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SHELF- LIFE STUDY OF FRESH- CUT FRUITS USING CHEMICAL PRESERVATIVES

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ABSTRACT

Fresh fruits are rich source of minerals and vitamins and thus, are necessary for nutritionally balanced meal. Any physical injury to the fruit shortens the shelf- life and deteriorates the quality. The present study was conducted to investigate the effect of chemical preservatives on the shelf- life of the fresh- cut packs (150g each) were when stored at 1˚C for 6 days. Apple and pineapple fresh- cut packs were prepared. The chemical preservatives included citric acid (1% and 0.2% w/v), ascorbic acid (1% and 0.1% w/v) and calcium chloride (1% and 1.5% w/v). The physical, chemical and microbiological parameters were analysed. The sensory aspects were also studied. The study showed that the best preservative for apples is calcium chloride (1.5%) increasing the shelf- life to 4 days. The most effective preservative for pineapple pack was citric acid (1%) providing a shelf- life of 5 days. More advanced tests for other preservatives and further investigation is required for the best packaging material to increase the shelf- life of fresh- cut fruits.

Keywords: Fresh- cut fruits, chemical preservatives and shelf- life

INTRODUCTION

Fruits and vegetables are an important source of minerals and vitamins. They are abundant of antioxidants which act as receptors of free radicals and help in the alleviation of many degenerative diseases including cardiovascular diseases (CVDs), cancer and ageing (Kaur C, Kapoor, HC, 2001, Rico D, et al 2007). The United States Department of Agriculture (USDA) has defined “fresh” and minimally- processed” fruits and vegetables as the products which have been freshly- cut, washed, packaged and maintained with refrigeration (Lamikanra, O, 2002). Shelf- life, i.e. the time before the product attributes drop below the acceptance limit under standardized storage conditions, is a limiting factor of fresh- cut fruits (Tijskens, LMM, 2000). Fresh- cut processing induces increased respiration rate, water loss and microbial growth (King AD, Bolin HR , 1989, Watada AE, et al, 1990, Qi L, Watada AE , 1999, Wiley, RC , 1994). High levels of sugars in fruits lead to a more rapid microbial decay in fresh- cut fruits than vegetables. Reducing the initial yeast and mould counts along with the low temperature storage (at <5°C) in order to slow down the growth (as growth is not suppressed by the acidity of the fruit) impacts product shelf- life (O’Connor- Shaw RE, *et al*, 1994, Qi L, *et al*, 1999).Therefore, the major limitations for shelf- life of fresh- cut products are microbial spoilage (Brackett, RE, 1994), desiccation, discoloration or browning, bleaching, textural changes and development of off-flavor or off-odor. The attributes which appeal to the consumer include appearance, flavour, taste and nutritional value, in addition to convenience. Based on these, the factors which may affect the quality of the fresh- cut fruits include cultivar (Kim DM, et al, 1993), physiological status of the raw material, postharvest handling and storage (Watada AE, et al, 1990), processing technique (Bolin HR, et al, 1977, Saltveit ME, 1997, Wright KP & Kader AA, 1997), sanitation, packaging (Solomos, T, 1994) and temperature management during shipping and marketing (Beaulieu JC,Gorny JR. 2001).

The quality and acceptance of fresh- cut fruits is dependent oncolor and firmness. Color is a critical quality attribute of fruits like pear, apple and banana, since cutting operations may lead to enzymatic browning (Oms- Oliu G, et al, 2010). Enzymatic browning is caused by polyphenol oxidase (PPO), an enzyme present in the cellular fluids and resulting in undesirable taste and loss of nutrient quality (Beaulieu JC,Gorny JR. 2001). The fresh-cut fruits that maintain firm, crunchy texture with an inherent flavour and aroma are highly desirable, therefore, important to store them at the appropriate temperature and relative humidity to preserve their quality (Bourne, M, 2002). The softening of fresh- cut fruit is mainly due to the enzymatic degradation of the cell wall by enzymes like pectinmethylesterase (PME) and polygalacturonase (PG) (Oms- Oliu G, et al, 2010). Therefore, tissue softening and enzymatic browning are serious problems with fresh-cut fruit products that can limit shelf-life.

