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# Effect of modified atmosphere packaging (MAP) on quality and shelf-life of cucumber during cold storage

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## ABSTRACT

**This study investigated the influence of MAP on storage of cucumber cultivar "Malini" fruit at 10 and 15°C storage temperature. Fruits were packed in expanded polyethylene biopolymer (20µFlexfresh) and assessed for quality, storability and sensory parameters during storage. Minimum weight loss (10.09%) was observed in packaged cucumber, while control fruit exhibited maximum weight loss (60.72%) after 18 days of MAP storage at 15°C. Initial firmness at harvest was 8.24N, which reduced to 4.68N and 4.72N in control after four weeks at 10 and 15°C, respectively. The losses in ascorbic acid (71.6 and 79.3%) and total phenolics content (72.6 and 75.4%) were higher in control after 28 days at 10 and 15°C, respectively. Polyphenol oxidase enzyme activity was higher in untreated cucumber fruit. The overall acceptability sensory score indicated "Like Moderately" for packaged cucumber fruit after 28 days of storage. Based on our results, the most optimum treatment was the MAP storage of cucumber fruit at 15°C, which extended storability by lowering shrivelling, yellowing, loss of firmness and preserving quality.**

**Key words:** *Cucumis sativus*, enzyme, sensory, storage evaluation.

## INTRODUCTION

Cucumber (*Cucumis sativus*) belongs to the Cucurbitaceae family and is mainly consumed as salad and pickle for its functional properties (Mukherjee *et al*., 7). They usually have a short storage life of about 3-4 days, even at cold storage conditions (10-12°C) and high relative humidity (80%). After the harvest, high qualitative degradation and quantitative losses have been observed in cucumber fruit. Various factors such as harvesting time, handling and microbial load during storage affect the post-harvest quality. Generally, after harvest, cucumber are packed in gunny bags with rough handling, which causes quality losses such as rupture of skin and loss of glossiness, which ultimately results in a lower price. Moreover, some practices used by traders in markets to reduce weight loss, like frequent sprinkling with water, eventually cause fungal spoilage during storage (Scully and Horsham, 13).

In addition, chilling injury occurs during storage temperatures below 10°C, which causes pitting and water-soaked spots on the skin. Therefore, they should be stored at temperatures between 10 and 15°C (Rao *et al*., 11; Nasef, 8). Other workers noted that cucumber cultivars 'Opera' and 'Troy' could be stored at 4-10°C with low spoilage in different gaseous combinations (Ozer *et al*., 9). Previously, effects of putrescine and lipid based coatings on postharvest quality of cucumber fruit during storage have also been evaluated (Jia *et al*., 3; Rux *et al*., 12).

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Packaging cucumber fruit in the presence of proper gaseous environments retains the nutritional and sensory quality for a longer time (Manjunatha and Anurag, 5). Modified atmosphere packaging (MAP) is highly likely to extend post-harvest storage and lower decay among various packaging systems. The atmosphere modification affects respiration and ethylene production, causes accumulation of $CO_2$, depletion of $O_2$, and hinders adverse enzymatic and microbiological developments, resulting in maintenance of quality of fresh produce (Sun *et al*., 18). In conjunction with cold storage, packaging creates an optimum gas composition around the commodity, positively influencing shelf life and marketability (Tazny *et al*., 19). Previously, cucumber (cv. "Pusa Uday") stored under MAP with 2 perforations in low-density polyethylene bags remained acceptable for only 12 days at 4±1°C and 90±2% RH (Manjunatha and Anurag, 5). This study was done to address the gap to evaluate possibility of a further increase in the storability of cucumber fruit at higher cold storage temperatures, which may prove helpful in reducing the refrigeration costs. Thus, this study evaluated the effects of MAP on enzymatic and quality attributes of freshly harvested cucumber fruit in 20µ Flexfresh biopolymer MAP storage at 10 and 15°C and 90-95% relative humidity.

## MATERIALS AND METHODS

Fruits of cucumber cultivar "Malini" were harvested from the field after 7 days of anthesis. They were sorted and graded based on the fruit's length, diameter

and colour. Uniform fruits without any bruising were selected for the experiment. Fruits were divided into four lots of 20 kg each. The cucumber packaged in 20 µ Flexfresh™ expanded polyethylene biopolymer with oxygen transmission rate (OTR) of 2500 cc/kg/24 h and stored at 10°C were marked as treatment T1. The unpacked fruit stored at 10°C was marked T2 control. The cucumber fruit packed in 20 µ flexfresh™ expanded polyethylene biopolymer with OTR of 6000 cc/kg/24 h and stored at 15°C was marked as treatment T3. The unpacked fruit stored at 15°C was labelled T4 control. The relative humidity was 90-95% RH for all treatments.

