# Effects of Ethrel, packaging and waxing on degreening, quality and shelf life of sweet oranges

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## ABSTRACT

Post harvest handling practices of sweet oranges are very poor in the Sudan and result in great losses. Oranges grown in central Sudan reach the ripe stage while they are still green in colour. The lack of orange colour development is due to the relatively high temperatures in this region. Therefore, the objective of this research was to find out the effects of Ethrel, packaging and waxing on sweet orange degreening, quality and shelf life. Experiments were conducted at the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan, during the seasons of 2013-2014. Ripe, green oranges were treated with Ethrel at two concentrations: 1ml/l, 2ml/l or left untreated as a control. Packaging treatments consisted of wrapping oranges in intact or perforated polyethylene film, waxed or left unpackaged as control. Treatments were arranged in a completely randomized design with two replicates. Results showed that treatment of oranges with Ethrel at both concentrations significantly resulted in degreening of oranges and development of a uniform orange colour as compared to the control. Oranges packaged in intact polyethylene film or waxed recorded the minimum weight loss followed by those wrapped in perforated film, whereas the highest weight loss was recorded for the unpackaged and unwaxed oranges. Also, packaging in intact film or waxing of oranges resulted in the longest shelf life compared to the other treatments. Total soluble solids and vitamin C contents were highest in oranges packaged in intact film or waxed, whereas the least contents were recorded for the control. Ethrel treatment had no significant adverse effects on orange chemical composition. It is recommended to degreen oranges using Ethrel at 2ml/l and package them in intact polymeric film or coat them with wax.

# INTRODUCTION

The Sudan, with its vast cultivable land and suitable climatic conditions is best suited for sweet orange production and offers good opportunities for its export to other parts of the world. In the Sudan, sweet oranges are mainly produced in Western Darfur (mainly Jebel Marra), River Nile, Kassala, Southern Darfur, Gezira and Khartoum States. Sweet orange production was estimated at 133500 ton produced from 8750 ha (FAO, 2012). The most important introduced sweet orange cultivars were Frost, Valencia, Hamlin, Campbell, Butler Valencia and Olinda Valencia. Orange cultivars introduced to Jebel Marra were Frost, Gillette, Parent and Thackery. In recent years, there is a decrease in area planted with sweet orange in the Sudan due to diseases, nematodes, poor management and absence of proper fertilization programs.

Sweet oranges grown in central Sudan remain green even after they reach the ripe stage, which lowers their quality and consumers think that they are still unripe. Colour development of sweet oranges needs night temperatures in the range of $15^0$C to $20^0$C. Post- harvest degreening of sweet oranges can be done by the application of ethephon (2-chloroethane phosphonic acid). Ethephon applied at 0.2% degreened the fruits in 3-5 days while the untreated fruits remained green. There was no negative effect of ethephon on total soluble solids, ascorbic acid, acidity or juice content (Yadava, 2008).

The quality of Sudanese sweet oranges has been negatively affected by improper post- harvest handling practices which result in losses, rapid deterioration in quality and weight loss, which is mainly due to water loss and usually results in fruit shriveling. One of the most important factors which determine produce shelf life during storage is the proper packaging material and method of packaging. Polymeric films should be thin or perforated to permit adequate gas exchange, otherwise, fermentation may result from insufficient oxygen (Wills *et al*.,1998). Packaged produce is a dynamic system in which respiration and permeation are occurring simultaneously. Selection of the proper film type and thickness could reduce water loss and favorably modify the in- package atmosphere, thereby extending the produce shelf life. Most of the recent work on film packaging has been performed with citrus fruit. Ben-Yehoshua *et al.,* (1987*)* found that sealing citrus fruits in plastic films reduced weight loss significantly and preserved fruits for six months. Fruits lost less weight and had a higher percentage of marketability than unsealed ones. Elkashif *et al.* (2003*)* reported that mango fruits packaged in intact polyethylene film resulted in the lowest weight loss, followed by those packaged in perforated films, whereas unpackaged fruits showed the highest weight loss and lowest quality manifested in shriveling. Banana fruits packaged in intact polyethylene film and stored at $14^O$C showed the lowest weight loss while unpackaged fruits showed the highest weight loss (Hassain *et al.*, 2004; Elkashif *et al.*, 2005; Khan *et al.*, 2007).

Waxing is widely used as a coating material for citrus fruits to improve their appearance and reduce water loss and shriveling. Wax may be used as a carrier of fungicides or growth regulators. The thickness of the wax coating is very important. Too thick coating encourages anaerobic respiration and alcoholic fermentation. Waxing and surface coating materials significantly alter the permeability of the fruit skin to gases. The commodity, through the respiration process, reduces oxygen and increases carbon dioxide. Under such conditions, a modified atmosphere may be generated resulting in the reduction of the rate of respiration (Kader and Arpaia., 2002). Waxing was reported to delay ripening of fruits, reduce water loss and extend the shelf life of mango (Mohamed and Abu-Goukh, 2003) tomato (Ahmed and Abu-Goukh, 2003), lime (Ayoub, 2004) and grapefruit (Abu-Goukh and Elshiekh, 2008; Elhadi *et al*., 2011).

