Extension of the shelf life of guava by individual packaging with cling and shrink films

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Abstract Guava is a climacteric fruit so physico-chemical changes continuously occur after harvest till fruit become unfit for consumption and suffers from post harvest losses. The main objective of this work was to assess the effectiveness of individual film in form of Shrink and Cling wrap on shelf life of guava. Fruits were individually packed in polythene bags (LDPE) of 200 gauge thickness by Shrink and Cling wrapping and stored at 7 ± 3 °C. Individual wrapping reduced the magnitude of changes during storage i.e., ripening process drastically as evident from lower total soluble solids, higher ascorbic acid, polyphenol content with lower polyphenol oxidase activity and physiological loss of weight (PLW) was less than 3.5 %. Film wrapping preserved freshness of wrapped fruits as they remained acceptable for whole storage time in contrast to control fruits which turned unacceptable by 15th day of storage. Control fruits showed significant compositional changes as well as in polyphenol content, ascorbic acid and reduced number of marketable fruits while Cling and Shrink wrapping enhanced the shelf life by 10 days.

Keywords Cling wrap · Shrink wrap · Individual packaging · Post harvest losses · *Psidium guajava*

Introduction

Guava (*Psidium guajava* L.) is a productive and remunerative crop grown commercially in sub-tropical and tropical regions. It is a highly perishable fruit known for its delightful flavour, nutritional status and moderate price in market. Guava fruit is an excellent source of vitamin C (228.3 mg/100 g), containing about 17 % dry matter and 80 % moisture along with appreciable amount of minerals such as phosphorus, calcium, iron as well as vitamins like niacin, pantothenic acid, thiamin, riboflavin and vitamin A. It excels most other food crops in productivity, toughness and adaptability.

Guava is the fourth most widely grown fruit crop in India under the cultivation area of about 0.20 million ha producing 2.50 MT in 2010-2011 (Bijay 2011). The well known Indian varieties of guava are Allahbad Safeda, Lucknow-49, Nagpur seedless and Dharwar etc. India ranks second in production of fruits and vegetables, but suffers from postharvest losses due to improper packaging and processing. The avoidance of significant cumulative post-harvest losses i.e., 5–18 % for fruits and vegetables is a challenging task. According to CIPHET (2010) the post-harvest loss at national level was of Rs 44,143 crore per annum.

The physiological and biochemical changes persistently occur after harvest till fruit become unfit for consumption with short shelf life. Nowadays, individual wrapping of fresh commodities have gained widespread interest to extend their shelf life. Individual wrapping have potential merits over traditional methods of packaging i.e., reduction in weight loss and deformation, maintenance of firmness, alleviation of chilling injury, reduction of decay from secondary infection, delay in colour development and senescence (Risse 2001). “Cling film” the plastic packaging film has revolutionized the food industry by protecting and preserving the food. Cling film is very thin polyethylene film that adheres to the surface of fruit and serves

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as an extra covering. Film improved physico-chemical characteristics of Guava i.e., appearance, weight loss, total soluble solids, titrable acidity, ascorbic acid content and total sugars by retarding respiration and transpirational losses (Chandra and Kumar 2012). Cling film also extended the shelf life of Mung bean sprouts upto 5 days (Goyal and Siddiqui 2012).

Individual Shrink wrapping is the latest trend in fresh produce packaging uses shrinking property of thermoplastic films by applying heat. The flexible film of loosely packed fruit shrunk tightly around the produce on short exposure to hot blown air in heat shrunk tunnel. Besides controlling moisture loss individual shrink wrapping have other beneficial effects like maintenance of firmness, reduction in deformation, alleviation of chilling injury, reduction of decay from secondary infection, delay in colour development and senescence. Shrink film maintained superior quality of pear fruits by significant reductions in weight loss, total soluble solids, desired firmness and extended storage life up to 3 weeks in contrast to LDPE and HDPE films (Mahajan et al. 2013). Packaging of apples with CFB boxes, polyethylene liners and shrink wrapped tray in storage conditions (2 ± 1 °C, 85–90 % RH) have desired effect on physico-chemical characteristics and retained better storage life (Wijewardane and Guleria 2009).

