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Quality evaluation of modified atmosphere packed minimally processed garlic cloves

J. Venu Madhav, Shruti Sethi*, Charanjit Kaur and R.K. Pal**

Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, New Delhi - 110 012, India

ABSTRACT

In this study, the quality of modified atmosphere packed minimally processed garlic cloves of two Indian varieties, *viz*., Yamuna Safed (G-1) and Yamuna Safed-4 (G-323) were evaluated during storage. To select the most appropriate modified atmosphere conditions, 3 concentrations each of oxygen (1, 2 and 3%) and carbon dioxide (5, 10 and 15%) were selected. The minimally processed garlic cloves were packed in these 9 combinations and stored at 10ºC and 75-85% RH for 28 days. The technique of repeated measures was applied by using Proc mixed methodology to statistically measure the changes in various parameters during storage. Among the different gas compositions, samples stored with 1-2% O_2 and 5% CO_2 were found to be the most effective for retaining firmness, colour, total antioxidant capacity, total phenolic content and pyruvic acid of the samples and minimizing the physiological loss in weight and respiration rate throughout the storage period of 28 days irrespective of variety used.

Key words: Firmness, garlic, modified atmospheric packaging, pyruvic acid, total antioxidant capacity.

INTRODUCTION

Owing to rapid urbanization and more women joining the workforce, use of ready-to-eat, minimally processed convenience foods is gaining increasing popularity (Cantwell and Suslow, 2). Garlic (*Allium sativum* L.) is the second most widely cultivated allium vegetable next to onion. Madhav *et al*. (9) have reported protein, fat and fibre in the range of 5.6-6.12%, 0.87-0.91% and 0.73-0.77%, respectively in two popular garlic varieties. They also reported ascorbic acid content, total phenolic content and total antioxidant activity in the range of 5.16-6.55 mg/100 g, 141.3-142.1 mg GAE/ 100 g and 12.75-14.63 µmol TE/ g, respectively in fresh garlic cloves. Since, it is an important ingredient in daily Indian diet and the peeling of garlic is a laborious and time consuming process, developing minimally processed peeled garlic cloves will help to reduce drudgery and also reduce the dirt and garbage in kitchen. Peeled garlic cloves have short shelf-life because they have high tendency towards surface discoloration, moisture loss and microbial spoilage (Kang and Leedong, 5). Other important causes of quality loss are sprouting and rooting, which occur because of high humidity conditions in plastic packaging and storage above the recommended temperatures (Cantwell and Suslow, 2). There are many preservation techniques that are currently being used by the fresh-cut industry such as antioxidants, chlorines, modified atmosphere packaging (MAP) and ionizing radiations to increase the shelf-life of minimally processed products (Sudhir and Indira, 16) in addition to storage at low temperatures (Cantwell and Suslow, 2). Modified atmosphere packaging (MAP) of fresh fruits and vegetables is based on modifying the levels of O_2 and CO_2 in the atmosphere inside a package sealed with some type of polymer film. Additionally, the desired atmosphere can reduce the respiration rate, ethylene production and the growth of organisms that cause decay. Further, it can inhibit chemical, enzymatic and microbiological mechanisms associated with the decay of fresh products, thus avoiding the use of other chemical or thermal process such as freezing, dehydration and sterilization (Saltveit, 12). The objectives of this study were to determine the optimum gas composition for packaging of minimally processed garlic cloves of two popular garlic varieties of India and to investigate the changes in various quality parameters such as PLW, firmness, colour, total phenolic content, total antioxidant capacity and pyruvic acid during storage at low temperature.

MATERIALS AND METHODS

The garlic varieties Yamuna Safed (G-1) and Yamuna Safed-4 (G-323) were procured from National Horticultural Research Development Foundation, Karnal, Haryana. Garlic bulbs were harvested at 70% neck fall stage and curing was done for 7 days. Bulbs were then brought to ICAR-IARI, New Delhi for conducting the experiment. The cloves of garlic varieties G-1 and G-323 were peeled manually

