Effects of packaging and waxing on fruit quality and shelf life of some introduced mango cultivars

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ABSTRACT

Mango is one of the most important fruit crops in the Sudan. It is annually exported to Saudi Arabia, Gulf States and Western Europe. Recently, some internationally popular cultivars have been introduced to the Sudan. The objective of this research was to determine the effects of packaging and waxing on postharvest fruit quality and shelf life of some introduced mango cultivars from South Africa. Treatments consisted of three introduced mango cultivars; Tommy Atkins, Kent and Keitt and the local cultivar Abusamaka. Packaging treatments consisted of intact polyethylene film, perforated film, waxing and control. Treatments were arranged in a completely randomized design with three replicates. Data taken consisted of weight loss, total soluble solids (TSS), titratable acidity (TA), vitamin C and shelf life. Results showed that Abusamaka cultivar had the highest weight loss and Keitt had the lowest in both seasons. Packaging mango fruits in intact polymeric film resulted in the lowest weight loss, followed by perforated film, waxing and the highest weight loss was recorded for the control in both seasons. Abusamaka cultivar had the highest vitamin C and TA contents but had the lowest TSS content. However, Tommy Atkins had the highest TSS content but the lowest vitamin C and TA contents in both seasons. The longest shelf life was shown by Keitt cultivar, followed by Kent, Abusamaka and the shortest shelf life was recorded for Tommy Atkins in both seasons. Packaging mango fruits in intact polymeric film resulted in the lowest TSS, the highest TA, the highest vitamin C content and the longest shelf life. However, the highest TSS, the lowest TA, the lowest vitamin C and the shortest shelf life were recorded for the control. It is recommended to grow Keitt cultivar, harvest fruits at the mature green stage and package them in intact polymeric film or waxed to increase their shelf life and improve their quality.

INTRODUCTION

The Sudanese mango industry should gear up for competition with other mango producing countries in order to maintain and increase its share in the world trade. The most important problem facing mango export industry is the lack of cultivars suitable for export. The most popular mango cultivar in the Sudan is Kitchener, which is fibrous and not acceptable in international markets. Therefore, there is a need for the introduction of internationally popular mango cultivars to replace the local cultivar. Although more than 500 mango cultivars exist, only a few are important in the international trade. These include Haden, Irwin, Keitt, Kent and Tommy Atkins, which have fruits with a red blush, less fibrous, firmer and more suited for long-distance transportation than other cultivars (Ahmed *et al*., 2014). Recently, some newly introduced mango cultivars have been introduced from South Africa such as Tommy Atkins, Keitt, Kent and Sensation Tommy Atkins and Keitt cultivars represent 50% of the commercial crop worldwide (Ministry of Agriculture, 2013).

Although mangoes are successfully grown in many parts of the Sudan, yet the quality of mango fruit, whether exported or locally marketed, is very poor. This is mainly due to the lack of modern packinghouses for proper postharvest handling practices, fruit fly and the lack of reliable transport facilities (Elkashif *et al.,* 2003).

Postharvest losses are mainly caused by physical injury, rotting and rapid deterioration in quality. Physical injury such as wounding, scratching, bruising and short shelf-life are mainly caused by improper harvesting methods. Also, the lack of postharvest handling practices such as washing, sorting, grading and packaging result in poor fruit quality and rapid deterioration (Elkashif *et al.*, 2010).

Packaging is the art, science and technology of enclosing or protecting products for distribution, storage, sale and use. It makes product handy by putting them in containers to enhance mobility and exclude contaminants such as pathogens, dirt and undesirable reactions with the environment in order to improve their shelf-life and make them presentable to the consumer. The types of packages commonly used for mango in the world are corrugated cartons lined with polyethylene film, plastic containers or wooden boxes. The re-use of packages is common and can be a major source of decay and infection. (Appiah and Kumah, 2009).

Waxing is widely used as a coating material for mango fruits to improve their appearance and reduce water loss and shriveling. Waxing was reported to delay ripening, reduce water loss and extend the shelf life of grapefruits (Elhadi *et al.,* 2011; Abu-Goukh and Elshiekh, 2008). Waxing significantly decreased respiration rate, water loss, fruit softening, delayed the onset of the climacteric peak, delayed fruit ripening, retained ascorbic acid, improved fruit quality, reduced postharvest losses and extended the shelf life of fruits (Mohamed and Abu-Goukh 2003).

Therefore, the objective of this research was to find out the effects of packaging and waxing on the shelf life and postharvest quality of fruits of introduced mango cultivars.

MATERIALS AND METHODS

Source of fruits

Mature green mango fruits of three introduced cultivars, namely, Tommy Atkins, Keitt and Kent and the local cultivar Abusamaka were harvested from an orchard in Alkamlin, Gezira State, Sudan, in the seasons of 2012 and 2013.

Packaging material

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

Treatments

Mature green fruits of uniform size, free from scratches, bruises and blemishes from the previously mentioned cultivars were subjected to the following packaging treatments:

1. Cartons lined with intact polyethylene bags.
2. Cartons lined with perforated polyethylene bags.
3. Fruits were waxed and placed in cartons.
4. Fruits were neither packaged nor waxed and placed directly in cartons (control).

Data collection

Determination of weight loss

Initial weight of fruits which were subjected to the previously mentioned packaging and waxing treatments was determined and then they were weighed every day till they were fully ripe. Weight loss was determined using the following formula.

$$\text{Weight loss (\%)} = [(w_0 - w_t) / w_0] \times 100$$

W_0 = initial weight

W_t = weight at designated time

Determination of chemical characteristics

The chemical characteristics of mango fruits which were subjected to the packaging and waxing treatments were determined at the ripe stage.