Keeping in view the significant effect of individual wrapping on shelf life of fruits, the characteristics and thickness of film used, the techniques of wrapping and the storage temperatures exercise their influence on outcome of wrapping, the present project work was planned to assess the effect of individual film packaging of guava fruits on its shelf life.

Material & methods

Fruits

Guava cv. ‘Hisar Safeda’ fruits of late spring season crop with excellent quality traits at green mature stage were harvested in horticultural orchard located at Hisar, India receiving standard horticultural practices. Fruits were placed in plastic boxes, disinfected by immersion for 60 s in 1 % household bleach solution and rinsed with tap water by 30 s plunges.

Wrapping materials & treatments

Fruits were individually packed in polythene bags (LDPE) of 200 gauge thickness by two different methods i.e., Shrink and Cling wrapping. 1. Shrink wrap: Fruits were packed in sealed polybags by shrink wrap machine. 2. Cling wrapping:- Fruits were wrapped manually in Cling film (Clean wrap). The unpacked fruits served as Control. The packed and control fruits were placed in BOD incubator at low temperature (7 ± 3 °C) having 10 fruits per pack and six replicates per

treatment. Each pack served as one replicate and sampling was done on 2 days interval up to 21 days of storage.

A. Physical parameteres

Physiological loss in weight (PLW) % & Respiration rate

At harvest, individually numbered fruit with pack were weighed and at the end of each shelf life three replicates were reweighed. The weight loss was determined and expressed as percent loss from initial weight. Decay loss was assessed as total rotted decayed fruits in terms of percentage on number basis.

Respiration rate of packaged guava fruits was measured at harvest and on particular date of observation with modified atmosphere packaging (MAP) testing machine (Quantek USA, Model 902D). After removal from the pack, fruits were kept in respiration jars for 2 h and O₂ and CO₂ concentrations was measured by injecting the needle of MAP testing machine in jars. Results were expressed as μ mole of CO₂ evolved/hour/ kilogram of fruit.

Ripening % & firmness

Hunter colorimeter D25 optical sensor (Hunter Associates Laboratory, Trestoa, VA, USA) was used to determine intensity of the yellow to green colour for ripening percentage on the basis of three variables (L, a, b value). The ‘L’ value signifies the lightness (100 for white and 0 for black), ‘a’ value represents greenness and redness (-80 for green and 80 for red), while ‘b’ value signifies changes from blueness to yellowness (-80 for blue and 80 for yellow). In particular, readings were taken on opposite sides of visibly sound fruit and results were presented in terms of ΔE value (Licciardello and Muratore 2011).

Firmness was measured by manual Pressure tester (Ogawa, Seiki, Japan) fitted with a cylindrical plunger of 11 mm diameter. Fruit firmness was measured at two opposite sides of fruit and expressed as Kg/cm².

B. Biochemical parameters

Chemical analysis was carried out on the juice obtained by squeezing the crushed pulp through muslin cloth with hand.

Titration Acidity (TA) & Total soluble solids (TSS)

Titration acidity was determined by titrating four times diluted aliquots of Extracted juice samples to an endpoint of pink colour with 0.5 N NaOH using 1 % phenolphthalein as an indicator A.O.A.C. (2005). Results were expressed as g of citric acid per 100 gm of fruit pulp. Total soluble solids were determined by using Abbe’s hand refractometer of 0–32 % range at room temperature and expressed as % total soluble solids of fruit.

Fig. 1 Respiration activity in individually wrapped guava fruits stored at low temperature for 21 days. Bars followed by different letters are significantly different at $P < 0.05$. Vertical bars represents SE ($n=3$)

Total phenols, Ascorbic acid content and Polyphenol oxidase activity

Total phenols were estimated by using Folin–Ciocalteu reagent (Amorium et al. 1997). Phenols were extracted from 2 g pulp with 20 ml of 80 % acetone solution. To 0.5 ml of four times diluted aliquot, 8.5 ml of distilled water and 0.5 ml of Folin reagent were added and mixed. After 3 min, 1 ml of 20 % Na_2CO_3 was added vigorously and allowed to stand for 30 min. Absorbance was determined at 760 nm and values were expressed as tannic acid equivalent. Standard curve was prepared using graded concentration of tannic acid.

