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Chemical Properties and Shelf Life of Banana (*Musa sapientum* L.) as Influenced by Different Postharvest Treatments

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Abstract

An experiment was conducted to evaluate the changes in the chemical properties of banana fruits and their shelf life as influenced by different postharvest treatments. There were two varieties viz. Amritasagar (V_1) and Sabri (V_2) and seven storage treatments viz.: control (open space, 30±2ºC) (T_0); perforated polyethylene, 30±2ºC (T_1); non-perforated polyethylene, 30±2ºC (T_2); benzyl adenine (BA 30 ppm, 30±2ºC) (T_3); gibberellic acid (GA_3 150 ppm, 30±2ºC) (T_4); benzyl adenine (BA 30 ppm, 15°C) (T_5) and gibberellic acid (GA_3 150 ppm, 15°C) (T_6). A factorial experiment was laid out in the Completely Randomized Design (CRD) with three replications. Data were recorded on titratable acid content, total sugar content, reducing sugar content, non-reducing sugar content, total soluble solids and pulp pH. Among the chemical parameters, total soluble solids (TSS) and pH of pulp increased while titratable acidity decreased during storage in all the treated and untreated banana fruits. Among the treatments gibberellic acid (GA_3 150 ppm, 15°C) treatment exhibited the best storage performance. The treatment combinations of Sabri with gibberellic acid (GA_3 150 ppm, 15°C) showed the longest shelf life (16.25 days), whereas the lowest shelf life was in Amritasagar with control (open space, 30±2ºC) treatment combination (6.78 days).

Keywords: Banana, chemical properties, shelf life, storage environment

1. Introduction

Banana (*Musa sapientum* L.) is one of the important tropical fruits with a global annual production of about 145.4 million metric tones of which Asia contributes 69 million tonnes (FAO, 2011). It is a good source of income to the farmers in their respective growing regions (Bridge, 2000; Akinyemi *et al*., 2010). Bangladesh produces 4.22 million tonnes of fruits annually from 0.15 million hectares of which banana ranks first in respect of area (0.06 million hectare) and second in production (0.82 million tones) (BBS, 2010). The minimum dietary requirement of fruits per day per person in Bangladesh is 115 g, whereas, availability is only 30- 35 g (Siddiqui *et al.*, 1995). Sometimes this per capita availability of fruits decreased further due to high level of postharvest losses (Mondal *et al*., 1995).

Fruit growth and development involve many changes in its morphology, anatomy, physiology and biochemistry (El-Otmani *et al*., 1987). When a fruit matures, the changes occur in rind texture, juice composition and taste (Chahidi *et al*., 2008). pH and mineral composition may also influence the catalytic activity of cell wall enzymes and can have a profound effect on anthocyanin stability and color expression (Huber and O'Donoghue, 1993; Almeida and Huber, 1999; Holcroft and Kader, 1999). A total soluable solid (TSS) is an important quality attribute for many fresh fruits during ripening (Lu, 2004). It was reported that fruit pH changes was 3.0 in orange juices (Kelebek *et al*., 2008), 4.2 to 4.4 during storage in peaches (Zhang *et al*., 2008) and 3.0 to 3.5 in citrus fruits (Chahidi *et al*., 2008) during storage. During fruit ripening and softening process, starch is broken down to the simple soluble sugars and also the amount of soluble pectin will increase, leading to fruit softening (Afshar *et al*., 2010).

Kulkarni and Aradhya (2005) suggested that a slow decrease in acidity, concomitant with increased TSS and total sugar content, is an intrinsic process during the ripening of fruits to impart the flavor. The effects of the chemical dip, calcium chloride, ascorbic acid and modified atmosphere storage improved the quality and shelf life of banana (Reis *et al.*, 2004). The objectives of the present study were to find out the chemical and bio-chemical changes of two banana varieties in response to different postharvest treatments and identify the suitable storage treatments to maintain the quality and to increase shelf life of banana fruits.