Total soluble solids (TSS)

Total soluble solids were determined using a hand refractometer (model HRN-32, Bellingham and Stanley, England).

Total titratable acidity

Total titratable acidity was determined by taking 5g of mango fruit pulp and blended with 200ml of distilled water and titrated against 0.1 NaOH to a phenolphthalein end point (light pink color) and calculated as percentage of citric acid. Total titratable acidity was determined using the following formula.

$$\text{Titratable acidity} = \frac{\text{ml of NaOH used x normality of Na OH x 0.064 x 100}}{5\ \text{g}}$$

Determination of vitamin C using the iodine method

An amount of 400 mg of iodine powder was dissolved in 100ml of H_2O and then 25ml of dilute H_2SO_4 were carefully added to make 0.1 N I_2. One ml of 0.1 N I_2 equals 8.81mg vitamin C/100ml juice. One gram of wheat flour was dissolved in 100 ml of distilled H_2O and then boiled and cooled.

One ml of mango juice was taken and diluted with 25ml of distilled water, 10 drops of starch solution were added and the mixture was titrated against 0.1 N I_2.

The number of ml of 0.1 N I_2 was determined and vitamin C was calculated as follows :

Vitamin C (mg/100g) = number of ml of 0.1 N I_2 x 8.81 x 25 (dilution factor)

Statistical analysis

Data were analysed using the standard analysis of variance procedure and means were separated according to Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Weight loss

Weight loss of mango cultivars during storage is shown in Fig. 1. The highest weight loss was recorded for Abusamaka cultivar, followed by Tommy Atkins, Kent and the least weight loss was shown by Keitt in both seasons. This was probably due to the thin peel and more number of stomates in the epidermal layer of the skin of Abusamaka cultivar.

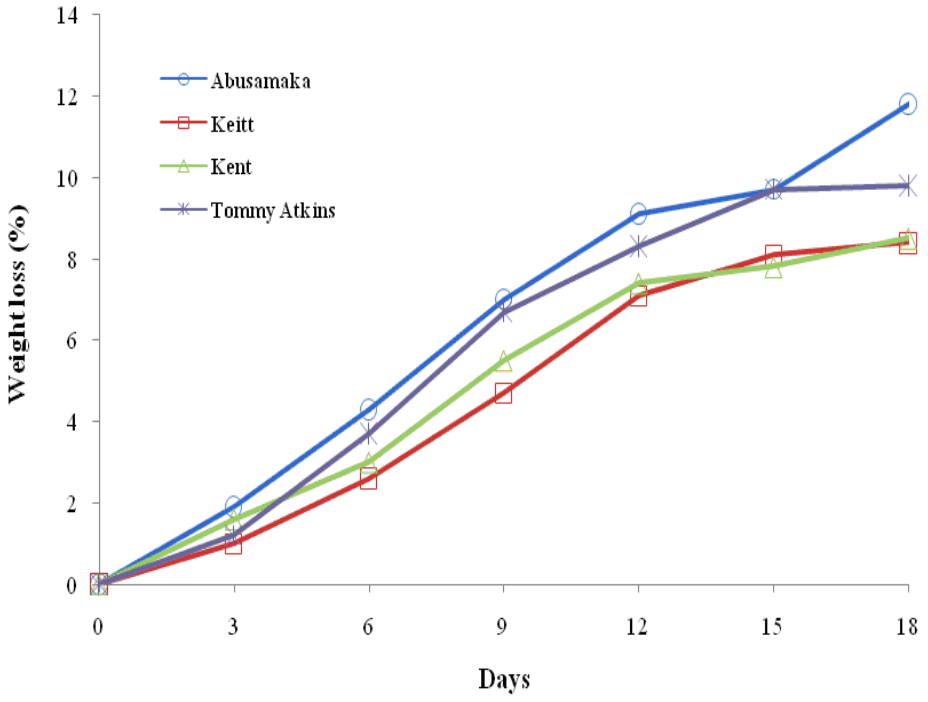

Fig. 1. Weight loss of fruits of mango cultivars.

The effects of packaging and waxing treatments on weight loss of mango fruits during storage are shown in Fig.2. Weight loss progressively increased during storage of mango fruits. Packaging mango fruits in intact polyethylene film resulted in the lowest weight loss, followed by perforated film, waxing and the highest weight loss was observed in the control in both seasons .These results are consistent with the findings of Elkashif *et al.* (2003) who showed that polymeric film packaging has been very effective in the reduction of weight loss and enhancement of fruit quality. Elkashif *et al.* (2005) reported that banana packaged in intact polyethylene film had the lowest weight loss, followed by those packaged in perforated ones, whereas unpackaged fruits had the highest weight loss.

