ISSN 2229-5518

Influence of pretreatments and low temperature condition on postharvest quality characteristics and the shelf life extension of cashew apple with and without nut

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Abstract: In the present study, an attempt was made to prolong the shelf life and to maintain the post-harvest quality of cashew apple with and without nut under the influence of surface coating with fruit hardening chemical agents and low temperature (LT) storage condition. Optimally matured (TSS 8-9 ºBrix) cashew apple (cv. Ullal-1) fruits with nuts and without nuts were water washed, sorted and graded for uniform size, colour, texture and hydro cooled in cold water for 10 minutes, followed by the post-harvest dip treatments(T1-untreated control, T2-3.0% calcium chloride, T3-4.5% calcium chloride and T4-1.5% calcium lactate)for 15 minutes. Both control and treated fruits were surface air dried, then packed into CFB boxes with proper cushioning and stored at low temperature(LT) condition(2+10C, 90-95% RH). Results indicated that response of cashew apple with nuts to T2-3.0% calcium chloride, T3-4.5% calcium chloride salts was remarkable, in terms of retention of most of the physico-chemical parameters as compared to cashew apple stored without nut. Among the fruit hardening pretreatments, 4.5% CaCl2 (T3) was most effective in extending shelf-life up to 18 days without fruit spoilage, with retention of colour, texture, fruit weight, ascorbic acid, titrable acidity, tannins content and other fruit quality attributes as against 12 days and 6 days in untreated control fruits stored at LT and at RT conditions respectively.

Key words: Fruit hardening chemical agents, Cashew apple with nut, Fruit quality, Shelf life

Introduction

Cashew (*Anacardium occidentalis*) a tropical fruit tree from northeastern coast of Brazil, belongs to *Anacardiaceae* family (Queiroz, 2011). The cashew nut has been used worldwide as an important dried fruit(Akinhanmi and Atasie 2008), while Cashew apple is a pseudo fruit(Assuncao et al.,2003), which is a by-product of cashew nut industry (Morton, 1987).The nutritive and qualitatively characters of the apple have clearly indicated its superior position compared to other fruits. Cashew apple rich in sugars, amino acid, tannin, ascorbic acid and minerals and crude fiber. Cashew apple is very rich in ascorbic acid (200mg/100g) which is almost five times that of citrus fruits (40mg/100g).The cashew apple can be utilized for several value added products like juices, syrup, squash, carbonated beverages, jam, fruit bars, candy, tutty fruity, chutney, pickle, vinegar, liquor, fenni, wine etc. However, most often the food industries in India given very less attention and even the research laboratories and reports on the commercial exploitation of cashew apple are very limited.

The seasonal production of cashew apple is one of the greatest handicaps for the processing industry, along with its astringent and acrid principles. The astringent principle present in cashew apple gives an unpleasant biting sensation on tongue and throat when used in the raw form. It is highly susceptible to physical injury, which leads to microbial spoilage during harvest, transportation and storage. Yeasts and molds are the primary and secondary invaders respectively, responsible for the spoilage of cashew apple. The insect maggots and non-insect pests are also responsible for the spoilage of fallen apple in the field along with the soil microbes. Transport of apples for processing is another problem. When the soft and delicate apples are stacked in thick layers, those in the lower ones may burst because of the weight and lose their juice. Fragmented and scattered nature of cashew plantation also creates problem in collection and utilization of cashew apple in some cases. All this resulted in poor shelf life of cashew apple (Mini et al., 2005). This necessitates researchers to develop appropriate postharvest handling and preservation methods that may extend its shelf life in order to endorse carry across the world.

