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Changes in physicochemical properties of pineapple at different ripening stages during storage

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Abstract: The effects of variety and ripening stage on physicochemical changes and quality of pineapple were studied. A completely randomized design with three replications was laid out for this experiment. Fruits of Giant Kew and Honey Queen variety were tested at three ripening stages viz., Stage I (25% yellow) Stage II (50% yellow) and Stage III (75% yellow). Ripening stages significantly influenced most of the parameters studied. Among the physicochemical parameters, color, firmness, total weight loss, dry matter content and Total Soluble Solids (TSS) contents significantly increased, whereas moisture and vitamin C content decreased during storage. Reducing sugar, non-reducing sugar and total sugar increased at 6th days of storage but decreased at 9th days of storage period. The longest shelf life (13 days) was observed in the Honey Queen variety under Stage I and the shortest shelf life (8.50 days) was observed in Stage III of Giant Kew variety. Ripening stage III of Honey Queen contained the highest (18.74%) amount of total sugar followed by Stage III of Giant Kew (17.82%). TSSs were higher in Honey Queen than Giant Kew. TSS content in fruits at 9th day of storage was maximum (18.85%) under Stage III and minimum (16.55%) in Stage I.
Key words: Physicochemical parameters, Variety, Ripening stage, Storage.

Introduction

Pineapple (*Ananas comosus* L. Merr.) belongs to the family Bromeliaceae and is one of the most important commercial fruits of the world. Pineapple is one of the major commercial and popular fruits in Bangladesh because of its distinct flavor, pleasant aroma, delicious taste, nutritional and medicinal values (Mondal, 2000). The main varieties that grow better in Bangladesh are Honey Queen, Giant Kew, and Ghorashal.

Pineapple is cultivated under tropical climate. The quality of pineapple largely depends on its sugar and acid content, while the amount of sugar depends on the ripeness of the fruit, also on the variety, soil condition and climatic condition. Pineapple is a good source of carotene and ascorbic acid and is rich in vitamins B and B2 (Lal and Pruthi, 1995). Pineapple contains moisture 85%, sugar 13%, protein 0.6%, acid 6%, vitamin C 8.76 mg/100g (Sen et al., 1980). It is also a source of bromelin, a digestive enzyme (Lodh *et al*., 1973). Various food items such as squash, syrup, jelly etc. are prepared from pineapple. Vinegar, alcohol, citric acid, calcium citrate etc. are also produced from it. Pineapple is also recommended as medical diet for certain diseased persons (Moniruzzaman, 1988). The diversified uses of pineapple have led to develop many fruit processing industries in all over the world. Unexpectedly, Bangladesh is lagging far behind of developing such industries.

Fresh pineapple is quite perishable. It bruises easily in spite of its seemingly armored exterior and ferments if kept at room temperature for too long. Storing at room temperature increases the acidity level of the pineapple, but would not improve sweetness (Hassan, 2010). Consumers judge fruit quality by skin colour and aroma. Fruits do not continue to ripen or sweeten after harvest. Fully-ripe, yellow fruits are unsuitable for transporting to distant markets, so slightly less mature fruits are selected for this purpose (Akamine, 1963; Cancel, 1974). Also immature fruits should not be shipped, since they do not develop good flavor, have low brix, and are more prone to chilling injury (Rohrbach and Paull, 1982).

Pineapple fruits, harvested at different maturity stages, are not of uniform quality, and they show significant variations in the shelf life and physico-chemical changes during storages (Ahmed and Bora, 1989). It is found that In Bangladesh due to substandard post-harvest handling, storage, improper transport and marketing, inadequate processing and preservation facilities, a large portion of harvested fruit is sold at a price less than the production cost. Therefore, the need to reduce post-harvest losses of the fruit is of permanent importance.

As a non-climacteric fruit, no further quality improvement is therefore expected from pineapple after harvesting. Therefore, harvesting at the correct stage of maturity is essential. In India, Chanda *et al*. (1998) reported that the stage of harvesting in pineapple is very important. Gortner *et al.* (1967) stated that the period of fruit development covers the stages of pre-maturation and maturation, the latter of which includes ripening. Primarily chemical changes take place during ripening period. Wyman and Palmer (1964) defined the stage of ripening based on amount of CO_2 production and they also showed a relationship of these stages with skin colour. Mookerji *et al.* (1969) found harvesting at 137 days after flowering as optimum in Thrissur (Kerala) for canning purposes. Studies on optimal harvest maturity of Kew pineapple in North Bengal have shown that fruits harvested between 115 and 130 days after flowering were better suited for Canning (Bose, 1985).

