Studies on effectiveness of packaging on storability of broccoli Cv. Aishwarya

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Abstract

Research work was carried out in the department of Post-Harvest Technology of Horticultural Crops after procuring the broccoli samples cultivated in Horticulture Research Station, Mondouri. Effectiveness of packaging for storing broccoli head in room condition was done using polypropylene bags, CFB box, polyethylene bags and stretch wrap with different perforation to find the best packaging which would extend the shelf life as well as good physicochemical properties compared to the control. The changes during the storage period was analysed by completely randomised design with three replications regarding ascorbic acid, chlorophyll, total soluble solids etc. No yellowing occurred in polypropylene (PE) and polyethylene bag with no perforation. Fungal decay was least in polypropylene (PP) bag with no perforation while there was no decay in unpacked broccoli while sensory analysis gave best smell as well as texture score in PP with no perforation which is the most important acceptability criteria.

Keywords: ascorbic acid, chlorophyll, polypropylene, polyethylene, physiological loss in weight, yellowing

Introduction

Broccoli is an important exotic vegetable crop and a new introduction to India cherished mainly for the delicious taste, flavour and nutritive value. It is also known as calabrese or green sprouting broccoli, Italian broccoli, asparagus broccoli from family Brassicaceae and closely related to cauliflower. It is rich in vitamins, antioxidants, anti-carcinogenic 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). Glucosinolates accounts for the flavour of broccoli and in general consumer prefers broccoli that has a sweet, crisp, and characteristic broccoli flavour, rather than broccoli that has an intense bitter, pungent and green or grassy flavour.

Exotic vegetables like broccoli have opened up new opportunities for vegetable growers for diversification and offseason production in metropolis. Broccoli is usually stored for only a brief period as needed for orderly marketing. Broccoli is available in the winter months for a very short period. At room temperature (20-25°C), it turns yellow in 2 days after harvest under ambient atmospheres. Though it is grown abundantly in the foothills of Himalayas, it is gaining popularity among the vegetable growers but due to the high perishable nature of the vegetable, the shelf life of the crop is very short. Even though the crop is very nutritious and costly, there is lack in research regarding packaging information of the crop. So the current work was done to extend the shelf life of broccoli by doing different packaging to see the changes during storage at room temperature and monitoring was done to select the best packaging among the various packaging being used in the current research.

Materials and Methods

Crop cultivation of broccoli was done in the Horticultural Research station, Mondouri and the laboratory work was carried out in the Department of Post-Harvest Technology of Horticultural Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal in 2014. To carry out the experiment, fully grown immature broccoli heads with tender and dark green colour with unopened florets of variety Aishwarya were harvested and brought immediately to the laboratory in plastic crates and room cooled for few minutes. Consequently they were packed with different packaging materials of different perforations as follows:
**Experiment details**

\( T_1 \) - Polypropylene bags without perforation  
\( T_2 \) - Polypropylene bags with perforation (1%)  
\( T_3 \) - Polypropylene bag with CFB boxes  
\( T_4 \) - CFB box with inside plastic laminated  
\( T_5 \) - Polyethylene bag with perforation (1%)  
\( T_6 \) - Polyethylene bag with perforation  
\( T_7 \) - Stretch wrap  
\( T_8 \) - Control (without any packaging material)

**Method of treatment**

Polypropylene bags (100 gauge), polyethylene bag (150 gauge) and stretch wrap (50 gauge) were used for packing during the experiment. After each type of packaging, the broccoli heads were stored in room (weather data in Fig. 1.). The physiochemical changes during the storage period were evaluated to find out the best treatment with good physiochemical constitution among the various packaging’s tested.

**Number of replication:** 3  
**Statistical design:** Completely randomised Design.

**Observations recorded**

**Physiological loss in weight (%)**

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

**Marketability (%)**

The marketability of broccoli was determined taking into consideration the quality (colour, texture or crispiness, flavour and defects like yellowing, browning and decay) and was expressed in percentage (%).

