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Original Research

Changes in Physico-Chemical and Sensory Fruit Quality Attributes of Apricot during Ripening

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ABSTRACT

Varietal variation in apricot causes differential changes in fruit quality during ripening. A study was executed to evaluate the effect of apricot varietal variation on fruit physico-chemical and sensory attributes during fruit ripening. Fruits of two apricot cultivars, 'Old Cap' and 'Red Flesh' obtained from Baluchistan were monitored at ambient conditions (25 ± 2 °C and 60-65% RH) during fruit ripening for physico-chemical and sensory attributes. Irrespective to days at shelf during fruit ripening, fruits of 'Red Flesh' apricot exhibited significantly reduced fruit weight loss with greater fruit firmness, total soluble solids (TSS), total phenolic content (TPC), ascorbic acid and antioxidant scavenging activity (ASA) than 'Old Cap' apricot fruits. However, titratable acidity (TA) of 'Old Cap' apricot fruits remained significantly higher than 'Red Flesh' apricot fruits during ripening. At eating soft stage, sensory attributes including fruit pulp colour, taste, flavour and overall acceptability of 'Red Flesh' apricot fruits were superior to 'Old Cap' apricot fruits. In conclusion, 'Red Flesh' apricot showed better fruit physico-chemical attributes during fruit ripening and fruit sensory attributes at eating soft stage than 'Old Cap' apricot fruits.

Keywords: *Apricot phenology, fruit size, Prunus armeniaca, shelf life, total phenolic content.*

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INTRODUCTION

Apricot (*Prunus armeniaca* L.), a stone fruit with soft and fleshy mesocarp belongings to *Rosacea* family, is generally grown in the Northern Hemisphere, the Mediterranean and Central Asian regions contributing more than 80% of the world's apricot production. It is cultivated in more than 40 countries throughout the temperate regions of the world (Chadha, 2003). Turkey, Uzbekistan, Algeria, Iran and Pakistan are the leading apricot producing countries. Pakistan ranks at 5th spot in the world apricot fruit production, contributing about 23% of world's total apricot production (FAOSTAT, 2018). Within the country, Baluchistan province shares most of the apricot fruit production, which is about 93% of the country's total production. Baluchistan province is also the home of very diverse apricot genotypes. According to a report, most of the apricot commercial cultivars of the country (about 60 types) are being grown in the province (Anonymous, 2018). As for as the nutritive value of apricot is concerned, it is a rich source of phenolics, phytochemicals, antioxidants, and carotenoids, that are considered important for human health (Lichou et al., 2003). Despite the huge production, the country did not rank in top apricot exporters due to enormous postharvest losses pertaining to high perishable nature of the fruits. Moreover, apricot has a limited postharvest life at ambient conditions experiencing rapid fruit ripening and deterioration after harvest (Yan et al., 2017). Postharvest fruit related changes are dependent on type of cultivar, storage conditions, and management strategies including packaging and pre-and postharvest treatments of ripening delaying chemicals alone and in combination with low temperature storage. After harvest, potential shelf life, sensory characteristics (flavour, aroma) and nutrient composition are greatly influenced by apricot genotypes (Bureau et al., 2006). Therefore, during ripening, fruits of individual cultivar must be observed for changes, because fruit ripening pattern in one cultivar may not be applicable to other cultivars within the same species (Goulao and Oliveira, 2008). Previously, the traditional attributes like fruit appearance, sugars and organic acids had been studied in relation to fruit quality in different apricot cultivars during on-tree ripening stages (Drogoudi et al., 2008; Piagnani et al., 2013; Iordanescu et al., 2018) and after harvest during fruit ripening (Bureau et al., 2006). Locally no work on apricot has been reported to address cultivar dependent response during fruit ripening. However, only scanty work on fresh and dried apricots has been reported (Ali et al., 2011; Hussain et al. 2015), which was not focused on postharvest fruit quality of contrasting cultivars during fruit ripening. The reported work is limited to commercial apricot cultivars of Gilgit Baltistan (GB) region of the country, which only shares a small proportion of Pakistan's total apricot production. So, the current study was executed to

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compare response of two commercial apricot cultivars of Baluchistan on fruit quality during fruit ripening at ambient conditions.

