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Effect of package lining on quality and shelf-life of papaya fruits

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ABSTRACT

The effect of package lining on quality and shelf-life of ‘Baladi’ and ‘Ekostika II’ papaya fruits at 18 ± 1^{o}C and 85% – 90% relative humidity was evaluated. Package lining with paper or polyethylene sheets significantly delayed fruit ripening by one and three days, respectively, compared to unlined fruits (control) in both cultivars. Polyethylene film liners were more effective in extending the shelf-life of fruits than paper liners, due to more restriction to gas exchange than with paper liners. The effect of package lining in delaying papaya fruit ripening was reflected in reduced respiration rate, delayed the onset of climacteric peak, decreased water loss, delayed fruit softening, accumulation of TSS, total and reducing sugars and ascorbic acid content in fruits.

INTRODUCTION

Papaya, (*Carica papaya* L.) is an important tropical fruit crop. It is commercially grown in all tropical countries and in many sub-tropical regions. Papaya fruit is highly accepted worldwide and the consumer demand for fresh papayas is increasing for its nutritional and medicinal value (Lobo and Cano, 1998).

Papaya fruit is a typical climacteric fruit that exhibits characteristic rise in ethylene production and respiration rate during ripening (Kader, 2002). The high rate of respiration, which is usually associated with a short shelf-life, soft texture and high moisture content, makes papaya a very perishable fruit that requires absolute care during handling and transportation.

Although Sudan has a great potential to produce high quality papaya fruits for both local and export markets, its production is still very low and its marketability is limited to local markets. This is due to the delicate nature of the fruit, poor handling practices and inadequate packing and transportation facilities. Therefore, proper packaging and handling techniques to minimize physical damage reduce water loss and control fruit ripening are crucial for the development of a sound papaya industry in Sudan.

Water loss is a serious cause of deterioration of horticultural commodities because it results not only in direct quantitative losses (loss of weight), but also in qualitative losses in appearance (shriveling), textural and nutritional quality (Wills *et al*., 1998). Water loss can be reduced effectively by placing an additional physical barrier between the produce and the surrounding air. This can also reduce air movement across the produce surface (Wills *et al*., 1998). Paper or plastic films are often used to line packing boxes in order to reduce water loss and prevent friction damage (FAO, 1989).

The use of plastic films to achieve a modified atmosphere is increasing. Polyethylene box liners have been used for several years in the storage of pears and apples, but only to a limited extent with other produce (Wills *et al*., 1998). It has been shown that bananas packed in polyethylene-lined boxes have a longer shelf-life than control fruits (Kader, 2002). The greatly increased storage life was attributed to the reduction in the rate of natural ethylene production by the bananas and also to reduced sensitivity of fruit to ethylene (John and Marshal, 1995; Wills *et al*., 1998).

This study was carried out to evaluate the effect of paper and polyethylene lining on quality and shelf-life of papaya fruits.

MATERIALS AND METHODS

Experimental material

Mature-green papaya fruits of 'Baladi' and 'Ekostika II' cultivars were harvested from the Demonstration Farm, Faculty of Agriculture, University of Sennar, Abu- Namma (12° 44′ N, 38° 08′ E). Fruits were selected for uniformity of size, maturity and freedom from blemishes. Fruits were washed, air-dried and transported in carton boxes to the laboratory for further treatments.

The fruits from each cultivar were distributed among three treatments (40 fruits each), in a completely randomized design with four replicates. The fruit packed in cartoon boxes (67x35x10 cm) were either lined with paper or polyethylene sheets (0.0015 mm) or packed without lining as control. All treatments were stored at 18 ± 1 ºC and 85% -90% relative humidity.

Parameters studied

Respiration rate and weight loss in fruits were determined in ten fruit from each replicate every two days and later every day during the storage period. Respiration rate (mg CO_2 / kg-hr) was determined using the total absorption method (Mohamed-Nour and Abu-Goukh, 2010). Weight loss in fruits was determined according to the formula: $w_1 = [(w_0 - w_t)/w_0] \times 100$, where w_1 is the percentage weight loss at the designated time, w_0 is the initial weight of fruits, and w_t is the weight of fruits at the designated time.