2. Materials and Methods

The experiment was conducted at the laboratories of the Department of Horticulture and Department of Biochemistry, Bangladesh Agricultural University, Mymensingh, during September, 2004 to December, 2004. The study consisted of two factors; factor A: varieties, V_1: Amritasagar and V_2: Sabri; factor B: different postharvest treatments,T_0: control (open space, 30±2ºC), T_1: fruits were kept at 30±2ºC in perforated polyethylene bag, T_2: fruits were kept at 30±2ºC in non perforated polyethylene bag , T_3: fruits were treated with benzyl adenine (BA 30 ppm, 30±2ºC), T_4: fruits were treated with gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5: fruits were treated with benzyl adenine (BA 30 ppm,15^0C), T_6: fruits were treated with gibberellic acid (GA_3 150 ppm, 15^0C). The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The post harvest treatments were randomly assigned to the selected banana fruits. After the application of treatments, some of the fruits were kept on a brown paper previously placed on the laboratory floor at room temperature (30±2ºC) and others were kept in a refrigerator. Each treatment comprised of eight banana fingers.

One banana finger of each treatment was collected at 3, 6, 9 and 12 days of storage for chemical analysis. Titratable acid content was determined according to Ranganna (1979). Total sugar content was determined colorimetrically using the anthrone method (Jayaraman, 1981). Reducing sugar content was determined using the dinitrosalicylic acid method (Miller, 1972). Non-reducing sugar content was calculated using the following formula: % Non-reducing sugar = Total sugar - Reducing sugar. Total soluble solids (TSS) content of pulp was estimated using Abbe's refractometer. A drop of banana juice squeezed from the fruit pulp was placed on the prism of the refractometer. Percent TSS was obtained from the direct reading of the instrument.

The collected data were statistically analyzed following F variance tests. The difference between the pair of means was compared using LSD (Gomez and Gomez, 1984).

3. Results and Discussion

3.1. Titratable acidity

Of the two varieties, V_2 (Sabri) contained higher titratable acidity (0.51%) than V_1 (Amritasagar) (0.49%) at the 9^{th} day of storage. Titratable acidity decreased gradually with the passage of the storage period in all treatments (Fig. 1). The maximum titratable acidity (0.63%) was found at the 9th day of storage in T_6 while the minimum (0.41%) was noticed in T_0 (Fig. 2). The decrease in titratable acidity during the storage may be attributed to the utilization of organic acids in various bio-degradable reactions. The highest titratable acidity (0.65%) was recorded in V_2T_6 but the lowest (0.40%) was observed in V_1T_0 at the 9th day of storage (Table 1). Pinaki *et al.* (1997) conducted an experiment with mature and fully developed banana fruits of uniform size dipped in GA_3 @150 ppm and found that GA_3 retained higher titratable acidity and slowed the decrease in ascorbic acid content of fruits during their storage.

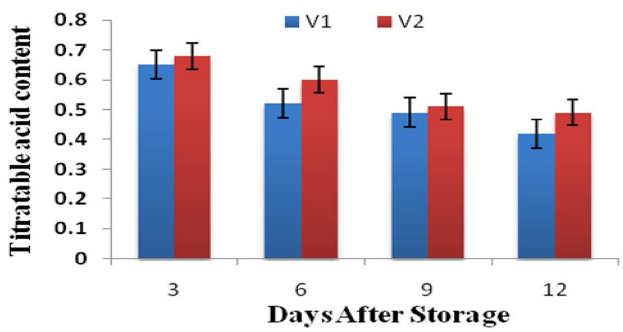

Figure 1. Effect of varieties on the titratable acid content of banana (vertical bars represent SE of the three replications)

