

Effects of Gibberellic Acid (GA₃) and Salicylic Acid (SA) postharvest treatments on the quality of fresh Barhi dates at different ripening levels in the Khalal maturity stage during controlled atmosphere storage

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Abstract: Barhi dates at Khalal maturity stage are well-known with their pleasant taste, crispy texture, and bright yellow color. It is necessary to extend the duration of Barhi Khalal stage which is too short for effective marketing. This study aimed to inspect the effects of Gibberellic Acid (GA₃) and Salicylic Acid (SA) postharvest treatments on retaining the high quality of Khalal Barhi fruits during controlled atmosphere storage. Fresh samples of Barhi fruits at Khalal stage harvested at three different ripening levels were dipped after harvesting in GA₃ (150 ppm) or SA (2.0 mmol/L) and subsequently stored in controlled atmosphere (0°C, 5% O₂, 5% CO₂, 80%±5% RH). The results revealed that the GA₃ and SA treatments reduced the percentage of weight loss and decay in the fruits, while the total soluble solids increased. Moreover, GA₃ and SA treatments were significantly efficient in limiting the changes in fruit color and texture of Barhi dates compared to the control. Sensorial results support the experimental data and disclosed that the GA₃ (150 ppm) treatment in the controlled atmosphere (CA) storage was better in conserving the quality of Barhi at the Khalal maturity stage and delaying ripening process.

Keywords: Barhi dates, Khalal maturity stage, Gibberellic Acid (GA₃), Salicylic Acid (SA), postharvest treatments, controlled atmosphere (CA) storage

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1 Introduction

The date fruits of the palm tree (*Phoenix dactylifera* L.) represent an important segment of the economy in many producing countries, especially in the Middle East and North Africa countries^[1]. The date fruit is a good source of fiber, carbohydrates, minerals and vitamins^[2-6]. Date fruits maturation goes through five stages: Hababouk, Kimri, Khalal (Bisir), Rutab and Tamer Figure^[1]. Normally, dates are harvested and marketed at the last three stages of maturity and can be consumed soft, semi-dry or as dry fruits, depending on cultivar features, climatic conditions and market demand^[7-9].

Fresh dates, such as Barhi cultivar, are popular and widely consumed at the Khalal stage of maturity (first edible stage) when the fruits are crispy and sweet with a bright yellow color. Barhi fruits at the Khalal stage are more favorable and sold at higher rates compared to the Rutab and Tamer stages, however, the time for

effective marketing is too short. A critical challenge is the preservation of the high quality of Barhi dates for the longest possible period after harvesting and during the marketing process^[10,11].

Monitoring and controlling the optimum fruits harvesting time can play a significant role in maintaining quality, reducing losses, and maximizing shelf life in storage. Delay in fruits harvesting could possibly induce ripening, color and texture changes, and thus less ability to withstand storage conditions^[12,10].

Postharvest storage life of fruits and vegetables can be extended by the application of controlled atmosphere (CA), modified atmosphere (MA) or modified atmosphere packaging (MAP)^[13]. Nevertheless, the application of these techniques might be accompanied by chemical and physical changes, which result in losses in quality and reducing the consumer acceptance. Postharvest treatments such as dipping in gibberellic acid (GA₃) could be used to prevent these changes. Dipping in GA₃ prior to storage is applied to a wide range of fruits and achieved good results in quality preservation. Al-Qurashi and Awad^[9] reported that postharvest dipping in GA₃ inhibited ripening and slightly improved the quality of cold stored Barhi dates at Khalal (bisir) stage. In addition, GA₃ at 150 ppm concentration significantly slowed down rate of fruit color changing and softening.

Likewise, SA as a natural and safe signaling molecule was recommended by Asghari and Aghdam^[14]. The authors showed high potential in delaying ripening, enhancing quality and controlling postharvest losses of fruits and vegetables by SA acid application. SA could be considered as an endogenous plant growth regulator involved in the regulation of physiological processes and disease resistance mechanisms^[15]. Treatment of SA

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at 2.0 mmol/L on plum fruit was the most effective concentration in preserving firmness and reducing weight loss, color progress, and disease incidence^[16]. Some other studies showed that SA could be used at 1.0 mmol/L, 2.0 mmol/L, 3.0 mmol/L and 4.0 mmol/L to preserve strawberry, peach and pears fruits for up to five weeks without decay. However, high concentrations of SA increase in

oxidative damage^[9,17].

The objective of this study was to inspect the effects of GA₃ and SA postharvest treatments on the texture, color, total soluble solids (TSS), weight loss, and fruit decay percentage of fresh Barhi dates at three different ripeness levels of the Khalal maturity stage during controlled atmosphere storage.



Figure 1 Five stages of maturation of Barhi fruit

2 Materials and methods

2.1 Barhi fruits

Barhi dates at the Khalal stage of maturity were obtained from a local farm in Riyadh, Saudi Arabia during 2016 season (10 July - 15 September). The fruits were picked at three different harvesting times (7 days' interval) i.e. at different ripening levels (R1, R2, and R3). The first collection (R1) was done at the early Khalal stage (about 94 d from pollination), the second (R2) at the

middle of the stage, and the third (R3) near the end of Khalal stage and before the beginning of the Rutab stage. Each collection of fruits was brought on the day of harvesting to the Food Processing Laboratory at King Saud University, Riyadh. For each time, the fruits were cleaned with mildly pressurized air and sorted to remove the defected ones. The sound fruits were used for further experiments. The initial physical properties of the Barhi fruits of the three ripening levels (R1, R2 and R3) were determined and the obtained data were listed in Table 1.

Table 1 Mean value of the physical properties for the fresh Khalal Barhi fruits at three ripening degrees

	Mass/g	Volume/cm ³	Length/mm	Diameter/mm	Moisture content (w.b)/%	TSS/%	Color		
							L	a	b
R1	8.76±0.84	9.78±0.34	27.85±0.18	22.53±0.25	76.00±0.81	15.07±0.52	49.89±0.94	1.63±0.45	27.43±0.59
R2	9.08±0.23	10.08±0.18	28.67±0.09	22.77±0.48	70.99±1.1	20.31±0.37	50.91±0.69	1.82±0.31	29.18±0.37
R3	9.23±0.42	10.08±0.65	28.70±0.14	23.19±0.25	66.28±1.02	26.31±0.27	52.48±0.91	2.04±0.40	30.40±0.54
n	50	50	50	50	50	50	50	50	50

2.2 Postharvest treatments and storage methods

Khalal Barhi fruits from each batch (R1, R2 and R3) were divided into three groups for the following treatments: the first group was dipped in GA₃ (150 ppm), the second group was dipped in SA (2.0 mmol/L), and the third group was dipped in water only (control). GA₃ and SA concentrations were chosen from preliminary experiments. SA treatment was prepared at 2 mmol/L. GA₃ was prepared at 150 ppm concentration. Large perforated rigid plastic boxes (each ~10 kg) were used for dipping the fruits. The fruits were dipped for 3 min. Subsequently, the treated fruits were dried at room temperature for 30 min then all samples (treated and control) were packed in the plastic boxes and loaded into CA storage room (0°C, 5% O₂, 5% CO₂, 80%±5% RH)^[18].

