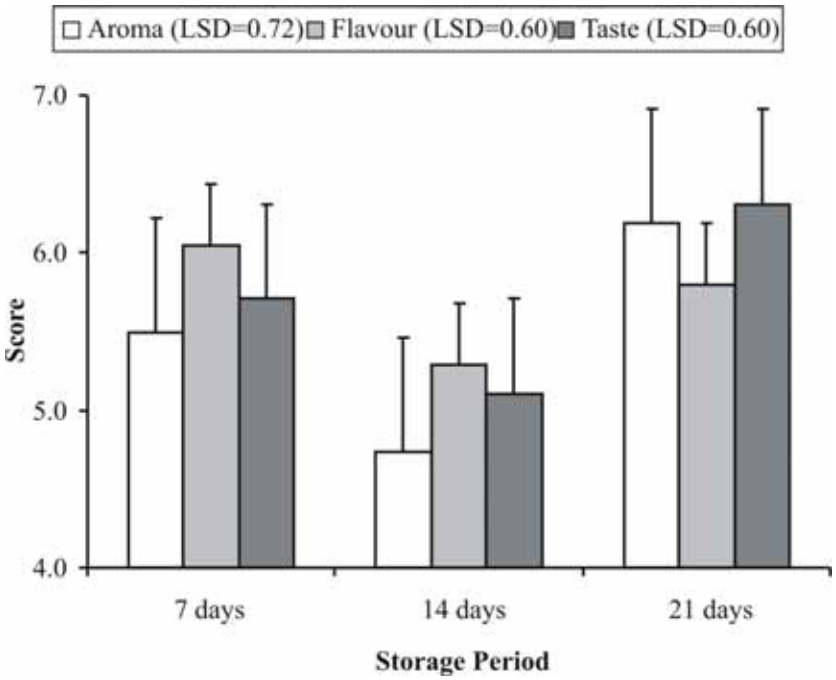

Figure 3. Significantly different ($p \leq 0.05$) organoleptic parameters among storage periods. Standard deviation for aroma (0.72), flavour (0.39) and taste (0.60) is presented in vertical bars.

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