Therefore, the objective of this research was to determine the effects of Ethrel, packaging and waxing on degreening and shelf life of sweet oranges.

## MATERIALS AND METHODS

**Experimental site**

Experiments were conducted in the Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan, during two consecutive seasons of 2013 and 2014, to determine the effects of Ethrel on degreening of sweet oranges and packaging and waxing on their post-harvest quality.

**Source of fruits**

Green oranges, local cultivar Sinnari, were purchased from Khartoum local market at the ripe stage. The fruits were selected for uniformity of size, and freedom from physical injury and blemishes.

**Packaging material**

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

**Degreening experiment**

Sweet orange fruits were degreened using Ethrel, which is the trade name of 2-chloroethane phosphonic acid. Orange fruits were divided into three groups. The first and second groups were dipped in Ethrel solutions at concentrations of 1 ml/l or 2 ml/l for 5 min. The third group was dipped in distilled water as control. Then fruits were air dried to remove surface water and then subjected to the following packaging and waxing treatments:

**Packaging and waxing experiment**

Sweet orange fruits from the previously mentioned three groups were then subjected to the following treatments:

1. Fruits were placed directly in cartons (control).
2. Fruits were placed in intact polyethylene bags and then placed in cartons.
3. Fruits were placed in perforated polyethylene bags and then placed in cartons.
4. Fruits were waxed and then placed in cartons. Wax was applied in a thin layer by brushing over the surface of the fruit.

Fruits were stored at ambient conditions till they were out of quality. Treatments were arranged in a completely randomized design with two replicates.

**Determination of chemical characteristics**

Chemical characteristics of sweet oranges from the different treatments were determined every 3 days. They consisted of total soluble solids (TSS), titratable acidity, and vitamin C content.

**Total soluble solids (TSS)**

Total soluble solids (TSS) were determined using Kruss hand refractometer (model HRN-32).

**Total titratable acidity**

Total titratable acidity was determined on a 5 ml juice sample diluted to 200 ml with distilled water and titrated against 0.1 N NaOH to a phenolphathaline end point (light pink color) and calculated as percentage citric acid.

$$\text{Titratable acidity} = \frac{\text{ml of NaOH used} \times \text{Normality of NaOH} \times 0.064 \times 100}{\text{m1 of juice}}$$

**Determination of vitamin C**

A sample of 4 ml of juice was diluted to 50 ml with distilled water and then 20 ml were taken and blended with a reasonable amount of 0.4% oxalic acid and titrated against 2,6 –dichlorophenol – indophenol dye to a faint pink color. Vitamin C was calculated using the following formula:

$$\text{Vitamin C (mg/100 ml)} = \frac{\text{Titer} \times \text{strength of the dye} \times 100}{}$$

Dilution factor*

*Dilution factor = $\frac{\text{4 ml of juice x20 ml taken}}{\text{500 (dilution)}} = 1.6$

**Determination of colour**

Colour was rated visually according to a scale of 1 to 3 as follows: 1, green; 2, greenish yellow and 3, yellow.

**Determination of weight loss**

Sweet orange fruits were subjected to the previously mentioned packaging and waxing treatments. Treatments were arranged in a completely randomized design with two replicates. Initial weight of fruits was determined and then fruits were weighed every two days till they were out of quality. Weight loss was determined as follows:

Weight loss (%) $= \frac{(W_0 - Wt) \times 100}{W_0}$

where:

$W_0$ = initial weight

Wt = weight at designated time.

**Statistical analysis**

Data were analysed using the standard analysis of variance procedures. Means were separated using Duncan's Multiple Range Test at 5% level of significance.

## RESULTS AND DISCUSSION

This experiment was conducted during two consecutive seasons of 2013 and 2014. Since the results of both seasons were similar, only the results of the first season will be reported.

**Weight loss**

The effects of packaging and waxing treatments on weight loss of sweet orange fruits during storage are shown in Fig 1. Weight loss progressively increased during storage of sweet orange fruits. Packaging orange fruits in intact polyethylene film resulted in the lowest weight loss, followed by waxing and perforated film. The highest weight loss was observed in the control treatment. Waxing treatment resulted in more weight loss than the intact film, but more or less equal to 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 peel and hence significantly reduced water loss. These results support the findings of Osman and Abu-Goukh (2008) and Elkheir and Abu-Goukh, (2010). Packaging orange fruits in intact or perforated film resulted in high relative humidity inside the package and hence reduced weight loss (Elkashif *et al*., 2005; Osman and Abu- Goukh, 2008). Polymeric film packaging has been extensively used to reduce water loss and enhance fruit quality (Wills *et al*., 1998). Osman and Abu- Goukh (2008) 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. Nevertheless, waxing also improved fruit quality, reduced postharvest losses and extended storability of grapefruits (Elhadi *et al*., 2011). Sweet orange fruits packaged in intact polyethylene film were of good quality up to 19 days of storage, whereas the unpackaged control fruits lost their quality in less than one week of storage. Sweet orange fruits packaged in perforated polyethylene film or waxed maintained their

quality for 12 days in storage. Therefore, sweet orange fruits intended for export or the local market should be packaged in intact thin polymeric film.