Various physical and chemical methods have been used to preserve the fresh- cut fruit quality. Physical methods include storage temperature, hurdle technology and modified atmosphere packaging (MAP). The temperature management decreases metabolic reactions, respiration rate, permeability of gases through packaging film and slow microbial growth (Watada AE, et al, 1996). Effective packaging is necessary to control the gas exchange in and out of produce, minimize moisture loss and microbial growth. The chemical treatments include the application of chlorine, ascorbic acid, citrate and/ or calcium salts for preservation. Chlorine based washing systems reduce microbial contamination of fresh- cut fruits with good efficiency but form harmful compounds (Sapers GM, et al, 2001) when reacts with organic compounds, thus, increasing the risk of cancer (Silveira C, et al, 2008). Sorbitol (a sugar alcohol) exhibits properties of disinfectant as it tends to reduce the surface tension and results in better cleaning of the surface (De Ell JR, et al, 2006). Ascorbic acid converts quinines back to phenolic compounds. Calcium treatments (like calcium chloride) extend the shelf- life of fresh produce. Calcium helps to maintain the cell wall integrity by interacting with pectin to form calcium pectate therefore, delaying senescence, reducing postharvest decay, controlling the development of physiological disorders, and making the texture firmer (Sila DN , et al, 2004, Soliva- Fortuny RC. *et al.,* 2003) but may confer undesirable bitterness to the product (Luna- Guzman I, Barrett DM, 2000). In fresh- cut processing, surface treatments delay physiological decay in fruit tissues as the enzymes and substrates released from injured cells during cutting operations are rinsed from the product surface.

Thus, the present study was conducted to investigate the effect of chemical preservatives a) on physio-chemical properties b) on microbiological parameters c) overall acceptability by sensory evaluation and c) shelf- life of fresh- cut fruits stored in polypropylene containers at 1°C.

METHODS AND MATERIALS

Appleand pineapple fruits, obtained from the Azadpur unit (Delhi, India) of Bharti Delmonte Company and local fruit seller respectively, were used for this study. The Food and Drug Administration (FDA) approved chemical preservatives i.e. ascorbic acid (AA), citric acid (CA) and calcium chloride ($CaCl_2$). The concentrations used of chemical preservatives are AA (1% and 0.1% w/v), CA (1% and 0.2% w/v) and $CaCl_2$ (1% and 1.5% w/v). The packs, each weighing 150gms, were prepared for all the chemical preservatives.

PROCEDURE

The chemical preservatives were applied as dipping solutions on the cut surface of the fruits. Thus, the portability of water (to prepare dipping solutions) was analysed as per BIS standard (IS 10500: 1991). The fruits were peeled and washed with sorbitol solution (acting as disinfectant; 2.5% w/v). After washing, a sample (from each pack) was taken for initial analysis of the quality parameters. The packs were stored at 1°C for a period of 6 days for shelf- life study after the application of preservatives.

SWAB METHOD

Hygiene of the cutting surface, chopping board and knives along with initial microbial load of the fruits was tested using Swab Method (Ranganna, S, 0). Briefly, the swabs were made of sterile, non- absorbent cotton wool on wooden sticks about 7-8 inches long to form a swab of about 0.5 inch in diameter. These swabs were placed in a pair of test tubes containing Ringer's Solution and plugged with non- absorbent cotton wool and sterilized in a hot oven for 90 minutes at 150 °C. All the steps were performed in shortest possible time to prevent contamination. The swabs were then rubbed on the surface to be analysed and again transferred to the test tube containing Ringer's solution and vigorously agitated. 1mL of this solution was poured into the petri plates using Pour Plate Technique. After 24 hours, the plates were examined for growth/ no growth/ or extent of growth (Ranganna, S, 0). The number of colonies in each petri plate was counted and recorded.

