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Storability and Fruit Properties of Hass Avocado as Affected by Moringa Seed Oil, Algae Extract and Arabic Gum Postharvest Treatments

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Abstract

This research was carried out over an average of two successive seasons (2020 and 2021), at postharvest laboratory. The experiment aimed to investigate the effectiveness of using seed oil of three *Moringa species* [(*peregrina* Forssk. Ex, *stenopetala* (Baker f.), *oleifera* Lam.)] and algae extract each at 1000 ppm combined with Arabic gum at two concentrations (5% and 10%) as a natural ecofriendly products in parallel with untreated fruits as a control on quality and storability of Hass avocado fruits under cold storage conditions (5°C and 85 - 90% RH). The acquired results displayed that, all implementing parameters were affected affirmatively by different utilized treatments. However, it's obvious that, *Moringa oleifera* seed oil at 1000 ppm+ 10% Arabic gum treatment was the most effective one and gave positive results concerning fruit firmness, titratable acidity and the activity of polyphenol oxidase (PPO) and improved total phenol, chlorophyll a, b and carotenoids. On the other hand, fruit weight loss, titratable acidity and PPO activity were excessed; however, fruit firmness, TSS, ascorbic acid, total phenol, carbohydrates and carotenoids values were relatively decreased due to the untreated fruits (control).

***Key words*:** Avocado fruits, Moringa seed oil, Algae extract, Arabic gum, Cold storage.

1. Introduction

Avocado (*Persea americana*) is a tropical fruit that is eaten and grown all over the world. It is a valuable ware with strong customer demand due to its considerable economic impact, excellent nutritive content, and fantastic taste. Hass avocados account for 80 to 95 percent of all avocados harvested globally, making them the most important commercial variety **[1]**. In 2017, 5.92 million metric tonnes of avocados were produced worldwide and an increase in production by about 52% was detected from 2000 **[2].**

Apart from their economic importance, avocados have attracted attention due to their high lipidic content, a feature not found in many other fruits **[3]**. The fat fraction accounts for approximately 15% of the total composition, with 66.2–71% of it being monounsaturated fatty acids, which have been shown to help reduce the prevalence of cardiovascular diseases, high cholesterol, diabetes, and obesity, all of which have direct links to modifiable lifestyle factors such as eating habits **[4, 5, 6].** They are also accompanied by other key bioactive compounds such as folate (81 g), potassium (485 mg), calcium (12 mg), fiber (6.7 g), lutein (271 g), carotenoids, fat, soluble vitamins, sterols, and others, all of which are present in every 100 grams of ordinary weight **[7].**

Despite the important role avocados play in the economy and human health, they have a relatively short shelf life and contribute to the waste of 66 percent of fruits and vegetables each year **[8].** In

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2012, approximately 20% of avocados were reported to have deteriorated at the retail level. The quick loss of firmness, which reduces the consumer acceptability time to only a few days once ripe, is due to the fruit's natural climacteric nature.

Because avocados might travel vast distances from their point of origin to their point of consumption, proper preservation measures are required to preserve their quality and longevity.

Covering avocado with edible coating (EC) could improve quality and shelf-life produce and reduce deleterious effects concomitant with minimal processing. Edible coating contains essential oil which enriches the value of fruits and retards the microbial growth **[9].**

Algae extract containing some macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Zn, Fe, Mn, Cu, Mo and Co) as well as some growth regulators, polyamines, vitamins and polyphenols which it contain antihyperlipidemic, antihypertensive and antibacterial properties which is required to improve fruit quality and delay microbial growth **[10, 11].**

Arabic gum is an ecological biopolymer obtained from the branches and stems of Acacia trees (*Acacia spp*.) and is one of the natural polymers used to produce edible coatings. Rhamnose, galactose, arabinose, and glucuronic acid are present, along with Ca, Mg, and K ions. Arabic gum has been hailed as one of the most promising materials, owing to its ease of use, low cost, and outstanding performance. Their strong hydrophilicity, on the other hand, allows H_2O to develop quickly **[12, 13].** Numerous researches on using Arabic gum for nullity purposes have been done **[14,15]** on tomatoes and papayas who noticed that Arabic gum coatings have efficiently kept the antioxidative polyphenols of lowered browning and vitamin C of cold-stored fruits. Khaliq (2015) **[16]** reported that application of 10% Arabic gum edible coating combined with 3% calcium chloride on mango successfully reduced weight loss, soluble solids concentration and maintained high firmness, titratable acidity and ascorbic acid during storage. Furthermore, with a modest increase in total soluble solids, pH, and sugars, Arabic gum-coating considerably reduced weight loss, chilling damage, membrane leakage, and decay prevalence. **[17, 18].**