Firmness of fruit flesh, total soluble solids (TSS), total and reducing sugars and ascorbic acid content were determined at two days intervals and later every day in two fruits picked randomly from each replicate, other than those used for respiration and weight loss determination. Fruit firmness was measured by Magness and Taylor firmness tester (D-Ballautf Meg. Co.) equipped with an 8 mm-diameter plunger tip. Two readings were taken from opposite sides of each fruit after the peel was removed and firmness was expressed in kg/cm^2. TSS was determined directly from the fruit juice extracted by pressing the fruit pulp in a garlic press, using a Kruss hand refractometer (Model HRN-32). Two readings were taken from each fruit and the mean values were calculated and corrected according to the refractometer chart.

Thirty grames of fruit pulp were homogenized in 100 ml of distilled water for one minute in a Sanyo Solid State Blender (Model SM 228P) and then centrifuged at 10 000 rpm for 10 minutes using a Gallenkamp portable centrifuge (CF-400). The volume of the supernatant, which constituted the pulp extract, was determined. Total sugars were determined according to the anthrone method of Yemm and Willis (1954). Reducing sugars were determined according to the technique described by Somogyi (1952). Total and reducing sugars were expressed in g/100g fresh weight. Ascorbic acid content in the pulp extracts was determined, using the 2, 6 -dichlorophenol- indophenol titration method of Ruck (1963), and expressed in mg /100g fresh weight.

Statistical analysis

Analysis of variance and Fisher's protected LSD test with a significance level of $P \leq 0.05$ were performed on the data (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Package lining with paper or polyethylene sheets significantly delayed fruit ripening by one and three days, respectively, compared to the control in both papaya cultivars. Similar results were reported in banana (Elkashif *et al*., 2005; Elamin and Abu-Goukh, 2009) and guava (Bhullar and Farmahan, 1980). Package lining is regarded as one of the treatments used to manipulate the environment by creating a modified atmosphere surrounding the produce (Kader, 2002). The process of respiration of packed fruits resulted in a modified atmosphere, with lower oxygen (O_2) and higher carbon dioxide (CO_2) concentrations. Low O_2 concentration suppresses ethylene biosynthesis and high CO_2 inhibits ethylene action (John and Marshal, 1995).

The use of plastic films to achieve a modified atmosphere is increasing. Polyethylene box liners, either sealed or perforated, have been used for several years in storage of pears and apples, but only to a limited extent with other produce (Wills *et al*., 1998). Polymeric film packaging has been extensively used to minimize weight loss, reduce abrasion and enhance fruit quality (Bhullar and Farmahan, 1980; Elamin and Abu-Goukh, 2009). It was reported that bananas packed with polyethylene liners, sealed or perforated, had a longer green-life than unlined fruits (Elkashif *et al*., 2005; Elamin and Abu-Goukh, 2009). The greatly increased storage life was attributed to the reduction in the rate of natural ethylene production by the fruits and also to the reduced sensitivity of fruits to ethylene action (Wills *et al*., 1998; John and Marshal, 1995).

The delay in fruit ripening and extended shelf-life of papaya fruits due to package lining was reflected in changes in respiration rate, weight loss, fruit flesh firmness, total soluble solids, total and reducing sugars and ascorbic acid content.

Effect on respiration rate

Fruits of the two papaya cultivars exhibited a typical climacteric pattern of respiration (Fig. 1-A). The unpacked fruit reached a climacteric peak of 83.3 mg CO_2 /kg-hr in the 'Baladi' and 95.6 mg CO_2 /kg-hr in 'Ekostika II' papaya fruits after eight days in both cultivars. The climacteric peak was lowered by an average of 2.5% and 6.2% and the onset of the climacteric was delayed by one day and three days in papaya fruits packed in boxes lined with paper and polyethylene sheets, respectively, compared to the control (Fig. 1-A). The package liners manipulated the environment by restricting gas exchange. The packed fruit, through the respiration process, resulted in a modified atmosphere with lower O_2 and higher CO_2 concentrations (Kader, 2002). Such a condition will slow-down respiration rate and ethylene production (John and Marshal, 1995; Wills *et al*., 1998). Similar results were reported for banana (Elamin and Abu-Goukh, 2009) and guava (Bhullar and Farmahan, 1980).

