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Effect of Packaging and Waxing on Quality and Shelf-life of Grapefruit (*Citrus paradisi* Macf.)

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Abstract

Experiments were conducted in the laboratory of Kassala and Gash Research Station, Kassala, Sudan, to evaluate the effect of packaging and waxing on quality and storability of grapefruit during May and August of 2022 and 2023. The experiments were carried out at two level of temperature viz; 35°C and 20°C. Fruits were packaged in intact or perforated polyethylene bag, waxed, waxed with packaged in intact or waxed with perforated polyethylene bag or left unpackaged and unwaxed as control. Treatments were arranged in a completely randomized design with three replicates. The results of the two experiments showed that packaging grapefruit in wax with intact polyethylene bag resulted in lowest weight loss and titratable acidity and higher value of TSS compared to control in both seasons under 35°C and 20°C conditions. Moreover, longest shelf life was observed in case of waxed intact polyethylene bag treatment and the lowest shelf life was recorded for the control in both seasons under 35°C and 20°C conditions.

Key words: grapefruit, packaging, polyethylene bag, wax, shelf-life.

اثر التغليف والتشميع على جودة وتخزين ثمار القريب فروت

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المستخلص

اجريت تجارب في معمل محطة بحوث كسلا والقاش، كسلا، السودان، لتقييم اثر التغليف والتشميع على جودة وتخزين ثمارالقريب فروت صنف رد بلش خلال شهري مايو واغسطس لعامي 2022 و 2023. تم تعبئة ثمار القريب فروت في كيس بولي إيثيلين سليم أو مثقوب ، مشمع ، مشمع مع تعبئتها كيس بولي إيثيلين سليم أو مثقوب أو تركت غير معبأة وغير مغلفة بالشمع . تم ترتيب المعاملات في التصميم العشوائي الكامل بثلاث مكررات .أظهرت النتائج أن معاملة ثمار القريب فروت بالشمع وتعبئتها في كيس بولي إيثيلين سليم أدى إلى أقل خسارة في الوزن وحموضة اقل، وقيمة أعلى من المواد الصلبة الذائبة والفيتامينات مقارنةً بالشاهد في الموسمين .علاوة على ذلك، تم تسجيل أطول عمر للتخزين عند الشمع مع كيس بولي إيثيلين سليم وتم تسجيل أقل عمر تخزين مع الشاهد.

كلمات مفتاحية: القريب فروت، التغليف، كيس البولي إيثيلين، التشميع، عمر التخزين

Introduction

Citrus (*Citrus paradisi* Macf.) is an important cash crop and an essential source of vitamin C (Mohamed, 2014). In Sudan the total production of grapefruit was 65000 tons and ranked second after South Africa in Africa. Estimated total area of grapefruit in Sudan was 42,000 ha (SNHA, 2001) and (FAOSTAT, 2013).

Fruits and vegetables have a high-water content ranging from 70-95% Bajwa and Anjum (2007). To reduce the postharvest losses, there is need to enhance shelf-life of fruits under ordinary marketing conditions because 25-30% of the horticultural produce goes waste due the absence of an efficient marketing and poor post-harvest handling (Mahajan *et al*, 2002).

Plastic packaging by polyethylene film is very important method for maintaining fruit quality during storage. It allows control of gas and in turn can affect physiological processes in fruit (Lange, 2000). Sonkar and Ladaniya (1999) reported that wrapping reduced the rate of water loss, respiration, fruit softening, and total acidity of mandarin.

Treating fruits with wax increased the shelf-life and at the same time improve quality of fruits. Application of wax slows down the permeability of water vapour and other gases (Mahajan *et al*, 2002). Moreover, Bajwa and Anjum (2007) reported that waxing reduced the chilling injury, rind staining and weight loss in mandarins. However, there is need to conduct trails to study the effect of waxes alone or in combination with packaging in horticultural fruits. Farmers in Kassala need simple technology to preserve their product for weeks and at the same time such treatment may enable the farmers to sell their products directly to the consumer avoiding whiteout any need to the brokers. Therefore, the objective of this study was to determine the effect of packaging and waxing on quality and shelf-life of grapefruit, at two levels of temperature.

Materials and Methods

Two experiments were conducted in the laboratory of Kassala and Gash Research Station, Kassala, latitude 15° 27´ N, longitude 36° 21´ E and altitude 505 masl during May and July of 2022 and 2023 at two levels of temperature *viz*; 35°C and 20°C.

Grapefruit fruits of the Red Blush cultivar were harvested from orchard at uniform size and colour and free from blemishes and other defects. The waxes were applied by brushing over the surface of the fruits in a thin layer. Cartons and polyethylene bags were used; some of the polyethylene bags were perforated while others were left intact.