Moringa oleifera has a high phytochemical content that can be used in the pharmaceutical, agricultural, and food industries. Proteins, β-carotene, vitamins, phenolic compounds, flavonoids, fatty acids, and other bioactive chemicals have all been found in significant concentrations in leaves, seeds, flowers, and bark **[19]**. Furthermore, its extracts were used to create a covering that efficiently retains the quality of citrus fruits after harvest **[20].** Through lowering respiration, ethylene generation rates, and improving firmness during storage, moringa extract preserves and extends the shelf life of avocado fruit **[21, 22, 23]**. Moringa leaves have been shown to have potential as a functional ingredient for food products and applications in a number of studies **[20].** According to Tesfay **[19]**, lipophilic chemicals found in moringa extracts bind to the cytoplasmic membrane increased permeability, slowed development, reduced mass and firmness loss**.** Moringa leaf extract with Arabic gum coatings for Maluma avocados was the subject of another investigation. Coatings using 10% Arabic gum and 10% moringa extract or 10% CMC and moringa displayed the best capacity to reduce mass loss while maintaining the highest stiffness **[24].**

Therefore, this study aimed to explore the effects of seed oil of three *Moringa species* and algae extracts integrated with Arabic gum as natural products on quality and storability of Hass avocado fruits under cold storage conditions.

2. Material and Methods

Fruits:

Hass avocado fruits (*Persea americana* Mill) were taken from a private orchard (Salmya) in Nubaria, Al-Behera governorate, Egypt. Fruits were harvested at maturity (at 1st November, 2020 and 2021seasons) from 15-years-old trees with identical growth vigour and were given to standard horticultural treatments to prolong storage duration and maintaining fruit quality. Then the fruits were transferred to postharvest laboratory.

Treatments:

The fruits were washed under running tap water, air dried, placed in carton boxes, and sorted into identical groups for the treatments that followed:

1- Control (without treatment).
2- Algae extract at 1000 ppm+5% Arabic gum.
3- Algae extract at 1000 ppm+10 % Arabic gum.
4- *Moringa peregrina* oil at 1000 ppm+ 5% Arabic gum.

5- *Moringa peregrina* oil at 1000 ppm +10% Arabic gum.
6- *Moringa stenopetala* oil at 1000 ppm +5% Arabic gum.
7- *Moringa stenopetala* oil at 1000 ppm +10% Arabic gum.
8- *Moringa oleifera* oil at 1000 ppm +5% Arabic gum.
9- *Moringa oleifera* oil at 1000 ppm +10% Arabic gum.

Moringa oils were obtained from Moringa Production Unit, while algae extract was obtained from Nutrition Department, NRC. The fruits were packaged in one layer in storage carton boxes after postharvest treatments and stored at 5°C and 85-90 percent relative humidity (RH) for 45 days. Each treatment consisted of three replicates, each of which contained two fruits. After each sampling date (7 days), the fruit quality was examined. The results are shown as a composite of the two seasons (2020 and 2021).

Physical Properties Assessments:

Fruit weight loss (FWL, %): Fruits were weighed at the start and at a 7-day interval for 45 storage days. Fruit weight loss percent = wt. of 1st interval − wt. of 2nd interval x100 / wt. of 1st interval was computed using conventional technique.

Fruit Firmness: The Ametek pressure tester was used to determine the hardness of the fruit. The firmness of two fruits from each replicate was tested at two different positions on the equator of each fruit, and the results were expressed in $Ib/inch^2$ **[25].**

Chemical Properties Assessments:

Total soluble solids content (TSS %) was calculated using a T/C hand refractometer Instrone, Brixreadings 0-30 ranges (Model 10430, Bausch and Lomb Co. Calif., USA) and expressed as a percentage.

Total acidity percentage (expressed as oleic acid) was determined by titration against 0.1 Na OH using phenolphthalein as an indicator.

Ascorbic acid content (V.C., mg /100 ml juice) was determined using 2, 6 dichlorophenol indophenols' titration method as described in A.O.A.C. **[25].**

Chlorophyll and Total carotenoids content (mg/g F.W.): The concentrations of chlorophyll and carotenoids in avocado pulp (three duplicates) were analysed spectrophotometrically using the method of Wellburn **[26]**. Using a spectrophotometer Jenway 6715UV-Vis, the absorbance of the extract was measured at 663 nm for chlorophyll a, 646 nm for chlorophyll b, and 470 for total carotenoids (USA). The following equations were used to calculate pigment content:

Chlorophyll a ($\mu g\ mL^{-1}$) = 12.21 E663 − 2.81 E646
Chlorophyll b ($\mu g\ mL^{-1}$) = 20.13 E646 − 5.03 E663
Total carotenoids ($\mu g\ mL^{-1}$) = [(1000 E470) − (3.27 × Chlorophyll a + 104 × Chlorophyll b)]/198

Total phenol content (TPC, mg /100 g FW): The total phenol content was measured using the Folin–Ciocalteu test, which was modified slightly by Villa **[27]**. Five millilitres of diluted Folin–Ciocalteau reagent were combined with one millilitre of extract (1:10). After 6 minutes, 4 mL of Na_2CO_3 (20%) was added to the mixture, which was allowed at room temperature for 2 hours before the absorbance against the reagent blank was measured with a UV-Visible spectrophotometer at 760 nm. Gallic acid equivalents/100 g of fruit was used to calculate total phenolic content (wet base). All of the tests were carried out in duplicate.