**Chlorophyll (µg/g):** Total chlorophyll content was determined by spectrophotometric method (Ranganna, 2017)\(^{[22]}\). 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 up to known volume with 80% acetone and the Optical Density 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 = \( (7.12 \times OD \text{ at 660nm}) + (16.8 \times OD \text{ at 642.5nm}) \)

**Yellowing (%):** Whole green broccoli head is divided into four equal parts (out of 100 percent). The area which becomes yellow is recorded visually according to the 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 (ºB):** TSS was determined by Hand Refractometer which works on the principle of total reflection and it is calibrated at 0ºB before use by placing few drops of distilled water on the prism in the specimen chamber of the refractometer. A refractometer calibrated with a sugar concentration (ºBrix) 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.  
ºBrix is used as an indicator of total soluble solids in the juice of fruits and vegetables (Varnam and Sutherland, 1994)\(^{[22]}\). A few drops of broccoli juice were taken for each sample for estimating the TSS which was expressed in terms of degree brix (ºB). For determining the TSS (Erma Hand Refractometer I.S.O 2173), a drop of sample juice is placed on the prism and the percentage of dry substance in it read directly.

**Ascorbic acid (mg/100g):** 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, 2017)\(^{[22]}\).

\[
\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Wt or vol of the sample taken for estimation} \times 100}
\]

**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 5 point hedonic scale (Ranganna, 2017)\(^{[22]}\).

**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 = 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

**For dry broccoli**

**Colour**

5 = green  
4 = slight faded green  
3 = moderately faded  
2 = severely faded  
1 = extremely faded
Physiological loss in weight (%)
The effect of packaging on the physiological loss in weight of broccoli var. Aishwarya during the storage period has been presented in Table 1. The loss in weight increased with the prolong storage for all the types of packaging. There were significant differences in PLW among all the treatments on each day of observation. Maximum loss in weight (4.96 to 16.75%) throughout the storage period was observed in control i.e. unpack broccoli while the least loss in weight (0.01 to 2.23%) was noted in polypropylene packed broccoli with no perforation (T2) during the storage study.

Packaging alters the atmosphere surrounding the plant product mainly due to respiration and generate a modified atmosphere. The packed broccoli had overall lesser loss of weight compared to without any packaging material which is supported by Toivonen (1997) who reported that wrapping of broccoli resulted in the best firmness retention and least water loss, independent of storage temperature which may be due to high moisture loss caused by high rate of transpiration and respiration through uninterrupted O2 supply and lower relative humidity compared to wrapped treatments. Package with no perforation gave lesser weight loss than the perforated types of packages due to lack of aeration and polypropylene was the best in reducing weight loss compared to polyethylene which were in agreement with Esmail (2006) who had reported that large boxes (45x30x14cm) and non-perforated polyethylene bags were the promising ones in minimizing the heads loss in weight and the unmarketable percentage. The increasing trend of loss in weight during the period of study was supported by Hong et al., 2010 who evaluated that vegetable weights lost gradually as time went along and a linear relationship was found. PLW in shrink wrapped was lowest during the storage compared to other packages with perforation which was in Agreement with Sajeev and Gupta (2007). Non perforated polypropylene package gave better PLW than non-perforated polyethylene package.

Table 1: Effect of packaging on physiological loss in weight (%) and marketability of broccoli var. Aishwarya in room condition