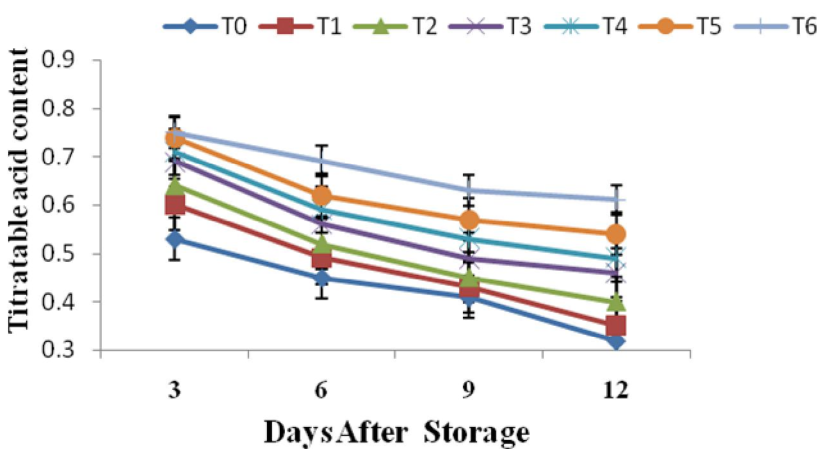

Figure 2. Effect of postharvest treatments on the titratable acid content of banana (vertical bars represent SE of the three replications)

V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C), SE= standard error

3.2. Total sugar contents

At the 9th day of storage, the highest total sugar contents (21%) were recorded in V_1 while the lowest (20.13%) was observed in V_2 (Fig. 3). The maximum sugar content (25.74%) was recorded in control whereas the minimum (15.31%) was found in T_6 (Fig. 4). The most striking chemical changes occured during the postharvest ripening of banana fruits were hydrolysis of starch and accumulation of sugars (Patil and Magar, 1976). Considering the interaction effects of banana varieties and different postharvest treatments, significant variations where found on total sugar contents in fruit pulp at the 9th and the 12th days of storage. However, the highest total sugar content (26.9 %) was recorded in V_1T_0 while the minimum (15%) was in V_2T_6 at 9th day of storage (Table 1).

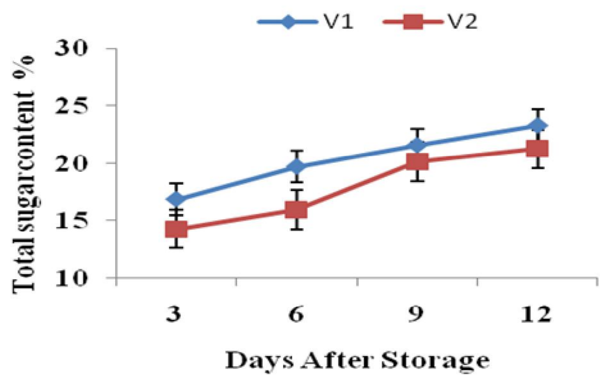

Figure 3. Effect of varieties on the total sugar content (%) of banana (vertical bars represent SE of the three replications)

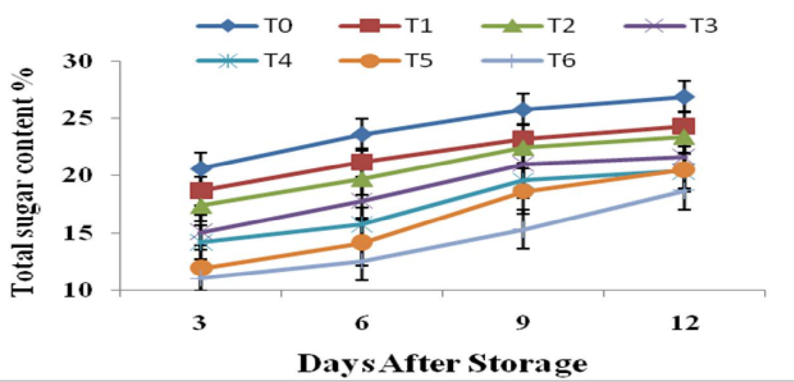

Figure 4. Effect of postharvest treatments on the total sugar content (%) of banana (vertical bars represent SE of the three replications)

