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Calcium chloride extends the keeping quality of fig fruit (*Ficus carica* L.) during storage and shelf-life

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ABSTRACT

The effects of postharvest application of fruit hardening chemical agents on fig (*Ficus carica* L. cv. Poona) fruit were compared with untreated figs during storage. The impact of calcium chloride (4%) was notable in terms of retention of fruit color, texture and increased accumulation of ascorbic acid, compared to untreated control figs. Pretreatment with calcium chloride (4%) was found to be most effective in checking the growth of both mesophilic aerobic bacteria and yeast and molds at low temperature ($1 \pm 0.5\,^{\circ}C$; 95–98% RH) storage and it further delayed ripening and senescence of figs and was beneficial in prolonging the postharvest life twofold. Treated figs without microbial spoilage could be used for short term storage, transportation, distribution and marketing for long distance domestic markets in India.

1. Introduction

Low temperature storage is the major means of controlling spoilage of fresh figs. Literature on preservation of fresh fig fruit at low temperature is limited (Ito et al., 1987; Morton, 1987; Park et al., 1998; Celikel and Karacal, 1998). Baccaunaud et al. (1995) claimed that storage of 'Sultane' figs at 6–8 °C was preferable to 2 °C, as the 2 °C stored fruit underwent faster degradation after transfer to ambient temperature. The fig fruit is not sensitive to chilling injury and therefore, Crisosto and Kader (2004) suggested conditions of low temperatures of −1 °C to 0 °C and 90–95% relative humidity (RH) for fresh fig storage.

Postharvest handling and storage of fresh figs is difficult as the thin fruit skin is easily ruptured, leading to rapid loss of nutritional contents and increased permeability for microbial entry for secondary infection. Fig fruit can not be stored during off seasons due to their highly perishable nature and lack of appropriate postharvest technologies. Hence there is a need to improve the shelf-life of fig fruit in low temperature conditions and maintain the initial fruit quality attributes of harvested fruit through thickening and hardening of the fruit skin, without losing nutritional quality. However, information on the effecta of dip treatments with calcium salts on fruit quality and the storage life of fig fruit under different storage conditions is very limited, since it is an under-utilized and minor fruit crop. Therefore, the objective of the present study was to evaluate the response of fig fruit to dip treatments with calcium and sodium salts, to improve the fruit texture and to retain initial fruit quality attributes during storage, and to extend storage life.

2. Materials and methods

2.1. Plant material

Green, firm and optimally mature (15–18% soluble solids content) figs (*Ficus carica* L. cv. Poona) fruit were harvested from a commercial orchard from Rampura near Bellary, India, during 2009. The fruti were de-latexed for 15 min, sorted, and graded for uniform size and color. The selected fruit lots were divided into five groups of 90 kg/group, water-washed, dipped in the solutions of various chemicals [2,4% calcium chloride(T_2,T_3); 2% calcium lactate(T_4); 2% sodium benzoate(T_5); and untreated control(T_0)] for 15 min and the surface of the fruit air-dried under shade for 30 min. Both the treated and untreated control fruit were packed into Corrugated Fiber Boards (CFB) with cushioning with paper strips in a single tier system at the base, and transported to CFTRI, Mysore, India, over 8 h.

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2.2. Storage conditions

Fig fruit packaged in the CFB boxes were transferred to a precooler room (2 + 1 °C, 92–95% RH) for 6 h. There were six replicates per treatment. The physico-chemical and microbiological quality parameters were analyzed at the beginning of the experiment (1 d after harvest, day 0). The fruit were stored in a low temperature storage room (1 ± 0.5 °C, 95–98% RH).

2.3. Sampling method for the storage experiment

For each treatment, six replicates of samples with 15 kg of figs per replicate were used. From each treatment, three replicates of samples were labeled for recording of physiological loss in weight (PLW) on each sampling day. The remaining samples (three replicates of each treatment) were placed in CFB boxes and stored at 1 ± 0.5 °C. For measuring physical and chemical quality parameters, samples were periodically (0, 7 and 14 days) withdrawn and used for analysis. For measuring microbiological quality parameters, samples were drawn on 0 and 14 days and were used for analysis. The data were obtained for each measurement in three replicates for each treatment.

2.4. Physical quality

2.4.1. Fruit texture

Fruit firmness was determined using a Texture analyzer (LR5 K, Lloyd Industry Co. Ltd., UK) equipped with a 2 mm diameter probe. The maximum deformation (%) applying a 100 N force at a speed of 50 mm min^{-1} was registered on opposite sites on the equatorial part of the fruit at the site of probe insertion, and was expressed as penetration force in *N*.

