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# Preservation of pineapple (*Ananas comosus* L.) slices by hurdle technology

**Manjunath Totad, Doreyappagowda IN, Suresh GJ, Vasudev KR, Sreenivas KN, Shivashankar KS, Venugopalan R and Ranjitha K**

## Abstract
Hurdle processed pineapple slices stored at low temperature storage condition were better compared to samples stored at ambient temperature. Results showed that the highest overall acceptability sensory score and maximum total sugar content was observed in samples stored under low temperature storage condition, specifically Queen variety samples, treatment combination of blanched slices, 60°B syrup, Citric acid 0.50 per cent, Calcium Chloride 0.50 per cent, Sodium Benzoate 150 ppm followed by blanched slices, 60°B syrup, Citric acid 0.50 per cent, Calcium Chloride 0.50 per cent, KMS 350 ppm after six months of storage, in contrast to lower score in the samples stored at ambient temperature. Whereas titrable acidity, ascorbic acid, water activity and Non enzymatic browning index were recorded more in treatment combination of blanched slices, 60°B syrup, Citric acid 0.50 per cent, Calcium Chloride 0.50 per cent, KMS 350 ppm after six months of storage.

**Keywords:** $^{0}$Brix, overall acceptability, sugars, hurdle technology and pineapple

## Introduction
Pineapple (*Ananas comosus* L.) belongs to family Bromeliaceae and originated in South America. Pineapple is one of the most important fruit crops of India. Fresh cut pineapple fruits are more perishable than the unprocessed form because of higher susceptibility to microbial spoilage, increased respiration rate and ethylene production, which leads to enzymatic browning, texture decay, rapid microbial growth, weight loss and undesirable volatile production, reducing the shelf life of the product (Corbo *et al.*, 2009) [4].

Pineapple marketing may become a problem because of the highly perishable nature. Further, during glut periods, surplus as well as scarred fruits which consist of high sugar and better edible flesh need to be utilized for processing into value added products using suitable technology. Hurdle processing technology is one of the important means to decrease the energy demand of food preservation and also improves the safety of preserved foods especially in developing country like India.

Thus, considering the fast increasing area under pineapple cultivation, simple preservation and processing technology needs to be developed in order to prevent huge post-harvest losses and regulate prices during glut period and thereby protecting the interest of the growers. However, there are not many popular commercial products and by-products of pineapple in the market. Hence, there is a need to develop a low cost technology for processing pineapple fruits into value added products, which have ready acceptability in the market. Therefore, the present investigation is undertaken with the following objectives:

1) To standardize the techniques for the preservation of pineapple slices using hurdle technology. 2) To study the physico-chemical changes and interaction effects of hurdle treatments, varieties and storage condition on the stability and quality of the product. 3) To assess the sensory quality, shelf life of the products.

## Material and Methods
The present investigation on, "Preservation of Pineapple fruit slices by Hurdle Technology," was conducted during 2016-2018 for 2 seasons. The experiment was conducted at the Product Development Laboratory of Division of Postharvest Technology and Agricultural Engineering, ICAR-Indian Institute of Horticultural Research, Hesaraghatta, Bengaluru-Karnataka-India during the year 2016-2018.

Queen and Kew varieties of pineapple fruits were procured from farmer's field near Bangalore. Fresh pineapple fruits with uniform size and shape, free from injuries, bruises, insect damages and diseases were selected for making the hurdle processed pineapple slices. Uniformly matured (70-80%), good colored and shape, pineapple fruits were selected, washed, weighed, hand peeled with knife. Core was removed by core remover and individual eyes were also removed with scissor. Then fruit is cut in to uniform slices of about 1cm thick. Prepared pineapple slices of 1.0 kg each were dipped in 60°B sugar syrup having different preservatives or additives in the ratio of 1:2 (fruit : syrup) in different treatments and allowed for osmosis for 4h at ambient temperature (25-30°C). After taking samples for analysis, known weight of osmosed slices, of pineapple slices were spread thinly on stainless steel trays which were kept in a cabinet tray drier for the removal of surface moisture and to reduce water activity.

Pineapple slices were dried at 55-60°C temperature till the slices reached the desired moisture level and product quality. The time required for drying the product to optimum moisture was recorded in different treatments. Then the product was processed in boiling water for 25 minutes, cooled immediately and stored at room temperature. Using 'Erma-hand refractometer' total soluble solids content was recorded, titrable acidity and total sugars, no enzymatic browning index (NEBI) were estimated by using Ranganna (1977) and Somogyi (1945) method, water activity by digital probe humidity meter respectively. Organoleptic evaluation of the product was done by a panel of 10 Judges by numerical scoring (100 points) method (Amerine, 1965) and finally observed data were analyzed using Factorial Completely Randomized Design (FCRD) statistical design.

