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Changes in Quality of Broccoli Stored under Modified Atmosphere Packaging in Polymeric Films

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A B S T R A C T

The study was under taken to assess the impact of differential in-pack gaseous conditions generated through modified atmosphere packaging (MAP) using different packaging films (low density polyethylene (LDPE) and polypropylene (PP), having thickness 150 guage and bag area 0.14m^2) with and without perforations and variable head space (HS) on the quality of broccoli stored for 10 days at 15°C and relative humidity (RH) of 75%. Quality of stored broccoli was adjudged on the basis of retention of chlorophyll for all the packaging treatments, for the storage period. Quality parameters *viz.*, β carotene and ascorbic acid that affect the chlorophyll retention were also recorded. The final retention levels of quality parameters were influenced by package gaseous condition. The Chlorophyll and β-carotene retention were recorded better in perforated LDPE film packages having 0.8 HS than in PP film packages at the end of storage period. Similar results were recorded for ascorbic acid *i.e.* higher values in perforated LDPE packages having 0.8 HS. The low in-pack O_2 concentration (approximately 4-5 %) along with high CO_2 concentration (approximately 9-11 %) may have enhanced the retention of antioxidant components *i.e.* β-carotene and ascorbic acid for longer period, which in turn have resulted in increase in chlorophyll retention. The results indicated that packaging film permeability for O_2 and CO_2 or head space might be such that equilibrated O_2 concentration remains near to 4-5% and CO_2 concentration to 9-11%, so as to affect a beneficial retention of chlorophyll with lesser browning.

Introduction

Practical applications

Broccoli is a high value crop and is an important source of vitamins and anti-carcinogenic substances (Nestle, 1998). Broccoli is a high respiring crop, which results in reduction of shelf- life and quality in a short time. Traditional methods of packaging and handling reduce the shelf-life and various nutritional and phyto-chemical components of fresh produce. Temperature control and atmospheric modifications help to maintain the produce quality as they reduce the respiration rate and thus enhance the shelf-life of produce. The present study was taken up to know respiratory behavior of fresh broccoli at 15°C temperature and 75% relative humidity (commonly maintained during transportation and retail distribution in India) and also to see the effect of different polymeric films and packing conditions on its quality parameters. The results showed that the use of polymeric film packages can help in maintaining the sensory and nutritional quality of broccoli and hence shows the potential of MAP for packaging of broccoli. MAP can be beneficial method for safe storage, transportation and handling of this highly perishable produce in the food chain, as compared to traditional storage techniques.

Vegetables are the natural source of vitamins, minerals and other nutrients required for human development. However, they suffer losses in their quality and quantity between harvest and consumption. Since, fruits and vegetables are highly perishable, efficient post harvest treatment is an absolute necessity for effective extension of shelf life. Broccoli is a good source of vitamins A and C. It is also reported to have anti-cancerous properties and medicinal properties which can cure heart ailments and diabetes. The broccoli contains 89.1 percent moisture, 3.6 g protein, 0.3g fat, 5.9g carbohydrates, 2500 IU vitamin A, 113mg vitamin C, 78 mg phosphorus, 1.1mg iron, 0.23mg riboflavin, 0.9mg niacin and 0.1mg thiamin per 100 g (Dhaliwal, 2007).

Today's consumer prefers perishable produce in fresh form and their demand is growing day by day in daily food requirement. The fresh produce is sold in variety of commercial packages. Broccoli have high respiration rate and hence improper selection of temperature and packaging material shortens its shelf-life at the retailer's level. Broccoli also has shorter life at room temperature due to immaturity of texture at the moment of the harvest as well as due to various other physiological factors regulated by the genetic mechanisms (Vamos, 1981). Chemical treatments, temperature control and atmospheric modifications by packaging in polymeric films can maintain produce quality and enhance shelf-life of fruits and vegetables viz. decay, browning, discoloration of pigments, loss of flavor, texture and nutritional quality (Wiley, 1994; Brecht, 1995). The green broccoli is preferred by the buyer and fetch premium price. Chlorophyll is related with the bright green colour and if not properly cared after harvest it degrades during storage, transport and handling. The major changes taking place during its senescence include degradation of chlorophyll, opening of the flower buds, loss of turgidity, off-odors development, loss of nutritional value and an increase in the peroxidase activity (Hansen, 2001). Hence, it is necessary to avoid senescence of green coloured crops such as broccoli to retain its chlorophyll content and thus the commercial value.

Modified atmosphere packaging (MAP) of produce in polymeric films in combination with storage at low temperature extends the shelf-life of fresh produce, through interaction of the natural process of respiration of produce with the restricted gaseous exchange across the polymeric film package to control the in-pack O_2 and CO_2. The steady state in-pack gaseous concentrations have been reported to delay the senescence, maintenance of physico-chemical constituents and extension of shelf-life of different crops (Pentima *et al.*, 1995; Saito *et al.*, 2000; Rai and Paul, 2007). Selection of an appropriate packaging film (perforated, non-perforated) for broccoli is an important criterion for its storage, as improper selection will lead to development of off-flavour and loss of quality in a very short period. The package fill weight (or in-pack head space) also affects the various physico-chemical constituents of the packaged produce through creation of different in-pack gaseous concentrations of O_2 and CO_2.