2.4.2. Fruit color

Fruit color measurement were made from three portions of each individual fruit using a color measuring system (UV 2100, Shimadzu, Japan) at wavelengths ranging from 400 to700 nm and expressed in terms of Hunter values *L*, *a* and *b*. The average of three replicates for *L*, *a* and *b* was considered for the calculation of Hue angle (h°) and Chroma (Hunter, 1975).

2.5. Chemical quality

Three replicates of figs were obtained after replicate samples were blended in a blender (Kenstarmixi, India). For analysis of the chemical parameters, the homogenate of a composite sample was used. The pH, titratable acidity (TA) and soluble solids contents (SSC) were measured. The titratable acidity was expressed as % citric acid after a titration with 0.1 N NaOH (Ranganna, 1986). The soluble solids contents (SSC) were measured with a handheld refractometer (Erma, Japan) and expressed as %. The content of ascorbic acid (AA) was determined as described by Ranganna (1986). Samples of 5 g of blended figs were homogenized in 100 mL of extraction solution containing 3% metaphosphoric acid. An aliquot of 10 mL of the extract was titrated against standard dye 2, 6-diclorophenol indophenols sodium salt by titration. The dye, blue in alkaline and red in acidic solution was reduced by ascorbic acid to pink to an end point, which persisted for at least 15 s, and was expressed as mg/100 g. The sugars present in the fruit in terms of total sugar, reducing sugar and non-reducing sugar, were estimated by the Lane and Eynon method (AOAC, 1990), and the sugar content was expressed as %.

Table 1
Effect of dip treatments on changes in textural characteristics in terms of penetration force of fig fruit stored at 1 ± 0.5 °C and 95–98%RH ($n = 3$).

Treatments	Penetration test (*N*)		
	STORAGE (days)		
	0th day	7th day	14th day
T_1	3.37ab	3.12ab	1.89a
T_2	3.37ab	3.72ab	2.53a
T_3	3.37ab	5.06b	5.51b
T_4	3.37ab	3.82ab	4.18ab
T_5	3.37ab	3.27ab	4.16ab

Mean scores with different letters differ significantly (*$P < 0.05$) by DMRT ($n = 3$). T_1-control; T_2-2% calcium chloride; T_3-4% calcium chloride; T_4-2% calcium lactate; T_5-2% sodium benzoate.

2.6. Microbiological quality analysis

Samples of 10 g were analyzed on days 0 and 14 of storage for microbiological evaluations as described by Carl Vanderzant and Don F. Splittstoesser (1992). Samples were transferred aseptically into a stomacher (Lab Blender 400, Seward Laboratory, London, UK) bag containing 90 mL of Butterfields phosphate buffer and the mixture was homogenized for 60 s and further serial diluted as needed under aseptic conditions at room temperature. 0.1 mL of appropriate dilutions was spread-plated and 1 mL pour-plated on plates of various agar materials in triplicates. Mesophilic aerobic bacteria were enumerated by the pour plate method using plate count agar (PCA) (Himedia, Mumbai, India) and incubated at 37 °C for 2 days. Yeast and molds were counted by the spread plate technique using rose bengal choramphenicol agar (Himedia, Mumbai, India) and incubated at 37 °C for 4 days. After an incubation period of 2 days for mesophilic aerobic bacteria and yeast and molds for 4 days, the colony count was recorded using a colony counter (Serwell instruments Inc., India). Three replicates were analyzed and microbiological counts were expressed as log of colony forming units (CFU) g^{-1} of sample. The data from independent triplicate trials were pooled and the means and the standard deviations calculated.

2.7. Statistical analysis

For statistical analyses of variances, procedure of the Statistical Analysis System (SAS Institute, Cary, NC, USA) was used for all the collected data. All determinations were conducted three times at least and Analysis of Variance (ANOVA) of the data was evaluated by Statistical Analysis System (SAS). Duncans Multiple Range Test (DMRT) at the 5% significance level was employed to determine the statistical significance of differences between the means $P \leq 0.05$ (SAS, 1985).

3. Results and discussion

3.1. Fruit texture

Results of penetration values of figs treated with various compounds (Table 1) showed that among the treatments T_3 (5.06 N and 5.51 N and T_4 (3.82 N and 4.18 N) recorded higher values and T_1 (3.12 N and 1.89 N) had the least values on days 7 and 14 of storage at 1 ± 0.5 °C.

Results on the changes in fruit texture of fig fruit treated with postharvest dips (Fig. 1) in low temperature storage for 14 days indicated that among the treatments, only T_3 improved fruit texture over the control. This could be attributed to the crucial role of calcium in maintaining the integrity of the fruit cell wall and middle lamella by increased influx of calcium in the matrix, promoting the cross linking of pectin polymerase in the cell wall resulting in