Therefore, the efforts are focused to find out the innovative approaches to extend the storage life of cashew apples and to maintain its fruit quality after harvest at low temperature. One method is by means of chemical treatment using calcium salts that has several advantages such as controlling the post-harvest decay, reduces fruit respiration rate, maintaining the fruit firmness, increasing the calcium content. More ever the direct application of calcium salts to the fruit surface is more effective as little or no subsequent translocation of calcium from leaves to the fruit occurs, when it is applied as pre-harvest foliar sprays. Calcium salts frequently have been used in food preservation by food industry as pre-harvest applications of calcium compounds and post-harvest treatment in calcium salt solution in order to prolong the storage life of fruits (Gupta et al., 2011).These salts are being used in preservation of fruits by retaining fruit firmness and visual quality attributes with a longer shelf life of the fresh and semi processed products as well. It can play a positive role in improvements such as fruit storability (Irfan, et al., 2013), the nutritive value (Brant, 2002), the product firmness (Alzamora, et al., 2005), firming agents for canned fruits and vegetables (Camire, et al., 1994; Baker, 1993). Among these calcium salts calcium chloride has been broadly used as preservative and firming agent in the fruits and vegetables industry for whole and fresh-cut merchandises (Chardonnet, et al., 2003) and has shown the significant improvement in the quality of the final product(Baker,1993). As calcium from these salts has been reported to crosslink with middle lamella pectin from cell walls and to stabilize cell membranes and/or affect cell turgor potential (Manganaris, et al., 2007; Picchioni, et al., 1995). However, the information on effect of surface coatings with calcium salts on the fruit quality and the storage life of cashew apple with and without nut under different storage conditions is very limited, because it's underutilized and minor fruit crop. Therefore, the present study was undertaken.

Materials and methods

Selection of Raw materials

Optimally matured (TSS 8-9^{0}Bx) cashew apple (cv. Ullal-1) fruits with and without nuts were harvested early in the morning from well managed cashew apple fruit orchards (Ullal-1), Agricultural Research Station Ullal, near Mangalore, Karnataka. Water washed, sorted, graded for uniform size, colour and texture, hydro cooled in cold water for 10 minutes to reduce field heat and fruit metabolic activity to control fruit respiration rate. Fruit hardening chemical reagents calcium chloride and calcium lactate. These chemical agents, calcium chloride and calcium lactate were obtained from SRL and Mark chemicals Ltd., India.

The objective of use of calcium chloride salt at 3% and 4.5% levels was to optimize the concentration and to increase apple flesh calcium content. While selection of calcium lactate at 1.5% for the present study, was mainly as the preservative and as the firming agent to reduce postharvest decay and to control microbial fruit spoilage.

Storage studies

Cashew apple fruits with nuts (320 kg) after precooling were grouped into two fruit lots (160 kg of fruits with nuts, 160 kg of fruits without nuts) for post-harvest dip treatments. Aqueous solutions of calcium chloride (3%, 4.5%) and calcium lactate (1.5%) were prepared in potable water. Further, two lots of cashew apple fruits were equally divided into eight groups of each 40 kg per treatment. Each group of fruits divided into triplicates per treatment. Each group was dipped in the above chemical solutions for 15 minutes. Both the Control(T_1-untreated control) and the treated (T_2-3.0% calcium chloride, T_3-4.5% calcium chloride and T_4-1.5% calcium lactate) fruits were surface air dried, then packed into CFB boxes with proper cushioning and stored at low temperature(LT) condition(2 ± 1^0C, 90-95% RH). As these fruits are grown under high humid and relatively low temperature conditions, for prolonging shelf life and for maintaining initial quality attributes, storage at low temperature at 2 ± 1^0C with high humidity of 90-95% was considered as most ideal storage condition. These ideal temperature and high humidity conditions were maintained during experimentation by continuous blowing of fine jet sprinkling of moist air by use of humidifiers and temperature control panels fitted with cold storage system. The stored fruits were periodically (on 0^{th}, 6^{th}, 12^{th} and 18^{th} days) analyzed during 18 days of LT storage, for fruit compositional changes in terms of following physico-chemical quality attributes and observations in triplicates were recorded and the average values for each quality parameters are presented.

Physicochemical characteristics

Physiological loss in weight (PLW, %)

PLW was worked out based on initial weight and loss in weight during LT storage. The difference between initial and final weight divided by initial weight is PLW and is expressed in percentage.

Fruit texture

Fruit texture was measured in terms of penetration test by using the Texture measuring system (LLOYD, Model LR5K) fitted with the needle probe of 8 mm diameter with load cell 1(KN) and cross speed of 50 mm/min. The randomly selected fruits were placed at the base of the Texture measuring system. The maximum force (N) used was defined as firmness.

