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Shelf-life study of Guava (*Psidium guajava* L.) under active packaging: An experiment with potassium permanganate salt as ethylene absorbent

Haltbarkeitsstudie über aktiv verpackte Guaven (Psidium guajava L.): Ein Versuch mit Kaliumpermanganatsalz als Ethylen-Absorber

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Summary

Shelf-life of Guava (*Psidium guajava* L.) under active packaging was studied based on produce, film and system parameters such as respiration rate of produce, film permeability and in-pack environmental conditions. Potassium permanganate embedded in silica crystals were used in the form of sachets as active ingredient for ethylene absorption inside packages. The designed modified atmosphere (MA) packages using LDPE film (76.2 µm thickness) were stored at 8 ± 2 °C. Most of the physico-chemical and textural properties of guava fruits during storage were affected by incorporation of ethylene absorbent in a dependent manner. The in-pack gaseous composition was significantly suppressed in MA packages with and without absorbent under refrigerated storage condition. The reduced changes in fruit firmness, total soluble content (TSS), titratable acidity (TA) and color showed the effectiveness of use of absorbent sachets in extending shelf life of guava fruit. A significant reduction in decay (%) was noticed in active MAP samples in combination with refrigerated storage. The proposed post-harvest tool under active packaging using potassium permanganate salt provide a promising way to enhance the storage life of guava up to 7 weeks.

Keywords: Active packaging, MAP, Ethylene absorbent, Storage, Firmness, colour

Zusammenfassung

Untersucht wurde die Haltbarkeit von aktiv verpackten Guaven (*Guave* L.) anhand von Parametern wie Atmungsrate des Produktes, Durchlässigkeit der Folie und Umgebungsbedingungen in der Verpackung. Verwendet wurde Kaliumpermanganat eingebettet in Silica-Kristallen zur Ethylen-Absorption innerhalb der Verpackung. Die mit modifizierter Atmosphäre behandelten Verpackungen (MAP) aus LDPE-Folie (76,2 µm Dicke) wurden bei 8 ± 2 °C gelagert. Die meisten der physikalisch-chemischen und strukturellen Eigenschaften der Guaven-Früchte wurden während der Lagerung durch das Ethylen-Absorptionsmittel beeinflusst. Die Zusammensetzung der Gase in der Verpackung wurde signifikant mit und ohne Absorber unter gekühlter Lagerung verändert. Die Veränderungen bezüglich der Festigkeit der Frucht, titrierbarer Säuregehalt und Farbe zeigte die Wirksamkeit von absorbierenden Sachets durch die Verlängerung der Haltbarkeit. Eine signifikante Verringerung von Fäulnis (%) wurde bei den aktiv verpackten MAP-Proben in Kombination mit der Kühllagerung festgestellt. Die vorgeschlagene Nacherntebehandlung der aktiven Verpackungen mit Kaliumpermanganatsalz bietet eine vielversprechende Methode, um die Haltbarkeit von Guaven bis zu 7 Wochen zu verlängern.

Schlüsselwörter: Aktive Verpackungen, MAP, Ethylen-Absorption, Lagerung, Festigkeit, Farbe

Introduction

Guava (*Psidium guajava* L.) is a commercially important fruit crop in India, Brazil, Mexico and many other tropical countries (Singh et al, 2012). Short postharvest life, high susceptibility to chilling, mechanical damage and pathogens limit its distribution to the domestic and export markets. One of the limiting factors that influence their economic value is the relatively short ripening period and reduced post-harvest life. Fruit ripening is a highly coordinated, genetically programmed, and an irreversible phenomenon involving a series of physiological, biochemical, and organoleptic changes that finally leads to the development of a soft edible ripe fruit with desirable quality attributes (Prasanna et al, 2007).

Above all the main post harvest problem is short shelf life of guava fruits. Ethylene is a natural plant hormone produced by metabolism in most fruit. It initiates and accelerates the ripening of fruit and causes fruits and vegetables to deteriorate. This unavoidable process is a major problem, since in almost all applications non-compatible fruits and vegetables (i. e., ethylene emitters and ethylene sensitive items) are stored and/or shipped in the same container. Ripening in stored fruits could be slowed by controlling the level of ethylene with the help of ethylene absorbents (Guill en et al, 2006).

Modified atmosphere packaging (MAP) and Controlled atmosphere (CA) storage are well established technologies effectively used for prolonging the shelf-life period of fresh or minimally processed foods. Two aspects involve in using these technologies/ process are the respiration of the products and the gas exchanges properties through the pakkage materials, both lead to the increase of CO_2 and depletion of O_2 in MAP and control O_2 and CO_2 atmosphere in CA (Rai and Paul, 2007). The package should maintain an optimal atmosphere that will reduce respiration and slow down the physiological and microbiological changes that decrease shelf life. Most of the climacteric fruits such as Mango, Banana, Guava etc. are packed in modified atmospheric packages to control the respiration and ripening rates. For fresh produce, the use of passive MAP is limited mainly by the unavailability of appropriate film with desired thickness that provide both gases fluxes, selectivity, and temperature compensation to function effectively (Exama et al, 1993). Furthermore, these packaging technologies in combination with refrigeration can delay the deterioration of the fresh produce but, not always sufficient for maintaining the quality for the desirable marketing period.