The present study was conducted to investigate the impact of polymeric films and variable in-pack head space on physico-chemical constituents of broccoli stored at 15^oC and relative humidity of 75 % under modified atmospheres.

Materials and Methods

The farm-fresh broccoli obtained from the farmer of village Bargari, district Faridkot was sorted for uniform head-size. The harvested broccoli heads were then air-cooled for 2 h, inside a cold room (Frig India Ltd., New Delhi, India) maintained at 15°C and 75% relative humidity. Pre-cooling prepared the broccoli heads for subsequent storage temperature regime.

Packaging and storage

After pre-cooling, the broccoli heads were packed in packages (27.5x 25.5 cm; bag area 0.14m^2) made from two types of polymeric film (LDPE and PP). Different quantities of the produce were packed to vary the headspace volume. The perforated (2 perforation per package) and non-perforated packages were selected for the study. The diameter of each perforation was 0.3 mm (Schreiner *et al.,* 2007; Rai *et al.,* 2008). Macro perforations provide additional gaseous diffusion across the film packages (Techavises and Hikida, 2008) and therefore can be used to increase the gas permeability of ordinary polymeric films. The package used for packaging were procured from market of same gauge (150 gauge), but on actually measuring the thickness in laboratory with the help of thickness tester (Labthink, model CHY-C2, China) it was found that thickness of LDPE film was 40µm and that of PP film was 36μm. The gas permeability coefficients of the LDPE packaging film for O_2 and CO_2 at 15°C, measured by a gas permeability tester (Labthink, model BTY-B1P, China) were observed to be 5.96 × 10^{-5} and 2.52× 10^{-4} ml m m^{-2} h^{-1} kPa^{-1}, respectively and for the PP packaging film, they were observed to be 1.49 × 10^{-5} and 5.24× 10^{-5} ml m m^{-2} h^{-1} kPa^{-1}, respectively. Effective permeability of gases and water vapour through perforations was estimated by the following relationship given by Techavises and Hikida (2008) which is valid for temperature range of 5-25^{o}C and film thickness of less than 0.025 mm. The effective permeability of the perforation was 0.986 ml.h^{-1}kPa^{-1}, taken to be equal for both O_2 and CO_2. Packaging was done inside the cold room itself, to minimize the respiration changes. The sample size was 250g and 350g resulting in head space (HS) of 0.8 and 0.7 respectively. The packages containing fresh broccoli heads were then heat sealed and kept for storage in an environmental control chamber (Vista Biocell Ltd., New Delhi, India). The gaseous concentration of O_2 and CO_2 in all the packages was assumed to be is 21.16% and 0.03% at the beginning of the storage. The control samples were kept unsealed under the similar environmental conditions. The experiments were replicated thrice. The observations were recorded after first, third, sixth and tenth day of storage. The weighing was done with help of an electronic weighing balance (having least count 0.001g). An average of four readings was taken for calculating the loss in weight (%) of the material.

Gas analysis of package headspace

The headspace concentration of O_2 and CO_2 were analyzed using a portable headspace gas analyzer (Model 902 D Dualtrak, Quantek, USA). The instrument measured in-pack gas concentration using an electrochemical and infrared sensor (sensitivity: 0.1% O_2 and 0.1% CO_2, accuracy 0.1% O_2 and 0.1% CO_2) for O_2 and CO_2 concentrations respectively. The instrument was calibrated before any experiment with standard gases. A particulate filter and a removable needle with dual side-port holes were used on the sampling probe to draw the headspace sample from the package with the help of an electronically controlled miniature pump. The drawn sample was fed simultaneously to the O_2 and CO_2 sensors and the concentration O_2 and CO_2 were directly read on the digital display panel of the instrument.

Quantitative analysis of pigments

The quantification of pigments (chlorophyll and β-carotene) was carried out as per Nagata and Yamashita (1992). One gram of broccoli sample was homogenized with 10 ml of acetone and n-hexane (4:6) solution using a tissue homogenizer (Labco Ltd., India) for 30 s over ice. The homogenized solution was allowed to stand for 30 s. One ml of the supernatant was taken and was diluted with 9 ml of the extract solution. The resulting solution was analyzed spectrophotometrically with the help of an UV-Vis spectrophotometer (Spectroscan 80DV, Biotech Engineering Management Company Limited, UK). Optical density of the solution was measured at wavelengths of 663, 645, 505 and 453 nm. Acetone and n-hexane (4:6) solution was used as standard solution. The pigments were quantified and then expressed as mg/100g fresh weight (fw) of sample.