Fruit Color

Fruit colour measurement was taken out at three portions of each individual fruit using colour measuring system (Hunter Lab scan, Model: Hunter XE, USA) at wavelength ranging from 400 to700nm and expressed in terms of L*, a* & b* values (Hunter 1975).The Hue angle and Chroma values is calculated by using these hunter values based on the formulae.1.Hue angle= $Tan^{-1}b/a$, 2.Chroma value = $(a^2+b^2)^{1/2}$.

Total Soluble Solids (TSS in ^{o}Brix)

The TSS of the homogenate sample was measured by using Hand Refractometer (Model: Erma, Tokyo, Japan) and is expressed in terms of ^{o}Brix.

Titrable Acidity (in % anhydrous citric acid content)

Acidity of homogenate sample was estimated by the method suggested by Ranganna (1999) and is expressed as % anhydrous citric acid.

Ascorbic acid (in mg/100g).

The Ascorbic acid content in homogenate sample was determined using 2, 6 Dichloro-phenol indophenol sodium salt by visual titration method as described by Ranganna (1999). The dye is blue in alkaline solution and pink in acidic solution was reduced by ascorbic acid (mg/100g).

Sugars (as % total sugars and reducing sugars)

Sugars such as % total sugars and reducing sugars in homogenate of samples were estimated as per the procedure of Lane and Eynon method (AOAC, 1990).

Tannins by Colorimetric method: Colorimetric estimation of total tannins is based on the measurement of blue colour formed by the reduction of phospo tungstomolybdic acid by tannin like compounds in alkaline solution (Ranganna, 1999).

Statistical Analysis of Data

All determinations were conducted in triplicate. An analysis of Variance (ANOVA) of the data was evaluated by Statistical Analysis System (SAS). Duncan's Multiple Range Test was employed to separate out the statistical significance ($p\leq 0.05$) of differences between the means (SAS, 1985).

Results and discussion

Fruit quality attributes

Physiological loss in weight (%)

The results on PLW (Table 1) showed that cashew apple stored with nut showed better response in terms of PLW reduction as compared to cashew apple without nut. However, the fruit weight loss in T_1 (untreated control) was progressively increased with storage time with maximum weight loss on the 18th day of LT storage in both cases of cashew apple stored with and without nuts. Among the treatments, T_3(4.5% calcium chloride) recorded the least PLW values on the 6th day, 12th day and 18th days LT storage period as compared to T_1 (untreated control). Thus, PLW was ($p \leq 0.05$) reduced in T_3 (4.5% calcium chloride) in both cashew apple with and without nut.

The marked reduction in fruit weight loss in both cashew apple with and without nut due to the post-harvest dip treatment with T_3(4.5% calcium chloride)indicated that availability of calcium directly to the fruit surface of cashew apple. Most of calcium entering the fruit through natural openings called lenticels and gets accumulated in the fruit's cell wall by cross linking with pectin polymers as calcium pectate and in cell membranes also. As calcium known to increase the fruit cell wall turgidity. It is also supposed to reduce water diffusion over the fruit cuticle to reduce differences in osmotic potential that are driving force for water diffusion and to strengthen the walls of epidermal cells resulting in improved resistance to cell degradation when the fruit cells meet free water (Sakse and Yataas, 1997). This could be one of the reasons for significant reduction in the PLW (%) with storage time in the calcium treated fruits with and without nuts up to 18 days. Similarly, Mir and Bhat (1993) reported that dip treatment of Red Delicious apples with 4% calcium chloride slowed down the PLW and fruit texture loss, when stored at ambient conditions for 60 days.