As an alternative, active packaging open up an effective and economical way of increasing shelf life of fresh produce. Active MAP technology consists essentially the inclusion of subsidiary constitutes into the packaging material or the package headspace to enhance the performance of the packaging system and senses environmental changes and responds by changing its properties. The active technology using absorbents have been successfully used for non-respiring products (Brody and Budny, 1995). For respiring produce such as fresh fruits and vegetables, research is needed into the use of absorbents to regulate the gases such as O_2/CO_2 and ethylene (C_2H_4) especially in climacteric fruits and vegetable that is useful to maintain a desired in-pack atmosphere. Among the large number of reagents and techniques that have been tested over the years to remove ethylene from the atmosphere of storage rooms when ventilation cannot be used, only potassium permanganate is presently in common commercial use. A number of commercial potassium permanganate scrubbers are available in sachets, filters, blankets, and other specialized trapping devices (Sherman, 1985).

Ethylene has been shown to be involved in the regulation of flesh softening, skin color development and other ripening processes in guava fruit leading to limited shelf-life (Reyes and Paull, 1995). Ethylene production in guava is strongly influenced by harvest maturity (Mercado-Silva et al, 1998), cultivar (Brown and Wills, 1983) and storage atmosphere (Pal et al, 2007). The response of guava to exogenous application of ethylene also depends upon the maturation stage (Reyes and Paull, 1995). Thus, interference with the capacity of fruit to synthesize ethylene and its perception may retard ripening and maintain fruit quality for longer durations. The objective of this work was to evaluate the effects of MAP with potassium permanganate sachets on postharvest quality attributes and shelf life extension of Guava for commercial use.

Materials and Methods

Fruit material

Guava (*Psidium guajava* L., cv. 'Safeda') fruits harvested at commercial maturity stage from the farm of Central Institute of Agricultural Engineering, Bhopal were used experimentation and study. Maturity levels were determined by measuring standard parameters like TSS, Titratable acidity, skin color and firmness. The fruits were graded manually to remove damaged, infested and non-uniform fruit. The graded fruits were washed, their surface moisture dried and stored at 20 °C prior to MA packaging.

Packaging material

Low density polyethylene (LDPE) and polypropylene (PP) were used for designing bulk (20 kg) packaging of fruit. Both polymeric films were provided by Systec Packaging, (Ludhiana, India). Other technical characteristics of the packaging films are detailed in Table 1.

Ethylene absorbent

For control of ethylene production, potassium-permanganate salt embedded in silica crystals were used. Sachets

TABLE 1: *Technical characteristics of the designed packaging films.*

Type of film	Film properties							
	Surface area, m^2	Thickness, µm	No of perforation and size, mm*	WVTR, ml/m².h	O_2TR ml/m²-h-kPa	CO_2TR, ml/m²-h-kPa	Water adsorption, %	Tensile strength, psi
LDPE	0.820	76.2	2 no. 3 mm	8	08	16	<0.03	4550
PP	0.820	50.8	2 no. 3 mm	12	12	18	<0.02	9600

* Gas permeance from single hole of 3mm thickness was 0.98 ml/m²-h (Techavises & Hikida., 2008).

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were prepared by preparing saturated solution of potassium-permanganate salt (9 g/kg of fruits) in distilled water and imbedded in silica crystals. The weight of each sachet was 280 g and their maximum ethylene absorption capacity was about 150 ml-C_2H_4. This developed product is in agreement with agro-alimentary standards (Pérez-Pérez et al, 2006).

Design of polymeric MA packages

Active MA packages were designed based on the respiration rates of the products and film parameters. The respiration rate of guava was determined as per the method adopted by Singh et al (2011). Film parameters (WVTR, O_2TR and CO_2TR) of the films were measured. Based on design calculation package size of 0.76 x 0.53 m^2 was selected for bulk packaging of guava (20 kg). MAP experimentation was conducted by comparing the values of required permeability with those of commercially available films. It was found that the best suitable film (nearest to the design calculations) for extending the shelf life and maintaining the quality of guava was LDPE having film thickness of 76.2 µm with 02 perforations of 3 mm (Tab. 2).