Polyphenoloxidase enzyme activity (PPO, Unit/g/FW): [28] reported a method for determining the activity of polyphenol oxidase (PPO). 5g of mesocarp was homogenized for one minute in 15ml of a 50mM phosphate buffer for each treatment (pH 6.5). The mixture was centrifuged for 30 minutes at 4°C at 12000 rpm, with the supernatant utilized as the enzyme extract. The substrate consisted of 500µl of 20 mM catechol, 900µl of 50 mM phosphate buffer (pH 6.5), and 100µl of enzyme extract. 500µl of 10% trichloroacetic acid (TCA) was poured to the blank. The reaction was stopped by adding 500µl of 10% TCA to the mixture and incubating it for 20 minutes at 25°C. The absorbance was measured at 410nm with a spectrophotometer. With the addition of 500µl of 10% TCA, the reaction was brought to a halt. A spectrophotometer Jenway 6715UV-Vis was used to measure the absorbance at 410nm (USA). After a reaction time of 100 µl of extract, the PPO activity was observed as a rise in absorbance.

Statistical analysis: A completely randomized design (CRD) with three replicates was used in this study. The analysis of variance (ANOVA) procedure of the COSTAT programme was used to examine the data. According to Duncan **[29]** the means were compared at 5% level of probability.

3. Results

The impact of algae extract, moringa seed oils and Arabic gum on physical properties of Hass avocado fruits:

Fruit weight loss percentage: In terms of the effects of the treatments that, were evaluated, Table (1) shows that all treatments had a favorable effect on diminish the percentage of avocado fruit weight lost midst storage duration in comparison with the untreated fruits (control). Generally, treatment included *Moringa oleifera* oil at 1000 ppm +10 % Arabic gum proved to be the most efficacious treatment in this concern, followed by *Moringa stenopetala* oil at 1000 ppm +10% Arabic gum.

As for the effect of storage periods, it is quite clear from Table (1) that, avocado fruits showed gradual losses in their weight with the advancement of storage period. Therefore, 45 days storage period under cold condition recorded the highest value, whereas the lowest value was obtained after 15 days. The statistical analysis emphasizes that the differences between the aforesaid cold storage periods were significant.

Considering the interaction effect between storage period and tested postharvest treatments, results presented in Table (1) show that, the interaction of 15 days storage duration under cold storage at 5°C recorded the lowest percentages of weight loss. On the opposite, the highest percentage of weight loss was observed on those of 45 days storage period combinations, particularly the "control" treatment and algae extract at 1000 ppm + 5% Arabic gum. The other combinations showed intermediate values in this concern.

Table (1): Effect of algae extract and different moringa species oil combined with Arabic gum on weight loss % of Hass avocado during cold storage

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	0.00 x	3.33 vw	6.66 q-s	10.66 k-m	13.33 g-i	16.66 cd	19.33 b	**9.99 b**
Algae extract+ 10% Arabic gum	0.00 x	2.66 w	6.00 r-t	8.66 n-p	11.33 j-l	14.00 f-h	16.00 c-e	**8.37 d**
Moringa peregrina oil + 5% Arabic gum	0.00 x	4.00 u-w	6.66 q-s	9.33 m-o	12.00 i-k	14.66 e-g	16.66 cd	**9.04 c**
Moringa peregrina oil + 10% Arabic gum	0.00 x	2.66 w	6.00 r-t	8.00 o-q	10.00 l-n	12.66 h-j	14.00 f-h	**7.60 e**
Moringa stenopetala oil + 5% Arabic gum	0.00 x	4.00 u-w	6.00 r-t	8.00 o-q	10.00 l-n	12.00 i-k	14.00 f-h	**7.71 e**
Moringa stenopetala oil + 10% Arabic gum	0.00 x	3.33 v w	5.33 s-u	7.33 p-r	10.00 l-n	13.33 g-i	15.33 d-f	**7.80 e**
Moringa oleifera oil + 5% Arabic gum	0.00 x	4.00 u-w	6.66 q-s	8.66 n-p	10.66 k-m	14.00 f-h	16.66 cd	**8.66 cd**
Moringa oleifera oil + 10% Arabic gum	0.00 x	2.66 w	5.33 s-u	8.00 o-q	9.33 m-o	12.00 i-k	14.00 f-h	**7.33 e**
Control	0.00 x	4.66 t-v	12.66 h-j	15.33 d-f	17.33 c	19.33 b	22.00 a	**13.04 a**
Mean	**0.00 g**	**3.47 f**	**6.81 e**	**9.33 d**	**11.55 c**	**14.29 b**	**16.44 a**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Fruit firmness (Ib/inch^2):

From Table (2) it could be argued that treating fruits with *Moringa oleifera* oil at 1000ppm +10% Arabic gum followed by *Moringa stenopetala* oil at 1000 ppm +10% Arabic gum resulted in the highest values of fruit firmness in the treated avocados compared with the uncoated ones.