Ascorbic acid determination

The ascorbic acid concentration was estimated quantitatively as per the modified 2, 6 dichlorophenolidophenol (DIP) method proposed by Klein and Perry (1982). One gram of broccoli sample was homogenized with 10 ml of 1% metaphosphoric acid (v/v) over ice to avoid any chemical changes during extraction, using a tissue homogenizer for 1 min. The extract was centrifuged at 3000 rpm in a cold centrifuge at 3^oC for 15 min. One ml of supernatant was mixed with 9 ml of 0.05 mM DIP using a vortex shaker (Labco Ltd., India) for 15s and optical density of the solution was measured against the blank at wavelength of 515 nm. The standard curve for ascorbic acid was obtained within the linear range of 0-500 µg ascorbic acid per ml. The ascorbic acid content was expressed as mg/100g (fw) of sample.

Sensory evaluation

In-pack water accumulation and anaerobic head space generally results in odour development. In the present investigation, sensory analysis was carried out to evaluate odour and water accumulation. The sensory assessment for stored broccoli was carried out by a three member trained panel. The aroma was evaluated by modifying the procedure of Carvalho and Clemente (2004) and the water accumulation was evaluated as per the nine point scale proposed by (Rai *et al.*, 1999). The complete score chart is presented in table 1.

During scoring, the intermediate scores were also given to the samples depending upon the perceived condition of the samples.

Statistical analysis

One-way analysis of variance (ANOVA) and multiple comparisons (Fisher's least significant-difference test) were used to evaluate the significant difference among different treatments at $p < 0.05$ (Sun *et al.*, 2007) using a statistical package (Statgraphics Plus, Statpoint Inc., USA). Data were expressed as means ± standard deviation.

Results and Discussion

Headspace concentration of O_2 and CO_2

There was sharp change in the gaseous concentration of the packages during the first 24 hours and a near-steady was observed thereafter (Fig. 1). The gaseous concentration for O_2 ranged between 3-8% and for CO_2 it ranged between 6-9% at the end of storage for all the perforated packages and for non perforated packages it ranged between 0 - 0.4 % for O_2 and 10-18% for CO_2 in both the films. As clear from figure 1a that in LDPE film packages, the concentration of O_2 arrived at 7.3% in perforated and 0.00% in non-perforated packages having head space (HS) 0.8 and it comes to 5.0% in perforated and 0.00% in non-perforated packages having HS 0.7; at the end of 1st day of storage. The concentration of O_2 in perforated LDPE packages remained above anaerobic levels till the end of storage period *i.e.* 6.0% in packages having 0.8 HS and 3.9% in packages having 0.7 HS, but in non-perforated it became anaerobic after 1st day and remained anaerobic till the end of storage. The concentration of CO_2 in LDPE packages ranged between 6.0–8.1% in perforated and 15.9–10.0 % in non perforated in 0.8 HS packages; and in 0.7 HS packages it ranged from 7.6–9.0% in perforated and 18.1–10.4 % in non perforated. In LDPE perforated packages having 0.8 HS, enough amount of oxygen was available for aerobic respiration till the end of storage.

The concentration of O_2 in PP packages arrived at 7.6 % in perforated and 0.4 % in non perforated packages having 0.8 HS; and it arrived at 5.1 % in perforated and 0.3 % in non perforated 0.7 HS packages, at the end of storage period (Fig. 1b). The CO_2 concentration recorded in PP packages was 5.9–7.2 % in perforated and 15.2–10.1 % in non perforated 0.8 HS packages, and 7.6–8.3% in perforated and 17.5–10.5 % in non perforated packages having 0.7 HS. Concentration of O_2 remained higher than concentration of CO_2 in perforated PP packages having 0.8 HS during the storage. The CO_2 evolution rate of broccoli was recorded nearly 0.57 times the O_2 consumption rate, which shows that small amount of water vapour might also be produced. The equilibrated values of in-pack concentration of O_2 and CO_2 for the different head spaces were observed to be significantly different, which shows that variability in the head space results in this type of behaviour.

Weight loss

The weight loss is a physiological event that can be limited by controlling storage temperature and humidity but also by using appropriate packaging. The weight loss (WL) was significantly higher in control samples than the samples packed in the films. The WL is less in PP films than LDPE films although the difference in the mean values was not significant. A glance at figure 2a and 2b show that WL at the end of storage was negligible in samples sealed in polymeric films as compared to control samples that lost 8.34% of their initial weight. Even the change in head space did not produce any significant effect on WL of different samples kept in different films. The results obtained are quite comparable with the previous studies that packaging in polymeric films checked weight loss in perishable produce.

Effect of MAP on pigments

The present study reveals that, MAP resulted in a substantial maintenance of chlorophyll content of broccoli heads as compared to control samples. The retention of chlorophyll is more in LDPE as compared to PP films. In perforated and non-perforated samples in both type of package film significant difference in chlorophyll retention was recorded (Fig. 3a and 3b). In non perforated samples increase in chlorophyll was observed samples, which may be attributed to the high concentration of CO_2 in these packages, but non-perforated packages become anaerobic and sample become non fit for human consumption after 24 hrs, (discussed in subsequent heading Sensory Evaluation). As shown in figure 3, an initial decrease in the chlorophyll was observed under all the packaging treatments, when the in-pack O_2 was being consumed and a gradual increase in the CO_2 levels was taking place. Under these conditions, the decrease in chlorophyll content was largely influenced by higher levels of in-pack O_2

alone. These results were in agreement with the earlier reported observations of Moretti *et al.,* (2003) where an initial decrease in the chlorophyll content was observed for green collards under the influence of high or ambient levels of O_2. As the storage period progressed and a steady state was attained, CO_2 build-up took place inside the film packages leading to stabilization in the chlorophyll retention levels in both types of film packages. This is in agreement with the earlier reported observations of Kader (1986) that storage of fruits and vegetables at high CO_2 concentration may result in membrane protection due to direct action of CO_2 on the membrane or by slowing senescence.

