Effects of Ethrel, packaging and waxing on quality and shelf life of guava (*Psidium guajava* L.) fruits

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ABSTRACT

Guava is one of the most popular fruits in the Sudan. It is usually harvested at the ripe stage which results in quick deterioration and huge post-harvest losses. Therefore, the objective of this work was to find out the effects of Ethrel, packaging and waxing on quality and shelf life of guava (*Psidium guanjava* L.) fruits. Experiments were conducted at the University of Gezira, Wad Medani, Sudan, during December of 2013 and March of 2014. Guava fruits were harvested at the mature-green stage and treated with Ethrel or left as control. Fruits were packaged in either intact or perforated polyethylene film, waxed or left unpackaged. The treatments were set up in a completely randomized design with two replicates. Results showed that Ethrel treatment significantly accelerated the rate of fruit ripening as shown by an increase in total soluble solids, skin colour development, vitamin C content, taste and a decrease in fruit firmness in both seasons. Packaging and waxing treatments had significant effects on weight loss, TSS, vitamin C content, firmness, taste and skin colour in both seasons. Packaging guava fruits in intact polyethylene film resulted in the lowest weight loss, followed by waxing, perforated polyethylene film and the highest weight loss was recorded for the control treatment in both seasons. The highest vitamin C content, the best skin colour and the longest shelf life were recorded in fruits packaged in intact polyethylene film followed by perforated, waxing and control treatments in both seasons. However, the highest TSS content, the best taste and the shortest shelf life were recorded for the control fruits in both seasons. It could be recommended that, in order to prolong the shelf life and maintain the quality of guava fruits, they should be packaged in intact polyethylene film or waxed and treated with Ethrel at destination markets.

INTRODUCTION

Guava (*Psidium guajava* L.) is a popular fruit crop in the Sudan. It is grown in almost every State. The fruit is delicate and can be stored only for a few days at ambient conditions. Although the Sudan has a great potential to produce high quality guava and export it to other countries, yet its marketability is still limited to local markets. This is due to the delicate nature of the fruit, poor handling practices, and inadequate refrigerated transportation and storage facilities (Mohamed-Nour and Abu-Goukh, 2013).

Guava fruit has a rapid rate of ripening. Therefore, it has a relatively short shelf life ranging from 3 to 8 days depending on cultivar, harvest time, and environmental conditions. Visually, the ripeness level of guava can be characterized by it's skin colour ranging from dark green when unripe to bright yellow at full ripeness (Basseto *et al.*, 2005).

Guava is a climacteric fruit showing a typical increase in respiration and ethylene production during ripening. Ripening can be induced by exposing fruits to exogenous ethylene. When mature-green guava fruits were treated with Ethrel solution at a concentration of 2ml/l and kept at 15-20^{0}C and 90%-95% relative humidity for 2-3 days, their rate of ripening was accelerated and they reached the full yellow stage. This treatment resulted in uniform ripening, which is more important for guavas destined for fresh market or processing (Abu-Goukh and Bashir, 2002).

The technique of polymeric film packaging has been used to modify O_2 and CO_2 concentrations within the package, improve water retention and reduce weight loss (Elkashif *et al.*,2013). However, the buildup of high relative humidity inside the package may result in water condensation which promotes decay and rot (Medlicott *et al.*,1990). In a similar study, bell peppers which were stored in perforated packages had a lower decay incidence than those stored in non-perforated packages (Yehoshua *et al.*, 1998). Polyethylene film packaging has been found to extend the shelf-life of bananas (Elamin and Abu- Goukh, 2009; Elkashif *et al.*, 2005; Mahmoud and Elkashif, 2003;), okra (Elkashif *et al.*,2013) and citrus fruits (Hussain *et al.*, 2004).

Waxing was reported to delay fruit ripening and senescence, reduce water loss, maintain quality, turgidity, firmness and covers injuries on the surface of horticultural commodities. It was reported to extend the shelf life of limes , 2004), grapefruits (Elhadi *et al.*,2011) and sweet oranges (Elkashif *et al*., 2015).

Hence, this study was carried out to determine the effects of Ethrel, packaging and waxing treatments on quality and shelf life of guava fruits.

MATERIALS AND METHODS

Source of fruits

Mature-green fruits of white-fleshed guava were obtained from an orchard at Wad Medani, Sudan. It is located at latitude 14^0 6′N, longitude 33^0 38 ′E and altitude 40 masl. The fruits were picked in December of 2013 (season one) and in March of 2014 (season two). Fruits were selected for uniformity of size, colour and freedom from blemishes. The fruits were washed, air-dried to remove water from the surface and transported in plastic baskets lined with perforated polyethylene sheets to the laboratory for further treatments.

Packaging material

Cartons and polyethylene films were purchased from the local market; some of these polyethylene films were perforated, while others were left intact.