2.3 Measurements

The measurements on the various quality attributes of the Barhi fruits were taken initially for the fresh fruits and then observed every 20 d during the CA storage. The stored fruits were allowed to reach room temperature before running the planned tests. The measurements were continued for 40 d and 120 d in cold storage and CA storage, respectively, when the stored fruits became 50% ripen into rutab or started to deteriorate.

Fruit weight loss was measured by means of a digital balance and the percent weight loss was calculated on the initial weight basis. The TSS of Barhi fruits was measured at room temperature (25°C) using a digital refractometer (Abbe 5 Refractometer, Bellingham + Stanley (BS), Jena, Germany) and expressed as a percentage^[19]. Fruit decay percentage was calculated as defined by Alhamdan et al.^[18]

The color of the Barhi fruits was measured with a Hunter Lab-scan XE spectrophotometer in terms of Hunter basic color parameters L, a and b, where L indicates (whiteness or brightness/darkness), a (redness/greenness) and b (yellowness/blueness). The mean values of the basic color parameters (L, a and b) were used to calculate the derivatives color values (total color difference (ΔE), and Hue angle (H)) as described by Maskan^[20].

The textural parameters of the Barhi fruits were measured using a texture analyzer (TA-HDi, Model HD3128, Stable Micro Systems, Surrey, England). Fruit samples were compressed with a rod velocity of 1.5 mm/s to a depth of 5 mm. The obtained force-time deformation curves were used to calculate the following textural parameters: hardness, elasticity and chewiness^[11].

2.4 Sensory evaluation

Sensory evaluation of the quality of the fresh and stored Barhi fruits was performed by ten semi-trained panelists (arbitrators). The sensory evaluation experiments were completed using the 9-point hedonic scale^[21,22]. The selected sensory attributes were: color, texture, taste and overall acceptability. The responses are converted to numerical values ranging from 1 for 'dislike extremely' to 9 for 'like extremely' with a central point of 'neither like nor dislike'.

2.5 Statistical analysis

The IBM SPSS software package (IBM SPSS version 22) was used for analyzing the experimental data by means of analysis of variance (ANOVA). The least significant difference (LSD) multi-comparison test was carried out to establish statistical

differences between the calculated means and significant differences were reported ($p \leq 0.05$).

3 Results and discussion

3.1 Weight loss

It is clear that the fruit weight loss of all samples rises considerably with time after the first 20 d in CA storage (Figure 2a). However, there were no significant further rises in fruit weight loss and it almost comes to be constant for most of the samples.

After 60 d in CA storage, the weight loss in R1 samples increased by 1.35%, 1.01% and 0.49% of control, SA-treated and GA₃-treated samples, respectively, and R2 samples were 1.55%, 1.34% and 1.13%, respectively. While the increases were 2.24% 1.98% and 1.53% of R3 samples, respectively. After 120 d in CA storage, the R1 fruits weight loss increased by 1.51%, 1.02% and 0.79% of the control, SA-treated and GA₃-treated samples, respectively, and the R2 were 1.73%, 1.44% and 1.35%, respectively. But, the R3 fruits weight loss increased by 2.14%, 2.01% and 1.58%, respectively. The lowest weight loss was apparent in R1 (GA₃-treated) fruits and the highest weight loss was achieved by R3 (control) fruits. At the middle of the storage period (60th day), there were no significant differences between R3 (GA₃) and R3 SA-treated fruits. However, significant differences were seen between R3 (GA₃-treated) fruits and the rest of samples at the end of the storage period of 120 d.

Fruit weight loss is mostly owed to the loss of water caused by transpiration, respiration and vapor pressure deficit (VPD) between the fresh fruit and the surrounding air. Water loss leads to a fast increase in the sugar concentration initiating ripening of the fruits^[23]. Postharvest treating by GA₃ and SA restricted water transfer through the fruit skin and delayed respiration by constraining ethylene biosynthesis hence reducing weight loss^[24]. Dipping in GA₃ revealed to be more efficient in decreasing weight loss compared to SA-treated and untreated control Barhi dates. The influence of GA₃ dipping in decreasing weight loss can be attributed to the increase of moisture holding capacity and reduced moisture evaporation. Similar findings in the effect of GA₃ were stated^[9, 25].