**Experimental details**
**Treatments**

| | |
|---|---|
| $T_1$ | Control - Freshly prepared slices without Osmosis |
| $T_2$ | Steeping for 4h in 60°B sugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 % |
| $T_3$ | Steeping for 4h in 60°B sugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 %+KMS 350 ppm |
| $T_4$ | Steeping for 4h in 60°Bsugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 % + Sodium Benzoate 150 ppm |
| $T_5$ | Blanching for 15 min (steam) + Steeping for 4h in 60°B sugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 % |
| $T_6$ | Blanching for 15 min (steam) + Steeping for 4h in 60°B sugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 %+ KMS 350 ppm |
| $T_7$ | Blanching for 15 min (steam) + Steeping for 4h in 60°B sugar syrup + Citric Acid 0.50%+ $CaCl_2$ 0.50 %+ Sodium Benzoate 150 ppm |

**Results and Discussion**

Present results are pooled mean analysis of 2016-17 and 2017-18 seasons. The results of the changes in chemical composition of hurdle processed pineapple slices as follows.

Titrable acidity content was gradually declined during storage and among the treatments at the end of storage period $T_6$ (steam blanching + steeping in 60°B sugar syrup + citric Acid 0.50% + $CaCl_2$ 0.50%+ KMS 350ppm) and $T_7$ (steam blanching + steeping in 60°B sugar syrup + citric Acid 0.50% + $CaCl_2$ 0.50% + sodium benzoate 150ppm) managed retention of acidity and influenced product to safe storage (as shown in Table-1). Similar results were observed by Rashmi *et al.* (2005) [9] in pineapple, Silveira *et al.* (1996) [15] for osmo-air dehydration of in osmo dehydration of sapota. Hurdle processed pineapple slices (Michael, 2012) [7].

Ascorbic acid gradually declined during storage and maximum ascorbic acid was observed in $T_1$ in Queen at ambient temperature (25.66 mg/100g) at initial stage, whereas, minimum ascorbic acid noticed in $T_6$ in Kew at low temperature (16.83mg/100g) at six months of storage. This phenomenon mainly due to thermal degradation during processing and subsequent oxidation and light reaction were the other possible causes of reduction in ascorbic acid content (Brockmann *et al.*, 1998) [2], Surabhi *et al.* (2007) [17] in osmo-dehydrated pineapple slices, Ayub *et al.* (1995) [1] in IMF guava slices (as shown in Table-2).

A little variation in $a_w$ in all the samples was recorded and $a_w$ varied from 0.685 to 0.305. $T_6$ (steam blanching + steeping in 60°B sugar syrup + citric Acid 0.50% + $CaCl_2$ 0.50%+ KMS 350ppm) and $T_7$ (steam blanching + steeping in 60°B sugar syrup + citric Acid 0.50% + $CaCl_2$ 0.50%+ sodium benzoate 150ppm) treatments are balanced and retains $a_w$ 0.648 and 0.627 respectively, at the end of storage period (as shown in Table-3). It might be due to effect of osmotic dehydration in all the treatments which might have reduced the$a_w$ (Valencia *et al.*, 2011) [20]. The similar findings from Silva *et al.* (2014) [14] in pineapple, Saleem *et al.* (1997) [12] and Tapia *et al.* (1996) [18] have also reported the effect of water activity on stability of processed products.

Total sugars increased with the increasing storage period irrespective of treatments throughout the storage period in both seasons. The highest total sugar was noticed in $T_7$ (Blanching + 60°B syrup+ Citric acid 0.50% +$CaCl_2$ 0.50%+ SB 150ppm) i.e.(66.64%) under low temperature storage condition in Queen variety (as shown in Table-4). It could be attributed to the acid hydrolysis of polysaccharides which resulted in increase in soluble sugars content. Similar trend was also seen in osmo-dehydrated and hurdle processed ripe pineapple slices by Michael, (2012) [7], Rao and Roy (1980b) [10].in mango pulp dehydration, Mehta *et al*. (1982) in dehydration of pineapple, Tomar *et al*. (1990) [19] in osmotic dehydration of pear.

