Impact of storage temperatures and modified atmospheres on quality of fresh-peeled garlic cloves

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Abstract

Fresh-peeled garlic is an increasingly important product for foodservice and retail markets. Two storage tests were conducted using garlic cloves ('California Late') that were peeled and packaged commercially. In Test #1 (MAP bags of 454 g), O_2 concentrations averaged 15, 10 and 5% at 0, 5 and 10°C, respectively; the corresponding CO_2 concentrations averaged 8, 15 and 23%. In Test #2 with small vacuum packed bags (30 g) inside larger master packages (170 g), atmospheres in the former averaged 1.5-3% O_2 and 20-30% CO_2 at all storage temperatures (0, 2.5, 5 and 7.5°C), while the master bags averaged 20-21% O_2 and 0.5-0.8% CO_2. In both tests, discoloration occurred in areas damaged during mechanical peeling, and was associated with lower L* and increased chroma values. In Test #1, decay was a significant contributor to loss of quality. In Test #1 excellent visual quality was maintained during 21 and 16 d at 0 and 5°C, respectively, and acceptable quality was maintained for about 10 d at 10°C. In Test #2, very good visual quality was maintained up to 28 d at 0 and 2.5°C, and acceptable quality was maintained for 21 d at 5 and 7.5°C. No important changes in texture were observed due to temperature or storage time. Pungency (thiosulfinate and pyruvate concentrations) decreased with time and the decrease was greater at higher storage temperatures. A reasonable expected storage-life of commercially peeled and modified atmosphere packaged garlic is 3-4 weeks at 0°C, 2-3 weeks at 5°C and 1-2 weeks at 10°C.

Keywords: visual appearance, color, pungency, dry weight, storage-life

INTRODUCTION

Peeled garlic cloves are a convenient minimally processed vegetable for both retail and foodservice markets (Cantwell and Suslow, 2002; Kang and Lee, 1999). While intact garlic has a very low respiration rate and can be stored for long periods, the physical damage incurred during the peeling process contributes to increased respiration rates and perishability in the minimally processed product (Ramirez-Moreno et al., 2000). The main defects of commercially peeled and modified atmosphere packaged garlic are discoloration and decay. Most of the discoloration is associated with damaged areas (Cantwell et al., 2003a). High carbon dioxide atmospheres retard discoloration and decay of peeled garlic at 5 and 10°C (Kang and Lee, 1999; Ramirez-Moreno et al., 2000) and intact garlic at lower temperatures (Cantwell et al., 2003a). Other important causes of quality loss are sprouting and rooting, which occur because of high humidity in plastic packaging without modified atmospheres and because of storage at higher than recommended temperatures (Cantwell and Suslow, 2002). Modified atmospheres with high CO_2 concentrations reduce sprout development but are less effective in control of adventitious rooting under high humidity conditions (Kang and Lee, 1999). Pre- or post-peeling hot water dips also can control rooting and sprouting (Cantwell et al., 2003b). Recent research on peeled garlic has focused on disinfection protocols (Veríssimo et al., 2010; Park and Kim, 2015) and edible coatings (Geraldine et al., 2008; Sothornvit and Tangworakit, 2015) as means to extend quality and shelf-life.

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The objective of this study was to better document the impact of storage temperature on quality attributes of commercially peeled and modified atmosphere packaged garlic. The temperatures used cover the range that may be found during commercial distribution.

MATERIALS AND METHODS

Two storage tests were conducted using garlic cloves ('California Late') that were peeled and packaged commercially for retail sale. Preparation involves 'cracking' the bulbs, forced-air peeling of the cloves, chlorine rinse and cold air tunnel drying. In Test #1, peeled garlic was packaged in l pound (454 g) packages stored at 0, 5 or 10°C while in Test #2 peeled garlic was packed in small vacuum packs of 30-40 g in a 170 g master package and stored at 0, 2.5, 5 or 7.5°C (Figure 1). Product in both tests were obtained from a local wholesaler within 2-3 d after processing, with Test #1 from garlic processed in October 2014 and Test #2 from garlic processed in January 2015. Prior to the weekly evaluations, gas concentrations were determined in the bags and vacuum packages. Gas concentrations were also determined on the master bag in Test#2 but did not differ notably from an air atmosphere at any temperature (20-21% O_2 and 0.5-0.8% CO_2). Gas samples of 0.5 mL were taken from a sample port from the bags (Test #1) or two vacuum packs per replicate (Test #2). The CO_2 was measured on an Infrared analyzer (Horiba PIR-2000, Japan) and O_2 was determined on an Oxygen analyzer (S-3A, Applied Electrochemistry, USA). Bags or vacuum packs were opened and cloves were placed on white trays for evaluation. Digital photographs were taken to illustrate quality changes. For overall visual quality assessment, three replicates of about 100 g each (Test #1) and six vacuum packs per replicate (Test #2) were evaluated using a 9-1 scale, where 9 = excellent; 7 = good; 5 = fair; 3 = poor; and 1 = unusable. A score of 6 was regarded as the limit of marketability. Defects (decay, mechanical damage, discoloration) were evaluated using a 1-5 scale, where 1 = none, 2 = slight, 3 = moderate, 4 = moderately severe, and 5 = severe.