Packaging treatments were arranged in the as following:

1. Unwrapped and unwaxed fruits placed in cartons (control).
2. Fruits were wrapped in intact polyethylene bags, and then placed in cartons.
3. Fruits were wrapped in perforated polyethylene bags, and then placed in cartons.
4. Fruits were waxed, and then placed in cartons.
5. Fruits were waxed and wrapped in intact polyethylene bags, and then placed in cartons.
6. Fruits were waxed and wrapped in perforated polyethylene bags, and then placed in cartons.

The six treatments of each experiment were arranged in a completely randomized design (CRD) with three replicates. Each experimental unit contained 10 grapefruit fruits.

Initial weights of fruits were determined then their weight was recorded weekly till they were out of quality. Weight loss was determined using the following formula:

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

Where:

w_o = initial weight and w_t = weight at designated time.

Total soluble solids (TSS) were determined weekly using a hand refractometer (Model HRN-32).

Total titratable acidity was determined weekly on a sample of 2ml juice diluted to 200 ml with distilled water and titrated against 0.1 N NaOH to a phenolphthalein end point (light pink colour) and calculated as percentage of citric acid. Total titratable acidity was determined using the following formula:

$$\text{Titratable acidity} = \frac{\text{ml of NaOH used} \times 0.1\text{N of NaOH} \times 0.064 \times 100}{\text{ml of Juice}}$$

Marginal rate of return was analyzed according to CIMMYT (1988) and used the field information and data collected for evaluation.

Data were subjected to analysis of variance procedures. Treatment means were separated using Duncans Multiple Range Test at 5% level of significance.

Results and Discussion

Effects of packaging and waxing on weight loss and shelf-life of grapefruit

Weight loss and shelf-life of the two experiments showed very highly significant differences in both seasons at 35°C and 20°C (Table 1, 2, 3 and 4). The lowest weight loss of grapefruits was recorded in fruits treated by wax and packaging in intact

polyethylene bag, while the highest weight loss was recorded for the control at 35°C and 20°C in both seasons (Table 1and 2). The longest shelf-life was recorded in wax with intact polyethylene bags and intact polyethylene bags, followed by waxed with perforated poly ethylene bags compared to control in both seasons at 35°C and 20°C (Table 3 and 4). This might be due to reduction of water loss when using wax or wrapping, subsequently increasing the shelf-life of the fruits. Similar results were reported by Elhadi *et al*. (2011) who reported that waxing fruit reduced weight loss and improved shelf-life of grapefruits. Moreover, Ibtihal *et al*. (2016) reported that packaged lime in intact film had longer shelf-life and lower weight loss compared to control in two seasons.

Table 1. Effect of packaging and waxing on weight loss of grapefruit under 35°C during two seasons.

Packaging treatments	Weight loss (%)	
	Season one	Season two
Control	24.4a	23.5a
Perforated poly ethylene bag	16.9b	23.2a
Intact poly ethylene bag	8.4c	7.9c
Wax	8.6c	8.7b
Wax with perforated poly ethylene bag	7.7c	6.5d
Wax with intact poly ethylene bag	4.6d	4.7e
Significance level	***	***
$SE^{\pm}$	0.79	0.21
CV%	11.59	2.95

****: indicated significant at P≤0.001.*

Table 2. Effect of packaging and waxing on weight loss of grapefruit under 20°C during two seasons.

Packaging treatments	Weight loss (%)	
	Season one	Season two
Control	31.0a	27.5a
Perforated poly ethylene bag	19.1b	24.7b
Intact poly ethylene bag	6.6cd	12.5d
Wax	7.4c	18.7c
Wax with perforated poly ethylene bag	6.1d	5.5e
Wax with intact poly ethylene bag	3.2e	4.2f
Significance level	***	***
$SE^{\pm}$	0.28	0.30
CV%	4.02	3.39

****: indicated significant at P≤0.001.*

Table 3. Effect of packaging and waxing on shelf-life of grapefruit under 35°C during two seasons.

Packaging treatments	Shelf-life (Days)	
	Season one	Season two
Control	7.0f	5.5f
Perforated poly ethylene bag	11.0e	12.4e
Intact poly ethylene bag	20.0b	23.0b
Wax	13.4d	18.0d
Wax with perforated poly ethylene bag	16.3c	20.0c
Wax with intact poly ethylene bag	26.8a	28.0a
Significance level	***	***
$SE^{\pm}$	0.43	0.50
CV%	4.71	4.81

****: indicated significant at P≤0.001.*

Table 4. Effect of packaging and waxing on shelf-life of grapefruit under 20°C during two seasons.