MATERIALS AND METHODS

Plant material

The apricot trees used for the study was grown in a commercial orchard located at District Loralai (30.3071° N, 68.8109° E), Baluchistan, Pakistan during 2017-18. Apricot plants of uniform size with healthy growth, without attack of any disease and insect were selected. Eight-year-old plants of two apricot cultivars 'Old Cap' and 'Red Flesh' were maintained in a square system with row to row and plant to plant distances of 4.5 meters.

Plant phenology and physical fruit characteristics at harvest

For determination of critical plant phenological stages, four plants of each cultivar were tagged before bud burst stage. Full bloom, fruit setting and commercial maturity stages were determined on the visual observation basis in the tagged and overall plants of same age in the orchard. At commercial maturity stage based on the fruit ground colour development (when 10-15% fruit ground colour changed from green to yellow), the uniform sized fruit free from any disease and insect-pest attack were harvested, packed in corrugated card board boxes and immediately transported to Postharvest Science and Technology Laboratory, MNS-University of Agriculture, Multan. The harvested fruits were distributed into two lots, 1st was evaluated immediately at harvest for various fruit physical and biochemical attributes, while the 2nd was kept at ambient condition (25 ± 2 °C and 60-65% RH) for fruit ripening. Data regarding various fruit physico-chemical attributes were taken on daily basis (from harvest to 4th day of fruit ripening) till fruit reached at eating soft stage, while the fruit sensory evaluation was executed only on day-4 of fruit ripening. The experiment was arranged in a completely randomized design under factorial arrangement replicated three times.

Fruit weight loss, ground colour and firmness during fruit ripening

During the period of fruit ripening, fruit weight loss was determined based upon the difference between fruit initial weight of previous day to final weight of fruit on the present day and was expressed in percent loss of fruit weight by using a formula outlined by Ullah (2014). Fruit ground colour development was determined by visual observation of peel colour based on a scale with some modification as outlined by Ullah et al. (2013). A scale was used with a score range of 1 to 5 (1 = 0% yellow or 100% green, while 5 = 100% yellow or 0% green). Fruit firmness was assessed based upon subjective evaluation of the fruits to thumb pressure as outlined by Anwar and Malik (2007) with some modification. For this purpose, a rating scale ranging from 1 to 5 was used with score 1 means eating soft flesh to 5 means very hard flesh.

Total soluble solids (TSS), titratable acidity (TA), TSS:TA ratio and ascorbic acid content during fruit ripening

A handheld digital refractometer (PR 101, Atago, Japan) was used to measure fruit juice TSS and expressed as °Brix as described by Ullah et al. (2013). The TA of fruit juice was assessed through titration method using phenolphthalein as an indicator and expressed as percent malic acid as per protocol of Ullah et al. (2013). Ascorbic acid content was determined titrimetrically using dye 2,6-dichlorophenol indophenol as an indicator and expressed as mg per 100 mL as described by Hughes (1983).

Total phenolic content (TPC) and antioxidants scavenging activity (ASA) during fruit ripening

For determination of TPC and ASA, frozen (-80 °C) sample of fruit pulp of 1 g was added in 5 mL extraction solution with composition of HCl, acetone and methanol in ratio of 1:8:90, respectively, and was homogenized using pre-chilled pestle and mortar. It was followed by centrifugation at 10,000 × g for 5 min at 4 °C. Supernatant was collected for further determination of TPC and ASA. TPC and ASA of fruit pulp were determined by using the protocols of Ainsworth and Gillespie (2007) and Mimica-Dukic et al. (2003), respectively with some modifications as suggested by Ullah et al. (2013). The supernatant was reacted with Folin Ciocalteu reagent and sample was read at 795 nm on a spectrophotometer. TPC was expressed as mg GAE 100 g^{-1} (gallic acid equivalent) by using gallic acid as reference. A free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used to determine the ASA of fruits and was expressed as percentage inhibition of DPPH.