3.2 TSS

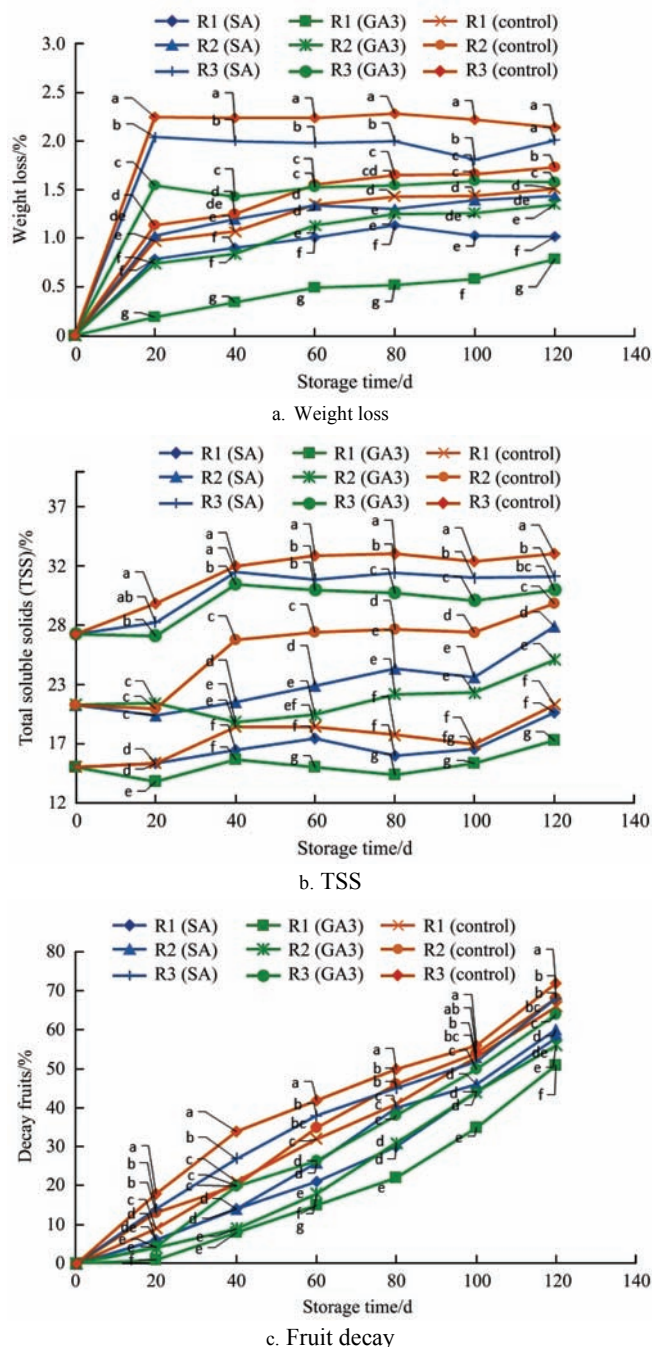
It can be seen that the TSS of the treated and untreated control samples of Barhi dates showed an increasing trend with storage time during CA storage (Figure 2b). The minimum changes in TSS were observed for the GA₃-treated samples at the three ripening levels.

After 60 d in CA storage, the TSS of R1 samples increased by 22.5%, 15.83% and 0.015% of the control, SA-treated and GA₃-treated, respectively, and R2 samples increased by 30.5%, 8.12% and 4.08%, respectively. However, the TSS of R3 samples increased by 25.06%, 17.46% and 14.15% respectively. At the end of the storage period (120 d) the TSS of the fruits of the ripening level R1 increased by 34.99%, 30.74% and 15.09% of the control, SA-treated and GA₃-treated samples, respectively, while, the increases of R2 fruits were 42.01%, 32.77% and 18.75% , respectively. TSS increased by 34.99%, 30.74% and 15.09% for the control, SA-treated and GA₃-treated samples of the R3 fruits, respectively.

Throughout the CA storage, the changes in TSS of the GA₃-treated samples at R1 were significantly different compared to the rest of samples. After 60 d in CA storage, no significant differences were seen among the GA₃-treated fruits at R2 and the

untreated fruits at R1. At the end of CA storage, there are no significant differences between all treated fruits at R3, while a significant difference exists between GA₃-treated fruits at R2 and the rest of the samples.

The increase of TSS in fruits during storage is owing to the reduction in moisture and to the enzymatic conversion of higher polysaccharides into simple sugars^[26]. The increase in TSS of dates by developing of ripening was also reported previously^[10,27]. The minor increase of TSS in the treated samples might be due to the fact that dipping in GA₃ or SA formed a thin layer on the surface of Barhi fruits which slowed down moisture reduction conversion process of polysaccharides. Alike results were informed by other researchers^[9,25].



Note: Means with different letters in treatment indicate significant differences according to LSD test ($p \leq 0.05$) ($n=5$).

Figure 2 Changes in weight loss, TSS and fruit decay of Khalal Barhi fruits at three degrees of ripening as affected by GA₃ and SA dip treatments and storage time during CA storage

3.3 Fruit decay

The fruit decay of the treated and control samples increased with time during CA storage is shown in Figure 2c. The minimum changes in fruit decay were detected in the GA₃-treated samples, particularly at R1 and R2.

After 60 d in CA storage, the fruit decay in R1 samples increased by 32.0%, 21.0% and 15.0% of the water treated, SA-treated and GA₃-treated, respectively, and it increased by 35.0%, 26.0% and 18.0% of R2 samples, respectively. But, the fruit decay of R3 samples increased by 42.0%, 38.0% and 26.4%, respectively. At the end of the storage period, the fruit decay in R1 samples increased by 66.0%, 58.0% and 51.0%, respectively, and it increased by 68%, 60.0% and 56.0% of R2 samples, respectively. But, the fruit decay of R3 samples increased by 72.0%, 68.0% and 64.0%, respectively.

At the middle of the storage period, no significant differences were observed among the R3 (GA₃-treated) and R3 (SA-treated) fruits. While there are significant differences between the GA₃-treated fruits at the third level of ripening and the rest of sample for the three levels of ripening at the end of the storage period.

Enhancement in storability Khalal Barhi fruits was probably credited to the ability of SA and GA₃ to form a semi-permeable membrane, which adjusted the internal temperature of the fruits and reduced transpiration losses. Both SA and GA₃ treatments preserved peroxidase activity at regular levels resulting in steady production of free radicals, which enhanced storability and quality of the fruits. Furthermore, Zhang et al.^[28] stated that the SA treatment reduced respiration and weight loss of fruit by closing the minute openings in the fruit skin and hence delay fruit ripening, senescence and fruit decay during storage.

Al-Qurashi and Awad^[9] stated that the rutab percentage in treated bisir (Khalal) Barhi fruits was significantly reduced by the application of GA₃ compared to control and other treatments. GA₃ treatment of banana had a positive effect on delaying biochemical and physiological processes leading to ripening^[29].

