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Chemical profiling and natural compounds of Indian ber cv. Gola as influence by various storage regimes

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Abstract
The effect of different storage temperatures on nutritional and antioxidant potential of jujube fruit cv. 'Gola' was investigated. Freshly harvested fruits were procured from an experimental orchard. Fruits were stored at ambient (as control), 10 °C and 15 °C and evaluated for 35 days. The nutritional parameters such as total soluble solids, pH, acidity, sugars, phenolic, carotenoids and antioxidant content were analyzed during storage. The results showed that the low temperature successfully enhanced the nutritional and antioxidant potential of Indian jujube without any risk of disorder development. In comparison with control, fruit especially stored at 10 °C, showed a significant effect on nutritional and antioxidant content of jujube. However, pH, acidity and carotenoid content was least affected by storage temperature in comparison to other parameters. In addition, storage temperatures also enhance the antioxidant potential of jujube due to low temperature, resulting lower conversion of bioactive compounds such as ascorbic acid, phenols, organic acids and titratable acidity to their derivatives during metabolic reactions.

Keywords: Antioxidant, bioactive compounds, acidity, shelf life, storage temperature

Introduction
Indian jujube (*Ziziphus mauritiana* Lamk.) is a strong tree that adapts to high temperatures and well acclimatized under dry situation. Jujube fruit successfully cultivated under drought, diversified soil and adverse climatic conditions *i.e.* salinity, uneven distribution of rainfall and water logging condition (Baloda *et al*., 2012) [1]. It is appropriate for the cultivation in arid and semi-arid tract of the world *viz*., India, Pakistan, Sri Lanka, Afghanistan, Iran, Syria, Myanmar and Australia (Pareek *et al*., 2009) [2]. Indian jujube considered as poor man's apple because of high nutritive worth. The nutritive wealth of the fruit has been broadly perceived. Ber fruits contain a significant amount of protein, phosphorus, calcium, ascorbic acid and carotene rather than apple and have more P, Fe, ascorbic acid, carbohydrates and caloric value than oranges (Bakhshi and Singh, 1974) [3]. Fruit contain different amino acids like serine, glutamic acid, asparagine, glycine, and threonine. Indian jujube has delicious taste and a good source of minerals (Jat *et al*., 2012) [4]. Various processed products such as jam, jelly, candy, pickle, squash, preserved and osmo-dehydrated products were made from ber fruit (Pareek and Yahia, 2011) [5].

Low temperature or/ cold storage is a feasible strategy for improving the storage life of many fruit and vegetable. Several workers has been examined the response of low storage temperature on physiological and bio-chemical observation of ber fruit (Abbas, 1995) [6]. Such studies demonstrated that jujube fruit could be safely stored up to 1-5 weeks under temperature range of 4-10°C. However, the chilling symptoms appears on later stage of storage; whereas, at ambient condition, fruit exhibited short shelf life (Jat and Lakhawat, 2021) [7]. The past experiment completed in this laboratory under MAP condition showed that the ber fruit cv. 'Gola' safely stored for 35 days at 6 °C, but chilling symptoms were seen on later stage of storage and CI symptoms deteriorate quality of fruit (Jat *et al*., 2012) [4]. In India, low-temperature storage is rarely used to increase shelf-life of fruit due to absence of standard recommendation for specific cultivar and shortage of low-temperature storage facilities. This is major constraints faced by producers, retailers and growers. Consequently, the effect of different storage temperatures on nutritional and antioxidant potential of jujube fruit cv. 'Gola' was investigated.

Materials and Methods

Plant materials

'Gola' Jujubes were procured from an experimental farm located at Bikaner, Rajasthan, India. Freshly harvested fruits were immediately transported to MPUAT, Udaipur, where experiment was conducted. On arrival, 450 fruits were selected, (according to shape, size and maturity), washed and air-dried, and were packed in 20 µm thickness LDPE bags. 15 fruit packets per treatment were prepared in triplicates and subjected to three-storage temperature (ambient, 10 and 15 °C). Fruits were analyzed for nutritional and bioactive compounds at 7 d interval up to 35 days.