Fruit sensory attributes at fruit ripening

Sensory evaluation (pulp colour, taste, flavour and texture) of the fruits was executed by observing Hedonic scale ranging from 1-9 (1 dislike extremely to 9 like extremely) at eating soft stage on day-4 of fruit ripening. Fruit samples were presented to a panel of 10 members consisting of postgraduate students and staff. The panellists evaluated the samples and rated for general acceptability as described by Anwar and Malik (2007).

Statistical analysis

The experimental data were subjected to ANOVA by using window-based software Statistix 10 under factorial arrangement (factors include cultivars and days at shelf). The significant means at $P \leq 0.05$ were further subjected to least significant differences test (Fisher's LSD). However, the data regarding fruit physical characters at harvest and sensory attributes at fruit ripening were subjected to Paired T-test. Standard deviation of means was calculated by MS Excel.

RESULTS

Plant phenology and physical fruit characteristics at harvest

Under the agro-ecological conditions of Baluchistan, full bloom stage of 'Old Cap' apricot plants reached earlier than plants of

Table 1: Phenological stages and fruit physical attributes of two apricot cultivars grown under agro-ecological conditions of Baluchistan, Pakistan.

Apricot cultivars	Phenological stages			Days taken after full bloom	
	Full bloom	Fruit setting	Fruit maturity/ harvesting	Fruit setting	Fruit maturity/ harvesting
'Old Cap'	March 10, 2018	March 22, 2018	July 12, 2018	12	134
'Red Flesh'	March 15, 2018	March 30, 2018	July 17, 2018	15	137
Physical fruit characteristics at harvest					
Apricot cultivars	Fruit length (mm)	Fruit width (mm)		Average fruit weight (g)	Fruit juice (%)	Fruit rag (%)
		Polar	Equatorial			
'Old Cap'	28.9 ± 0.42 a	26.6 ± 1.04 b	24.5 ± 1.16 b	51.1 ± 0.52 a	49.0 ± 0.53 b	38.0 ± 0.40 a
'Red Flesh'	28.5 ± 0.51 a	32.1 ± 0.41 a	28.5 ± 0.98 a	52.7 ± 1.64 a	52.0 ± 0.64 a	32.0 ± 0.52 b

The values followed by ± are standard deviation of means (n = 45). Means were separated through Paired T-test.

'Red Flesh' (Table 1). The fruit setting stage and commercial fruit maturity of 'Old Cap' cultivar reached after 12 and 134 days after full bloom, respectively. While, the plants of 'Red Flesh' cultivar took about 15 and 137 days to reach fruit setting and commercial maturity, respectively after full bloom. Fruits of both the cultivars exhibited similar length and average weight; however, the fruits of 'Red Flesh' cultivar exhibited about 17%, 14% and 6% higher polar and equilateral width, and fruit juice percentage than fruits of 'Old Cap' cultivar, respectively at harvest (Table 1).

Fruit weight loss, ground colour and firmness during fruit ripening

Fruit weight loss significantly varied between the cultivars, among days at shelf and interaction of both cultivars and days at shelf. Irrespective to days at shelf, fruits of 'Old Cap' cultivar exhibited higher weight losses (about 25% more losses) as compared to 'Red Flesh' fruits. During fruit ripening, an increased fruit weight loss was exhibited in both the cultivars with advanced days at shelf. The highest fruit weight loss (about 25%) was observed in fruits of 'Old Cap' cultivar on 4th day at shelf during fruit ripening (Fig. 1A).