3.4 Color

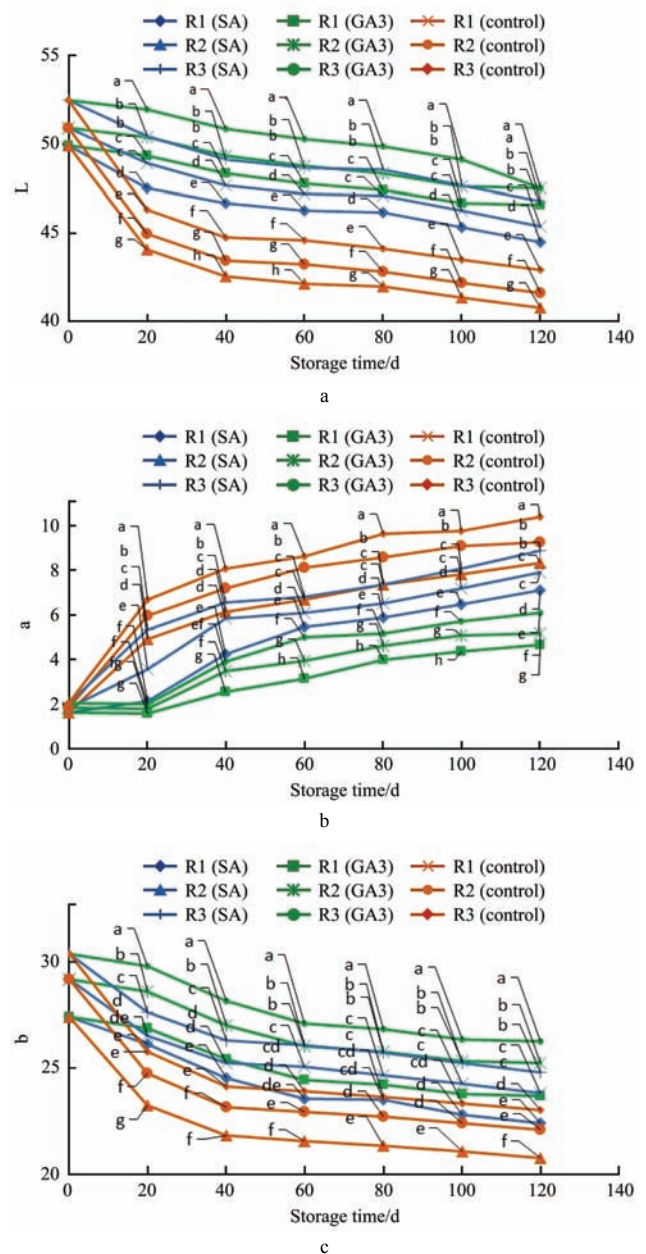
3.4.1 Basic color parameters

The initial mean values of the basic color parameters L, a, and b for the fruits at R1, R2 and R3 were presented in Table 1. It is obvious that the higher values of L, a and b parameters are for the Barhi fruits at R3 followed by R2 which indicates that the color of Barhi dates at Khalal stage changed from yellow/green to yellow/orange by progressing of ripening. The effects of GA₃ and SA dipping on the basic color parameters (L, a and b) of Barhi fruits at the ripening levels during CA storage methods are depicted in Figure 3.

Figures 3a and 3b show that L and b values decreased for all samples with the advancement of storage period showing that the bright yellow color of the samples was turning darker and browner. The L- and b- values of the untreated samples decreased significantly compared to the treated ones for the three ripening levels. As well, significant differences were noticed between L and b values of the R3 (GA₃-treated) samples and L and b values for all other samples. The highest reduction in L- and b- values was detected for the control fruits, while the least reduction in their values was observed for fruits treated with GA₃ at the three ripening levels. Figure 3b shows that a-value increased with storage time for all samples of Barhi dates at the three ripening levels. The increase in parameter a-value indicates more redness in the fruits skin color. The a-parameter values of the control at

the three ripening levels were higher compared to that of the treated samples. The minimum changes in parameter a- values were observable in the GA₃-treated fruits at the three ripening levels.

The highest color change was observed in control (untreated fruits), but GA₃-treated samples showed the lowest changes. The observed delay in color change of treated Barhi fruits with GA₃ as compared to Barhi fruits in control group could be due to the retarding effect of this hormone on the synthesis of ethylene and, hence, reduced the respiration rate of the fruits in concentration dependent manner. The results are also in agreement with previous reports that GA₃ retarded color development in banana^[30].



Note: Means with different letters in treatment indicate significant differences according to LSD test ($p \leq 0.05$) ($n=5$).

Figure 3 Changes in basic color parameters of Khalal Barhi fruits at three degrees of ripening as affected by GA₃ and SA dip treatments and storage time during CA storage methods

3.4.2 Derivative color parameters

As seen in Figure 4a, the total color difference (ΔE), which is a colorimetric parameter widely used to describe the changes in colors during food processing, increased with storage time for all samples at the three ripening levels. The increase of ΔE was

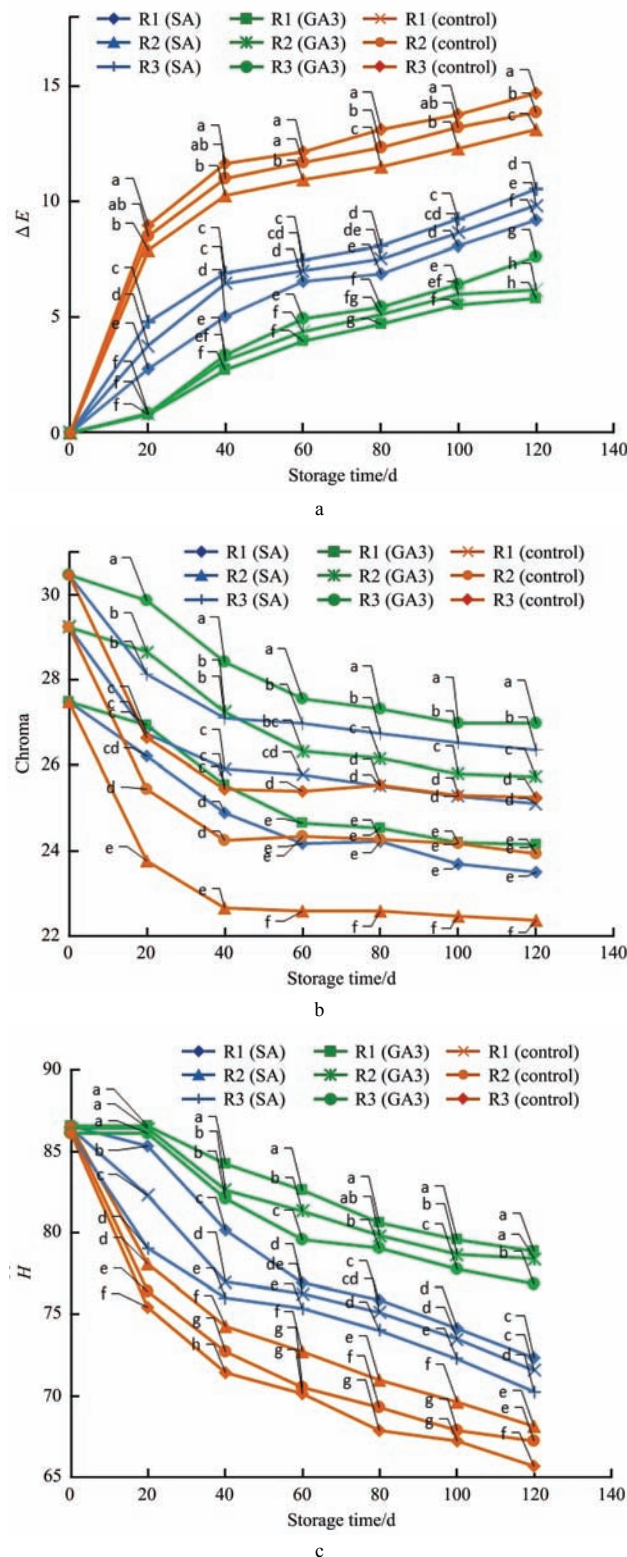
significantly higher in the control fruits compared to the treated fruits for the three ripening levels. The minimum change in ΔE was detected in The GA₃-treated fruits for the three ripening levels. After 60 d in storage, ΔE values of R1 of the control, SA-treated and GA₃-treated fruits were 10.95, 7.01 and 4.38, respectively, and the values of R2 were 11.70, 7.74 and 4.38, respectively. While, the values of R3 were 12.15, 7.47 and 4.94, respectively. After 120 d in storage, ΔE values of R1 were 13.11, 9.22 and 5.83, respectively, and the values of R2 were 13.85, 9.83 and 6.19, respectively. However, the values of R3 were 14.70, 10.52 and 7.62, respectively. Throughout the storage period, ΔE of the treated samples was significantly lower than that of the untreated samples for the three ripening levels. Also, significant differences in ΔE values were observed between the GA₃ and SA treatments for the three ripening levels in favor of GA₃. The results revealed that GA₃ treatment is better in retaining Barhi color at Khalal stage than SA treatment, especially at the first and second ripening levels.