Effect on weight loss

Weight loss progressively increased during storage of both papaya cultivars (Fig. 1-B). After 16 days in storage, weight loss was 18.2% in the 'Baladi' and 16.8% in 'Ekostika II' cultivars. Packing the fruit in carton boxes lined with paper or polyethylene sheets reduced the weight loss by an average of 9.5% and 20.8%, respectively, compared to the control (Fig. 1-B).

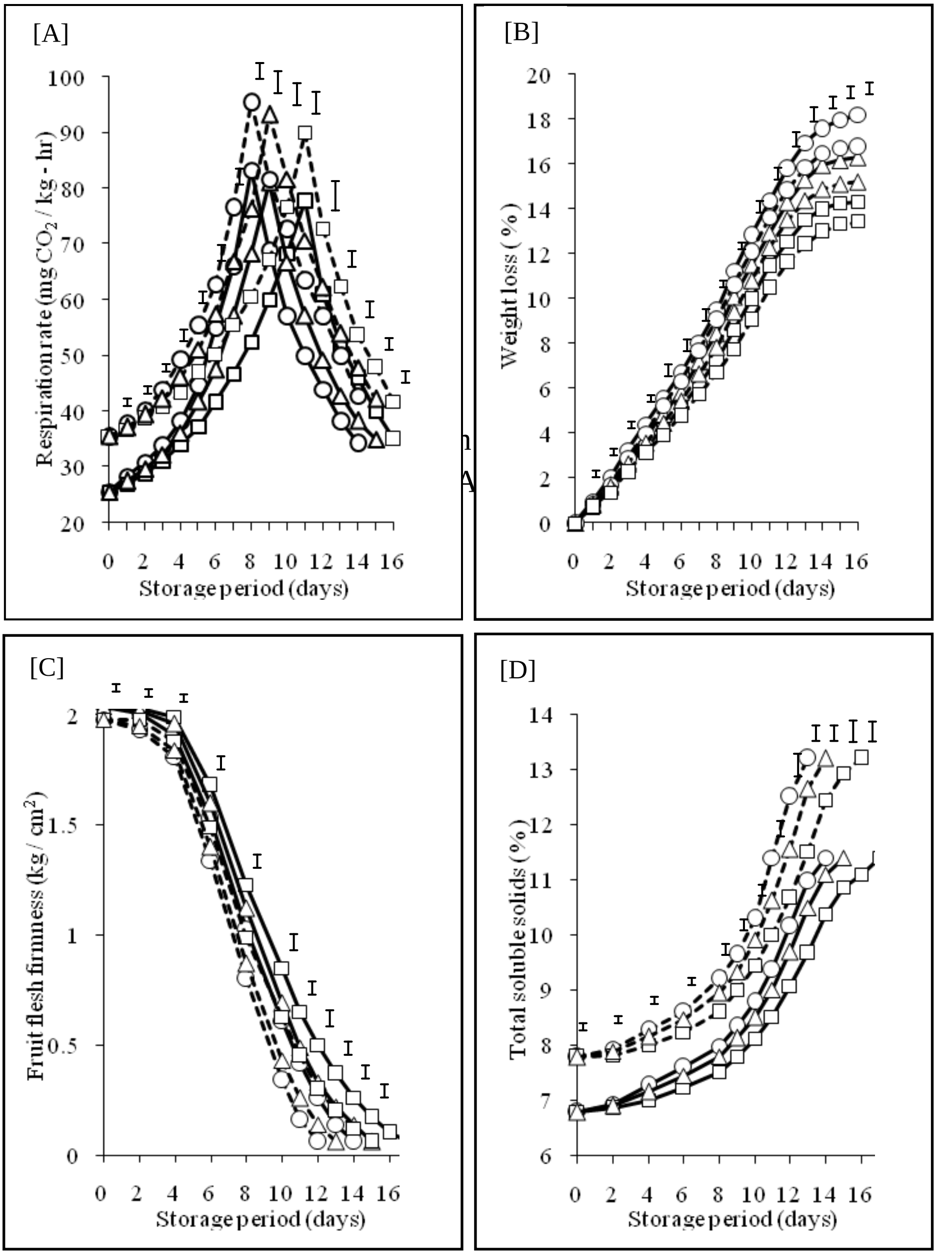

Fig. 1. Changes in respiration rate [A], weight loss [B], fruit flesh firmness [C] and total soluble solids [D] during storage of 'Baladi' (_____) and 'Ekostika II' (……...) papaya fruits in carton boxes lined with paper (Δ) or polyethylene sheets (☐), compared to fruits in unlined boxes (O) at 18±1ºC and 85-90% relative humidity. Vertical bars represent LSD (5%).

These results were in line with previous reports in banana (Elkashif et al., 2005, Elamin and Abu-Goukh, 2009), guava (Bhullar and Farmahan, 1980) and mango (Thompson, 1971).

Water loss can be reduced effectively by placing additional physical barriers between the produce and the surrounding air (Wills *et al*., 1998). Polyethylene liners were more effective than paper liners in reducing weight loss, since the rate of water transfer is low compared with that of paper and fiberboard, which have a high permeability to water vapor (Wills *et al*., 1998). Packing fruit in intact or perforated polyethylene film liners results in a higher relative humidity inside the package and hence reduces weight loss in the produce (Elkashif *et al*., 2005; Elamin and Abu-Goukh, 2009). Polymeric film packaging have been extensively used to minimize weight loss, reduce abrasion damage and to enhance fruit quality in banana (Elkashif *et al*., 2005; Elamin and Abu-Goukh, 2009), guava (Bhullar and Farmahan, 1980) and mango (Thompson, 1971).

Effect on fruit flesh firmness

