Effects of hydrogen peroxide, modified atmosphere and their combination on quality of minimally processed cluster beans

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Abstract The aim of this study was to determine the potential of hydrogen peroxide (H_2O_2) and modified atmosphere packaging (MAP) on quality of fresh-cut cluster beans. Fresh-cut cluster beans were dipped in a solution of 2% H_2O_2 for 2 min, packed in an atmosphere of (5% O_2 , 10% CO_2 , 85% N_2) and stored in polypropylene bags at 5 °C for 35 days. Passive MAP was created by consuming O_2 and producing CO_2 by fresh-cut cluster beans. The combined effect of H_2O_2 and MAP on physico-chemical analysis (Headspace gas, weight loss, chlorophyll, hardness and color), microbial quality (mesophilic aerobics and yeasts and molds) and sensory analysis were studied. Chemical treatment and MAP both are equally effective in extending the shelf life at 5 °C for 28 days. Hence, MAP can be an alternative for chemical treatment to achieve a shelf life of 28 days for fresh-cut cluster beans. Control samples, without chemical treatment and modified atmosphere, stored at 5 °C were spoiled after 14 days. Chemical treatment followed by MAP underwent minimum changes in weight, chlorophyll, hardness and color of fresh-cut cluster beans. Combination treatment gives a storage life of 35 days.

Keywords *Cyamopsis tetragonoloba* · Chemical preservatives · Packaging · Shelf-life

Introduction

Cluster bean (*Cyamopsis tetragonoloba*) is an annual crop of various tropical countries and important industrial crop in India. It is a good source of soluble dietary fibre present as guar gum, the storage polysaccharide in the endosperm. Guar gum has been shown to lower the serum cholesterol levels (Pande and Srinivasan 2012; Arora and Pahuja 2008). Pulse grains are very good source of carbohydrates, protein, dietary fibre, vitamins and minerals (Singh 2017).

Minimally processed products are one of the most important rising segments in food retail establishments (Soliva-Fortuny and Martin-Belloso 2003). However, fresh-cut produce are extremely perishable and more vulnerable to spoilage than whole fresh produce. The cutting operations involved in the preparation of fresh-cut fruits and vegetables induce synthesis of secondary metabolites, membrane disruption and activation of defense mechanisms. It also increases respiration rates and ethylene production rates (Waghmare and Annapure 2013). Hence, the marketing of minimally processed products is restricted due to a short shelf life, rapid deterioration of their components and the microbial growth (Watada and Qui 1999).

Hydrogen peroxide (H_2O_2) is oxidant which is directly toxic to pathogens. It possess bacteriostatic as well as bactericidal activity, also due to its ability to produce oxidizing species, such as hydroxyl radicals. Generally, a concentration of 1–5% of H_2O_2 is used as sanitizer for some food contact surfaces (Alexandre et al. 2012; Rico et al. 2007). Hydrogen peroxide is usually recognized as

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friendly due to its low impact on environment. Its residue in food after treatment can be removed by action of endogenous catalase or by rinsing water immediately after treatment (Sapers 2001; Sapers and Simmons 1998). H₂O₂ solution dipping treatment reduced microbial populations of fresh-cut bell peppers, cucumber, zucchini, cantaloupe and honeydew melon (Beuchat and Ryu 1997; Park and Beuchat 1999). Modified atmosphere packaging (MAP) is a technique which is already in use for the preservation of fresh-cut produce. In MAP, the gases surrounding a commodity are modified so that its composition is other than that of air (Al-Ati and Hotchkiss 2002). Low levels of O₂ and high levels of CO₂ reduce respiration rate, minimize metabolic activity, delay enzymatic browning and retain visual appearance, thus extend the storage life of the whole and pre-cut commodities (Waghmare et al. 2013). Reduced storage temperature and MAP are widely used to extend the shelf-life of various fresh-cut produce (Gorny 1997).

The use of modified atmospheres alone or in combinations with chemical preservative have proved useful in controlling microbial growth and maintaining quality during storage of various fresh-cut produce such as papaya (Waghmare and Annapure 2013), honeydew (Bai et al. 2003), banana (Bico et al. 2009), green asparagus (An et al. 2007). There is limited literature dealing with preservation of different beans (Patras et al. 2011; Krebbers et al. 1985; Berrios et al. 1999). However, as per our knowledge, no reports have been found on the shelf life extension of cluster beans by using combination of H₂O₂ and MAP. Therefore, this study was undertaken to investigate the effects of H₂O₂, MAP and combination of H₂O₂ with MAP on physicochemical (headspace gas, weight loss, chlorophyll, hardness and color), microbiological (mesophilic aerobics and yeast and molds count) and sensory characteristics of fresh-cut cluster beans at 5 °C.