In LDPE film packages retention in chlorophyll was recorded in all the treatments at the end of storage. Among the perforated LDPE packages having 0.8 and 0.7 HS non-significant difference was observed, though maximum chlorophyll retention (67.44%) was recorded in 0.7 HS packages (Fig. 3a) this may be due to low in-pack O_2 and high CO_2 values recorded in these packages, which is in accordance with the earlier reported work of various researchers on broccoli, asparagus and some other vegetables (Barth *et al* 1993; Zhuang *et al.*, 1994; Hirata *et al.*, 1995; Saito and Rai, 2005). In the perforated PP film packages, chlorophyll retention was highest in 0.8 HS packages (Fig. 3b) at the end of storage, but no significant difference was observed with 0.7 HS packages. The decrease in chlorophyll was less in LDPE packages as compared to those kept in PP packages this may be due to higher retention of antioxidants, particularly ascorbic acid and β-carotene, in LDPE packages as compared to PP packages. The antioxidants generally present in vegetables are ascorbic acid and β-carotene, which protect chlorophyll by inhibiting with the reactions that degrade it (Schwartz and von Elbe, 1983). The control samples turned yellowish orange under the normal atmospheric levels of 21% O_2 and 0.03% CO_2, at the end of storage, which indicated that even low temperature storage could not avoid senescence in the broccoli florets which led to loss of chlorophyll. Under the MAP condition the β-carotene remains largely unaffected. A decrease in β-carotene content was observed during first 24 hours of storage for broccoli florets kept in both LDPE and PP films, but it became more or less stable when gaseous concentration in packages arrived at steady state (Fig. 4a and 4b). At the end of storage, no significant change in the β-carotene content was observed for the broccoli packed in LDPE. However, in PP films, β-carotene of the broccoli florets was more in packages having 0.8 HS as compared to 0.7 HS packages and non perforated samples. This result was in conformation with the earlier reported findings (Weichmann, 1986; Saito and Rai, 2005), that β-carotene remains largely unaffected and is generally retained under MAP conditions of low O_2 and high CO_2. The control samples showed higher values of β-carotene content.

Changes in ascorbic acid content

A decrease in ascorbic acid content was recorded in all the packaging treatment for both the films at the end of storage. The retention of ascorbic acid content was higher in LDPE packages as compared to PP packages. The ascorbic acid content decreased sharply (Fig. 5a and 5b) in all the packaged samples and in control till 1st day of storage. In LDPE packages during the steady state, ascorbic acid increased slightly on the 3rd day; and then declined to 9.740 mg/ 100g fw in perforated packages having 0.8 HS and 9.169 mg/ 100g fw for packages having 0.7 HS; followed by 9.402 and 9.102 for non perforated LDPE packages having 0.8HS packages and 0.7HS respectively at the end of storage. In PP packaged samples final ascorbic acid content was recorded highest in non perforated packages having 0.8 HS *i.e.* 7.853 mg/ 100g fw followed by 7.267 mg/ 100g fw for perforated packages having 0.8 HS samples at the end of storage period. In control samples ascorbic acid content of 5.17 mg/ 100g fw was recorded at the end of storage. The final level of ascorbic acid content was substantially higher for LDPE packaged samples than for PP packaged samples, indicating that different gaseous atmospheres had significant effect on ascorbic acid of broccoli packaged in LDPE and PP films.

Sensory quality

The shelf-life of the stored produce is influenced largely by the sensory quality parameters such as odour and water accumulations which suggest its suitability for human consumption; irrespective of objectively or instrumentally determined parameters. The results of the study suggest that perforated samples in both the films having 0.8 HS remained sufficiently fresh till the end of storage in comparison 0.7 HS which showed deterioration in odour after 1st day of storage which changed to unacceptable odour at the end of storage period. The non perforated packages become anaerobic and unfit for consumption after 24 hours of storage. No off-odour was observed in perforated 0.8 HS packages till 1st day in LDPE, till 3rd day in PP; and till 1st day in 0.7 HS perforated PP packages (Fig. 6a and 6b). For the sample stored in perforated PP film very light off-odour was observed in packages having 0.8 HS on 6th day and for 0.7 HS packages on 3rd day of storage. For LDPE perforated samples, traces of off-odour were observed at the end of 3rd day of storage in 0.8 HS packages; whereas for 0.7 HS packages it was by the end of 1stday. The odour in the 0.8 HS packages in both films changed to light off odour at the end of storage while in 0.7HS packages it changed to nearly strong off odour at the end of storage. Traces of off-odour were observed in control after 1st day of storage which changed to very strong off odour at the end of storage period. The water accumulation was recorded less in LDPE films than PP films. It was also observed water accumulation was less in non perforated packages than in perforated packages. The water accumulation recorded was less for 0.8 HS packages as compared to 0.7 HS packages In LDPE packages having 0.7 HS slight water accumulation was observed for non perforated packages, but moderate water accumulation was observed in perforated packages at the end of 3rd of storage (Table 2).