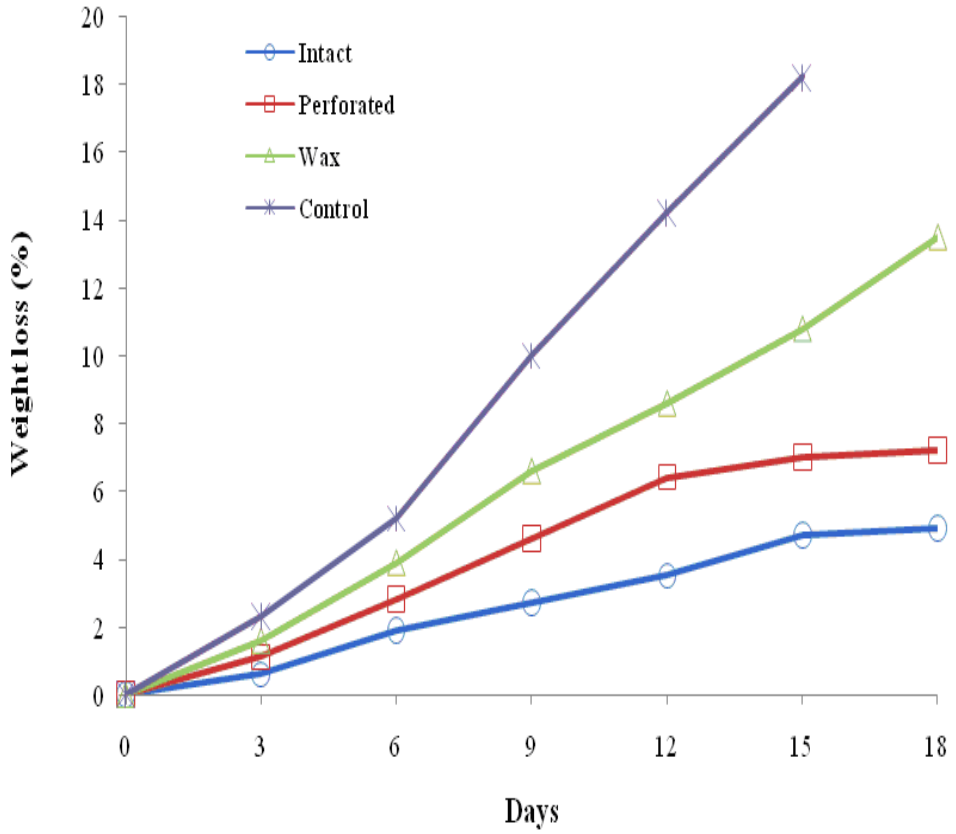

Fig. 2. Effects of packaging and waxing treatments on weight loss of mango fruit.

Waxing of fruits reduced water loss, improved fruit quality, reduced postharvest losses and extended the storability of fruits (Abu-Goukh and Elshiekh, 2008). Elhadi *et al.* (2011; 2013) reported that packaging and waxing significantly reduced water loss, improved fruit quality and extended the shelf life of grapefruit.

Chemical composition and shelf life of mango fruits

Total soluble solids (TSS)

Fig. 3 shows total soluble solids of fruits of mango cultivars. Mango cultivars differed significantly in their total soluble solids content. Tommy Atkins had the highest TSS content followed by Keitt, Kent and the least TSS content was recorded for Abusamaka in both seasons. Abdelazim *et al.* (2011) reported that Abusamaka fruits had the lowest total soluble solids content.

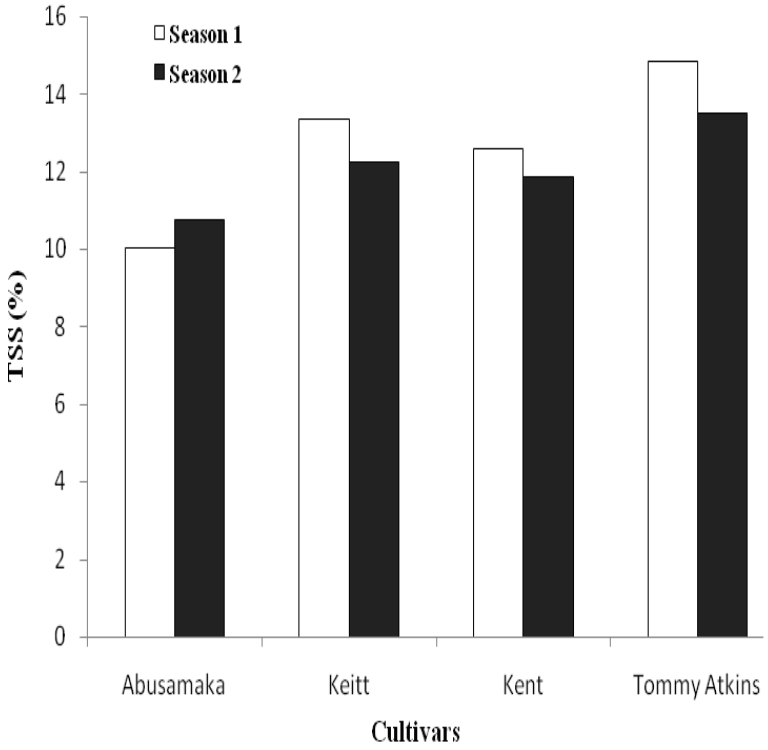

Fig. 3. Total soluble solids content of mango cultivars.

Vitamin C

Fig. 4 shows vitamin C content of fruits of mango cultivars. Mango cultivars differed significantly in their vitamin C content. Abusamaka had the highest vitamin C content followed by Keitt, Kent and the least vitamin C content was recorded for Tommy Atkins in both seasons. Similarly, Abourayya *et al*. (2011) reported that the maximum value of vitamin C was detected in Tommy Atkins (44.8) followed by Keitt (41.4) and Kent (37.7). These results confirmed the findings of Ahmed *et al*. (2014) who found that vitamin C content of fruits of Tommy Atkins mango cultivar was the highest at the full maturity stage (58.5 mg/100 ml juice) followed by Keitt

(48.13). In contrast, Abdelazim *et al.* (2011) found that Abusamaka fruit contained less vitamin C than those of Galb Altour. These variations in vitamin C content were most probably due to variations in the stage of maturity of fruits at the time of determination. John and Veazie (2009) stated that vitamin C content varied with cultivar and location. They found that fruits of Tommy Atkins had different values of vitamin C in different locations. They were 15.5, 21.9, and 19 mg/100ml juice in Brazil, Ecuador and Mexico, respectively. However, vitamin C content of fruits of Kent cultivar in Ecuador, Peru and Mexico were 24.9, 26.7 and 27 mg/100ml juice, respectively.

