Food Chemistry 253 (2018) 55–62

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Selection of the best active modified atmosphere packaging with ethylene and moisture scavengers to maintain quality of guava during low-temperature storage

Sanchita Biswas Murmu*, Hari Niwas Mishra

Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, Kharagpur, West Bengal 721302, India

ARTICLE INFO

Keywords:
Ascorbic acid
Total phenol
Sensory quality
Chilling injury
Mold growth

ABSTRACT

In modified atmosphere packaging of guava, moisture scavenger (MS) sachet containing 30–50 g of coarse silica gel and ethylene scavenger (ES) sachet containing 0–4 g of potassium permanganate was added as per central composite rotatable design. The headspace O_2 and CO_2 of the packages were studied at 4, 8 and 12 °C for 30 days and thereafter the guava were left for two days to ripen at 30 °C. After that the chilling injuries, percentage acceptable guava, peel color and pulp texture was analyzed. After two days ripening at 30 °C the samples with 3 g ES and 46 g MS registered higher L^*, lower a^* value & firmness (16.65 N), lowest chilling injury score. About 95% of guava was found acceptable in this treatment with 1.89–2.79% reducing sugar, 0.95–1.1% titrable acidity, 59% and 46.61% retention of total phenols and ascorbic acid respectively, resulting 32 days shelf-life of guava.

1. Introduction

Guava is a perishable fruit with limited shelf-life and is susceptible to chilling injury at storage temperature below 13 °C (Murmu & Mishra, 2018). However, several works showed chilling injury free storage of guava below 13 °C under modified atmosphere packaging (MAP) or controlled atmosphere (CA) storage. For example, Reyes and Paull (1995) highlighted the fact that storage below 10 °C completely suppressed disease development of guava. At further lower temperature (4.5 °C) Combrink, Kock, and Van Eeden (1990) observed 14 days shelf-life of guava treated with fungicide & skin coating and packed in MAP. At 5 °C Pereira et al. (2004) recorded 24 days shelf-life of osmotically dehydrated guava stored in MAP. At 7 ± 3 °C, Rana, Siddiqui, and Goyal (2015) reported 21 days shelf-life of guava cv. Hisar Safeda in LDPE film of 800 μm thickness. Gaspar et al. (1996) and Singh and Pal (2008) noted 21–30 days shelf-life of guava at 8 °C, stored under different CA storage conditions. About 21 days shelf-life of guava Cv. Kumagai was suggested by Jacomino, de Luca Sarantópoulos, Sigrist, Kluge, and Minami (2001), Jacomino, Kluge, Sarantopoulos, and Sirrist (2001) at 10 °C. Antala, Varshney, Davara, and Sangani (2015) also reported 21 days shelf-life for guava cv. L-49 at 10 °C stored in MAP flushed with 9% O_2 and 5% CO_2. At 8–12 °C Sahoo, Panda, Bal, Pal, and Sahoo (2015) recommended 28 days shelf-life of guava Cv. Allahabad safeda stored under MAP in polypropylene (PP) with pin holes; Teixeira, Júnior, Ferraudo, and Durigan (2016) stated 28 days at 10 °C during storage at 5 kPa O_2 and maximum 5 kPa CO_2 for guava cv. Pedro Santo. From all the stated literature, it appeared that storage of guava in CA or MAP below 13 °C has the potential to extend its shelf-life without being affected by chilling injury but, the storage temperatures were chosen randomly in the above-mentioned works. Hence, the study of MAP of guava in the temperature range of 4–12 °C was felt necessary to specifically select one temperature which gives the best quality and shelf-life of MAP stored guava. Moreover, in most of the studies, fungicide like benomyl or sodium hypochlorite were used on guava to prevent fungal infection which further had a synergistic effect in shelf-life extension. But, the use of fungicide is banned in some countries like Australia and Denmark due to carcinogenic issues; and globally there is increasing trend towards consumer preference to chemically untreated food. Hence, there are urgent needs to search alternative technologies to extend shelf-life of fruit and vegetables without chemical treatment.