V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C), SE= standard error

3.3. Reducing sugar content

Highly significant variations were observed in the reducing sugar content between the two varieties at different days of storage. The maximum reducing sugar content (11.41%) was recorded in V_1 and the minimum (10.59%) in V_2 at the 9th day of storage (Fig. 5). The highest reducing sugar content (14.77%) was found in T_0 but the lowest (8.79%) was in T_6 at the 9th day of storage (Fig. 6). The increase in reducing sugar may be attributed to enzymatic conversion of starch to reducing sugar (Islam, 1998). The higher amount of reducing sugar content (15.85) was recorded in V_1T_0 while the smaller amount (8.23%) was in V_2T_6 (Table 1). Bhadra and Sen (1999) mentioned that the total sugar and reducing sugar contents increased with in the progress of the storage period.

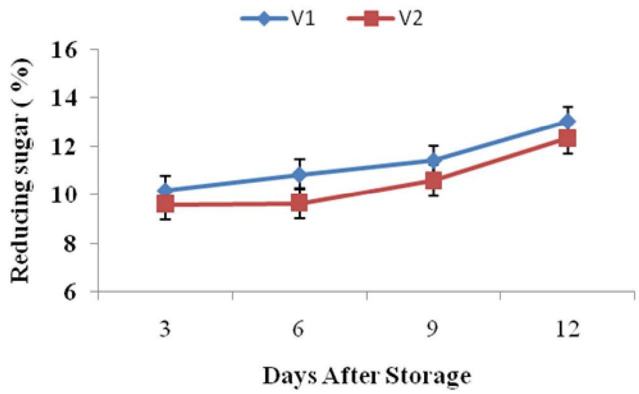

Figure 5. Effect of varieties on the reducing sugar content (%) of banana (vertical bars represent SE of the three replications)

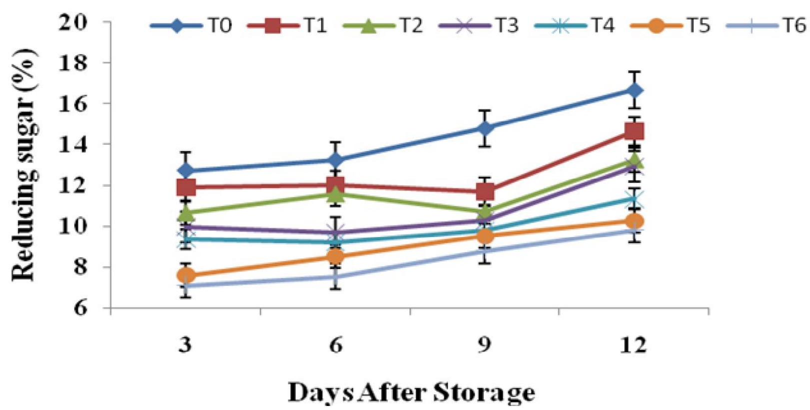

Figure 6. Effect of postharvest treatments on the reducing sugar content (%) of banana (vertical bars represent SE of the three replications)

V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C), SE= standard error

3.4. Non-reducing sugar content

Higher non-reducing sugar content (7.51) was observed in V_1 while V_2 contained the lower amount of non-reducing sugar (6.91%) at the 9th day of storage (Fig. 7). At the 9th day of storage, the maximum non-reducing sugar content (9.46%) was obtained from T_0 and the least value 5.64% in from T_6 (Fig. 8). At the 9th day of storage, the highest (10.05) non-reducing sugar content was observed in V_1T_0 and the lowest (5.02 %) was in V_2T_6 (Table 1). The non-reducing sugar content increased rapidly from the 3rd to the 9th day of storage and then changed slowly after the 9th day of storage. Rapidly increased non-reducing sugar was probably due to breakdown of starch into non-reducing sugar and then that non-reducing sugar was converted into reducing sugar resulting slowly increase in non-reducing sugar. In mango, Rangavalli *et al.* (1993) found a gradual increase in the non-reducing sugar content during its storage.