Fruit flesh firmness progressively declined in both papaya cultivars. It decreased in control fruits packed in carton boxes without lining from 2.04 to 0.06 kg/cm^2 in 14 days in 'Baladi' and from 1.98 to 0.06 kg/cm^2 in 12 days in 'Ekostika II' (Fig. 1-C). Fruit packed in carton boxes lined with paper or polyethylene sheets were more firm throughout the storage period and reached the final soft stage (0.06 kg/cm^2) after one day and three days later, respectively, compared to the control (Fig. 1-C). Polyethylene liners were effective in reducing fruit softening and firmness retention during storage of fruits and vegetables. Similar results were reported in banana (Elamin and Abu-Goukh, 2009), guava (Bhullar and Farmahan, 1980) and mango (Thompson, 1971). Package lining through restriction of gas exchange and respiration of packed fruits creates a modified atmosphere condition with relatively low O_2 and high CO_2 (Kader, 2002). Such a condition decreases solublization and depolymerlization of pectic substances during fruit ripening (Smock, 1979), which is associated with tissue softening during fruit ripening (Ali and Abu-Goukh, 2005).

Effect on total soluble solids

Total soluble solids (TSS) showed progressive increase during storage of both papaya cultivars in all treatments (Fig. 1-D). The maximum TSS value reached by the control fruits was 11.4 % in ‘Baladi’ after 14 days and 13.2% in ‘Ekostika II’ after 13 days. Package lining delayed the accumulation of TSS during storage of papayas. When the control fruits reached the maximum TSS values, the fruits lined with paper and polyethylene sheets were 3.4% and 10.8% less, and had reached the maximum TSS value one and three days later, respectively, compared to the control (Fig. 1-D). Similar results were reported in banana (Elamin and Abu-Goukh, 2009) and mango (Thompson, 1971). Package lining creates a modified atmosphere condition surrounding the produce (Kader, 2002), which delays fruit ripening (John and Marshal, 1995; Elamin and Abu-Goukh, 2009), and hence TSS accumulation.