Moisture content in all cucumber samples was determined by drying at 100°C (Ranganna, 10). The weight of all the packaged and control cucumber fruit was recorded at 2-day intervals and expressed as g/100 g loss. TSS was measured by Atago, Japan digital refractometer and expressed in °Brix. Ascorbic acid content was measured using the dye reduction method, and the values were expressed as mg of ascorbic acid/100g fresh weight (Ranganna, 10). Total phenolics content (TPC) was estimated using the Folin-Ciocalteu reagent (Singleton *et al*., 17). It was expressed as mg gallic acid equivalent (GAE)/100 g fresh pulp weight.

The firmness of all packaged and control cucumber with peel was estimated by texture analyzer (Texture Expert Exceed, Ver. 2.64. Stable Microsystem, U.K.) and expressed as newton (N). A needle probe was used with pre and post-test speeds of 2.0 and 1.0 mm/s, respectively. The gaseous composition of $O_2$ and $CO_2$ was monitored in all treatments by a headspace gas analyzer (Checkmate 9900, PBI Dansensor Co., Denmark). Polyphenol oxidase (PPO) and peroxidase (POD) enzyme activities were determined in cucumber fruit pulp samples (Ikediobi *et al*., 2). Optical density was measured at 420 nm for PPO and 470 nm for POD enzyme. It was expressed as units/min/g FW.

Sensory evaluation of packaged cucumber and control was done by a panel of 10 semi-trained evaluators at regular intervals during storage according to the Hedonic scale for the liking of colour, appearance, and overall acceptability score (OAA) (Lawless and Haymann, 4). Both whole and slices of cucumber were presented to them. In the present study, sensory score 7, 'liked moderately,' was taken as the limit of acceptable sensory score for acceptance of cucumber fruit.

Experiments were set up in factorial CRD with two factors (storage time and treatment conditions) in three replicates. Data were analyzed statistically (ANOVA-analysis of variance) using SPSS (version 16.0) and presented as mean ± standard error.

## RESULTS AND DISCUSSION

Moisture loss reduces the market value of fresh vegetables. Maximum moisture loss (10.23%) occurred in the control cucumber (T4). In comparison, packaged fruit (T1) showed the lowest decline (2.38%) compared to initial value after four weeks of storage at 15 and 10°C, respectively (Fig. 1A). The decrease in firmness and softening of fruit tissue aggravates rates of water loss. A maximum reduction in WL (weight loss) was noted in control brinjal fruit of long type due to higher metabolism rates (Sharma *et al*., 15). Higher $CO_2$ concentrations in the package atmosphere might have been attributed to slower respiration rates in packaged cucumber fruit stored at 15°C (T4), leading to lower WL and higher moisture retention (Fig. 1A).

Surprisingly, weight loss (WL) was significantly lower in the packaged cucumber fruit during storage at 15°C as compared to cucumber fruit stored at 10°C (Fig. 1B). The WL was in the range of 15.1-27.1% and 21.1-54.2% after 7 and 14 days of storage of untreated cucumber fruit at 10 and 15°C, respectively (Fig. 1B). Minimum WL (10.94%) was obtained in MAP stored cucumber fruit at 15°C, while control cucumber fruit exhibited highest WL (68.1%) after 21 days of storage at 15°C. Similarly, the packaged