Fruit quality analysis

All samples were evaluated at 0 day, 7, 14, 21, 28 and 35 days for quality attributes. Ten fruits from each treatment were randomly selected and used for total soluble solids determination using a digital refractometer (Otago, Tokyo, Japan) and average value were expressed in °Brix. To measure the titratable acidity, 5 mL of the fruit extract is titrated with a standard reagent (e.g., 0.1 N NaOH to an end point of pH 8.2). Acid (%) (meq. citric acid = 0.06) was calculated as equation (i). The pH of the fruit samples were determined using a digital pH meter (Model, 827, pH Lab, Metrohm, Swiss Mode, Switzerland). The total sugars were analyzed using a colorimetric method (Dubois *et al*., 1951) [8]. Briefly, we prepared a 100-fold dilution of 1 mL fruit extract with 0 TDS water and filtrates were obtained after adding 4 mL anthrone reagent, warmed for 15 minutes, then cooled at room temperature and absorbance was measured at 630 nm. The glucose was used to plot a celebrative curve, and outcomes were expressed as percentage. For determination of reducing sugar a dinitrosalicylic acid (DNS reagent) method outlined by Miller (1959) [9] was used with slight modification proposed by Islam *et al*. (2013) [10].

$$\text{Acid (\%)} = [(\text{mL NAOH}) \times (0.1\ \text{N NAOH} \times (0.064) \times (100)]/\ \text{volume of sample (i)}$$

Bioactive compounds

The scientific methodologies/ procedures were used for quantification of bioactive compounds in jujube during storage. The ascorbic acid (mg $100g^{-1}$ FW) was determined according to the Indophenol method described by AOAC, International (2000) [11] using a (3% w/v) acid metaphosphoric (HPO_3) and outcomes was presented as mg $100g^{-1}$ on the fresh weight basis. For determination of total phenol, a scientific procedure (Folin-Ciocalteu method) described by Makkar (2000) [12] was used. The absorbance of samples were measured at 725 nm via a double beam UV-Visible spectrophotometer (Model SL 210 (Elico Ltd, Hyderabad, India) and results were expressed as Gallic acid equivalent in 100 g FW. Total antioxidant activity and total carotenoid content were quantified according to methodology outlined by Arnao *et al.* (2001) [13], with slight modification proposed by Reche *et al*. (2019) [14]. For this purpose, the hydrophilic TAA (H-TAA) and lipophilic TAA (L-TAA) fruit extracts were used. The absorbance for carotenoids (450 nm) and antioxidant content (730 nm) weremeasured spectro-photometrically using a Double beam UV-Visible spectrophotometer, Model SL 210 (Elico Ltd, Hyderabad, India). The results of carotenoids and antioxidant content were presented as β-carotene per 100gram and Trolox equilent (mg $100g^{-1}$) on fresh weight basis, respectively.

Statistical analysis

Nutritional and bioactive compounds of jujube fruits were determined in triplicate. Data were subjected to analysis of variance (ANOVA) in completely randomized design using a 'SPSS 18.0' for window (SPSS Inc., Chicago, IL, USA) software. Comparison of mean were performed by Duncan's multiple range test at $p< 0.05$ level of significance and values presented as mean ± SD in each treatment.

Results and Discussion

Total soluble solids, acidity and pH value

The TSS content of ber fruit was continuously increased till the peak and then declined slightly, irrespective of storage temperature (Table 1). Conversely, the pace of rise and fall in TSS content was significantly lower in fruit stored at lower temperature. The determination of °Brix in fruit stored at ambient temperature was discontinued after 21st day of storage due to high decay incidence. Results of the study suggested that TSS content is coincides with ripening and attributed to conversion of starch into simple sugar at beginning of experiment. Furthermore, the lower temperature causes reduction in consumption of sugars in respiration during senescence (Ding *et al*., 1998) [15]. Acidity per cent in jujube fruit was continuously decline during storage. However, the rate of reduction rate was slow at 10°C, whereas, minimum in control fruit (Table. No fruits were survived after 21st day of storage at ambient temperature due to high decay loss (Table 1). As expected, the positive impact of storage temperature in retaining higher acidity content in fruit comparison to control as observed in present study agreement with the results of Najafabadi *et al.* (2017) [16]. It is possible that low temperature significantly reduced the respiratory activities of fruit, which causes lower consumption or conversion of organic acids into sugars during respiratory metabolism (Mane and Patel 2010) [17]. Storage temperature also influences the pH level in 'Gola' fruit during storage. However, increment in pH value was always lower in fruit stored at 10 °C followed by 15 °C as compared to ambien (Table 1). The present results are supported by findings of Jat *et al.* (2016) [18] and Mahajan *et al.* (2005) [19] in ber fruit. They concluded that ber fruit stored at lower temperature considerably lower good pH value over control. So, slower conversation or organic acid in to sugar & derivates can be a possible reason of lower increment of pH value in fruit stored at low temperature (Shahbaz *et al*., 2014) [20].