Packaging treatments	Shelf-life (Days)	
	Season one	Season two
Control	17.5f	18.4f
Perforated poly ethylene bag	22.0e	21.3e
Intact poly ethylene bag	71.0b	65.0b
Wax	28.0d	25.0d
Wax with perforated poly ethylene bag	65.5c	58.0c
Wax with intact poly ethylene bag	76.0a	73.0a
Significance level	***	***
$SE^{\pm}$	0.50	0.51
CV%	1.86	2.01

****: indicated significant at P≤0.001.*

Effects of packaging and waxing on total soluble solids and titratable acidity of grapefruit

Total soluble solids of grapefruit under 35°C and 20°C during both seasons are shown in Fig. 1, 2, 3 and 4. Total soluble solid increased during the storage period and the highest values of total soluble solids were observed in control while, the lowest values were recorded under wax with intact polyethylene bag followed by intact polyethylene bag in both seasons at 35°C and 20°C (Fig 1, 2, 3 and 4). The results recorded that the increase during storage in the control was higher compared to other treatments and this might be due to the high water losses in unpacked and unwaxed treatments. This result is in an agreement with Elhadi *et al*. (2011) who reported that packing and waxing affected total soluble solids levels during the storage period of grapefruit and the highest value of total soluble solids was observed in control treatment.

The effect of packing and waxing on titratable acidity of grapefruit under 35°C and 20°C during the both seasons were shown in Fig. 5, 6, 7 and 8. There is a clear decrease in titratable acidity during the storage period, but waxing with the packaging was less than those of the packaging alone and the control under 35°C. Wax with

intact poly ethylene bag recorded the lowest value of titratable acidity compared to control in both seasons (Figure 5and 6). Under 20°C there were an increase in titratable acidity in all treatments, until the week 6 and then it began to decrease, but it was noted that the lowest acidity was recorded with wax within intact poly ethylene bag treatment in both seasons (Figure 7 and 8). This may be due to the fact that reduction of water loss in wax and polyethylene bags being less compared to the control which in turn led to higher titratable acidity. These results are in arrangement with the findings of Abu-Goukh and Elsheikh, (2008) who found that waxing, decreased acidity during storage of grapefruit. However, Ahmed *et al*. (2007) reported that waxing decreased titratable acidity during storage of orange.

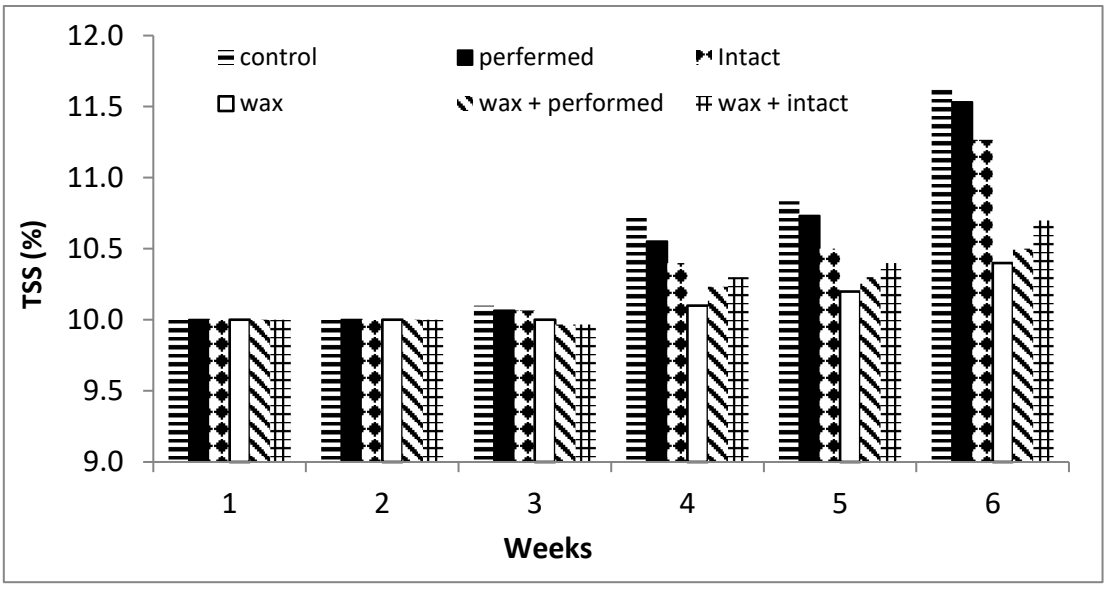

Figure 1. Effect of packaging and waxing on total soluble solids of grapefruit under 35°C during season one.