TABLE 2: *Design details of packaging film.*

Polymeric materials	Thickness, µm	Required permeability, ml-m²/day*		Observed permeability, ml-m²/day	
		O_2	CO_2	O_2	CO_2
LDPE	76.2	3.5	12.1	3.2	11.9
	50.8			3.9	13.2
PP	76.2			4.3	13.6
	50.8			4.6	13.9

* Respiration rate (RR) of guava: 34 ml-m²/h at 10 °C (Singh et al, 2012); Gas permeance from single hole of 3 mm thickness was 0.98 ml/m²-h (Techavises & Hikida., 2008).

MA packaging experiments in refrigerated conditions

Pre-cooled fruit samples (20 kg each) were exposed to UV light treatment for 5 minutes for surface disinfestation. Samples were packaged in 76.2 µm thick LDPE polymeric flexible packages containing about 20 kg fruit. A pre-designed potassium-permanganate sachet was placed in the headspace of the packages for active MAP study of fruits. The bags were air-tight sealed with silicon thread with and without ethylene absorbents along with control sample. The packages were immediately stored at 10 ± 2 °C and 75 % relative humidity (RH) in an Environmental Test Chamber (Model CHM-10S, Remi Instruments, India) and analyzed at every 4 days intervals until the end of the shelf life. By the end of the experiments, the fruit packages were immersed in water to test for probable leakage and to evaluate the free volume inside the package.

MA packaging experiments and storage at ambient conditions

In another experiment, fruit lots were similarly packaged in LDPE polymeric flexible packets containing about 20 kg fruits by placing a pre-designed potassium-permanganate sachets in the headspace of the packets for active MAP study and storage at ambient conditions. The in pack gaseous composition was monitored at every 4 day's interval until the end of the shelf life. Fruits were evaluated for various quality parameters on every 7th day.

Physiological loss in weight (PLW)

Physiological loss in weight was determined by weighing all samples with a laboratory level weighing scale (Model CT-35K2, Contech Instruments Ltd. India) having least count ± 2 g at the beginning and end of the storage period. The difference between the two values was considered as weight loss and expressed in percentage.

$$PLW\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100$$

In-pack gaseous composition

The in-pack gaseous composition of O_2 and CO_2 were analyzed using a portable headspace gas analyzer (Model GS3M, Systech Instruments Ltd. UK). The apparatus uses an electrochemical and an infrared sensor to evaluate the headspace gas concentration and express in percent. The sensor probe was inserted in the headspace of polymeric package and sensor signals were converted to gas concentration values of O_2 and CO_2, which were directly read on the digital display panel.

Fruit quality evaluation

Fruit firmness was analyzed by measuring the maximum compression force using Texture Analyzer Stable Micro Systems, Model TA.XT. *plus* (Surrey, UK), fitted with a stainless steel compression plate (length 15 cm, circular dia. 7.5 cm) using a 50 N load cell. Texture analysis was done on 3 fruits per replication with each fruits punctured on the side at the equatorial region. The Data were recorded in triplicate and the mean values were expressed as newtons (N). Color development of fruit was measured at harvesting and during storage using a handle colorimeter (chromameter) (Miniscan XE plus, Hunter associates, USA) appropriately calibrated with a standard white tile (UE certificated) with the following parameters: X=83.47, Y=84.43, Z=95.16 with illuminant C/2°, (light source used for the day lighting), according to CIE L*, a*, b* scale. The color of the fruit skin was measured using *'L' and 'a',* parameters. On every 7th days of storage, the 'L' and 'a' values were reported as an average of 3 measurements. For determination of total soluble solids (TSS) and titratable acidity (TA), three fruits per replications were homogenized and filtered through cheese cloth to obtain clear juice. The TSS (%) was recorded with hand refractometer (Model: Atago 3810 PAL-1, USA) and the values were corrected to 20 °C. The titratable acidity was calculated by diluting the fruit juice with distilled water, against 0.1 N NaOH solution using phenolphthalein as an indicator. The titratable acidity was expressed as a percentage in terms of citric acid.

Decay

Percentage of fruit decay was obtained from the number of fruit that showed signs of decay over the initial number of fruit. The cumulative decay every week by the end of the storage period was recorded and expressed as a percentage.

Statistical analysis

The results were statistically analyzed by the analysis of variance (ANOVA-two way) to determine the significant difference between the two samples, using the software STATISTICA 6.0. The analysis of means was performed using the Tukey's procedure at $p<0.05$.

Results and Discussion

In pack gaseous composition during storage period

The whole experiment was carried out in three different packages of LDPE having thickness of 75.4 µ each with different treatments of MAP (ambient storage at 37±2 °C), MAP (refrigerated storage at 8±2 °C) and active MAP (ethylene absorbents and storage at 8±2 °C).

The in-pack headspace oxygen composition (O_2) decreased with the progression of storage period in all the treatments. The decrease was 4.26 folds on day 35 compared to initial day 1 of storage in MAP (refrigerated) treatment and 4.35 folds on day 49 compared to initial day 1 of storage in active MAP. However, the MAP (ambient) package declined and become anaerobic soon after 21 days of storage (Fig. 1).