During the whole storage period there was increasing trend in non-enzymatic browning. It was highest in slices were stored in ambient (0.222) condition compare to low temperature (0.184) condition at the end of storage period. Similar results were obtained by Chauhan *et al.* (1997) [3] in mango-soy fruit bar, Sujatha *et al.* (2014) [16] in osmotically dried pineapple (Table-5).

Sensory score for overall acceptability value ranged from 71.28 to 77.76 at initial stage which were at par each other. In general all the sensory score values at initial stage rated good to very good. But, during subsequent storage period there was reduction in overall sensory score irrespective of the treatments. However, best score for overall acceptability was recorded in low temperature storage, with maximum score 71.22 in treatment $T_7$ (Blanching + 60°B syrup+ Citric acid 0.50% + $CaCl_2$ 0.50%+ SB 150ppm) of Queen under low temperature up to six months of storage (as shown in table-6). Similar findings have been reported by Rashmi *et al.* (2005) [9] in pineapple, Shobana (2003) [13] in banana, Jose *et al.* (2008) [5] in mango slices.

**Conclusion:** It is concluded from the current studies that different storage conditions have profound effect on quality of hurdle processed pineapple slices. Samples stored under low temperature conditions were able to maintain the better quality till the end of storage period. Varietal differences were also noticed as Queen variety yielded better products in comparison to Kew.

**Table 1:** Effect of treatment, storage conditions, varieties and their interaction on the titrable acidity (%) of hurdle processed pineapple slices. (Pooled mean analysis)

| **INITIAL STORAGE** | | | | | | | | | | | **3 MONTHS OF STORAGE** | | | | | | | | | | **6 MONTHS OF STORAGE** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 0.590 | 0.558 | 0.575 | 0.573 | 0.592 | 0.587 | 0.557 | 0.558 | 0.574 | $T_1$ | - | - | - | - | - | - | - | - | - | $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | 0.903 | 0.894 | 0.852 | 0.945 | 0.847 | 0.958 | 0.857 | 0.931 | 0.898 | $T_2$ | - | - | - | - | - | - | - | - | - | $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 0.913 | 0.923 | 0.899 | 0.937 | 0.885 | 0.941 | 0.912 | 0.933 | 0.918 | $T_3$ | 0.849 | 0.716 | 0.844 | 0.721 | 0.831 | 0.867 | 0.857 | 0.575 | 0.783 | $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | 0.905 | 0.826 | 0.786 | 0.946 | 0.870 | 0.940 | 0.701 | 0.951 | 0.866 | $T_4$ | 0.863 | 0.701 | 0.824 | 0.740 | 0.833 | 0.894 | 0.815 | 0.586 | 0.782 | $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | 0.926 | 0.916 | 0.885 | 0.957 | 0.902 | 0.950 | 0.868 | 0.963 | 0.921 | $T_5$ | - | 0.698 | 0.404 | 0.294 | - | - | 0.808 | 0.588 | 0.349 | $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 0.932 | 0.891 | 0.877 | 0.946 | 0.904 | 0.959 | 0.849 | 0.934 | 0.912 | $T_6$ | 0.852 | 0.698 | 0.838 | 0.712 | 0.852 | 0.852 | 0.824 | 0.571 | 0.775 | $T_6$ | 0.679 | 0.700 | 0.671 | 0.708 | 0.638 | 0.719 | 0.703 | 0.697 | 0.689 |
| $T_7$ | 0.933 | 0.901 | 0.881 | 0.953 | 0.914 | 0.951 | 0.847 | 0.954 | 0.917 | $T_7$ | 0.854 | 0.688 | 0.827 | 0.715 | 0.853 | 0.854 | 0.800 | 0.576 | 0.771 | $T_7$ | 0.671 | 0.691 | 0.641 | 0.722 | 0.604 | 0.739 | 0.678 | 0.705 | 0.681 |
| M | 0.872 | 0.844 | 0.822 | 0.894 | 0.845 | 0.898 | 0.799 | 0.889 | | M | 0.488 | 0.500 | 0.534 | 0.455 | 0.481 | 0.495 | 0.586 | 0.414 | | M | 0.193 | 0.199 | 0.187 | 0.204 | 0.177 | 0.208 | 0.197 | 0.200 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.009 | 0.025 | T | * | 0.005 | 0.013 | T | * | 0.002 | 0.006 |
| S | * | 0.005 | 0.014 | S | * | 0.002 | 0.007 | S | * | 0.001 | 0.003 |
| V | * | 0.005 | 0.014 | V | * | 0.002 | 0.007 | V | * | 0.001 | 0.003 |
| T × S | * | 0.007 | 0.019 | T × S | * | 0.003 | 0.01 | T × S | * | 0.001 | 0.004 |
| T × V | * | 0.013 | 0.036 | T × V | * | 0.007 | 0.019 | T × V | * | 0.003 | 0.008 |
| S × V | * | 0.013 | 0.036 | S × V | * | 0.007 | 0.019 | S × V | * | 0.003 | 0.008 |
| T × S × V | * | 0.018 | 0.051 | T × S × V | * | 0.009 | 0.026 | T × S × V | * | 0.004 | 0.012 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+Cacl$_2$0.50%, $T_3$-osmosis+ CA0.50%+Cacl$_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+Cacl$_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+Cacl$_2$0.50%, $T_6$-osmosis+CA0.50%+Cacl$_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+Cacl$_2$ 0.50%,+SB 150ppm