Figure 1. Peeled garlic in a 454 g MAP bag in Test #1 (left) and peeled garlic in 1 of 6 individual vacuum packs inside a master consumer package of 170 g for Test #2 (right).

Objective L*, a* and b* color values were obtained with a color meter (Minolta, CR-300, Japan) measured at midpoint of the cloves on the convex surface. Texture was measured on a TA-XT2i analyzer (Texture Technologies, Scarsdale, NY) as newton-force to penetrate the convex side of the clove with a 3-mm flat cylindrical probe at 1 mm s^{-1} to a depth of 5 mm.

Compositional analyses included dry weight and pungency measured by two methods (pyruvate produced by the enzyme alliinase and thiosulfinate content). About 50 g sliced garlic was weighed, freeze dried and reweighed to calculate % dry weight. For determination of pungency, cloves were cut longitudinally; half were microwaved (for background pyruvate) and both sets were frozen at -20°C and freeze-dried. For pyruvate measurement, a modified version (Anthon and Barrett, 2003) of the standard pyruvate acid method (Schwimmer and Weston, 1961) was used. A 0.5 g garlic powder sample was homogenized 1 min in 20 mL water; let stand 10 min at room temperature, centrifuged 10 min at 14 000 rpm and 4°C. An aliquot of 0.5 mL of the supernatant was added to 2 mL water, 25 µL diluted sample + 1 mL distilled water + 1 mL DNPH (25 µL distilled water instead of diluted sample was used for blank). Sample was vortexed and held for 10 min at 37°C in a water bath. After adding 1 mL NaOH, the sample tube was vortexed, held 10 min at room temperature and the absorbance was measured at 515 nm. A standard curve from 0 to 0.75 µmol mL^{-1} of sodium pyruvate was used for calibration. The same procedure was used to measure residual pyruvate (background) on the microwaved freeze dried samples which was subtracted from total pungency values to determine enzyme-generated pyruvate. For measurement of total thiosulfinates, the same extract from the pyruvate assay was used. An aliquot 1 mL was centrifuged at 5°C, 14 000 rpm for 20 min and the supernatant was diluted 10 times with water. To a 375 µL diluted sample in a test tube on ice, or 375 µL water for reference, 625 µL 0.8 mM cysteine solution was added and the mixture was shaken and held 10 min at room temperature. An aliquot of 200 µL of sample/cysteine solution or water/cysteine solution was added to test tubes containing 0.8 mL of 200 µM DTNB (5,5'-dithio-bis-(2-nitrobenzoic acid) in 50 mM HEPES buffer, pH 7.5. For a blank, 200 µL of pure water was added to the DTNB tube. After shaking, tubes were held 10 min at room temperature for color development. Absorbance was measured at 412 nm (Shimadzu UV-1700 PhamaSpec Spectrophotometer, Kyoto, Japan), and thiosulfinate concentrations were calculated according to Han et al. (1995) and expressed on a dry weight basis.

Data were based on 3 replicates per treatment per evaluation with each replicate containing 20 cloves in Test #1 and 10 cloves in 6 vacuum packs in Test #2. Data were analyzed by ANOVA with mean separation by calculation of LSD.05. Gas concentrations data were based on three replicates in Test #1 (1 bag = 1 replicate) and 5 replicates (1 vacuum pack = 1 replicate) in Test #2 ± standard deviation.