The values of Chroma of all samples decreased with storage time for the three tested ripening levels in Figure 4b. Chroma values decreasing designate a reduction in the degree of saturation and intensity of fruit color^[31]. The minimum reduction in Chroma values was gotten by GA₃-treated samples of the three ripening levels. After 60 d in storage, Chroma values of the control, SA-treated, and GA₃-treated fruits of R1 decreased by 17.8%, 12.03% and 10.24%, respectively, and the decreasing of R2 were 16.77%, 11.8% and 9.96%, respectively. Though at R3, the reductions in Chroma of the control, SA-treated, and GA₃-treated fruits values were 16.6%, 13.48% and 9.52%, respectively. After 120 d in storage, Chroma values decreased by 18.61%, 14.50% and 12.08% of R1, respectively, and for R2 by 18.09%, 14.50% and 12.08%, respectively. But, the reductions of R3 in Chroma values were 17.13%, 13.48% and 11.46% respectively. These results showed a greater increase in Chroma values of the fruits at the first ripening level compared to the second and third levels, indicating that the degree of saturation and intensity of fruit color were better retained at the second and the third ripening levels.

Figure 4b displays the values of hue angle for the treated and untreated control samples. Values of hue angle parameter which normally used to describe color in food products decreased with storage time for the three ripening levels. The least reduction in hue angle values was attained by GA₃-treated samples for the three ripening levels. After 60 d in storage, hue angle values of the control, SA-treated and GA₃-treated fruits of R1 decreased by 15.98%, 11.10% and 4.54%, respectively, and the values of R2 decreased by 18.37%, 11.70% and 5.86%, respectively. While the reduction of R3 in hue angle values was 18.54%, 12.50% and 7.60%, respectively. After 120 d in storage, hue angle values decreased by 21.25%, 16.43% and 8.84% for the control, SA-treated, and GA₃-treated fruits of R1, respectively, and by 22.16%, 17.14% and 9.24% of R2, respectively. Whereas, the reductions in Chroma values of R3 were 23.74%, 18.42% and 10.71% for the control, SA-treated, and GA₃-treated fruits, respectively. These results showed a greater decrease in hue angle values of the Barhi fruits at R1 compared to the other two ripening levels. It is clear that at the middle of the storage period there were significant differences between the GA₃-treated fruits at R1 and the rest of the treated and untreated samples (Figure 4b). At the end of the storage period, there were no significant differences between R1 and R2 for the GA₃-treated samples.

The results on the basic and derivative color parameters showed that the GA₃ treatment gave the best results in preserving

the color of Barhi fruits during CA storage followed by the SA treatments. Minimum change in color values of GA₃-treated during storage may be ascribed to the positive effect of GA₃ in deferring ethylene evolution, respiration rate, and enzyme activity thus delaying ripening and senescence. These findings are verifying other researches that indicated the useful effects of GA₃ dip treatment in delayed fruit ripening and color changes^[9,32,33].



Note: Means with different letters in treatment indicate significant differences according to LSD test ($p \leq 0.05$) ($n=5$).

Figure 4 Changes in derivative color parameters of Khalal Barhi fruits at three degrees of ripening as affected by GA₃ and SA dip treatments and storage time during CA storage