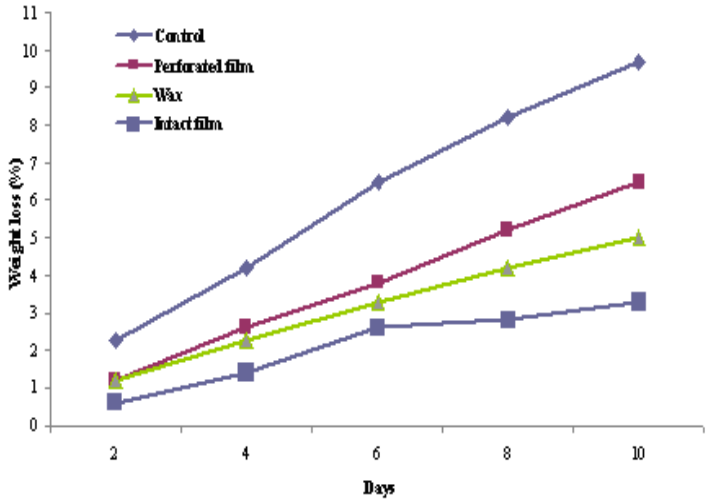


Fig. 1. Effects of packaging and waxing treatments on weight loss of sweet oranges.

**Degreening of orange fruits**

The effects of Ethrel on degreening of sweet orange fruits during storage are shown in Fig 2. Ethrel treatment significantly enhanced colour development in sweet oranges. The higher concentration of Ethrel was more effective in colour development than the lower one. Similar results were reported by Elkashif *et a*l., (2003) who found that ethylene treatment not only maintained mango fruit quality but also enhanced colour development and shortened the ripening time.

The effects of packaging and waxing treatments on colour development of sweet orange fruits during storage are shown in Fig 3. Sweet orange fruits packed in intact polymeric film developed full yellow colour during storage. However, waxed fruits developed colour slowly and did not reach full yellow colour till the end of the storage period. This was most probably due to the fact that the intact film trapped ethylene hormone which was released from Ethrel and hence resulted in the degreeing of oranges. The delay in colour development of waxed fruit was probably due to the build up of high $CO_2$ concentration inside the fruit as a result of respiration, which acted as an inhibitor to ethylene action and hence slowed down colour development. This is in agreement with the findings of Elkashif *et al.* (2005).

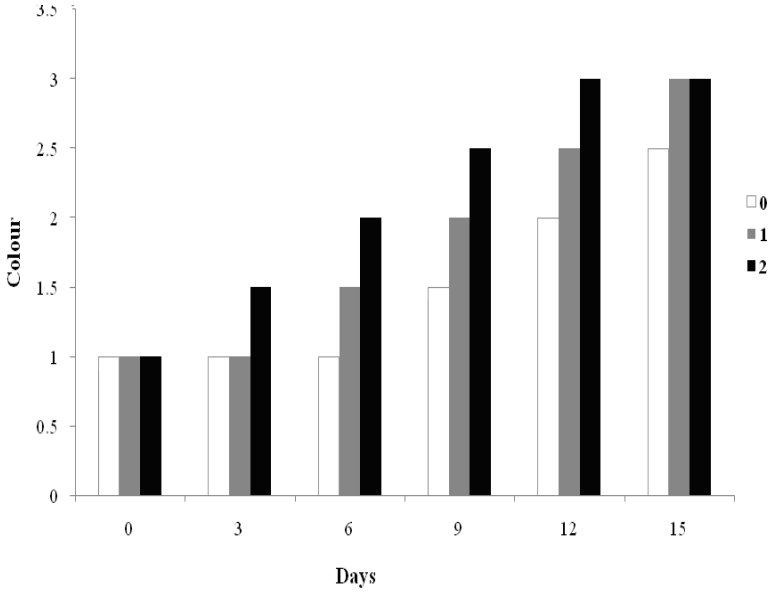


Fig. 2. Effects of Ethrel on colour development of sweet orange fruits

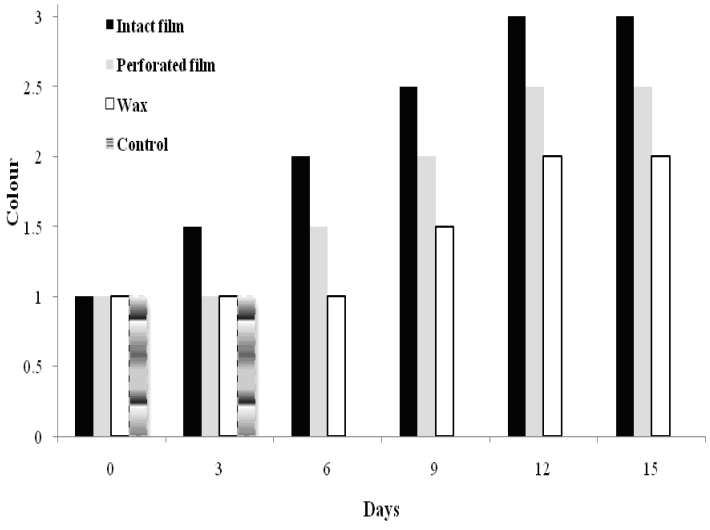


Fig. 3. Effects of packaging and waxing treatments on colour development of sweet orange fruits.

