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Original Research Article

Studying the Difference in Effectiveness of Post Harvest Chemical Treatment on Storability of Broccoli var. Aishwarya in Room Condition

Chingtham Chanbisana* and A. K. Banik

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur Nadia, West Bengal-741252, India

**Corresponding author*

Keywords

Ascorbic acid, Benzyl adenine, Chlorophyll, Fungal decay, Marketability, Salicylic acid

A B S T R A C T

A research work was conducted in the departmental laboratory of Post Harvest Technology of Horticultural Crops, Bidhan Chandra Viswavidyalaya, Mohanpur on the effectiveness of post harvest chemical treatments on broccoli var. Aishwarya harvested from the Horticultural Research Station, Mondouri. Harvested broccoli were brought in plastic crates and room cooled for few hours and trimmed and treated with freshly prepared solution of benzyl adenine (BA) at 50ppm and 25ppm for 10min, hot water at 48 °C and 45 °C for 4 min, Salicylic acid at 1000ppm and 500ppm for 10 min, calcium hypochlorite at 10 min and control. After the treatment, they were given a gentle shake and surface dried and packed in polyethylene bags of 150 gauge. During the storage period, the physicochemical analysis were taken regarding chlorophyll content, ascorbic acid, total soluble solids (TSS), physiological loss in weight (PLW), sensory analysis for colour, smell, texture and browning as well as yellowing % and amount of fungal decay along with marketability. The minimum water loss and no yellowing without any sign of fungal decay was reported in BA 50ppm. The highest marketability was also reported in broccoli treated with BA 50ppm while the minimum desirable parameters were visible in the control during the 4 days storage period.. Hence BA treatment with higher concentration gave the highest desirable parameters among the various postharvest treatment performed in the room condition.

Introduction

India is the second largest producer of broccoli after China, while the US ranks third (Annon, 2013). In West Bengal, broccoli is grown in hilly region of Darjeeling, Kalimpong while in plains it is cultivated in some sub urban areas of Kolkata. It is cherished for its delicious taste, flavour and nutritive value. It is highly valued due to its richness in vitamins, antioxidants, anticarcinogenic compounds (Nestle, 1998) and health promoting phytochemicals (Yuan *et al.*, 2010). Broccoli contains on an average 1.20-6.24μmol of glucosinolates/g fresh weight (Song and Thornalley, 2007).

Being highly perishable, there arise problem of bruising in post harvest management during handling. Colour and texture are two important quality attributes of vegetables affected by storage conditions, such as temperature, relative humidity, light and the composition of the surrounding atmosphere. Green-coloured florets of broccoli (looking fresh) are preferred by consumers. The broccoli quality is highly reduced after harvesting because of the loss of green color and the consequent yellowing of its sepals. Broccoli reaches the retail markets at least one or two days after harvest and, by the time it reaches market, the quality begins to deteriorate. The deterioration in quality of this vegetable is very rapid in both ambient and refrigerated conditions. Yellowing due to loss of chlorophyll is the most important problem for successful marketing of broccoli. Green coloured florets of broccoli (looking fresh) are preferred by consumers. Weight loss was significantly higher in non packaged broccolis compared to packaged ones with increase in temperature and storage time.

Broccoli contains on an average 1.20-6.24µmol of glucosinolates/g fresh weight (Song and Thornalley, 2007). It is harvested when the floral heads, branchlets, and florets are totally immature, with sepals completely surrounding the flower i.e., when still tight and compact. Generally the broccoli head with a small portion of the stalk is harvested. The heads are cut off with about 15cm of the stem attached after cutting, part of the foliage is removed from the harvested shoots. The head may be 15-25cm in diameter and weighs 250 to 600g. This type of harvesting provokes a sudden disruption in nutrient, energy and hormone supplies which in turn triggers the senescence process. Loss of quality in broccoli during storage usually results from wilting, yellowing of the buds and florets, loosening or opening of the head and decay (Toivonen and Forney, 2004). The broccoli quality is highly reduced after harvesting because of the loss of green color and the consequent yellowing of its sepals.