Ethrel treatment

Mature-green fruits were washed in 5.3% sodium hypochlorite solution for disinfection. Then they were divided into two lots: one lot received Ethrel treatment and the other remained as control. Fruits were dipped for two minutes in Ethrel solution at a concentration of 4 ml/l or in distilled water (control). Then they were dried and subjected to the following packaging treatments.

Packaging treatments

The fruits were placed in the following packages: 1, cartons lined with intact polyethylene film; 2, cartons lined with perforated polyethylene film; 3, fruits were waxed and placed in cartons and 4, fruits were placed directly in cartons without film packaging or waxing (control). The experiments were arranged in a completely randomized design with two replicates. Data were taken every 2 days for a period of 10 days.

Weight loss experiment

Mature-green fruits were washed and then subjected to the previous packaging and waxing treatments, but without ethylene treatment. Cartons were initially weighed and then weighed every day until the fruit were fully ripe.

$$\text{Weight loss (\%)} = [(Wo-Wt)/Wo] \times 100$$

Where :

Wo = Initial weight.

Wt = Weight at designated time.

Data taken consisted of the following

Total soluble solids (TSS)

Total soluble solids were determined using a hand refractometer (Bellingham and Stanly Ltd, Tunbridge, Wells).

Skin colour

Fruit skin colour was visually assessed using a scale of 1 to 3 as follows: 1, green; 2, greenish yellow and 3, yellow.

Firmness

It was evaluated by measuring the resistance of fruit to hand pressure using the fore finger and thumb and was rated according to a scale of 1 to 5 as follows: 1, very soft; 2, soft, 3, fairly soft, 4, firm and 5, very firm.

Fruit taste

It was determined using a taste panel. Panelists were asked to rate the taste of guava fruit samples taken from the different treatments according to a scale of 1 to 5 as follows: 1, unacceptable; 2, slightly acceptable; 3, acceptable; 4, good and 5, excellent.

Vitamin C

It was determined using the iodine method. A sample of 400mg of iodine powder was dissolved in 100ml distilled water and then 25ml of diluted H_2SO_4 were added. This makes 0.1 N iodine. Starch solution was prepared by dissolving 1 g of wheat flour in 100ml distilled water then boiled and cooled. A sample of 10g of guava flesh were taken and blended in 250ml H_2O and filtered. A sample of 25ml of guava juice was taken and 10 drops of starch solution were added and titrated against 0.1N iodine to a faint blue colour. One ml of 0.1 N iodine is required for each 8.806mg vitamin C.

Ascorbic acid (mg/100g guava flesh) = number of ml of 0.1 N iodine x 8, 806 x10

Statistical analysis

Data were analysed using the standard analysis of variance procedure. Means were separated using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Since the results of both seasons were similar and showed the same trend, only the results of the first season will be reported to avoid redundancy.

Weight loss

The effects of packaging and waxing treatments on weight loss of guava fruits are shown in Fig. 1. Weight loss progressively increased during storage of guava fruits. Packaging of guava fruits in intact polyethylene film resulted in the lowest weight loss, followed by waxing, perforated film and the highest weight loss was observed in the control treatment.Waxing treatment resulted in lower weight loss than that of the perforated film and much less than the control treatment. This was most probably due to the fact that the wax layer covered most of the stomatal openings in the epidermal layer of the skin and hence significantly reduced water loss. These results support the findings of Elhadi *et al.* (2011). Packaging of guava fruits in intact film resulted in high relative humidity inside the package and hence reduced weight loss (Elkashif *et al.*, 2005; 2015) Polymeric film packaging has been extensively used to reduce water loss and enhance fruit quality. Elkashif *et al.*, (2013) reported that okra packaged in intact polyethylene film had the lowest weight loss followed by those packaged in perforated ones whereas unpackged pods had the highest weight loss. Furthermore, waxing also improved fruit quality, reduced post-harvest losses and extended storability of guava fruits. Similar results with grapefruit were also reported by Elhadi *et al.* (2011). Therefore, guava fruits intended for the local market or export should be packaged in intact thin polymeric film or coated with wax.