3.5 Textural parameters

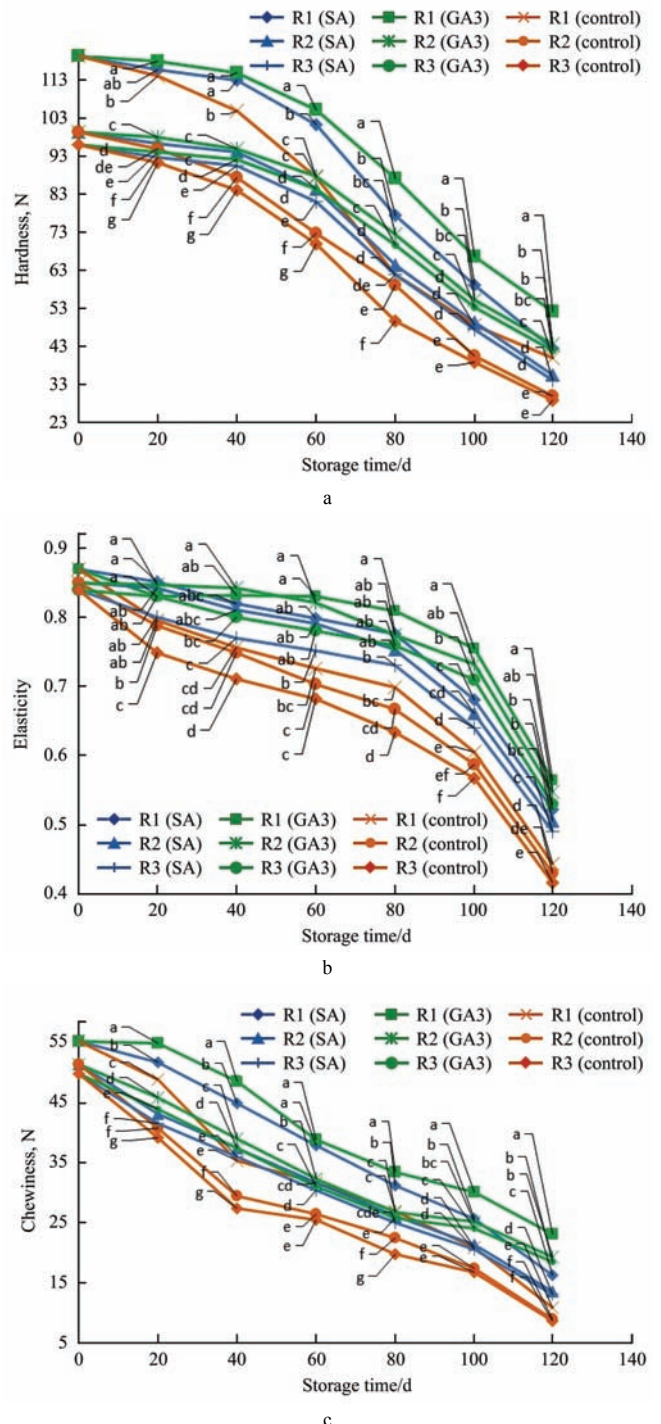
The data on the effects of GA₃ and SA dip treatments on the textural parameters (hardness, elasticity and chewiness) of Khalal Barhi fruits harvested at three different ripening levels (R1, R2 and R3) during storages is depicted in Figure 5. Fruit hardness, elasticity, and chewiness are indicators of fruits texture which is a very important feature that affects consumer acceptance.

The initial mean values of the fruit hardness of Khalal Barhi dates of R1, R2 and R3 ripening levels were 119.96 N, 99.81 N and 96.64 N, respectively, showing that the increase of hardness/firmness of Barhi fruits at Khalal stage by progressing of ripening level. The fruit hardness decreased with storage time in all tested samples during CA storage (Figure 5a). After 60 d in storage, R1 fruits hardness decreased by 26.60%, 15.60% and 12.30% of the control, SA-treated and GA₃-treated samples, respectively, and R2 fruits hardness decreased by 26.5%, 15.03% and 11.98% respectively. While, R3 fruits hardness decreased by 27.03%, 15.60% and 12.30%, respectively. After 120 d in CA storage, R1 fruits hardness decreased by 66.20%, 64.10% and 56.00%, respectively, and R2 fruits hardness decreased by 69.40%, 64.03% and 55.90% respectively. But, R3 fruits hardness decreased by 69.64%, 64.28% and 55.90%, respectively. The minimum reduction in fruit hardness values during storage was noted for R1 (GA₃-treated) fruits, whereas, the maximum values were attained by R3 (control). Throughout the storage period, the reduction in hardness of the R1 (GA₃-treated) fruits was significantly lower compared to all other samples.

The initial mean values of the fruit elasticity of the Khalal Barhi dates at R1, R2, and R3 were 0.91, 0.89 and 0.88, respectively. Figure 5b displays the reduction of elasticity values of the treated and control fruits with storage time. The minimum reduction of elasticity values was achieved by the GA₃-treated fruits followed by SA-treated fruits of R1 and R2. However, the maximum reduction in elasticity values was seen in the control at the three ripening levels. After 60 d in CA storage, the reduction in elasticity values of R1 fruits were 15.86%, 7.82% and 4.40% of the control, SA-treated, and GA₃-treated samples, respectively, and of R2 fruits were 16.42%, 6.68% and 3.25%, respectively. While, the fruits hardness of R3 decreased by 17.95%, 10.11% and 6.82%, respectively. After 120 d in CA storage, R1 fruits elasticity decreased by 46.85%, 38.20% and 33.57%, respectively, and of R2 were 47.20%, 38.60% and 34.00%, respectively. However, the fruits elasticity of R3 decreased were 48.18%, 39.80% and 35.22%, respectively. At the middle of CA storage (60th day), there were no significant differences between the reduction in the elasticity values of GA₃-treated samples at the three ripening levels and that of SA-treated samples at R1 and R2. Likewise, at the end of storage, there were no significant differences in the reduction in the elasticity values of GA₃-treated at R1 and R2 samples.

The initial mean values of the fruit chewiness of Khalal Barhi dates at R1, R2 and R3 were 55.28 N, 51.42 N and 49.83 N, respectively. It is evident that the chewiness of the Barhi fruits decreased with storage time for all tested samples (Figure 5c). The lowest decrease of chewiness values was achieved by R1 (GA₃-treated) fruits and the R3 (control) attained the highest decrease. After 60 d in storage, the fruits chewiness of R1 decreased 42.47%, 31.25% and 29.69% of the control, SA-treated, and GA₃-treated samples, respectively, and of R2 were 48.47%, 38.40% and 37.00%, respectively. While, the fruits chewiness of R3 decreased 48.86%, 37.50% and 38.89%, respectively. After

120 d in CA storage, R1 fruits chewiness decreased 80.38%, 70.50% and 58.00%, respectively, and of R2 were 82.40%, 73.56% and 62.40% respectively. But, fruits chewiness of R3 decreased 82.56%, 73.70% and 62.70%, respectively. The reduction in chewiness values of R1 (GA₃-treated) and R1 (SA-treated) samples were significantly comparable at the middle of CA storage (60th day). Whereas, at the end of storage chewiness values of R1 (GA₃-treated) samples were significantly higher than the rest of samples.



Note: Means with different letters in treatment indicate significant differences according to LSD test ($p \leq 0.05$) ($n=5$).

Figure 5 Changes in textural parameters of Khalal Barhi fruits at three degrees of ripening as affected by GA₃ and SA dip treatments and storage time during CA storage

These findings show that GA₃ treatments followed by SA treatments retained Barhi fruits texture during both storage methods.