**Table 2:** Effect of treatment, storage conditions, varieties and their interaction on the ascorbic acid (mg/100gm) of hurdle processed pineapple slices (Pooled mean analysis)

| **INITIAL STORAGE** | | | | | | | | | | **3 MONTHS OF STORAGE** | | | | | | | | | | **6 MONTHS OF STORAGE** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 24.35 | 22.56 | 24.62 | 22.28 | 25.66 | 23.04 | 23.59 | 21.52 | 23.45 | $T_1$ | - | - | - | - | - | - | - | - | - | $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | 23.77 | 22.37 | 23.53 | 22.61 | 23.92 | 23.61 | 23.13 | 21.61 | 23.07 | $T_2$ | - | - | - | - | - | - | - | - | - | $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 23.33 | 22.85 | 24.02 | 22.16 | 25.07 | 21.59 | 22.96 | 22.73 | 23.09 | $T_3$ | 21.41 | 20.52 | 21.65 | 20.29 | 22.97 | 19.86 | 20.34 | 20.71 | 20.97 | $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | 24.84 | 23.19 | 24.38 | 23.65 | 24.87 | 24.81 | 23.89 | 22.49 | 24.01 | $T_4$ | 22.32 | 20.27 | 21.46 | 21.13 | 22.51 | 22.13 | 20.41 | 20.13 | 21.29 | $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | 24.47 | 23.10 | 24.58 | 22.98 | 25.12 | 23.81 | 24.04 | 22.15 | 23.78 | $T_5$ | - | 20.59 | 10.43 | 10.16 | - | - | 20.87 | 20.32 | 10.30 | $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 24.29 | 22.83 | 24.46 | 22.66 | 25.14 | 23.44 | 23.78 | 21.89 | 23.56 | $T_6$ | 22.03 | 20.36 | 21.64 | 20.75 | 22.40 | 21.66 | 20.88 | 19.83 | 21.19 | $T_6$ | 19.33 | 17.79 | 19.55 | 17.58 | 20.35 | 18.32 | 18.76 | 16.83 | 18.56 |
| $T_7$ | 24.26 | 22.77 | 24.34 | 22.69 | 24.90 | 23.63 | 23.79 | 21.75 | 23.51 | $T_7$ | 22.43 | 20.36 | 21.91 | 20.87 | 23.10 | 21.75 | 20.73 | 20.00 | 21.39 | $T_7$ | 19.02 | 17.36 | 18.59 | 17.79 | 19.49 | 18.54 | 17.68 | 17.04 | 18.19 |
| M | 24.19 | 22.81 | 24.28 | 22.72 | 24.95 | 23.42 | 23.60 | 22.02 | | M | 12.60 | 14.59 | 13.87 | 13.31 | 13.00 | 12.20 | 14.75 | 14.43 | | M | 5.48 | 5.02 | 5.45 | 5.05 | 5.69 | 5.27 | 5.20 | 4.84 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.24 | 0.69 | T | * | 0.12 | 0.33 | T | * | 0.05 | 0.15 |
| S | * | 0.13 | 0.37 | S | * | 0.06 | 0.18 | S | * | 0.03 | 0.08 |
| V | * | 0.13 | 0.37 | V | * | 0.06 | 0.18 | V | * | 0.03 | 0.08 |
| T × S | N.S | - | - | T × S | * | 0.09 | 0.25 | T × S | * | 0.04 | 0.12 |
| T × V | N.S | - | - | T × V | * | 0.16 | 0.47 | T × V | * | 0.08 | 0.22 |
| S × V | * | 0.34 | 0.97 | S × V | * | 0.16 | 0.47 | S × V | * | 0.08 | 0.22 |
| T × S × V | * | 0.48 | 1.37 | T × S × V | * | 0.23 | 0.66 | T × S × V | * | 0.11 | 0.31 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+Cacl$_2$0.50%, $T_3$-osmosis+ CA0.50%+Cacl$_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+Cacl$_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+Cacl$_2$0.50%, $T_6$-osmosis+CA0.50%+Cacl$_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+Cacl$_2$ 0.50%,+SB 150ppm