As for the effect of storage periods, it is quite clear from Table (2) that, avocado fruit firmness decreased gradually with the progress of storage period. Therefore, 45 days storage period under cold condition recorded the lowest values. The statistical analysis emphasizes that the differences between the aforesaid cold storage periods were significant.

The interplay between storage duration and different treatments had a substantial impact on the firmness of Hass avocado fruits. This could be explained by the rapid loss of firmness in control fruits compared to the gradual loss of firmness in treated fruits. For both treated and untreated fruits,

the loss of firmness increased with storage time (Table, 2). Untreated fruits had the lowest firmness at the end of the storage period (14.24 Ib/inch^2). On the other hand, *Moringa oleifera* oil at 1000 ppm +10% Arabic gum gave 20.40 Ib/inch^2 and *Moringa stenopetala* oil at 1000 ppm +10% Arabic gum recorded 20.01 Ib/inch^2, maintained higher firmness throughout the study.

Table (2): Effect of algae extract and different moringa species oil combined with Arabic gum on fruit firmness of Hass avocado during cold storage

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	30.2 a	21.0 f-i	18.6 j-l	14.7 m	12.4 op	10.7 q-t	9.5 t	**16.72 f**
Algae extract+ 10% Arabic gum	30.2 a	23.3 b-d	21.6 e-h	18.4 j-l	14.6 m	11.7 o-r	10.2 r-t	**18.57 d**
Moringa peregrina oil + 5% Arabic gum	30.2 a	22.3 c-g	19.7 ij	15.5 m	14.2 mn	12.6 no	10.6 q-t	**17.87 e**
Moringa peregrina oil + 10% Arabic gum	30.2 a	22.6 c-f	20.4 hi	19.5 i-k	17.9 kl	14.3 m	11.2 o-s	**19.44 bc**
Moringa stenopetala oil + 5% Arabic gum	30.2 a	24.6 b	22.8 c-e	18.3 j-l	14.2 mn	11.9 o-q	9.9 st	**18.84 cd**
Moringa stenopetala oil + 10% Arabic gum	30.2 a	23.3 b-d	21.9 d-h	20.8 g-i	17.9 kl	14.8 m	11.2 o-s	**20.01 ab**
Moringa oleifera oil + 5% Arabic gum	30.2 a	21.5 e-h	19.5 i-k	15.7 m	14.3 m	11.2 o-s	10.1 r-t	**17.50 e**
Moringa oleifera oil + 10% Arabic gum	30.2 a	23.7 bc	22.9 c-e	21.5 e-h	17.7 l	15.3 m	11.5 o-s	**20.40 a**
Control	30.2 a	21.6 e-h	18.4 j-l	10.9 p-t	10.2 r-t	5.4 u	3.0 v	**14.24 g**
Mean	**30.20 a**	**22.65 b**	**20.64 c**	**17.25 d**	**14.82 e**	**11.98 f**	**9.68 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

The impact of algae extract, moringa seed oils and Arabic gum on chemical properties of Hass avocado fruits:

Total soluble solids (%): Results in Table (3) reveal that, TSS of Hass avocado fruits was affected by using the different tested postharvest treatments. However, the highest value of this parameter was recorded by *Moringa oleifera* oil at 1000 ppm +10% Arabic gum treated fruits which significantly scored the highest TSS as compared with the other treatments.

Referring to the effect of the cold storage period, Table (3) show that, TSS of Hass avocado fruits progressively were decreased with advancing the storage periods till reach the maximum decrease after 45 days under storage.

In terms of the interaction impact between the studied postharvest treatments and storage periods, the greatest values of this parameter were obtained with *Moringa oleifera* oil at 1000 ppm + 10% Arabic gum under cold storage for 45 days, as shown in the same table. On the other hand, the lowest values of this parameter were associated with 45 days storage duration with control, algae at 1000 ppm, and 5% Arabic gum treatment.

Total acidity percentage: As for the specific effect of tested postharvest treatments, Table (4) indicate that, all tested treatments decreased to some extent, total fruit acidity over control.