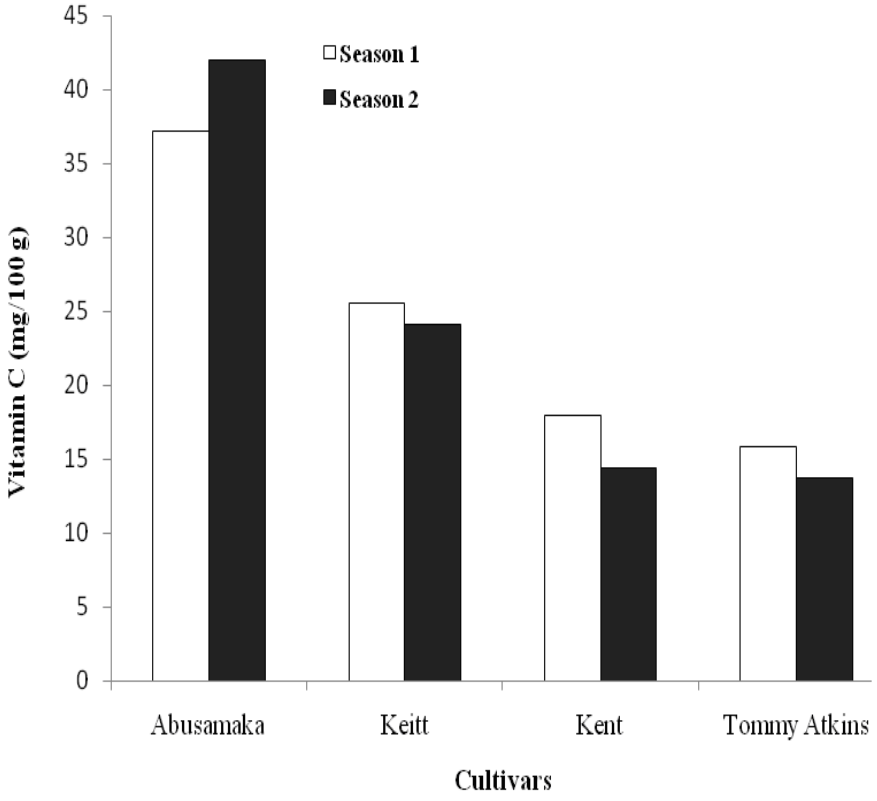

Fig. 4. Vitamin C content of mango cultivars.

Titratable acidity (TA)

Figs.5 shows titratable acidity of fruits of mango cultivars. Mango cultivars differed significantly in their titratable acidity content. Abusamaka had the highest T.A content followed by Keitt, Kent and the least TA content was recorded for Tommy Atkins in both seasons. There is a direct relationship between titratable acidity and vitamin C content. Abusamaka cultivar which had the highest T.A, also had the highest vitamin C content. Abdelazim *et al*. (2011) observed that titratable acidity of Abusamaka fruits was moderate between those of Gulbeltor and Malgoba. Abourayya *et al*. (2011) reported that fruits of Kent, Keitt and Tommy Atkins had the acidity values of 1.1, 1.2 and 1.3, respectively, and that acidity depended on cultivar and stage of ripening.

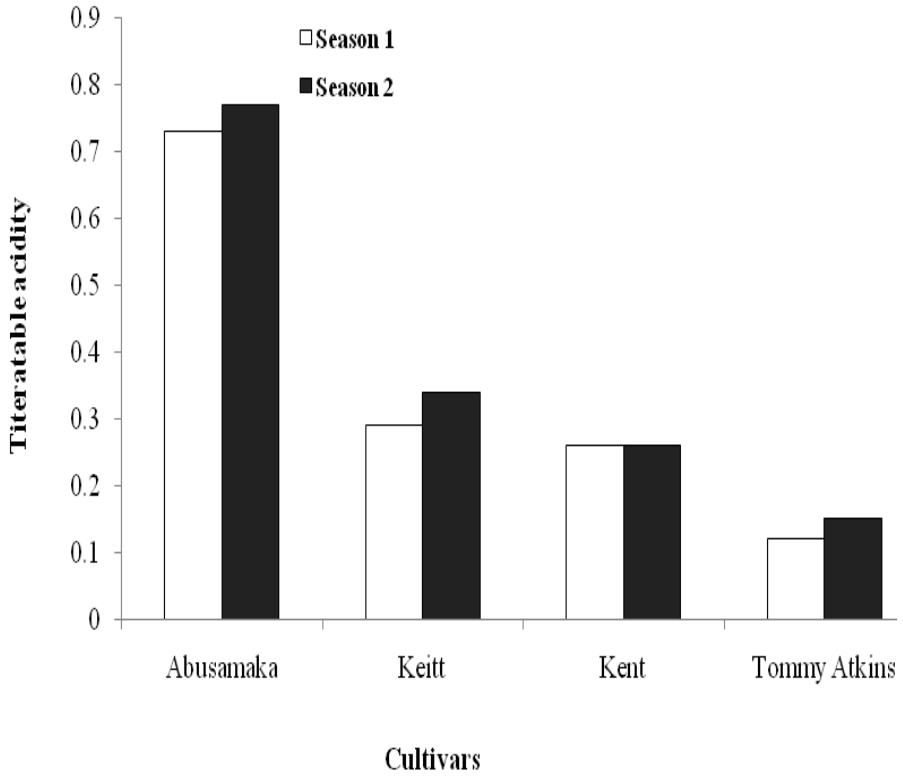

Fig. 5. Titratable acidity of mango cultivars.