**Table 3:** Effect of treatment, storage conditions, varities and their interaction on the water activity ($a_w$) of hurdle processed pineapple slices (Pooled mean analysis)

| INITIAL STORAGE | | | | | | | | | | 3 MONTHS OF STORAGE | | | | | | | | | | 6 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 0.678 | 0.652 | 0.663 | 0.667 | 0.682 | 0.675 | 0.645 | 0.660 | 0.665 | $T_1$ | - | - | - | - | - | - | - | - | - | $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | 0.601 | 0.666 | 0.674 | 0.593 | 0.678 | 0.523 | 0.669 | 0.662 | 0.633 | $T_2$ | - | - | - | - | - | - | - | - | - | $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 0.650 | 0.654 | 0.649 | 0.654 | 0.645 | 0.655 | 0.654 | 0.654 | 0.652 | $T_3$ | 0.664 | 0.550 | 0.666 | 0.549 | 0.669 | 0.659 | 0.662 | 0.500 | 0.615 | $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | 0.637 | 0.653 | 0.650 | 0.640 | 0.638 | 0.635 | 0.661 | 0.645 | 0.645 | $T_4$ | 0.647 | 0.551 | 0.656 | 0.542 | 0.647 | 0.648 | 0.666 | 0.570 | 0.616 | $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | 0.609 | 0.683 | 0.702 | 0.591 | 0.705 | 0.512 | 0.698 | 0.669 | 0.646 | $T_5$ | - | 0.580 | 0.348 | 0.231 | - | - | 0.697 | 0.580 | 0.305 | $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 0.684 | 0.683 | 0.692 | 0.675 | 0.699 | 0.669 | 0.686 | 0.681 | 0.684 | $T_6$ | 0.650 | 0.660 | 0.640 | 0.660 | 0.702 | 0.699 | 0.680 | 0.690 | 0.673 | $T_6$ | 0.695 | 0.577 | 0.696 | 0.600 | 0.670 | 0.691 | 0.692 | 0.560 | 0.648 |
| $T_7$ | 0.691 | 0.680 | 0.686 | 0.684 | 0.690 | 0.691 | 0.682 | 0.678 | 0.685 | $T_7$ | 0.631 | 0.683 | 0.636 | 0.678 | 0.568 | 0.693 | 0.703 | 0.664 | 0.657 | $T_7$ | 0.651 | 0.573 | 0.690 | 0.590 | 0.640 | 0.606 | 0.685 | 0.580 | 0.627 |
| M | 0.650 | 0.667 | 0.674 | 0.643 | 0.677 | 0.623 | 0.671 | 0.664 | | M | 0.370 | 0.432 | 0.421 | 0.380 | 0.369 | 0.386 | 0.487 | 0.429 | | M | 0.192 | 0.164 | 0.198 | 0.170 | 0.187 | 0.185 | 0.197 | 0.163 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.007 | 0.019 | T | * | 0.004 | 0.011 | T | * | 0.002 | 0.006 |
| S | * | 0.003 | 0.010 | S | * | 0.002 | 0.006 | S | * | 0.001 | 0.003 |
| V | * | 0.003 | 0.010 | V | * | 0.002 | 0.006 | V | * | 0.001 | 0.003 |
| T × S | * | 0.005 | 0.014 | T × S | * | 0.003 | 0.008 | T × S | * | 0.001 | 0.004 |
| T × V | * | 0.009 | 0.027 | T × V | * | 0.005 | 0.015 | T × V | * | 0.003 | 0.008 |
| S × V | * | 0.009 | 0.027 | S × V | * | 0.005 | 0.015 | S × V | * | 0.003 | 0.008 |
| T × S × V | * | 0.013 | 0.038 | T × S × V | * | 0.008 | 0.022 | T × S × V | * | 0.004 | 0.011 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_3$-osmosis+ CA0.50%+$Cacl_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+$Cacl_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_6$-osmosis+CA0.50%+$Cacl_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+$Cacl_2$ 0.50%,+SB 150ppm