The strong oxidizing agent like potassium permanganate ($KMnO_4$) oxidizes indigenously produced ethylene in guava to CO_2 and water (Yan & Schwartz, 1999). When the calculated mass of ethylene scavenger (ES) sachet is added inside MAP of guava, it further helps to extend shelf-life. Similarly the use of $KMnO_4$ as ES in MAP was reported to enhance quality and shelf-life of "Sharwil" avocado (Sanxter, Nishijima, & Chan, 1994); potato shoot (Park et al., 2004); sweet apple (Chaves et al., 2007); tomato (Martínez-Romero et al., 2009);

* Corresponding author.
E-mail address: sanchita1600@agfe.iitkgp.ernet.in (S.B. Murmu).

https://doi.org/10.1016/j.foodchem.2018.01.134
Received 11 May 2017; Received in revised form 4 January 2018; Accepted 21 January 2018

"Silverbell" pear (Nugraha, Bintoro, & Murayama, 2015); banana cv. "Sucrier" (Choehom, Kesta, & Doorn, 2004; Nguyen, Kesta, & Doorn, 2004); banana Cv. "Robusta" (Kudachikar, Kulkarni, & Prakash, 2011), etc. However, the scanty studies are available about the use of ES in MAP of guava. Moreover, guava has high transpiration rate, and if the evaporated water from the fruit surface is not removed from the package headspace, it condenses as water inside MAP. The in-package condensed water accelerates the growth of bacteria and molds. Hence, packaging films with high water vapor transmission rate are required for MAP of guava. Combrink et al. (1990) strongly suggested the use of LDPE packs embedded with natural mineral compounds which absorbed in-package free moisture for storage of guava. Mangaraj, Goswami, Giri, and Joshy (2014) used laminated film from biaxially oriented poly propylene and polyvinyl chloride to meet the oxygen and carbon dioxide transmission rates of guava. The laminated films are product specific and are uneconomical for versatile applications (Exama, Arul, Lencki, Lee, & Toupin, 1993). Guava may be packed in commonly available packaging films with the addition of calculated mass of moisture scavenger (MS) like silica gel in MAP to prevent in package condensation (Murmu & Mishra, 2017a). Silica gel as MS was used in MAP for "Pachbale" banana (Chauhan, Raju, Dasgupta, & Bawa, 2006); "Pleurotus" mushrooms (Villaescusa & Gil, 2003), etc.

The respiration rate (Bron, Ribeiro, Cavalini, Jacomino, & Trevisan, 2005), ethylene production rate (Singh & Pal, 2008), and transpiration of guava changes with temperature hence, the requirement of scavengers may also vary.

The objective of this work were: (i) to evaluate the effect of temperature (4, 8 and 12 °C), mass of ES and MS and their interaction effects in maintaining quality of guava in MAP during long-term storage; (ii) to find the optimum combination of temperature, ES, and MS, at which the best quality of guava was maintained; and (iii) to study the chemical quality of the guava stored at the optimum condition.

2. Materials

Guavas (*Psidium guajava*) cv. Baruipur were purchased from the local market of Kharagpur on the day of harvest. Sorting of bruises free guava was done based on the uniformity in diameter 40–50 mm, weight 185–215 g and surface greenness (a^* value of the CIE color scale) −11 to −12 (Murmu & Mishra, 2017a). The top loading electronic balance (Afcoset, GmbH) was used for measurement of weight; the vernier caliper (Mitutoyo, Japan) for diameter; and colorimeter (Konica Minolta, CM-5) with 30 mm diameter target mask for exterior surface peel color.

The polyvinyl chloride (PVC) film of 40 μm thickness, purchased from the Vintech polymer, Kolkata was used for the MAP of guava. The use of PVC film for MAP of guava was reported by Pereira et al. (2004) and Murmu and Mishra (2017a).

The oxygen transmission rate (OTR) and carbon dioxide transmission rate (CTR) of the PVC film at 4, 8 and 12 °C were determined following the method of Murmu and Mishra (2017a, 2017b). The OTR of the film at 4, 8, and 12 °C was 3324, 3325 and 3326 $cm^3\,m^{-2}\,h^{-1}\,MPa^{-1}$, respectively; the corresponding CTR was 20,279, 20,282 and 20,288 $cm^3\,m^{-2}\,h^{-1}\,MPa^{-1}$, respectively. The OTR and CTR of the selected film matched with the maximum OTR and CTR requirements for packaging of guava viz. 9577 ± 350 and 22,560 ± 478 $cm^3\,m^{-2}\,h^{-1}\,atm^{-1}$ at 12 °C, estimated based on preliminary experimental respiration rate studies and using equations suggested by Exama et al. (1993) and (Murmu & Mishra, 2017a, 2017b). The water vapor transfer rate of the PVC 40 film was 1.01 ± 0.35 and 3.2 ± 0.58 $g\,m^{-2}\,day^{-1}$ at 5, and 10 °C, respectively (Murmu & Mishra, 2017a).