Materials and methods

Materials

Fresh cluster beans (*Cyamopsis tetragonoloba*) were procured from Agriculture Produce Market Committee (APMC), Mumbai. Packages made from polypropylene (PP) film, supplied by Dhvani Poly Prints Private Limited, India, were used in the study. The PP bags had the dimensions of 25 µm thickness, 20 cm length × 15 cm width. Oxygen and carbon dioxide transmission rate of PP bags were 4.9×10^{-9} and 1.3×10^{-7} mL m⁻² s⁻¹ Pa⁻¹ respectively. Chemicals were supplied from Himedia (Mumbai, India).

Processing and sampling design

Fresh cluster beans, free from defects were sorted out and washed with water. Cluster beans were dried with blotting paper and cut to a length of 2 cm. Cluster beans were divided into two parts. One part of the total fresh-cut cluster beans was dipped in a solution of hydrogen peroxide (2% v/v) for 2 min. Hydrogen peroxide is safe option to chlorine-based disinfectant, because it degrades to form oxygen and water and it is generally recognized as safe as an antimicrobial agent. Other half part was used as it is for packaging. Packed fresh-cut cluster beans samples were prepared by placing H₂O₂ treated and non-treated samples in PP bags. 70 g of fresh-cut cluster beans was packed in one Polypropylene (PP) bag. 70 g of sample weight was chosen by considering the size of packet and amount required for analysis. Polypropylene easily permeated by oxygen and carbon dioxide which is required for fresh produce. 5 °C is the optimum temperature required for storage of cluster bean. These PP bags were packed in modified atmosphere packaging unit (consist of Reepack packaging machinery supplies and PBI Dansensor, MAP Mix 9001 ME, Ringsted, Denmark) with gas composition of 5% O₂, 10% CO₂ and 85% N₂. Passive MAP is generally used to sell the packed food in MAP. Passive MAP has been done by flushing the desired gases at the initial stage. H₂O₂ treated and non-treated samples were packed in air and used as a control. Bean temperature, temperature of the different solutions and temperature of the processing room at the time of processing was room temperature (32 °C). Relative humidity was 72% and the samples were stored in darkness. Hence the samples were tagged as T1 (control), T2 (H₂O₂ treated), T3 (MAP) and T4 (H₂O₂ + MAP). Packaged fresh-cut cluster beans were held at 5 °C and stored for 35 days. Samples were analyzed at the interval of 0, 7, 14, 24 and 35 days. Three replicate packets were used for all treatments on each storage day. The experiments were performed 3 times during summer season.

Physicochemical analyses

Headspace gas analysis

The headspace contents of oxygen (%) and carbon dioxide (%) of fresh-cut cluster beans in the packages were measured in order to evaluate the effects of both H₂O₂ and MAP on respiration. Just before being measured, packages were removed from storage and headspace gas composition inside the package was measured through a septum with the help of a needle connected to the O₂/CO₂ gas analyzer (PBI Dansensor, Checkmate 9900, Ringsted, Denmark). After nearly 30 s, screen displays the O₂ and CO₂ percentages, which was developed due to respiration of fresh

produce. This instrument helps to measure changes in O₂ and CO₂ concentrations within a sealed jar directly. The apparatus uses a highly stable zirconium sensor for O₂ determination and an infrared detector to detect CO₂.

Weight loss

The net weight of each package was determined by weighing the whole individual package on the day of observation using a laboratory level weighing balance having 0.0001 g accuracy (Anamed electronic balance, India). Values are reported as percent of weight loss per initial fruit weight.

Chlorophyll

Total chlorophyll (mg/100 g) was measured by spectrophotometric procedure described by Goncalves et al. (2009). 1 g sample was homogenized with 80% acetone, and then centrifuged at 5000 rpm for 10 min. The supernatant was dilute to 50 mL with acetone and kept in darkness for 3 h. Chlorophylls concentrations were determined by spectral analysis (Schmidzu, Japan) by measuring the absorbance at 649 and 665 nm. Readings were taken with a control sample of 80% acetone. Total chlorophyll content was obtained as the sum of chlorophylls a and b contents.

