Quality of osmotically pre-treated and vacuum dried pineapple cubes on storage as influenced by type of solutes and packaging materials

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Abstract The quality and stability of osmotically pre-treated and subsequently vacuum dried pineapple cubes using three different solutes and packed in three different types of packaging materials on storage was evaluated. The experiment was laid out in completely randomized block design with two factors and three replications for each treatment. Treatment combinations were considered as one factor and storage interval as another factor. Pineapple cubes stored in glass bottle showed very little percentage variation in moisture content due to its high moisture barrier properties. In all treatment combination, acidity values were invariably found to increase as the storage progressed. For all three different osmotic treatments, HDPE pouch packet always showed highest acidity followed by PVDC pouch. Again among three solutes under consideration, invert sugar recorded a rapid increase in acidity than other solutes. In pineapple cubes osmotically treated with sucrose solution, the rates of decrease of total sugar content were lower than that of invert sugar and sorbitol treated pineapple cubes. The percentage decrease of total sugar content was highest when the osmotically dehydrated pineapple cubes were packed in HDPE pouch and it was least in glass bottles. There was a gradual decrease in ascorbic acid content with the extension of storage period and this decrease was statistically significant at all storage intervals up to six-month. Lowest value of ascorbic acid content (15.210 mg per 100 g initial solid) was recorded in invert sugar treated pineapple cube packed in HDPE pouch after 6 months of storage.

Keywords Invert sugar · Osmotic dehydration · Pineapple · Sorbitol · Storage · Sucrose

Introduction

Pineapple (*Ananas comosus* L.) is one of the most important commercial fruit crops of India. The fruit, due to its high juice content, pleasant taste, and flavour, has become one of the favourite fruit all over the world. Pineapple is a good source of vitamin A, B and fairly rich in vitamin C and minerals like calcium, magnesium, potassium and iron. The fruit is eaten as fresh and can also be canned and processed in different forms.

Osmotic dehydration can be described as partial dehydration of fruits and other biological materials through the process of osmosis, which involves immersing of samples for a given time period in hypertonic solution with water activity lower than that of the food stuff. During osmotic treatment several flows occur simultaneously: loss of water from the product to the hypertonic solution, solute impregnation from the solution to the food matrix and, additionally, loss of other compounds (mainly soluble solids) from the product to the solution (Chenlo et al. 2002). The process of osmotic dehydration removes up to 50 % of the initial weight of moisture in the food with minimal solid uptake (5–25 g per 100 g of fresh sample) from the solution (Li and Ramaswamy 2005). Osmotic dehydration of fruits and vegetables is a convenient method of improving the quality of a product since nutritional, organoleptic and physical aspects are preserved better than other dehydration methods (Raoult-Wack 1994). It is used as a pre-treatment to many processes and improves nutritional, sensorial and functional properties of food without changing its integrity (Torreggiani 1993). Further, the economics of the process was positive

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compared to other dehydration methods (Lazarides et al. 1997). Energy consumption and quality of dried products are critical parameters in the selection of drying process (Sagar and Suresh Kumar 2010) and as such osmotic dehydration is deemed as better option for drying fruits and vegetables.

Unlike conventional drying processes, osmotic dehydration does not produce a stable product and as such further steps like drying, freezing, pasteurization, canning and frying, or the addition of preservatives are needed (Nanjundaswamy et al. 1978). Therefore, storage stability of osmotically pre-treated products needs to be evaluated critically in order to ensure microbial safety of such products.

Storage of osmotically dehydrated apricot in polythene pouch, glass jars and laminated pouches were studied over 6 months at 13–28 °C and laminated pouch was found to be the best packaging material with a minimum change in chemical composition and sensory attributes (Sharma et al. 2000).

The storage of osmotically dehydrated guava (cv. Lucknow-49 and Hafsi) in sugar solution, salt solution, sugar-salt solution, spice solution were studied over a period of 6 months in 100 and 200 gauge bags and found that the percentage of absorbed moisture was increased at the end of 6 months. The highest absorption of moisture was observed in sugar solution treated sample packed in 200 gauge bags. Acidity content increased over a period of 6 months, but the differences were found to be very small. There was also an increase in reducing sugar during the storage period and it was highest in Lucknow-49 treated with salt and packed in 100 gauge bags. Both ascorbic acid content and pH values were decreased at the end of the 6-month storage period (Kannan and Thirumaran 2002).