Fruit Textural characteristics

The results on penetration force of fruit treated with various hardening agents (Table 2) showed that firmness in both the cases was reduced gradually with storage time. However, the cashew apple stored with nut had slightly better fruit textural values as compared to fruit stored alone without nut. Among the treatments, only T_3 (4.5% calcium chloride) ($p\leq 0.05$) improved the firmness of both types of cashew apple with storage period (up to 18 days) as it had the ($p\leq 0.05$) higher value. However, the firmness in T_1(untreated control) of both types of cashew apple was maximum (5.68N) at 0th day and gradually decreased with storage time (3.20 N). Maintaining ($P\leq 0.05$) higher firmness in the fruit alone and with nuts treated with T_3 (4.5% calcium chloride) could be attributed to higher accumulation of calcium ions and its higher degree of binding with fruit cell wall components (pectic acid) that led to formation of calcium pectate in the fruit cell wall by promoting the cross linking of pectin polymerase in the cell wall that results in to the rigidification of fruit cell wall and further, it acts as a cementing agent to maintain the structural integrity of cell membrane and cell wall by improved mechanical strength of the fruit cell wall consistency of the treated fuits (Paliyath et al., 1984; Poovaiah 1985, Conway and Sams 1987, Yan and chen,2015). It makes the fruit cell wall more resistant to break down by cell wall degrading enzymes (pectin esterase and poly galacturonate) during LT storage and this action might led to retention of improved fruit firmness in 4.5% $CaCl_2$ treated cashew apple alone and with nuts up to 18 days. Similarly, exogenous application of calcium salt during post-harvest storage of fruit to maintain the texture has been reported in apples (Wang et al., 1993; Conway et al., 1994) and many other fruits.

Fruit colour

Chroma value: The result (Table 3) revealed that fruits stored with nuts showed a slightly higher value than those without nuts in terms of chroma values. Among the treatments, both fruits without and with nuts pretreated with calcium salts T_2 (3.0% calcium chloride), T_3 (4.5% calcium chloride) were ($p\leq 0.05$) recorded higher values up to 12th day of LT storage.

Hue angle (in ^{0}):

Results on hue angle (Table 3) showed fruits stored with nuts had higher Hue angle values than those stored without nuts. In both the cases the T4 and T1 treatment showed the maximum and minimum values. Among the treatments, fruits in both the cases, pretreated with calcium salts T_2(3.0% calcium chloride, T_3(4.5% calcium chloride) had ($p\leq 0.05$) recorded higher values up to 12th day of storage.

Results on the changes in the fruit colour parameters (Hue angle, chroma values) of fruits with post-harvest dip treatments with calcium salts during 12 days of storage((Table 3) indicated that calcium pretreated cashew apple fruits with nut had retained light green colour during 12 days of storage. However, only T_3-4.5% calcium chloride treatment ($p\leq 0.05$) retained better fruit colour in both cases of cashew apple with nuts and without nuts, as compared to untreated control on the last day of LT storage. Pretreatment with calcium salts in the above fruits might had led to aid to inhibition of pigments degradation, as there was delay in the loss of major pigments fruit skin (chlorophylls) that could be resulted due to fruit cell wall thickening and binding of calcium ions with calmodulin like protein molecules. This our results are supported by the fact of Poovaih (1985) that calcium known to play intracellular messenger role on plant growth and development by regulating the various biochemical processes of plant cell metabolism. Our results in agreement with those reported by Silva and Vietes (2000) that there was delay in initiation of fruit colour changes during LT storage of passion fruits pretreated with 1% calcium chloride.

Chemical changes during low temperature (LT) storage of pre-treated cashew apple fruits

Titrable Acidity (%)

Titrable acidity is unswervingly related to the deliberation of total organic acids present in the fruit, which is a significant factor in maintaining the quality of fresh fruits. Results indicated(Table 4) that even though there was no ($p \leq 0.05$) much difference in terms of acidity of the fruit between the fruits stored with nut and fruits without nuts, however, among the treatments T_4-1.5% calcium lactate had the higher acid content with storage time (upto 12th day of storage) as compared to T_1(untreated control).

Ascorbic acid (mg/100g)

Results (Table 4) revealed that there was similar trend in ascorbic acid content of the fruit in both types of fruit observed with storage time as it was noticed in terms of acidity. In both cases, ascorbic acid content was ($p \leq 0.05$) reduced with storage time (from 0th day to 18th day). In both the cases, T_3(4.5% calcium chloride) had ($p \leq 0.05$) recorded higher ascorbic acid content at the end of storage time as compared to T_1-untreated control and other treatments.