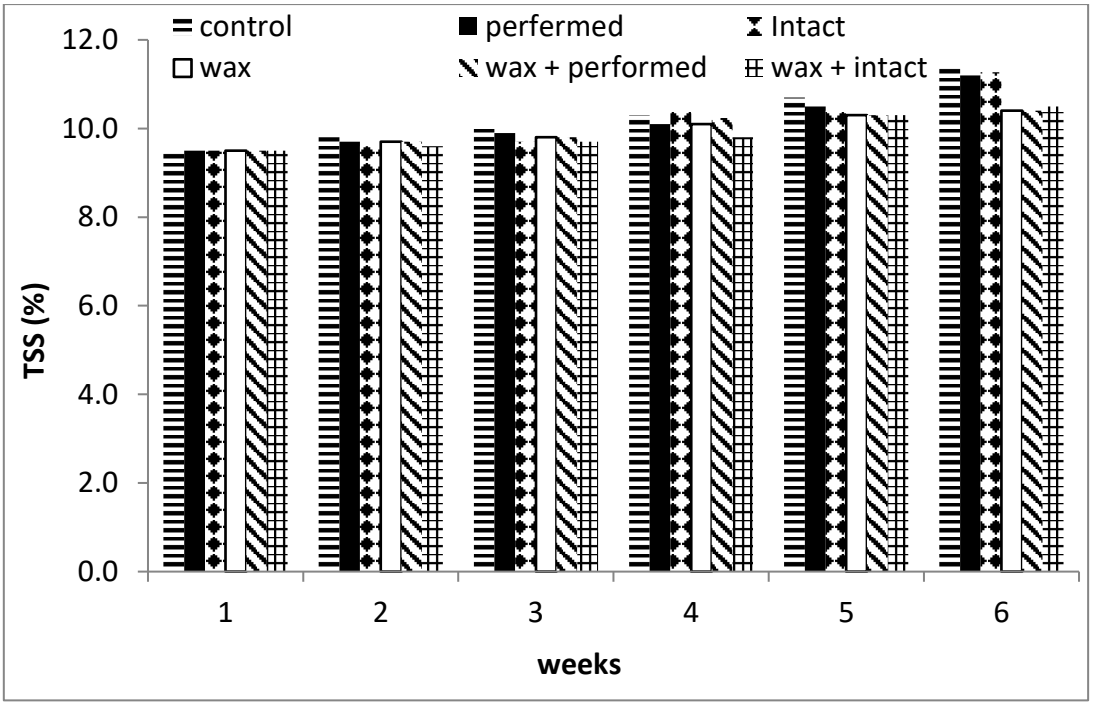

Figure 2. Effect of packaging and waxing on total soluble solids of grapefruit under 35°C during season two.

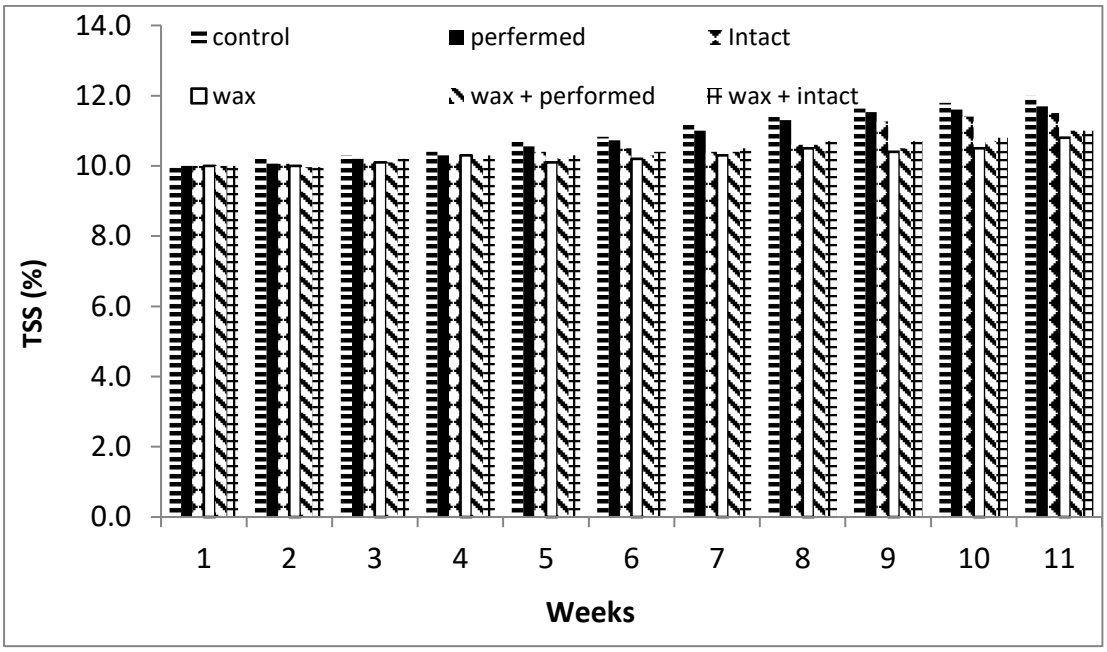

Figure 3. Effect of packaging and waxing on total soluble solids of grapefruit under 20°C during season one.