Few literatures on osmotic dehydration kinetics of pineapple in different geometry are available but works on after-process quality for osmotically pre-treated and subsequently dehydrated pineapple product has not been sufficiently evaluated. In most osmotic dehydration studies, particularly on fruits, sucrose has been universally used as osmotic agent. The potentiality of invert sugar and sorbitol as osmotic agents has not been evaluated. Therefore, the present work was carried out to evaluate the stability of osmotically pre-treated and subsequently vacuum dried pineapple cubes using three different solutes and packed in three different types of packaging materials on storage.

Materials and methods

Raw material preparation

Pineapple (*Ananas comosus* L.) cv. Giant Kew fruits of commercial maturity were collected from the university orchard. The fruits, after receiving in the laboratory, were

crowned and washed thoroughly in running tap water and air-dried to remove the surface moisture. They were then manually peeled and cored. The prepared fruits were then cut in to cubes measuring $10 \pm 0.5 \text{ mm}^3$ using a sharp knife from the central portion of fruit. The cut surfaces of the cubes were blotted gently with a tissue paper to remove the surface moisture before the osmotic treatment.

Packaging materials

Three different types of packaging materials namely glass bottles (P_1), HDPE film of 25 μm (P_2) and PVDC film of 25 μm (P_3) thickness were used in the study. Packaging materials for this experiment were selected based on their water vapour transmission rates (WVTR) ($\text{g.m}^{-2}.\text{day}^{-1}$) measured across 25 μm thick film at 75 % relative humidity and 25 °C temperature (Mathlouthi 2003). The packaging materials were sanitized previously by dipping them in 1 % sodium hypochlorite solution for 5 min and dried. Dimension of the flexible packaging materials was $10 \times 10 \text{ cm}$ and 50 g of dried pineapple cubes were kept in each packet. Glass bottles of 150 ml internal volume were used for 50 g of dried pineapple cubes.

Osmotic treatment

Pineapple cubes were treated osmotically using previously optimized conditions for three different solutes namely sucrose (O_1), invert sugar (O_2) and sorbitol (O_3). Optimized conditions for sucrose (O_1) were 50 % (w/w) solute concentration, 200 min of process time and 32.15 °C process temperature; whereas, for invert sugar (O_2) these were 47.76 % (w/w) solute concentration, 158.28 min of process time and 30.0 °C process temperature; and for sorbitol (O_3) these were 35.40 % (w/w) solute concentration, 200 min of process time and 30.94 °C process temperature. These osmotically pre-treated pineapple cubes were then dried to reduce the moisture percentage and thereby water activity (a_w) in a vacuum oven at 60 °C and under vacuum, at a pressure of 50 mmHg for 12 h. Thereafter, these dried cubes were rapidly cooled by placing them in a vacuum desiccator and packed in designated packages.

Statistical analysis

The experiment was laid out in completely randomized block design with two factors and three replications for each treatment. Treatment combinations were considered as one factor and storage interval as another factor.

Treatment combinations

A total of nine treatments from combination of three different solutes and three different packaging materials were

obtained and evaluated in this storage study under ambient conditions of 28 ± 2 °C temperature and 70 ± 5 % RH. These were –

- T₁:** Osmotically pre-treated in sucrose solution (O_1) and packed in glass bottle (P_1);
- T₂:** Osmotically pre-treated in sucrose solution (O_1) and packed in HDPE pouch (P_2);
- T₃:** Osmotically pre-treated in sucrose solution (O_1) and packed in PVDC pouch (P_3);
- T₄:** Osmotically pre-treated in invert sugar solution (O_2) and packed in glass bottle (P_1);
- T₅:** Osmotically pre-treated in invert sugar solution (O_2) and packed in HDPE pouch (P_2);
- T₆:** Osmotically pre-treated in invert sugar solution (O_2) and packed in PVDC pouch (P_3);
- T₇:** Osmotically pre-treated in sorbitol solution (O_3) and packed in glass bottle (P_1);
- T₈:** Osmotically pre-treated in sorbitol solution (O_3) and packed in HDPE pouch (P_2) and
- T₉:** Osmotically pre-treated in sorbitol solution (O_3) and packed in PVDC pouch (P_3).