Tannins (in g/100g):

Results (Table 5) revealed that there is no marked difference with respect to the tannin content between the cashew apple stored with nut and without nut. As storage advanced, the tannin content decreased in all the treated fruits with nut and without nut. Similar trend in tannins accumulation was observed with storage time as it was observed with respect to ascorbic acid content.

Results on the changes in the chemical characteristics such as the pools of titrable acidity, ascorbic acid and tannins content of the cashew apple fruits alone and with nuts(Tables 5)showed that all the above three parameters were decreased with storage time(upto18 days). Our results are supported by the fact of Figueiredo et al., (2007) that at different concentrations of calcium chloride dip treatment total titrable acidity, ascorbic acid content and tannins content decreased during storage. The ascorbic acid content decreased during ripening and storage. There was a reduction in ascorbic acid content through storage (Manolopoulou and Papadopoulou, 1998).

Unlike the pools of ascorbic acid and acidity, there was no definite trend in changes in the pools of tannins in all the treated apples alone as well as treated apples with nut during LT storage, even though they are decreasing. In the case of acidity of cashew apple fruit alone and with nut, the treatment T_3-4.5% calcium chloride and T_4-1.5% calcium lactate seems to be best for retaining the acidity of cashew apple. Among the treatments, cashew apple alone and with nut treated with same above treatments were retained ($p \leq 0.05$) higher ascorbic acid content during 18 days of LT storage as compared to untreated control and the losses in ascorbic acid content of these treated cashew apple fruits minimized during 18 days of LT storage, considerably by maintaining higher acidity and higher tannin content. As the titrable acidity in these treated cashew apple fruits was predominantly due to accumulation of higher concentration of organic acid (mallic acid and anacardic acid) that led to prevention of oxidation of ascorbic acid to dehydro-ascorbic acid during 18 days of LT storage and therefore, only treatments were found superior over control.

The other major contributing factor that prevented the losses in ascorbic acid content of above treated cashew apple fruits with nuts initially during 12 days of LT storage could be by accumulation of higher amount of tannins. The major tannins are gallic acid, protocatechuric acid, caffeic acid and catechins that might have contributed towards the retention of higher concentration of ascorbic acid content. Chemically the tannins of cashew apple are the complex esters of phenolic acids and sugars. The pools of these organic acids are slowly decreased during storage of cashew apple fruits in general. However, this decline trend in the pool of these organic acids is slow and delayed in T_3-4.5% calcium chloride and T_4-1.5% calcium lactate treated cashew apple fruit by calcium ions. The effect of calcium ions was ($P \leq 0.05$) noticeable after 6th and 12th day of LT storage.

Total Soluble Solids (TSS in ^{o}Brix)

Results (Table 5) showed that among the treatments T_4-1.5% calcium lactate recorded the least values of TSS throughout the storage period in both fruits stored alone and without nuts. However, the TSS values increased in all the treatments with storage time in both the cases.

Total sugars (in %)

Results (Table 6) indicated that among the treatments there no much difference with respect to total sugar content in both the cashew apple stored with nut and without nuts. However, none of these treatments specific trend in the pools of total sugar content with storage time.

Reducing sugars (in %)

Results (Table 6) revealed that response of pretreated fruits alone was distinct as compared to those pretreated fruits with nuts irrespective of treatments. Among the treatments, T_1(untreated control recorded the highest reducing sugar content in fruits without nut with storage time (on 6th, 12th and 18th day of LT storage) as compared to treated ones. However, there was least reducing sugar content in T_3-4.5% calcium chloride pretreated fruits without nuts with storage time (on 6th, 12th and 18th day of LT storage) as compared to treated ones.