There are some research works done on the storage process and about the quality of the fruit. Bartolome *et al.* (1995) concluded that freezing of pineapple fruit slice led to minimal chemical changes after one year of frozen storage. Reinhardt *et al.* (2003) found significant differences when analyzed between two different varieties of pineapples where two stages of maturation (up to 15% of surface yellow or more than 40% of surface yellow) were used and analyzed for pH, total soluble solids, total titrable acidity and vitamin C content. Researchers are now trying different postharvest treatments to reduce postharvest losses and to extend shelf life and to control diseases of fruits. However, very little information has been gathered so far. Acquiring data on the physicochemical properties of different pineapple varieties at different ripening stages can help in the storage process and maintain the quality of the product reaching to the customers.

Materials and Methods

The experiment was conducted in the laboratories of the Department of Horticulture and the Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh during the period from April to May 2015. A total of 90 unblemished, similar fruits of more or less uniform size and shape representing three stages of maturity were harvested manually from plant of varieties Giant Kew and Honey Queen. The stages were Stage I (25% yellow) Stage II (50% yellow) Stage III (75% yellow). The experiment was laid out in a completely randomized design (CRD) with three replications of five fruits per replication. The data were collected at 0, 3, 6 and 9 days after storing. The maximum and minimum ambient temperatures of the storage room were 32°C and 25.6°C, respectively with a relative humidity (R.H.) range of 74 to 98%. Different physical parameters studied were colour, firmness, moisture content, dry matter content, weight loss and shelf life. The chemical parameters studied were total soluble solids (TSS), (% brix), reducing sugar, non-reducing sugar, total sugar and vitamin C contents of pulp. For chemical analysis fruit pulps were extracted and stored in frozen condition (-20°C).

Days required to reach different stages of colour during storage and ripening were determined objectively using numerical rating scale of 3-7, where, 3 = one-quarter-yellow (< 25%), 4 = two-quarter fruit skin yellow (<50%), 5 = three quarter yellow (<75%), 6 = fully yellow (75-100%), and 7 = blackened/rotten (fully yellow & black) (Hassan, 2006). Days required to reach different stages of ripening in relation to firmness were determined objectively using numerical rating scale of 1-5, where 1 = hard and green, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe and 5 = over ripe. Similar rating scale was used by Hassan (2006).

Vitamin C content was determined following 2,6-dichlorophenol-Indophenol Visual Titration method (Ranganna, 1994). Total Soluble Solid (TSS) content of each stage (three stages) of pineapple fruit pulp was estimated using Abbe's refractometer. Total sugar content of pineapple pulp was determined colorimetrically by the method Jayaraman (1981). Extraction of sugar from pineapple pulp was done by following the method of Loomis and Shull (1937).vReducing sugar content of the pulp was determined according to the method of Miller (1972). The data obtained from the experiment on various parameters were statistically analyzed in MSTAT computer program. The significance of difference between pair of means was tested by the least significant difference (LSD) test at 5% and 1% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

The objective of the experiment was to study the quality of fruits during storage. There were significant effects of pineapple variety and ripening stages in relation to postharvest quality of pineapple.

Changes in fruit colour: Colour change of the pineapple varied significantly with the pineapple varieties during storage. The fruits of Honey Queen showed greater (6.32) colour change than the fruits Giant Kew (6.00) at the 9th day of storage. The colour scores increased with the duration of storage (Table 1). During storage period, the colour of pineapple changes from green to yellow. The change of peel colour involved chlorophyll degradation or qualitative and quantitative of green pigments into other pigments (Salvador, 2007). The change in colour of Honey Queen Fruits was faster than Giant Kew fruits during storage.

Changes in the firmness of fruits: Firmness of pineapple varied significantly with the pineapple varieties during storage (Fig 1A). Giant Kew fruits showed slighter (4.58) increase in firmness than Honey Queen fruits (4.88) at the 9th day of storage. In general, the firmness of fruits also decreased with longer storage showing higher scores for increase in softness. V_1S_1 (Giant Kew x stage I) fruits showed lower (4.00) change in firmness among all other combinations at the 10th days of storage. Changes of firmness in Giant Kew fruits was slower than Honey Queen Fruits. Stage III (S_3) fruits were softer with highest score (5.25) compared to Stage I (S_1) fruits with lowest score (4.25) at the 10th days of storage. In combined effect Honey Queen Fruits under Stage III were softest with score (5.50) while Giant Kew fruits under Stage I were with relative firmness (4.00) (Table 1).