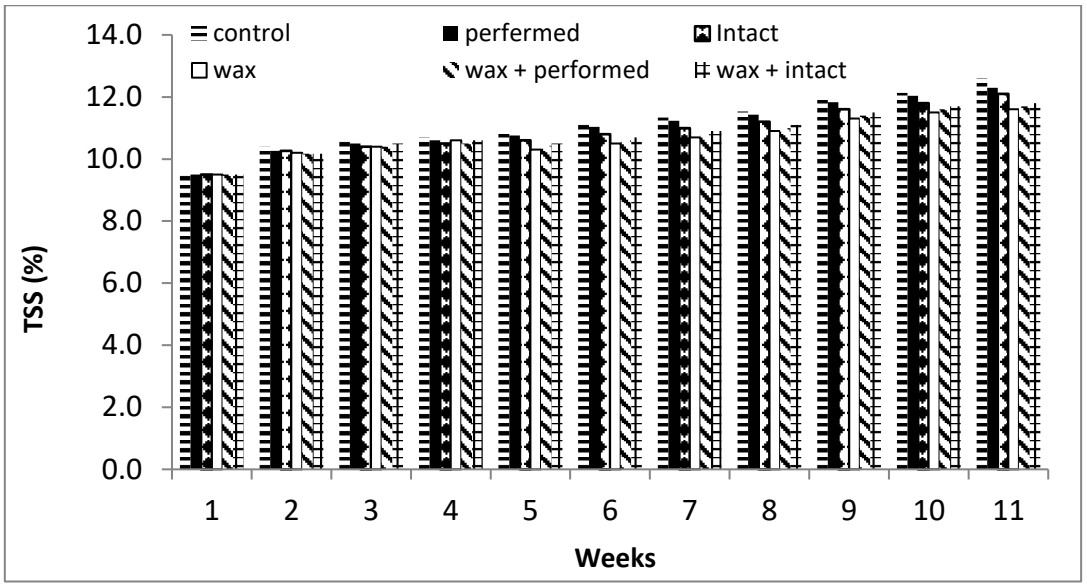

Figure 4. Effect of packaging and waxing on total soluble solids of grapefruit under 20°C during season two.