Demand for broccoli has been increasing among common consumers mainly due to its high content of bioactive compounds. High demand of broccoli is ordered from five star hotels and restaurants. However, broccoli is a perishable commodity with a short shelf life mainly due to dehydration, yellowing and losses of bioactive compounds. Thus, some postharvest treatments may be done to preserve broccoli quality. Hence this research work was taken up taking into consideration the need of post harvest treatments to enhance the shelf life of broccoli.

Material and methods: In order to study the effect of post harvest treatments on broccoli, fully grown broccoli heads but tender, firm and dark green in colour with unopened florets of cv. Aishwarya were harvested from field in the end of December,2014 and storage studies was carried in January, 2015. They were brought immediately to the laboratory, cooled in room for 3 hours. Then they were trimmed and treated with freshly prepared chemical solutions to compare the effectiveness of different postharvest treatments.

Experiment details

T_1 - BA at 50ppm for 10min
T_2 - BA at 25ppm for 10min
T_3 - Hot water at 48°C for 4min
T_4 - Hot water at 45°C for 4min
T_5 - Salicylic acid at 1000ppm for 10min
T_6 - Salicylic acid at 500ppm for 10min
T_7 - Calcium hypochlorite 100ppm for 10min
T_8 - Calcium hypochlorite 50ppm for 10min
T_9 -Control

Method of treatments

The chemical solutions for the different post harvests treatment were freshly prepared. Solution of Benzyl Adenine (BA), salicylic acid(SA) and calcium hypochlorite at different concentrations were prepared separately by dissolving in methanol, then made up the volume with distilled water then broccoli heads were dipped for stipulated time duration. After the treatment, the broccoli heads were given gentle shake and then air surface dried for few minutes after which they were packed in polyethylene (PP) bags of 150 gauge and kept in room.

Number of replication : 3
Statistical design : CRD

Observations recorded

Physiological loss in weight (%), yellowing (%), TSS (ºB), chlorophyll (µg/g), ascorbic acid (mg/100g), sensory evaluation for colour, smell, texture and browning (5point Hedonic scale), fungal decay (%), bacterial decay(%), marketability(%) were estimated following standard procedure as mentioned in physico-chemical analysis at regular intervals.

Physico-chemical analysis

Physiological loss in weight (PLW)

PLW was calculated as cumulative% loss in weight, based on the initial weight (before storage) and loss in weight was recorded at the time of periodical sampling during storage (A.O.A.C, 1990).

$$PLW = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

Ascorbic acid

Volumetric method of ascorbic acid determination (2,6- Dichlorophenol-Indophenol Visual Titration Method) was done using 2, 6-dichlorophenol indophenols which gets reduced to a colourless leuco-base by ascorbic acid and the ascorbic acid gets oxidised to dehydroascorbic acid. Though the dye is a blue coloured compound, the end point is the appearance of pink colour. The dye is pink coloured in acid medium (Ranganna, 2008).

Ascorbic acid (mg/100 g)=

$$\frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Wt: or vol: of the sample taken for estimation}} \times 100$$

Chlorophyll

Total chlorophyll content was determined by spectrophotometric method (A.O.A.C,1990). A known amount of tissue sample by weight is taken and chlorophyll is extracted in 80% acetone until the residue has no more green colour. The filtrate or supernatant is made upto known volume with 80% acetone and the Optical Density (OD) value is then measured through 660nm and 642.5nm wavelength in a colorimeter against blank. Using the adsorption coefficients, the amount of chlorophyll is calculated as follows

Total chlorophyll (a+b), µg/ ml = (7.12 × OD at 660nm) + (16.8 × OD at 642.5nm)

Yellowing percentage

Whole green broccoli head is divided into four parts out of 100 percent. The area which becomes yellow is recorded visually according to the four parts divided. There were two conditions of yellowing, one where there was gradual yellowing while the other was with the patchy development of colour.