The reduction in hardness, elasticity, and chewiness, during ripening may be due to breakdown of insoluble solids into soluble solids or by cellular breakdown leading to membrane porousness. Equivalent results of the efficacy of GA₃ in preserving fruit texture are stated by other authors for different fruits^[9,11,33-36]. Preservation of fruit texture by SA pretreatment has been identified earlier in several fruits^[37,38].

3.6 Sensorial results

Sensory evaluation is a very important fruits quality indicator for the consumer's satisfaction. The sensory results for the selected quality attributes of Khalal Barhi fruits harvested at three different harvesting time (ripening levels R1, R2 and R3) as affected by treatments and storage time during cold storage are tabulated and presented in Table 2.

Table 2 Sensorial scores for the quality attributes of Khalal Barhi dates at three different ripening levels as affected by postharvest treatments during CA storage

Ripening levels		R1			R2			R3		
Days	Quality attributes	Treatments			Control	SA	GA ₃	Control	SA	GA ₃
		Control	SA	GA ₃						
0	Color	6.30±0.18b	6.30±0.18b	6.30±0.18b	8.30±0.25a	8.30±0.25a	8.30±0.25a	8.70±0.30a	8.70±0.30a	8.70±0.30a
	Texture	8.90±0.64a	8.90±0.64a	8.90±0.64a	8.40±0.65a	8.40±0.65a	8.40±0.65a	8.40±0.80a	8.40±0.80a	8.40±0.80a
	Taste	7.00±0.18b	7.00±0.18b	7.00±0.18b	8.70±0.17a	8.70±0.17a	8.70±0.17a	8.70±0.10a	8.70±0.10a	8.70±0.10a
	Over all acceptance	6.80±0.38b	6.80±0.38b	6.80±0.38b	8.40±0.46a	8.40±0.46a	8.40±0.46a	8.40±0.40a	8.40±0.40a	8.40±0.40a
20	Color	4.4±0.18d	5.9±0.82c	6.3±0.52bc	4.8±0.25d	6.3±0.68bc	6.8±0.41b	4.9±0.11d	6.6±0.95b	7.6±0.63a
	Texture	6.8±0.69c	7.4±0.84b	8.2±0.33a	5.2±0.54e	6.1±0.96d	7.1±0.37bc	4.2±0.84f	6±0.93d	6.4±0.29f
	Taste	4.8±0.48f	5.8±0.38de	6.1±0.71cd	5±0.61e	7.6±0.42b	7.8±0.7b	4.6±0.36f	6.5±0.34c	8.4±0.73a
	Over all acceptance	3.7±0.63e	4.6±0.5d	4.9±0.76d	5.9±0.73c	6.9±0.57b	7.3±0.57ab	4.5±0.54d	6.3±0.43c	7.8±0.94a
40	Color	3.1±0.47e	4.2±0.64c	5.4±0.23b	3.3±0.55de	4.5±0.75c	6.1±0.28a	6.3±0.38d	5.1±0.54b	6.4±0.19a
	Texture	5.4±0.3bc	5.9±0.32b	7.1±0.45a	4.2±0.37d	5.2±0.53c	6.4±0.46ab	2.8±0.23e	4.1±0.12d	4.3±0.45d
	Taste	3.5±0.82e	4.4±0.49d	5.7±0.51c	3.7±0.78e	6.4±0.44b	6.8±0.35b	4.2±0.85de	5.7±0.54c	7.6±0.67a
	Over all acceptance	2.7±0.9e	3.5±0.14d	4.5±0.37c	4.2±0.89c	5.5±0.07b	6.5±0.53a	3.1±0.91de	4.6±0.04c	6.9±0.2a
60	Color	2.8±0.6e	3.9±0.46d	4.8±0.28b	3.2±0.49e	4.2±0.72cd	5.5±0.2a	3.3±0.72e	4.5±0.2bc	5.9±0.36a
	Texture	4.7±0.55c	5.4±0.28b	6.3±0.55a	3.1±0.6d	4.1±0.08c	5.8±0.62ab	2.5±0.5e	2.9±0.47de	3.3±0.48d
	Taste	3.2±0.68e	3.9±0.57d	4.7±0.23c	3.4±0.66e	5.7±0.45b	6.1±0.41ab	3.3±0.71e	4.5±0.7c	6.3±0.04a
	Over all acceptance	2.4±0.8e	3.1±0.14d	3.7±0.79c	4±0.75c	5±0.07b	5.8±0.72a	3.1±0.86d	4±0.21c	6±0.86a
80	Color	2.7±0.29e	3.5±0.57d	4.2±0.06bc	2.6±0.34e	3.9±0.76cd	4.5±0.08b	2.7±0.25e	4.1±0.38bc	5.2±0.04a
	Texture	3.5±0.58b	4.7±0.44a	5.1±0.62a	2.5±0.47c	3.8±0.37b	4.7±0.49a	1.3±0.69d	2.5±0.5c	3±0.76bc
	Taste	2.7±0.69f	3.6±0.21e	4.1±0.8d	2.8±0.79f	4.9±0.37bc	5.1±0.81ab	3.4±0.6e	4.6±0.04c	5.4±0.79a
	Over all acceptance	2.2±0.56e	2.9±0.71de	3.3±0.57d	3.3±0.49d	4.4±0.51b	4.8±0.56ab	2.4±0.63e	3.9±0.91c	5.2±0.57a
100	Color	2.2±0.33d	3.2±0.42c	4±0.21b	2.5±0.24d	4±0.79b	4.4±0.3ab	2.6±0.42d	4.4±0.04ab	4.9±0.11a
	Texture	2.4±0.23c	4.2±0.7ab	4.7±0.38a	2.4±0.21c	3.7±0.61b	4.3±0.54ab	0.8±0.24d	2.3±0.8c	2.6±0.22c
	Taste	2.5±0.74e	3.4±0.59d	4.1±0.81c	2.6±0.51e	4.5±0.35b	4.6±0.8b	3±0.97de	4.6±0.83b	5.2±0.83
	Over all acceptance	1.9±0.27d	2.7±0.73c	3.2±0.54c	3.1±0.2c	4.3±0.85b	4.5±0.53ab	1.7±0.34d	3.1±0.6c	4.9±0.55a
120	Color	2±0.05d	2.9±0.55c	3.8±0.49b	2.5±0.05cd	3.8±0.97b	4±0.49ab	2.9±0.05c	4±0.12ab	4.3±0.49a
	Texture	2.8±0.18bc	3.8±0.37a	4±0.86a	2.3±0.18bc	3.4±0.51ab	3.9±0.86a	1.8±0.18c	2±0.23b	2.9±0.86b
	Taste	2.9±0.04d	2.9±0.59d	3.7±0.77c	3±0.04d	4.1±0.3bc	4.4±0.77ab	3±0.04d	4.7±0.87a	4.6±0.77a
	Over all acceptance	2±0.06c	2.3±0.68c	3±0.5b	3.3±0.06b	4±0.78a	4.2±0.5a	1.9±0.06c	2.2±0.58c	4.3±0.5a