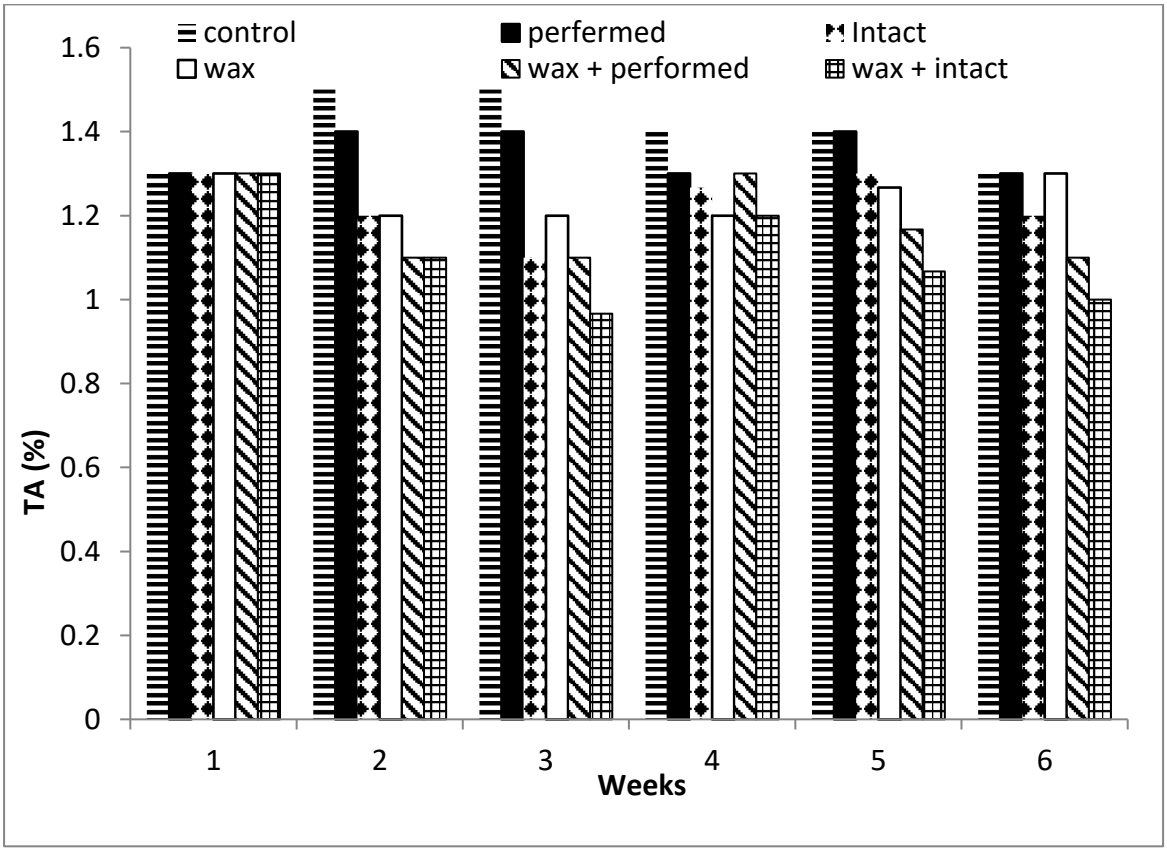

Figure 5. Effect of packaging and waxing on titratable acidity of grapefruit under 35°C during season one.

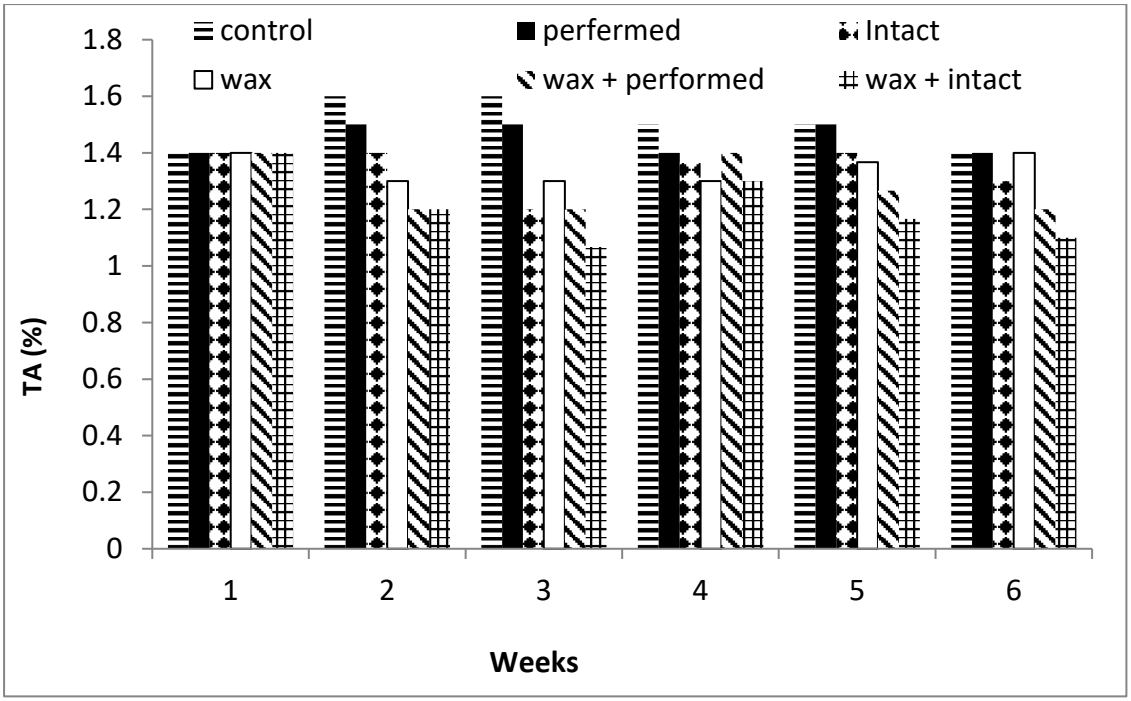

Figure 6. Effect of packaging and waxing on titratable acidity of grapefruit under 35°C during season two.