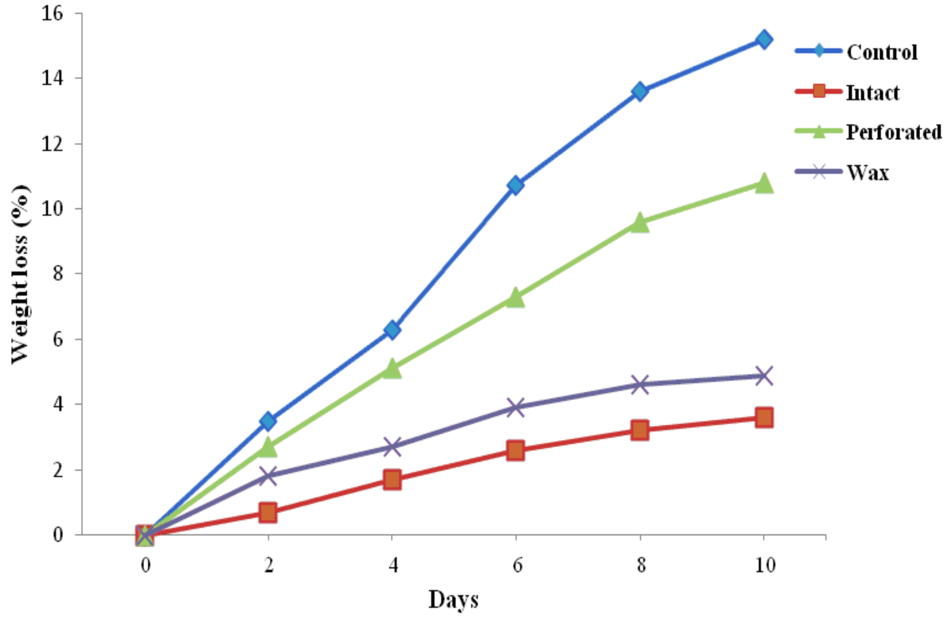

Fig. 1. Effects of packaging and waxing treatments on weight loss of guava fruit.

Total soluble solids (TSS)

The effects of Ethrel treatment on TSS content of guava fruits during storage are shown in Fig. 2. Generally, TSS content increased and then decreased with storage period and the highest TSS content was recorded after 6 days of storage. Guava fruits treated with Ethrel had higher TSS content than the control. Ethrel released ethylene hormone which triggered the ripening processes in fruits and resulted in early ripening as compared to the control. Similar results were obtained by Mahmoud and Elkashif (2003).

The effects of packaging and waxing treatments on TSS content of guava fruits during storage are shown in Fig. 3. The highest TSS values were recorded in unpackaged control fruits, whereas, the lowest values were recorded for fruits packaged in intact film. This was because packaging in intact polyethylene film maintained high relative humidity around fruits which reduced water loss from them, conserved their turgidity and hence resulted in reduced TSS content.

On the other hand, guava fruits packaged in perforated film or unpackaged had higher TSS values because these treatments encouraged water loss from fruits during storage and hence resulted in the concentration of fruit juice which was manifested in higher TSS content. These results were consistent with the reports that TSS increased during storage of lime (Ayoub 2004), and mango (Elkashif *et al.*, 2003).

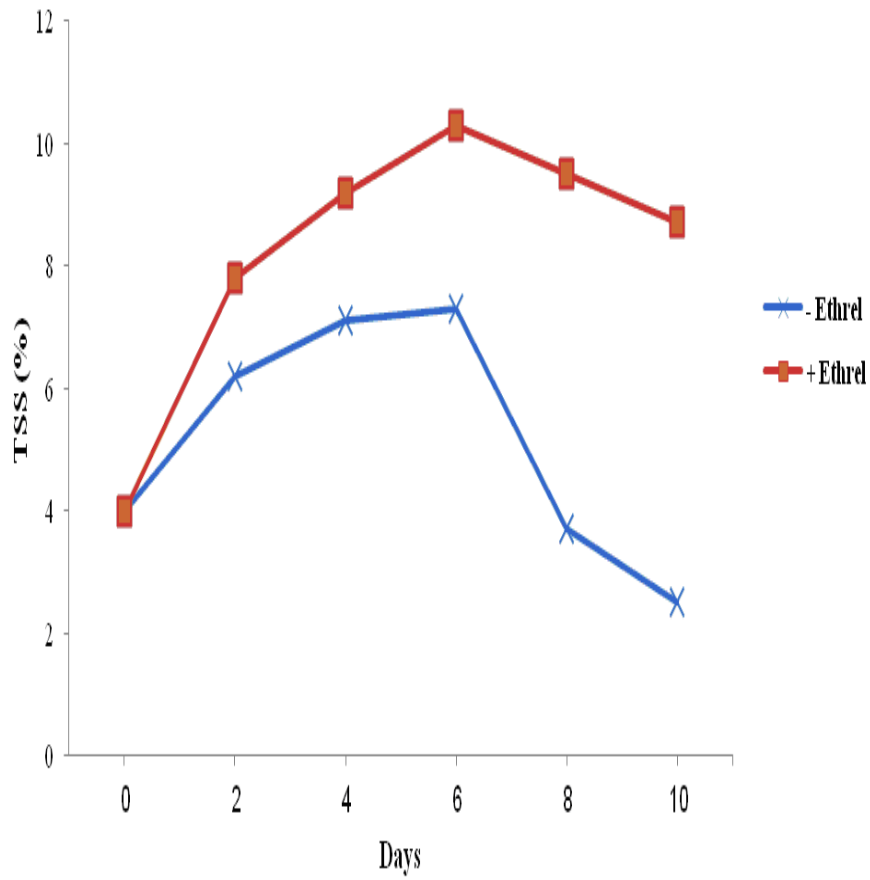

Fig. 2. Effects of Ethrel treatment on total soluble solids content of guava fruit.