Table 1. Combined effect of variety and ripening stage on changes in fruit colour and firmness of pineapple cv. Giant Kew and Honey Queen

Treatment combination	Changes in fruit colour at different days after storage (DAS)				Fruit firmness at different DAS			
	0	3	6	9	0	3	6	9
V_1S_1	1.50	2.65	3.33	3.67	1.50	2.65	3.33	3.67
V_1S_2	1.83	3.25	3.67	4.35	1.83	3.25	3.67	4.35
V_1S_3	3.00	4.00	4.33	4.65	3.00	4.00	4.33	4.65
V_2S_1	2.10	3.17	3.50	4.00	2.10	3.17	3.50	4.00
V_2S_2	2.50	3.30	3.75	4.40	2.50	3.30	3.75	4.40
V_2S_3	3.33	4.33	4.67	5.00	3.33	4.33	4.67	5.00
$LSD_{0.05}$	0.097	0.138	0.126	0.159	0.097	0.138	0.126	0.159
$LSD_{0.01}$	0.138	0.195	0.178	0.226	0.138	0.195	0.178	0.226

V_1 = Giant Kew, V_2 = Honey Queen, S_1 =25% yellow, S_2 = 50% yellow and S_3 =75% yellow. Colour scale: 3 = one-quarter yellow (< 25%), 4 = two-quarter fruit skin yellow (<50%), 5 = three-quarter yellow (<75%), 6 = fully yellow (75-100%) and 7 = blackened/ rotten. Firmness scale: 1 = hard and green, 2 = sprung, 3 = between sprung and eating ripe, 4 = eating ripe and 5 = over ripe.

Total weight loss: Total weight loss in Giant Kew variety was always higher than that in Honey Queen during entire period of storage (Fig 1 C and D). At the 6th day of storage, the total weight loss in Giant Kew fruit was 7.02% that risen to 10.87% at 9th day, whereas the total weight loss in Honey Queen fruit was 6.73% at 6th day that risen to 9.97% at 9th day of storage. The weight loss in Giant Kew fruit was relatively higher probably because of higher rate of dehydration and also higher water content of fruit than Honey Queen. The Giant Kew variety had higher total weight loss than Honey Queen. At the 9th day of storage, total weight loss in Giant Kew variety and Honey Queen were 10.87% and 9.97%, respectively (Table 2).