Firmness

Firmness was measured using TA-XT2i texture analyzer (Stable Micro System, Ltd. in Godalming, Surrey, UK) with a 50 kg load cell equipped with 2 mm diameter cylindrical probe. Cluster bean was placed on the square metal plate and probe was inserted inside the bean. The test speed was 0.5 mm/s, pretest speed 10 mm/s, probe reversing speed 10 mm/s and trigger force was 15 g and the distance travelled by the probe inside the sample was 3 mm. Firmness was expressed in *N* force by determining the peak value of graph.

Color

The color of cluster beans was determined using a Hunter Lab Colourimeter, (LabScan XE, Hunter Lab Colourimeter, DP-9000 D25A, Reston, USA). Instrument was calibrated with a black and white standard tiles. The results were expressed in terms of *L**, *a**, and *b** values, where *L** represents lightness, *a** represents chromaticity on a green (–) to red (+) axis and *b** represents chromaticity on a blue (–) to yellow (+) axis.

Sensory evaluation

Sensory evaluation of fresh-cut cluster beans was evaluated by a 15 member trained panel by suitably modifying the procedure of Carvalho and Clemente (2004). Texture was scored on a 1–5 scale, where 5 = very firm, 4 = firm, 3 = slightly wilted, but acceptable, 2 = wilted, 1 = very much wilted. Aroma was evaluated as per the scale: 5 = no off-odour, 4 = very light off-odour, 3 = light off-odour, 2 = medium off-odour and 1 = strong off-odour. Visual appearance was scored as per Deza et al. (2003), where 5 = very good, 4 = good, 3 = normal, 2 = limited quality and 1 = not acceptable. Decay was evaluated by modifying the procedure of Loaiza and Cantwell (1997), where 5 = extremely diseased, 4 = moderately severe diseased, 3 = moderately diseased, 2 = slightly diseased and 1 = no disease. Overall acceptance ratings were based on a nine point hedonic scale, where 9 = excellent, 7 = very good, 5 = good and limit of marketability, 3 = fair and limit of usability and 1 = poor and unusable (Larmond 1977).

Microbial studies

Fresh-cut cluster beans from each packet were evaluated to determine microbial load as per the standard plate count method. Total plate count agar and potato dextrose agar (HiMedia Laboratories, India) were used to determine mesophilic aerobics and yeast and molds count, respectively. A 10 g sample was diluted with 90 mL of sterile NaCl solution. Solution was homogenized with sterilized kitchen blender homonizer for 10 min and was then further diluted to get serial dilutions. Serially diluted samples were plated onto total plate count agar, potato dextrose agar. 1 mL of each dilution was transferred to sterile petri plate and 15–20 mL of sterile agar media at temperature 40–45 °C was poured, mixed well and allowed to set. Plates were incubated at 37 ± 0.5 °C for 48 h. At the end of the incubation period the colony forming unit (cfu) were counted and multiplied by appropriate dilution factor to obtain total plate count and yeast and molds count. All the experiments were performed in triplicates.

Statistical analysis

All data were expressed as means ± standard errors of triplicate measurements and analysed by SPSS for Windows (ver. 16.0). One-way analysis of variance (ANOVA): Post Hoc multiple comparison were carried out to test significant differences. Statistical comparisons between variables (control, chemical treated and MAP samples) were performed with Least Square Differential method

(LSD). Differences were considered significant at $P < 0.05$.

Results and discussion

Gas composition

Evolution of O_2 and CO_2 concentration inside the PP bags for 35 days of storage at 5 °C are plotted in Fig. 1.

Polypropylene

The O_2 concentration decreased and CO_2 concentration increased during the storage period due to the respiratory activity of the fresh-cut cluster beans. A significant

difference was found in O_2 and CO_2 concentration between all samples ($P < 0.05$). Fresh-cut produce usually have high rate of respiration than intact products, probably due to the increased metabolic activity of injured cells and increased surface area exposed to the atmosphere (Luna-Guzman et al. 1999). O_2 concentration decreased more sharply in control samples (T1) compared to relatively gradual decrease in H_2O_2 treated (T2), stand-alone MAP (T3) and H_2O_2 treated + MAP (T4) samples. This indicates that control samples have a higher rate of respiration. The decrease in O_2 concentration and increase in CO_2 concentration of T4 sample was slower which could be attributed to lower respiratory activity of the samples and inhibition of respiration rate by H_2O_2 treatment. Hence, the combination treatment could be more useful to slow down the respiration rate of fresh-cut cluster beans. The above reported results were in agreement with those of Saxena et al. (2009) for jackfruit and Almenar et al. (2009) for blueberry.