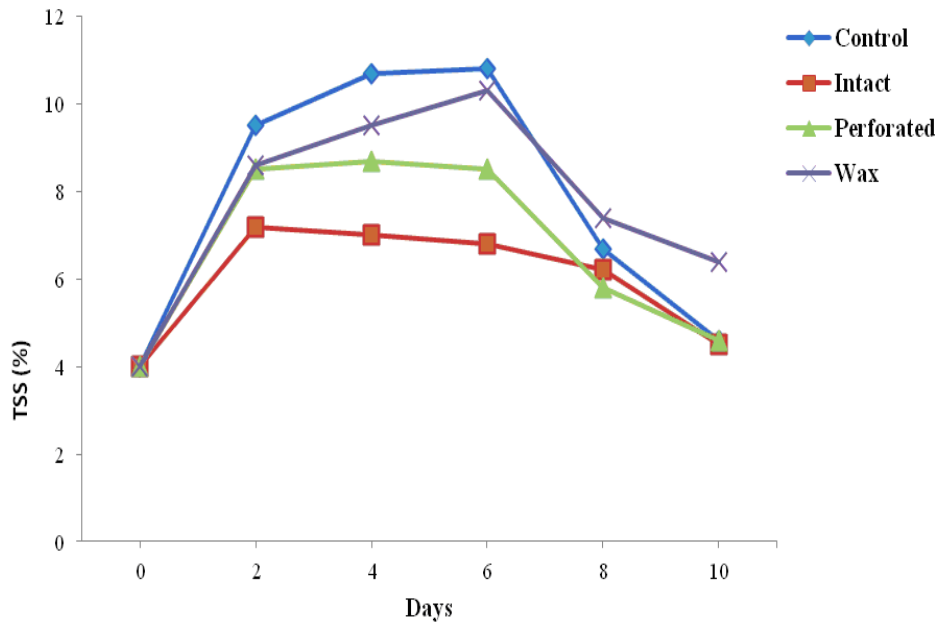

Fig. 3. Effects of packaging and waxing treatments on total soluble solids content of guava fruit.

Vitamin C content

The effects of Ethrel treatment on vitamin C content of guava fruits are shown in Fig. 4. Vitamin C content was significantly increased with the advancement of fruit ripening and then declined during the senescence stage. The highest vitamin C content was recorded for fruits treated with Ethrel compared to the control fruits which lost vitamin C rapidly. Ethylene has been shown to increase vitamin C content of climacteric fruits such as mango (Elkashif *et al.*, 2003) and guava (Abu-Goukh and Bashir, 2002).

The effects of packaging and waxing treatments on vitamin C content of guava fruits are shown in Fig. 5. Vitamin C content increased with storage and then slowly decreased. The highest vitamin C content was found in fruit packaged in intact polyethylene film, followed by perforated treatment. However, the control and waxing treatments were comparable and had the lowest values of vitamin C during storage.

This was probably due to the fact that fruits packaged in intact or perforated polyethylene film resulted in higher relative humidity inside the package and hence reduced moisture loss from guava fruits. However, the unpackaged control fruits lost more water, were shriveled and, hence, resulted in more vitamin C loss. Similar results were reported by Elkashif *et al.* (2015).

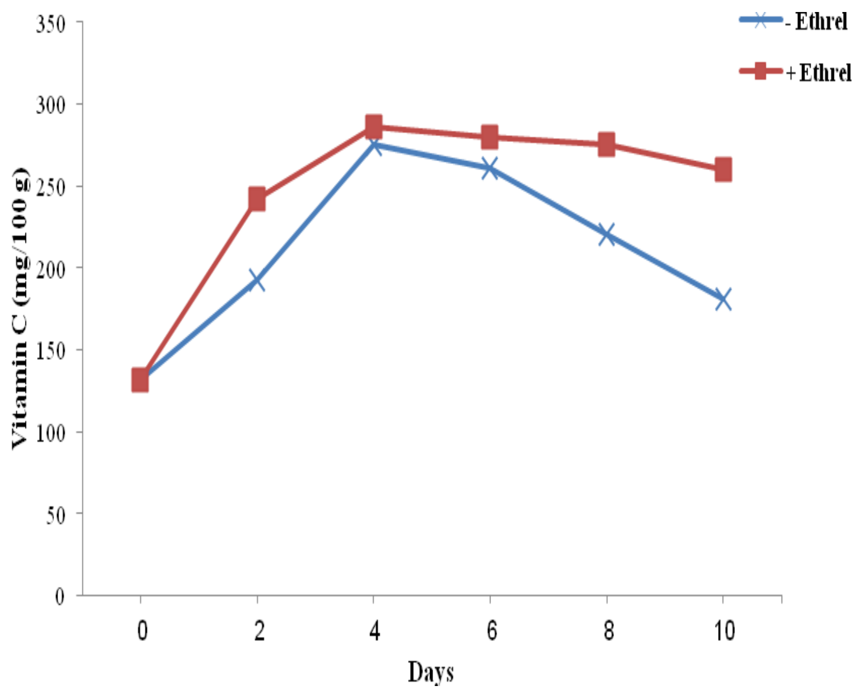

Fig. 4. Effects of Ethrel treatment on vitamin C content of guava fruit.