**Table 4:** Effect of treatment, storage conditions, varities and their interaction on the total sugar (%) of hurdle processed pineapple slices. (Pooled mean analysis)

| INITIAL STORAGE | | | | | | | | | | 3 MONTHS OF STORAGE | | | | | | | | | | 6 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** | | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 29.61 | 30.11 | 30.25 | 29.46 | 29.92 | 29.29 | 30.58 | 29.63 | 29.86 | $T_1$ | - | - | - | - | - | - | - | - | - | $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | 58.61 | 60.07 | 60.96 | 57.72 | 61.07 | 56.15 | 60.85 | 59.28 | 59.34 | $T_2$ | - | - | - | - | - | - | - | - | - | $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 57.46 | 59.88 | 60.27 | 57.07 | 60.38 | 54.54 | 60.16 | 59.60 | 58.67 | $T_3$ | 59.95 | 58.69 | 61.22 | 57.42 | 61.00 | 58.89 | 61.43 | 55.95 | 59.32 | $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | 54.72 | 59.24 | 59.80 | 54.16 | 60.32 | 49.12 | 59.29 | 59.19 | 56.98 | $T_4$ | 57.21 | 58.59 | 61.01 | 54.80 | 60.74 | 53.68 | 61.27 | 55.91 | 57.90 | $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | 59.75 | 60.85 | 60.98 | 59.62 | 60.97 | 58.53 | 61.00 | 60.71 | 60.30 | $T_5$ | - | 59.04 | 31.24 | 27.80 | - | - | 62.48 | 59.20 | 29.97 | $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 59.75 | 61.14 | 60.89 | 60.00 | 60.51 | 58.99 | 61.27 | 61.01 | 60.45 | $T_6$ | 60.25 | 58.47 | 60.87 | 57.84 | 60.49 | 62.01 | 61.25 | 65.68 | 60.86 | $T_6$ | 61.30 | 65.22 | 62.82 | 63.70 | 59.60 | 62.99 | 66.03 | 64.41 | 63.26 |
| $T_7$ | 59.68 | 60.17 | 60.78 | 59.06 | 60.96 | 58.40 | 60.61 | 59.72 | 59.92 | $T_7$ | 60.45 | 58.22 | 61.20 | 57.47 | 61.29 | 59.60 | 61.11 | 62.63 | 60.25 | $T_7$ | 63.09 | 65.55 | 65.14 | 63.50 | 63.64 | 62.55 | 66.64 | 64.45 | 64.32 |
| M | 54.22 | 55.92 | 56.28 | 53.87 | 56.30 | 52.15 | 56.25 | 55.59 | | M | 33.98 | 41.86 | 39.36 | 36.48 | 34.79 | 33.45 | 43.94 | 42.77 | | M | 17.77 | 18.68 | 18.28 | 18.17 | 17.61 | 17.93 | 18.95 | 18.41 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.60 | 1.71 | T | * | 0.34 | 0.96 | T | * | 0.19 | 0.53 |
| S | * | 0.32 | 0.92 | S | * | 0.18 | 0.52 | S | N.S | - | 0.29 |
| V | * | 0.32 | 0.92 | V | * | 0.18 | 0.52 | V | * | 0.10 | 0.28 |
| T × S | * | 0.45 | 1.30 | T × S | * | 0.25 | 0.73 | T × S | * | 0.14 | 0.40 |
| T × V | * | 0.85 | 2.42 | T × V | * | 0.48 | 1.36 | T × V | * | 0.26 | 0.76 |
| S × V | * | 0.85 | 2.42 | S × V | * | 0.48 | 1.36 | S × V | * | 0.26 | 0.76 |
| T × S × V | * | 1.20 | 3.43 | T × S × V | * | 0.67 | 1.93 | T × S × V | * | 0.37 | 1.07 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_3$-osmosis+ CA0.50%+$Cacl_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+$Cacl_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_6$-osmosis+CA0.50%+$Cacl_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+$Cacl_2$ 0.50%,+SB 150ppm