**Total soluble solids**

The effects of Ethrel treatment on total soluble solids (TSS) of sweet orange fruits during storage are shown in Fig 4. Generally, TSS decreased with storage period. Ethrel treatment had no consistent effects on TSS content. Similar findings were reported by Yadava *et al.* (2008) who found that Ethrel treatment did not significantly affect total soluble solids of oranges. Similar findings were also reported by Elkashif *et al*, (2003) who worked on different mango cultivars and found no significant differences between Ethrel treated and untreated fruits with respect to total soluble solids.

The effects of packaging and waxing treatments on TSS content of sweet orange fruits during storage are shown in Fig 5. The highest TSS values were recorded in orange fruits packaged in intact polyethylene film and the lowest values were recorded in the waxed fruits . This was most probably due to the fact that fruits packaged in intact polymeric film had high relative humidity around the fruits which reduced water loss and hence maintained the original concentration of TSS. However, the low TSS content of waxed fruits was mostly due to the fact that waxing might have caused low internal $O_2$ concentration which might have triggered anaerobic respiration that led to a significant decrease in TSS. (Elkashif *et al*., 2005).

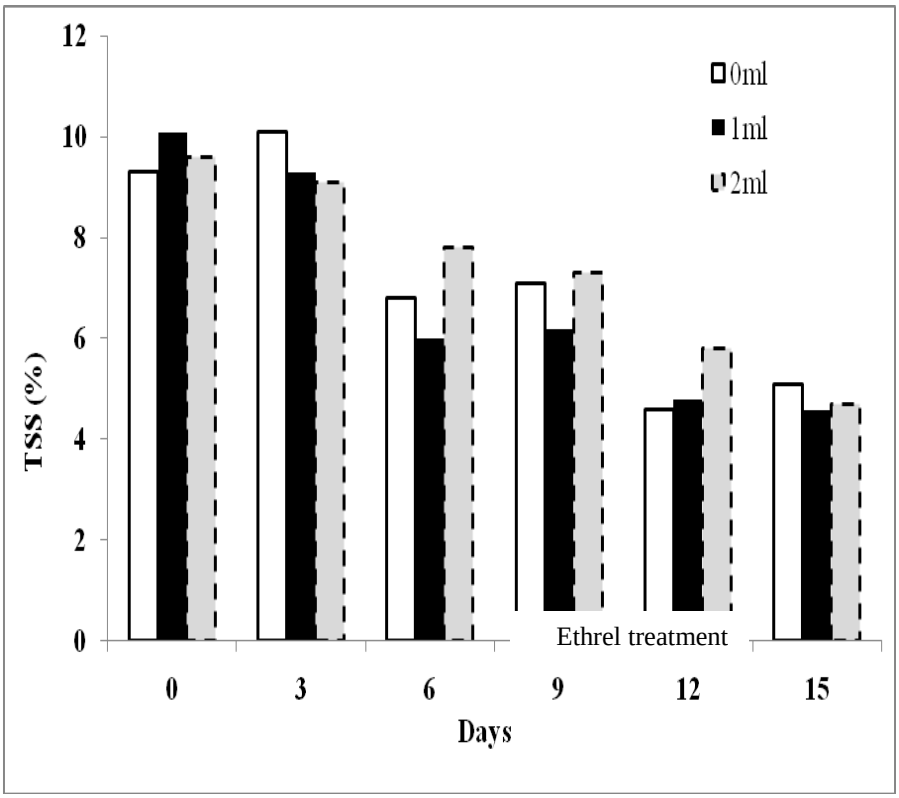


Fig. 4.Effects of Ethrel treatment on total soluble solids of sweet orange fruits.