Weight loss

Important difference in weight loss was observed for all the samples stored at 5 °C Fig. 2a. Throughout storage, weight loss increased in all samples during 35 days of storage. Higher weight loss was observed in control sample, reached to a value of 1.87%. No significant difference was observed between T2, T3 and T4 samples till 14th day. However, among all the samples, significant weight loss was observed from 21 to 35th day ($P < 0.05$). Softness was observed in control fresh-cut cluster beans on 21st day, whereas no softness was observed in treated samples throughout the storage period. Hydrogen peroxide and modified atmosphere helps to maintain the quality of cluster beans and preserve its texture, hence softness was not observed in treated samples. Less significant difference was observed between H_2O_2 treated and stand-alone MAP samples. This indicated that stand-alone MAP and only H_2O_2 treated sample was not more effective than combined treated samples in preserving quality of fresh-cut cluster beans. Further, the chemical treatment combined with MAP prevented the weight loss in conformation with the earlier reported results for fresh-cut banana (Bico et al. 2009).

Chlorophyll

Chlorophyll is extremely vulnerable to degradation during processing. Green vegetable discolour during processing due to mainly by decrease in pH (Koca et al. 2007). Chlorophyll concentration decreased as storage period increased in all the samples Fig. 2b and this corroborated earlier findings Martins and Silva 2002 for green beans. At

Fig. 1 Changes in **a** % oxygen and **b** % carbon dioxide (means of three replicates $\pm$ standard deviation) of chemically treated fresh-cut cluster beans packaged in modified atmosphere and stored at 5 °C. Solid curve with triangle, control (T1); Solid curve with diamond, chemically treated (T2); Solid curve with square, MAP (T3) Solid curve with circle, chemically treated + MAP, (T4)

Fig. 2 Changes in **a** % weight loss and **b** Total chlorophyll (means of three replicates $\pm$ standard deviation) of chemically treated fresh-cut cluster beans packaged in modified atmosphere and stored at 5 °C. Solid curve with triangle, control (T₁); Solid curve with diamond, chemically treated (T₂); Solid curve with square, MAP (T₃) Solid curve with circle, chemically treated + MAP, (T₄)

the end of the storage period, chlorophyll content decreased from the initial value of 2.31 mg/100 g to 1.57, 1.91, 1.85 and 2.1 mg/100 g, respectively. Total chlorophyll content in T₁ samples was significantly lower ($P < 0.05$) than the other samples. Initially, there was no significant difference between the chlorophyll content of T₂, T₃ and T₄ samples. Slower changes in chlorophyll content occurred in the sample subjected to chemical dip pretreatment and packaged in MAP atmosphere (T₄). The lower pH values were observed for the T₄ samples followed by T₂, T₃ and T₁ samples.

Hardness

In this study, hardness of all the samples declined during the 35 days of storage period (Table 1). H₂O₂ treatment,

MAP and storage period have significantly affected the hardness of all the samples. No significant difference in hardness was observed between the H₂O₂ treated samples (T₂) and stand alone MAP samples (T₃) till 14th day. Higher hardness was observed in T₂ samples than T₃ samples on 21, 28 and 35th day. T₄ samples were best in texture as the weight loss were less in samples. Less moisture loss prevents the texture of T₄ samples followed by T₂, T₃ and T₁. Hence results indicate that H₂O₂ treatment helps to maintain better hardness of fresh-cut cluster beans than stand alone MAP samples. H₂O₂ solution dip fresh-cut cluster beans packed under modified atmosphere (T₄) presented the best hardness throughout the storage period. Alexandre et al. (2012) have observed that firmness of strawberries did not suffer any alteration when 5% H₂O₂ washings were applied. These results were in agreement with those from papaya fruit in which firmness decreased with increase in storage time (Waghmare and Annapure 2013).