PHYSICAL ANALYSIS

WATER LOSS

The weight of each pack was taken accurately. The package was placed in test atmosphere and re-weighed daily during the storage time. This physiological loss in water (PLW) of fruit was calculated on initial weight basis and expressed as percent (Gupta N, et al, 2007).

CHEMICAL ANALYSIS

TOTAL SOLUBLE SOLIDS (TSS)

Total soluble solids indicate percentage by weight of sugar. It was measured in °Brix. Abbe refractometer was used to determine the total soluble solids of all packs. The standard method of IS 13815: 1993 was followed. A few drops of the juice squeezed for the fruits were placed on the prism. The sample was allowed to stand for few seconds and a reading was obtained.

MICROBIOLOGICAL ANALYSIS

Microbiological analysis included total plate count, coliforms and yeast and moulds according to standard procedure given in ISI handbook of food analysis [Part I General Methods; Total Count (IS 5402: 2002), coliform (IS 5401 Part II: 2002) and yeasts and moulds (IS 5403: 1999)]. Five gram of the sample was removed aseptically and macerated using mortar and pestle. The sample was diluted with 45 mL of phosphate buffer. Appropriate dilutions were plated in duplicate.

FERMENTATION TEST

The fermentation test was conducted for the packs containing pineapple. Briefly, 89 mL of water was added to 9 gm of sugar in a 150 or 250 mL conical flask, closed with cotton- wool plug, sterilized at 120 °C for 30 minutes, and cooled. To this, 10 mL of the concentrate was added and diluted to 12° Brix with sterile water under aseptic conditions, and mixed. The sample was incubated at 26.5 °C for 14 days.

Gas formation accompanied by the formation of a white deposit of yeast cells was indicative of a positive result. The carbon dioxide effervescence might be seen when the solution became saturated. If a positive result was observed within 6 days of incubation, the sample was rejected; if observed during the last 8 days of incubation, and if the concentrate was preserved using sulphite, the concentration was raised to 1500 ppm and acidity to 3.5% w/v. Mixed thoroughly and allowed to remain for 14 days and retested. If a positive result was observed in the retest during 14 days of incubation, the sample was rejected, and if the test was negative, the sample might be considered to have passed the test (Ranganna, S, 0).

SENSORY EVALUATION

The consumer acceptance of cut-packed fruits was determined organoleptically by 10 member panelists. The samples were evaluated for the perceivable sensory attributes of color, texture, taste, aroma and overall acceptability as per BIS: 8153- 1986. The products were graded for the above characteristics on the five point hedonic scale given in Table 1.

Table 1: Hedonic scale for scoring

Scale	Points
Excellent	5
Very Good	4
Good	3
Satisfactory	2
Poor	1

RESULTS AND DISCUSSIONS

The water used for preparation of dipping solutions had no toxin causing organisms in accordance with BIS specifications. The hygiene of cutting surface, chopping board and knives were well maintained after disinfecting them using sorbitol solution (2.5% w/v). Sorbitol was used as a disinfectant to reduce the initial microbial load of the fruits.

PHYSICAL AND CHEMICAL ANALYSIS

WEIGHT LOSS

The weight loss in chemically treated apple and pineapple packs ranged from 0.35% to 0.55% and 0.21% to 0.46% respectively. This is consistent with other studies done (Kim DM, et al, 1993, Rocha AMCN, et, 1998, Kizil IS, et al, 1991). The weight loss in the packs increased as a function of storage time, due to juice leakage and reserve material consumption which is a consequence of transpiration and respiration respectively (S- Bierhals V, *et al*, 2011). The storage in plastic boxes could have led to saturated or nearly saturated humidity which probably minimized the water loss (Rocha AMCN, et, 1998). The minimum weight loss was observed in calcium chloride treated packs. This could be due to a reduction in respiration and increase in firmness retention (calcium cross- links with cell wall and middle lamella pectins) as well as reduction in the incidence of physiological disorder and decay. This decreases the enzyme activity responsible for disintegration of cellular structure and thus, decreasing the gaseous exchange (Rico D, et al 2007, Gupta N, et al 2007, Rico D,Martin-Diana AB, et al 2006, Figueiredo RMF, et al). The negative correlation between storage time and weight of the pack indicated an inverse relation (Table 2a and 2b).