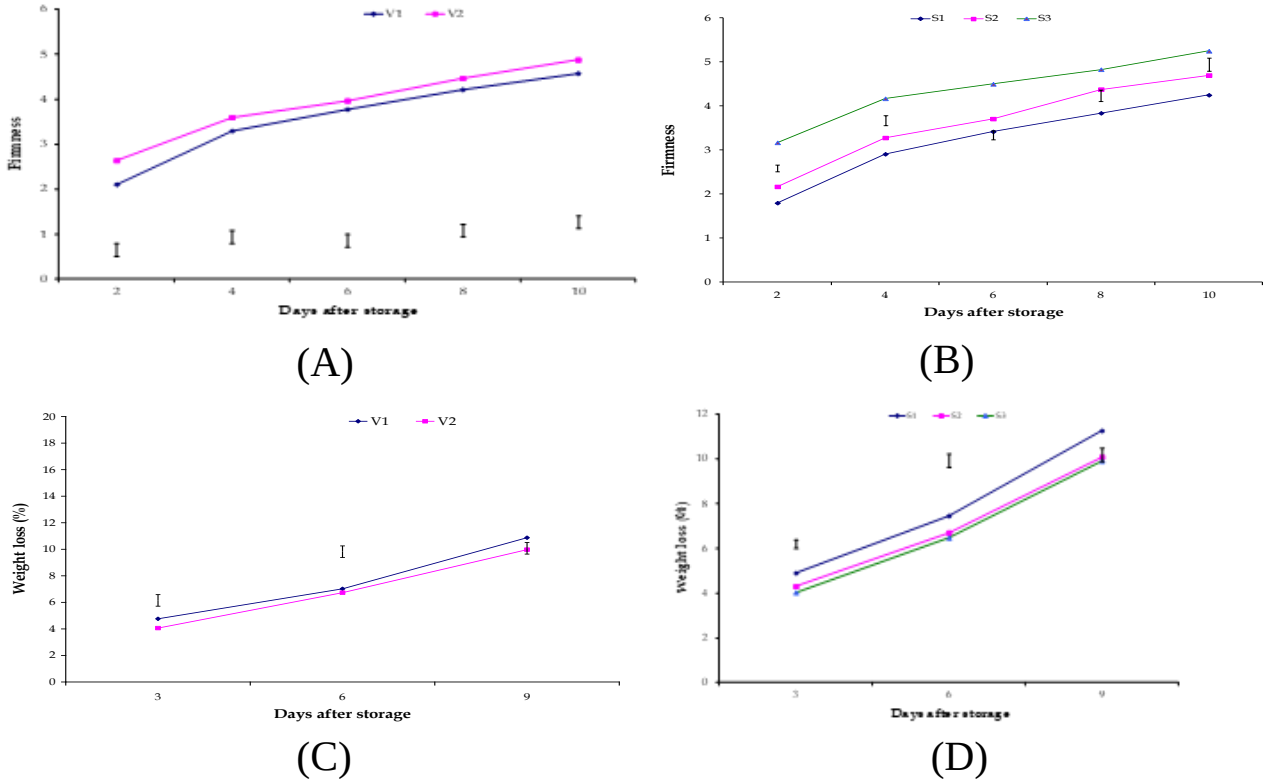

Figure 1 (A - D). Main effect of variety and ripening stage on the changes in firmness **(A and B)** and percent weight loss **(C and D)** in pineapple during storage. The vertical bars indicate LSD at 1% level of significance (V_1=Giant Kew variety, V_2=Honey Queen variety).

Moisture content: The combined effect of pineapple varieties and ripening stages in respect of moisture content was found to be significant. The maximum (78.26%) and minimum (73.52%) moisture contents were observed in V_2S_1 (Honey Queen × Stage I) and V_1S_2 (Giant Kew × Stage II) treatment combinations at the 9th day of storage (Table 2). The changes of moisture content and dry matter content are one of the important indicators for maintaining the quality of fruits. Moisture content and dry matter were significantly influenced by varieties and ripening stages. Moisture content decreased with the increase in storage period.

Table 2. Combined effect of variety and ripening stage on percent weight loss, percent moisture content and dry matter contents of pineapple cv. Giant Kew and Honey Queen

Treatment combination	Percent weight loss at different DAS				Percent moisture content at different DAS				Percent dry content of at different DAS			
	0	3	6	9	0	3	6	9	0	3	6	9
V_1S_1	-	5.52	7.86	11.75	81.30	78.65	76.42	75.15	19.70	22.35	23.58	24.85
V_1S_2	-	4.45	6.63	10.83	80.67	77.49	74.35	73.52	20.33	23.51	25.65	26.48
V_1S_3	-	4.30	6.58	10.04	79.45	77.87	75.47	74.35	20.55	22.18	24.53	25.67
V_2S_1	-	4.27	7.05	10.78	82.78	81.24	79.68	78.26	17.22	18.76	20.32	21.74
V_2S_2	-	4.15	6.77	9.35	81.11	79.55	77.93	76.34	18.89	20.35	22.07	23.67
V_2S_3	-	3.75	6.38	9.79	80.66	77.83	76.17	75.03	19.34	22.17	23.83	24.99
$LSD_{0.05}$		0.292	0.467	0.481	0.494	1.321	1.393	0.892	0.338	0.313	0.281	0.360
$LSD_{0.01}$		0.414	0.662	0.681	0.700	1.872	1.975	1.264	0.479	0.444	0.399	0.511

V_1 = Giant Kew, V_2 = Honey Queen, S_1 =25% yellow, S_2 = 50% yellow and S_3 =75% yellow.

Dry matter content: The combined effects of pineapple varieties and ripening stages in respect of dry matter content were found significant during storage. The maximum (26.48%) dry matter content was observed in

V_1S_2 (Giant Kew × Stage II) and minimum (21.74%) was in V_2S_1 (Honey Queen × Stage I) at the 9th day of storage (Table 2). The ripening stage showed highly significant differences in dry matter content. The dry matter content was in increasing trend during the entire period of storage. The maximum dry matter content (26.48%) was found in V_1S_2 (Giant Kew × Stage II) and the lowest (21.74%) was in V_2S_1 (Honey Queen × Stage I) at the 9th days of storage. The increase in dry matter percent with increasing storage period may be due to osmotic withdrawal of water from the pulp to peel through transpiration and evaporation as reported by Selvaraj *et al.* (1982).