Analytical determination

Three packets under each treatment combination were intended for use in analytical determinations of various physico-chemical parameters like moisture, acidity, total sugar, ascorbic acid content at monthly interval over a storage period of 6 month.

Moisture content of the samples after each storage interval was determined gravimetrically using a vacuum oven for drying to constant weight at 60 °C (AOAC 1997). Three measurements were taken for each replication and the mean values were recorded. The moisture content was expressed as percentage of initial dry solid.

Acidity was determined by titration of the aqueous solution of the sample against 0.1 N NaOH using phenolphthalein as indicator (Ranganna 2001). The acidity was expressed as citric acid in percentage of initial dry solid. Mean values of three determinations were recorded.

Total sugar was determined quantitatively by Waters® high performance liquid chromatography (HPLC) system (Waters Corporation, Milford, MA, USA) in isocratic conditions. Waters® Carbohydrate Analysis column (3.9 × 300 mm) and Waters® 2414 Refractive index detector was used. Acetonitrile and water in the ratio of 75:25 (v/v) was used as mobile phase. Both acetonitrile and water used were of HPLC grade. Mobile phase was delivered by Waters® 515 HPLC pump and controlled by a Waters® Pump

Control module II, with a flow rate of 1.0 ml/min. Data acquisition, integration and processing were performed by using Empower Pro 2 software. Mean values of three determinations were recorded and was expressed as g per 100 g of initial dry solid.

Ascorbic acid content of freshly prepared dried samples and the samples after different storage interval were estimated by visual titration method based on reduction of 2, 6-dichlorophenol indophenol by ascorbic acid (Ranganna 2001). Mean values of three determinations were recorded and was expressed as mg per 100 g of initial dry solid.

Results and discussion

Initial dry solid content after osmotic pre-treatment and subsequent vacuum drying was found to be 43.39, 47.76 and 41.07 g/100 g sample for sucrose, invert sugar and sorbitol solution system, respectively.

Moisture content

Initial moisture content and moisture content at specific storage intervals for nine different treatment combinations have been presented in Table 1.

Experimental data revealed that the moisture content in all the treatments were increased during entire storage duration and were found statistically significant. The effect of storage duration on moisture content values was also found to be statistically significant at 95 % confidence level. Moisture content was increased from 130.47 to 133.61 g per 100 g initial dry solids (2.41 % increases over initial moisture content) after six-month storage for sucrose treated pineapple cubes packed in glass bottles. This increment was 2.20 % for both invert sugar (from 109.38 to 111.79 g per 100 g initial dry solids) and sorbitol (from 143.48 to 146.64 g per 100 g initial dry solids) treated samples stored in glass bottles for 6 month. Increases in moisture content from 130.47 to 149.22 (14.37 % over initial values), from 109.38 to 127.15 (16.25 % over initial values) and from 143.48 to 161.42 g per 100 g initial dry solids (12.50 % over initial values) were recorded for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively, when stored in HDPE pouch for 6 month. These increments in PVDC pouch were from 130.47 to 136.85 (4.89 % over initial values), from 109.38 to 115.57 (5.66 % over initial values) and from 143.48 to 148.68 g per 100 g initial dry solids (3.62 % over initial values) after six-month storage for pineapple cubes treated with sucrose, invert sugar and sorbitol, respectively.

Table 1 Moisture content (g/100 g initial solids) of the osmotically dehydrated pineapple cube during storage