It is quite evident that, the reduction in fruit total acidity content is proportionate with the advancement of storage period (Table, 4). Hence the highest value of fruit total acidity content (irrespective the initial readings) was recorded with seven days cold stored fruits. The reverse magnitude was detected with the fruits stored for 45 days.

Moreover, the results in Table (4) reflect a real image to the relative higher response to the cold storage duration from one hand and the lower (very slight) on to the investigated postharvest treatments from the other. Generally, it could be concluded that, the lowest total acidity of fruit juice was always in concomitant to the *Moringa oleifera* oil at 1000 ppm +10 % Arabic gum treated fruits after 45 days duration.

Table (3): Effect of algae extract and different moringa species oil combined with Arabic gum on total soluble solids (TSS) percentage of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	1.80 a	1.50 c	1.10 l-p	1.08 m-p	0.75 wx	0.59 y	0.42 z	**1.03 f**
Algae extract+ 10% Arabic gum	1.80 a	1.20 g-k	1.17 i-l	1.04 pq	0.95 rs	0.89 s-u	0.76 v-x	**1.12 de**
Moringa peregrina oil + 5% Arabic gum	1.80 a	1.32 d-f	1.25 e-i	1.05 o-q	0.93 st	0.76 v-x	0.57 y	**1.09 e**
Moringa peregrina oil + 10% Arabic gum	1.80 a	1.35 d	1.27 d-h	1.19 h-k	1.07 n-p	0.84 uv	0.75 wx	**1.18 c**
Moringa stenopetala oil + 5% Arabic gum	1.80 a	1.30 d-f	1.24 f-j	1.13 k-o	0.90 s-u	0.82 u-w	0.71 x	**1.13 d**
Moringa stenopetala oil + 10% Arabic gum	1.80 a	1.50 c	1.27 d-h	1.16 j-m	1.05 o-q	0.97 q-s	0.83 u-w	**1.22 b**
Moringa oleifera oil + 5% Arabic gum	1.80 a	1.20 g-k	1.19 h-k	1.03 p-r	0.85 tu	0.72 x	0.55 y	**1.04 f**
Moringa oleifera oil + 10% Arabic gum	1.80 a	1.61 b	1.33 de	1.28 d-g	1.15 k-n	1.05 o-q	0.94 s	**1.31 a**
Control	1.80 a	1.30 d-f	1.15 k-n	1.05 o-q	0.93 st	0.59 y	0.33 A	**1.02 f**
Mean	**1.80 a**	**1.36 b**	**1.21 c**	**1.11 d**	**0.95 e**	**0.80 f**	**0.65 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Table (4): Effect of algae extract and different moringa species oil combined with Arabic gum on total acidity (%) of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	0.55 a	0.39 e	0.28 hi	0.15 op	0.12 r	0.09 s	0.04 wx	**0.231 e**
Algae extract+ 10% Arabic gum	0.55 a	0.42 cd	0.35 g	0.29 h	0.19 l	0.07 tu	0.02 y	**0.270 b**
Moringa peregrina oil + 5% Arabic gum	0.55 a	0.44 b	0.38 ef	0.22 k	0.13 qr	0.05 vw	0.02 y	**0.255 d**
Moringa peregrina oil + 10% Arabic gum	0.55 a	0.43 bc	0.35 g	0.24 j	0.18 lm	0.08 st	0.06 uv	**0.270 b**
Moringa stenopetala oil + 5% Arabic gum	0.55 a	0.42 cd	0.37 f	0.23 jk	0.16 no	0.08 st	0.05 vw	**0.265 bc**
Moringa stenopetala oil + 10% Arabic gum	0.55 a	0.44 b	0.39 e	0.27 i	0.14 pq	0.07 tu	0.03 xy	**0.270 b**
Moringa oleifera oil + 5% Arabic gum	0.55 a	0.42 cd	0.35 g	0.23 jk	0.16 no	0.08 st	0.04 wx	**0.261 cd**
Moringa oleifera oil + 10% Arabic gum	0.55 a	0.17 mn	0.02 y	0.04 wx	0.05 vw	0.07 tu	0.04 wx	**0.134 f**
Control	0.55 a	0.41 d	0.39 e	0.27 i	0.18 lm	0.08 st	0.07 tu	**0.278 a**
Mean	**0.55 a**	**0.39 b**	**0.32 c**	**0.21 d**	**0.14 e**	**0.07 f**	**0.04 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Ascorbic acid content (mg /100 ml juice): Results in Table (5) show that, all tested treatments statistically decreased vitamin C (V.C.) of Hass avocado fruits, with the superiority of *Moringa oleifera* oil at 1000 ppm+10% Arabic gum treated fruits as compared with the control.

As for the effect of storage periods presented in Table (5), V.C. of Hass avocado fruits were decreased with prolonging the storage periods. Therefore, 0 and 15 days storage periods scored the highest values in this criterion, while 45 days storage period recorded the lowest values in this respect.