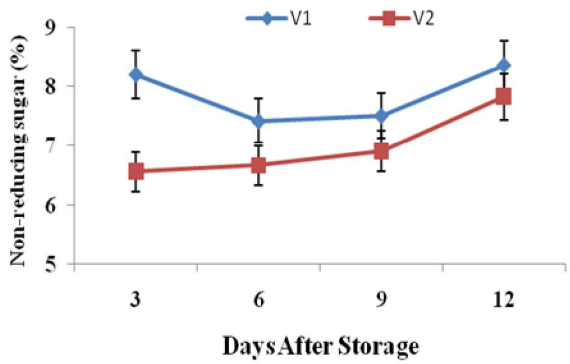

Figure 7. Effect of varieties on the non-reducing sugar content (%) of banana (vertical bars represent SE of the three replications)

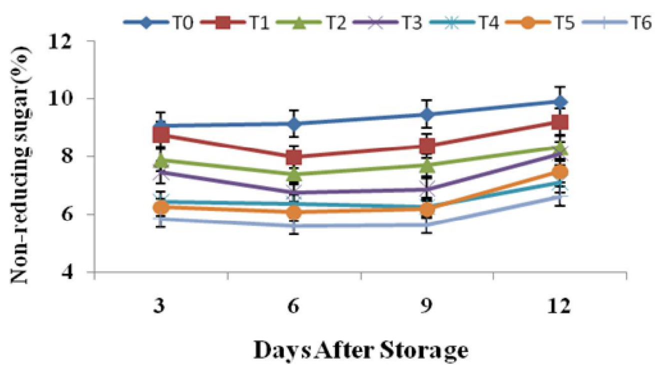

Figure 8. Effect of postharvest treatments on the non-reducing sugar content (%) of banana (vertical bars represent SE of the three replications)

V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C), SE= standard error

Table 1. Combined effects of varieties and postharvest treatments on titratable acidity, total sugar, reducing sugar and non-reducing sugar contents of banana

Variety × Treatments	Titratable acidity at DAS				% total sugar at DAS				% Reducing sugar at DAS				% Non-reducing sugar at DAS			
	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12
V_1T_0	0.52	0.42	0.40	0.29	21.49	25.53	26.9	27.8	13.87	14.21	15.85	17.43	9.61	9.48	10.05	10.73
V_1T_1	0.59	0.45	0.42	0.32	20.01	23.47	24.45	26.45	12.60	12.87	12.05	15.61	9.62	8.49	8.66	9.51
V_1T_2	0.63	0.47	0.45	0.36	18.69	21.12	23.95	25.72	10.97	11.8	10.64	13.21	8.66	8.15	8.27	8.84
V_1T_3	0.68	0.51	0.48	0.43	16.95	19.59	21.54	23.09	9.72	10.19	10.22	13.40	8.26	6.73	6.85	8.02
V_1T_4	0.68	0.55	0.53	0.46	15.69	17.18	19.96	20.75	9.49	9.77	9.54	11.39	7.07	6.41	6.36	7.03
V_1T_5	0.70	0.59	0.57	0.51	13.45	16.4	18.60	21.21	7.46	9.19	9.20	10.37	6.93	6.39	6.11	7.51
V_1T_6	0.73	0.66	0.61	0.55	11.67	14.62	15.62	18.00	7.12	7.77	8.34	9.79	7.25	6.30	6.26	6.88
V_2T_0	0.55	.49	0.43	0.35	19.74	21.67	24.57	25.9	11.55	12.23	12.70	15.90	8.52	8.77	8.87	9.04
V_2T_1	0.61	0.53	0.44	0.38	17.35	18.87	22.00	22.22	11.14	11.08	11.26	13.67	7.88	7.45	8.08	8.88
V_2T_2	0.65	0.57	0.45	0.44	16.05	18.28	20.88	21.03	10.30	11.31	10.78	13.25	7.08	6.64	7.10	7.78
V_2T_3	0.70	0.61	0.49	0.50	13.15	16.03	20.52	20.23	10.17	9.16	10.28	12.40	6.65	6.79	6.90	8.16
V_2T_4	0.73	0.63	0.54	0.52	12.67	14.35	19.22	20.05	9.19	8.64	10.07	11.24	5.84	6.33	6.15	7.14
V_2T_5	0.77	0.65	0.58	0.57	10.40	11.91	18.69	19.92	7.72	7.85	9.82	10.13	5.56	5.75	6.23	7.44
V_2T_6	0.78	0.71	0.65	0.60	10.42	10.53	15.00	19.45	7.11	7.28	8.23	8.80	4.40	4.91	5.02	6.36
LSD (0.01)	0.02	0.02	0.02	0.02	2.31	2.09	2.26	0.02	1.23	1.59	1.25	1.73	1.26	1.2	1.22	1.39
LSD (0.05)	0.02	0.02	0.02	0.02	1.71	1.55	1.62	0.02	0.91	1.18	0.93	1.28	0.93	0.89	0.09	1.03