The coarse silica gel and potassium permanganate (98.5% purity) were procured from Merck (Mumbai, India) were used as MS and ES, respectively. The grade 48B Tyvek film purchased from Dupoint (India) was used for packaging the ES, and MS in the form of pouches.

2.1. Experimental plan

Modeling and optimization of the active MAP of guava were done using central composite rotatable design (CCRD) with three independent variables viz: ES, MS, and storage temperature. The range of mass of MS was calculated to be 30–50 g of silica gel from Eq. (1).

$$\text{Requird mass of MS,g} = \frac{(TR \times M) - (WVTR \times A)}{A_c} \quad (1)$$

Where, TR was the transpiration rate of "Baruipur" guava (22.2 ± 05.1 $g\,kg^{-1}\,day^{-1}$ at 10 °C and 90% RH), measured by weight loss method (Murmu & Mishra, 2016); M was the mass of guava used in MAP (approximately 0.4 kg); WVTR was the water vapor transmission rate of the PVC film (1.01 $g\,m^{-2}\,day^{-1}$ at 10 °C); A was the available area of PVC film for water vapor transfer (0.06 m^2); A_c was the absorption capacity of silica gel as notified by one manufacturer (0.25 kg/kg at 20 °C).

The range of mass of ES ($KMnO_4$) was approximately estimated to be 0–4 g from Eq. (2)

$$\text{Requird mass of MS,g} = \frac{(R_e \times M)}{A_{c,e}} \quad (2)$$

Where R_e was the ethylene production rate of guava (approximately 0.59–17.7 $\mu g\,kg^{-1}\,h^{-1}$) (Brown & Wills, 1983); $R_{c,e}$ was the absorption capacity of potassium permanganate (40.94 $mg\,kg^{-1}$) estimated stoichiometrically.

The scavenger pouches were prepared by heat sealing (PEPS India, Polyseal, HUIr-07) the particular mass of ES and MS in Tyvek film corresponding to each experimental run. The film size just sufficient to hold the selected mass of scavengers was used.

The details of the experimental conditions in their actual and coded form were shown in Table 1. Before packaging guava was washed with tap water and wiped with tissue paper to remove the adhering moisture. Packages with 0.06 m^2 area for gas exchange was prepared by sealing two guavas (weighing about 200 ± 26 g each) and one MS sachet and one ES sachet (having mass according to the Table 1) in PVC film of 40 μm thickness. The sealing integrity was checked by dipping the packages in water filled in a bucket. The absence of bubble indicated hermetic sealing. At each temperature ten guavas without any packaging and also MAP of guava without any ES and MS was used as the control. Five replicates of each package were kept for 30 days in the environment chamber (Remi Instruments, Kolkata, India) thermostatically maintained at respective temperatures (Table 1) and 85% RH. The 30 days storage duration was selected as Mangaraj et al. (2014) registered similar (28 days) shelf-life of guava in MAP at 15 °C and Singh and Pal (2008) also observed 28 days shelf-life of guava under CA storage at 8 °C.

The headspace O_2 and CO_2 of the packages after 30 days storage were measured with a headspace O_2/CO_2 analyzer (Systech, New Delhi, India). The packages were opened, and the peel color of the guava was measured.

The mold growth score was visually examined as the presence of white cottony mold growth on the guava surface, if any. The mold appearance was evaluated on a 5-point scale where score 1 indicated absence and score 5 indicated severity (Murmu & Mishra, 2017a). The mold affected samples were discarded, while those unaffected were used for further study.

To ripen the disease free guava, they were transferred to another environmental chamber at 30 °C and 90% RH for two days. The guava peel and pulp color, pulp firmness, and chilling injury were measured after two days. Texture analyzer (Brookfield, CT3) with 6 mm diameter probe was used for measurement of pulp firmness at the two opposite equatorial diameter of each sample. The test speed of 1 mm/s was used with sample deformation up to 10 mm.