TSS

The decrease in TSS in apple and pineapple packs could be due to adjustment to the post- climacteric respiration in apples (Saftner RA, *et al,* 2005). Another study showed similar results in “Red Spanish” and “Smooth Cayenne” cultivars. The plausible reasons could be the type of cultivar, maturity stages etc. (Montera-Calderon M, et al, 2008). An opposite trend was observed in another study done in “Galia melon” due to the conversion of starches to simple sugars (Silveira C, et al, 2008). The ascorbic acid prevents the change in TSS content of apples. Another study also reported no significant changes in the TSS of the apple cubes (Rocha AMCN, et, 1998). A negative correlation was found between the TSS and the storage time indicating an inverse relationship (Table 2a and 2b).

MICROBIOLOGICAL ANALYSIS

All the chemically treated fruits showed an increase in microbial load with coliforms being non-detectable (Table 3a and 3b). The yeasts and moulds count increased with storage time which is consistent with other studies (Qi L, *et al*, 1999, Aguayo E, et al, 2003, Alandes L, *et al*, 2006). The reason could be attributed to decrease in the activity of the preservative added or cell integrity leading to the growth of micro- organisms (Montera-Calderon M, *et al*, 2008). A decrease in microbial load in citric acid treated fruits could be attributed to its antimicrobial action on the inherent flora of the fruit. These antimicrobial agents delay the microbial growth or cause microbial death when they are incorporated into a food matrix (Davidson PM and Zivanovic S, 2003). The antimicrobial action leads to a reduction in pH in the pack, disruption of membrane permeability, anion accumulation or a reduction in internal cellular pH by dissociation of hydrogen ions from the acid (Davidson PM & Zivanovic S, 2003, Beuchat, LF, 2000).

The pineapple shows spoilage by either the growth of fungus or by undergoing fermentation. Thus, the fermentation test was done to examine the change in aroma of the fruit as it cannot be visually observed. The results showed the starting of fermentation from 6^{th} day irrespective of the preservative used. The fermentation in pineapple occurs due to the presence of high sugar content which is the substrate for yeast (O’Connor- Shaw RE, et al, 1094).

SENSORY EVALUATION

The acceptance of the chemically treated fresh-cut fruits decreased with the storage time. A combination of sweet and sour taste was reported in CA and AA treated pineapple packs which changed to sour taste with the storage time. The CA and AA treated apples had a sweet taste. The taste of calcium chloride treated fruits became bland with the storage time (Table 4a and 4b). A similar result was shown by Luna- Guzman (Luna- Guzman I, Barrett DM, 2000) in fresh- cut cantaloupe. No bitter taste was reported by the present study panellists compared to the study done on cantaloupes but firmness was retained in the calcium chloride treated fruits.

Color and texture are critical quality parameters for acceptance of the product. Rapid browning of the CA and AA treated apples was observed resulting in color deterioration and thus, unacceptance of the product. This could be due to the exposure of the enzymes to oxygen caused by damage in the fruit tissue (Raybaudi- Massilia RM, et al, 2007). No such color changes were observed in calcium chloride treated fruits/ packs. No browning was observed in the pineapple packs. The chemically treated pineapples retained their color throughout the storage period irrespective of the preservative used. But a decrease in the lustre/ brightness of the pineapple pieces was

Table 2a: Physical and chemical changes in fresh- cut apple treated with preservatives and stored at 1˚C for 6 days