RESULTS AND DISCUSSION

Storage temperature greatly affected gas composition in the bags in Test #1, while there was little variation due to temperature in O_2 and CO_2 concentrations in Test #2 (Figure 2). The O_2 concentrations averaged 15, 10 and 5% at 0, 5 and 10°C, respectively, in Test #1, while the CO_2 concentrations averaged 8, 15 and 23% at the same temperatures (Figure 2). In Test #2, all O_2 concentrations in the small vacuum packs were in the range of 1.5-3% regardless of storage temperature, and corresponding CO_2 concentrations all decreased from an initial 35% to 22% at 28 d. The average O_2 and CO_2 concentrations in master bags were 20-21% O_2 and 0.5-0.8% CO_2 over the 28 d, respectively (data not shown).

Due to a high level of mechanical damage (>50% of cloves), initial quality was scored as very good but not excellent in Test #1. Both decay and discoloration were major contributors to quality loss of peeled garlic stored at 5 or 10°C (Figure 3B, C). Storage at 0°C effectively controlled these defects over the 28 d and overall visual quality was scored as very good throughout the test. At 5°C very good quality was maintained up to 14 d, and at 10°C good quality was maintained for about 10 d. L* color value changes generally corresponded to visual quality scores (Figure 3D). Texture of the peeled cloves ranged from 17.5-18.5 N over the course of the test with no significant differences due to storage temperature or time (data not shown).

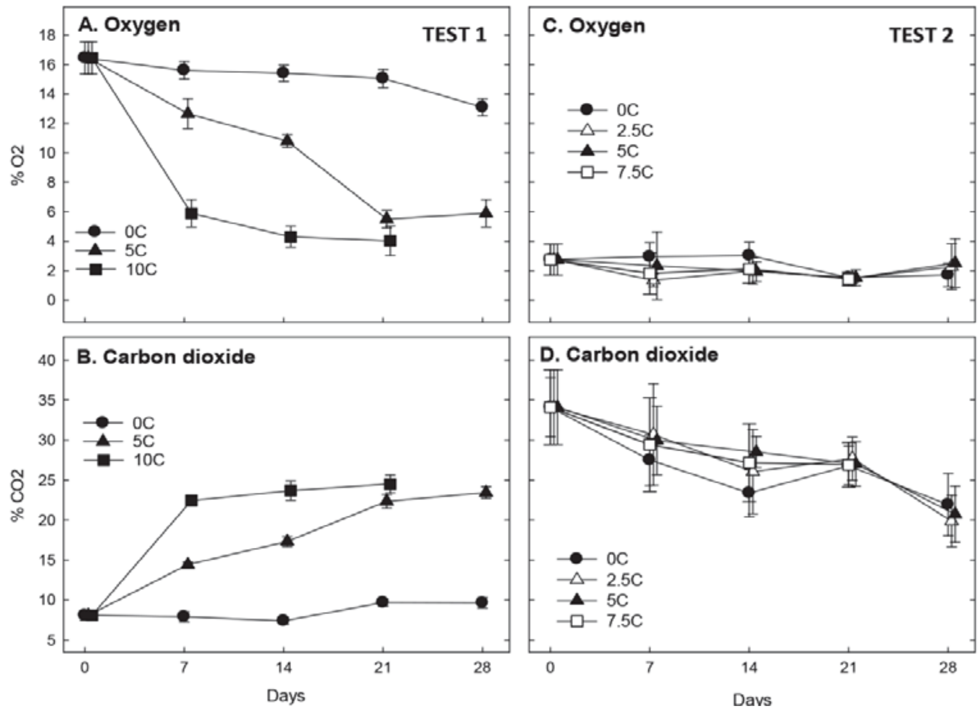

Figure 2. Gas composition of modified atmosphere packaged peeled garlic stored at 0, 5 or 10°C in Test #1 (454 g bag; A, B) and 0, 2.5, 5 or 7.5°C in Test #2 (vacuum packs in master bag; C, D). Data are means of 3 replicates ± standard deviation.

The initial quality of the garlic in Test #2 (Figure 3E-H) was near excellent (score of 9), with less mechanical damage (15-20% of cloves) than in Test #1. Consequently there was also less decay and discoloration than in Test #1. Quality changes in relation to temperature were less noticeable than in Test #1, although quality losses occurred more rapidly at 7.5°C. There was a continual decrease in L* values at all temperatures, perhaps demonstrating induction of injury by the very high CO_2 atmospheres. Cantwell et al. (2003a) reported increased yellowing and discoloration in garlic cloves stored in CO_2 atmospheres of 15% or higher, while Ramirez-Moreno et al. (2000) reported no discoloration due to atmospheres containing 10% CO_2. In Test #2, very good visual quality was maintained up to 28 d at 0 and 2.5°C, and acceptable quality was retained for 21 d at 5 and 7.5°C. In Test #2, a few of the vacuum packs failed and when there was no modified atmosphere, sprouting and rooting were observed (data not shown). As previously shown (Cantwell et al., 2003a), although temperature is important for retention of peeled garlic quality, CO_2 containing modified atmospheres are also essential.