The ascorbic acid was determined by the method as described in A.O.A.C. (2005). Ascorbic acid was extracted from 5 g pulp with 5 ml of 3 % metaphosphoric acid. Clear and filtered extract was made to 10 ml with 3 % metaphosphoric acid and titrated against 2, 6-dichlorophenol indophenol dye till light pink colour appeared. Results were expressed in mg of ascorbic acid per 100 g of fresh pulp weight.

Polyphenol oxidase was assayed by the method of Kaul and Farooq (1994). Enzyme extract was prepared by homogenizing 4 g pulp in 10 ml of cold 0.2 M tris–HCl buffer (pH=7.5) having 0.1 M each of cystine and EDTA. Homogenate was centrifuged at 15,000 rpm for 20 min at 4 °C. The supernatant (0.5 ml) was incubated with 4 ml of 0.05 M guaiacol in 0.2 M phosphate buffer for 20 min at 30 °C. The reaction was terminated by adding 1 ml of chilled 10 % TCA and the optical density was read at 430 nm against the reagent blank. The enzyme activity was measured in units/g fruit wt./h. One unit of enzyme represented increase in O.D. by one under the standard conditions.

Organoleptic evaluation

Guava samples were evaluated by a panel of 9 semi-trained members for taste, appearance, texture, flavour and overall

acceptability on 9 point hedonic scale, according to the intensity of attributes.

Statistical analysis

The data obtained in the present investigation were subjected to statistical analysis of variance (ANOVA) technique using two factorial completely randomized designs (CRD), except for parameters PLW, Decay loss and ripening%, where single factorial CRD was used. The critical difference at 5 % levels of significance was calculated and used for making comparison among different treatments during storage.

Results

Respiration Rate, Firmness and weight loss

Respiration activity, which at harvest was 5 ml/h/kg fruit, increased to 27.8 ml/h/kg fruit by 18th day and declined towards the end of storage (21st day) as shown in Fig. 1. For cling and shrink wrapped fruits increase was comparatively slower with maximum attained value of 18.6 and 19.1 ml/h/kg fruit respectively. After 6th day no significant difference was detected among control and cling wrapped fruits as respiration

Table 1 Effect of individual wrapping on firmness (Kg/cm^2) of fruits at different storage period

Treatments	Period of storage (days)							
	0	3	6	9	12	15	18	21
Control	8.8	8.7 ^a	8.6 ^a	8.0 ^a	7.3 ^a	7.0 ^a	6.8 ^a	6.2 ^a
Cling wrap	8.8	8.7 ^a	7.5 ^b	7.1 ^b	6.9 ^b	6.7 ^a	6.5 ^a	6.2 ^a
Shrink wrap	8.8	8.4 ^b	8.0 ^c	7.5 ^b	7.2 ^b	7.0 ^a	6.8 ^a	6.0 ^a

Means with different superscripts (a, b) in column differ significantly ($p < 0.05$) from each other in each table

Fig. 2 Polyphenol oxidase activity in individually wrapped guava fruits stored at low temperature for 21 days. Bars followed by different letters are significantly different at $P<0.05$. Vertical bars represents SE ($n=3$). *(1 unit=Change in 1.0 O.D /g/h under standard conditions for enzyme polyphenol oxidase at 430 nm.)

doubled to 10 ml/h/kg fruit while significantly lower for shrink wrapped fruit (8 ml/h/kg) at 7 ± 3 °C. An overall rise in respiration activity was detected from 9th to 18th days for control fruits (16.2 ml/h/Kg fruit) in contrast to wrapped fruits (8–10 ml/h/Kg fruit). Shrink wrapped fruits produced significantly lower rates of CO₂ than Cling wrapped ones.

A slight but significant decline in firmness of fruits occurred during cold storage (Table 1). Firmness at harvest was 8.8 Kg/cm² which decreased to 7.6 and 8 Kg/cm² for cling and shrink wrapped fruits, respectively at 6th day of storage. In contrast, firmness remained significantly higher for control fruits (8.6 Kg/cm²) and declined thereafter. At the end of storage no significant differences were observed among firmness of wrapped fruits and control ones (Fig. 2)

As evident from the Table 2, weight loss in control fruits was 9.2 % at 6th day, while in wrapped fruits was only 0.7–0.8 %. Weight loss increased to 15 % at 12th day in control fruits which underwent further reduction of the initial weight of 26.5 % against 3.5 % of wrapped fruits.