Total soluble solids (TSS) °Brix

TSS was determined by Hand Refractometer by principle of total reflection which was calibrated at 0°B is checked before use by placing few drops of distilled water on the prism in the specimen chamber of the refractrometer. A refractometer calibrated with a sugar concentration (°Brix) scale was used to measure the soluble solids of the broccoli juice. The refractive index is the ratio of the speed of light in vacuum to its speed in a substance and is used as a measure of concentration of solutes in solution (Peris, 2004). The ºBrix is numerically equivalent percentage (w/w) of sucrose and only accurate for pure sucrose solutions, but as it is determined by refractive index, ºBrix is used as an indicator of total soluble solids in the juice of fruits and vegetables (Varnam and Sutherland, 1994). A few drops of broccoli juice were taken for each sample for estimating the TSS which was expressed in terms of degree brix. For determining the TSS (Erma Hand Refractrometer I.S.O 2173), a drop of sample juice is placed on the prism and the percentage of dry substance in it read directly.

Fungal decay %

Observation on visual appearance of white growth on fresh broccoli which is mainly caused by fungus are recorded areawise on the whole head of broccoli on percentage basis and respective value in percentage was given for respective amount of decay.

Sensory evaluation

Sensory quality indices such as colour, texture, smell and browning were evaluated. The intensity of the attributes evaluated was quantified on a scale from 1 to 5point hedonic scale.

Rating on fresh broccoli were rated as follows:

Colour

5 = dark green, uniform colour
4 = slightly yellow
3 = moderately yellow
2 = very yellow
1 = extreme yellow

Browning

5 = no browning
4 = some browning
3 = moderate browning
2 = very much browning
1 = extreme browning

Texture

5 = crispy
4 = little rubbery
3 = rubbery
2 = soft
1 = extremely soft.

Smell

5 = no off-odour
4 = slight off odour
3 = moderately off odour
2 = severe off-odour
1 = extreme off-odour

Marketability (%)

The marketability of broccoli was determined on the basis of taking into consideration the quality (colour, texture or crispiness, flavour and defects like yellowing, browning and decay) and was expressed in percentage (%). Upto an amount of 50% was considered to be marketable.

Results and Discussion

PLW: Influence of different postharvest treatments had significant effect on physiological loss in weight. There was an increasing trend in PLW with prolong storage period in all the treatments. The minimum value (0.46%, 1.32% and 3.49%) was noted in broccoli treated with 50ppm calcium hypochlorite on 1, 2 and 4 days after storage and the maximum value (4.61 and 5.91%) was observed in control broccoli on 3 and 4 days after storage.

The lowest PLW throughout the storage period of 4 days, was seen in BA treatment with the lower concentration followed by treatment with calcium hypochlorite, hot water treatment and the highest PLW was in salicylic acid treatment. Higher concentration of SA gave lower PLW compared to the control which may be due to the fact that SA acid might have reduced respiration rate (Wolucka *et al*., 2005; Tareen *et al*., 2012) Irrespective of postharvest treatments given to the broccoli samples along with the packing material, an increasing trend of PLW was seen for all treatments during the 4 days' storage duration which may be attributed to the continuous process of respiration and transpiration. Pesis *et al.*, 2000 and Wang and Qi (1997) have also reported that low moisture permeability of film creates high-humid environment, which prevents broccoli water loss and wilting (Table 1–4).

Total soluble solids (TSS ºB)

The TSS contents increased on each day of observation till day 3 after which it decreased. Maximum TSS (7.93, 8.13 and 8.03ºB) was observed in broccoli dipped in calcium hypochlorite 100ppm (T_8) on 2, 3 and 4 days of storage while the least was 7.17, 7.07 and 7.03ºB in broccoli treated with SA 500ppm on same days of observation during the storage study. Total and reducing sugar levels decreased during postharvest senescence, with lower values in control samples (Buchert *et al*., 2011). Senescence is an active process and governed by a well defined cell death program. The initial increasing trend may be correlated with the finding of Ahmad *et al*., (2013) who stated that with progression of the storage period, TSS and total sugars tended to increase whereas acidity and overall acceptability decreased in Kinnow mandarin due to postharvest treatments. During senescence, a lot of macromolecules were degraded and lost. Sugars are essential substrates in the carbon skeleton and energy metabolism, and in polymer biosynthesis in plants which resulted in reduced soluble solids in the present study during the ending part of the storage period. Storage of broccoli florets at 22ºC resulted in lower values of total and reducing sugars as well as starch during the post harvest senescence (Augustin *et al*., 2011).