Referring to the interaction effect between postharvest treatments and storage periods in Table (5), the combination of 7 days storage period (regardless of the initial reading) showed to be the most promising in producing the highest values of V.C. especially when the fruits were treated with *Moringa oleifera* oil at 1000 ppm+10% Arabic gum. On the contrary, the lowest value of this parameter was scored by the combination of 45 days storage periods, particularly those of untreated fruits. The rest of the combinations came in-between the abovementioned treatments.

Table (5): Effect of algae extract and different moringa species oil combined with Arabic gum on ascorbic acid (mg /100 ml juice) of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	1.42 a	1.39 ab	1.27 g-i	1.14 m	1.08 n	1.03 o	1.00 o-q	**1.190 bc**
Algae extract+ 10% Arabic gum	1.42 a	1.37 bc	1.29 fg	1.18 j-l	1.09 n	1.03 o	0.99 pq	**1.195 b**
Moringa peregrina oil + 5% Arabic gum	1.42 a	1.34 c-e	1.26 g-i	1.19 jk	1.03 o	0.95 r	0.82 t	**1.144 e**
Moringa peregrina oil + 10% Arabic gum	1.42 a	1.36 b-d	1.25 hi	1.17 j-m	1.08 n	1.02 op	0.97 qr	**1.181 cd**
Moringa stenopetala oil + 5% Arabic gum	1.42 a	1.33 de	1.27 g-i	1.18 j-l	1.09 n	1.01 op	0.97 qr	**1.181 cd**
Moringa stenopetala oil + 10% Arabic gum	1.42 a	1.37 bc	1.28 gh	1.15 lm	1.02 op	1.00 o-q	0.95 r	**1.170 d**
Moringa oleifera oil + 5% Arabic gum	1.42 a	1.32 ef	1.25 hi	1.19 jk	1.03 o	0.99 pq	0.89 s	**1.155 e**
Moringa oleifera oil + 10% Arabic gum	1.42 a	1.35 c-e	1.24 i	1.20 j	1.18 j-l	1.09 n	1.03 o	**1.215 a**
Control	1.42 a	1.25 hi	1.16 k-m	1.10 n	1.03 o	0.94 r	0.85 s	**1.10 f**
Mean	**1.42 a**	**1.34 b**	**1.25 c**	**1.16 d**	**1.07 e**	**1.00 f**	**0.94 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Chlorophyll a content (mg /g. F.W.): From the results in Table (6), *Moringa oleifera* oil at 1000 ppm +10% Arabic gum followed by *Moringa oleifera* oil at 1000 ppm +5% Arabic gum treatment gave the highest significant value in chlorophyll "a" among all treatments (1.316 and 1.228 mg/g F.W., respectively). While the untreated treatment (control) showed the lowest value of chlorophyll "a" (0.953 mg/g F.W.) compared to all other treatments.

It is obvious that chlorophyll "a" was significantly decreased with all treatments compared with the control during the storage periods especially at 6th week.

Table (6): Effect of algae extract and different moringa species oil combined with Arabic gum on chlorophyll a of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	1.754 a	1.736 a	1.563 b-d	1.277 h-m	0.883 t-v	0.811 v-x	0.383 CD	**1.201 b**
Algae extract+ 10% Arabic gum	1.754 a	1.680 ab	1.630 a-c	1.036 q-t	0.712 w-z	0.554 z-B	0.406 B-D	**1.110 cd**
Moringa peregrina oil + 5% Arabic gum	1.754 a	1.496 c-f	1.370 e-j	1.356 e-j	1.047 p-s	0.551 z-B	0.328 D	**1.128 c**
Moringa peregrina oil + 10% Arabic gum	1.754 a	1.745 a	1.496 c-f	1.313 g-l	0.627 y-A	0.431 B-D	0.405 B-D	**1.110 cd**
Moringa stenopetala oil + 5% Arabic gum	1.754 a	1.439 d-g	1.216 j-o	1.203 k-p	1.157 l-q	0.523 A-C	0.423 B-D	**1.102 cd**
Moringa stenopetala oil + 10% Arabic gum	1.754 a	1.435 d-i	1.338 f-k	0.902 s-v	0.784 v-y	0.660 x-A	0.545 AB	**1.059 d**
Moringa oleifera oil + 5% Arabic gum	1.754 a	1.490 c-f	1.224 j-n	1.173 l-q	1.141 m-r	0.982r-u	0.834uvw	**1.228 b**
Moringa oleifera oil + 10% Arabic gum	1.754 a	1.514 c-e	1.455 d-g	1.438 d-h	1.156 l-q	1.096 n-r	0.805 v-x	**1.316 a**
Control	1.754 a	1.275i-m	1.057 o-s	1.039 q-t	0.720 w-y	0.530 A-C	0.300 D	**0.953 e**
Mean	**1.754 a**	**1.534 b**	**1.372 c**	**1.193 d**	**0.914 e**	**0.682 f**	**0.492 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Chlorophyll b content (mg /g F.W.): It is obvious that, *Moringa oleifera* oil at 1000 ppm +10% Arabic gum recorded the highest chlorophyll b content in avocado fruit at the 3rd, 4th, 5th and 6th week (1.067, 1.050, 0.931 and 0.859 mg/g F.W, respectively).