Ripening index and Hunter color values

As storage proceeded, the skin color of control fruits turned progressively at low temperature however, the magnitude of

ripening was much smaller as evident from L, a, b values (data not shown). Skin colour attributes 'L', 'a', 'b' which at harvest were 29.2, -12.4, 12.1 respectively increased with storage time mainly for cling wrapped fruits while slight lower for control and shrink wrapped fruits. Both treatments as well as control fruits showed marked color change. As evident from the Fig. 3 total color difference increased during storage being slower for shrink wrapped fruits among both treatments. At 12th day ΔE values for wrapped fruits were insignificantly different from control fruits and increased thereafter. Higher increase in ΔE value in control and cling wrapped fruits at 18th day may be because of higher positive 'b' value. However, Control and shrink wrapped fruits showed only 30 % ripening with non-significant differences among them in contrast to 40 % observed for cling wrapped fruits by final storage day.

In control fruit the loss of visual quality was evident even during cold storage. After 3 weeks of storage most fruit were graded at the limit of marketability with organoleptic score of 6 whereas at the end of 15 days all control fruit were unmarketable with 4.9 score on 9 point hedonic scale. Film wrapping preserved fruit freshness and accurate examination carried out by semi-trained assessors could detect the negligible reported defects.

TSS and Titrable Acidity

Reduction of TA was higher in control fruits than the wrapped ones (Table 3) with decline of about 40 % with respect to harvest time in contrast to 50 % for control. TSS at harvest was 4.9 g/100 g which increased to 8.5 and 6.9 for control and wrapped fruits respectively at 6th day of storage (data not shown). Control fruits showed an increasing trend up to 18 days (10.7 g/100 g) which decreased thereafter to 9.8, while cling (9.4) and shrink wrapped fruit (9.2) showed an increasing trend till end of shelf life. However during first week TSS increased at a higher rate and thereafter at slower

Table 2 Effect of individual wrapping on physiological loss in weight (%) at different storage period

Treatments	Period of storage (days)						
	3	6	9	12	15	18	21
Control	4.7 ^a	9.2 ^a	12.8 ^a	14.9 ^a	19.8 ^a	22.7 ^a	26.5 ^a
Cling wrap	0.3 ^b	0.8 ^b	1.5 ^b	1.9 ^b	2.4 ^b	3.1 ^b	3.5 ^b
Shrink wrap	0.3 ^b	0.7 ^b	1.3 ^b	2.1 ^b	2.6 ^b	3.0 ^b	3.5 ^b

Means with different superscripts (a, b) in column differ significantly ($p<0.05$) from each other in each table

Fig. 3 Delta E Values of colour in individually wrapped guava fruits stored at low temperature for 21 days. Bars followed by different letters are significantly different at $P<0.05$. Vertical bars represents SE ($n=3$)

rate. Non-significant differences were observed between treatments.

Total Phenols, Ascorbic acid and Polyphenol oxidase (PPO) activity

Total polyphenol content at harvest was 63.6 mg/100 g pulp which decreased significantly over the storage period (Table 4). Reductions were significantly higher in control fruits (12.8 mg/100 g) as compared to wrapped fruits (24–28 mg/100 g) at the end of trial. Among both wrapping treatments phenol content was significantly higher in shrink wrapped fruits.

Decrease in ascorbic acid content with the advancement of storage was observed (Table 5). At harvest ascorbic acid content was 42.4 mg/100 g which decreased to 25.4 and 27.4 mg/100 g for cling film and shrink wrapped fruit, respectively after 21st day of storage. For control fruits content was significantly lower (20.5 mg/100 g). However, decrease was higher during first 3 days of storage among control as well as wrapped fruits and slowed down thereafter.