Color

The effect of H₂O₂ treatment and MAP on the color of fresh-cut cluster beans was evaluated by monitoring the changes in color parameters (L^* , a^* , b^*) of samples stored at temperature 5 °C for 35 days (Table 1). L^* value, lightness of the sample, significantly decreased ($P < 0.05$) (darkening increased) for all the samples during its shelf life. There were no significant difference was found between the H₂O₂ treated (T₂), MAP (T₃) and combined treated (T₄) samples. Higher decrease in L^* value of control sample (T₁) was observed than the other samples. However, smaller changes in L^* value of T₄ sample was found. A similar effect was observed in alginate coated button mushrooms packed under a high oxygen modified atmosphere (Jiang 2013). Throughout storage period, a^* values, indicated redness when positive or greenness when negative, decreased in all samples. Similarly, higher decrease in a^* values value of T₁ sample was observed. Any significant difference between the all samples was not observed till 14th days. The b^* value, yellowness when positive or blueness when negative, also showed a decreasing trend during storage period. There was no significant difference between all the samples throughout the storage period. The results were in agreement with the results obtained by Fernandes et al. (2017) for mushrooms.

Sensory evaluation

The sensory evaluation was performed to found any sensorial difference between the control, H₂O₂ treated, MAP and combined treated samples. Five attributes, visual appearance, aroma, texture, decay and overall acceptability

Table 1 Changes in hardness and color parameters (means of three replicates $\pm$ standard deviation) of chemically treated fresh-cut cluster beans packaged in modified atmosphere and stored at 5 °C