Treatments	Storage (28±2 °C) period, months						
	0 (Initial)	1 (S ₁)	2 (S ₂)	3 (S ₃)	4 (S ₄)	5 (S ₅)	6 (S ₆)
T ₁ (O ₁ × P ₁)	130.47	131.4±0.48	132.1±0.67	132.5±0.81	133.0±0.46	133.3±0.40	133.6±0.25
T ₂ (O ₁ × P ₂)	130.47	138.1±0.48	140.5±0.16	142.7±0.45	144.7±0.38	146.4±0.13	149.2±0.21
T ₃ (O ₁ × P ₃)	130.47	133.1±1.30	133.6±1.22	135.1±0.54	135.9±0.51	136.4±0.34	136.8±0.44
T ₄ (O ₂ × P ₁)	109.38	110.1±0.24	110.5±0.17	111.0±0.15	111.1±0.44	111.3±0.27	111.8±0.32
T ₅ (O ₂ × P ₂)	109.38	113.7±0.88	116.8±1.44	119.6±0.33	122.2±0.22	125.1±0.32	127.2±0.17
T ₆ (O ₂ × P ₃)	109.38	112.3±1.00	113.0±0.17	113.8±0.47	114.5±0.21	115.2±0.12	115.6±0.11
T ₇ (O ₃ × P ₁)	143.48	144.3±0.56	144.9±0.38	145.6±0.32	146.0±0.14	146.3±0.28	146.6±0.30
T ₈ (O ₃ × P ₂)	143.48	147.2±0.22	151.8±0.49	155.2±0.33	157.9±0.60	159.3±0.21	161.4±0.20
T ₉ (O ₃ × P ₃)	143.48	145.5±0.18	146.0±0.68	146.6±0.25	147.1±0.19	148.0±0.15	148.7±0.31
CD _{0.05}		T=0.328		S=0.268		TxS = 0.804	

Each observation is a Mean ± SD (*n*=3)

All dried pineapple cubes treated with invert sugar always recorded minimum moisture percentage because solid content was higher due to its lower molecular weight as compared to other solutes. Pineapple cubes stored in glass bottle showed very little percentage variation in moisture content due to its high moisture barrier properties. The pineapple cubes stored in HDPE pouch recorded a high rate of moisture absorption due to its high moisture transmission rate compared to other packaging materials under consideration. Sra et al. (2011) also reported an increase in moisture content of dried carrot slices on storage.

Acidity

Initial acidity and acidity after different storage interval for different treatment combination are presented in Table 2. Initial acidity value was highest (1.345 %, dry basis) among

treatments that were osmotically treated with sorbitol solution and it was lowest (1.045 %, dry basis) among treatments that were osmotically treated with invert sugar solution. The treatments in which, the pineapple cubes were subjected to osmosis in sucrose solution was recorded initial acidity value of 1.236 % (dry basis). In all treatment combination, acidity values were invariably found to increase as the storage progressed. All of the treatment combinations and storage intervals had recorded statistically significant effect on acidity. Among treatments with sucrose solution, highest percentage increase in acidity value (8.09 %) was recorded in pineapple cubes packed in HDPE pouch after six-month storage followed by the pineapple cubes packed in PVDC pouch (T₃) (5.99 %) and glass bottles (T₁) (3.88 %). Among treatments with invert sugar solution, pineapple cubes packed in HDPE pouch recorded highest percentage increase in acidity value (11.77 %) after six-

Table 2 Acidity (g/100 g initial solids) of the osmotically dehydrated pineapple cube during storage

Treatments	Storage (28±2 °C) period, months						
	0 (Initial)	1 (S ₁)	2 (S ₂)	3 (S ₃)	4 (S ₄)	5 (S ₅)	6 (S ₆)
T ₁ (O ₁ × P ₁)	1.236	1.25±0.009	1.27±0.012	1.27±0.007	1.28±0.009	1.28±0.012	1.28±0.006
T ₂ (O ₁ × P ₂)	1.236	1.27±0.012	1.29±0.003	1.30±0.006	1.31±0.009	1.33±0.012	1.34±0.009
T ₃ (O ₁ × P ₃)	1.236	1.25±0.018	1.27±0.012	1.28±0.015	1.29±0.012	1.30±0.003	1.31±0.009
T ₄ (O ₂ × P ₁)	1.045	1.06±0.006	1.07±0.006	1.07±0.006	1.08±0.011	1.09±0.003	1.11±0.006
T ₅ (O ₂ × P ₂)	1.045	1.06±0.011	1.09±0.008	1.10±0.008	1.13±0.006	1.15±0.003	1.17±0.006
T ₆ (O ₂ × P ₃)	1.045	1.06±0.003	1.07±0.008	1.09±0.010	1.11±0.011	1.12±0.008	1.14±0.006
T ₇ (O ₃ × P ₁)	1.345	1.36±0.004	1.37±0.007	1.40±0.016	1.41±0.006	1.43±0.006	1.45±0.009
T ₈ (O ₃ × P ₂)	1.345	1.36±0.013	1.39±0.019	1.42±0.009	1.44±0.016	1.47±0.016	1.48±0.016
T ₉ (O ₃ × P ₃)	1.345	1.36±0.004	1.38±0.007	1.40±0.004	1.41±0.007	1.43±0.007	1.45±0.011
CD _{0.05}		T=0.006		S=0.005		TxS = 0.016	