Similarly the in-pack headspace carbon dioxide composition (CO2) increased sharply with the advance of storage period in all the treatments. The increase was 263.34 folds higher on day 35 compared to initial day 1 of storage in MAP (refrigerated storage at 8±2 °C) treatment and 250.0 folds higher on day 49 compared to initial day 1 of storage in active MAP. The O_2/CO_2 composition varied sharply during the initial day 7 of storage and subsequently achieved steady-state condition thereafter for entire storage period. The oxygen and carbon-dioxide gas composition was 4.9 and 7.9 % respectively in MAP (refrigerated) packages, whereas the oxygen and carbon-dioxide gas composition was 4.8 and 7.5 % in active MAP packages. For both the MAP (refrigerated) and active MAP treatments, the concluding oxygen and carbon-dioxide gas composition after 35 and 49 weeks of storage is in agreement with recommended gas composition of 5 % O_2 and 8 % CO_2 for safe MAP storage of guava (Singh et al, 2012). The in-pack micro environment was found to be significantly ($p<0.05$) influenced by storage temperature in MAP (ambient) with other treatments. However the difference was non-significant in refrigerated storage treatments of MAP and active MAP packages. The development of conducive micro-environment inside the MA package was obtained due to permeable properties (WVTR, O_2TR and CO_2TR) of the selected film in combination with respiration rate of guava and placement of active ingredient in the headspace (Fig. 1).

PLW (%)

In the present study, the PLW (Fig. 2) by day 49 was comparatively lesser in active MAP with other combination treatments. The weight loss was significantly different with other combination treatment except MAP refrigerated. Both the active MAP and MAP refrigerated samples resulted in non-significant weight loss.

Steep hike in PLW was reported in both the control (refrigerated) and MAP (ambient) samples by day 7. By day 14, the PLW was almost similar for control (refrigerated) and MAP (ambient) samples having PLW values of 8.65 % and 7.87 % respectively. Gradual increase in PLW was observed in MAP (ambient) sample by day 21 with PLW value of 18.54 %, highest among the combination treatments and reason being due to higher ambient temperature leading to unfavorable MAP condition inside the package whereas, the slight decline trend was observed in control (refrigerated) sample by day 21 with PLW value of 10.68 % might be due to lower temperature in the refrigerated condition without suitable packaging.

Almost similar trend of slow and steady PLW was observed in both the active MAP and MAP refrigerated samples up to day 35. The trend was similar for active MAP for next day 14 and the PLW value settled at 3.62 % which is minimal among the other treatments. It can be inferred from the trends that the active MAP had lesser weight loss followed by MAP (refrigerated), control (refrigerated) and MAP (ambient) samples. The reason for minimum PLW in active MAP could be due to favorable effect of placing ethylene absorbent in headspace for the development of active micro environment and appropriate temperature

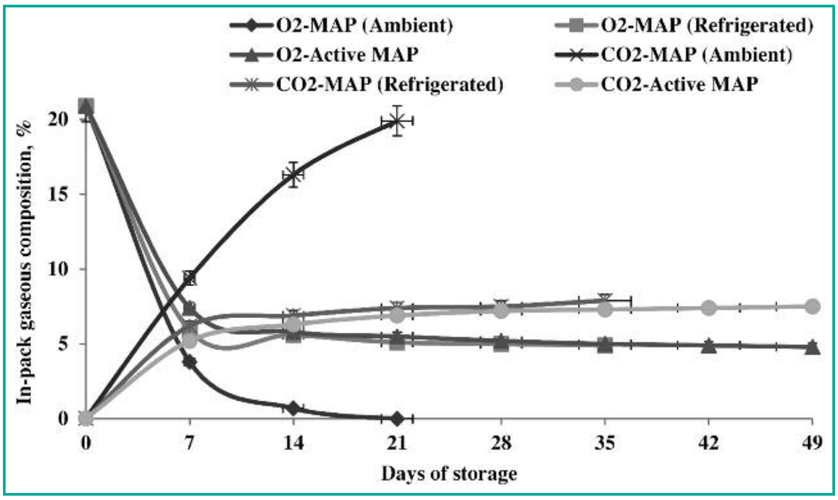

FIGURE 1: *O_2/CO_2 composition inside MA packages with and without ethylene absorbents and stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