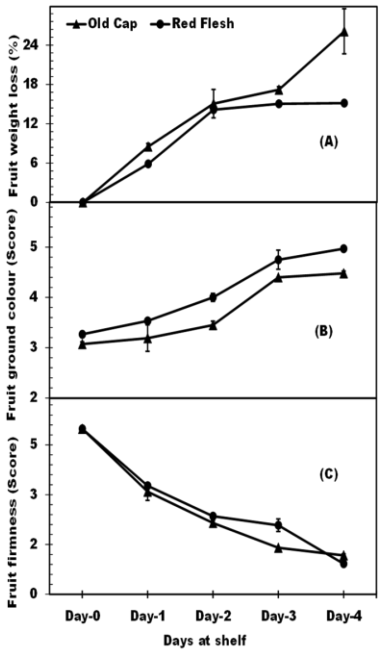

Figure 1: Fruit weight loss (A), fruit ground colour (B) and fruit firmness of two apricot cultivars during fruit ripening at shelf. Error bars are the ± SE of means (n = 15). LSD value at $P \leq 0.05$: Fruit weight loss: cultivars = 1.718**, days at shelf = 2.717**, cultivars × days at shelf = 3.843**; Fruit ground colour: cultivars = 0.163**, days at shelf = 0.258**, cultivars × days at shelf = NS; Fruit firmness: cultivars = 0.0978**, days at shelf = 0.0741**, cultivars × days at shelf = 0.2187**. NS, * and ** represent non-significant, significant and highly significant means at $P \leq 0.05$, respectively.

The cultivars and days at shelf significantly differed for development of fruit ground colour; however, the interaction of cultivar and days at shelf non-significantly influenced the parameter. During the whole period of fruit ripening at shelf, fruits of 'Old Cap' cultivar developed about 9% more ground colour compare with fruits of 'Red Flesh' cultivar (Fig. 1B). Irrespective to cultivar, with increase in days at shelf, development of fruit ground colour was significantly enhanced, so more fruit ground colour development was observed as the fruit ripening was advanced. Both apricot cultivars exhibited significant decreased fruit firmness during the fruit ripening (Fig. 1C). However, fruits of 'Red Flesh' cultivar retained significantly higher (about 6%) fruit firmness compared with those of 'Old Cap' cultivar. On 1st day of fruit ripening, fruits of both cultivars exhibited firmer fruits followed by a loss in firmness as the fruit ripening period advanced.

TSS, TA and TSS:TA ratio during fruit ripening

Irrespective of the apricot cultivars, the fruits exhibited significant increase in TSS and ripening index (TSS:TA ratio) during ripening (Fig. 2 A-C). However, non-significant variations were observed in TSS by the interactive effect of the cultivar and days at shelf. Irrespective to days at shelf, fruits of 'Red Flesh'

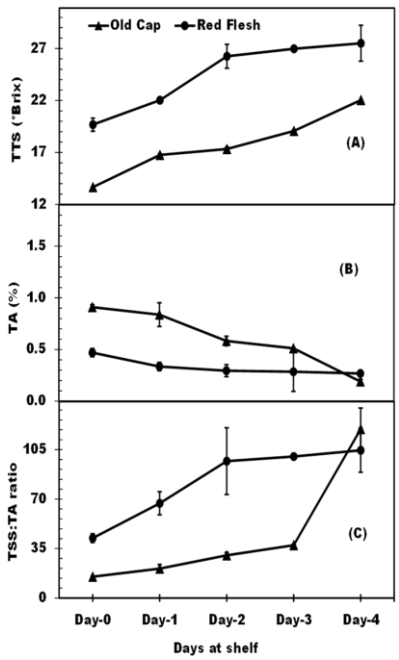

Figure 2: Total soluble solids (TSS; A), titratable acidity (TA; B) and TSS:TA ratio of two apricot cultivars during fruit ripening at shelf. Error bars are the ± SE of means (n = 3). LSD value at $P \leq 0.05$: TSS: cultivars = 1.033*, days at shelf = 1.633*, cultivars × days at shelf = NS; TA: cultivars = 0.066**, days at shelf = 0.105**, cultivars × days at shelf = 0.148**; TSS:TA ratio: cultivars = 15.119*, days at shelf = 23.905*, cultivars × days at shelf = 33.807*. NS, * and ** represent non-significant, significant and highly significant means at $P \leq 0.05$, respectively.