DAS- Days After Storage, V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C)

Table 2. Effect of varieties on the percent total soluble solids (TSS) and pH of banana

Variety	TSS (%) at DAS				pH at DAS			
	3	6	9	12	3	6	9	12
V_1	18.97	19.71	24.39	19.55	3.68	5.91	6.13	6.28
V_2	15.23	16.72	17.47	18.62	3.32	5.44	5.86	6.03
LSD (0.01)	0.76	**0.73**	0.74	0.76	0.22	0.39	0.49	0.55
LSD (0.05)	0.56	0.54	0.55	0.57	0.17	0.29	0.36	0.40

V_1 : Amritasagar ,V_2 : Sabri, DAS- Days After Storage

Table 3. Effect of postharvest treatments on percent total soluble solids (TSS) and pH of banana

Treatments	TSS (%) at DAS				pH at DAS			
	3	6	9	12	3	6	9	12
T_0	24.16	24.54	26.86	23.99	4.80	5.94	6.28	6.81
T_1	22.57	21.93	24.06	22.58	4.58	5.79	5.98	6.96
T_2	19.96	20.15	22.34	21.46	3.90	5.92	5.87	6.41
T_3	16.47	17.99	20.68	18.95	3.55	5.53	5.56	5.94
T_4	14.09	15.69	18.71	16.98	2.91	5.88	5.14	4.60
T_5	12.02	14.41	17.73	15.36	2.46	5.83	4.69	4.62
T_6	10.44	12.81	16.12	14.28	2.29	4.08	4.46	4.59
LSD (0.01)	1.40	1.37	1.39	1.37	0.42	1.04	0.92	1.02
LSD (0.05)	1.05	1.02	1.03	1.02	0.31	0.77	0.68	0.76

Table 4. Combined effects of varieties and postharvest treatments on total soluble solids (TSS) and pH of banana