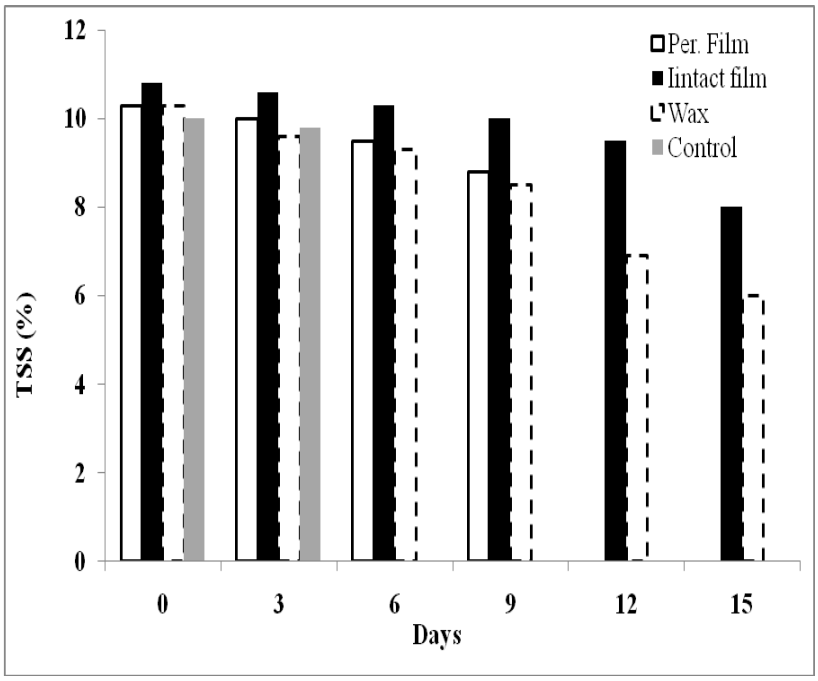


Fig. 5. Effects of packaging and waxing treatments on total soluble solids of orange fruits.

**Titratable acidity**

The effects of Ethrel treatment on titratable acidity of sweet orange fruits during storage are shown in Fig 6. Ethrel treatment had no consistent effects on titratable acidity. Similar findings were reported by Elkashif *et al*, (2003) who found that ethylene treatment did not significantly affect titratable acidity of mango fruits. Titratable acidity progressively decreased towards the end of the storage period which was probably due to the oxidation of organic acids or their conversion to sugars. These results are in agreement with the findings of Abu-Goukh and Elshiekh (2008) and Elkheir and Abu-Goukh (2010).

The effects of packaging and waxing treatments on titratable acidity of sweet orange fruits during storage are shown in Fig 7. Generally, there was a decrease in titratable acidity during storage in the same trend which was observed in Fig 6. Sweet orange fruits packed in intact film or waxed had the highest titratable acidity. Polyethylene film liners and waxing usually result in a modified atmosphere with low $O_2$ and high $CO_2$ concentrations. These conditions mostly reduced respiration rate, decreased the degradation of organic acids and hence, resulted in higher titratable acidity content. Modified atmosphere had been shown to decrease respiration rate in banana (Osman and Abu- Goukh, 2008).

It was also reported that waxing, which reduced water loss, decreased acidity during storage of tomato (Ahmed and Abu- Goukh, 2003) grapefruit (Abu-Goukh and Elsheikh, 2008) and lime (El-Kheir and Abu- Goukh, 2010).

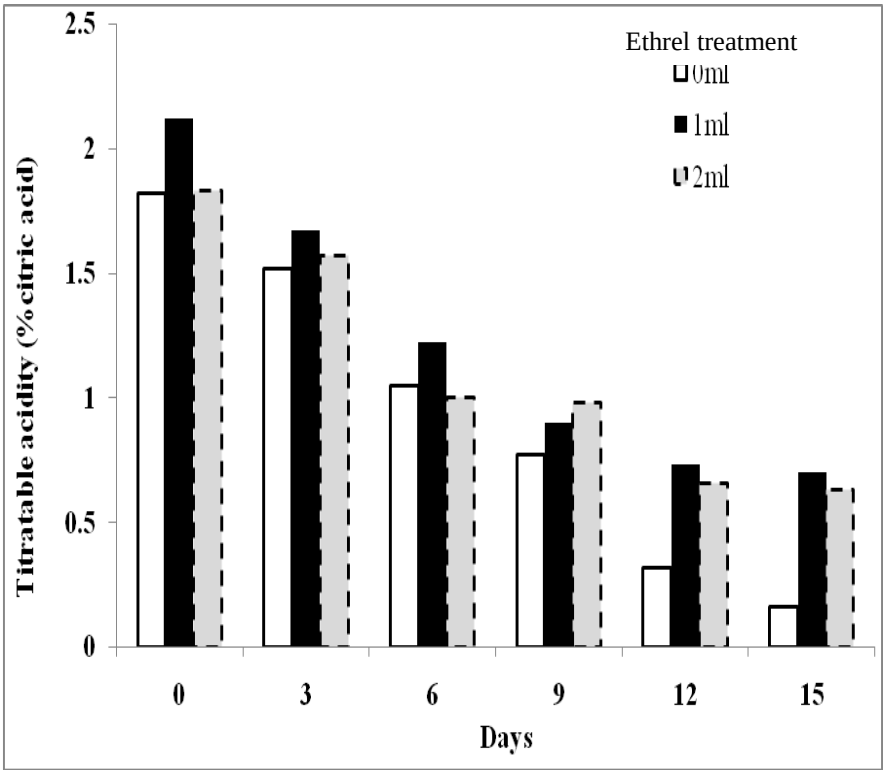


Fig.6. Effects of Ethrel treatment on titratable acidity of sweet orange fruits.