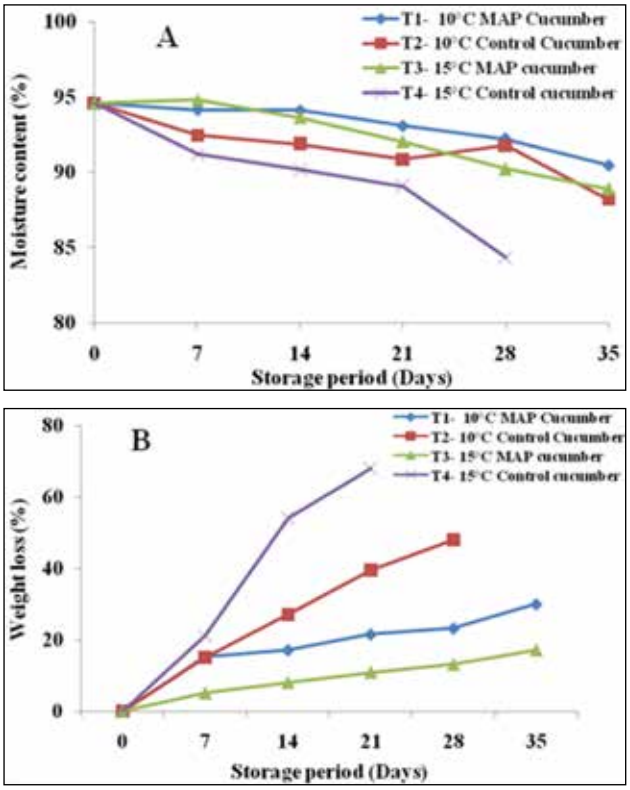


**Fig. 1.** Changes in moisture content (A) and weight loss (B) of cucumber fruit during storage (T1 - Fruit in MAP, OTR 2500 cc/kg/24h at 10°C; T2 - Control at 10°C; T3 - Fruit in MAP, OTR 6000 cc/kg/24 h at 15°C; T4 - Control at 15°C)

cucumber fruit had a WL of 21.6% compared to 39.7% in control cucumber fruit after 21 days of storage at 10°C. Manjunath and Anurag (5) also reported minimum WL (1.62%) in cucumber fruit packed in low-density polyethylene pouches with 2- perforations and maximum WL (12.89%) in control cucumber fruit after 12 days of storage at 4°C. Lower WL in packaged cucumber fruit during MAP storage at 15°C can be attributed to the build-up of higher concentration of $CO_2$ (3.0-3.7%) compared to lower $CO_2$ concentration (1.1-1.5%) after 20 days at 10°C.

Total soluble solids in cucumber fruit at harvest were found at 4.3°Brix. Hereafter, the TSS was found to decline in all treatments progressively with the storage period. At the same time, it showed a slight rise and then remained steady in the modified atmosphere packaged cucumber fruit (Table 1). The control cucumber (T4) stored at 15°C showed a sharp decline in TSS after 21-days of storage. The increase in TSS was found to be non-significant, while the decrease could be due to higher respiratory and metabolic activity in control compared to MAP fruit. An increase followed by a decline in soluble sugars was found in control fruit after storage at 4°C for 2 weeks, followed by 2 days at 20°C (Nasef, 8). The initial TSS was recorded at ~3.9°brix in the "Beinongjiaxiu" cucumber variety (Jia *et al*., 3). Manjunatha and Anurag (5) also reported that MAP preserves cucumber quality by slowing the metabolic rates in the packed fruit.

Ascorbic acid decreased in cucumber with advancement in storage. 68.3 and 65.8% loss in ascorbic acid after four weeks in packed fruit were observed at 10 and 15°C, respectively (Table 1). Nevertheless, untreated fruit showed maximum loss (71.6 and 79.3%). Ascorbic acid degradation depends on oxygen, temperature, pH and storage conditions. Maximum reduction in ascorbic acid content in control might have been due to considerably higher deterioration rates in such fruit and higher enzymatic activities.

Total phenolic content is a good indicator of antioxidant capacity. It lowered in all cucumber samples with progression in storage. Total phenolic content decreased from 29.48-12.38 and 29.48-13.73 mg/100 g fresh weight in packaged cucumber fruit after four weeks at 10 and 15°C, respectively (Table 1). On the other hand, untreated cucumber showed a maximum decrease in total phenolics content by 72.6 and 75.4% after 28 days at 10 and 15°C, respectively (Table 1). Control cucumber fruit exhibited minimum total phenol content as compared to packaged cucumber. Data on phenol content could be attributed to the increased levels of PPO and POD in control cucumber, which are responsible for the degradation of phenolic compound to a greater extent in control cucumber.

The firmness in fruit is related to pectin, cellulose, and hemicellulose. At harvest, the firmness in cucumber was 8.24N, which declined by about 50% to 4.68 and 4.72N in control cucumber after 28 days at

**Table 1.** Changes in total soluble solids (°Brix), ascorbic acid (mg/100 g FW) and total phenolics content (mg GAE/100 g FW) of cucumber fruit during storage.