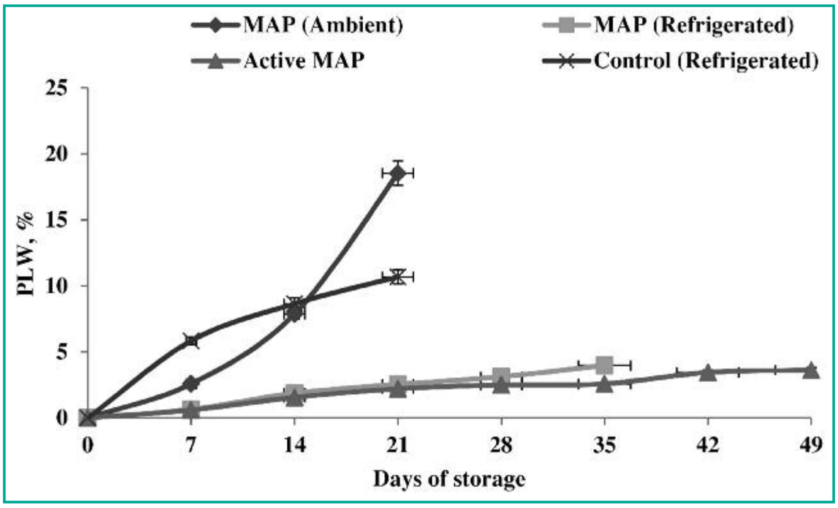

FIGURE 2: *Physiological weight loss (%) in MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

combination established inside the package headspace during the length of storage period. The results demonstrated that MAP in addition with absorbent is suitable to prevent the PLW, supporting the development of barrier properties and establishment of micro environment under MAP by Singh et al (2011), Kaur et al (2011) and Gonzalez-Aguilar et al (2004).

Titratable acidity (TA)

A decrease in titratable acidity of guava fruit was noticed during storage as compared to levels at initial day of harvest (Fig. 3). An overall decline trend was observed in all the treatments in four different packages. Fruits package treatment in MAP (ambient) had titratable acidity value of 0.31 by the end of storage life (day 14) followed by declined TA value of 0.36 in MAP (refrigerated) samples by day 21 and further declined TA value of 0.41 in control (ambient) samples by the end of storage life (day 35). Active MAP packages using ethylene absorbents had a significant marked effect on the reduction in titratable acidity (TA) during storage period depending upon the modified atmosphere by day 35. A high level of TA in fruits pakkages using ethylene absorbents by the end of 49 days storage period at 8±2 °C condition indicated a retarded ripening process, as TA underwent a significant decline throughout the length of storage period of 35 days and finally settled at TA value of 0.43. The findings were well supported by the previous work conducted by Singh and Pal (2008) on guava (cv. *Alahabadi Safeda*) and Bassatoo et al (2005) for higher retention of TA in 1-MCP-treated 'Pedro Sato' guava.

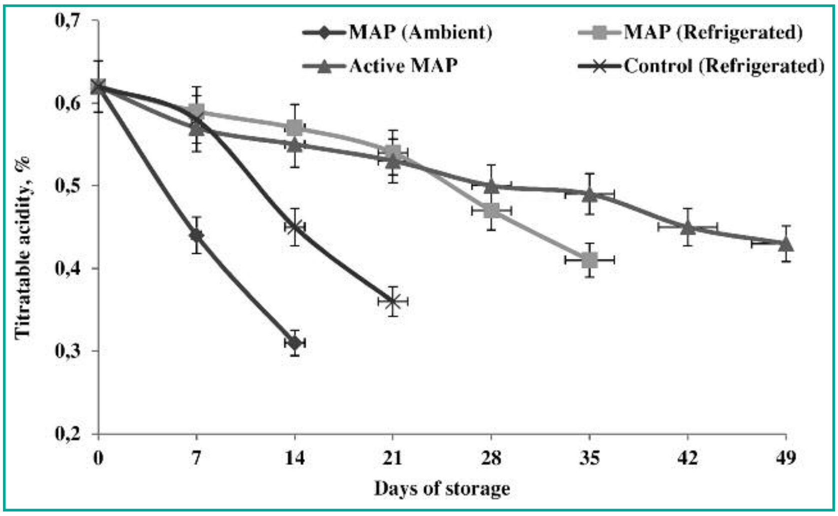

FIGURE 3: *Titratable acidity (TA, %) in MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

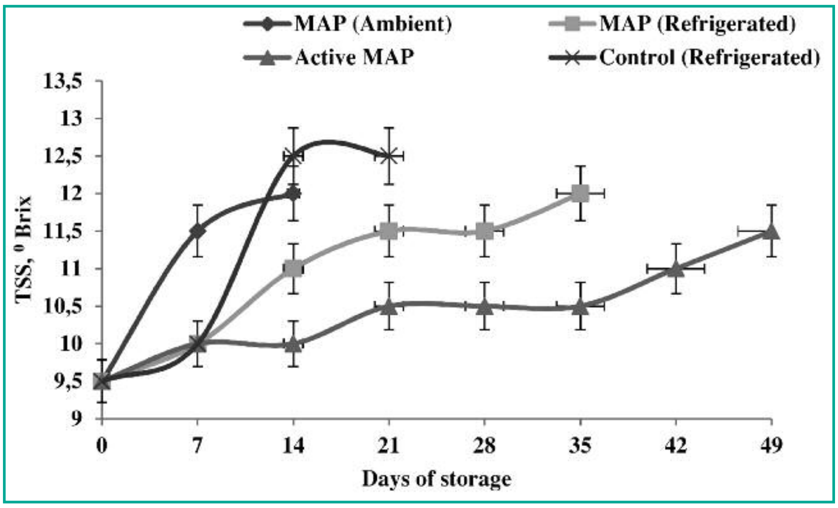

FIGURE 4: *Total soluble solids (TSS, oBrix) in MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