Ascorbic acid (mg/100g)

Ascorbic acid contents among the treatments followed a drastically decreasing trend till the end of storage with significant changes among the treatments. Maximum ascorbic acid was 130.33, 128.33 and 116.67mg/100g in broccoli with hot water treatment at 48˚C on day 1, 2 and 3 during the storage study but on day 4, the maximum value was given by broccoli treated with BA 50ppm while the minimum ascorbic acid was and the least was 105, 86.13, 73, 61.53mg/100g in control broccoli on 1,2,3 and 4 days of storage. Ascorbic acid followed a decreasing trend during the storage period with significant change Pedro *et al.,* (2013) among the treatments was higher in the control. Ascorbic acid content was always lower in control compared to the postharvest treated broccoli which was in agreement with the finding of Yuan *et al.,* (2010). Except BA treatment, decrease in ascorbic acid was smallest in water treated samples which was similar with the finding of Kazami *et al*., (1991) in the 5 days' storage at 20ºC.

Chlorophyll (µg/g)

There were significant differences in chlorophyll content among the treatments on each day of observation. The content started decreasing from day 1 showing maximum chlorophyll retention (287.33, 207.67, 193.53µg/g) on day 1, 2 and 3 days of storage study in broccoli with BA 25ppm with maximum chlorophyll 171 µg/g on day 4 in broccoli dipped in BA 50ppm and the lowest chlorophyll content during the storage was 268 and 146.17 µg/g in broccoli treated with calcium hypochlorite 100ppm on day1 and day2 respectively while the least on day 4 was observed in control i.e, broccoli without any treatment. High loss of chlorophyll was seen in control i.e., without any post harvest treatment. High chlorophyll retention throughout the storage period was found in broccoli BA 50ppm among all the postharvest treatments performed.

Yellowing percentage

Yellowing trend in post harvest treated broccoli during the storage study. Yellowing % followed an increasing trend with prolong storage. Yellowing did not occur in broccoli treated with BA 50ppm throughout the period of study while it started from day 3 in broccoli treated with BA 25ppm while it started from day 2 in broccoli treated with hot water at 48˚C, 1000ppm calcium hypochlorite and the control. Yellowing on day1 was least (0.33%) in broccoli treated with SA 1000ppm (T_5) and maximum (2.33%) in broccoli treated with SA 500ppm (T_6). On day 3, the maximum yellowing was 56.67% in control (T_9) and the least (1.33%) in broccoli dipped in BA 25ppm. On day 4, maximum yellowing was 90.33% in control (T_9) and the least was 3.00% in broccoli with BA 25ppm (T_2).

Yellowing of leafy and green vegetables has been attributed to peroxidase activity (Baardseth and von Elbe, 1989; Yamauchi and Watada, 1991) and lipoxygenase activity (Zhuang *et al*., 1995).

The activities these two enzymes could be responsible for yellowing of broccoli (Toivonen, 1997). External application of cytokinin is addressed to delay the floret yellowing of broccoli (Clarke *et al*., 1994).

Fungal decay (%).

No visible fungal growth was observed in treatment with BA 50ppm. On day 2, fungal decay started with 1.33% in broccoli with hot water treated at 45˚C (T_4), broccoli dipped in SA 1000ppm (T_5), 0.33% in those dipped in SA 500ppm (T_6) which was at par with treatment of calcium hypochlorite 50ppm (T_8) and with Calcium hypochlorite 100ppm (T_7) while remaining were intact. On day 3, the highest decay was in 18.33% in broccoli dipped in SA1000ppm (T_5) and the least was 0.5% in broccoli with 100ppm calcium hypochlorite (T_7). On day 4, BA 50ppm still showed no growth while the maximum decay was in hot water treated broccoli at 45˚C and SA 1000ppm having 50% decay and the least was 4.78% in broccoli with 100ppm calcium hypochlorite (T_7)**.**

Sensory evaluation

Colour

The colour change during the period of study followed a decreasing trend. On day 1, the maximum colour score was 4.97, 4.73, 4.73, 4.20, 2.67 in broccoli treated with BA 50ppm (T_1) throughout the storage period while the least was 4.13 and 3.07 in broccoli hot water treated at 45˚C on day 2 and day 3 while the minimum score was 2.87 in broccoli dipped in calcium hypochlorite 100ppm (T_7). On the last day of storage period, the least 1.40 in SA 1000ppm treatment (T_5).