Table.1 Score chart for sensory evaluation

Designated score	Aroma / Odour	Water Accumulation
0	--	Heads completely wet and water accumulation
1	Strong off odour	Heads and film moderately wet
2	Medium off-odour	--
3	Light off- odour	Heads moderately wet
4	Very light off-odour	--
5	No off-odour	Heads and film slightly wet
6	--	--
7	--	Heads slightly wet
8	--	--
9	--	No water accumulation

During scoring, the intermediate scores were also given to the samples depending upon the perceived condition of the samples.

Table.2 Changes in various quality components of broccoli florets under different treatments

Component	Packaging Film	Treatment	Initial Value	Final Value
Total Chlorophyll (mg/100g fw)	LDPE	Perforated 0.8HS	131.58	82.16
		Perforated 0.7 HS		88.73
		Non perforated 0.8HS		142.40
		Non perforated 0.7HS		146.77
		Control		39.08
	PP	Perforated 0.8HS	131.58	70.74
		Perforated 0.7 HS		79.26
		Non perforated 0.8HS		140.53
		Non perforated 0.7HS		143.98
		Control		34.52
β-carotene (mg/100g fw)	LDPE	Perforated 0.8HS	31.23	26.59
		Perforated 0.7 HS		25.97
		Non perforated 0.8HS		25.02
		Non perforated 0.7HS		25.19
		Control		27.05
	PP	Perforated 0.8HS	31.23	26.36
		Perforated 0.7 HS		25.72
		Non perforated 0.8HS		24.61
		Non perforated 0.7HS		24.11
		Control		27.09
		Non perforated 0.8HS		140.98
		Non perforated 0.7HS		149.74
		Control		191.85
Ascorbic acid content (mg/100g fw)	LDPE	Perforated 0.8HS	51.48	9.74
		Perforated 0.7 HS		9.17
		Non perforated 0.8HS		9.4
		Non perforated 0.7HS		9.00
		Control		6.21
	PP	Perforated 0.8HS	51.48	7.27
		Perforated 0.7 HS		6.64
		Non perforated 0.8HS		7.85
		Non perforated 0.7HS		7.12
		Control		5.17

Fig.1 Gaseous concentration (O_2 and CO_2) of broccoli florets at different levels of package head space stored under modified atmosphere. The plotted values are means of three replications per treatment along with their standard deviations

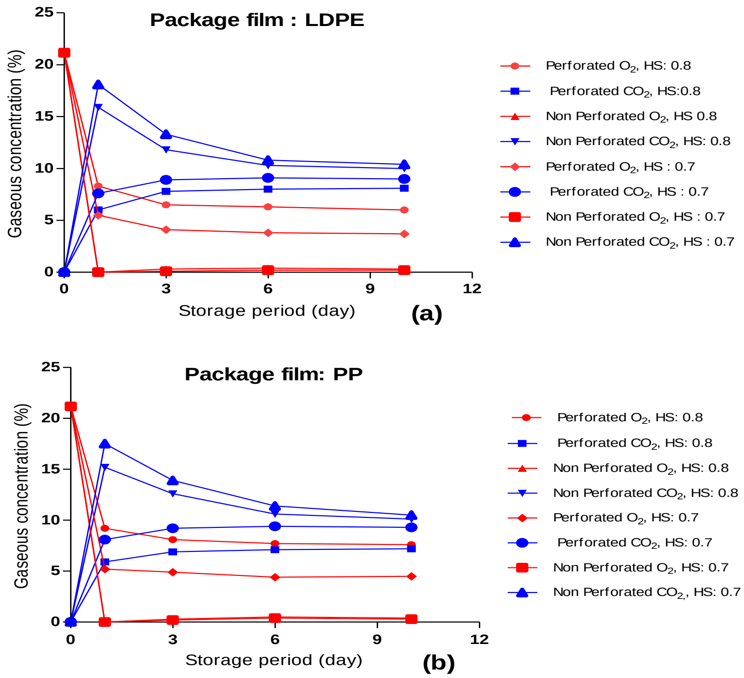


Fig.2 Weight loss (%) of broccoli florets at different levels of package head space stored under modified atmosphere. The plotted values are means of three replications per treatment along with their standard deviations