Total Soluble Solids

An increasing trend in total soluble solids (TSS) content was observed in all the MAP and control samples. The TSS content was found maximum in control (refrigerated sample) by the end of day 21 followed by MAP (ambient) and MAP (refrigerated) samples (Fig. 4). The changes in TSS content were significantly restricted well in active MAP packages using ethylene absorbents even after the end of day 49 of storage period at 8±2 °C temperature. The use of ethylene absorbent sachets in the headspace of active MAP fruit packages with longer exposure resulted in greater and marked reduction in the increase in TSS content during storage period by day 49. A change in TSS content in active MAP samples was largely affected by ethylene absorbent sachets in the package headspace. The present findings were in disparity to a previous report on 'Pedro Sato' guava which found no influence of ethylene absorbent (1-MCP) on changes in TSS content during storage period (Bassatoo et al, 2005).

Firmness

A continuous decline in fruit firmness was observed in all the samples after start of the storage period irrespective of treatment. Fruit firmness was significantly protected by the use of ethylene absorbent sachets in the headspace of active MAP fruit packages by the end of day 49. Initially the fruit firmness was 8.24 kgf. But a steep significant decline in fruit firmness was observed for both the MAP (ambient) and control (refrigerated) samples by the end of day 14 and day 21 respectively. However, remaining MAP (refrigerated) and active (MAP) samples followed almost a similar trend of decline, and fruit firmness finally settled at 12 and 11.5 kgf for MAP (refrigerated) and active (MAP) samples by the end of storage period of 35 and 49 days respectively. Non-treated fruits MAP (ambient), control (refrigerated) and MAP (refrigerated) samples had about 1.6 - 32 fold reduction in firmness after end of respective storage life in contrast to about 1.4 fold decline in active MAP packages using ethylene absorbents by the end of 49 days of storage period. It can be concluded that, the use of ethylene absorbents along with suitable MAP conditions samples had better firmness retention than other treatments under study. Softening of fruit was remarkably delayed with the use of ethylene absorbents sachets treatment during MAP storage period (Fig. 5). Ethylene has been implicated in post-harvest fruit firmness and acceleration in overall ripening in guava fruit (Reyes and Paull, 1995). The increase in pectin solubilization and disruption of micro-fibril network of guava fruit has been proposed to be associated with the rapid softening of fruit (Ali et al, 2004) therefore use of ethylene absorbents sachets in headspace induced ethylene inhibition and may responsible for delay in fruit softening during MAP storage. The retardation of fruit softening in response to 1-MCP treatment has been reported in many fruit such as guava (Bassetto et al, 2005), plum (Abdi et al, 1998), grapes (Mart ınez-Romero et al, 2003), avocado (Pesis et al, 2002; Hershkovitz et al, 2005) and papaya (Manenoi et al, 2007). Differences in the responses of climacteric-type guava in our study in similarity to a previous study (Bassetto et al, 2005) could be attributed to the cultivar factor (Abdi et al, 1998; Mart ınez-Romero et al, 2003; Hershkovitz et al, 2005; Guill en et al, 2006).

Decay

In the present study, a major cause of decay in guava fruit during MAP storage as well as in control samples was anthracnose and *Rhizopus* rot diseases. The decay was largely exhibit in all the treatments in four different packages and differ significantly (P<0.05). Fruits package treatment in MAP (ambient) had maximum decay value of 21.2 % by the end of storage life (day 14) followed by decay value of 16.2 % in control (Refrigerated) by the end of storage life (day 21), decay value of 4.8 % in MAP (refrigerated) samples by day 35 and less than 2 % decay in active MAP with absorbent by the end of storage life (day 49). After 35 days, the decay percentage in MAP refrigerated samples increased rapidly, and fruit firmness also decreased to an unacceptable level. Hence its life was considered as 35 days. The fruit decay during MAP storage was significantly reduced by the use of ethylene absorbents sachets treatment during MAP storage period. Use of absorbent in headspace had an 8.5-11 fold reduction in the decay compared to MAP (ambient) and control (refrigerated) during MAP storage 8±2 °C temperature (Fig. 6). The favorable effect of using absorbent in fruit package headspace along with refrigerated MAP storage in reducing the decay percentage of guava fruit was clearly revealed in our study. Anthracnose and *Rhizopus* rot are two serious diseases and are prominent postharvest constraints in guava. The inhibition of decay by the use of ethylene absorbent sachets using potassium-permanganate salt in fruit during MAP storage (Fig. 6) could be related to exacerbate the disease incidence in guava fruit (González-Aguilar et al, 2004). The decay was also significantly differs during storage in other treatments. Delayed and reduced ethylene production in active MAP sample might have increased its resistance to infection and lesion development resulting in lower decay (Watkins, 2006). Such other studies have shown similar results in which the fruit rotting was significantly reduced by the use of ethylene absorbent using 1-MCP (Pesis et al, 2002; Guillén et al, 2006).