No. of days	Weight (g)							Total Soluble Solids, TSS (˚Brix)						
	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	$CaCl_2$ (1%)	$CaCl_2$ (1.5%)	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	$CaCl_2$ (1%)	$CaCl_2$ (1.5%)
0	150.00	150.77	150.51	150.42	150.12	150.03	150.53	10	9	7	8	8	9	11
1	149.68	150.59	150.42	150.36	150.00	149.94	150.44	10	9	7	8	8	9	11
2	149.38	150.42	150.34	150.22	149.93	149.86	150.36	8	9	7	8	8	9	11
3	149.08	150.32	150.27	150.14	149.81	149.73	150.23	8	9	7	8	8	9	10
4	148.81	150.20	150.11	149.89	149.69	149.69	150.19	7	8	6	8	8	9	10
5	148.50	150.11	149.94	149.71	149.53	149.59	150.00	7	8	6	8	8	9	9
6	148.34	149.93	149.89	149.60	149.42	149.51	149.95	6	8	6	8	8	9	9
Correlation Coefficient (r)	-0.99	-0.99	-0.987	-0.986	-0.995	-0.996	-0.990	-0.959	-0.866	-0.866	-0.959			-0.943
% weight loss	1.1%	0.55%	0.41%	0.54%	0.47%	0.38%	0.35%	Decrease	Decrease	Decrease	No change	No change	No change	Decrease

Table 2b: Physical and chemical changes in fresh- cut pineapple treated with preservatives and stored at 1˚C for 6 days

No. of days	Weight (g)							Total Soluble Solids, TSS (˚Brix)						
	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	$CaCl_2$ (1%)	$CaCl_2$ (1.5%)	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	$CaCl_2$ (1%)	$CaCl_2$ (1.5%)
0	150.23	150.23	150.20	150.00	150.32	150.00	150.01	14	14	14	15	15	17	17
1	149.99	150.19	150.00	149.93	150.29	149.93	149.98	13	14	14	15	15	17	17
2	149.90	150.00	149.93	149.88	150.15	149.82	149.89	13	14	14	15	15	17	17
3	149.83	149.93	149.81	149.72	150.00	149.79	149.80	13	14	14	15	15	16	16
4	149.69	149.86	149.75	149.64	149.82	149.70	149.79	13	14	14	14	14	16	16
5	149.56	149.73	149.69	149.59	149.73	149.68	149.71	13	14	14	14	14	16	16
6	149.46	149.61	149.60	149.50	149.69	149.61	149.69	13	14	14	14	14	16	16
Correlation Coefficient (r)	-0.990	-0.991	-0.983	-0.991	-0.985	-0.986	-0.979	-0.707			-0.866	-0.866	-0.866	-0.866
% weight loss	0.51%	0.41%	0.39%	0.33%	0.46%	0.26%	0.21%							

Table 3a: Microbiological changes in fresh- cut apple treated with preservatives and stored at 1˚C for 6 days

No. of days	TPC (log cfu/g)							Yeasts and Moulds (log cfu/g)						
	Control	CA (1%)	CA (0.2%)	AA (0.1%)	AA (1%)	CaCl2 (1%)	CaCl2 (1.5%)	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	CaCl2 (1%)	CaCl2 (1.5%)
1	3.24	2.85	3.31	3.40	2.96	2.47	2.4	2.89	2.98	3.06	3.31	3.27	3.1	3.18
3	3.36	2.66	3.28	3.48	3.11	3.14	3.1	2.91	3.12	3.23	3.42	3.51	3.4	3.40
5	4.40	2.55	3.21	4.08	4.08	3.34	3.3	4.00	3.22	3.45	3.70	4.41	4.5	3.89

Table 3b: Microbiological changes in fresh- cut pineapple treated with preservatives and stored at 1˚C for 6 days

No. of days	TPC (log cfu/g)							Yeasts and Moulds (log cfu/g)						
	Control	CA (1%)	CA (0.2%)	AA (0.1%)	AA (1%)	CaCl2 (1%)	CaCl2 (1.5%)	Control	CA (1%)	CA (0.2%)	AA (1%)	AA (0.1%)	CaCl2 (1%)	CaCl2 (1.5%)
1	3.45	4.30	5.41	4.42	4.12	4.15	4.15	4.67	5.54	4.62	4.29	4.12	4.23	4.35
3	3.50	3.42	4.75	4.70	4.19	5.30	5.22	5.54	4.66	3.67	4.44	4.19	4.32	4.52
5	3.61	3.34	4.46	4.94	4.31	6.10	5.74	5.58	4.59	3.57	4.89	4.31	4.40	4.60