Shelf life

Fig. 6 shows that the longest shelf life was recorded for Keitt cultivar followed by Kent, Abusamaka and the shortest shelf life was recorded for Tommy Atkins in both seasons. In contrast, Araiza *et al*. (2005) reported that Tommy Atkins and Kent had longer shelf lives than Ataulfo, Gouveia and Osteen mango cultivars in Mexico. This might be due to factors related to differences in location, or to the maturity stage at harvest. Ahmed *et al*. (2014) reported that Tommy Atkins, Kent and Keitt had usually long shelf lives compared to other mango cultivars. The extension of postharvest life of mango is important to permit transport, distribution and commercialization to distant export markets.

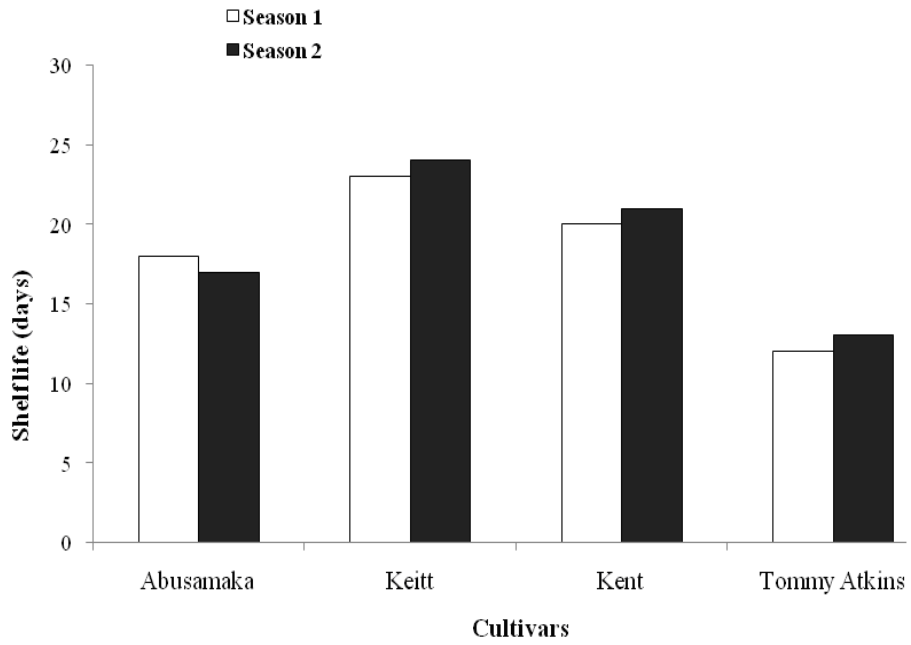

Fig. 6. Shelf life of fruits of mango cultivars.

Effects of packaging and waxing treatments on the chemical composition and shelf life of mango fruits

Total soluble solids (TSS)

Fig. 7 shows significant effects of packaging and waxing treatments on total soluble solids content of mango fruits. The unpackaged and unwaxed control resulted in the highest TSS, followed by the perforated film, waxed and the least TSS content was recorded for fruits packaged in intact polyethylene film in both seasons. The high TSS content of the control fruits was most probably due to the fact that fruits lost water during storage and hence resulted in the concentration of fruit juice which was manifested in higher TSS values. On the contrary, the low TSS values obtained by fruits packaged in intact film or waxed was because packaging in intact polyethylene film and waxing maintained high relative humidity around the fruits which reduced water loss and hence maintained TSS content. These findings are consistent with reports about mango (Elkashif *et al*.,2003; Mohamed and Abu-Goukh, 2003), banana (Elkashif *et al*., 2005) and grapefruit (Elhadi *et al.* 2011; 2013).

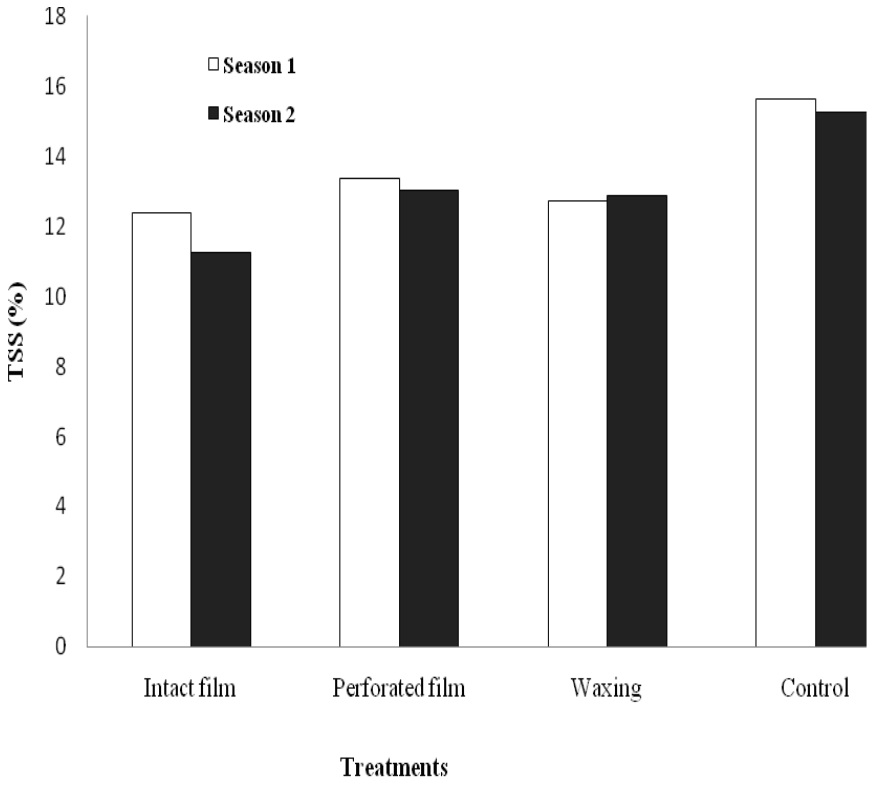

Fig. 7. Effects of packaging and waxing treatments on TSS (%).