*Corresponding author's E-mail: docsethi@gmail.com

**Director, National Research Centre for Pomegranate, Solapur, Maharashtra, India

followed by packing in modified atmosphere conditions (combinations of CO_2 @ 5, 10 and 15%; O_2 @ 1, 2 and 3%) by a modified atmosphere packaging machine (Dansensor, Denmark) in polypropylene trays with polyamide sheet as covering material. Each pack had 500 ml volume and contained 100 g of peeled garlic cloves. After packaging garlic cloves were stored at low temperature (10 ± 1°C). During storage, the samples were analyzed for a period of 28 days at regular interval of 7 days for studying the changes in their various quality attributes (data shown only for the last storage period). Three replicate observations were taken for each sample and mean value was calculated. Physiological loss in weight (PLW) was measured by subtracting the initial sample weight from the final weight at a particular time interval. It was expressed in percentage. Clove firmness was determined using a texture analyser (Model TA+Di; Stable Microsystems, Godalming, UK) using compression test and expressed in Newton (N). Colour of the minimally processed garlic cloves was measured using Hunter Colour Lab Scan XE and the CIE L, a, b colour scale. The rate of respiration was measured using the static headspace technique by measuring the concentrations of O_2 and CO_2 using an auto-gas analyser (Checkmate 9900; PBI Dansensor, Ringsted, Denmark) and expressed as mg CO_2 kg^{-1} h^{-1} (Sharma *et al*., 13).

The total phenolic content of garlic extracts were determined by the method of Singleton and Rossi (14), with slight modifications and expressed in mg gallic acid equivalents (GAE) 100 g^{-1} of extract. Total antioxidant capacity in garlic cloves was determined by the CUPRAC method (Apak *et al*., 1) and expressed as µmol TE (trolox equivalent) g^{-1} FW of garlic. Pungency was estimated according to method described by Ketter and Randle (6) and results were expressed as µmol pyruvic acid/ g^{-1} sample.

In the experiment conducted on modified atmospheric packaging of minimally processed garlic cloves, repeated measures two-way analysis of variance (ANOVA) was performed on the data sets using PROC MIXED procedure of SAS 9.3. Further, Tukey's HSD test was done for pair-wise comparison of different factors and their interactions and the effects which are significantly different were represented by different alphabets.

RESULTS AND DISCUSSION

Physiological loss in weight of the modified atmosphere packaged samples during storage of the two garlic varieties G-1 and G-323 are showed in Fig. 1a & b, respectively. The experimental results showed that the increase in PLW is very less in both the varieties, during storage for 28 days at 10 ± 1°C. Minimum PLW was observed for samples packed in 5% CO_2 and 2% O_2 with a value of 1.07 ± 0.09% for garlic cv. G-1 whereas least PLW (1.26 ± 0.09%) was observed for samples of var. G-323 under 5% CO_2 and 1% O_2 conditions. This can be attributed to the suppression of the overall metabolic activity of plant tissues owing to the modified atmospheres as highlighted by Rojas-Grau *et al*. (11). Although PLW is mainly due to loss of moisture by transpiration and desiccation but in the current experiment it is owing to losses of respiratory substances and it was observed that MAP could drastically control the loss in weight of garlic cloves.

Degree of colour change (ΔE) of the peeled garlic cloves varied significantly (P ≤ 0.05) with CO_2 and O_2 concentrations and storage duration (Fig. 2 a & b). Minimally processed garlic cloves packed with high CO_2 atmospheres (10 and 15%) showed maximum degree of colour change. Minimum colour change was observed in samples stored in 5% CO_2 and 1% O_2 in garlic var. G-1 (ΔE 2.57 ± 0.16) and var. G-323 (ΔE 2.70 ± 0.12) at the end of 28 days of storage. This might be due to low levels of O_2 concentration around the clove tissues that retards the browning reactions by reducing the enzymes activity. Similar findings were reported by various authors in different fruits and vegetables (Va´mos-Vigya´zo´, 17). It is also evident that high concentration of CO_2 is detrimental to the cell integrity

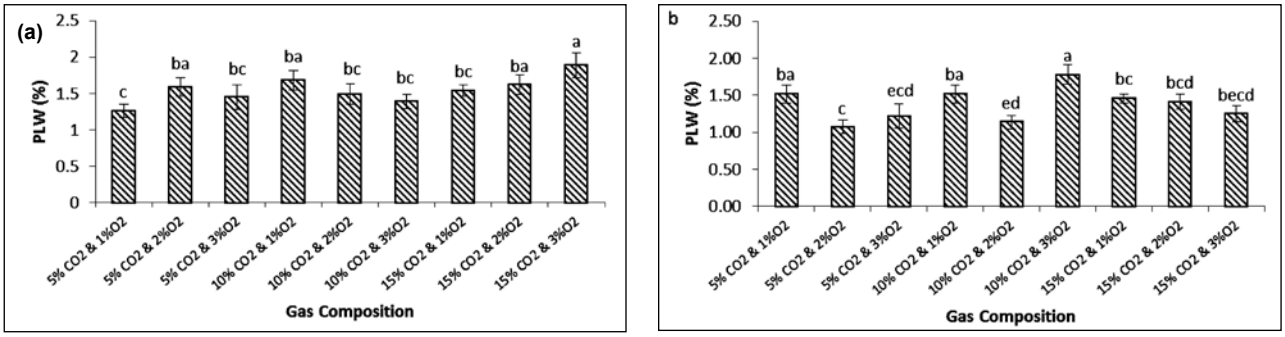

Fig. 1. Effect of MAP on PLW (%) of garlic var. G-1 (a) and G323 (b) after the storage of 28 days at 10°C.