Regarding chlorophyll b content in avocado fruit samples, results in Table (7) indicate that, all treatments showed significant decrease compared to the untreated fruits (control) from the 3rd week until to the 6th one.

Table (7): Effect of algae extract and different moringa species oil combined with Arabic gum on chlorophyll b of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	1.417 a	1.209 c-f	0.628 t-v	0.517 u-x	0.417 wx	0.384 xy	0.132 z-B	**0.672 e**
Algae extract+ 10% Arabic gum	1.417 a	1.305 a-c	0.964 i-m	0.750 p-t	0.242 yz	0.137 z-B	0.109 z-B	**0.703 de**
Moringa peregrina oil + 5% Arabic gum	1.417 a	1.134 e-h	0.974 i-l	0.854 k-q	0.735 q-t	0.243 yz	0.070 B	**0.775 c**
Moringa peregrina oil + 10% Arabic gum	1.417 a	1.022 g-j	0.992 h-k	0.942 i-n	0.823 m-q	0.562 u-w	0.077 B	**0.833 b**
Moringa stenopetala oil + 5% Arabic gum	1.417 a	0.897 j-p	0.801 n-r	0.741 q-t	0.663 r-u	0.515 u-x	0.092 AB	**0.732 cd**
Moringa stenopetala oil + 10% Arabic gum	1.417 a	1.135 e-h	0.919 i-o	0.845 k-q	0.782 o-s	0.648 s-u	0.236 y-A	**0.854 b**
Moringa oleifera oil + 5% Arabic gum	1.417 a	1.290 a-d	1.250 b-e	0.850 k-q	0.828 l-q	0.519 u-x	0.035 B	**0.884 b**
Moringa oleifera oil + 10% Arabic gum	1.417 a	1.280 a-e	1.146 d-g	1.067 f-i	1.050 g-i	0.931 i-o	0.859 k-q	**1.107 a**
Control	1.417 a	1.386 ab	0.755 p-t	0.492 v-x	0.098 z-B	0.084 B	0.026 B	**0.608 f**
Mean	**1.417 a**	**1.184 b**	**0.936 c**	**0.784 d**	**0.626 e**	**0.447 f**	**0.182 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Total carotenoids content (mg /g. F.W.): From Table (8) it is noticed that, significant increases in total carotenoids contents related to the long storage time in all avocado fruits under investigation included the control. Moreover, total carotenoids content were significantly increased in all treatments at the 3rd week to 6th week of storage.

It is obvious that *Moringa oleifera* oil at 1000 ppm +10% Arabic gum and *Moringa stenopetala* oil at 1000 ppm +5% Arabic gum treatments gave the highest carotenoids content among all treatments at the 3rd week to 6th week. Whereas, the control treatment showed the lowest carotenoid contents compared with all treatments.

Table (8): Effect of algae extract and different moringa species oil combined with Arabic gum on total carotenoids of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	2.779 y	2.896 y	3.211 wx	3.934 s	4.361 pq	4.869 klm	5.310 i	**3.908 g**
Algae extract+ 10% Arabic gum	2.779 y	3.107 x	3.523 tu	3.923 s	4.494 op	4.880 kl	5.245 ij	**3.993 f**
Moringa peregrina oil + 5% Arabic gum	2.779 y	3.213 wx	3.638 t	4.231 qr	4.726 lmn	5.256 ij	5.725 g	**4.224 e**
Moringa peregrina oil + 10% Arabic gum	2.779 y	3.640 t	4.321 q	4.798 klm	5.223 ij	5.814 fg	6.226 e	**4.686 d**
Moringa stenopetala oil + 5% Arabic gum	2.779 y	3.283 vw	3.958 s	4.898 k	5.958 f	6.875 c	7.823 a	**5.080 b**
Moringa stenopetala oil + 10% Arabic gum	2.779 y	3.860 s	4.371 pq	4.889 k	5.558 h	6.322 e	6.812 c	**4.941 c**
Moringa oleifera oil + 5% Arabic gum	2.779 y	3.460 u	3.947 s	4.718 mn	5.669 gh	6.649 d	7.694 a	**4.988 c**
Moringa oleifera oil + 10% Arabic gum	2.779 y	3.892 s	4.585 no	5.142 j	6.382 e	6.885 c	7.320 b	**5.283 a**
Control	2.779 y	3.224 wx	3.407 uv	3.879 s	4.136 r	4.552 o	4.860 klm	**3.834 h**
Mean	**2.779 g**	**3.397 f**	**3.883 e**	**4.490 d**	**5.167 c**	**5.789 b**	**6.335 a**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Total phenols content (mg /100g. F.W.): Table (9) indicates that, the changes in total phenolic content in Hass avocado samples during the storage using different edible materials. All treatments including the control fruit samples showed a decrease in total phenolic compounds contents with the increase in storage period, on the other hand total phenolic compounds content of avocado fruits were increased with all treatments compared with the control at 28 days until the end of storage.