Each observation is a Mean ± SD (*n*=3)

month storage followed by PVDC pouch (9.09 %) and glass bottles (6.51 %). Among treatments with sorbitol solution, highest percentage increase in acidity value (10.33 %) was observed in pineapple cubes packed in HDPE pouch after six-month storage followed by the pineapple cubes packed in glass bottles (T_7) (8.03 %) and PVDC pouch (T_9) (7.88 %).

For all three different osmotic treatments, HDPE pouch always showed highest acidity followed by PVDC pouch. This may be due to higher moisture transmission rate of HDPE compared to other packaging materials used which enabled the pineapple cube to absorb more moisture. And at higher moisture level, the molecular mobility of reactant, particularly sugar molecules increased (Reid and Fennema 2008) and these sugar molecules were readily oxidised to organic acids which increased the acidity. Again among three solutes under consideration, invert sugar recorded a rapid increase in acidity than other solutes. Invert sugar having lower molecular size was mobilized more readily than other solutes and this accounted for faster rate of acidity development. An increase in acidity over a period of 6 month storage of osmotically dehydrated guava in 100 and 200 gauge bags was reported by Kannan and Thirumaran (2002).

Total sugar content

The values of total sugar content at initial stage and at different storage intervals for different treatments have been presented in Table 3. The initial values of total sugar of 97.25, 97.60 and 97.17 g/100 g of initial dry solid were recorded for osmotically dehydrated pineapple cubes treated with sucrose, invert sugar and sorbitol, respectively.

A gradual decrease in total sugar content of osmotically dehydrated pineapple cubes was noticed over the six-month

storage period and the total sugar content was found to be significantly affected by the different storage intervals during six-month storage period. Among the different treatments, T_1 was found to be significantly better in retaining total sugar and recorded highest level of total sugar (83.03 g/100 g initial solids) whereas T_8 was found to have lowest level of total sugar (70.16 g/100 g initial solids) at the end of six-month storage period. ' T_3 and T_4 '; ' T_2 and T_7 '; ' T_5 and T_9 ' were found to be statistically at par in total sugar level after six-month of storage.

Percentage decreases in total sugar content over the initial values after six-month storage in HDPE pouch were 20.86 (from 97.25 to 76.96 g/100 g initial solids), 23.79 (from 97.60 to 74.38 g/100 g initial solids) and 27.80 (from 97.17 to 70.16 g/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively. Whereas, these percentage reduction values were 14.62 (from 97.25 to 83.03 g/100 g initial solids), 17.79 (from 97.60 to 80.23 g/100 g initial solids) and 21.42 (from 97.17 to 76.36 g/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively, when packed in glass bottles. In PVDC pouch, the percentage reduction of total sugar content over the initial values after six-month storage was 17.02 (from 97.25 to 80.70 g/100 g initial solids), 20.38 (from 97.60 to 77.71 g/100 g initial solids) and 24.94 (from 97.17 to 72.94 g/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively.

It was found that the percentage decrease was highest when the osmotically dehydrated pineapple cubes were packed in HDPE pouch and it was least in glass bottles. In pineapple cubes osmotically treated with sucrose solution, the rates of decrease were lower than that of invert sugar and sorbitol treated pineapple cubes. Rates of decrease in total sugar content were highest in sorbitol treated pineapple

Table 3 Total Sugar content (g/100 g initial solids) of the osmotically dehydrated pineapple cube during storage