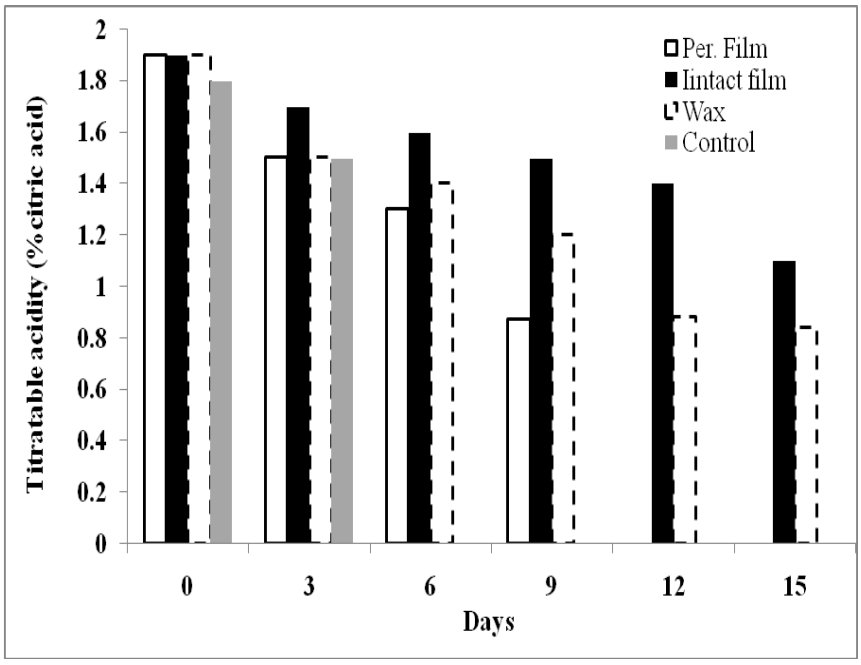


Fig. 7. Effects of packaging and waxing treatments on titratable acidity of sweet orange fruits.

**Vitamin C**

The effects of Ethrel treatment on vitamin C content of sweet orange fruits during storage are shown in Fig 8. Generally, vitamin C content decreased during storage due to degradation. Ethrel treatment had no significant effects on vitamin C content of sweet orange fruits. However, vitamin C content was inconsistent with respect to Ethrel treatment.

The effects of packaging and waxing treatments on vitamin C content of sweet orange fruits during storage are shown in Fig 9. Vitamin C content decreased with storage in the same trend shown in Fig 8. The highest vitamin C content was found in fruit packaged in intact polyethylene film, followed by waxing, perforated and control treatments. The reason why the intact film and waxing treatments resulted in the highest vitamin C values during storage was most probably due to the fact that fruits packaged in intact film or waxed lost less moisture and hence conserved their vitamin C contents. Similar results were reported by Elkashif *et al*., (2005) and Osman

and Abu-Goukh (2008). Waxed fruits lost less moisture as compared to the control and hence conserved more vitamin C which was higher than the perforated polyethylene film treatment. These results are consistent with those reported by El- Kheir and Abu- Goukh (2010).

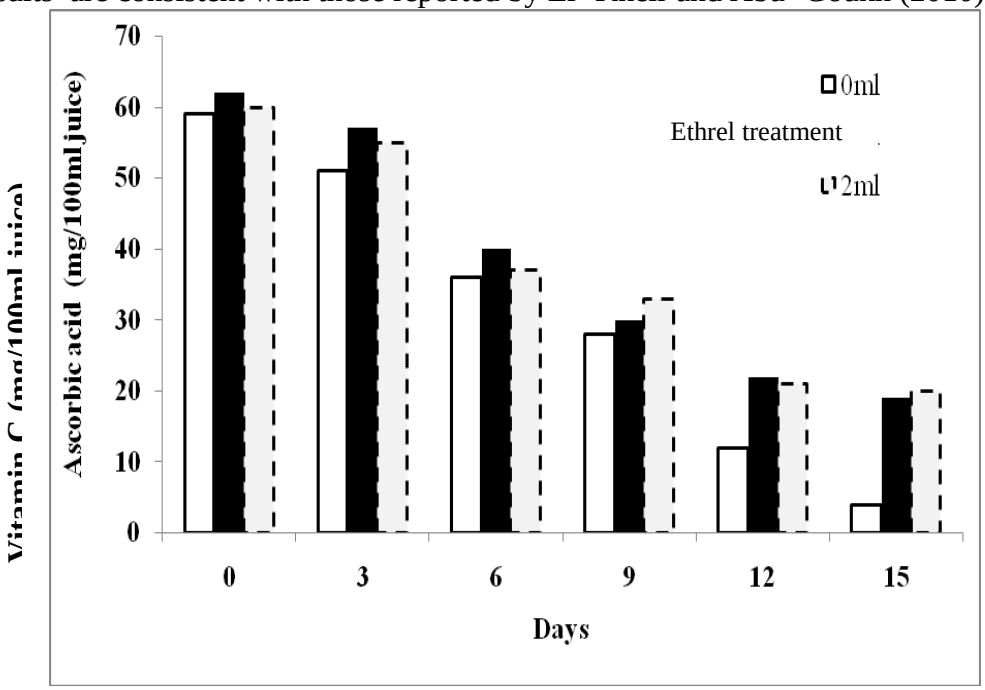


Fig.8. Effects of Ethrel treatment on vitamin C content of sweet orange fruits.