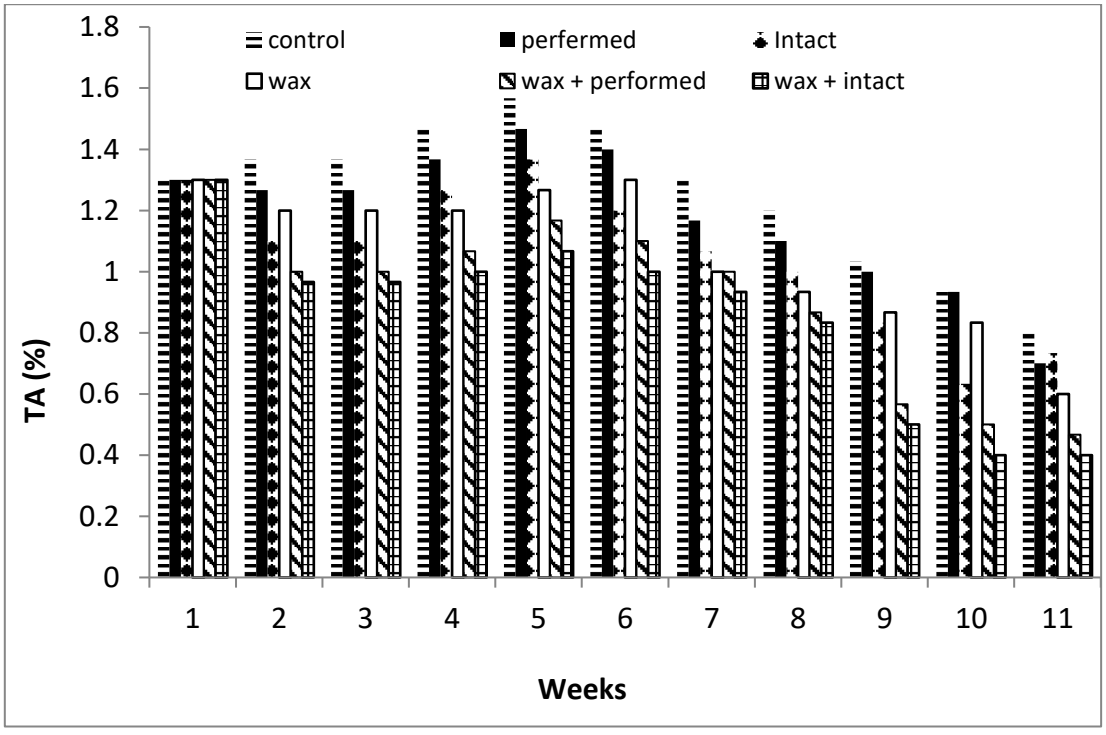

Figure 7. Effect of packaging and waxing on titratable acidity of grapefruit under 20°C during season one.

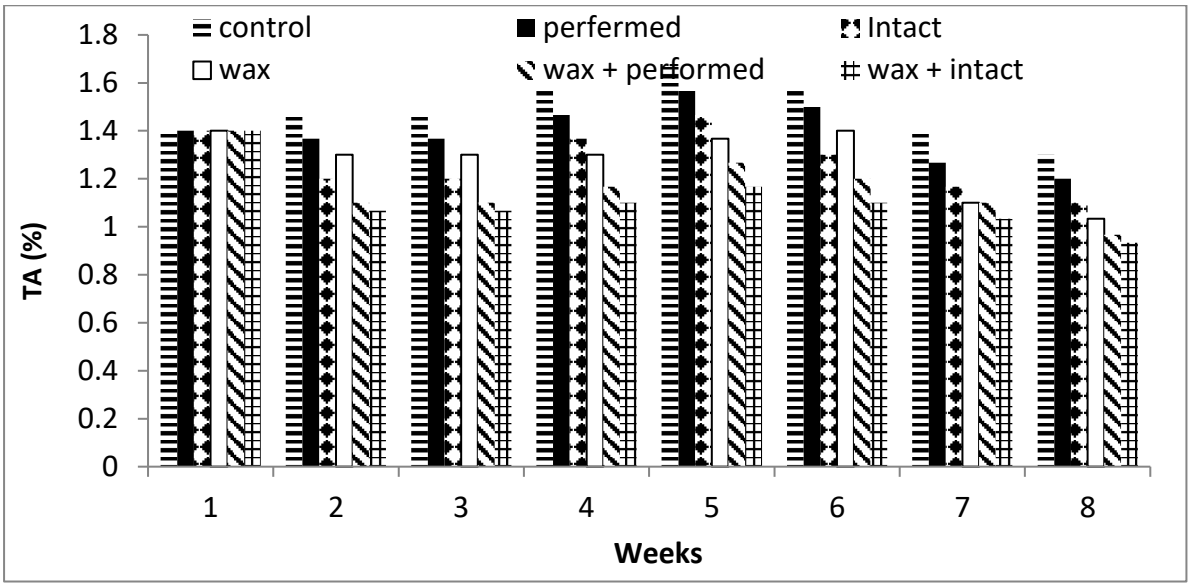

Figure 8. Effect of packaging and waxing on titratable acidity of grapefruit under 20°C during season two.