Vitamin C

Fig. 8 shows significant effects of packaging and waxing treatments on vitamin C content of mango fruits. Packaging mango fruits in intact polyethylene film resulted in the highest vitamin C content followed by perforated film, waxing and the least vitamin C content was recorded for the control in both seasons. This was probably due to the fact that packaging mango fruits in intact polyethylene film resulted in higher relative humidity inside the package and hence reduced moisture loss from mango fruits and preserved vitamin C content. Waxed fruits lost less moisture as compared to the control and hence conserved more vitamin C which was comparable to the perforated polyethylene film treatment. These results were consistent with those reported by Elkheir and Abu-Goukh (2010).

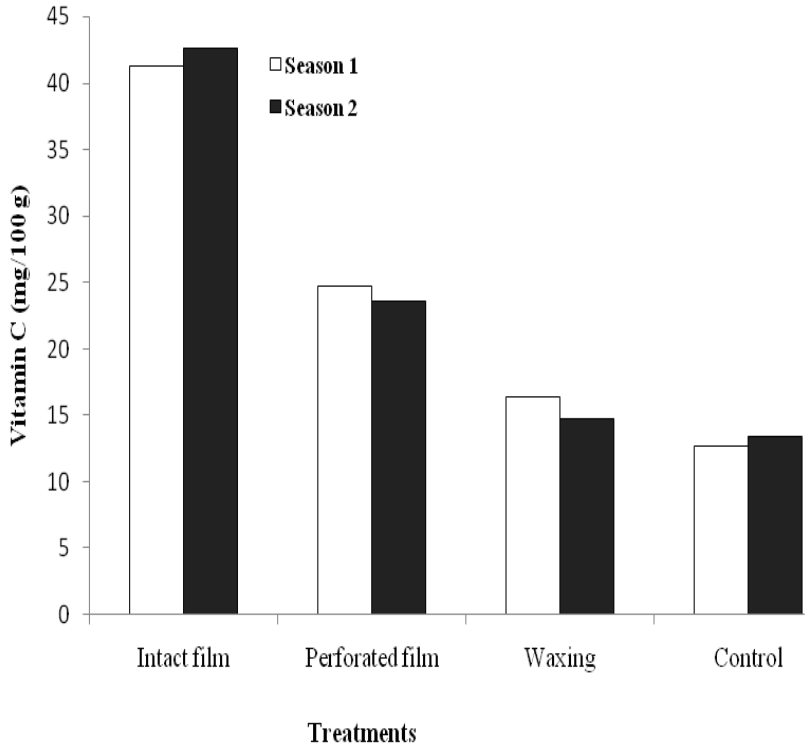

Fig. 8. Effects of packaging and waxing treatments on vitamin C content of mango fruits.

Titratable acidity (TA)

Fig.9 shows significant effects of packaging and waxing treatments on TA content of mango fruits. Packaging mango fruits in intact polyethylene film resulted in the highest TA content, followed by perforated film, waxing and the least TA content was recorded for the control fruits in both seasons. These results have the same trend observed for vitamin C content (Fig. 8). The high value of TA content observed in fruits packaged in intact polyethylene film was most probably due to the fact that the intact film resulted in the buildup of CO_2 and low O_2 which consequently reduced the rate of respiration of fruits. This reduction in the rate of respiration reduced the rate of catabolism of organic acids in fruits and hence resulted in high TA content. On the other hand, the unpackaged and unwaxed control fruits respired freely and hence degraded organic acids which resulted in low TA content. Similar results were reported by Elhadi *et al.* (2011).

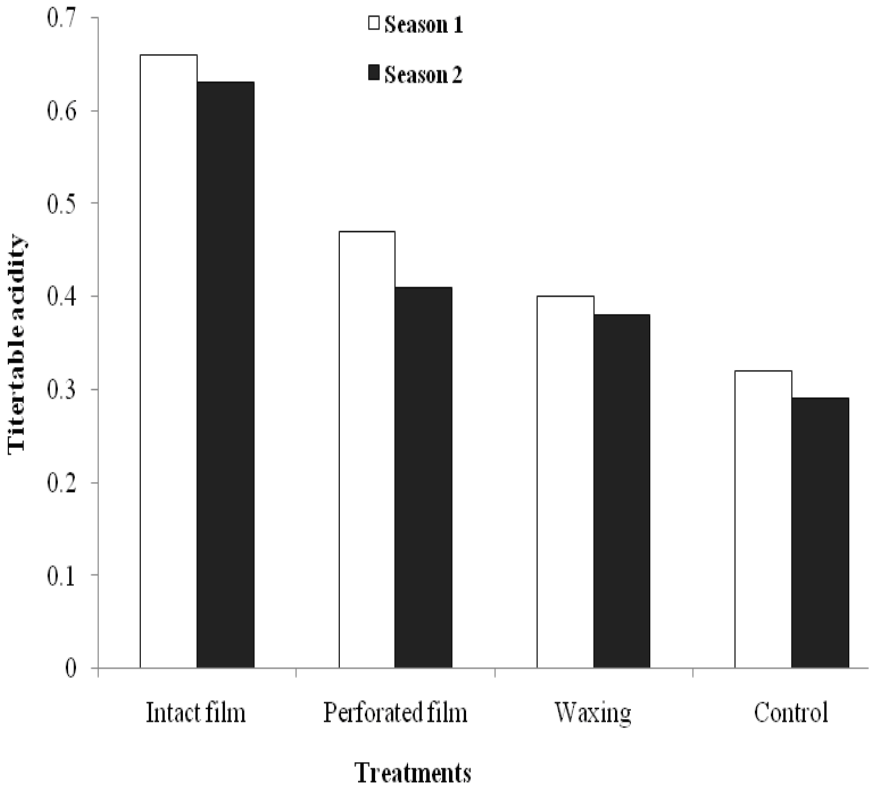

Fig. 9. Effects of packaging and waxing treatments on titratable acidity of mango fruits.