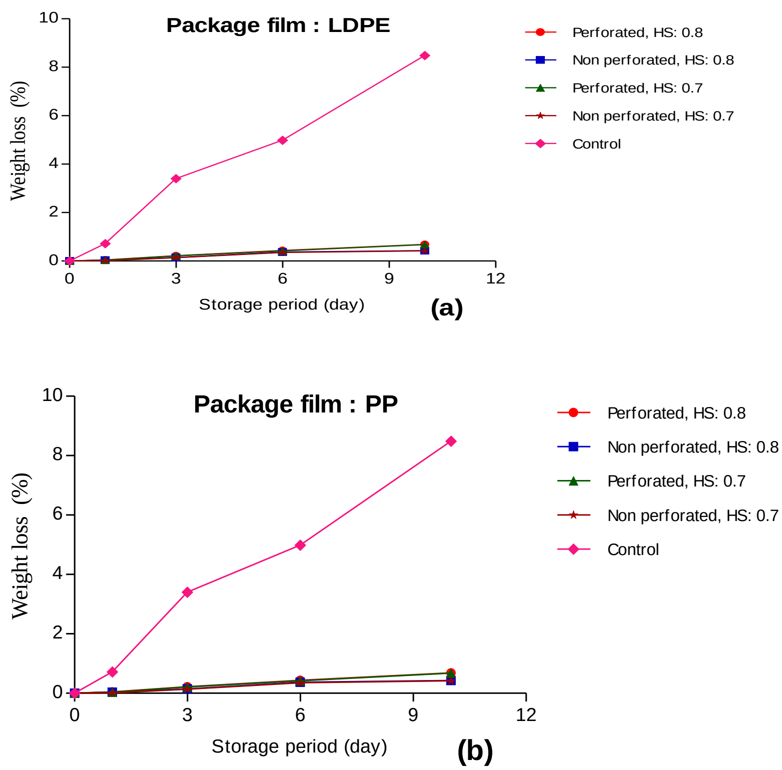


Fig.3 Chlorophyll content of broccoli florets at different levels of package headspace stored under modified atmosphere. The plotted values are means of three replications per treatment along with their standard deviations

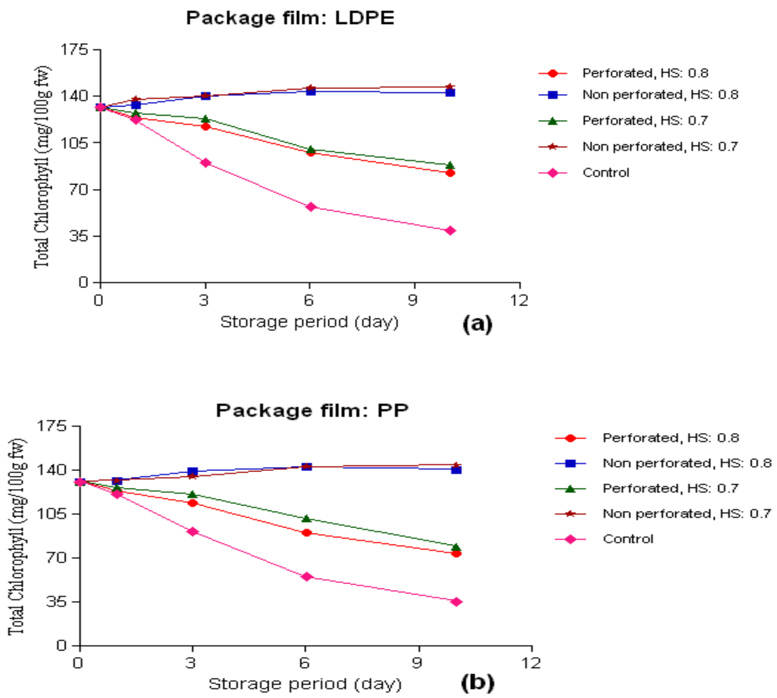


Fig.4 β-carotene content of broccoli florets at different levels of package headspace stored under modified atmosphere. The plotted values are means of three replications per treatment along with their standard deviations

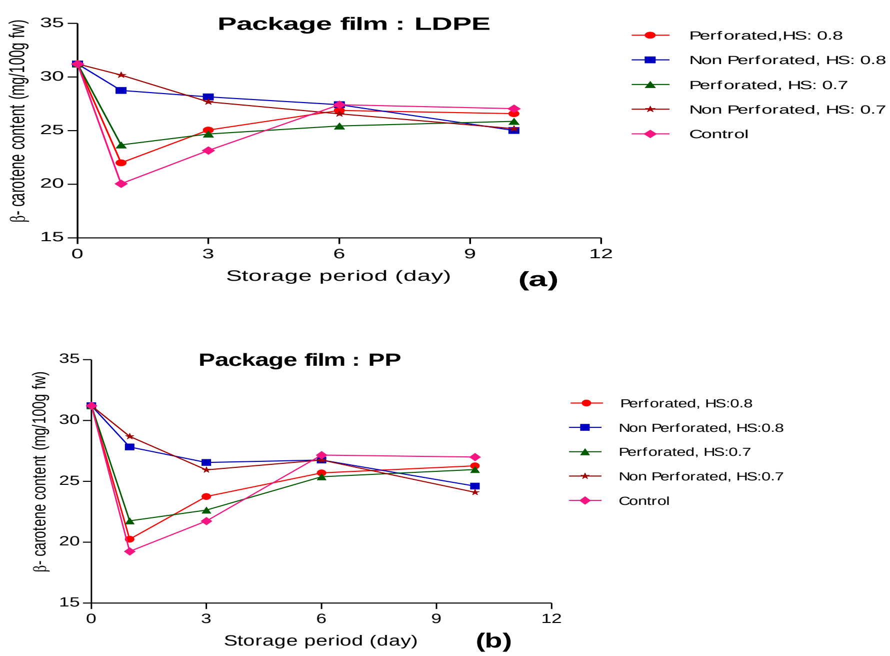


Fig.5 Ascorbic acid content of broccoli florets at different levels of package head space stored under modified atmosphere The plotted values are means of three replications per treatment along with their standard deviations