Optimum green colour was seen in T_1 while the yellow colour intensity was highest in T_5(SA 1000ppm). Yellowing and quality loss of broccoli is usually accelerated by ethylene (Cao *et al*., 2015). Garitta *et al*., 2013 concluded that appearance of fresh broccoli was the critical attribute as evaluated by consumers.

Table.1 Effect of post harvest treatments on physiological loss in weight (%) of broccoli var. Aishwarya in room condition

Treatment	**Physiological loss in weight (%)**				**Market-ability(%) on 4th day**	**Yellowing (%)**			
	Days in storage					**Days in storage**			
	1	**2**	**3**	**4**		**1**	**2**	**3**	**4**
T_1(BA 50ppm)	1.09(5.99)	2.53(9.14)	4.19(11.81)	5.53(13.59)	82	*	*	*	*
T_2(BA 25ppm)	0.91(5.47)	2.19(8.51)	2.61(9.30)	3.06(10.07)	80	*	*	1.33(6.53)	3.00(9.88)
T_3(HWT at 48˚C)	0.86(5.32)	1.95(8.03)	2.10(8.32)	3.62(10.97)	75	*	1.67(7.33)	4.00(11.02)	20.00(26.06)
T_4(HWT at 45˚C)	0.94(5.56)	2.19(8.51)	3.73(11.13)	4.69(12.49)	71	0.67(3.85)	2.00(7.95)	48.33(44.02)	76.67(61.15)
T_5(SA1000ppm)	1.71(7.52)	2.84(9.61)	2.91(9.82)	4.93(12.83)	70	0.33(1.91)	4.00(11.47)	55.00(47.86)	89.33(70.93)
T_6(SA 500ppm)	1.28(6.49)	2.63(9.33)	3.40(10.61)	3.98(11.50)	73	2.33(8.13)	3.67(11.01)	20.00(26.06)	39.33(38.83)
T_7(100ppm calcium hypochlorite)	0.49(4.01)	1.12(6.07)	3.29(10.45)	4.36(12.04)	70	*	1.67(7.14)	56.00(48.44)	89.33(70.93)
T_8(50ppm Calcium hypochlorite)	0.46(3.90)	1.32(6.60)	2.53(9.15)	3.49(10.76)	78	1.00(5.73)	2.67(9.36)	10.00(18.37)	14.33(22.23)
T_9(Control)	0.93(5.54)	2.49(9.07)	4.61(12.34)	5.91(14.03)	55	*	4.67(12.45)	56.67(48.83)	90.33(71.86)
SEm±	**0.04**	**0.19**	**0.23**	**0.25**		0.47	0.42	1. 2.72	2.14
CD(P=0.05)	**0.11**	**0.58**	**0.70**	**0.74**		1.41	1.25	8.15	6.42

Note: values in brackets denote angular transformed data and * denotes no visible yellowing

Table.2 Effect of post harvest treatments on ascorbic acid (mg/100g) and total soluble solids (ºB) content of broccoli var. Aishwarya in room condition

	Ascorbic acid (mg/100g)					**Total soluble solids(ºB)**				
Treatment	**Days in storage**					**Days in storage**				
	At harvest	**1**	**2**	**3**	**4**	**At harvest**	**1**	**2**	**3**	**4**
T_1(BA 50ppm**)**	132	116.67	111.00	105.00	104.00	7.35	7.47	7.87	8.00	7.63
T_2(BA 25ppm**)**		119.00	100.00	101.67	97.57		7.80	7.70	7.57	7.03
T_3(HWT at 48˚C**)**		130.33	128.33	116.67	99.33		7.17	7.37	7.87	8.03
T_4(HWT at 45˚C**)**		110.67	102.00	90.60	82.67		7.23	7.43	7.37	7.23
T_5(SA1000ppm**)**		105.00	105.00	100.67	90.67		7.87	7.87	7.60	7.57
T_6(SA 500ppm**)**		114.00	108.67	101.80	93.33		7.30	7.17	7.07	7.03
T_7(100ppm Calcium hypochlorite**)**		106.67	92.67	75.01	62.34		7.83	7.90	7.63	7.63
T_8(50ppm Calcium hypochlorite**)**		122.33	111.67	105.34	94.70		7.70	7.93	8.13	8.03
T_9(Control**)**		105.00	86.13	73.00	61.53		7.73	7.93	8.03	7.10
SEm±		4.67	5.91	2.34	2.35		0.11	0.09	0.13	0.11
CD(P=0.05)		13.97	17.69	7.00	7.04		0.34	0.27	0.39	0.32