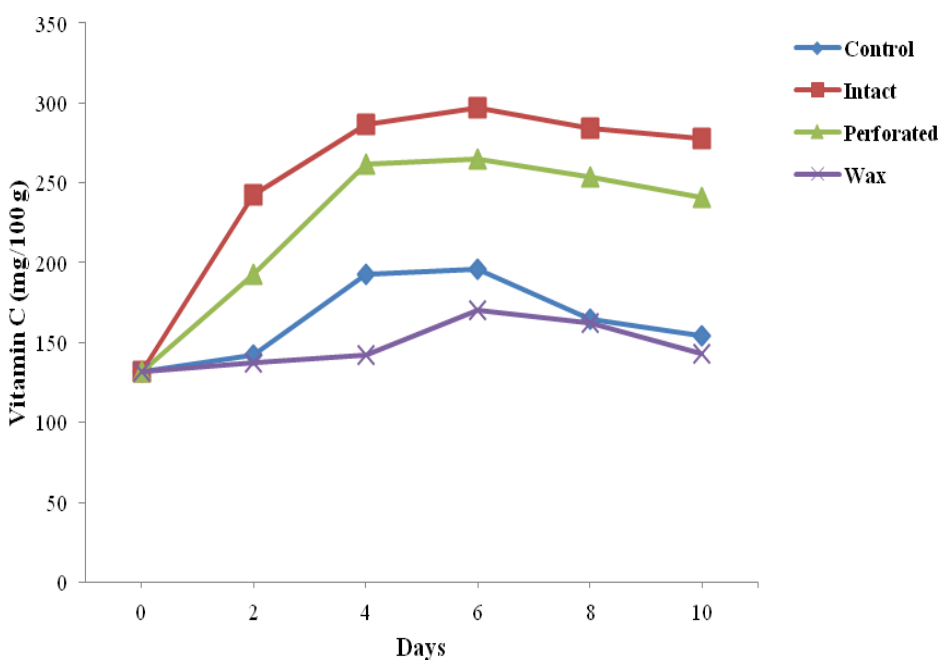

Fig. 5. Effects of packaging and waxing treatments on vitamin C content of guava fruit

Skin colour

The effects of Ethrel treatment on skin colour of guava fruits during storage are shown in Fig. 6. Ethrel treatment significantly enhanced colour development in both seasons. Ethylene released from Ethrel caused the degradation of chlorophyll and enhanced the development of carotene. Mahmoud and Elkashif (2003) showed that ethylene accelerated banana fruit ripening which was reflected in rapid fruit yellowing as compared to the untreated control. These results are also in agreement with the results of Elkashif *et al.* (2015) who demonstrated the role of ethylene in degreening of sweet oranges.

The effects of packaging and waxing on skin colour of guava fruits during storage are shown in Fig.7. Skin colour score progressively increased during storage of guava fruits. The intact and perforated polyethylene films encouraged the development of yellow colour of guava. Polyethylene film liners trapped ethylene hormone which resulted in the degradation of chlorophyll and enhancement of carotene. Elkashif *et al.* (2003) reported that mango fruit packaged in intact polymeric film developed excellent yellow colour followed by those held in perforated ones and unpackaged fruits had
the least colour development. Waxing was less effective in colour development because waxed fruits were not able to trap ethylene hormone which was responsible for chlorophyll degradation. This agrees with reports that waxing slowed down chlorophyll degradation and peel colour development in sweet oranges (Elkashif *et al*., 2015).