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days in storage</th>
<th>Marketability (%) on 3rd day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>T1 (PP+ no perforation)</td>
<td>0.01(0.57)</td>
<td>1.88 (7.88)</td>
</tr>
<tr>
<td>T2 (PP+1% perforation)</td>
<td>0.75(4.98)</td>
<td>1.39(6.77)</td>
</tr>
<tr>
<td>T3 (PE+CFBB)</td>
<td>1.11(6.04)</td>
<td>1.63(7.33)</td>
</tr>
<tr>
<td>T4 (CFBB + inside laminated)</td>
<td>2.26(8.63)</td>
<td>4.09(11.66)</td>
</tr>
<tr>
<td>T5 (PE+ no perforation)</td>
<td>1.05(6.0)</td>
<td>1.87(7.8)</td>
</tr>
<tr>
<td>T6 (PE+1% perforation)</td>
<td>1.94(7.99)</td>
<td>2.65(9.88)</td>
</tr>
<tr>
<td>T7 (Shrink wrap)</td>
<td>0.77(5.04)</td>
<td>1.75(7.59)</td>
</tr>
<tr>
<td>T8 (control)</td>
<td>4.96(12.86)</td>
<td>11.79(20.0)</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.36</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Table 2: Effect of packaging on yellowing (%) and fungal decay (%) of broccoli var. Aishwarya in room condition

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yellowing (%)</th>
<th>Days in storage</th>
<th>Fungal decay (%)</th>
<th>Days in storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>T1 (PP+ no perforation)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>T2 (PP+1% perforation)</td>
<td>5.67(13.16)</td>
<td>36.00(38.82)</td>
<td>68.33(55.83)</td>
<td>*</td>
</tr>
<tr>
<td>T3 (PE+CFBB)</td>
<td>*</td>
<td>*</td>
<td>73.3(64.91)</td>
<td>*</td>
</tr>
<tr>
<td>T4 (CFBB + inside laminated)</td>
<td>0.67(3.83)</td>
<td>1.67(7.33)</td>
<td>63.33(52.83)</td>
<td>*</td>
</tr>
<tr>
<td>T5 (PE+ no perforation)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>
The less PLW in refrigerated storage may be attributed to more RH within the refrigerated unit as compared to ambient atmosphere and slow rate of respiration and transpiration under low temperature condition.

**Ascorbic acid (mg/100g)**

The data presented in Table 3 indicated variation of ascorbic acid content among the treatments during the storage period. Among the various types of packaging decreased in content occurred till the end of 3 days’ storage period. Non perforated packaging gave better amount of ascorbic acid content compared to perforated or unpacked ones. Maximum ascorbic acid content (125 to 117.65mg/100g) was observed in broccoli packed in polypropylene bag with no perforation (T₁) throughout the storage period while the least content (117.33 to 66.67mg/100g) was recorded in unpacked broccoli (T₄) during the storage period. Polypropylene bag retained higher amount of ascorbic acid among other types of packaging. Fair amount of ascorbic acid retained in the PE packed broccoli with 1% perforation during the period of study was. The overall low value of ascorbic acid in unpacked broccoli as compared to packed one may be correlated with the finding of Barth et al., 1993 where ascorbic acid in packaged asparagus spear was greater than unpacked ones at 20ºC.

**TSS (°B)**

The effect of packaging on total soluble solids content of broccoli during storage period was significant in Table 3. A decreasing trend in TSS was recorded for each day of observation. Maximum TSS, ranging from 8.30 to 8.00°B from 1 to 3 days after storage, was recorded in broccoli packed in PE with no perforation (T₃) while the minimum value of TSS ranged from 6.17 to 4.67°B from 1 to 3 days after storage in PP bag with no perforation (T₁). All the treatments followed a decreasing trend from day 1 during the period of study while broccoli packed in PE with no perforation (T₃) and those packed in PE with 1% perforation (T₄) remained constant on day 2 and 3. Decrease of Brix value was observed during storage of broccoli as reported by Castro et al. (2011) [8].