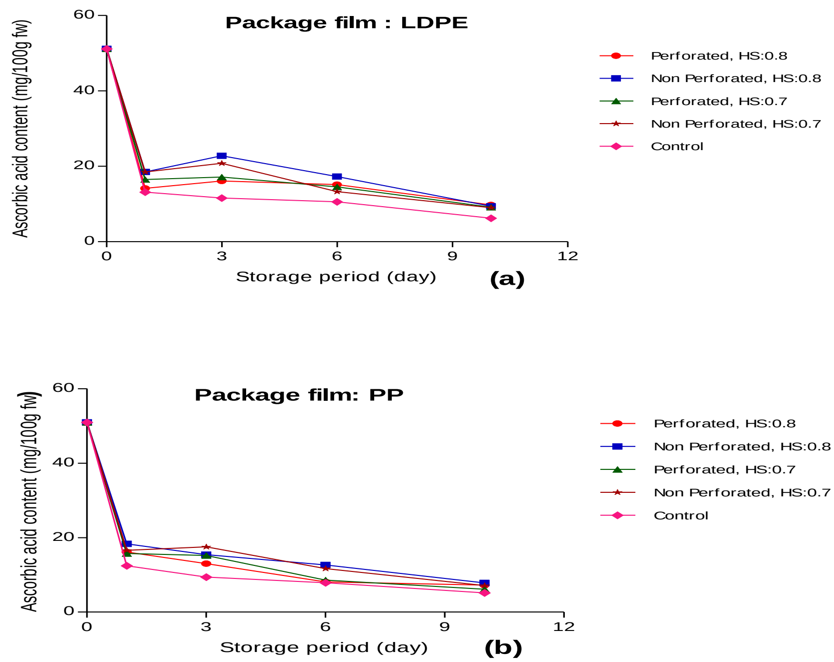


Fig.6 Odour rating of broccoli florets at different levels of package head space stored under modified atmosphere

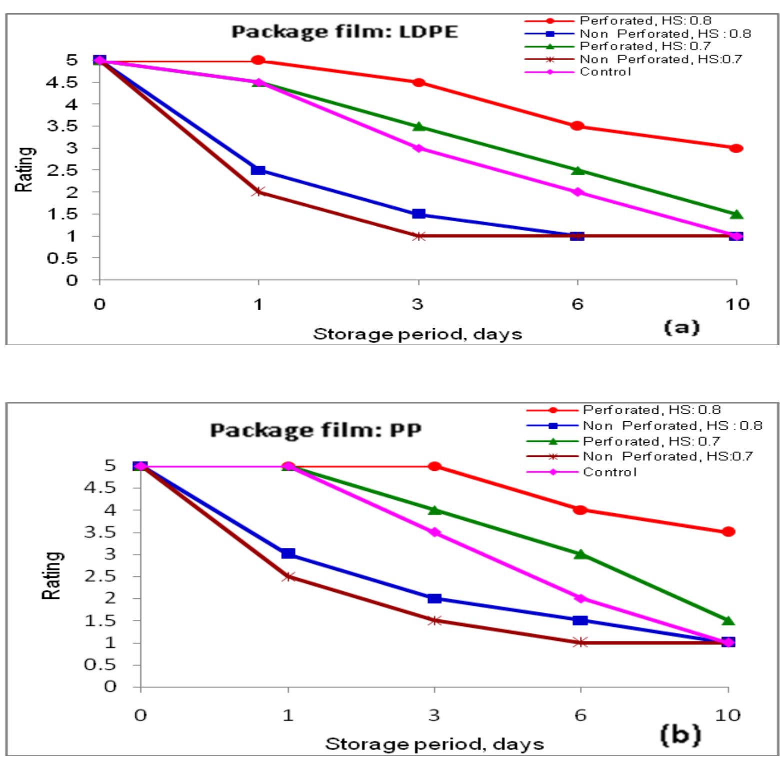
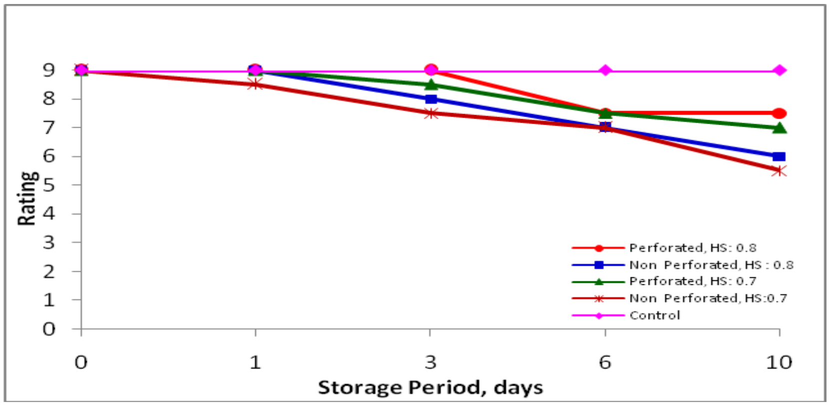
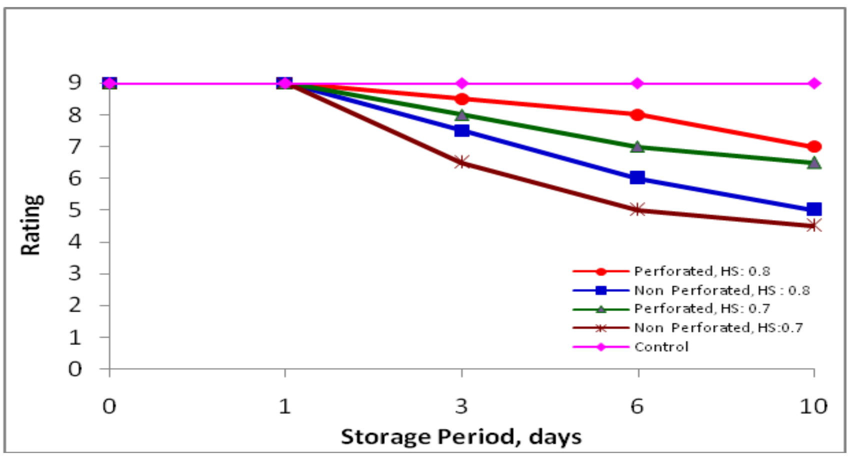