Table 4a: Sensory Evaluation of fresh- cut chemically treated apple packs stored at 1˚C for 6 days; Mean (± SD) hedonic scale ratings

Sensory Parameter	Sample	Storage Time (Days)					
		1	2	3	4	5	6
Taste	Control	4.6±0.5	3.7±0.7	2.8±0.8	1.8±0.6	1.5±0.5	1±0
	CA (1%)	4±0.8	3±0.7	1.5±0.5	1.4±0.5	1.3±0.5	1±0
	CA (0.2%)	3.7±0.7	2.1±0.6	1.6±0.5	1.6±0.5	1.1±0.3	1±0
	AA (1%)	4±0.7	2.6±0.5	1.6±0.5	1.3±0.5	1±0	1±0
	AA (0.1%)	2.8±0.4	1.9±0.6	1.6±0.5	1.5±0.5	1±0	1±0
	$CaCl_2$ (1%)	4.3±0.5	3.4±0.5	2.3±0.5	1.6±0.5	1±0	1±0
	$CaCl_2$ (1.5%)	4.3±0.5	3.4±0.5	2.3±0.5	1.6±0.5	1±0	1±0
Color/ Appearance	Control	4.8±0.4	2.3±0.5	1.4±0.5	1±0	1±0	1±0
	CA (1%)	4.4±0.5	2.3±0.5	1±0	1±0	1±0	1±0
	CA (0.2%)	3.7±0.7	1.4±0.5	1.3±0.5	1±0	1±0	1±0
	AA (1%)	3.7±0.5	2.1±0.7	1.3±0.5	1.2±0.4	1±0	1±0
	AA (0.1%)	2.6±0.5	1.2±0.4	1.1±0.3	1±0	1±0	1±0
	$CaCl_2$ (1%)	4.6±0.5	3.9±0.7	2.6±0.5	1.6±0.5	1.3±0.5	1±0
	$CaCl_2$ (1.5%)	4.6±0.5	3.9±0.7	2.6±0.5	1.6±0.5	1.3±0.5	1±0
Texture	Control	4.6±0.5	3.6±0.7	2.4±0.5	1.8±0.4	1.6±0.5	1±0
	CA (1%)	4.4±0.5	1.5±0.5	1±0	1±0	1±0	1±0
	CA (0.2%)	3.5±0.5	2±0.7	1.5±0.5	1.2±0.4	1±0	1±0
	AA (1%)	3.6±0.5	2.3±0.8	1.4±0.5	1.3±0.5	1±0	1±0
	AA (0.1%)	2.7±0.5	1.5±0.5	1.3±0.5	1.2±0.4	1±0	1±0
	$CaCl_2$ (1%)	4.7±0.5	3.9±0.7	3.2±0.6	2.5±0.5	1.5±0.5	1±0
	$CaCl_2$ (1.5%)	4.7±0.5	3.9±0.7	3.2±0.6	2.5±0.5	1.7±0.5	1±0
Aroma	Control	4.6±0.5	4±0	1.9±0.6	1.5±0.5	1.2±0.4	1±0
	CA (1%)	4.3±0.5	2.7±0.5	1.9±0.7	1.8±0.6	1.4±0.5	1±0
	CA (0.2%)	3.5±0.5	2±0.5	1.7±0.5	1.4±0.5	1.4±0.5	1±0
	AA (1%)	4.2±0.6	2.2±0.6	2.2±0.4	1.6±0.8	1±0	1±0
	AA (0.1%)	2.9±0.3	2±0.7	1.7±0.7	1.4±0.5	1±0	1±0
	$CaCl_2$ (1%)	3.8±0.6	3.4±0.5	2.6±0.5	1.6±0.5	1±0	1±0
	$CaCl_2$ (1.5%)	3.8±0.6	3.4±0.5	2.6±0.5	1.6±0.5	1±0	1±0
Overall Acceptability	Control	4.5±0.5	2.7±0.7	1.3±0.5	1.4±0.5	1.2±0.4	1±0
	CA (1%)	4.2±0.4	2.3±0.5	1.3±0.5	1.2±0.4	1.2±0.4	1±0
	CA (0.2%)	3.3±0.5	2.3±0.5	1.7±0.5	1.2±0.4	1.1±0.3	1±0
	AA (1%)	4±0.7	2.5±0.5	1.9±0.6	1.3±0.5	1±0	1±0