Variety × Treatments	TSS (%) at DAS				pH at DAS			
	3	6	9	12	3	6	9	12
V_1T_0	25.89	25.12	28.35	24.98	4.99	6.60	6.79	6.82
V_1T_1	24.78	23.67	25.79	22.28	4.81	6.35	6.29	6.54
V_1T_2	22.61	22.31	24.7	21.62	4.49	6.54	6.38	6.01
V_1T_3	19.32	19.45	24.39	19.54	3.92	5.37	6.25	6.55
V_1T_4	16.44	17.71	23.67	17.45	2.92	5.80	5.91	5.41
V_1T_5	13.12	15.71	22.28	15.81	2.40	5.64	5.49	5.79
V_1T_6	10.65	13.98	21.58	15.20	2.24	5.05	4.79	4.34
V_2T_0	22.43	23.96	25.38	23.00	4.62	5.29	6.77	6.30
V_2T_1	20.35	20.20	22.33	22.88	4.34	5.22	5.68	6.39
V_2T_2	17.3	17.98	19.98	21.31	3.32	5.30	5.35	5.81
V_2T_3	13.62	16.52	16.97	18.37	3.18	5.69	4.87	5.33
V_2T_4	11.73	13.67	13.76	16.51	2.91	5.96	4.36	4.79
V_2T_5	10.92	13.10	13.18	14.92	2.52	6.02	4.89	4.45
V_2T_6	10.23	10.67	11.65	13.35	2.33	4.07	4.12	4.12
LSD (0.01)	2.45	2.37	2.41	2.02	0.72	1.27	1.29	1.44
LSD (0.05)	1.82	1.76	1.79	1.49	0.53	0.94	0.96	1.07

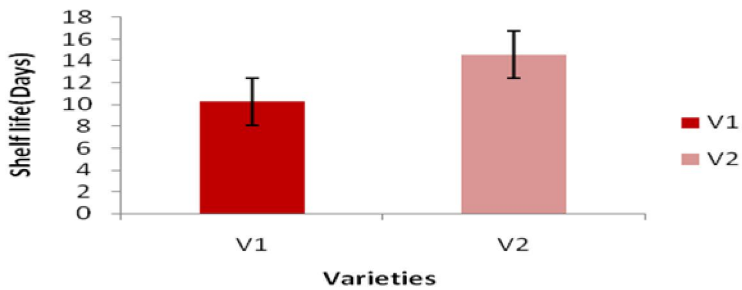

Figure 9. Effect of varieties on the shelf life of banana (vertical bars represent SE of the three replications)

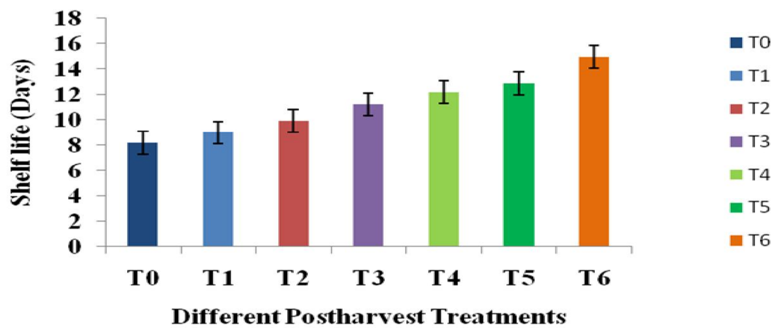

Figure 10. Effect of postharvest treatments on the shelf life of banana (vertical bars represent SE of the three replications)

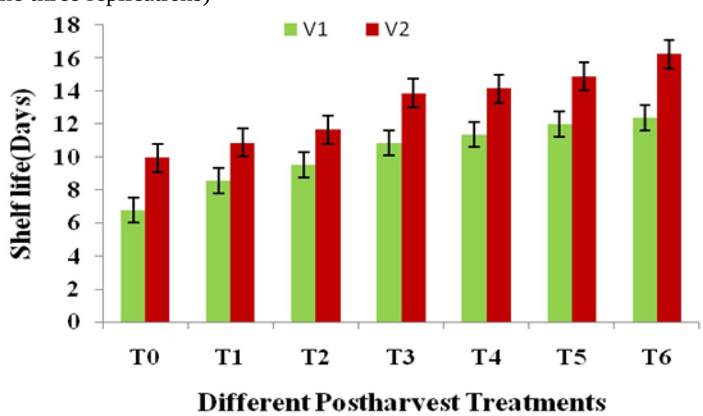

Figure 11. Combined effects of varieties and different postharvest treatment on the shelf life of Banana (vertical bars represent SE of the three replications)