Shelf life

Fig.10 shows significant effects of packaging and waxing treatments on the shelf life of mango fruits. Mango fruits packaged in intact polyethylene film had the longest shelf life, followed by perforated polyethylene film, waxing and the least shelf life was recorded for the unpackaged control in both seasons. This was because fruits packaged in intact polymeric film had high relative humidity around them which delayed their deterioration and increased their shelf life. However, unpackaged fruits lost water, were shriveled, deteriorated rapidly and consequently had a short shelf life. These results support the finding of Elkashif *et al*. (2003; 2005) and Elhadi *et al.* (2013).

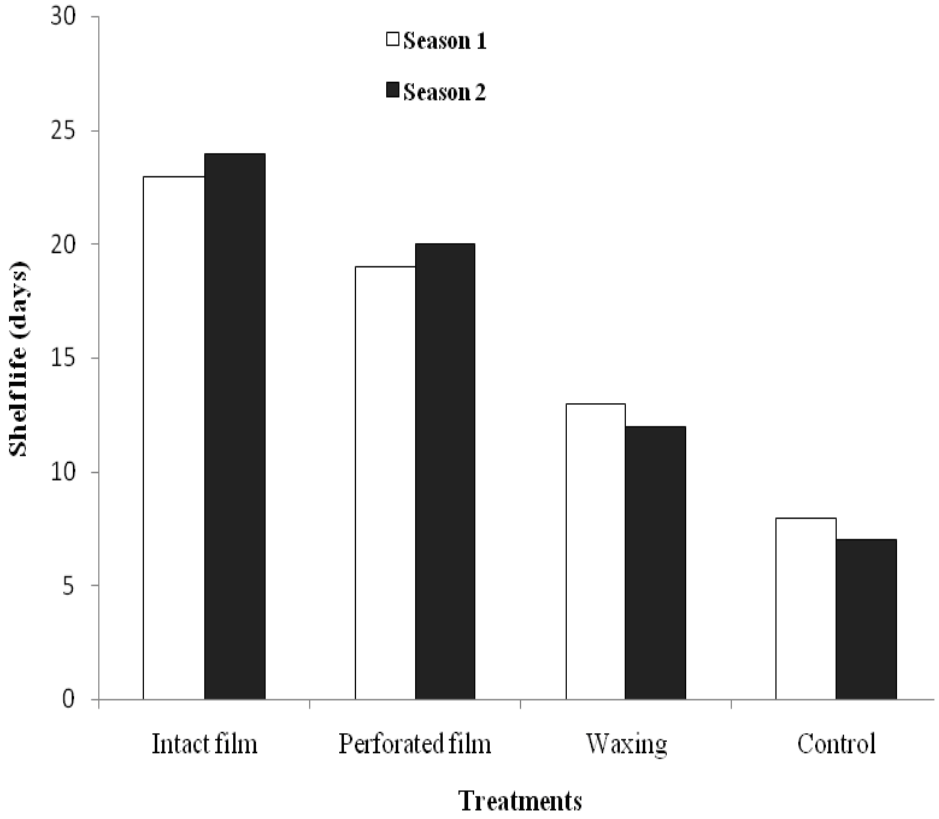

Fig. 10. Effects of packaging and waxing treatments on the shelf life of mango fruits.

Interaction effects of mango cultivars and packaging and waxing treatments on the chemical characteristics and shelf life of mango fruits

Tables 1 and 2 show significant interaction effects of mango cultivars and packaging and waxing treatments on all chemical characteristics parameters and shelf life of mango fruits in both seasons. Under all packaging and waxing treatments, Abusamaka cultivar had the lowest TSS, the highest vitamin C and the highest titratable acidity, whereas Tommy Atkins had the highest TSS, and the lowest vitamin C and titratable acidity. Also, under all packaging and waxing treatments, Keitt cultivar had the longest shelf life and Tommy Atkins had the shortest in both seasons.

Considering all cultivars, packaging fruits in intact polymeric film resulted in the lowest TSS, the highest vitamin C content, the highest titratable acidity and the longest shelf life. However, the unpackaged and unwaxed control had the highest TSS, the lowest vitamin C, the lowest titratable acidity and the shortest shelf life for all cultivars in both seasons. The perforated film and waxing treatments were comparable for all parameters under all cultivars and in both seasons.

It could be concluded that, in order to prolong the shelf life and maintain the quality of mango fruits, they should be harvested at the mature green stage and packaged in intact polyethylene film or waxed**.**

Table 1. Interaction effects of mango cultivars and packaging and waxing treatments on TSS, vitamin C, titratable acidity and shelf life of mango fruits (season one).