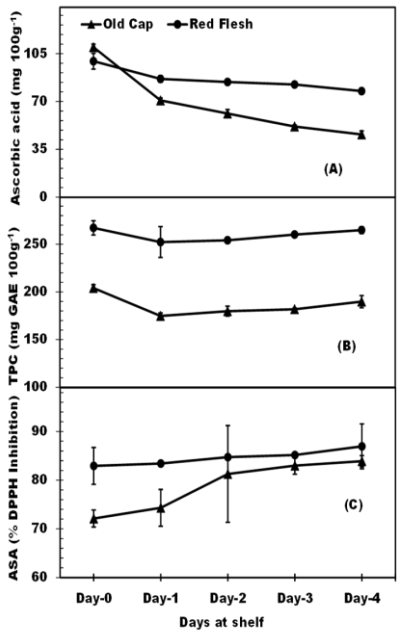

Figure 3: Ascorbic acid (A), total phenolic contents (TPC; B) and antioxidants scavenging activity (ASA;C) of two apricot cultivars during fruit ripening at shelf. Error bars are the ± SE of means (n = 3). LSD value at $P \leq 0.05$: Ascorbic acid: cultivars = 3.417**, days at shelf = 5.403**, cultivars × days at shelf = 7.641**; TPC: cultivars = 8.642*, days at shelf = 13.665*, cultivars × days at shelf = NS; ASA: cultivars = 5.222*, days at shelf = NS, cultivars × days at shelf = NS. NS, * and ** represent non-significant, significant and highly significant means at $P \leq 0.05$, respectively.

cultivar exhibited higher TSS than 'Old Cap' fruits during ripening (Fig. 2A). Overall, about 25% higher TSS was observed in 'Red Flesh' fruits than fruits of 'Old Cap' cultivar. Significantly higher TA was retained by the fruits of 'Old Cap' cultivar than those of 'Red Flesh' cultivar from harvest to 4th day of fruit ripening (Fig. 2B). During the whole ripening period, an overall about 45% higher TA was retained by 'Old Cap' fruits than 'Red Flesh' ones. However, TA tended to decrease in both the cultivars as the fruit ripening advanced. However, on day-4 of fruit ripening, 'Red Flesh' fruits retained significant higher (0.27%) TA than 'Old Cap' fruits. Irrespective to days at shelf, Red Flesh fruits exhibited higher TSS:TA ratio (about 45% higher) as compared to 'Old Cap' fruits. From 1st days to 3rd day of fruit ripening, a significantly higher TSS:TA ratio was exhibited by the fruits of 'Red Flesh' cultivar than those of 'Old Cap' cultivar, followed by an overlay of fruits of 'Old Cap' over 'Red Flesh' fruits on 4th day of fruit ripening (Fig. 2C).

TPC, ascorbic acid content and ASA during fruit ripening

Fruit of both the cultivars exhibited significant decrease in ascorbic acid content, while non-significant differences were observed in fruit TPC and ASA during fruit ripening (Fig. 3A-C). Regardless to days at shelf, fruits of 'Red Flesh' cultivar retained about 21% higher ascorbic acid than those of 'Old Cap' cultivar (Fig. 3A). On 4th day of fruit ripening, about 40% more ascorbic acid was recorded in 'Red Flesh' fruits than 'Old Cap' fruits. TPC decreased till day-1 followed by an increase in TPC up to day-4 of fruit ripening in both the cultivars (Fig. 3B). Overall, during the whole ripening period, fruits of 'Red Flesh' exhibited about 28% higher TPC than fruits of 'Old Cap' cultivar. Significantly higher ASA was observed in 'Red Flesh' fruits than 'Old Cap' fruits irrespective to days at shelf during fruit ripening (Fig. 3C).