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ascorbic acid (mg/100g)</th>
<th>Total soluble solids(°B)</th>
<th>Chlorophyll content(µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Days in storage</td>
<td>Days in storage</td>
<td>Days in storage</td>
</tr>
<tr>
<td>T₁ (PE+1% perforation)</td>
<td>At harvest</td>
<td>1  2  3</td>
<td>At harvest</td>
</tr>
<tr>
<td>T₂ (Shrink wrap)</td>
<td>133</td>
<td>125.00 120.67 117.65</td>
<td>8.05</td>
</tr>
<tr>
<td>T₃ (Control)</td>
<td>11.67(19.88)</td>
<td>50.00(44.98)</td>
<td>18.33(25.29)</td>
</tr>
<tr>
<td>S EM (±)</td>
<td>137.00 96.77 73.33</td>
<td>8.05 6.17 5.17 4.67 301 270.00 250.00 233</td>
<td></td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>131.00 100.27 90.33</td>
<td>8.00 6.17 5.17 4.67 301 270.00 250.00 233</td>
<td></td>
</tr>
</tbody>
</table>

The decreasing trend in TSS may be explained with the finding of Li and Gao (2000) [16] who showed that the senescence of packed broccoli stored at 16℃ was very fast; the content of total soluble protein, total acids, vitamin C and chlorophyll decreased rapidly.

**Chlorophyll (µg/g)**

It was observed in Table 3 that chlorophyll content followed a decreasing trend during the storage period. Chlorophyll content remained highest in broccoli packed with PE with no perforation ranging from 300 to 246.67µg/g during the storage period while the lowest contents (176 and 91µg/g on 2 and 3 days after storage) were recorded in broccoli packed in PE with CFBB (T₃). Post-harvest storage of packed broccoli followed decreasing trend of chlorophyll during the 3 days’ storage period with the maximum chlorophyll content in polyethylene bag with no perforation. Chlorophyll content declined as the florets began to yellow when held at 20°C in darkness. After 3 days at 20°C in darkness, chlorophyll was lost from the control florets. Florets attached to broccoli heads began to degreen immediately after harvest, with large degreening between 48 and 72 hours during which the florets yellowed. After 3 days at 20°C, chlorophyll was lost from the control floret (Tian et al., 1994) [28].

The decrease in chlorophyll content in packed broccoli and packaging may have delayed the loss of chlorophyll by retarding the chlorophyllase activity and the progressive decline of ascorbic acid was supported with the finding of Yan and Liu, 2012 [33] which is in accordance with finding of Serrano et al. (2006) [25]. The decreasing trend in chlorophyll content was supported by the finding of Nath et al. (2011) [18] where they reported that total chlorophyll content decreased linearly in both the open ambient in plastic tray and ambient micro-perforated-packed broccoli florets.

Toivonen and Sweeney (1998) [31] explained a constant decline in chlorophyll content of broccoli variety Emperor over 4 days at 13°C. Catalase activity was higher in Emperor,
suggested that catalase is not important in providing resistance to chlorophyll loss in broccoli while Hong et al. (2010) [10] have confirmed that chlorophyll contents of cucumber, pakchoi and broccoli showed an increasing trend with time, no matter they were wrapped or unwrapped. The rapid decline in chlorophyll content indicates high oxidative damage that in high temperatures is more rapid than in low temperature (Zahra et al., 2011) [39].

**Yellowing (%)**

Yellowing of broccoli had been shown in the Table 2 with significant effect due to different packaging. Maximum yellowing ranged from 5.67 to 68.33% in broccoli packed in PE with no perforation during the storage period while minimum yellowing (18%) was observed in broccoli with shrink wrap on 3 days after storage. Broccoli packed in PP with no perforation (T₁) and those packed with PP with no perforation (T₂) did not show yellowing throughout the storage period. Tian et al. (1994) [28] reported ethylene production from harvested broccoli cv. Shogun florets stored at 20ºC increased as the sepal tissues yellowed since broccoli is an immature inflorescence with developing reproductive and vegetative structures, which harvest stress forces into premature senescence. Eason et al. (2007) [7] reported that broccoli in control starts to senesce and yellow after 48 hours. Senescence of broccoli stored at 0ºC and 5ºC was delayed and the storage life was 30 and 24 days respectively. Atmospheric air leads to senescence and loss of green color. Hence, the natural biological variance and the packaging technology used lead to different respiration rates and thus color changes in packaged wild rocket (Martinez et al., 2008 [17]; Seefeldt et al., 2012 [24]).