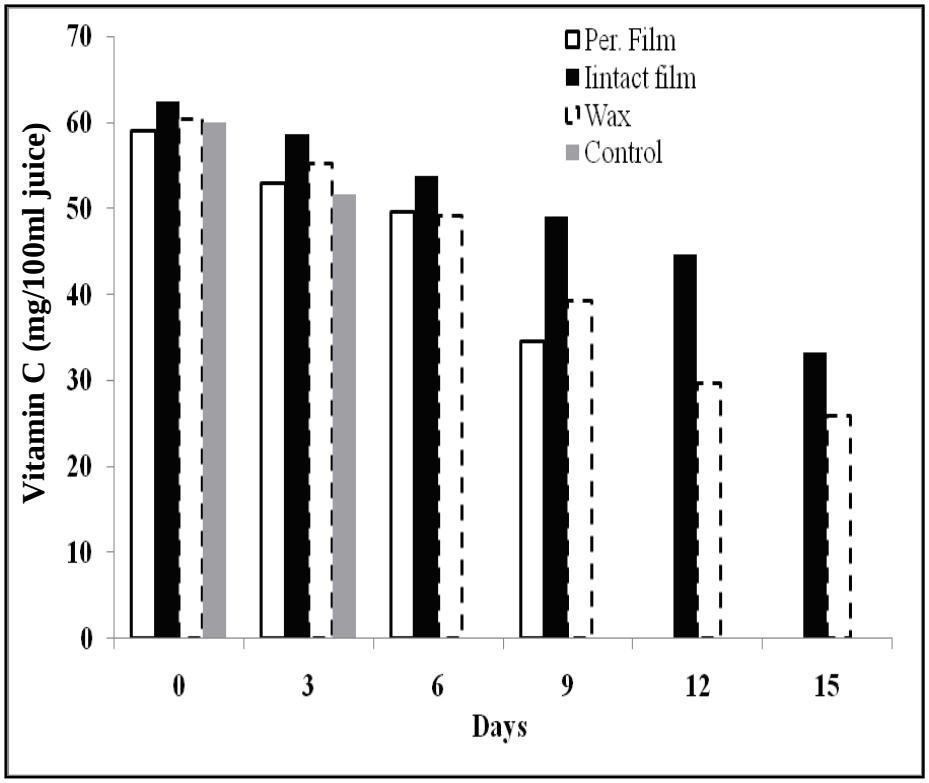


Fig.9. Effects of packaging and waxing treatments on vitamin C content of sweet orange fruits.

**Interaction effects of packaging, waxing and Ethrel treatments on the chemical composition, colour and shelf life of sweet oranges:**

Table 1 shows significant interaction effects of packaging and waxing treatments on one hand and Ethrel concentration on the other hand, on vitamin C content, colour and shelf life of sweet orange fruits. Sweet orange fruits packaged in intact polyethylene film or waxed recorded the highest vitamin C content followed by fruits packaged in perforated film, whereas the lowest values were recorded in the control fruits. This was probably because packaging of orange fruits in intact polymeric film reduced water loss and maintained vitamin C content. However, unpackaged control fruits lost water rapidly and hence resulted in accelerated destruction of vitamin
C. Previous reports indicated that weight loss and shrivellig significantly reduced vitamin C content (Elhadi *et al*., 2011).

Vitamin C content was also slightly affected by Ethrel treatment (Table 1). The higher Ethrel concentration resulted in the lowest vitamin C content, followed by the lower concentration and the highest vitamin C content was recorded in the untreated fruits, under all packaging and waxing treatments. This is most probably due to the fact that sweet oranges are non-climacteric fruits which produce negligible amounts of endogenous ethylene. However, exogenous ethylene in the form of Ethrel is usually harmful to sweet oranges especially if applied at relatively high concentrations. This harmful effect was manifested in the form of vitamin C destruction and loss.

Interaction effects of packaging, waxing and Ethrel treatments were not significant on total soluble solids content and acidity of sweet oranges. This was because these chemical constituents reached their maximum concentration during the ripe stage and hence were not affected by further post-harvest treatments.

The interaction effects of packaging, waxing and Ethrel treatments were also significant on colour of sweet orange fruits. The higher concentration of Ethrel resulted in the best colour development of

oranges, followed by the lower concentration, whereas the control untreated fruits did not develop orange colour during storage and remained green (Table 1). Ethylene hormone has been shown to degreen mango (Elkashif *et al.*, 2003) and bananas (Elkashif *et al.*, 2005). The positive effect of Ethrel on sweet orange degreening was consistent under all packaging, waxing and even the unpackaged control fruits. This finding emphasizes the importance of using Ethrel for degreening of sweet oranges produced in central Sudan. Actually, Ethrel can be mixed with water during washing of oranges without any additional operations or costs.