| Treatment | Total soluble solids (°B) | | | | | |
|---|---|---|---|---|---|---|
| | 0 day | 7 day | 14 day | 21 day | 28 day | 35 day |
| T1 | 4.3 ± 0.03 | 4.2±0.06 | 4.4±0.09 | 4.1±0.08 | 3.9±0.06 | 3.6±0.07 |
| T2 | | 4.2±0.09 | 4.2±0.09 | 3.8±0.09 | 3.8±0.06 | - |
| T3 | | 4.0±0.04 | 3.9±0.08 | 3.9±0.04 | 3.8±0.03 | 3.7±0.04 |
| T4 | | 3.8±0.08 | 3.6±0.07 | 3.2±0.03 | 2.4±0.09 | - |
| | Ascorbic acid (mg/ 100 g FW) | | | | | |
| T1 | 5.91 ± 0.48 | 2.86± 0.19 | 2.28± 0.18 | 2.14± 0.09 | 1.87± 0.08 | 1.21± 0.05 |
| T2 | | 2.63± 0.16 | 1.99± 0.05 | 1.90± 0.08 | 1.68± 0.06 | - |
| T3 | | 2.86± 0.08 | 2.65±0.17 | 2.61±0.15 | 2.02± 0.09 | 1.32± 0.05 |
| T4 | | 2.31±0.17 | 1.91± 0.08 | 1.45±0.06 | 1.22± 0.04 | - |
| | Total phenolics content (mg GAE/ 100 g FW) | | | | | |
| T1 | 29.48 ± 2.16 | 26.55± 1.15 | 23.95±0.89 | 18.50± 0.69 | 12.38±0.46 | 8.17± 0.33 |
| T2 | | 22.14± 0.83 | 19.02±0.25 | 14.77±0.59 | 8.09±0.30 | - |
| T3 | | 28.68± 1.25 | 22.22±0.95 | 17.51±0.65 | 13.73±0.67 | 3.22± 0.10 |
| T4 | | 20.05±0.75 | 16.12±0.69 | 12.85±0.48 | 7.25±0.32 | - |

T1 - Fruit in MAP, OTR 2500 cc/kg/24h at 10°C; T2 - Control at 10°C; T3 - Fruit in MAP, OTR 6000 cc/kg/24 h at 15°C; T4 - Control at 15°C

10° and 15°C, respectively (Fig. 2A). Higher firmness of 6.86 and 4.1 N were noted in packaged cucumber over control at 15 and 10°C, respectively at the end of storage period. Manolopoulou *et al*. (6) observed lower firmness in untreated bell peppers over those packed under modified atmospheric conditions. The lower activity of cell wall degrading enzymes in modified atmosphere conditions helps preserve firmness.

Gaseous composition under MAP is essential to assess the quality and marketability of packaged vegetables. The gaseous composition of $O_2$ and $CO_2$ under MAP storage of cucumber fruit at 10° and 15°C is presented in Fig. 2B. The oxygen concentration trend showed an increase followed by a plateau at 10°C and a slight decrease followed by the rise and plateau at 15°C storage. Conversely, the carbon dioxide concentration in treatments at 10° and 15°C slightly increased, followed by a decline and plateau. Changes in the gaseous regime can be attributed to higher respiration levels in the transient state of stabilization and equilibration. Our results correspond with Manjunatha and Anurag (5). However, with a further increase in storage beyond 20 days, there had been an increase in $O_2$ and a corresponding decrease in $CO_2$ concentration in packaged cucumber fruit at 10 and 15°C. $O_2$ (19.5 and 19.8%) and $CO_2$ (1.4 and 4.1%) concentrations varied after four weeks of fruit storage at 10 and 15°C, respectively, in 20µ flexfresh expanded polyethylene biopolymer (Fig. 2B). The $CO_2$ content was increasing (4.5 and 10.3%) in packaged cucumber fruit up to 7 days of storage at 10 and 15°C, respectively. The build-up of higher concentration of $CO_2$ (4.1 and 1.4%, respectively) at 15°C can be attributed to the increase in the shelf life of packaged cucumber fruit as compared to storage of cucumber at 10°C after 21 days of storage (Fig. 2B). Earlier studies also suggested that there had been a decrease of 4.45% $O_2$ concentration and increase of 9.85% $CO_2$ concentration between 7 and 49 days of active modified storage of capsicum at 3°C (Singh *et al*., 16).