Table 3 Effect of individual wrapping on Titrable acidity (%) at different storage period

Treatments	Period of storage (days)							
	0	3	6	9	12	15	18	21
Control	0.43	0.40 ^a	0.36 ^a	0.30 ^a	0.27 ^a	0.25 ^a	0.20 ^a	0.43 ^a
Cling wrap	0.46	0.41 ^b	0.39 ^b	0.36 ^b	0.34 ^b	0.31 ^b	0.29 ^b	0.46 ^b
Shrink wrap	0.46	0.43 ^c	0.40 ^c	0.37 ^b	0.35 ^b	0.32 ^b	0.30 ^c	0.46 ^c

Means with different superscripts (a, b) in column differ significantly ($p<0.05$) from each other in each table

Increase in PPO activity over the storage period was observed at low temperature (Fig. 2) however magnitude of increase was lower. At harvest PPO activity was very low (0.14) which increased to 0.55 for control fruits, while lower 0.44 and 0.49 for shrink wrapped and cling wrapped fruits, respectively. Both wrapping treatments were significantly effective in slowing down the PPO activity with respect to control being lower in shrink wrapped than cling wrapped fruits.

Organoleptic score

Objective measurements of fruits showed significant changes in colour, taste and appearance of fruit. At low temperature storage conditions, the overall acceptability of control fruits improved up to 3rd day (7.4) only and turned unacceptable by 15th day (4.9). Among wrapped fruits acceptability of cling (7.8) and shrink wrapped (7.8) fruits improved up to 6th day and 9th day, respectively due to optimum ripening and desirable texture. Later on it decreased by last sampling date (21st day) to 6.1 (cling wrapped) and 5.9 (Shrink wrapped) but still of acceptable quality. Organoleptic score of wrapped fruits

Table 4 Effect of individual wrapping on phenol content (mg/100 g) during different storage period

Treatments	Period of storage (days)							
	0	3	6	9	12	15	18	21
Control	63.6	54.5 ^a	43.6 ^a	34.5 ^a	27.3 ^a	21.8 ^a	16.4 ^a	12.8 ^a
Cling wrap	63.6	58.2 ^b	50.9 ^b	45.5 ^b	41.8 ^b	36.4 ^b	30.9 ^b	24.5 ^b
Shrink wrap	63.6	60.9 ^c	54.5 ^c	49.1 ^c	42.7 ^b	39.1 ^c	32.7 ^c	27.3 ^c

Means with different superscripts (a, b) in column differ significantly ($p<0.05$) from each other in each table

Table 5 Effect of individual wrapping on ascorbic acid (mg/100 g) content during different storage period

Treatments	Period of storage (days)							
	0	3	6	9	12	15	18	21
Control	42.0	35.7 ^a	33.7 ^a	30.3 ^a	27.8 ^a	25.4 ^a	22.0 ^a	20.5 ^a
Cling wrap	42.0	38.2 ^b	35.6 ^b	34.0 ^b	31.9 ^b	29.0 ^b	27.6 ^b	25.4 ^b
shrink wrap	42.0	39.0 ^c	37.6 ^c	35.2 ^c	32.3 ^c	31.1 ^c	29.8 ^c	27.4 ^c

Means with different superscripts (a, b) in column differ significantly ($p < 0.05$) from each other in each table

remained low despite of lower PLW, delay in ripening, retention of green colour and maintenance of sufficient TSS at later storage period.

Discussion

The significance of respiration rate measurement in assessment of packaging system's performance relies on the principle that amount of oxygen consumed by the produce is directly related to the extent of metabolic activities (senescence level) associated with its respiration (Del Nobile et al. 2007). In our analysis respiration activity of fruits during storage at 10 °C was significantly higher than at harvest and its intensity increased during shelf life periods. Consequently storage conditions appeared to have an unfavorable impact on respiration activity because of climacteric nature of fruit rise in respiration takes place during ripening in storage when harvested at green maturity stage.

Respiration rate increased progressively in individually wrapped fruits while at a higher rate in control fruits up to 18th day, thereafter progressive decline occurred. Higher respiration rate detected in control fruits is in accordance to the results of Brar et al. (2000) could be due to post climacteric decline and skin dryness preventing the exchange of gases. Reduced respiration rate observed in polythene packed fruit, as per previous study could be consequence of O₂ depletion and CO₂ accumulation in pack as polythene prevented the moisture loss, maintained the turgidity and modified the atmosphere around the fruit (Patel et al. 2009).