Effects of packaging and waxing on economic evaluation of grapefruit

In determining the most economically acceptable treatment, partial, dominance and marginal analysis were conducted for data of 10 grapefruits conducted in the laboratory of the Kassala and Gash Research Station, Kassala, Sudan under two types of temperature *viz*; 35°C and 20°C. All costs and returns were calculated on per-ton weight basis in SDG. Results showed treatment of waxing with packaging in intact polyethylene bag followed by intact polyethylene bag improved the quality and storability of grapefruit fruits under 35 and 20°C conditions and realized the highest returns of investment. Return to investment in this treatment was estimated in the form of marginal rate of return (MRR), which came out to be 9.15 and 4.87 for improved quality and storability of grapefruit fruits under 35 and 20°C conditions, respectively (Tables 5 to 8).

Therefore, the economic evaluation based on partial budget and marginal analysis indicated that to improve the quality and storability of grapefruit fruits under 35 and 20°C conditions, respectively using of waxing with packaging in intact polyethylene bag followed by intact polyethylene bag improved the quality and storability of grapefruit fruits under 35 and 20°C conditions and realized the most stable and economically feasible treatment.

Table 5. Partial and dominance analyses for grapefruit in per ton basis in Kassala area under 35°C.

Packaging treatments	Weight loss (%)	Shelf life (days)	Net weight (ton)	Price of (1 ton)	Loss in price	Variable cost (SDG/ton)	Gross return (SDG/ton)	Net return (SDG/ton)	Dominated
Normal	0	0	1.00	100000	0	0	100000	100000	
Control	24	6	0.80	130000	31135	1000	97865	96865	D
Perforated poly ethylene bag	20	12	0.80	160000	32080	11000	116920	105920	
Intact poly ethylene bag	8	22	0.92	240000	19560	19300	201140	181840	
Wax	9	16	0.91	200000	17300	21300	161400	140100	D
Wax with perforated poly ethylene bag	7	18	0.93	200000	14200	29300	156500	127200	D
Wax with intact poly ethylene bag	5	27	0.95	280000	13020	31300	235680	204380	

Table 6. Marginal analysis for grapefruit in per ton basis in Kassala area under 35°C.

Packaging treatments	Gross return (SDG/ton)		Net return (SDG/ton)	MC	MR	MRR
Normal	100000	0	100000			
Perforated poly ethylene bag	116920	11000	105920	11000	5920	0.54
Intact poly ethylene bag	201140	19300	181840	8300	75920	9.15
Wax with intact poly ethylene bag	235000	31300	204380	12000	22540	1.88

Table 7. Partial and dominance analyses for grapefruit in per ton basis in Kassala area under 20°C.

Packaging treatments	Weight loss (%)	Shelf life (days)	Net weight (ton)	Price of (1 ton)	Loss in price	Variable cost (SDG/ton)	Gross return (SDG/ton)	Net return (SDG/ton)	Dominated
Normal	0	0	1.00	100000	0	0	100000	100000	
Control	29	18	0.71	240000	69600	10000	170400	160400	
Perforated poly ethylene bag	22	22	0.78	260000	56940	22000	203060	181060	
Wax	13	27	0.87	320000	41760	34800	278240	243440	
Intact poly ethylene bag	10	68	0.90	380000	36290	53300	343710	290410	
Wax with perforated poly ethylene bag	6	62	0.94	340000	19720	60300	320280	259980	D
Wax with intact poly ethylene bag	4	75	0.94	380000	14060	68800	365940	297140	

Table 8. Marginal analysis for grapefruit in per ton basis in Kassala area under 20°C.

Packaging treatments	Gross return (SDG/ton)		Net return (SDG/ton)	MC	MR	MRR
Normal	100000	0	100000			
Control	170400	10000	160400	10000	60400	6.04
Perforated poly ethylene bag	203060	22000	181060	12000	20660	1.72
Wax	278240	34800	243440	12800	62380	4.87
Intact poly ethylene bag	343710	53300	290410	18500	46970	2.54
Wax with intact poly ethylene bag	365940	68800	297140	15500	6730	0.43

Conclusion

Waxing with packaging in intact polyethylene bag followed by intact polyethylene bag improved the quality and storability of grapefruit fruits under 35 and 20°C conditions.

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