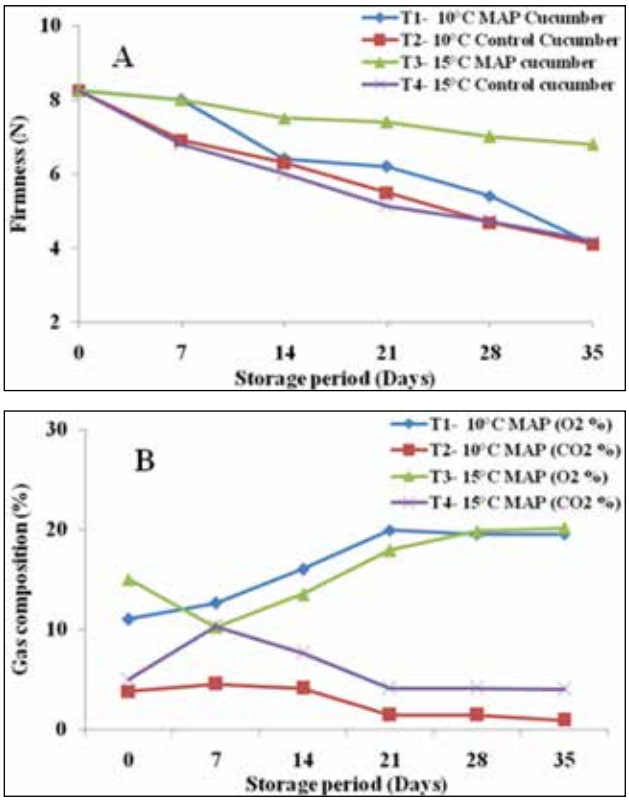


**Fig. 2.** Changes in firmness (A) and gas composition (B) of cucumber fruit during storage (T1- Fruit in MAP, OTR 2500 cc/kg/24h at 10°C; T2- Control at 10°C; T3- Fruit in MAP, OTR 6000 cc/kg/24h at 15°C; T4- Control at 15°C).

PPO and POD activities in plants are primarily responsible for browning reactions (Sharma *et al*., 14). The PPO activity was about 2 and 3 folds higher in control cucumber fruit over packaged cucumber fruit after four weeks of MAP storage at 10 and 15°C, respectively (Fig. 3A). It is evident that maximum PPO activity was recorded in control unpacked fruit stored at 15°C after four weeks of storage. Cucumber fruits kept under control treatment exhibited 93.5 and 189.5% increase in PPO activity after 28 days than packaged cucumber under MAP storage at 10 and 15°C, respectively (Fig. 3A). Increased level of PPO activity is predictive of oxidative browning in cucumber during storage at 10 and 15°C which is related to the main cause of quality loss during post-harvest storage. Similarly, higher polyphenol oxidase activity was reported in untreated eggplant over coated fruit (Sharma *et al*., 15). The PPO enzyme activity was found 69.2 units/g FW in cucumber fruit under greenhouse growing conditions and with rockwool used as a soilless substrate (He *et al*., 1). A strong relationship has been found between residual peroxidase activity and off-flavour development in foods. Our results showed that control cucumber fruit exhibited an 8-fold and 16-fold increase in POD activity after four weeks at 10 and 15°C, respectively (Fig. 3B). Judges also noted shriveling and off flavour development in control cucumber after 21 days at 15°C.

The 9-point Hedonic scale mentions sensory score 7.0 as 'liked moderately' which was judged as the acceptable sensory score for cucumber fruit. Initially, all the packaged and control cucumber fruit samples showed a higher overall sensory score for quality like flavour, colour and appearance, and body and texture of the fruit. The overall acceptability (OAA) score was '8', liked very much on the 9-point Hedonic scale. Freshly packaged cucumber fruits