Nishikawa et al. (2005) [20] have also shown that broccoli florets senesced rapidly after harvest at ambient temperatures, accompanied by the yellowing of sepals, ethylene production and degradation of sugars. During postharvest senescence, the green chlorophyll pigments are oxidized into colorless substances revealing the yellow carotenoids (Toivonen and Brummell, 2008) [30]. Jia et al. (2009) [11] have shown that broccoli florets with no perforation at 4 and 20ºC treatment maintained the visual quality compared to micro hole, macro hole package and without pack broccoli.

**Table 4**: Effect of packaging on sensory characteristics of broccoli var. Aishwaryain room condition

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days in storage</th>
<th>Smell score</th>
<th>Texture score</th>
<th>Browning</th>
<th>Days in storage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T₁ (PP+ no perforation)</td>
<td>5</td>
<td></td>
<td></td>
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<tr>
<td>T₂ (PP+1% perforation)</td>
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<tr>
<td>T₃ (PE +CFBB)</td>
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<tr>
<td>T₄ (CFBB + inside laminated)</td>
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<td></td>
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<tr>
<td>T₅ (PE+ no perforation)</td>
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<td></td>
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<tr>
<td>T₆ (PE+1% perforation)</td>
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<td></td>
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<tr>
<td>T₇ (Shrink wrap)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>T₈ (Control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S EM (±)</td>
<td>0.14 ± 0.05</td>
<td>0.19 ± 0.01</td>
<td>0.18 ± 0.01</td>
<td>0.17 ± 0.14</td>
<td>0.11 ± 0.15</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.44 ± 0.58</td>
<td>0.58 ± 0.54</td>
<td>NS ± 0.53</td>
<td>0.42 ± 0.35</td>
<td>0.45 ± 0.51</td>
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</table>

<table>
<thead>
<tr>
<th>Sensory score for colour</th>
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</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>Sensory score for colour</td>
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<tr>
<td></td>
<td>Sensory score for colour</td>
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<tr>
<td></td>
<td>Sensory score for colour</td>
</tr>
<tr>
<td>T₁ (PP+ no perforation)</td>
<td>5</td>
</tr>
<tr>
<td>T₂ (PP+1% perforation)</td>
<td></td>
</tr>
<tr>
<td>T₃ (PE +CFBB)</td>
<td></td>
</tr>
<tr>
<td>T₄ (CFBB + inside laminated)</td>
<td></td>
</tr>
<tr>
<td>T₅ (PE+ no perforation)</td>
<td></td>
</tr>
<tr>
<td>T₆ (PE+1% perforation)</td>
<td></td>
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<tr>
<td>T₇ (Shrink wrap)</td>
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<tr>
<td>T₈ (Control)</td>
<td></td>
</tr>
<tr>
<td>S EM (±)</td>
<td>0.14 ± 0.05</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>0.44 ± 0.58</td>
</tr>
</tbody>
</table>

**Fungal decay (%)**

Fungal growth started from day 3 during the storage period in broccoli packed in PE with CFBB (T₃) and those packed in CFBB with lamination inside (T₅) showing 1.90% and 9.33% respectively.

It was evident from Table 2 that there was not any visible fungal growth during the 21 days among all the treatments. No significant differences were found in total aerobic microorganism population growth between packaged and non-packaged broccoli (Barth et al., 1993) [4]. High CO₂ concentration effectively retarded microbial growth in low permeable polyamide or polyethylene samples of broccoli (Cefola et al., 2010) [6].