Sugars

The impact of different storage temperature on sugar per cent in postharvest jujube presented in Table 1. The data revealed that total sugar as well as reducing sugar was significantly ($p \leq 0.05$) increased from pre-maturation phase to maturation; reached highest at climacteric peak and then declined during phase of senescence. Although, the lower storage temperature caused an increase in the amount of both the sugars in jujube fruit with control ones. Total sugar and reducing sugar levels in fruit stored at 10 °C was significantly higher than those stored at 15 °C at later stages of experimentation. Fruits at control was not monitored for sugar (%) estimation after 21st day of storage. The adequacy of storage temperature in retaining sugar (%) and delayed ripening of fruit in contrast with control (ambient = 22±2 ºC) as seen in present examination can be authenticated by Jat *et al.* (2016) [18] in 'Gola'. The initial increase in glucose and fructose content could be due to hydrolysis of sucrose, yielding glucose and

fructose (Ding *et al*., 1998) [15]. Low temperature storage maintained higher levels of all these soluble sugars in Chinese bayberry (Yang *et al*., 2010) [21]. Total sugars decreased over 9 days of storage in litchi fruit but did not differ according to packaging treatment (Somboonkaew and Terry, 2010) [22]. Sucrose content has been correlated with TSS in litchi (Paull and Chen, 1987) [23]. The TSS content in the present study also correlated with the concentrations of total sugars and supported by the study of Paull and Chen (1987) [23].

Bioactive compounds

Ascorbic acid content (mg/100 g pulp) of Indian jujube fruit continuously decreased during storage, with a higher rate of reduction in fruit stored at higher temperature. However, fruit stored at 10°C was retained highest amount of ascorbic acid throughout the experimental period (Table 2). Fruits stored at room temperature had a higher decay loss and their evaluation was discontinued after 21st days of storage. The effectiveness of storage temperature in retention of ascorbic acid and prolonging the storage life of fruit in comparison to control (ambient = 22±2ºC) as observed in present study can be corroborated by the results of Jat *et al*. (2012) [4] and Mahajan *et al*. (2005) [19] in ber fruit stored at different storage temperature. The possible reasons to retained higher ascorbic acid content by reducing enzymatic activity in irradiated fruit in which conversion of ascorbic acid into dehydroascorbic acid is also reduced (Baghel *et al*., 2005) [24]. The results of total phenolics in 'Gola' as influenced by different storage temperatures. The findings are indicates that phenolic content was declined during storage, irrespective of treatment. However, the rate of decrease was considerably slower in fruit stored at 10°C as compared to control and 15 °C. (Table 2) Fruit stored at 10ºC tended to have a higher phenolic content than fruit stored at 15ºC or control. The minimum decreased in phenol (%) was recorded under 10ºC might be due to low temperature reduced the pace of hydrolysis of phenolic compounds into sugars, acids or any other compounds or owing to their transformation from soluble to insoluble form (Valverde *et al*., 2015) [25]. Low temperatures significantly conserve the higher antioxidant potential over control fruits, irrespective of storage condition. Fruits stored at low temperature (15°C and 10°C) showed storage life up to 35th days, while fruit at ambient temperature had early ripening and discarded due to complete of their shelf life after 21st day of storage (Table 2). The maximum antioxidant activity (183.56 mg TE/100 g^{-1} f.w.) was observed at 10°C treatment, whereas, minimum (177.21 mg TE/100 g^{-1} pulp in control fruit. Storage environment is a main factor affecting antioxidant activity of fruit during storage. In previous studies, Diaz-Mula *et al*. (2009) [26] have also reported the positive correlation between antioxidant and total phenolics in plum and Ghasemnezhad *et al*. (2010) [27] in apricot. The fruit stored at lower temperature retained higher antioxidant during storage probably due to higher phenolic and ascorbic acid levels at low storage temperature. Changes in carotenoids profile due to different storage temperature regimes during storage of Indian jujube fruits. Total carotenoids of fruit continuously increased during storage, irrespective of treatments. The degree of increment in total carotenoides was significantly higher in fruit stored at higher storage temperature. On 35th day of storage, the maximum amount of total carotenoids (0.210 mg/100 g pulp) were recorded in 10°C, whereas, minimum total carotenoids 0.204 mg/100 g pulp at 15°C (Table 2). In general, the development of colour during postharvest storage of fruit might be due to degradation of chlorophyll content in fruit and increase synthesis of total carotenoides and anthocyanin pigments (Kaur *et al*., 2013) [28]. The inhibition of carotenoides accumulation in fruit coincides with fruit ripening during low temperature storage. The results of present study showed that PAL activities were inhibited by irradiation and low temperatures were consistent with the retard carotenoides accumulation fruit. This study was conformity with the findings of Ravi (2014) [29] works on 'Gola' ber.