Table 3. Combined effect of variety and ripening stage on percent vitamin C and total soluble solids (TSS) contents of pineapple cv. Giant Kew and Honey Queen

Treatment combination	Vitamin C content (mg/ 100g) at different days after storage DAS)				Total soluble solid (%) at different DAS			
	0	3	6	9	0	3	6	9
V_1S_1	27.15	25.00	23.66	21.59	11.20	12.50	15.00	16.60
V_1S_2	23.66	20.49	18.38	16.56	12.40	13.20	15.40	17.20
V_1S_3	20.49	18.17	16.02	14.25	13.25	14.30	16.80	18.60
V_2S_1	22.74	20.54	18.27	16.18	11.40	12.60	14.30	16.50
V_2S_2	21.65	19.02	17.51	15.88	13.35	14.25	16.50	18.70
V_2S_3	19.89	17.05	15.13	13.04	14.20	15.50	17.90	19.10
$LSD_{0.05}$	0.838	0.823	0.744	0.814	0.298	0.516	0.659	0.447
$LSD_{0.01}$	1.188	1.167	1.055	1.153	0.422	0.731	0.933	0.633

V_1 = Giant Kew, V_2 = Honey Queen, S_1 =25% yellow, S_2 = 50% yellow and S_3 =75% yellow.

Vitamin C contents: Giant Kew had higher vitamin C content than Honey Queen and the vitamin C content of the pineapple fruits decreased significantly during storage. At the on-set of experiment (fresh pulp of storage), vitamin C contents in Giant Kew variety and Honey Queen were 23.77 and 21.43 mg/100g, respectively, while on the 9th day of storage these values were 17.47 and 15.03 mg/100g, respectively. At the 9th day of storage, the maximum (21.59 mg/100g) vitamin C content was recorded in V_1S_1 (Giant Kew × Stage I) and the minimum (13.04 mg/100g) was in V_2S_3 (Honey Queen × Stage III) (Table 3). The results of the present study have been supported of Mondal *et al.* (2000). They reported that vitamin C content decreased gradually during storage, ripening and transport. The decreased in vitamin C content with storage duration is attributed to the oxidation of ascorbic acid into dehydro ascorbic acid by enzyme ascorbic acid oxidase (Singh *et al.* 1990).

Total soluble solids (TSS): Honey Queen had higher TSS content than Giant Kew throughout the storage period. The total soluble solids of the pineapple fruits were found to increase during storage. The percentage of TSS varied significantly up to 9 days of storage. The maximum (14.20 and 19.10%) and minimum (11.20 and 16.60%) TSS contents were recorded from V_2S_3 (Honey Queen × Stage III) and V_1S_1 (Giant Kew × Stage I), respectively, on 0 day (fresh pulp) and 9th day of storage (Table 3). Mia (2003) noted that TSS increased significantly during storage in all treated and untreated fruits.

Reducing sugar content: The reducing sugar content of fruit pulp varied significantly between two varieties during storage. The reducing sugar content was higher in Giant Kew than Honey Queen. The maximum reducing sugar content (4.70 and 5.38%) and minimum (3.32 and 4.09%) were observed in V_1S_3 (Giant Kew × Stage III) combination and V_2S_1 (Honey Queen × Stage I), respectively, on 0 day (fresh pulp) and 6th day of storage (Table 4). During the 9th days of the storage period the reducing sugar content of the pulp, gradually decreased. The changes in reducing sugar contents in the pulp might be due to the hydrolysis of fruits sugar and or added sugar by the acid present in the pulp.

Table 4. Combined effect of variety and ripening stage on reducing sugar, non-reducing sugar and total sugar contents of pineapple cv. Giant Kew and Honey Queen