V_1: Amritasagar ,V_2 : Sabri ,T_0 = control (open space, 30±2ºC), T_1= (perforated polyethylene, 30±2ºC), T_2 = (non-perforated polyethylene, 30±2ºC), T_3 = benzyl adenine (BA 30 ppm, 30±2ºC), T_4= gibberellic acid (GA_3 150 ppm, 30±2ºC), T_5 = benzyl adenine (BA 30 ppm, 15°C) T_6 = gibberellic acid (GA_3 150 ppm, 15°C), SE= standard error

3.5. Total soluble solids (TSS)

Varietal difference in terms of total soluble solids content was significant at different days of storage. The variety V_1 had the higher TSS content (24.39%) at the 9^{th} day of storage and TSS value for V_2 was lower (17.47%) (Table 2). The highest TSS (26.86%) was recorded in T_0 while the least TSS (16.12%) was recorded in T_6 at the 9^{th} day of storage (Table 3) but after the 9^{th} day the TSS content decreased. The highest TSS (28.35%) was observed in V_1T_0 while the lowest (11.65%) was recorded in V_2T_6 at the 9^{th} day after storage (Table 4). Increasing in the TSS content observed in the present investigation was in partial agreement with the report by Patil and Hulamani (1998) who that GA_3 treated fruits had the highest TSS at the end of storage. An increase in the TSS content up to certain period during storage was possibly due to hydrolysis of starch into sugar. Increase in the TSS of banana during ripening was also noticed by Tripathi *et al.* (1981), Abdullah *et al.* (1985) and Munasque and Mendoza (1990).

3.6. pH of banana pulp

The maximum pulp pH (6.13) was recorded in V_1 and the minimum (5.86) in V_2 was at the 9^{th} day of storage (Table 2). GA_3 + 15°C treated fruit showed comparatively lower pH value (4.46) at the 9^{th} day of storage. On the other hand, the higher pH values (6.28) were recorded in T_0 and lower (4.46) in T_6 at the 9^{th} day of storage (Table 3). At the 9^{th} day of storage, V_1T_0 had the highest pH value (6.79) and the lowest (4.12) was noticed in V_2T_6 (Table 4). The increase in pH may be due to continuous reduction of acidity during ripening. In the present investigation, increase in pH was recorded during the storage and this result is in agreement with the findings of Pathak and Sanwal (1999) who observed that pH of fruit pulp got accelerated when banana fruits were soaked in 0.2% GA_3 solution. The finding of the present investigation was also similar with these of Kumar and Singh (1993) who observed that the pulp pH of mango increased during its storage.

3.7. Shelf life

Highly significant variations were obtained for the shelf life of two varieties of banana. The shelf life of V_2 (14.56 days) was higher than that of V_1 (10.25 days) (Fig. 9). The maximum shelf life (14.97 days) was observed in T_6 whereas the minimum (8.20 days) was in T_0 (Fig. 10). Pinaki *et al*. (1997) reported that the matured and fully developed banana fruits of uniform size dipping into GA_3 (150 ppm) was most effective for prolonging the shelf life of banana. The treatment GA_3 causes the decrease in the tissue permeability and thereby reduced the rate of water loss leading to delayed fruit ripening (Nirupama *et al*., 2010). This finding is also in agreement with those of Ranwala and Miller (2000) and Singh *et al.* (2008). The maximum shelf life (16.25 days) was found in V_2T_6 and the minimum (6.78 days) was recorded in V_1T_0 (Fig. 11).

4. Conclusions

The chemical properties of banana were greatly influenced by different kinds of postharvest treatments and varieties. The findings indicated that the total soluble solids, sugars (reducing, non-reducing and total sugar) and pulp pH of fruits increased during the storage treatments. The increasing trend was slower both in GA_3 + 15°C and BA + 15°C treated bananas. At the same time titratable acidity decreased but that was not rapid in fruits treated with GA_3 kept at 15°C. Among the treatments, GA_3 + 15°C appeared to be more suitable for extending the shelf life as well as other desirable quality attributes of harvested banana fruits.

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