Low respiration rate obtained at lower storage temperature is proportional to ethylene production. This principle is a critical component for successful application of individual wrapping as observed in the present study also (De Santana et al. 2011). However ethylene measurement was not included in experiment which may further elaborate respiratory activities associated with low temperature storage.

Weight loss is a major deciding factor of visual quality loss of agricultural products. In our study 'Hisar Safeda' Guava was susceptible to transpiration and indicated PLW of 26 %, yet the effect of individual polythene wrapping was

impressive, with a final weight loss of just 3–3.5 % and enhanced the storability of guava. Mahajan et al. (2013) detected least PLW (3.5 %) in shrink packed pear fruits as compared to unpacked control fruits (6.20 %). Maximum moisture retention (87.4 %) reported in plastic bag wrapped guava stored at 16 °C in shrink wrapped Royal-delicious apples and in Nagpur Mandarin (Miano and Jokhio 2010; Wijewardane and Guleria 2009) may be due to retardation in respiration, evapo-transpiration and metabolic processes. The impact of LDPE film used in present study was comparative to HDPE film in PLW reduction of packed grape fruits, Shamouti orange and lemons (Jawandha et al. 2012). Besides storage conditions, moisture loss can be affected by harvesting time and cultivar. Miano and Jokhio (2010) reported weight losses of 33.6 % in 'Allahbad Safeda' guava stored for 4 days at room temperature while in another experiment cv. 'Pant Prabhat' showed more than 30 % reduction of initial weight in 7 days.

At low temperature storage conditions, no decay loss was observed in both treatments throughout the storage period. Outcome of study demonstrated no significant effect of wrapping on decay. Storage temperature is the determining variable for deterioration. Individual shrink wrapping maintained freshness, inhibited husk scald and extended the shelf-life of pomegranates for 6 weeks at 5–6 °C while seal packed kinnow fruits (LDPE) at ambient temperature showed more spoilage due to accumulation of more humidity in vicinity of fruits which aggravates microbial attack (Jawandha et al. 2012; Aquino et al. 2010).

Beneficial effect of plastic films in improving storability of guava has been demonstrated in previous studies on modified atmosphere packaging. Sealing 'Allahbad Safeda' Guava in polythene bags highly permeable to gases, prevented transpirational loss and any physiological disorders both during room temperature (24 °C) and low temperature (16 °C) storage (Miano and Jokhio 2010). Similarly individual cling film wrapping maintained physiological parameters rating and extended shelf life of 'Pant-prabhat' guava up to 7 days at 25 °C (Chandra and Kumar 2012). Banana fruits packed in polysheets took the longest period of 11 days to complete its shelf life as compared to wooden box and straw packed (Tadesse 2014). In individually wrapped fruit the passively modified atmosphere around the fruit remains different from ambient air which is advantageous over controlled atmosphere where fruits are continuously exposed to conventional atmosphere.

Although MA packaging can reduce respiration activity thus delaying compositional changes and prolonging postharvest life of fruit, elevated concentrations of CO₂ can be toxic to tissue, while low levels of O₂ can induce anaerobic respiration, hasten degradation of respiratory substrates and promote build-up of fermentative volatiles. Storage of guava in 5 KPa O₂ and 2.5 KPa CO₂ reduced the respiration and ethylene productions rates, ascorbic acid loss and retained

firmness but no adverse effect on TSS, TA and flavor (Singh and Pal 2008). ‘Kumagai’ Guava wrapped in 25 μm thick LDPE plastic film resulted in reduced weight loss, lower acidity and TSS and lower chilling injury while same cultivar packed in thicker LDPE film (69 μm) developed an intense off flavour in addition to substantial loss of ascorbic acid (Gasper et al. 1994). In our experiment Individual wrapping decelerated elevate in TSS with significant reduction in TA. Excessive increase in TSS observed in control fruits indicates quality deterioration, may be attributed to the utilization of organic acid in pyruvate decarboxylation reaction occurring during the ripening process of fruits or due to breakdown of complex polymer into simple sugars by hydrolytic enzymes which might be further metabolized during respiration and level decreased during subsequent storage. Combined effect of Packaging and low temperature regime reduced the respiration rate and retards compositional changes such as TSS and TA. Similarly delayed increase in TSS in individually packed ‘Kinnow’ (HDPE of 0.1 μ thickness) and tomatoes (LDPE film) stored at ambient (12 ± 1 °C, 90–95 % RH) condition was reported with minimum rotting, maximum palatability rating and maintained acidity without much deterioration in quality (Randhawa et al. 2009; Mathew et al. 2007).