Fig.7 Water accumulation rating of broccoli florets at different levels of package head space stored under modified atmosphere





At the end of 6th day visible water accumulation was observed in perforated and non perforated 0.7 HS LDPE package. In LDPE having 0.8 HS traces of water accumulation were observed in perforated packages at the end of 3rd day and slight water accumulation in non perforated packages at the end of 6th day (Fig. 7a). In PP packages, no water accumulation was observed in all the samples till 1st day of storage. At the end of 3rd day slight water accumulation in non perforated and perforated packages having 0.8 HS was recorded; and visible water accumulation in non perforated and perforated 0.7 HS packages was observed (Fig. 7b). This shows that decrease in head space increases the production of water vapour and the number of perforation and water vapour permeability of film are not enough to diffuse out the water vapour produced inside the packages. This results in water vapour condensation within the packages and in turn deterioration in sensory quality. Whereas in control samples no water accumulation was observed, but gives an unacceptable odour; florets get dried and turned yellowish brown making the control sample unfit for human consumption.

In conclusion, the broccoli heads were stored for 10 days at 15°C and relative humidity (RH) of 75% under different modified atmospheres created by using different packaging films (LDPE and PP) perforated (2 holes, 0.3mm diametre each) and non perforated, having bag area of $0.14m^2$ and thickness of 150 gauge; and by packaging different weight of broccoli resulting in the head space (HS) of 0.8 and 0.7 in polymeric film packages. The stored produce quality was adjudged on the amount of retention of chlorophyll at the end of storage period. The results of the study showed that broccoli packed in LDPE give higher chlorophyll retention in comparison to packed in PP may be due to lower in-pack O_2 concentration.

Increase in chlorophyll content was recorded for non perforated packages in comparison decrease perforated packages. The non perforated packages became anaerobic after one day of storage and hence they are not fit for packaging of broccoli. The chlorophyll retention was higher in packages having 0.7 HS in comparison to the packages having 0.8 HS for both the films. The maximum retention of chlorophyll was recorded in perforated LDPE packages having 0.7 HS, but sensory evaluation showed that the sample showed intense off odour in comparison to slightly less retention of chlorophyll in perforated LDPE packages having 0.8 HS with acceptable sensory quality. The β-carotene retention was observed higher in perforated LDPE packages having 0.8 HS as compared to perforated PP packages having 0.8 HS. The retention ascorbic acid was also higher in the perforated LDPE packages having 0.8 HS than the perforated PP package having 0.8 HS. It may be concluded that increase in CO_2 concentration (7-9 %) along with decrease in in-pack O_2 concentration (3-6 %) might have enhanced the retention of antioxidant components *i.e.* β-carotene and ascorbic acid for longer period, which in turn have resulted in increase in chlorophyll retention. The sensory evaluation and experimental data recorded shows that perforated LDPE package (2 perforation) of thickness 150 gauge and surface area $0.14m^2$ having 0.8 head space generates a gaseous condition that could be beneficial for retention of various quality components of broccoli heads stored for 10 days at 15°C and 75% relative humidity.

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