The initial mean scores of R1 samples were 6.30, 8.9, 7.0 and 6.8 (on a scale of 9) for color, texture, taste, and overall acceptance, respectively, and of R2 samples were 8.30, 8.40, 8.70 and 8.40, respectively. While, the initial mean scores of R3 samples were 8.70, 8.40, 8.70 and 8.40, respectively. This reveals the high quality of the fresh Barhi fruits particularly R3 and R2 fruits. The relatively lower scores for R1 may be due to high tannins and pectin and low total solid contents. The improved sensory scores achieved by R3 samples show that the harvesting time of R3 was optimal for harvesting Barhi dates. From the data in the table, it is apparent that the sensory scores of the quality attributes decreased with storage time for the three ripening levels. This indicated the deterioration of the quality of Barhi fruits with the advancement of storage.

Table 2 displays that after 40 d in CA storage, the highest sensory scores for fruits color were attained by R3 (GA₃-treated)

samples followed by R2 (SA treated) samples which without significant differences between them, whereas, the minimum score was gotten by R1 (control) samples. The texture sensory score for R1 (GA₃-treated) samples was significantly higher compared to the scores of the rest of the evaluated samples. The R3 (GA₃-treated) samples grasped the maximum score for taste and the lowest score was gotten by R1 (control). The best overall acceptance score was grasped by R3 (GA₃-treated) samples, however the lowest score for overall acceptance was left for R1 (control) samples. The mean scores of the overall acceptance of R1 samples were 2.7, 3.5 and 4.5 of control, SA-treated, GA₃-treated samples, respectively, signifying poor quality for the control and modest quality of the SA-treated samples and average quality for the GA₃-treated samples. The mean scores of the overall acceptance of R2 were 4.2, 5.5 and 6.5 of control, SA-treated and GA₃-treated samples, respectively, indicating below average for the control and

moderate quality of the SA-treated samples and satisfactory quality for the GA₃-treated samples. R3 were 3.1, 4.6, and 6.9, respectively, displaying modest quality for the control and average quality for the SA-treated samples and good quality for the GA₃-treated samples.

At the middle of the storage period (the 60th day), the minimum reduction in the sensory scores for the fruit color was achieved by R3 (GA₃-treated), while the maximum reduction was observed for R1 (control). The highest score for the fruit texture was noticed for R1 (GA₃-treated), whereas, the lowest score was perceived R3 (control). The lowest reduction in the sensory scores for the fruit taste was noticed for R1 (control) and the highest score was attended by R3 (GA₃-treated) and R2 (GA₃-treated) samples without significant differences between them. The highest overall acceptance score was gotten by R3 (GA₃-treated) and minimum was left for R1 (control). The mean scores of the overall acceptance of R1 samples were 2.4, 3.1 and 3.7 for control, SA-treated and GA₃-treated samples, respectively, signifying lower quality of the control and modest quality of the SA-treated samples and average quality for the GA₃-treated samples. The mean scores of the overall acceptance of R2 were 4.0, 5.0 and 5.8, respectively, indicating below average for the control and moderate quality of the SA-treated samples and satisfactory quality of the GA₃-treated samples. R3 were 3.1, 4.0 and 6.0 of control, SA-treated and GA₃-treated samples, respectively, showing modest quality for the control and below average quality for the SA-treated samples and satisfactory quality for the GA₃-treated samples.

At the end of the storage period, the highest score for fruit color was observed for R3 (GA₃-treated), and the lowest score was recorded for the R1 (control). The highest score of fruit texture was achieved by R1 (GA₃-treated), whereas the lowest score was observed for R3 (control). The lowest sensory scores for the fruit taste were gotten by the control and SA-treated samples at R1 ripening levels without significant difference among them. The highest score for the fruit taste was attended by R3 (GA₃-treated) and R2 (GA₃-treated) samples without significant differences between them. The highest overall acceptance score was gotten by R3 (GA₃-treated) with minimum was left of R1 (control). The mean scores of overall acceptance of R1 samples were 2.0, 2.3 and 3.0 of control, SA-treated, GA₃-treated samples, respectively, representing inferior quality for the control and poor quality for the SA-treated samples and below average quality for the GA₃-treated samples. Whereas, the mean scores of overall acceptance for R2 samples were 3.3, 4.0 and 4.2, respectively, demonstrating poor quality of the control and modest quality of the SA-treated samples and below average quality for the GA₃-treated samples. The mean scores of overall acceptance of R3 were 1.9, 2.2 and 4.3, respectively, indicating poor quality for both control and SA-treated fruits, yet for GA₃ treated samples below average quality was acquired.

Throughout the CA storage period, the highest sensory quality scores were achieved by the R3 (GA₃-treated) samples. The postharvest GA₃ treatment was able to preserve the good quality of Khalal Barhi fruits harvested at the third ripening level up to 40 d in the CA storage. This supports the experimental results which revealed that the GA₃ treatment in the CA storage is the best in preserving the quality of Barhi at the Khalal maturity stage and delaying ripening process. The lowest scores were observed for the control after 120 d in the CA storage. This might be owing to the influence of increased enzyme activity, decreased TSS, and

texture softening on the quality attributes of Barhi dates during the long storage period.

4 Conclusions

Both GA₃ (150 ppm) and SA (2.0 mmol/L) postharvest treatments preserve the quality of Barhi fruits at the Khalal maturity stage picked at different ripeness levels. Dipping in GA₃ and SA reduced fruit weight loss, fruit decay, and increases the TSS with time in CA storage. GA₃ (150 ppm) postharvest treatment provided the best performance in preserving the fruit color and texture of Khalal Barhi dates during CA storage. After 60 d in controlled atmosphere storage, sensorial quality of Barhi dates treated with GA₃ and harvested at the third ripening level (R3) was satisfactory.

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