Cultivars	Treatments	TSS (%)	Vitamin C (mg/100g)	Titratable acidity	Shelf life (days)
Abusamaka	Intact	12.61 bc	36.35 a	0.97 a	19.62 b
	Perforated	13.28 b	28.31 b	0.85 a	17.23 c
	Wax	12.13bc	30.35 b	0.66 b	16.51 c
	Control	14.72 ab	25.10 bc	0.43 c	14.85 d
Keitt	Intact	12.30 bc	24.72 bc	0.58 b	26.63 a
	Perforated	13.42 b	20.85 c	0.46 c	24.12 a
	Wax	13.71 b	21.62 c	0.43 c	21.71 b
	Control	14.78 ab	18.61 d	0.38 d	18.45 c
Kent	Intact	13.33 b	23.45 c	0.48 c	23.34 a
	Perforated	13.40 b	17.25 d	0.45 c	20.62 b
	Wax	14.12 ab	21.56 c	0.38 d	19.45 b
	Control	15.20 a	15.20 e	0.37 d	18.12 c
Tommy Atkins	Intact	14.82 ab	24.97 bc	0.41 d	15.31 d
	Perforated	15.75 a	20.43 e	0.35 e	13.02 e
	Wax	15.84 a	22.26 c	0.23 f	12.61 e
	Control	16.75 a	18.51 d	0.22 f	10.32 e
Sig. level		*	**	*	*
C.V (%)		10.09	10.82	13.19	15.70

Means in columns followed by the same letter(s) are not significantly different at P≤0.05 according to Duncan's Multiple Range Test.

* and ** Significant at P=5% and 1%, respectively.

Table 2. Interaction effects of mango cultivars and packaging and waxing treatments on TSS, vitamin C, titratable acidity and shelf life of mango fruits (season two).

Cultivars	Treatments	TSS (%)	Vitamin C (mg/100 g)	Titratable acidity	Shelf life (days)
	Intact	11.52 c	37.58 a	0.96 a	20.81 b
Abusamaka	Perforated	9.61 d	29.23 b	0.85 a	18.20 b
	Wax	10.33 d	32.23 a	0.65 b	17.36 b
	Control	12.40 b	26.45 b	0.45 c	15.27 c
	Intact	11.21 c	25.72 b	0.55 bc	27.73 a
Keitt	Perforated	11.32 c	21.71 c	0.42 c	24.52 a
	Wax	12.50 d	22.85 c	0.40 c	22.23 b
	Control	14.67 a	19.11 d	0.36 d	17.15 b
	Intact	10.31 d	23.92 c	0.52 bc	24.61 a
Kent	Perforated	12.70 b	18.26 d	0.41 c	18.23 b
	Wax	11.65 c	21.53 c	0.37 d	17.65 b
	Control	14.83 a	16.72 e	0.30 d	16.22 c
	Intact	13.57 b	25.47 b	0.38 d	14.50 c
Tommy	Perforated	14.82 a	21.62 c	0.32 e	12.63 d
Atkins	Wax	14.95 a	22.86 c	0.27 f	11.31 d
	Control	15.66 a	17.63 e	0.25 f	9.30 e
Sig. level		*	**	*	*
C.V (%)		11.32	9.51	12.76	13.81

Means in columns followed by the same letter(s) are not significantly different at P≤0.05 according to Duncan's Multiple Range Test.

* and ** Significant at P=5% and 1%, respectively.

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تأثير التغليف والتشميع على نوعية وفترة صلاحية بعض أصناف المانجو المستوردة

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الخلاصة

تعتبر المانجو من أهم محاصيل الفاكهة في السودان. وهي تصدر إلى المملكة العربية السعودية ودول الخليج وغرب أوروبا. لقد تم استقدام بعض الأصناف المرغوبة عالمياً إلى السودان في السنوات الأخيرة. الهدف من هذه الدراسة هو معرفة تأثير التغليف والتشميع على نوعية الثمار وفترة الصلاحية لثمار بعض أصناف المانجو المستجلبة من جنوب أفريقيا. اشتملت المعاملات على ثلاثة أصناف مستجلبة من المانجو وهي تومي أتكنز وكنت وكيت بالإضافة إلى الصنف المحلي أبو سمكة. معاملات التغليف شملت تغليف الثمار في أكياس البولي إثلين السليمة أو المخرمة أو تشميع الثمار وأخرى استخدمت كشاهد بدون كيس أو تشميع. أستخدم التصميم العشوائي الكامل بثلاثة مكررات. اشتملت البيانات على فقدان الوزن والمواد الصلبة الذائبة والحموضة المعايرة وفيتامين ج وفترة الصلاحية. أظهرت النتائج أن الصنف أبو سمكة أظهر أعلى معدل فقدان للوزن بينما الصنف كيت كان له أقل فقدان للوزن في كلا الموسمين. تغليف ثمار المانجو في أكياس البولي إثلين السليمة أعطى أقل فقدان للوزن ويليه الأكياس المخرمة ثم التشميع وكان أعلى فقدان للوزن في الثمار غير المغلفة أو المشمعة في كلا الموسمين. الصنف أبو سمكة أعطى أعلى محتوى لفيتامين ج والحموضة بينما أعطى أقل محتوى للمواد الصلبة الذائبة. الصنف تومي أتكنز أعطى أعلى محتوى للمواد الصلبة الذائبة ولكنه أعطى أدنى محتوى من فيتامين ج والحموضة في كلا الموسمين. الصنف كيت أعطى أطول فترة للصلاحية، يليه كنت ثم أبو سمكة وأقل فترة للصلاحية كانت للصنف تومي أتكنز في كلا الموسمين. تغليف ثمار المانجو في أكياس البولي إثلين السليمة أعطى أدنى محتوى من المواد الصلبة الذائبة وأعلى محتوى من الحموضة وفيتامين ج وأطول فترة للصلاحية. أما الثمار غير المغلفة أو غير المشمعة أعطت أعلى محتوى من المواد الصلبة الذائبة وأدنى محتوى من الحموضة وفيتامين ج وأقصر فترة للصلاحية. يوصى بإكثار وزراعة الصنف كيت وحصاد الثمار في طور النضج الاخضر وتغليفها في أكياس البولي إثلين السليمة لإطالة فترة صلاحيتها وتحسين نوعيتها.