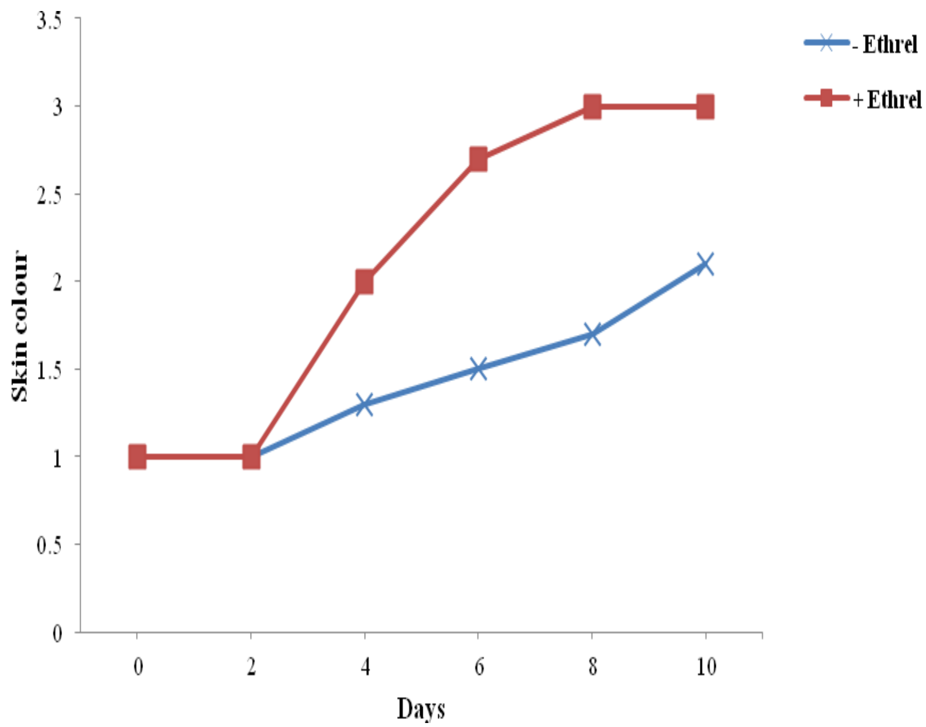

Fig.6. Effects of Ethrel treatment on skin colour of guava fruit.

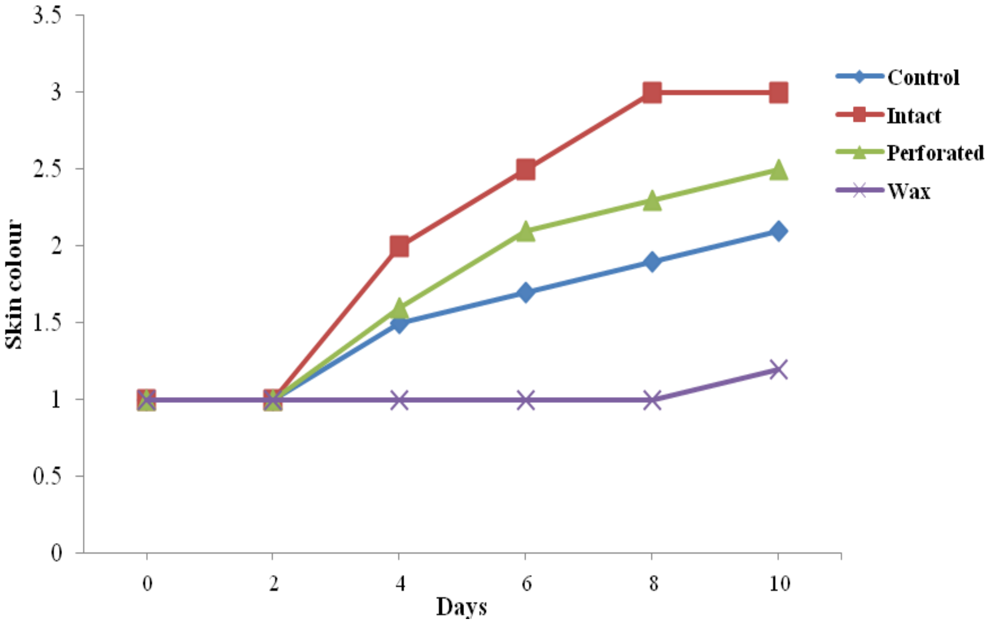

Fig. 7. Effects of packaging and waxing treatments on skin colour of guava fruit.

Firmness

The effects of Ethrel treatment on firmness of guava fruits are shown in Fig. 8. Generally, fruit flesh firmness progressively declined during storage of guava fruits in both seasons. Ethrel treatment significantly decreased fruit firmness in both seasons.

Ethylene released from Ethrel induced the biosynthesis of cell wall hydrolases which accelerated the hydrolysis of cell wall components and hence resulted in fruit softening. These results were in agreement with those shown by Elkashif and Huber (1983) who reported that exposure of fruit to exogenous ethylene resulted in the induction of hydrolytic enzymes such as cellulase and polygalacturonase which enhanced the hydrolysis of cellulose, hemicellulose and pectins and resulted in reduced fruit firmness.

The effects of packaging and waxing on firmness of guava fruits during storage were not significant and inconsistent.

