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 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.

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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.
Weight loss (%) = \([\frac{(w_0 - w_t)}{w_0}] \times 100\)

- \(W_0\) = 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:

\[
\text{Titratable acidity} = \frac{\text{ml of NaOH used}}{5\text{ g}} \times \text{normality of NaOH} \times 0.064 \times 100
\]

**Determination of vitamin C using the iodine method**

An amount of 400 mg of iodine powder was dissolved in 100ml of H\(_2\)O and then 25ml of dilute H\(_2\)SO\(_4\) 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\(_2\)O 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:

\[
\text{Vitamin C (mg/100g)} = \text{number of ml of 0.1 N I}_2 \times 8.81 \times 25 \text{ (dilution factor)}
\]

**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.](image-url)
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.
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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.
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.
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).
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).
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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 CO₂ and low O₂ 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).
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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.

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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).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Treatments</th>
<th>TSS (%)</th>
<th>Vitamin C (mg/100g)</th>
<th>Titratable acidity</th>
<th>Shelf life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abusamaka</td>
<td>Intact</td>
<td>12.61 bc</td>
<td>36.35 a</td>
<td>0.97 a</td>
<td>19.62 b</td>
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<td></td>
<td>Perforated</td>
<td>13.28 b</td>
<td>28.31 b</td>
<td>0.85 a</td>
<td>17.23 c</td>
</tr>
<tr>
<td></td>
<td>Wax</td>
<td>12.13 bc</td>
<td>30.35 b</td>
<td>0.66 b</td>
<td>16.51 c</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>14.72 ab</td>
<td>25.10 bc</td>
<td>0.43 c</td>
<td>14.85 d</td>
</tr>
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<td></td>
<td>Intact</td>
<td>12.30 bc</td>
<td>24.72 bc</td>
<td>0.58 b</td>
<td>26.63 a</td>
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<tr>
<td>Keitt</td>
<td>Perforated</td>
<td>13.42 b</td>
<td>20.85 c</td>
<td>0.46 c</td>
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<td>0.43 c</td>
<td>21.71 b</td>
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<td>18.61 d</td>
<td>0.38 d</td>
<td>18.45 c</td>
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<td>13.33 b</td>
<td>23.45 c</td>
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<td></td>
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<td>21.56 c</td>
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</tr>
<tr>
<td></td>
<td>Control</td>
<td>15.20 a</td>
<td>15.20 e</td>
<td>0.37 d</td>
<td>18.12 c</td>
</tr>
<tr>
<td></td>
<td>Intact</td>
<td>14.82 ab</td>
<td>24.97 bc</td>
<td>0.41 d</td>
<td>15.31 d</td>
</tr>
<tr>
<td>Tommy</td>
<td>Perforated</td>
<td>15.75 a</td>
<td>20.43 e</td>
<td>0.35 e</td>
<td>13.02 e</td>
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<td>Atkins</td>
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<td>0.23 f</td>
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<td></td>
<td>Control</td>
<td>16.75 a</td>
<td>18.51 d</td>
<td>0.22 f</td>
<td>10.32 e</td>
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</table>

Sig. level

<table>
<thead>
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<th>C.V (%)</th>
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<th>**</th>
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<td>10.09</td>
<td>10.82</td>
<td>13.19</td>
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</table>

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.
Effects of packaging & waxing on fruit quality & shelf life of mango

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).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Treatments</th>
<th>TSS (%)</th>
<th>Vitamin C (mg/100 g)</th>
<th>Titratable acidity</th>
<th>Shelf life (days)</th>
</tr>
</thead>
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<td>37.58 a</td>
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<td>20.81 b</td>
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<td>17.36 b</td>
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<tr>
<td></td>
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<td>26.45 b</td>
<td>0.45 c</td>
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<td>Intact</td>
<td>11.21 c</td>
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<td>Keitt</td>
<td>Perforated</td>
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<td>18.26 d</td>
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<td>21.53 c</td>
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<td>13.57 b</td>
<td>25.47 b</td>
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<td>Tommy</td>
<td>Perforated</td>
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<td>Atkins</td>
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<td>17.63 e</td>
<td>0.25 f</td>
<td>9.30 e</td>
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</tbody>
</table>

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.

C.V (%)

11.32 9.51 12.76 13.81
REFERENCES