Fruit skin color

The color of guava fruit is the important post-harvest quality indices for greater acceptability and consumer appeal. Post-harvest guava skin color lighten, becoming green to light-green and turned yellow during storage. Decrease in ‘L’ value reflects loss in lightness of guava skin color. Shifting of hunter ‘a’ color value from -a towards +a reflects the color change of guava skin from green to yellow during post-harvest storage. Higher +a value reflects the

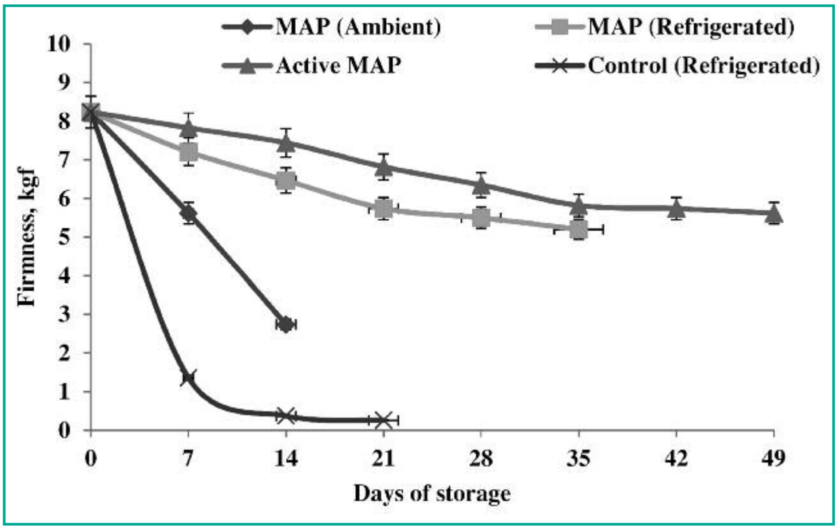

FIGURE 5: *Firmness (kgf) of MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

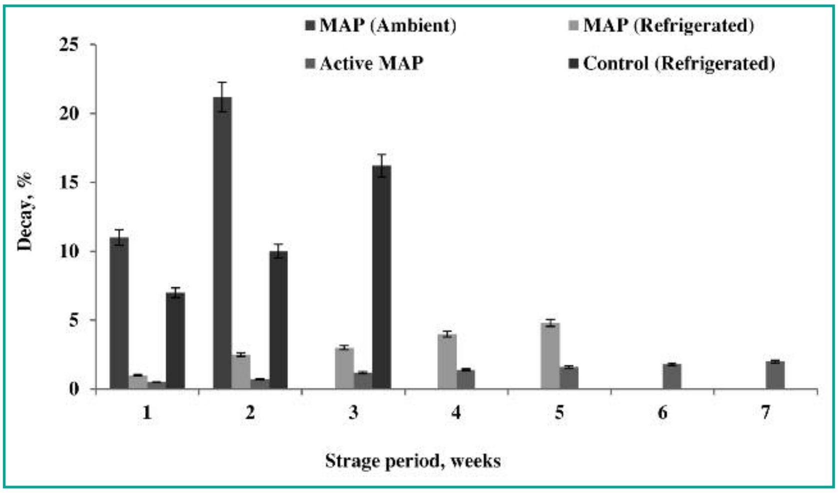

FIGURE 6: *Decay (%) in MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per packaging treatment along with their standard deviations and error bars).*

end of the post-harvest life of guava during which fruit become dark yellow and loss of texture was reported.