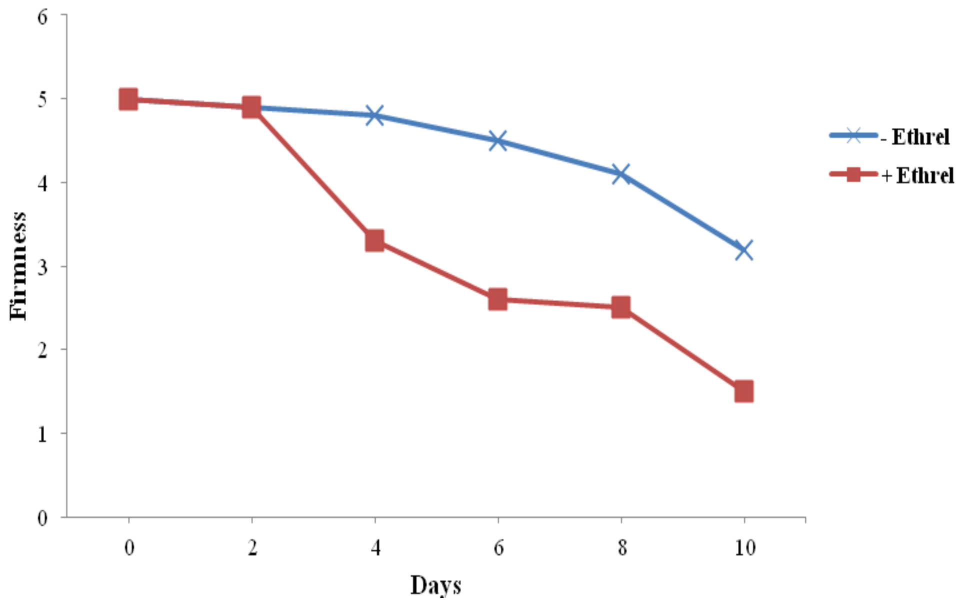

Fig. 8. Effects of Ethrel treatment on firmness of guava fruit.

Taste

The effects of Ethrel treatment on the taste of guava fruits after storage are shown in Fig. 9. Guava fruits treated with Ethrel had significantly better taste than the untreated control in both seasons. Ethylene hormone released from Ethrel triggered the ripening process and induced the biosynthesis of hydrolytic enzymes. These enzymes hydrolysed starch and cell wall components into sugars and, hence, resulted in high TSS contents. These results are supported by those presented in Figs. 3 and 4 which showed that guava fruits treated with Ethrel had significantly higher TSS content than the untreated control. These results are consistent with those of mango fruits reported by Elkashif *et al.* (2003).

The effect of packaging and waxing treatments on taste of guava fruits during storage are shown in Fig.10. The best taste was recorded for the control fruits, followed by the perforated film, waxing and the least acceptable taste was recorded for fruits packaged in intact polyethylene film.

This was most probably because fruits packaged in intact film trapped CO_2 which acted as a competitive inhibitor of ethylene, thereby preventing its action and consequently hindering the ripening process. These events impaired the hydrolysis of starch and cell wall components resulting in low TSS content and, hence, unacceptable taste (Elkashif and Huber, 1983). These results confirm those presented in Fig. 5 which showed that fruits packaged in intact film had the lowest TSS content.

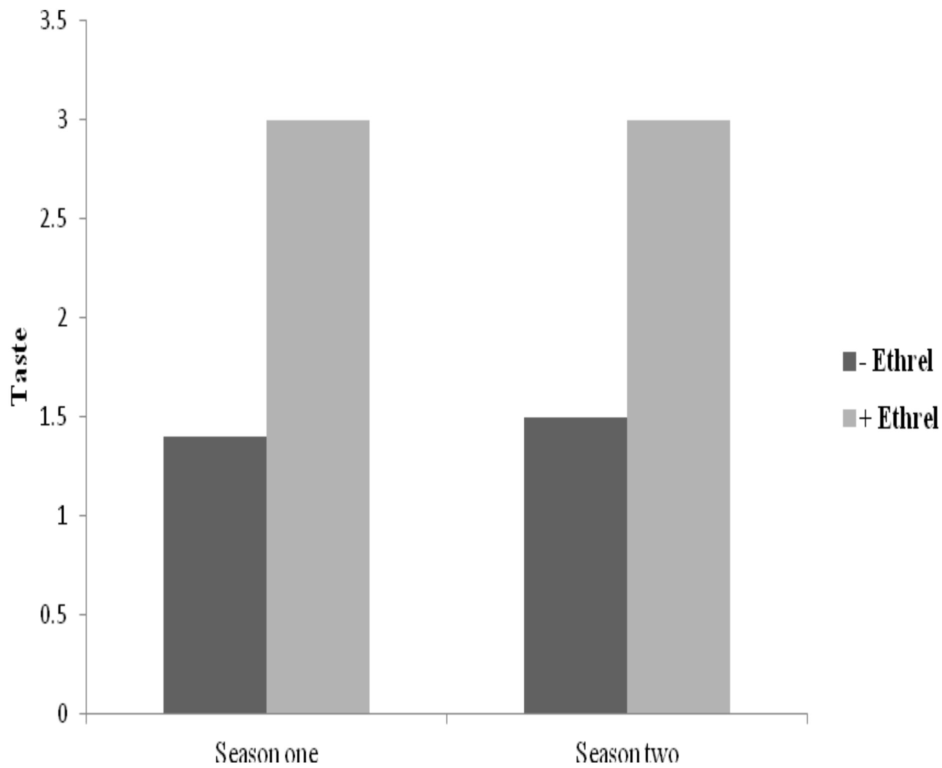

Fig. 9. Effects of Ethrel treatment on taste of guava fruit.