Parameters	Days	0	7	14	21	28	35
Hardness (<i>N</i>)	T ₁	3.65 $\pm$ 0.03 ^{aA}	3.13 $\pm$ 0.02 ^{bA}	2.42 $\pm$ 0.06 ^{cA}	1.77 $\pm$ 0.05 ^{dA}	1.38 $\pm$ 0.06 ^{eA}	1.08 $\pm$ 0.01 ^{fA}
	T ₂	3.65 $\pm$ 0.03 ^{aA}	3.34 $\pm$ 0.07 ^{bB}	3.15 $\pm$ 0.03 ^{cB}	2.96 $\pm$ 0.03 ^{dB}	2.74 $\pm$ 0.04 ^{eB}	2.42 $\pm$ 0.02 ^{fB}
	T ₃	3.65 $\pm$ 0.03 ^{aA}	3.25 $\pm$ 0.04 ^{bB}	3.11 $\pm$ 0.04 ^{cB}	2.85 $\pm$ 0.06 ^{dC}	2.52 $\pm$ 0.03 ^{eC}	2.20 $\pm$ 0.02 ^{fC}
	T ₄	3.65 $\pm$ 0.03 ^{aA}	3.53 $\pm$ 0.02 ^{bC}	3.41 $\pm$ 0.02 ^{cC}	3.25 $\pm$ 0.02 ^{dD}	3.11 $\pm$ 0.05 ^{eD}	3.08 $\pm$ 0.08 ^{eD}
<i>L</i> * value	T ₁	53.41 $\pm$ 0.24 ^{aA}	51.05 $\pm$ 0.16 ^{bA}	49.32 $\pm$ 0.13 ^{cA}	48.14 $\pm$ 0.11 ^{dA}	46.87 $\pm$ 0.14 ^{eA}	45.44 $\pm$ 0.20 ^{fA}
	T ₂	53.41 $\pm$ 0.24 ^{aA}	53.16 $\pm$ 0.11 ^{aB}	52.76 $\pm$ 0.08 ^{bB}	52.54 $\pm$ 0.12 ^{cB}	52.28 $\pm$ 0.11 ^{dA}	52.05 $\pm$ 0.28 ^{dA}
	T ₃	53.41 $\pm$ 0.24 ^{aA}	53.21 $\pm$ 0.24 ^{aB}	52.89 $\pm$ 0.16 ^{bB}	52.46 $\pm$ 0.16 ^{cB}	52.20 $\pm$ 0.24 ^{cA}	52.11 $\pm$ 0.21 ^{cA}
	T ₄	53.41 $\pm$ 0.24 ^{aA}	53.32 $\pm$ 0.12 ^{aB}	53.20 $\pm$ 0.11 ^{aC}	52.33 $\pm$ 0.24 ^{bB}	52.21 $\pm$ 0.13 ^{bA}	52.18 $\pm$ 0.12 ^{bA}
<i>a</i> * value	T ₁	12.23 $\pm$ 0.11 ^{aA}	11.74 $\pm$ 0.22 ^{bA}	11.06 $\pm$ 0.18 ^{cA}	10.63 $\pm$ 0.28 ^{cA}	10.17 $\pm$ 0.13 ^{dA}	9.55 $\pm$ 0.30 ^{eA}
	T ₂	12.23 $\pm$ 0.11 ^{aA}	12.05 $\pm$ 0.16 ^{aA}	11.87 $\pm$ 0.14 ^{aA}	11.51 $\pm$ 0.23 ^{aB}	11.14 $\pm$ 0.18 ^{aB}	10.74 $\pm$ 0.15 ^{bB}
	T ₃	12.23 $\pm$ 0.11 ^{aA}	12.12 $\pm$ 0.18 ^{aA}	11.73 $\pm$ 0.25 ^{aA}	11.43 $\pm$ 0.20 ^{aB}	10.95 $\pm$ 0.22 ^{bB}	10.56 $\pm$ 0.24 ^{bB}
	T ₄	12.20 $\pm$ 0.11 ^{aA}	12.14 $\pm$ 0.11 ^{aA}	11.93 $\pm$ 0.14 ^{aA}	11.78 $\pm$ 0.21 ^{aB}	11.66 $\pm$ 0.15 ^{aC}	11.62 $\pm$ 0.13 ^{aC}
<i>b</i> * value	T ₁	16.35 $\pm$ 0.8 ^{aA}	15.74 $\pm$ 1.1 ^{aA}	15.13 $\pm$ 1.4 ^{aA}	14.35 $\pm$ 1.2 ^{aA}	13.29 $\pm$ 0.7 ^{aA}	12.13 $\pm$ 1.2 ^{aA}
	T ₂	16.35 $\pm$ 0.8 ^{aA}	16.14 $\pm$ 1.8 ^{aA}	16.05 $\pm$ 1.5 ^{aA}	15.89 $\pm$ 1.3 ^{aA}	15.64 $\pm$ 1.3 ^{aB}	15.32 $\pm$ 1.1 ^{aB}
	T ₃	16.35 $\pm$ 0.8 ^{aA}	16.13 $\pm$ 2.1 ^{aA}	15.77 $\pm$ 0.9 ^{aA}	15.52 $\pm$ 1.5 ^{aA}	15.36 $\pm$ 1.4 ^{aB}	15.18 $\pm$ 1.9 ^{aB}
	T ₄	16.35 $\pm$ 0.8 ^{aA}	16.30 $\pm$ 1.3 ^{aA}	16.24 $\pm$ 0.5 ^{aA}	16.04 $\pm$ 0.4 ^{aA}	15.88 $\pm$ 1.6 ^{aB}	15.73 $\pm$ 2.3 ^{aB}

T₁, control; T₂, chemically treated; T₃, MAP; T₄, chemically treated + MAP. Different capital letters following the values in same column indicate differences during storage period for each attribute and different small letters in row indicate differences for each treatment ($P < 0.05$)

Table 2 Changes in sensorial attributes (means of three replicates $\pm$ standard deviation) of chemically treated fresh-cut cluster beans packaged in modified atmosphere and stored at 5 °C