In general ascorbic acid and total phenols content decreases with the advancement of storage. Negligible loss in vitamin-C content in individually shrink wrapped guava fruits stored at ambient temperature was also reported by Pal and Gupta (2004). High residual phenolics in vacuum packed than unpacked control fruits during frozen storage of apples and shrink wrapped bell pepper (150 gauge LDPE film) stored at 27 °C and 65 % RH were observed (Wu 2000; Sahoo and Matche 2006). The changes in ascorbic acid and total phenols detected in our experiment in film-wrapped fruit, generally are in accordance with the above cited studies of wrapping. Shrink and cling wrapping retained 60–65 % of original ascorbic acid as compared to 48 % retention in control fruits could be due to modified atmosphere (reduced O_2 concentration) around the fruits which slowed down the enzymatic oxidation of ascorbic acid and phenols to dehydroascorbic acid.

Wrapping can enhance retention if combined with coating materials such as 2 % CaCl_2 treated and polythene bag sealed apples retained 87 % of original acid (Hayat et al. 2005). In a different study concentration of competitive ethylene antagonists Calcium salts efficiently delayed the ripening of packed ‘Sardar’ guava fruits. The application of 1 % calcium chloride and calcium nitrate was efficient in delaying skin color loss and in keeping fruit firm for 12 days even at room temperature storage (Kumar et al. 2012). In our experimental setup use of coating material along with individual packaging may be highly beneficial to maintain marketability of fruits as reported in above stated study. In present study also delayed ripening process in wrapped fruits as compared to control ones is supported by color LAB values also. However firmness of

control fruits is not consistent with observed ripening attributes and insignificant over wrapped ones which could be the effect of low temperature storage. As evident from PLW skin of control fruits has hardened by loss of moisture which may led to higher firmness value. All physiological parameters that affect the quality of fruits are interrelated. Individual wrapping optimized the CO_2 and O_2 concentration in pack, reduced the metabolic activities, delayed compositional changes, ripening process, ethylene production and prolong postharvest life of fruit (Kader et al. 1989).

More retention of ascorbic acid and polyphenols in wrapped fruits could be related to slow increase in PPO activity over control fruits. Shrink wraps was more effective in slowing down PPO activity as compared to cling wrap. In control fruits higher degradation of polyphenols could be caused by moisture loss disrupting cellular compartmentalisation. This disruption allows release of PPO located in vacuole and increase in activity. Somboonkaew and Terry (2010) also reported production of melanin pigments from anthocyanin in litchi pericarp leading to their degradation and browning in unwrapped litchi stored at 13 °C when compared to Propafresh wrap packaged Litchi with no degradation of anthocyanin pigments and no browning. Individually wrapped pear in polythene bag and minimally processed fruits stored at ambient condition were superior to the unpackaged fruits by preventing phenol induced browning of the peel considerably (Nicoli et al. 2007).

In conclusion, the main objective of this experiment was to verify if individual wrapping could enhance the shelf life of guava fruits during cold storage. For this reason fruits were stored at 7 ± 3 °C which is sufficient to slow down the metabolic activities and higher enough to support ripening process.

As expected, individual wrapping reduced the magnitude of physico-chemical changes during storage and helped in retention of quality for longer time, while excessive weight loss, extensive soluble solid concentration associated with high respiration rate, strongly altered the visual appearance and reduced the percentage of marketable fruits in control ones. Optimized CO_2 and O_2 concentration achieved with film wrapping had a striking effect on respiration, in inhibiting ripening process, decelerating rise in TSS and maintaining freshness during storage period. Shrink wrapping reduced the PPO activity and restored polyphenol and ascorbic acid content effectively than cling wrapping. However, both treatments were equally effective in maintaining desirable characteristics and overall acceptability by minimizing the physico-chemical changes. Thus individual wrapping can improve storability of summer season guava fruits more susceptible to transpiration, spoilage and decay loss, for which lower temperature along with wrapping treatments are required.

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