	AA (0.1%)	2.8±0.4	1.7±0.5	1.4±0.5	1.2±0.4	1±0	1±0
	$CaCl_2$ (1%)	4.3±0.7	3.6±0.5	2.8±0.6	2.3±0.5	1.4±0.5	1±0
	$CaCl_2$ (1.5%)	4.3±0.7	3.6±0.5	2.8±0.6	2.3±0.5	1.6±0.5	1±0

Table 4b: Sensory Evaluation of fresh- cut chemically treated pineapple packs stored at 1C for 6 days; Mean (± SD) hedonic scale ratings

Sensory Parameter	Sample	Storage Time (Days)					
		1	2	3	4	5	6
Taste	Control	4.7±0.5	3.6±0.5	3.5±0.5	3.5±0.5	2.8±0.6	2.1±0.6
	CA (1%)	4.4±0.5	3.6±0.5	3.7±0.5	3.6±0.5	2.6±0.5	2.4±0.5
	CA (0.2%)	4.4±0.5	3.6±0.5	3.7±0.5	3.6±0.5	2.6±0.5	2.4±0.5
	AA (1%)	4.6±0.5	3.7±0.5	3.6±0.5	3.3±0.5	2.6±0.5	1.7±0.5
	AA (0.1%)	4.6±0.5	3.2±0.8	3.2±0.4	3.1±0.3	2.3±0.8	1.7±0.5
	$CaCl_2$ (1%)	4±0.7	3.5±0.5	3.1±0.3	2.9±0.3	2.2±0.6	1.5±0.5
	$CaCl_2$ (1.5%)	4±0.7	3.5±0.5	3.1±0.3	2.9±0.3	2.2±0.6	1.5±0.5
Color/ Appearance	Control	4.4±0.5	3.6±0.5	3.6±0.5	3.6±0.5	3.3±0.5	2.1±0.6
	CA (1%)	4.4±0.5	3.7±0.5	3.7±0.5	3.6±0.5	2.6±0.5	2.2±0.4
	CA (0.2%)	4.4±0.5	3.7±0.5	3.7±0.5	3.6±0.5	2.6±0.5	2.2±0.4
	AA (1%)	4.7±0.5	3.7±0.5	3.3±0.5	3.2±0.6	2.7±0.5	2.3±0.5
	AA (0.1%)	4.7±0.5	3±0.7	3.2±0.4	3.1±0.3	2.3±0.8	2.1±0.7
	$CaCl_2$ (1%)	4.4±0.5	3.6±0.5	3.6±0.5	3.6±0.5	2.2±0.8	1.7±0.5
	$CaCl_2$ (1.5%)	4.4±0.5	3.6±0.5	3.6±0.5	3.6±0.5	2.2±0.8	1.7±0.5
Texture	Control	4.5±0.5	3.6±0.5	3.6±0.5	3.6±0.5	2.6±0.5	1.9±0.6
	CA (1%)	4.4±0.5	3.6±0.5	3.6±0.5	3.5±0.5	2.3±0.5	2.2±0.4
	CA (0.2%)	4.4±0.5	3.6±0.5	3.6±0.5	3.5±0.5	2.3±0.5	2.2±0.4
	AA (1%)	4.3±0.5	3.5±0.5	3.3±0.5	3.3±0.5	2.5±0.5	1.7±0.5
	AA (0.1%)	4.3±0.5	3.1±0.7	3.2±0.4	3.1±0.3	2.5±0.5	1.5±0.5
	$CaCl_2$ (1%)	4.7±0.5	4.3±0.5	4.3±0.5	4.3±0.5	3.6±0.5	2.8±0.4
	$CaCl_2$ (1.5%)	4.7±0.5	4.3±0.5	4.3±0.5	4.3±0.5	3.6±0.5	2.8±0.4
Aroma	Control	4.4±0.5	3.6±0.5	3.5±0.5	3.5±0.5	2.7±0.5	1.7±0.5
	CA (1%)	4.4±0.5	3.6±0.5	3.7±0.5	3.6±0.5	2.7±0.5	2.3±0.5
	CA (0.2%)	4.4±0.5	3.6±0.5	3.7±0.5	3.6±0.5	2.7±0.5	2.3±0.5
	AA (1%)	4.3±0.5	3.6±0.5	3.3±0.5	3.1±0.5	2.4±0.5	1.9±0.6
	AA (0.1%)	4.3±0.5	3±0.7	3.2±0.4	3.1±0.3	2.1±0.7	1.9±0.6
	$CaCl_2$ (1%)	4.6±0.5	3.5±0.5	3±0	2.8±0.4	1.6±0.5	1.7±0.5
	$CaCl_2$ (1.5%)	4.6±0.5	3.5±0.5	3±0	2.8±0.4	1.6±0.5	1.7±0.5
Overall Acceptability	Control	4.6±0.5	3.6±0.5	3.5±0.5	3.5±0.5	2.7±0.5	2.2±0.4
	CA (1%)	4.4±0.5	3.7±0.5	3.7±0.5	3.6±0.5	2.8±0.4	2.2±0.4
	CA (0.2%)	4.4±0.5	3.7±0.5	3.7±0.5	3.6±0.5	2.8±0.4	2.2±0.4
	AA (1%)	4.7±0.5	3.6±0.5	3.3±0.5	3.3±0.5	2.7±0.5	1.9±0.6
	AA (0.1%)	4.7±0.5	3±0.7	3.2±0.4	3.1±0.3	2.4±0.8	1.7±0.7
	$CaCl_2$ (1%)	4.8±0.4	4±0.7	3.5±0.5	3.4±0.5	3.2±0.6	1.7±0.5
	$CaCl_2$ (1.5%)	4.8±0.4	4±0.7	3.5±0.5	3.4±0.5	3.2±0.6	1.7±0.5