Parameters	Days	0	7	14	21	28	35
Visual appearance	T ₁	5.0 $\pm$ 0 ^{aA}	4.0 $\pm$ 0.2 ^{bA}	3.6 $\pm$ 0.1 ^{cA}	2.5 $\pm$ 0.3 ^{dA}	1.9 $\pm$ 0.2 ^{eA}	1.4 $\pm$ 0.2 ^{fA}
	T ₂	5.0 $\pm$ 0 ^{aA}	4.6 $\pm$ 0.2 ^{bB}	4.2 $\pm$ 0.2 ^{bB}	3.7 $\pm$ 0.1 ^{cB}	3.3 $\pm$ 0.2 ^{dB}	2.8 $\pm$ 0.3 ^{dB}
	T ₃	5.0 $\pm$ 0 ^{aA}	4.5 $\pm$ 0.2 ^{bB}	4.1 $\pm$ 0.1 ^{cB}	3.6 $\pm$ 0.4 ^{cB}	3.2 $\pm$ 0.2 ^{cB}	2.6 $\pm$ 0.1 ^{dB}
	T ₄	5.0 $\pm$ 0 ^{aA}	4.8 $\pm$ 0.1 ^{bB}	4.7 $\pm$ 0.2 ^{bC}	4.4 $\pm$ 0.3 ^{bC}	4.1 $\pm$ 0.1 ^{bC}	3.8 $\pm$ 0.2 ^{bC}
Aroma	T ₁	5.0 $\pm$ 0 ^{aA}	4.3 $\pm$ 0.2 ^{bA}	3.3 $\pm$ 0.3 ^{cA}	2.8 $\pm$ 0.1 ^{dA}	2.2 $\pm$ 0.2 ^{eA}	1.7 $\pm$ 0.2 ^{fA}
	T ₂	5.0 $\pm$ 0 ^{aA}	4.8 $\pm$ 0.1 ^{bB}	4.0 $\pm$ 0.1 ^{cB}	3.8 $\pm$ 0.2 ^{cB}	3.5 $\pm$ 0.1 ^{cB}	3.0 $\pm$ 0.1 ^{dB}
	T ₃	5.0 $\pm$ 0 ^{aA}	4.8 $\pm$ 0.2 ^{aB}	4.1 $\pm$ 0.2 ^{bB}	3.5 $\pm$ 0.3 ^{cB}	3.3 $\pm$ 0.2 ^{cB}	2.8 $\pm$ 0.4 ^{cB}
	T ₄	5.0 $\pm$ 0 ^{aA}	4.9 $\pm$ 0.1 ^{aB}	4.7 $\pm$ 0.2 ^{aC}	4.6 $\pm$ 0.1 ^{aC}	4.4 $\pm$ 0.3 ^{aC}	4.2 $\pm$ 0.1 ^{aC}
Texture	T ₁	5.0 $\pm$ 0 ^{aA}	4.3 $\pm$ 0.3 ^{bA}	3.9 $\pm$ 0.1 ^{bA}	3.3 $\pm$ 0.2 ^{cA}	2.7 $\pm$ 0.3 ^{dA}	2.3 $\pm$ 0.3 ^{dA}
	T ₂	5.0 $\pm$ 0 ^{aA}	4.7 $\pm$ 0.1 ^{bA}	4.3 $\pm$ 0.2 ^{cB}	4.0 $\pm$ 0.3 ^{cB}	3.9 $\pm$ 0.2 ^{cB}	3.2 $\pm$ 0.2 ^{dB}
	T ₃	5.0 $\pm$ 0 ^{aA}	4.6 $\pm$ 0.2 ^{bA}	4.4 $\pm$ 0.4 ^{bB}	4.1 $\pm$ 0.1 ^{bB}	3.7 $\pm$ 0.1 ^{cB}	3.3 $\pm$ 0.2 ^{dB}
	T ₄	5.0 $\pm$ 0 ^{aA}	4.8 $\pm$ 0.2 ^{aA}	4.8 $\pm$ 0.2 ^{aB}	4.6 $\pm$ 0.2 ^{aC}	4.5 $\pm$ 0.2 ^{aC}	4.5 $\pm$ 0.4 ^{aC}
Decay	T ₁	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.8 $\pm$ 0.2 ^{bA}	2.9 $\pm$ 0.2 ^{cA}	3.6 $\pm$ 0.3 ^{dA}
	T ₂	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aB}	1.0 $\pm$ 0 ^{aB}	2.4 $\pm$ 0.1 ^{bB}
	T ₃	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aB}	1.0 $\pm$ 0 ^{aB}	2.7 $\pm$ 0 ^{bC}
	T ₄	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aA}	1.0 $\pm$ 0 ^{aB}	1.0 $\pm$ 0 ^{aB}	1.0 $\pm$ 0 ^{aD}
Overall acceptance	T ₁	9.0 $\pm$ 0 ^{aA}	8.1 $\pm$ 0.4 ^{bA}	7.5 $\pm$ 0.2 ^{bA}	6.6 $\pm$ 0.2 ^{cA}	5.8 $\pm$ 0.4 ^{dA}	5.1 $\pm$ 0.1 ^{eA}
	T ₂	9.0 $\pm$ 0 ^{aA}	8.6 $\pm$ 0.3 ^{bA}	8.2 $\pm$ 0.3 ^{bB}	7.6 $\pm$ 0.1 ^{cB}	7.2 $\pm$ 0.1 ^{dB}	6.9 $\pm$ 0.3 ^{dB}
	T ₃	9.0 $\pm$ 0 ^{aA}	8.5 $\pm$ 0.1 ^{aA}	8.2 $\pm$ 0.1 ^{bB}	7.2 $\pm$ 0.3 ^{cB}	7.0 $\pm$ 0.3 ^{cB}	6.6 $\pm$ 0.4 ^{cB}
	T ₄	9.0 $\pm$ 0 ^{aA}	8.7 $\pm$ 0.2 ^{bA}	8.1 $\pm$ 0.2 ^{cB}	7.7 $\pm$ 0.2 ^{cB}	7.4 $\pm$ 0.2 ^{cB}	7.3 $\pm$ 0.2 ^{cB}