The main compound responsible for garlic pungency is allicin, diallylthiosulfinate. It is a volatile sulfur compound and comprises more than 70% of total thiosulfinates. Thiosulfinates including allicin are produced through the action of allinase on sulfur-containing precursors, with pyruvate generated as a byproduct (Block et al., 2001; Corzo-Martínez et al., 2007). Pungency of garlic can be measured directly by determination of thiosulfinates or indirectly by analysis of pyruvate. In the latter case, background concentrations of pyruvate also need to be measured. In this study, pungency, either measured as thiosulfinates or pyruvate, decreased with time (Figure 4). Pyruvate concentrations decreased more at the higher storage temperatures of 7.5 or 10°C. Total thiosulfinate concentrations were maintained better in Test #2 than in Test #1, but the effect of the different modified atmospheres cannot be distinguished from differences in initial quality. The wounding caused in the fresh peeling process likely results in a more rapid decrease in pungency compared to changes in intact cloves and garlic bulbs (Cantwell et al., 2003a). Changes in pungency may also be associated with a more rapid loss of dormancy with subsequent rooting and sprouting (González et al., 2013).

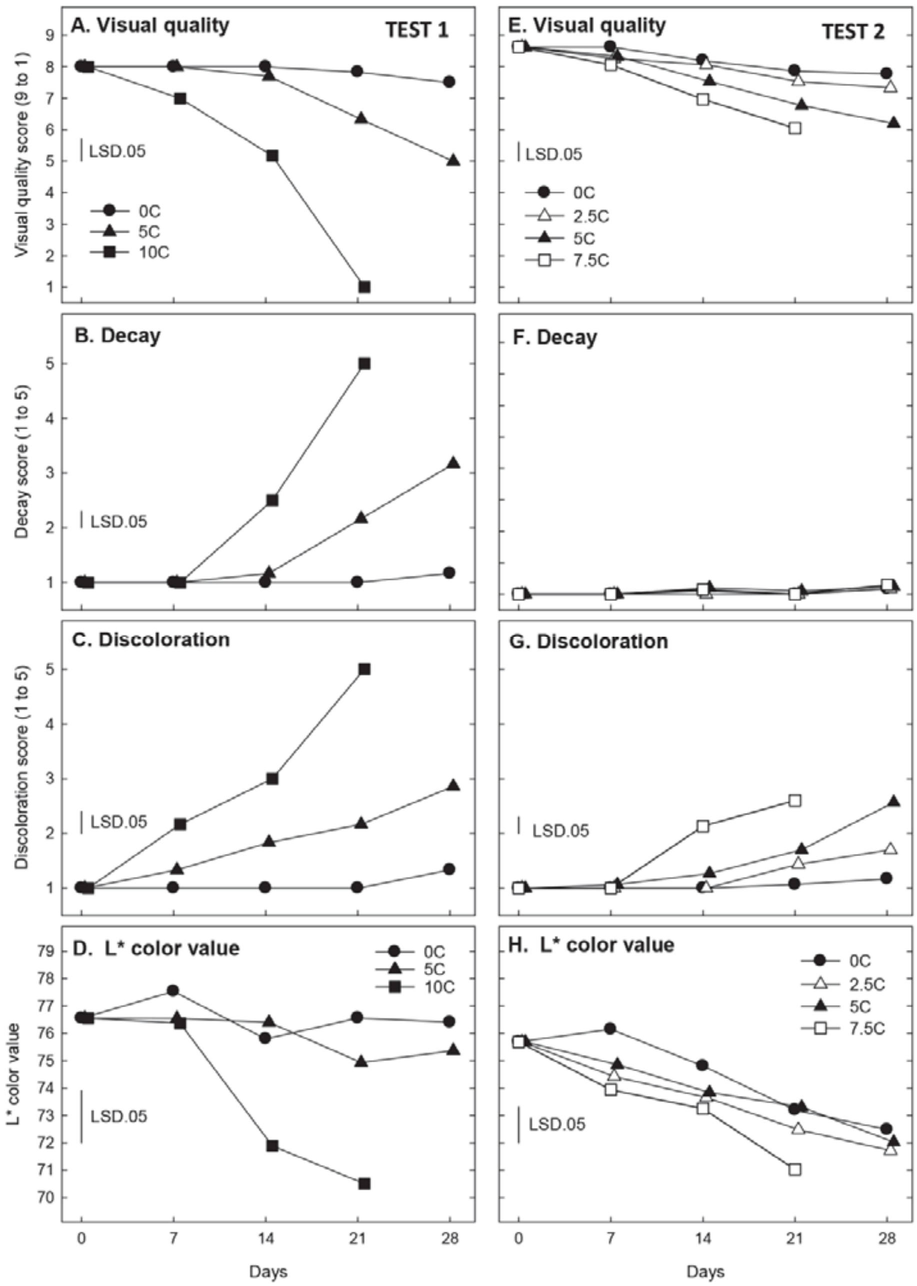