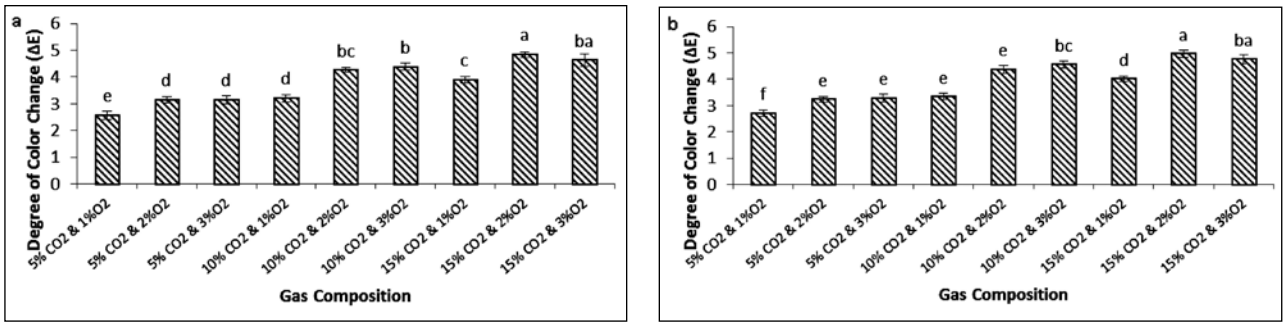

Fig. 2. Effect of MAP on degree of colour change of garlic var. G-1 (a) and G323 (b) after the storage of 28 days at 10°C.

and changes the colour and overall acceptability of the cloves. Earlier, some authors have attributed this greening phenomenon of the garlic cloves to cell injury caused by high concentrations of CO_2 (Lee *et al.*, 8).

The effect of modified gas compositions on the firmness of the minimally processed garlic cloves of the two garlic var. G-1 and G-323 are shown in Fig. 3 a & b, respectively. Maximum firmness was retained in samples packed in gas composition of 5% CO_2 and 2% O_2 for G-1 (3.75 ± 0.27 N) and G-323 (4.41 ± 0.27 N) varieties. Although texture in terms of firmness reduced significantly ($P \leq 0.05$) during the entire storage period of 28 days of minimally processed garlic cloves, all the samples remained acceptable till the end. In the present investigation, high CO_2 concentrations were found to adversely affect the firmness of garlic cloves. Specifically var. G-1 and G-323 showed lower firmness at 15% and 10% CO_2 concentrations, respectively. Earlier Soliva-Fortuny *et al*. (15) reported a damaging effect of high CO_2 concentrations in fresh-cut pear and apple tissues leading to loss of textural integrity. The effects on respiration rate of the minimally processed garlic cloves with changes in gas composition and storage duration are shown in Fig. 4 a & b. Respiration rate gradually increased during the storage period of 28 days in all the samples, the comparative increase being less in samples having low oxygen compared to that of high oxygen concentration in all the samples. A cut product has greater surface area, and is potentially subject to greater water loss, more damaged sites, higher respiration and ethylene production rates, and higher microbial growth. While MAP can delay these events, the cut product is more metabolically active than the whole product, as well as being more prone to decay, and therefore short lived. Overall least respiration rate was observed for samples packed in 5% CO_2 and 1% O_2 having mean values of 10.86 ± 1.07 mg CO_2/kg/h in garlic var. G-1 and 11.24 ± 1.36 mg CO_2/kg/h in var. G-323. No significant difference ($p \leq 0.05$) was found between the samples stored in 1% O_2 concentration. Similar findings have been reported earlier by Laughlin and O'Beirne (7). Atmospheres low in O_2 (1-5%) and high in CO_2 (5-10%) have been used to extend the shelf-life of fresh-cut fruits and vegetables by reducing respiration, transpiration and ethylene production, as O_2 is involved in the conversion of 1-amino-cycloprane-1-carboxylic acid to ethylene (Yang and Hoffman, 18).