Treatment combination	Reducing sugar content (%) at different days after storage (DAS)				Non-reducing sugar content (%) at different DAS				Total sugar content (%) at different DAS			
	0	3	6	9	0	3	6	9	0	3	6	9
V_1S_1	4.45	4.59	4.86	4.53	6.98	9.30	10.38	9.00	11.43	13.89	15.24	13.53
V_1S_2	4.54	4.70	4.92	4.69	8.20	9.46	11.49	9.76	12.74	14.16	16.41	14.45
V_1S_3	4.70	4.95	5.38	4.86	9.19	10.26	12.44	10.50	13.89	15.21	17.82	15.36
V_2S_1	3.32	3.62	4.09	3.56	9.59	10.54	12.75	10.53	12.91	14.23	16.84	14.09
V_2S_2	3.80	4.18	4.43	4.23	9.78	11.03	12.96	11.34	13.58	15.26	17.39	15.57
V_2S_3	4.20	4.78	5.35	4.79	10.62	11.91	13.39	11.70	14.82	16.69	18.74	16.48
$LSD_{0.05}$	0.338	0.298	0.414	0.303	0.149	0.225	0.461	0.169	0.373	0.394	1.103	0.232
$LSD_{0.01}$	0.479	0.422	0.586	0.429	0.211	0.319	0.653	0.239	0.529	0.558	1.563	0.329

V_1 = Giant Kew, V_2 = Honey Queen, S_1 =25% yellow, S_2 = 50% yellow and S_3 =75% yellow.

Non-reducing sugar content: Significant variation was found in non-reducing sugar content during storage of fruits. The maximum non-reducing sugar content (10.62 and 13.39%) and minimum (6.98 and 10.38%) were observed in V_2S_3 (Honey Queen × Stage III) and V_1S_1 (Giant Kew × Stage I), respectively, from 0 day (fresh pulp) and 6th day of storage (Table 4). Non-reducing sugar of the pulp decreased during 9th days of storage period. The decrease of non-reducing sugar might be due to conversion of some non-reducing sugar to reducing sugar through the process of glucogenesis.

Total sugar content: Significant variation was found at 3rd and 9th days of storage in total sugar content. The highest (18.74%) total sugar content was recorded in V_2S_3 combination and the lowest (15.24%) was in V_1S_1 combination at the 6th days of storage (Table 4). The highest total sugar content (14.82 and 18.74%) was recorded in V_2S_3 combination and the lowest (11.43 and 15.24%) was recorded in V_1S_1 combination at the 0 day (raw pulp) and 6th days of storage, respectively. Total sugar of the pulp decreased during 9th days of storage period. Reni *et al.* (2000) reported that total sugar in pulp decreased during storage, whereas a slight increase in reducing sugar.

Shelf life of fruit: The combined effect of variety and ripening stage was significant. The longest shelf life of 13.00 days was observed in fruits V_2S_1 (Honey Queen × Stage I) and the shortest shelf life of 8.50 days observed in V_1S_3 (Giant Kew × Stage III) (Fig. 2).

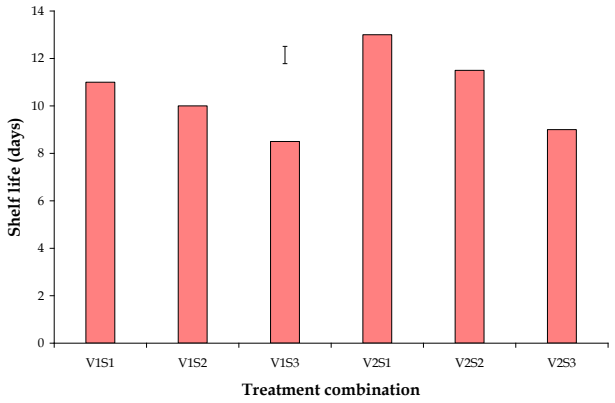

Figure 2. Combined effect of variety and ripening stage on shelf life of pineapple. The vertical bar represents LSD at 1% level of significance. (V_1 = Giant Kew, V_2 = Honey Queen, S_1 = 25% yellow, S_2 = 50% yellow, S_3 = 75% yellow).

The longest shelf life (13.00) was found in V_2S_1 (Honey Queen × stage I) followed by 11.50 days in V_2S_2 (Honey Queen × stage II). By contrast, the shortest shelf life of 8.50 days was found in V_1S_3 (Giant Kew × stage III) and 9.00 days in V_2S_3 (Honey Queen × stage III).

Conclusion

The findings of this study suggest that both the factors (varieties and ripening stages) had significant influences on the physical and chemical parameters of pineapple. Generally most of the physical parameters scored better in Giant Kew while higher scores of chemical parameters were found in Honey Queen. In terms of physical parameters Stage I (S_1) scored higher than Stage III (S_3) and in terms of chemical parameters Stage III (S_3) scored higher than Stage I (S_1). All ripening stages of Honey Queen showed higher nutritive value than Giant Kew variety. The nutritional changes were significant among the stages and varieties but in the same stage and varieties the nutritional change is negligible under the storage condition up to 9th days of storage.

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