T₁, control; T₂, chemically treated; T₃, MAP; T₄, chemically treated + MAP. Different capital letters following the values in same column indicate differences for each treatment and different small letters in row indicate differences during storage period for each attribute ($P < 0.05$)

scores for fresh-cut cluster beans are shown in Table 2. All the samples showed decrease in quality during storage period in all the parameters considered. In visual appearance, the rating of H₂O₂ treated (T2) and MAP (T3) samples were acceptable till 28th day. T2 samples received 3.3 visual appearance score on day 28, whereas T3 samples received 3.2 score. Thus, T2 samples were comparable with T3 samples on day 28. H₂O₂ treated samples packed in MAP (T4) had more acceptable appearance than T1, T2 and T3 samples throughout the samples. Degradation in aroma increased in all the samples. No off-odor and off-flavor were detected in T2, T3 and T4 samples. However, off-odor and off-flavor were detected in control samples on 21st day. Similarly, softness was observed in control samples on 21st day. Whereas, T1, T2 and T3 samples had acceptable texture throughout the storage period. Decay was observed in T1, T2 and T3 samples on 21, 35 and 35 day, respectively. However, no decay was found in T4 samples throughout the storage period. Combination treatment T4 received the highest overall acceptability score than other treatment alone and control samples. However, there was no significant difference between H₂O₂ and MAP treated samples.

Microbiology growth

The microbial counts of mesophilic aerobics and yeasts and moulds are shown in Fig. 3 for control (T1), chemical treated (T2), MAP (T3) and combination treated samples (T4) samples at 5 °C. Increase in microbial count was observed in all the samples throughout the storage period. Chemical treatment and MAP both tends to reduce microbial load in both mesophilic aerobics and yeasts and moulds. H₂O₂ treated samples packed in MAP (T4) showed better control over the both count compared with alone treated samples (T2 and T3). Control samples showed the highest microbial growth among all the samples. T4 samples showed the lowest microbial load, followed by T2, T3 and T1. However, very little difference was observed between the T2 and T3 samples. Hence, chemical treatment and MAP both equally and effectively reduced the microbial load of fresh-cut cluster beans. Similarly, Waghmare and Annapure, (2013) reported that combined effect of chemical treatment and MAP is more useful for inhibiting the growth of the aerobic and coliform bacteria than single treatment in fresh-cut papaya.

Conclusion

Cluster beans dipped in a solution of hydrogen peroxide (2% v/v) for 2 min, packed in modified atmosphere (5% O₂, 10% CO₂ and 85% N₂) maintained their weight,

Fig. 3 Changes in **a** mesophilic aerobics and **b** yeasts and molds (means of three replicates $\pm$ standard deviation) of chemically treated fresh-cut cluster beans packaged in modified atmosphere and stored at 5 °C. Solid curve with triangle, control (T₁); Solid curve with diamond, chemically treated (T₂); Solid curve with square, MAP (T₃); Solid curve with circle, chemically treated + MAP, (T₄)

slowed down the loss of color, chlorophyll and reduced microbial count at 5 °C. Passive modified atmosphere were maintained throughout the storage period. It means that the mixtures of gases were flushed only during packaging. Another important observation made was that the H₂O₂ treatment and MAP are equally effective in extending the shelf life of fresh-cut cluster beans. Hence, MAP can be used instead of chemical treatment to extend their shelf life of 28 days. Minimal processing of cluster beans might be a very attractive alternative for producers to increase shelf life and for consumer their ready use in food preparations.

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