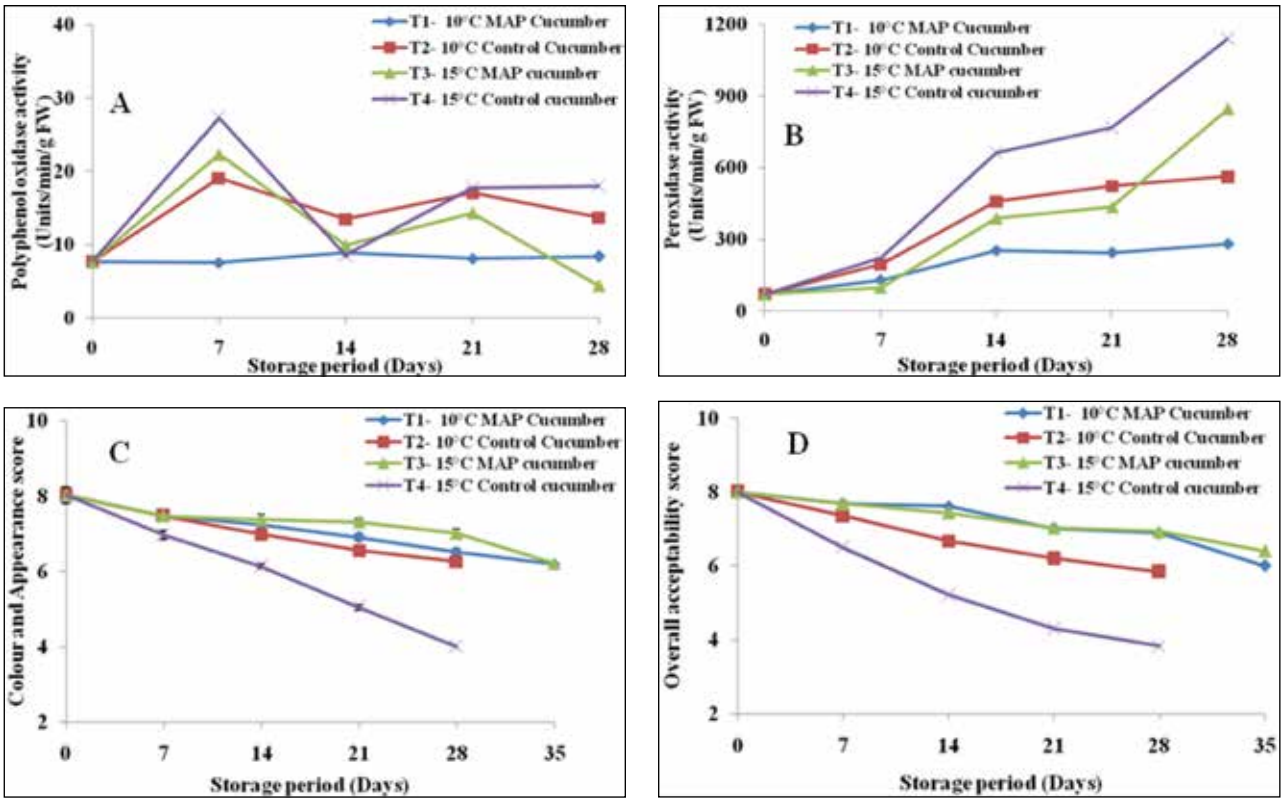


**Fig. 3.** Changes in polyphenol oxidase (A), peroxidase activity (B), colour and appearance score (C), overall acceptability score (D) of cucumber fruit during storage (T1- Fruit in MAP, OTR 2500 cc/kg/24 h at 10°C; T2- Control at 10°C; T3- Fruit in MAP, OTR 6000 cc/kg/24 h at 15°C; T4- Control at 15°C).

during storage at 15°C have a significantly higher sensory score than those stored at 10°C. Colour and appearance scores also decreased during storage in packaged cucumber at 10° and 15°C (Fig. 3C). OAA sensory score also followed a similar pattern. Decrease in the sensory score during storage (Fig. 3D). Similarly, the maximum OAA sensory score (7.1, 7.0) was reflected in packaged cucumber at the end of storage at 15° and 10°C, respectively (Fig. 3D). Judges observed shrivelling, pitting, shrinkage and yellowness in control cucumber after two weeks at 15°C which is reflected with maximum decrease (5.21) in OAA sensory score. The results conform with the observations of Manjunatha and Anurag (5) in which all cucumber fruit in perforated LDPE film bags were not acceptable due to change in colour to yellow, shrinkage, decay and off-flavour development during extended storage at ambient and 4°C (Manjunatha and Anurag, 5).

In conclusion, cucumber fruit packaged in 20 µ flexfresh expanded polyethylene biopolymer having OTR of 6000cc/kg/24 h (T3) maintained the desired MAP gaseous condition (19.8% $O_2$ and 3.0-3.7% $CO_2$) during MAP storage at 15°C. The gaseous composition lowered WL, retained moisture, firmness, total phenols and preserved fruit quality during storage. Cucumber fruit under MAP storage remained acceptable to judges with a sensory score of '7' after 21 and 28 days of advancement in storage at 10 and 15°C, respectively.

## AUTHORS' CONTRIBUTION

Conceptualization of research (SUS, SWS); Designing of the experiments (SUS, SWS); Contribution of experimental materials (SUS); Execution of lab experiments and data collection (SUS, SWS); Analysis of data and interpretation (SUS, SWS); Preparation of the manuscript (SUS, SWS, SNS, TKB).

## DECLARATION

The authors declare no conflict of interest concerning this manuscript.

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