Effect on total sugars

Total sugars steadily increased in the fruit of the two papaya cultivars with the advancement of storage period (Fig. 2-A). The maximum total sugars value reached by unlined fruits was 11.8 in ‘Baladi’ and 14.0 g/100g fresh weight in ‘Ekostika II’ cultivars after 14 days in both cultivars (Fig. 2-A). Package lining delayed accumulation of total sugars in a similar manner as TSS (Fig. 1-D). The fruits packed in carton boxes lined with paper or polyethylene sheets reached the maximum total sugars after one and three days, respectively, compared to the control. Total sugars were less in fruit with package lining throughout the storage period. After 14 days in storage, total sugars were reduced by an average of 2.4% and 7.2% in fruits lined with paper and polyethylene liners, respectively, compared to fruits packed without lining (Fig. 2-A). In papaya fruit, the increase in total sugars was attributed to the action of papaya–invertase enzyme (β fructo-furanoside enzyme) that catalyzes the inversion of sucrose (Chan and Kwok, 1975). Polyethylene liners resulted in a modified atmosphere with low O_2 and high CO_2 concentration (Kader, 2002), which may decreases the activity of papaya–invertase enzyme (β fructo-furanoside enzyme) that was reflected in slow total sugars accumulation compared to normal atmospheric conditions.

Effect on reducing sugars

Reducing sugars in fruits of the two papaya cultivars increased up to the climacteric peak and then decreased thereafter irrespective of the treatment applied (Fig. 2-B). Similar trends were reported during growth and development of papaya (Abu-Goukh *et al.*, 2010) and mango (Abu-Goukh *et al*., 2005) and ripening of guava (Bashir and Abu-Goukh, 2003). Fruit packed unlined reached reducing sugars peak of 4.5 in ‘Baladi’ and 5.0 g/100g fresh weight of ‘Ekostika II’ after eight days in both cultivars (Fig. 2-B).