**Table 5:** Effect of treatment, storage conditions, varities and their interaction on the non-enzymatic browning index (O.D value) of hurdle processed pineapple slices. (Pooled mean analysis)

| INITIAL STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 0.109 | 0.114 | 0.124 | 0.099 | 0.119 | 0.099 | 0.128 | 0.099 | 0.111 |
| $T_2$ | 0.124 | 0.138 | 0.145 | 0.117 | 0.138 | 0.110 | 0.152 | 0.124 | 0.131 |
| $T_3$ | 0.126 | 0.141 | 0.155 | 0.112 | 0.147 | 0.104 | 0.162 | 0.119 | 0.133 |
| $T_4$ | 0.132 | 0.141 | 0.162 | 0.112 | 0.157 | 0.107 | 0.166 | 0.116 | 0.136 |
| $T_5$ | 0.083 | 0.088 | 0.081 | 0.089 | 0.076 | 0.088 | 0.086 | 0.089 | 0.085 |
| $T_6$ | 0.085 | 0.094 | 0.093 | 0.086 | 0.086 | 0.085 | 0.100 | 0.088 | 0.089 |
| $T_7$ | 0.085 | 0.094 | 0.098 | 0.081 | 0.090 | 0.080 | 0.106 | 0.082 | 0.089 |
| M | 0.106 | 0.116 | 0.122 | 0.099 | 0.116 | 0.096 | 0.128 | 0.102 | |

| 3 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 0.164 | 0.185 | 0.189 | 0.160 | 0.182 | 0.146 | 0.196 | 0.175 | 0.174 |
| $T_4$ | 0.173 | 0.186 | 0.201 | 0.158 | 0.201 | 0.145 | 0.201 | 0.171 | 0.179 |
| $T_5$ | - | 0.141 | 0.072 | 0.071 | - | - | 0.141 | 0.141 | 0.071 |
| $T_6$ | 0.139 | 0.127 | 0.143 | 0.124 | 0.146 | 0.132 | 0.140 | 0.115 | 0.133 |
| $T_7$ | 0.125 | 0.130 | 0.141 | 0.114 | 0.132 | 0.118 | 0.149 | 0.111 | 0.127 |
| M | 0.086 | 0.110 | 0.106 | 0.089 | 0.094 | 0.077 | 0.118 | 0.102 | |

| 6 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 0.220 | 0.194 | 0.215 | 0.198 | 0.224 | 0.215 | 0.207 | 0.181 | 0.207 |
| $T_7$ | 0.214 | 0.184 | 0.205 | 0.192 | 0.216 | 0.211 | 0.194 | 0.174 | 0.199 |
| M | 0.062 | 0.054 | 0.060 | 0.056 | 0.063 | 0.061 | 0.057 | 0.051 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.0014 | 0.0040 | T | * | 0.0010 | 0.0030 | T | * | 0.0007 | 0.0020 |
| S | * | 0.0007 | 0.0020 | S | * | 0.0007 | 0.0020 | S | * | 0.0003 | 0.0010 |
| V | * | 0.0007 | 0.0020 | V | * | 0.0007 | 0.0020 | V | * | 0.0003 | 0.0010 |
| T × S | * | 0.0010 | 0.0030 | T × S | * | 0.0007 | 0.0020 | T × S | * | 0.0003 | 0.0010 |
| T × V | * | 0.0017 | 0.0050 | T × V | N.S | - | - | T × V | * | 0.0007 | 0.0020 |
| S × V | * | 0.0017 | 0.0050 | S × V | * | 0.0014 | 0.0040 | S × V | * | 0.0007 | 0.0020 |
| T × S × V | * | 0.0024 | 0.0070 | T × S × V | * | 0.0021 | 0.0060 | T × S × V | * | 0.0010 | 0.0030 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_3$-osmosis+ CA0.50%+$Cacl_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+$Cacl_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_6$-osmosis+CA0.50%+$Cacl_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+$Cacl_2$ 0.50%,+SB 150ppm