In the present study, the initial average 'L' and 'a' value of guava skin was 54.93 and –10.28 respectively at the time of harvest. An increasing trend in the average 'L' value was observed during the storage period by all the treatments. By the end of day 14, MAP (ambient) sample had 'L' and 'a' value of 65.7 and 1.66 showing light-yellow skin color. Similarly, control (refrigerated) sample had 'L' and 'a' value of 74.25 and 7.23 showing slight light-yellow skin color. Contrary, Both the MAP treatments (MAP refrigerated and active MAP) sample significantly restore the original skin color of guava fruits during storage. Active MAP sample with absorbent had 'L' and 'a' value of 59.89 and –9.9 showing green to slight light green skin color by day 49 followed by MAP sample witch had 'L' and 'a' value of 58.11and –8.31 showing green to light green skin color by day 35 of storage period however, the effect of both treatments (MAP refrigerated and active MAP) on 'L' and 'a' color value was non-significant (P>0.05) (Fig. 7). A minimal deviation in color 'a' value was observed in both the MAP (refrigerated) and active MAP samples ranging 0.38 to 1.97 units conforming light green color. Our study results were at par with more similar findings on effect of use of MAP in addition with low temperature storage in fruit skin color restoration by Singh et al (2011) for sprouts, Singh and Pal (2008); Sunjka et al (2003) on guava and Noomhorn and Potey (1993); Sen et al (2012) for banana experimentation.

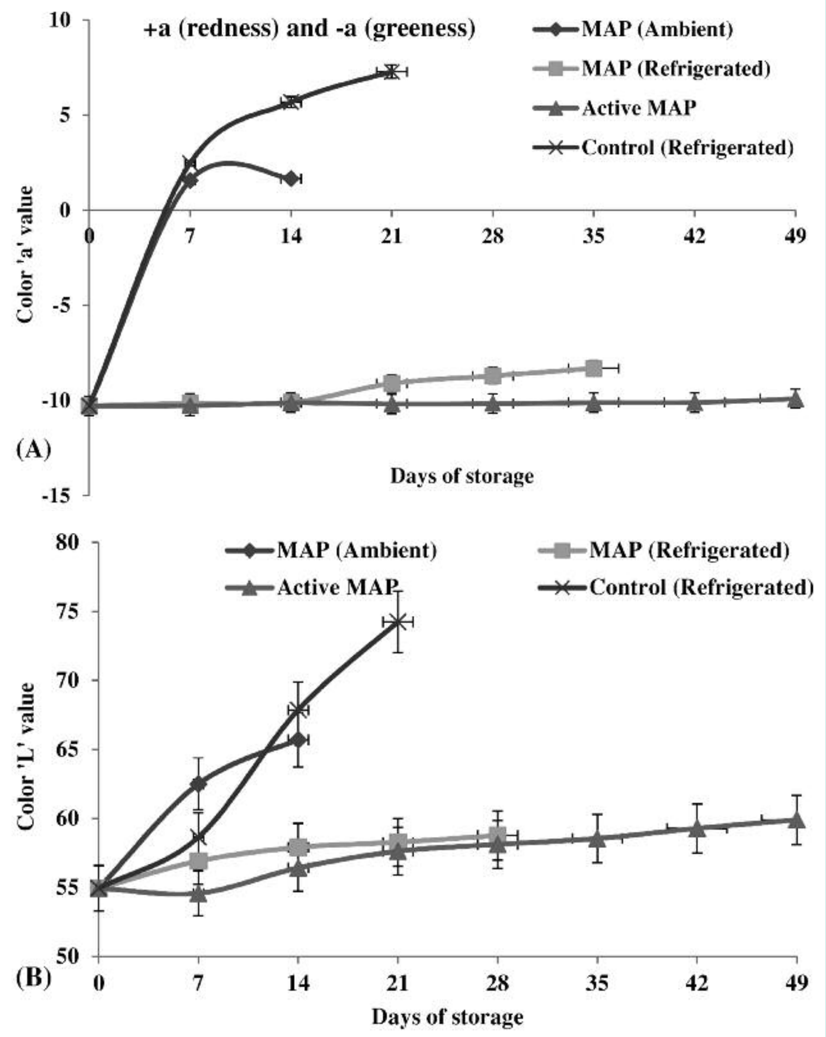

FIGURE 7: *Hunter color value 'a' (A) and color value 'L' (B) of MA packaged and control fruits stored at ambient (37±2 °C) and refrigerated (8±2 °C) conditions (The plotted values are means of three measurements per pakkaging treatment along with their standard deviations and error bars).*

Conclusions

Based on both pre-designed polymeric packaging system of LDPE having thickness of 76.2 µm for Guava storage in different treatments, and physico-chemical and textural data, it can be concluded that shelf life of guava samples was approximately 14 days for the MAP (ambient) packaged samples, 21 days for control (refrigerated) samples, 35 days for MAP (refrigerated) packaged samples and 49 days for active MAP (with ethylene absorbent) samples. Thus, both ethylene absorbent sachets in package headspace along with MAP packaging at refrigerated storage at 8±2 °C had a substantial effect on shelf life enhancement of guava (cv. *Safeda*) with acceptable quality. Active MAP exhibited better overall storage performance as compared to other treatments. In nutshell, the use of ethylene absorbent sachets using potassium-permanganate salt as a post-harvest tool may be assimilated into the supply chain management of guava fruit to enhance storage life and maintain quality during distribution to local/super markets and fulfillment of export oriented demands.

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