Sweet oranges shelf life was also significantly affected by the interactions of packaging, waxing and Ethrel treatments (Table 1). The longest shelf life was recorded for oranges packaged in intact polymeric film, followed by waxed fruits, perforated film and the shortest shelf life was recorded for the unpackaged and unwaxed control fruits. Orange fruits packaged in intact polymeric film could be stored for 21 days without any significant deterioration in quality, whereas the control fruits were out of

quality in less than a week. This was mostly due to the effectiveness of intact polymeric film wrap and waxing in reducing water loss, preventing shriveling and maintaining the turgidity of fruits. Therefore, in order to keep up the quality of sweet orange fruits and extend their shelf life, it is advisable to package them in intact thin polymeric film or coat them with wax. These results are consistent with those reported by Elkhashif *et al*. (2003; 2005).

It could be concluded that, in order to degreen sweet orange fruits, maintain good quality and extend their shelf life, it is recommended to dip them in Ethrel solution at 2ml/l, package them in intact thin polymeric film or coat them with wax.

Table 1. Interaction effects of packaging, waxing and Ethrel treatment on the chemical composition, colour and shelf life of sweet oranges.

| Packaging and waxing treatments | Ethrel conc. (ml/l) | Vitamin C (mg/100ml) | TSS (%) | Acidity | Colour | Shelf life (days) |
|---|---|---|---|---|---|---|
| Per. | 0 | 35.9 b | 9.0 | 1.6 | 1.0 c | 9 c |
| film | 1 | 31.4 b | 10.0 | 1.8 | 2.1 b | 8 c |
| | 2 | 27.4 c | 11.0 | 1.7 | 3.0 a | 8 c |
| Int. | 0 | 44.6 a | 10.5 | 1.5 | 1.0 c | 18 b |
| film | 1 | 42.2 a | 9.5 | 1.5 | 2.2 b | 21 a |
| | 2 | 33.0 b | 9.0 | 1.4 | 3.0 a | 21 a |
| Wax | 0 | 42.0 a | 10.0 | 1.4 | 1.1 c | 15 c |
| | 1 | 39.2 a | 9.0 | 1.4 | 2.2 b | 17 b |
| | 2 | 35.8 b | 10.0 | 1.5 | 3.0 a | 19 b |
| Control | 0 | 27.0 c | 10.0 | 1.6 | 1.2 c | 4 e |
| | 1 | 20.8 d | 9.0 | 1.6 | 2.3 b | 4 e |
| | 2 | 17.8 d | 9.5 | 1.7 | 3.0 a | 3 e |
| Sig. | | * | NS | NS | ** | * |
| CV( %) | | 13.6 | 8.7 | 13.8 | 8.3 | 7.7 |

*,** and NS: indicate significance at P ≤ 0.05, 0.01, and not significant, respectively, for columns, according to DMRT.

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# أثر مادة الإثرل والتغليف والتشميع على إزالة اللون الأخضر وجودة وفترة صلاحية البرتقال

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[2] وزارة الزراعة و الغابات والري، ولاية الجزيرة، السودان.

## الخلاصة

معاملات ما بعد الحصاد للبرتقال في السودان غير متطورة وينتج عنها خسائر كبيرة. يصل البرتقال المنتج في أواسط السودان إلى طور النضج وهو أخضر اللون. يعزى عدم تلوين البرتقال إلى ارتفاع درجات الحرارة في هذه المنطقة. الهدف من هذه الدراسة هو معرفة أثر مادة الأثرل على تلوين البرتقال وتأثير التغليف والتشميع على جودة وفترة صلاحية البرتقال. أجريت التجارب في كلية العلوم الزراعية، جامعة الجزيرة واد مدني السودان خلال موسمي 2013-2014م. تمت معاملة ثمار البرتقال الأخضر بمادة الأثرل 1 و 2 ملم/لتر أو ترك كشاهد. معاملات التغليف اشتملت على تغليف البرتقال في أكياس البولي إيثلين السليمة أو المخرمة أو التشميع أو بدون تغليف كشاهد. صممت التجارب نسق التصميم العشوائي الكامل بمكررين. أوضحت النتائج أن معاملة البرتقال بمادة الأثرل أدت إلى زوال اللون الأخضر وتلوين البرتقال بلون برتقالي جميل بالمقارنة مع الشاهد. تغليف البرتقال في أكياس البولي إثيلين السليمة أو تشميعه أدى إلى أدنى فقدان الوزن، يليه التغليف في أكياس مخرمة، بينما كان أعلى فقدان الوزن في الشاهد. محتوى المواد الصلبة الذائبة وفيتامين "ج" كان أعلى في البرتقال الذي تم تغليفه في أكياس البولي إيثلين السليمة أو التشميع، بينما كان أدنى محتوى في الشاهد. معاملة البرتقال بمادة الأثرل لم يكن لها أي تأثير ضار على التركيب الكيميائي للبرتقال. لذلك يوصي بمعاملة البرتقال الأخضر بمادة الأثرل لتلوينه وتغليف الثمار في أكياس البولي إيثلين السلمية أو التشميع للحفاظ على الجودة وزيادة فترة الصلاحية أو العمر التخزينية للبرتقال.