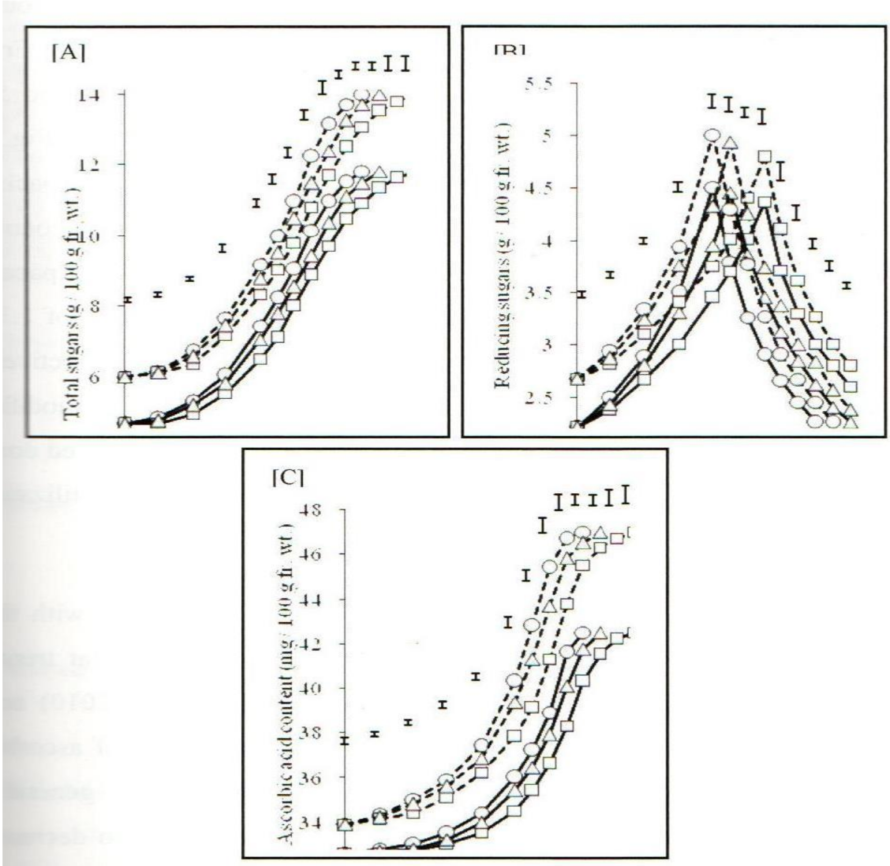

Fig. 2. Changes in total sugars [A], reducing sugars [B] and ascorbic acid content [C] during storage of ‘Baladi’ (______) and ‘Ekostika II’ (……...) papaya fruits in carton boxes lined with paper (Δ) or polyethylene sheets (☐), compared to fruits in unlined boxes (O) at 18±1ºC and 85% - 90% relative humidity. Vertical bars represent LSD (5%).

Development of papaya (Abu-Goukh *et al.*, 2010) and mango (Abu-Goukh *et al.*, 2005) and ripening of guava (Bashir and Abu-Goukh, 2003) Furit packed unlined reached reducing sugars peak of 4.5 in 'Baladi' and 5.0g/100g fresh weight of 'Elkostika II' after eight days in both cultivars (Fig .a).

B) Reducing sugars peak was delayed by one and three days in fruit packed with paper and polyethylene liners, respectively, compared to the control. Package liners decreased reducing sugars during storage of both papaya cultivars. The peak of reducing sugars was reduced by an average of 1.3% and 3.7% in fruits lined with paper and polyethylene liners, respectively, compared to the control (Fig. 2-B). Package liners created a modified atmosphere with lower O_2 and higher CO_2 (Kader, 2002) which slowed down respiration rate (Wills *et al*., 1998) and consequently lowered the utilization of reducing sugars.

Effect on ascorbic acid content

Ascorbic acid in fruit of the two papaya cultivars increased with the advancement of storage period in all treatments (Fig. 2-C). Similar trends were reported during ripening of papaya (Abu-Goukh *et al.*, 2010) and tomato (Ahmed and Abu-Goukh, 2003). This increasing trend of ascorbic acid during ripening and storage is an exception to what is generally reported in many fruit where ascorbic acid was demonstrated to decrease during ripening in mango (Abu-Goukh *et al.*, 2005) and guava (Bashir and Abu-Goukh, 2003). The control fruit reached the maximum value of ascorbic acid of 42.5% in 'Baladi' and 47.0% in 'Ekostika II' after 14 days in storage in both cultivars (Fig. 2-C). Fruit packed with paper and polyethylene liners reached the maximum value of ascorbic acid one and three days later, respectively, compared to the control, in both cultivars (Fig. 2-C). Since ascorbic acid increased during papaya fruit ripening (Abu-Goukh *et al.*, 2010) and package lining reduced respiration rate (Fig. 1-A) and delayed ripening and accumulation of TSS (Fig. 1-D) and sugars (Fig. 2-A), then the delay in ascorbic acid accumulation is obvious.

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تأثير تبطين العبوات على جودة ثمار الباباي وطول عمرها التسويقي

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الخلاصة

تم تقويم تأثير تبطين العبوات الكرتونية بشرائح الورق أو البوليثين على جودة ثمار الباباي من صنفي ′البلدي′ و′إكوستيكا II′ وطول عمرها التسويقي في درجة حرارة 18 ± 1 درجة مئوية و 85- 90% رطوبة نسبية. أدى تبطين العبوات بشرائح الورق أو البوليثين معنوياً لتأخير نضج الثمار ليوم و لثلاثة أيام، على التوالي، مقارنة بالثمار غير المبطنة. كان التبطين بشرائح البوليثين أكثر فعالية في إطالة عمر الثمار من شرائح الورق، نسبة لأن البولثين أكثر منعاُ لتبادل الغازات من الورق. أنعكس تأثير تبطين العبوات في تأخر نضج الثمار وفي تقليل معدل تنفسها وفي فقد الوزن وتأخير ذروة التنفس فيها وتأخير ليونة الثمار وتراكم المواد الصلبة الكلية الذائبة والسكريات الكلية و المختزلة وحامض الأسكوربيك فيها.