Fruit sensory attributes at fruit ripening

Concerning the fruit sensory attributes at fruit ripening of eating soft stage, based upon Hedonic scale rating, fruits of 'Red Flesh' cultivar exhibited about 17%, 7%, 8% and 20% more pulp colour, taste, flavour and overall acceptability, respectively, compared with fruits of 'Old Cap' cultivar (Table 2). However, texture was about 3% better in 'Old Cap' fruits compared with 'Red Flesh' fruits.

DISCUSSION

Both the apricot cultivars under study were categorized as early maturing apricot cultivars of the Baluchistan and harvested more or less with a 7-10 days interval as evident by our results (Table 1). Moreover, both the cultivars have similar physical fruit attributes including average fruit weight, fruit width and length (Table 1). Both the apricot cultivars exhibited fruit weight losses, development of fruit ground colour and fruit firmness loss throughout fruit ripening (Fig. 1). However, 'Red Flesh' cultivar fruits exhibited relatively reduced weight loss and retained higher fruit firmness. During fruit ripening, the development of ground colour can be ascribed to colour change of fruit epidermis from green to yellow linked to the degradation of chlorophyll and accumulation of carotene (Bureau et al., 2006). Loss of fruit firmness might be due to increased fruit softening enzymes activities leading to degeneration and de-polymerization of primary cell wall during ripening process and the enzymatic activity of fruit softening enzymes is also cultivar dependent in *Prunus* species (Ullah et al., 2013).

TSS and TSS:TA ratio increased, and TA decreased in fruit of both apricot cultivars during fruit ripening (Fig 2). Increased accumulation of sugars during fruit ripening might determine the ripening index and variation in accumulation vary among cultivars highlighting differential mechanism of sugar accumulation within *Prunus* species (Bureau et al., 2006). As the fruit ripening advanced, ascorbic acid significantly reduced while TPC and ASA increased in fruits of both the apricot cultivars (Fig. 3). During fruit ripening, decreased ascorbic acid might be linked with decrease in organic acid indicating partial degradation of acids, which also vary in contrasting cultivars (Bureau et al., 2006). The variable antioxidants, TPC and ascorbic acid in apricot during ripening depend upon cultivars type and growing conditions, as previously reported by Caliskan et al. (2012) for some Turkish apricot cultivars.

At fruit eating soft stage of both apricot cultivars, differences

Table 2: Fruit sensory attributes of two apricot cultivars at eating soft stage kept at ambient conditions obtained from Baluchistan, Pakistan.

Sensory characteristics	Apricot cultivars		Percentage difference between means
	'Old Cap'	'Red Flesh'	
Pulp colour	5.08±0.71b	6.10±0.71a	16.7
Taste	6.04±0.61b	6.50±0.54a	7.1
Flavour	6.47±0.70b	7.05±1.02a	8.2
Texture	6.52±1.03a	6.30±0.87a	3.4
Overall acceptability	6.02±0.97b	7.48±1.10a	19.5

*The values followed by ± are standard deviation of means (n = 30). Means sharing similar letter in a row are statistically non-significant at $P \leq 0.05$ (LSD test).

were evident in fruit pulp colour, taste, flavour, and overall acceptability of fruits (Table 2). Fruit sensory evaluation of diverse commercial apricot cultivars at fruit eating soft stage is a valuable tool to assess overall fruit quality. The highest overall acceptability of 'Red Flesh' fruits as compared to 'Old Cap' on day-4 of shelf was correlated to flesh overall texture, aroma, sweetness, and juiciness as evident by the findings of Piagnani et al. (2013). Apricot fruits show a very high variability between cultivars in texture and sensory attributes therefore good sensory attributes might be attributed to cultivar owned fruit characteristics (Piagnani et al., 2013).

CONCLUSION

Overall 'Red Flesh' apricot fruits produced under the climatic conditions of Baluchistan exhibited better physico-chemical and sensory attributes than 'Old Cap' fruits during fruit ripening under ambient conditions. Based upon higher quality attributes of 'Red Flesh' fruits during ripening, there is need to study in detail its postharvest storage potential under natural conditions and with some improved pre- and postharvest management practices.

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