Table 1: TSS, acidity, pH, total sugar and reducing sugar of Indian ber fruit cv. 'Gola' at different storage regimes

Storage temperature	Storage period (d)				
	7	14	21	28	35
Total soluble solids (°Brix)					
Ambient	13.63 [a]	14.67 [a]	9.62 [a]	—	—
15°C	10.51 [b]	12.41 [b]	12.99 [b]	11.07 [a]	9.38 [a]
10°C	10.01 [c]	11.63 [c]	13.40 [c]	10.88 [b]	9.72 [b]
Acidity (%)					
Control	0.502 [a]	0.458 [a]	0.349 [a]	—	—
15°C	0.514 [b]	0.471 [b]	0.366 [b]	0.346 [a]	0.325 [a]
10°C	0.522 [c]	0.500 [c]	0.393 [c]	0.371 [b]	0.351 [b]
pH					
Control	4.86 [a]	4.98 [a]	5.10 [a]	—	—
15°C	4.60 [b]	4.77 [b]	4.94 [b]	5.28 [a]	5.41 [a]
10°C	4.37 [c]	4.59 [c]	4.71 [c]	4.93 [b]	5.07 [b]
Total Sugar (%)					
Control	11.94 [a]	13.39 [a]	8.64 [a]	—	—
15°C	9.37 [b]	10.67 [b]	10.94 [b]	8.85 [a]	8.27 [a]
10°C	9.06 [c]	9.50 [c]	12.35 [c]	10.60 [b]	9.46 [b]
Reducing sugar (%)					
Control	5.25 [a]	5.75 [a]	3.82 [a]	—	—
15°C	3.25 [b]	4.28 [b]	4.83 [b]	4.44 [a]	3.66 [a]
10°C	3.08 [c]	3.82 [c]	5.79 [c]	4.58 [b]	3.81 [b]

Different suprscript letters within a column are significantly different at $p < 0.05$.
'—' denotes no fruit survive after 21 days of storage

Table 2: Ascorbic acid, total phenol, total carotenoid and antioxidant content of Indian ber fruit cv. 'Gola' at different storage regimes

Storage temperature	Storage period (d)				
	7	14	21	28	35
Ascorbic acid (mg 100g^{-1})					
Ambient	102.42 ^{a}	85.63 ^{a}	61.44 ^{a}	—	—
15 °C	108.57 ^{b}	98.79 ^{b}	83.72 ^{b}	71.93 ^{a}	56.25 ^{a}
10 °C	110.02 ^{c}	102.55 ^{c}	94.65 ^{c}	81.32 ^{b}	62.83 ^{b}
Total phenol (GAE mg 100g^{-1})					
Control	0.098 ^{a}	0.084 ^{a}	0.069 ^{a}	—	—
15 °C	0.101 ^{b}	0.093 ^{b}	0.076 ^{b}	0.071 ^{a}	0.064 ^{a}
10 °C	0.103 ^{c}	0.095 ^{c}	0.088 ^{c}	0.079 ^{b}	0.072 ^{b}
Antioxidant content (TE mg 100g^{-1})					
Control	237.27 ^{a}	217.00 ^{a}	204.45 ^{a}	—	—
S15 °C	241.94 ^{b}	224.42 ^{b}	213.13^{b}	194.27 ^{a}	177.21 ^{a}
10 °C	249.12 ^{c}	231.91 ^{c}	218.08 ^{c}	200.73 ^{b}	183.56 ^{b}
Total carotenoid (β-carotene mg 100g^{-1})					
Control	0.166 ^{a}	0.178 ^{a}	0.199 ^{a}	—	—
15 °C	0.155^{b}	0.168 ^{b}	0.182 ^{b}	0.200 ^{a}	0.210 ^{a}
10 °C	0.146 ^{c}	0.158 ^{c}	0.165^{c}	0.191^{b}	0.204 ^{b}

Different suprscript letters within a column are significantly different at $p< 0.05$.
'—' denotes no fruit survive after 21 days of storage

Conclusion

In conclusion, the results suggested that the storage temperature was effectively maintained the higher level of total soluble solid, acid content, ascorbic acid, phenolics, carotenoid and antioxidant content in jujube fruit during storage. However, the efficacy was being higher at 10°C. In addition, lower temperature also found effective to delays the ripening with extended shelf-life of jujube up to 35 days of storage.

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