Treatments	Storage (28±2 °C) period, months						
	0 (Initial)	1 (S_1)	2 (S_2)	3 (S_3)	4 (S_4)	5 (S_5)	6 (S_6)
T_1 ($O_1 \times P_1$)	97.25	93.8±0.62	91.7±0.63	88.2±1.01	85.9±0.67	84.5±0.46	83.0±0.35
T_2 ($O_1 \times P_2$)	97.25	92.6±0.59	87.8±0.75	83.9±0.68	80.9±0.73	78.5±1.01	77.0±0.94
T_3 ($O_1 \times P_3$)	97.25	93.8±0.54	90.7±0.32	87.7±0.38	85.6±0.43	82.8±0.67	80.7±0.51
T_4 ($O_2 \times P_1$)	97.60	94.8±0.39	90.9±0.46	87.8±0.35	85.2±0.66	82.2±0.25	80.2±0.87
T_5 ($O_2 \times P_2$)	97.60	91.0±0.74	86.6±0.43	82.0±0.54	78.5±0.48	75.8±0.73	74.4±0.85
T_6 ($O_2 \times P_3$)	97.60	92.9±0.19	88.2±0.23	85.6±0.49	83.0±0.10	80.4±0.53	77.7±0.59
T_7 ($O_3 \times P_1$)	97.17	91.5±1.11	88.5±0.53	84.2±0.63	80.4±0.22	77.3±0.04	76.4±0.81
T_8 ($O_3 \times P_2$)	97.17	89.9±0.63	84.0±1.06	78.7±0.59	75.6±0.35	72.6±0.38	70.2±0.18
T_9 ($O_3 \times P_3$)	97.17	91.9±0.77	86.6±0.75	81.9±0.35	78.7±0.29	75.8±0.35	72.9±0.44
CD _{0.05}		$T=0.397$		$S=0.325$		$T \times S = 0.974$	

Each observation is a Mean ± SD ($n=3$)

cubes. This decrease in total sugar content might be associated with increased moisture content which increased the mobility of sugar molecules within the pineapple tissue and helped them being utilized in Maillard reaction and other degradative reactions.

Ascorbic acid content

Table 4 indicated the values of ascorbic acid content at initial stage and at different storage intervals for different treatments. Initial values of ascorbic acid content were 69.14, 42.84 and 78.36 mg/100 g initial solid for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively.

There was a gradual decrease in ascorbic acid content with the extension of storage period and this decrease was statistically significant at all storage interval up to six-month. The ascorbic acid content in various treatment combinations was also found to vary significantly at 95 % confidence level. Lowest value of ascorbic acid content (15.210 mg/100 g initial solid) was recorded in invert sugar treated pineapple cube packed in HDPE pouch after 6 months of storage. Whereas, highest values for ascorbic acid (67.361 mg/100 g initial solid) after six-month storage was recorded in sorbitol treated pineapple cube packed in glass bottles. Percentage decrease over initial values in ascorbic acid content of pineapple cubes packed in HDPE pouch after six-month storage were 38.20 (from 69.136 to 42.729 mg/100 g initial solids), 64.49 (from 42.838 to 15.210 mg/100 g initial solids) and 23.22 (from 78.355 to 60.159 mg/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively. These values in glass bottles were 26.08 % (from 69.136 to 51.104 mg/100 g initial solids), 47.32 % (from 42.838 to 22.565 mg/100 g initial solids) and 14.03 % (from 78.355 to 67.361 mg/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively. These

percentage decrease values were 32.89 (from 69.136 to 46.400 mg/100 g initial solids), 52.19 (from 42.838 to 20.479 mg/100 g initial solids) and 16.08 (from 78.355 to 65.755 mg/100 g initial solids) for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively, when stored in PVDC pouch.

Therefore, it was observed that the glass bottles were better packaging material in preventing ascorbic acid degradation in storage while, HDPE pouch was least effective in preventing ascorbic acid degradation in storage. Among the solutes, highest degradation was obtained when pineapple cubes were treated in invert sugar, while highest retention was obtained with treatment in sorbitol solution. Progressive loss of ascorbic acid with storage duration might be due to increase in water activity (a_w). The rate of oxidation of ascorbic acid in low moisture food systems was found to increase progressively with water activity (a_w) and was thought to be associated with increased availability of water to act as solvent for reactants and catalysts (Dennison and Kirk 1978). Presence of fructose (ketoses) might have increased the rate of anaerobic degradation of ascorbic acid (Gregory 2008), which accounts for rapid loss of ascorbic acid in fructose treated pineapple cube. Sucrose had a similar effect at low pH because of pH-dependant generation of fructose from sucrose, which was manifested by relatively higher rates of ascorbic acid degradation in sucrose than sorbitol treated pineapple cubes. Significantly low degradation rates in sorbitol treated pineapple cube was due to the fact that sorbitol being a sugar alcohols exerted a protective effect against the oxidative degradation of ascorbic acid, possibly by binding metal ions and reducing their catalytic potency (Gregory 2008). A decrease in ascorbic acid content at the end of 6 month storage of osmotically treated guava packed in 100 and 200 gauge bags was also reported by Kannan and Thirumaran (2002). A gradual reduction in