Data displayed in Table 1 indicated that there was a significant ($p \leq 0.05$) effect of gas composition on the reduction in total phenols and total antioxidant capacity of minimally processed garlic cloves during the storage period of 28 days irrespective of variety. Minimum decrease in total phenols was observed in samples stored under low CO_2 (5%) along with low O_2 (2%) in G-1 (26.42%) and G-323 (23.35%). The decline

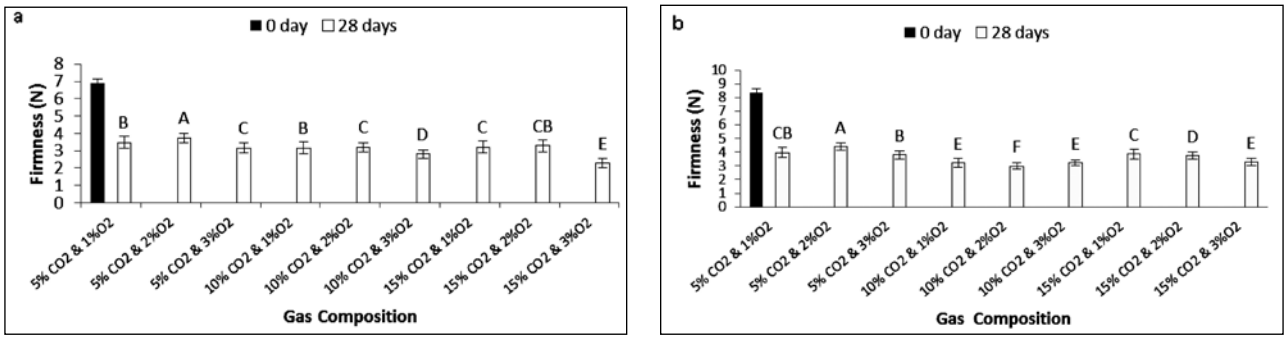

Fig. 3. Effect of MAP on firmness (N) of garlic var. G-1 (a) and G323 (b) during storage at 10°C.

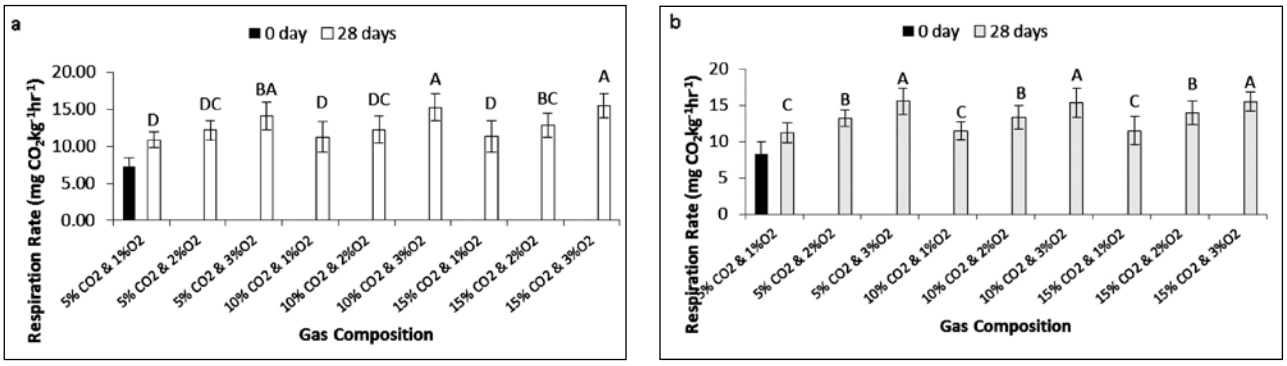

Fig. 4. Effect of MAP on respiration rate (mg CO_2/g) of garlic var. G-1 (a) and G323 (b) during storage at 10°C.

of phenolic content during the storage may be due to the possible oxidation of polyphenols to quinones (Queiroz *et al*., 10). Samples stored at low CO_2 and O_2 composition maintained higher total phenolic content because of retardation of oxidation processes. Maximum retention of total antioxidant capacity was observed by end of storage under MA conditions of 5% CO_2 and 1% O_2 for var. G-1 (5.21 ± 0.29 µmol TE/ g) and at 5% CO_2 and 2% O_2 for var. G-323 (5.89 ± 0.26 µmol TE/ g) at the end of the storage. There was a decline in the total antioxidant capacity throughout the storage period irrespective of the treatments and gas composition. The retention of high antioxidant capacity in samples stored under low CO_2 and O_2 gas composition might be due to the retention of high total phenolic content in these samples. Correlation between total phenolic content and the total antioxidant capacity was worked out and it was found to be highly correlated for both G-1 (r^2 = 0.89) and G-323 (r^2 = 0.86) varieties. Earlier, Queiroz *et al.* (10) also reported a decline in the *in-vitro* antioxidant capacity and attributed it to the decline of polyphenol content during the storage considering their action as antioxidants.