Results on the changes in the chemical characteristics such as the pools of TSS, total sugars and reducing sugars content of the cashew apple fruits alone and with nuts (Table 5 and 6) showed that the fruits stored with nuts comparatively had slightly less reducing sugars and the total reducing sugars than those stored without nuts. Among the treatments T_4(1.5% calcium lactate and T_1(untreated control were recorded the ($p \leq 0.05$) higher

ISSN 2229-5518
levels of TSS and reducing sugars during 18 days of LT storage as compared to others. These results are one of the indicators and the characteristics symptoms of initiation of

Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride		Calcium lactate

fruit ripening in untreated control and 1.5% calcium lactate treated cashew apples with increase in pools of TSS and reducing sugars accumulation with storage period. On the other hand, T_3(4.5% calcium chloride) treated cashew apple were registered ($p \leq 0.05$) the least reducing sugars content during 18 days of LT storage. Similarly, Antunes *et al* (2007) referred that kiwifruits dipped in 2% $CaCl_2$ postharvest showed too slightly lower soluble solids content after 6 months at 0ºC.

This could be attributed to the significant delay in the progression of several signs of fruit ripening by the calcium by inhibition of starch to sugar conversion that resulted mainly due to high amount of calcium deposition in the fruit cell wall of these treated fruits. As the cell wall components such as pectic substances, calmodulin (calcium binding cell wall protein) and hemi cellulose polysaccharides, which are most likely binding sites for calcium (Hanson, 1984). The bounded calcium with these pectic compounds preserved the fruit firmness and stability of the treated cashew apple fruits during 18 days of LT storage. This might have led to the higher fruit resistance against starch break down, by maintaining high calcium concentration in the cytosol and this further might led to inhibition of respiratory activity in these treated fruit cells (Faust and Shear, 1972) and therefore, less free sugars were released. As most of calcium entering the tissues gets accumulates in the fruit cell walls and cell membrane that are thought to be the sites of anti-senescence action (Glenn et al., 1988) that might have extended the shelf life of these calcium treated cashew apple fruits stored under LT conditions up to 18 days, without affecting the fruit's quality attributes.

Tab. 1: Effect of pretreatment with calcium salts on the changes in the PLW of cashew apple at low temperature (2 ± 1^0C; 90-95%RH) condition.

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			(3%)	(4.5%)	(1.5%)
PLW (%)	With nut				
	6	4.35^{d}	3.43^{b}	2.88^{a}	4.05^{c}
	12	12.48^{c}	11.35^{b}	8.44^{a}	12.80^{d}
	18	24.78^{c}	20.84^{b}	15.99^{a}	24.65^{c}
PLW (%)	Without nut				
	6	6.86^{f}	4.42^{d}	4.31^{d}	5.60^{e}
	12	17.99^{h}	17.32^{g}	13.31^{e}	16.47^{f}
	18	32.62^{f}	28.53^{e}	25.43^{d}	33.40^{g}

Mean scores with different letters differ significantly P<0.05) by DMRT

Tab. 2: Effect of pretreatment with calcium salts on the changes in the penetration value of cashew apple at low temperature (2±1^{0}C; 90-95%RH) condition.

Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride		Calcium lactate
			(3%)	(4.5%)	(1.5%)
Penetration value (N)**With nut**					
	0	5.68^{f}	5.68^{f}	5.68^{f}	5.68^{f}
	6	3.93^{bc}	4.53d	5.39ef	3.56ab
	12	3.51^{a}	4.23b	5.01c	3.33a
	18	3.20^{a}	3.97b	4.85c	3.17a
Penetration value(N)**Without nut**					
	0	5.68^{f}	5.68^{f}	5.68^{f}	5.68^{f}
	6	3.89abc	4.26cd	5.11e	3.48a
	12	3.57a	4.03b	4.97c	3.29a
	18	3.17a	3.89b	4.75c	3.09a

Mean scores with different letters differ significantly (P<0.05) by DMRT

Tab. 3: Effect of pretreatment with calcium salts on the changes in the fruit colour of cashew apple at low temperature (2±1^{0}C; 90-95%RH) condition.