**Sensory evaluation**

1. **Colour**

In Table 4, packaging gave significant effect on colour score of broccoli during the storage period. The colour remained dark green in all the treatments on day 0. Colour score showed reducing trend with progress in storage. Maximum score for colour was observed in broccoli packed in T₃ PE with no perforation (4.80 to 3.57 throughout the storage period) while minimum score ranging from 3.67 to 1.33 during the storage period was recorded in control i.e., unpacked broccoli.

Green colour was best retained in T (PE+ no perforation) at the end of the storage period among the treatments and the yellow colour was more in the broccoli without any packaging. Beer and Crouch (2013) [4] showed higher percentage of yellowing from 7 days throughout storage at 0ºC. By 21 days of storage the control had reached a mean colour score rating of above 25% yellowing and was therefore deemed unsalable. Packed broccoli maintained colour scores below 15-20% for the duration of storage.

II. **Smell**

Table 4 represented significant differences of smell core on day 2 to day 3 due to the effect of packaging. Decreasing colour score occurred from day 2 till the end of period of study. Maximum score was observed in control (T₅) i.e., unpacked broccoli with 14.10 and 3.80 on 2 and 3 days after storage while minimum score was noted in broccoli packed in PE with no perforation having scores of 3.03 and 2.20 on 2 and 3 days after storage.

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“5116”
MAP not correctly designed to match the respiration rate of the product, can lead either to anaerobic respiration due to too low transmission rates of gases over the packaging material or to an internal atmosphere composition close to atmospheric air at too high transmission rates. Anaerobic conditions lead to development of off-odors and tissue degradation due to respirational fermentation (Allende et al., 2004; Kim et al., 2004). III. Texture

The data presented in Table 4 indicated that there was a significant difference for texture score among the treatments during the storage period. Texture score followed decreasing trend with the progress of storage period. Maximum scores for texture of 4.20 to 4.40 during the storage period were observed in broccoli packed in PE with no perforation while minimum score for texture was noted in control (Tₐ), i.e., broccoli with no packing ranging from 1.17 to 1.93 during the storage period.

PE-packaging maintained the external appearance of fruits irrespective of storage systems (Ahmad et al., 2013; Toivonen, 1997) have also reported that wrapped packaging of broccoli gave the best firmness retention and least water loss independently of storage temperature.

IV. Browning

It could be concluded from Table D that there was no significant difference in score of browning during the period of storage study except in day 3. Maximum scores for browning were reported in broccoli packed in CFBB with lamination inside (T₄) with scores ranging with 4.93 and 4.67 on 1 and 3 days after storage respectively while minimum scores from 4.80 to 3.33 were recorded on 1 and 3 DAS in control (Tₐ) i.e., unpacked broccoli.

Kraker (1991) also showed that the incidence of brown discoloration occur 1 week after harvest in French beans and simulated for transport. Injuries of browning and off odours leading to unmarketability associated with CO₂ concentration have been reported by O’Hare et al. (2000). Broccoli consists of flavonoids while Sun et al. (2011) stated that major flavonoids from pericarp tissues of litchi serve as potential substrates for enzymatic browning reaction while Landrigan et al. (1994) observed that the superficial browning of rambutan pericarp is related to water loss. Esiyok et al. (2010) stated that the score for marketing quality visible in broccoli at ambient condition declined with the advancing shelf life period. The maximum storage life at 20°C was approximately 72 hours according to King and Morris (1994).

Marketability (%)

Highest marketability was recorded on broccoli treated with polypropylene bag with no perforation since there was lesser yellowing and good texture which was followed by broccoli in polyethylene with CFBB on 3rd day of storage. The least marketability was observed in unpacked broccoli (Table 1).

Conclusion

Yellowing is the main problem in post-harvest life of broccoli which leads to unmarketability of the crop in the market due to consumer dislike. Even though broccoli starts yellowing, it contain appreciable amount of ascorbic acid. Among the various packaging done in broccoli, broccoli packed with polypropylene gave the result on biochemical constitution as well as sensory value compared to the unpacked broccoli.

References