In this study pyruvic acid decreased significantly (P ≤ 0.05) with the progress of storage period up to 28 days in minimally processed garlic cloves of both the varieties (Table 1). Per cent retention of pyruvic acid was observed to be maximum in variety G-1 (62.64%) as compared to G-323 (53.01%) at 5% CO_2 and 2% O_2. As deduced from the results, pungency of minimally processed garlic decreased significantly with advancement of storage period. This may be attributed to hydrolysis of polysaccharides and non-reducing sugars, where acid is utilized for converting them to hexose sugars and degradation of pungency constituents. The findings are in contrast with Dronachari *et al.* (4) who reported an increase in pyruvic acid (pungency) with the advancement of

Table 1. Treatmentwise means for the different biochemical parameters for two garlic var. G-1 and G-323 on 0 and 28 days after storage.

Treatment	G-1			G-323		
	Total antioxidant capacity (µmol TE/g)	Total phenolic content (mg GAE/ 100 g)	Pyruvic acid (µmol/g)	Total antioxidant capacity (µmol TE/g)	Total phenolic content (mg GAE/ 100 g)	Pyruvic acid (µmol/g)
0 day	14.26 ± 0.81	140 ± 1.57	47.1 ± 0.26	12.05 ± 0.97	137 ± 1.21	45.2 ± 0.18
5% CO_2 & 1% O_2	5.21 ± 0.29^{a}	101 ± 1.87^{a}	26.2 ± 0.18^{ba}	5.48 ± 0.38^{a}	102 ± 1.33^{a}	19.94 ± 0.35^{b}
5% CO_2 & 2% O_2	4.25 ± 0.97^{b}	103 ± 1.46^{a}	29.5 ± 0.71^{a}	5.89 ± 0.26^{a}	105 ± 1.32^{a}	23.96 ± 0.24^{a}
5% CO_2 & 3% O_2	3.14 ± 1.04^{e}	98 ± 1.75^{b}	26.4 ± 0.26^{b}	3.95 ± 0.97^{cd}	98 ± 1.45^{ba}	18.93 ± 0.23^{c}
10% CO_2 & 1% O_2	3.65 ± 1.01^{cd}	92 ± 1.89^{d}	23.6 ± 0.15^{c}	3.82 ± 0.85^{cd}	92 ± 1.50^{bcd}	19.34 ± 0.12^{cb}
10% CO_2 & 2% O_2	3.98 ± 0.72^{cb}	85 ± 1.58^{f}	18.4 ± 0.27^{e}	3.15 ± 0.78^{e}	87 ± 1.42^{ecd}	14.73 ± 0.24^{f}
10% CO_2 & 3% O_2	3.67 ± 0.95^{cd}	91 ± 1.24^{d}	22.1 ± 0.24^{dc}	3.26 ± 0.96^{de}	91 ± 1.63^{cd}	17.33 ± 0.21^{e}
15% CO_2 & 1% O_2	3.25 ± 0.85^{ed}	95 ± 1.26^{c}	23.2 ± 0.11^{dc}	3.16 ± 0.49^{e}	93 ± 1.40^{bc}	17.56 ± 0.08^{e}
15% CO_2 & 2% O_2	3.28 ± 0.57^{ed}	88 ± 1.18^{e}	22.6 ± 0.15d^{c}	3.14 ± 0.68^{e}	81 ± 1.54^{e}	19.65 ± 0.12^{b}
15% CO_2 & 3% O_2	3.71 ± 0.79^{cd}	91 ± 1.58^{d}	21.0 ± 0.19^{d}	4.06 ± 0.36^{b}	85 ± 1.26^{e}	18.23 ± 0.16^{d}

$^{a-f}$Means with different superscripts in the same column differ significantly (P ≤ 0.05)

the storage period. Earlier, Cantwell *et al.* (3) reported that pyruvate concentrations in garlic bulbs and unpeeled cloves were maintained in CO_2 containing atmospheres, but increased in air and low O_2 stored garlic at 0-1°C for 6 months.

The results verified that modified atmosphere packaging could substantially extend the storage life of minimally processed garlic cloves. Out of the various combinations of gases used, gas composition of 1-2% O_2 and 5% CO_2 was most effective for overall quality retention of garlic cloves during modified atmosphere storage under 10 ± 1°C storage conditions. This gas composition was found best to reduce physiological loss in weight, degree of colour change and respiration rate of the minimally processed produce. Additionally, the total phenolic content, total antioxidant capacity and pyruvic acid content were best retained under these gas conditions.

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