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Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride (3%)	Calcium Chloride (4.5%)	Calcium lactate (1.5%)
Chroma value With nut					
	0	36.93[a]	36.93[a]	36.93[a]	36.93[a]
	6	37.32[a]	38.74[a]	40.18[a]	38.44[a]
	12	37.05[a]	40.33[a]	38.89[a]	37.27[a]
	18	38.21[a]	37.73[a]	37.46[a]	36.82[a]
Chroma value Without nut					
	0	36.93[a]	36.93[a]	36.93[a]	36.93[a]
	6	38.53[a]	38.48[a]	36.86[a]	40.13[a]
	12	35.62[a]	39.11[a]	37.95[a]	36.11[a]
	18	36.85[a]	36.06[a]	35.81[a]	36.10[a]
Hue angle With nut					
	0	-84.46[a]	-84.46[a]	-84.46[a]	-84.46[a]
	6	70.92[b]	74.25[b]	70.06[b]	71.31[b]
	12	63.92[b]	70.92[cd]	71.88[bcd]	73.93[cd]
	18	68.05[bc]	70.41[c]	70.65[c]	68.20[c]
Hue angle Without nut					
	0	-84.46[a]	-84.46[a]	-84.46[a]	-84.46[a]
	6	66.25[b]	70.59[b]	74.78[b]	77.51[b]
	12	71.19[bc]	67.77[bc]	71.63[bcd]	80.82[d]
	18	66.94[bc]	68.50[c]	75.01[d]	83.13[e]

Mean scores with different letters differ significantly (P<0.05) by DMRT

ISSN 2229-5518

Tab. 4: Effect of pretreatment with calcium salts on the changes in the titrable acidity (%), Ascorbic acid (mg/100g) of cashew apple at low temperature (2±1^{0}C; 90-95%RH) condition.

Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride (3%)	Calcium Chloride (4.5%)	Calcium lactate (1.5%)
Titrable acidity (%) With nut					
	0	0.396^{cd}	0.396^{cd}	0.396^{cd}	0.396^{cd}
	6	0.299^{ab}	0.323^{bc}	0.362^{de}	0.407^{d}
	12	0.287^{bc}	0.272^{ab}	0.272^{ab}	0.285^{bc}
	18	0.252^{b}	0.260^{ab}	0.266^{ab}	0.276^{b}
Titrable acidity (%) Without nut					
	0	0.396^{cd}	0.396^{cd}	0.396^{cd}	0.396^{cd}
	6	0.272^{a}	0.347^{cd}	0.351^{cd}	0.411^{d}
	12	0.261^{ab}	0.247^{a}	0.278^{abc}	0.310^{c}
	18	0.254^{a}	0.254^{a}	0.268^{ab}	0.280^{b}
Ascorbic acid (mg/100g) With nut					
	0	274.85^{e}	274.85^{e}	274.85^{e}	274.85^{e}
	6	149.44^{c}	158.50^{d}	117.09^{b}	149.21^{c}
	12	92.40^{a}	103.82^{a}	116.71^{b}	117.09^{ab}
	18	69.83^{ab}	71.11^{aab}	79.49^{d}	67.86^{a}
Ascorbic acid (mg/100g) With nut					
	0	274.85^{e}	274.85^{e}	274.85^{e}	274.85^{e}
	6	157.25^{d}	154.97^{d}	112.14^{a}	146.75^{c}
	12	100.58^{a}	98.57^{a}	119.31^{a}	109.08^{a}
	18	$73.81b^{c}$	73.66^{bc}	75.23^{c}	69.41^{a}

Mean scores with different letters differ significantly (P<0.05) by DMRT

ISSN 2229-5518

Tab. 5: Effect of pretreatment with calcium salts on the changes in the the tannin content (g/100g), total soluble solids (^{o} Brix) of cashew apple at low temperature (2±1^{0}C; 90-95%RH) condition.

Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride (3%)	Calcium Chloride (4.5%)	Calcium lactate (1.5%)
Tannin content (g/100g)With nut					
	0	0.135^{b}	0.135^{b}	0.135^{b}	0.135^{b}
	6	0.110^{a}	0.120^{b}	0.115^{b}	0.135^{b}
	12	0.110^{b}	0.110^{b}	0.115^{bc}	0.090^{a}
	18	0.100^{ab}	0.090^{a}	0.090^{a}	0.090^{a}
Tannin content (g/100g)Without nut					
	0	0.135^{b}	0.135^{b}	0.135^{b}	0.135^{b}
	6	0.115^{a}	0.135^{b}	0.110^{a}	0.135^{b}
	12	0.110^{b}	0.130^{d}	0.120^{d}	0.125^{cd}
	18	0.090^{a}	0.095^{a}	0.110^{b}	0.095^{a}
Total soluble solids (^{o} Brix) With nut					
	0	8.90^{a}	8.90^{a}	8.90^{a}	8.90^{a}
	6	9.40^{ab}	9.90^{b}	9.50^{abc}	9.00^{ab}
	12	10.00^{bc}	11.30e	10.60^{cde}	9.60^{ab}
	18	13.00^{c}	12.60^{bc}	13.20^{c}	12.60^{bc}
Total soluble solids (^{o} Brix) With nut					
	0	8.90^{a}	8.90^{a}	8.90^{a}	8.90^{a}
	6	9.30^{ab}	9.50^{ab}	9.40^{ab}	9.10^{a}
	12	10.20^{bcd}	10.80^{cde}	11.00^{de}	9.70^{bcd}
	18	12.20^{b}	12.80^{c}	13.10^{c}	12.80^{c}

Mean scores with different letters differ significantly (P<0.05) by

Mean scores with different letters differ significantly (P<0.05) by DMRT

Tab. 6: Effect of pretreatment with calcium salts on the changes in the reducing sugars (%) and the total sugars (%)

of cashew apple at low temperature (2±1^{0}C; 90-95%RH) condition.

Parameters	Storage period (days)	Treatment and Code			
		T1	T2	T3	T4
		Control	Calcium Chloride		Calcium lactate
			(3%)	(4.5%)	(1.5%)
Reducing sugars (%) With nut					
	0	7.10a	7.10a	7.10a	7.10a
	6	9.21b	8.90b	8.2	8.16b
	12	9.57b	8.95b	8.80b	9.01b
	18	9.71cd	9.10bc	8.63b	9.10bc
Reducing sugars (%) Without nut					
	0	7.10a	7.10a	7.10a	7.10a
	6	9.02b	9.05b	8.84b	8.99b
	12	9.41b	9.16b	9.12b	9.63b
	18	9.25bcd	9.20bcd	9.14bcd	9.80d
Total sugars (%) With nut					
	0	7.61^{a}	7.61^{a}	7.61^{a}	7.61^{a}
	6	9.34^{cd}	9.10^{bcd}	9.07^{bc}	9.00^{b}
	12	9.78^{d}	10.37^{e}	9.08^{b}	9.76^{d}
	18	11.10^{b}	10.85^{b}	11.60^{d}	11.85^{d}
Total sugars (%) Without nut					
	0	7.61^{a}	7.61^{a}	7.61^{a}	7.61^{a}
	6	9.16^{bcd}	9.38^{d}	9.37^{d}	9.18^{bcd}
	12	9.38^{bc}	9.59^{cd}	10.16^{e}	9.78^{d}
	18	11.07^{b}	11.06^{b}	11.88^{d}	11.60^{d}

Mean scores with different letters differ significantly (P<0.05) by DMRT

Conclusions

It may be inferred from the present investigation that among the treatments, pretreatment with T_3(4.5% calcium chloride) was found to be the most effective surface hardening chemical agent on both the fruit quality attributes and the shelf life extension of cashew apple fruits (var. Ullal-1) stored alone and with nut at low temperature conditions (2±1^{0}C; 90-95% RH). This particular treatment has greatly influenced and maintained the initial fruit quality of cashew apple fruits in terms of fruit colour, fruit texture, Titrable acidity, Ascorbic acid content and Tannins and also lowered the pools of TSS and reducing sugars during LT storage period up to 18 days. Therefore, the shelf life of these treated cashew apple fruits alone and with nuts was extended by 18 days as compared to untreated control fruits under same LT conditions for 12 days and untreated control fruits stored at room temperature for 6 days. These treated fruits could be used for short term storage, transportation, distribution and marketing for long distance domestic markets of India.

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