Table.3 Effect of packaging on ascorbic acid (mg/100g), total soluble solids(^{0}B) and chlorophyll (µg/g) content of broccoli var. Aishwarya in room condition

Treatment	Ascorbic acid (mg/100g)				Total soluble solids(^{0}B)				Chlorophyll content(µg/g)			
	Days in storage				Days in storage				Days in storage			
	At harvest	1	2	3	At harvest	1	2	3	At harvest	1	2	3
T_1(PP+ no perforation)	133	125.00	120.67	117.6 5	8.05	6.17	5.17	4.67	301	270.00	250.00	233
T_2(PP+1% perforation)		137.00	96.67	73.33		7.07	7.60	7.00		263.33	208.00	158
T_3(PE +CFBB)		131.00	100.27	90.33		8.13	8.00	7.00		258.33	176.00	91.00
T_4(CFBB+inside laminated)		130.67	111.33	78.33		7.53	6.77	6.60		290.00	247.67	138.67
T_5(PE+ no perforation)		129.33	103.33	84.00		8.30	8.00	8.00		300.00	276.67	246.67
T_6(PE+1% perforation)		125.00	117.67	83.33		8.07	8.00	8.00		263.33	263.33	240.00
T_7(Shrink wrap)		120.67	106.67	83.34		7.27	7.10	7.07		253.33	196.67	166.67
T_8(control)		117.33	101.17	66.67		7.33	6.30	6.07		246.67	183.33	113.67
SEm(±)		1.95	1.92	2.66		0.13	0.11	0.13		10.97	9.10	9.01
CD(P=0.05)		5.89	5.80	8.03		0.39	0.33	0.39		33.19	27.52	27.26

Table.4 Effect of post harvest treatments on sensory characteristics of broccoli var. Aishwarya in room condition

Treatment	Sensory evaluation of colour					Smell				Texture				Browning			
	Days in storage					Days in storage				Days in storage				Days in storage			
	At harvest	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
T_1(BA 50ppm**)**	5	4.97	4.73	4.20	4.00	4.57	3.49	3.45	3.43	4.16	4.23	3.77	3.17	4.97	4.67	3.97	3.50
T_2(BA 25ppm**)**		4.83	4.70	3.80	3.67	4.40	3.57	3.57	3.30	4.13	4.17	3.50	3.10	4.90	4.70	3.47	3.17
T_3(HWT at 48˚C**)**		4.60	4.03	3.60	3.33	4.27	3.73	3.73	2.87	4.47	4.20	3.27	2.83	4.67	4.23	4.03	2.67
T_4(HWT at 45˚C**)**		4.13	3.07	3.37	3.10	4.33	3.50	3.50	3.43	4.30	4.1	3.27	2.93	4.77	4.03	3.80	3.17
T_5(SA1000ppm**)**		4.37	4.07	3.33	3.13	4.33	3.83	3.83	2.67	4.40	4.10	3.27	3.03	4.67	4.17	3.50	2.87
T_6(SA 500ppm**)**		4.53	4.17	3.43	3.20	4.43	3.40	3.40	2.43	4.40	4.23	3.07	2.97	4.73	4.40	3.63	3.00
T_7(100ppm Calcium hypochlorite**)**		4.50	3.47	3.30	3.07	4.60	3.93	3.93	3.17	4.33	3.97	3.53	3.07	4.60	4.27	4.70	3.93
T_8(50ppm Calcium hypochlorite**)**		4.70	4.27	3.87	3.43	4.53	3.57	3.57	3.40	4.50	4.33	2.93	3.03	4.67	4.30	4.57	4.30
T_9(Control**)**		4.43	3.73	3.10	2.60	4.53	3.70	3.7	2.93	4.30	3.67	3.13	3.03	4.43	4.00	3.97	1.67
SEm±		0.18	0.16	0.13	0.10	0.07	0.35	0.35	0.26	0.12	0.14	0.19	0.09	0.11	0.21	0.21	0.26
CD(P=0.05)		NS	NS	0.38	0.29	NS	NS	NS	NS	NS	NS	NS	NS	0.26	NS	NS	NS