Figure 3. Changes in visual quality (9 = excellent, 1 = unusable), decay and discoloration (1 = none, 5 = severe) scores and L* color values of peeled and modified atmosphere packaged garlic stored at 0, 5 or 10°C in Test #1 (A, B, C, D) and at 0, 2.5, 5, or 7.5°C in Test #2 (E, F, G, H). Data are means of 3 replicates of 20 cloves each for Test #1 and 10 cloves from 6 packs each for Test #2 with mean separation by LSD.05.

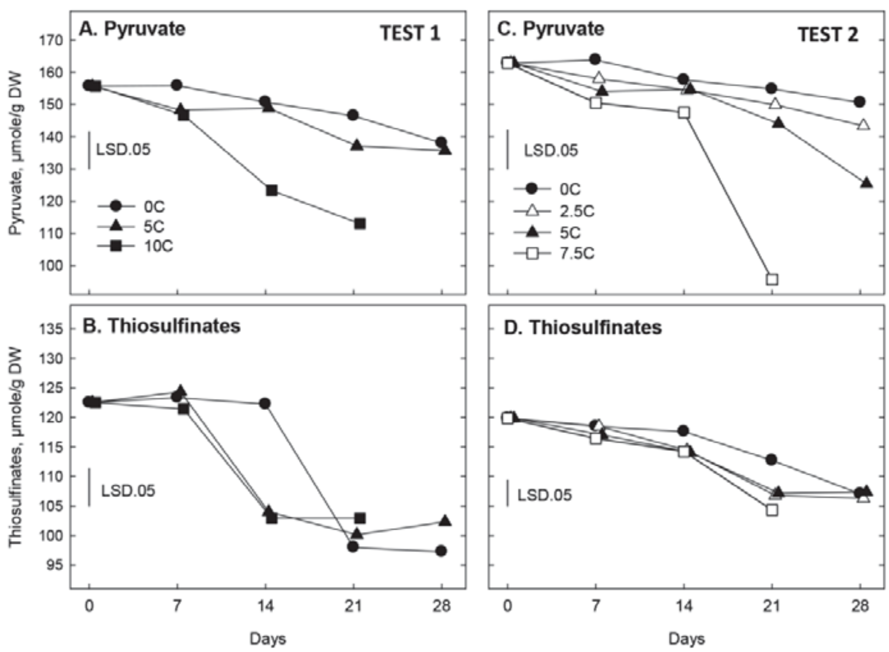

Figure 4. Pungency, determined by two methods, of peeled modified atmosphere packaged garlic stored at 0, 5 or 10°C in Test #1 (A, B) and at 0, 2.5, 5, or 7.5°C in Test #2 (C, D). Data are means of 3 replicates from 20 cloves each for Test #1 and 3 replicates from 10 cloves from 6 packs each for Test #2 with mean separation by LSD.05.

CONCLUSIONS

Both low temperature and modified atmospheres contribute significantly to maintaining the quality of peeled garlic cloves. The newer packaging (vacuum packs in a master bag) for fresh-peeled garlic provided consistent atmospheres across a range of possible distribution temperatures. The very high CO_2 atmospheres may have been responsible for the consistent decrease in L* color value during storage. The garlic in the vacuum packs at low temperatures also retained pungency better than the peeled garlic in bulk MAP, but the former cloves were also of higher initial quality.

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