**Table 6:** Effect of treatment, storage conditions, varities and their interaction on thesensory quality overall acceptability (100) of hurdle processed pineapple slices (Pooled mean analysis)

| INITIAL STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | 71.17 | 74.17 | 73.38 | 71.95 | 71.87 | 70.47 | 74.90 | 73.43 | 72.67 |
| $T_2$ | 69.78 | 72.78 | 70.40 | 72.16 | 68.89 | 70.67 | 71.91 | 73.64 | 71.28 |
| $T_3$ | 76.26 | 79.25 | 78.59 | 76.92 | 77.08 | 75.44 | 80.10 | 78.40 | 77.76 |
| $T_4$ | 71.21 | 78.14 | 76.48 | 72.87 | 74.97 | 67.45 | 77.99 | 78.29 | 74.67 |
| $T_5$ | 65.69 | 76.83 | 72.81 | 69.71 | 69.51 | 61.88 | 76.11 | 77.54 | 71.26 |
| $T_6$ | 73.75 | 76.74 | 74.52 | 75.97 | 73.01 | 74.49 | 76.03 | 77.46 | 75.25 |
| $T_7$ | 72.33 | 75.33 | 73.09 | 74.57 | 71.58 | 73.09 | 74.60 | 76.06 | 73.83 |
| M | 71.46 | 76.18 | 74.18 | 73.45 | 72.41 | 70.50 | 75.95 | 76.40 | |

| 3 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | 70.36 | 73.03 | 72.23 | 71.17 | 70.73 | 70.00 | 73.72 | 72.34 | 71.70 |
| $T_4$ | 63.43 | 69.91 | 69.63 | 63.72 | 69.23 | 57.64 | 70.02 | 69.80 | 66.67 |
| $T_5$ | - | 70.78 | 35.49 | 35.29 | - | - | 70.98 | 70.58 | 35.39 |
| $T_6$ | 70.25 | 73.16 | 71.50 | 71.91 | 70.06 | 70.45 | 72.94 | 73.38 | 71.71 |
| $T_7$ | 69.25 | 70.51 | 69.32 | 70.44 | 68.82 | 69.69 | 69.83 | 71.19 | 69.88 |
| M | 39.04 | 51.06 | 45.45 | 44.65 | 39.83 | 38.25 | 51.07 | 51.04 | |

| 6 MONTHS OF STORAGE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Trt** | **$S_1$** | **$S_2$** | **$V_1$** | **$V_2$** | **$S_1V_1$** | **$S_1V_2$** | **$S_2V_1$** | **$S_2V_2$** | **M** |
| $T_1$ | - | - | - | - | - | - | - | - | - |
| $T_2$ | - | - | - | - | - | - | - | - | - |
| $T_3$ | - | - | - | - | - | - | - | - | - |
| $T_4$ | - | - | - | - | - | - | - | - | - |
| $T_5$ | - | - | - | - | - | - | - | - | - |
| $T_6$ | 66.62 | 65.59 | 75.35 | 65.64 | 65.53 | 64.33 | 66.21 | 65.76 | 66.88 |
| $T_7$ | 62.94 | 69.28 | 64.51 | 64.71 | 63.80 | 62.08 | 71.22 | 67.34 | 65.74 |
| M | 18.51 | 19.27 | 19.98 | 18.62 | 18.48 | 18.06 | 19.63 | 19.01 | |

| | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % | | F Test | S Em± | CD 1 % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T | * | 0.81 | 2.32 | T | * | 0.49 | 1.39 | T | * | 0.20 | 0.57 |
| S | N.S | - | - | S | * | 0.26 | 0.74 | S | * | 0.11 | 0.30 |
| V | * | 0.43 | 1.24 | V | * | 0.26 | 0.74 | V | * | 0.11 | 0.30 |
| T × S | * | 0.61 | 1.76 | T × S | * | 0.37 | 1.05 | T × S | * | 0.15 | 0.43 |
| T × V | * | 1.15 | 3.28 | T × V | * | 0.69 | 1.97 | T × V | * | 0.28 | 0.80 |
| S × V | * | 1.15 | 3.28 | S × V | * | 0.69 | 1.97 | S × V | * | 0.28 | 0.80 |
| T × S × V | * | 1.62 | 4.64 | T × S × V | * | 0.97 | 2.78 | T × S × V | * | 0.40 | 1.14 |

M-Mean, -Spoiled, $V_1$-Queen, $V_2$-Kew, $S_1$-Ambient temperature, $S_2$-Low temperature, $T_1$- Slices without osmosis, $T_2$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_3$-osmosis+ CA0.50%+$Cacl_2$0.50%+KMS350ppm, $T_4$-smosis+CA0.50%+$Cacl_2$0.50%+SB150ppm, $T_5$-osmosis+CA0.50%+$Cacl_2$0.50%, $T_6$-osmosis+CA0.50%+$Cacl_2$ 0.50%,+KMS 350ppm, $T_7$-osmosis+ CA0.50%+$Cacl_2$ 0.50%,+SB 150ppm

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