*Score for colour: 5 = dark green, uniform colour; 4 = slightly yellow; 3 = moderately yellow; 2 = very yellow; 1 = extreme yellow
Score for smell:5 = no off-odour; 4 = slight off odour; 3 = moderately off odour; 2 = severe off-odour;1 = extreme off-odour
Score for texture: 5 = crispy; 4 = little rubbery; 3 = rubbery; 2 = soft; 1 = extremely soft
Score for browning: 5 = no browning; 4 = some browning; 3 = moderate browning; 2 = very much browning; 1 = extreme browning, NS= non

Smell

Smell score decreased continuously with prolong storage. On day 1, the highest smell score was 4.60 in calcium hypochlorite 100ppm broccoli treated (T_7) while the lowest score was 4.27 in hot water treated at 48˚C broccoli (T_3). On day 3, the highest was 3.93 again in calcium hypochlorite 100ppm treated broccoli (T_7) while the least score was 3.40 in T_6. On day 4, the highest score was 3.43 in T_1 and the least was 2.43 in SA 500ppm treated broccoli **(**T_6**)**. Smell score good was recorded in BA 50ppm and T_4(HWT at 45˚C) at the end of 4 days' storage period while the severe off odour almost started in SA 500ppm.

According to Khalili *et al.,* (2008) in storage of cytokinin-treated florets under modified atmosphere packages, the occurrence of changes related with the loss of quality was reduced and delayed compared to the control. This improved retention was mainly due to reduced ethylene production. The results indicated that cytokinin treatment significantly reduced fermentation product in packaged broccoli.

Texture

The texture started decreasing slowly with the highest texture score 4.50 in broccoli with calcium hypochlorite 50ppm (T_7) while the lowest score 4.13 in BA 25ppm treated broccoli (T_2) and it decreased till the end of the storage period. On day 3, the maximum score was 3.77 in broccoli with BA 50ppm (T_1) while the least was 2.93 in those with calcium hypochlorite 50ppm **(T_8)**. On day 4, again the maximum score was 3.17 in T_1(BA 50ppm) and the least 2.83 in hot water treated broccoli at 48˚C.

A decrease in firmness was observed during cold storage which was similar to the finding of Fernández *et al.,* (2013) due to loss of moisture. Texture was best in BA 50ppm at the end of storage period and the least texture score was in T_4(HWT at 48˚C).

Browning

From day1, the lowest score for browning of 4.43 in control (T_9) and the highest of 4.97 in T_1(BA 50ppm) While in day 3 and 4, the maximum score was 4.70 and 3.50 in broccoli dipped in calcium hypochlorite 100ppm (T_7) and the least score in 3.47 in broccoli with BA 25ppm (T_2) and 1.67 in control (T_9) respectively.

At the end of storage period, the maximum browning score was in T_1(BA 50ppm) while the least score was in T_9(control). Maximum browning score means lesser browning. Enzymatic browning is caused due to higher PPO activity responsible for browning in fruits and vegetables which are caused during ripening; senescence or stress condition coincided with membrane damage in fruits and vegetables (Mayer, 1987). According to Nasution *et al.,* (2013) inhibition of enzymatic browning catalyzed by the enzyme polyphenol oxidase is still one of the main challenges in postharvest handling of agricultural products.

Marketability (%)

Maximum marketability on day 3 was noted in broccoli with 50ppm BA treatment followed by broccoli with 25ppm BA with 82 and 80% respectively. Higher hot water treatment at 48˚C gave better marketability compared to 45˚C and broccoli dipped in calcium hypochlorite 50ppm gave better marketability than dipping in 100ppm calcium hypochlorite on 3rd day of storage and the least marketability was recorded in control i.e., broccoli without any treatment.

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