Table 4 Ascorbic acid content (mg/100 g initial solids) of the osmotically dehydrated pineapple cube during storage

Treatments	Storage (28±2 °C) period, months						
	0 (Initial)	1 (S ₁)	2 (S ₂)	3 (S ₃)	4 (S ₄)	5 (S ₅)	6 (S ₆)
T ₁ (O ₁ × P ₁)	69.14	66.2±0.79	62.0±1.38	57.7±1.70	55.0±1.54	52.8±1.43	51.1±1.65
T ₂ (O ₁ × P ₂)	69.14	61.7±0.60	56.0±1.31	51.7±1.18	47.4±0.95	44.9±0.55	42.7±1.19
T ₃ (O ₁ × P ₃)	69.14	64.1±0.49	60.1±0.83	55.2±0.88	51.2±0.87	48.8±0.99	46.4±1.09
T ₄ (O ₂ × P ₁)	42.84	39.0±0.41	35.7±0.48	31.5±1.39	27.6±1.12	25.0±0.90	22.6±1.05
T ₅ (O ₂ × P ₂)	42.84	36.1±0.83	31.0±1.26	25.7±2.13	21.5±1.08	18.2±0.24	15.2±1.03
T ₆ (O ₂ × P ₃)	42.84	37.2±0.39	33.3±0.56	29.5±0.71	26.4±0.79	23.0±0.70	20.5±0.76
T ₇ (O ₃ × P ₁)	78.36	76.6±0.31	74.5±1.65	71.9±0.99	69.7±0.85	68.4±0.44	67.4±0.89
T ₈ (O ₃ × P ₂)	78.36	74.5±0.44	70.5±0.45	67.6±0.41	64.6±0.59	62.0±0.45	60.2±0.21
T ₉ (O ₃ × P ₃)	78.36	76.3±0.17	73.5±0.36	70.1±0.55	68.8±1.15	67.3±0.24	65.8±0.39
CD _{0.05}		T=0.624		S=0.510		TxS = 1.532	

Each observation is a Mean ± SD (n=3)

ascorbic acid content in dried carrot slices during six-month storage was also reported by Sra et al. 2011.

Conclusion

Moisture content of the osmotically dehydrated pineapple cubes was found to increase in all treatments. Pineapple cubes packed in glass bottles were found to absorb less moisture as compared to other packaging materials. Increases in moisture content were 14.37, 16.25 and 12.50 % over initial values for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively, when stored in HDPE pouch for 6 month. These values in glass bottle were found to be 2.41, 2.20 and 2.20 % for pineapple cubes treated with sucrose, invert sugar and sorbitol, respectively. Among all treatments, highest percentage increase in acidity over a period of 6 month was observed in invert sugar treated pineapple cubes kept in HDPE pouch (11.77 %) and lowest percentage increase in acidity was recorded in sucrose treated pineapple cubes kept in glass bottles (3.88 %). Percentage decrease in total sugar content over initial value after six-month storage in HDPE pouch was 20.86, 23.79 and 27.80 for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively. Whereas, these values for glass bottles were 14.62, 17.79 and 21.42 % for sucrose, invert sugar and sorbitol treated pineapple cubes, respectively. Lowest value of ascorbic acid content (15.210 mg/100 g initial solid) was recorded in invert sugar treated pineapple cubes packed in HDPE pouch after 6 months of storage, whereas, it was highest (67.361 mg/100 g initial solid) for sorbitol treated pineapple cubes packed in glass bottles. Glass bottles were found to be the best packaging materials for storing osmotically dehydrated pineapple cubes up to 6 month. Glass bottles were closely followed by 25 μ m thick Polyvinylidene chloride (PVDC) pouch.

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