observed in the CA and AA treated fruits. This gave an appearance of less juiciness in the fruits (Gonzalez- Aguilar GA, et al, 2004). The texture of the apples became soggy and translucent in the CA (1% and 0.2%) and AA (1% and 0.1%) treated packs. A softness was reported in the AA treated pineapples. The reduction in firmness loss by antibrowning agents could be related to the suppression of deteriorative processes and lowering of metabolism, which in turn prevents breakdown of tissue. Thus, some amount of texture loss in CA and AA treated samples could be due to enzymatic hydrolysis of cell wall components (Gonzalez- Aguilar GA, et al, 2004). On the other hand, the $CaCl_2$ (1% and 1.5%) treated apples retained their texture due to the interaction of calcium with the cell wall and middle lamella pectins leading to an increase in the firmness retention (Rico D,Martin-Diana AB, et al 2006, Luna- Guzman I, et al, 1999). The overall acceptability of the packs was “satisfactory” upto 2 days of storage for CA and AA treated apple packs. The calcium chloride treated fruit was satisfactory till 4th day of storage. In pineapple packs, the overall acceptability was 5 days and 6 days for AA and calcium chloride treated and CA treated fruits respectively (Table 4a and 4b).

Therefore, the most effective preservative for fresh- cut apple and pineapple stored at 1˚C for 6 days was calcium chloride (shelf- life: 4 days) and citric acid (shelf life: 5 days) respectively.

CONCLUSION

There is a need to emphasize on washing of fruits as an important step in the fresh- cut fruit industry in order to decrease the microbial load of raw fruits. Hurdle technology, like the use of chemical preservatives with cold storage, is effective in providing a reasonable shelf- life of fresh- cut fruits. Further need arises to test for other preservatives and the best packaging material to be investigated to improve the quality and shelf- life of fresh- cut fruits.

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