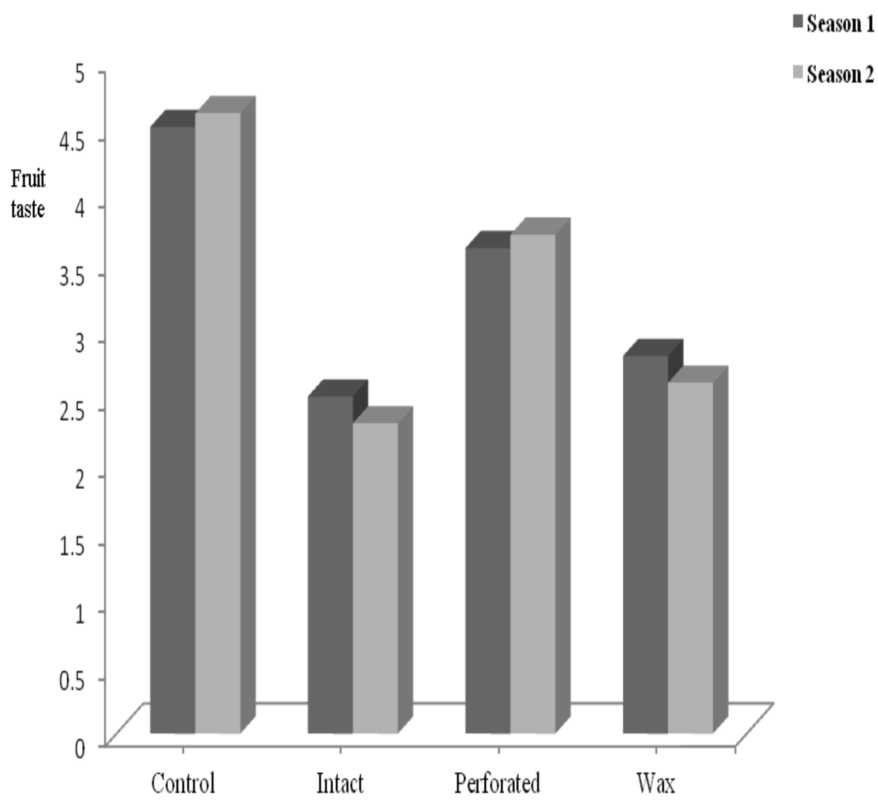

Fig. 10. Effects of packaging and waxing treatments on taste of guava fruit.

CONCLUSION

It could be concluded that, in order to prolong the shelf-life and maintain the quality of guava fruits, they should be packaged in intact polyethylene films or waxed and treated with Ethrel at destination markets.

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تأثير الإثرل والتغليف والتشميع على نوعية وفترة صلاحية ثمار الجوافة (*Psidium guajava* L.)

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الخلاصة

الجوافة من أكثر الفواكه شعبية في السودان. وهي عادةً تحصد في مرحلة النضج وهذا يؤدي إلى تدهورها السريع وعظم الفاقد ما بعد الحصاد. الهدف من هذا البحث هو العمل على دراسة تأثير الإثرل والتغليف والتشميع على نوعية وفترة صلاحية ثمار الجوافة. أجريت التجربة في جامعة الجزيرة، واد مدني، السودان خلال 13/2012 و14/2013. تم حصاد ثمار الجوافة في مرحلة البلوغ الأخضر ومعاملتها بالإيثرل أو تركها كشاهد. تم تغليف الثمار في أكياس بوليثين سليمة أو مخرمة أو تشميعها أو تركها كشاهد. صممت التجارب على نسق التصميم العشوائي الكامل بمكررين. معاملة الثمار بمادة الإثرل أدى إلى الإسراع في معدل نضج الثمار مما انعكس على زيادة محتوى المواد الصلبة الذائبة والتغيير في لون القشرة والزيادة الملحوظة في محتوى فيتامين ج وتحسين الطعم والانخفاض في صلابة الثمار في كلا الموسمين. معاملات التغليف بالبوليثين والتشميع كان لها تأثيرات معنوية على فقدان الوزن والمواد الصلبة الذائبة ومحتوى فيتامين ج وصلابة الثمار ومذاقها ولون القشرة في كلا الموسمين. تعبئة ثمار الجوافة في اكياس البولثين السليمة أدت إلى أقل فقدان في الوزن يتبعها التشميع ثم الكياس المخرمة وأكبر فقدان في الوزن لوحظ في الشاهد في كلا الموسمين. تعبئة ثمار الجوافة في أكياس البولثين السليمة أدت إلى أعلى محتوى من فيتامين ج وأفضل لون للثمار وأطول فترة صلاحية للثمار يتبعها الثمار المعبئة في الأكياس المخرمة ثم التشميع وأخيراً الشاهد في كلا الموسمين. الثمار الغير مغلفة (الشاهد) أعطت أعلى محتوى من المواد الصلبة الذائبة وأفضل طعم ولكن أقصر فترة صلاحية في كلا الموسمين. للحصول على أطول فترة صلاحية لثمار الجوافة وتحسين جودتها ، يوصى بتعبئتها في أكياس بولثين سليمة أو تشميعها ومعاملتها بمادة الإثرل خصوصاً عند ترحيلها للأسواق البعيدة.