Moringa oleifera oil at 1000 ppm +10% Arabic gum followed by *Moringa peregrina* oil at 1000 ppm+ 5% Arabic gum treatment recorded the highest values of total phenols content of Hass avocado fruit samples (94.811, 82.269 and 48.585 mg /100 g) and (93.369, 79.950 and 73.113 mg /100 g) at fourth week, fifth week and six week of storage, respectively.

Table (9): Effect of algae extract and different moringa species oil combined with Arabic gum on total phenols of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Mean**
Algae extract + 5% Arabic gum	257.377 a	132.051 i	122.357 l	91.672 z	66.832 N	61.111 PQ	39.845 Y	**110.177 h**
Algae extract+ 10% Arabic gum	257.377 a	113.555 p	112.039 q	103.278 v	85.640 D	74.270 I	44.515 U	**112.953 g**
Moringa peregrina oil + 5% Arabic gum	257.377 a	114.234 o	111.054 r	107.649 t	93.369 y	79.950 G	73.113 K	**119.535 c**
Moringa peregrina oil + 10% Arabic gum	257.377 a	164.404 d	105.346 u	87.573 B	73.550 I	68.645 M	41.353 W	**114.035 f**
Moringa stenopetala oil + 5% Arabic gum	257.377 a	241.419 b	146.941 g	78.982 H	72.318 L	65.879 O	44.285 V	**129.600 b**
Moringa stenopetala oil + 10% Arabic gum	257.377 a	155.502 f	119.357 m	99.676 w	86.284 C	55.378 R	39.756 Y	**116.190 e**
Moringa oleifera oil + 5% Arabic gum	257.377 a	133.716 h	126.101 k	114.674 n	83.490 E	61.053 O	40.287 X	**116.671 d**
Moringa oleifera oil + 10% Arabic gum	257.377 a	173.444 c	160.065 e	131.299 i	94.811 x	82.269 F	48.585 T	**135.407 a**
Control	257.377 a	155.460 f	110.267 s	91.385 A	61.267 P	49.733 S	38.709 Z	**109.171 i**
Mean	**257.377 a**	**153.753 b**	**123.725 c**	**100.687 d**	**79.729 e**	**66.476 f**	**45.605 g**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Polyphenoloxidase enzyme activity (Unit/g. F.W.): The results in Table (10) show an increase in enzyme activity in avocado fruit samples treated with algae, moringa, Arabic gum and the control during storage period.

Otherwise, all treatments decreased polyphenol oxidase (PPO) activity compared with the control during storage. The highest value of enzyme activity was recorded by the control followed by algae at 1000 ppm+5% Arabic gum and algae at 1000 ppm+10 % Arabic gum (0.780 , 0.652 and 0.645, respectively), at the 6th week of the storage. While, *Moringa oleifera* oil at 1000 ppm +10% Arabic gum showed the lowest value of enzyme activity compared with the control and other treatments during all the storage periods.

4. Discussion

The aforementioned results show that the usage products improved the storability and fruit attributes of Hass avocados, whether they were physical or chemical properties. In this regard, *Moringa oleifera* oil treatment combined with Arabic gum at a concentration of 10% was the most effective in preserving fruit firmness and reducing fruit weight loss percentage, with the highest content of TSS, ascorbic acid, total phenol, chlorophyll a and b, as well as total carotenoids, and the lowest acidity and polyphenol oxidase (ppo) activity.

Table (10): Effect of algae extract and different moringa species oil combined with Arabic gum on Polyphenoloxidase enzyme activity of Hass avocado during cold storage.

Treatments	Storage weeks							
	Zero	1st	2nd	3rd	4th	5th	6th	Mean
Algae extract + 5% Arabic gum	0.435 J	0.473 E	0.512 v	0.561 p	0.593 l	0.625 h	0.652 d	**0.550 c**
Algae extract+ 10% Arabic gum	0.435 J	0.483 C	0.510 w	0.562 p	0.604 j	0.624 h	0.645 e	**0.551 b**
Moringa peregrina oil + 5% Arabic gum	0.435 J	0.474 D	0.500 y	0.541 r	0.577 m	0.601 k	0.641 f	**0.538 d**
Moringa peregrina oil + 10% Arabic gum	0.435 J	0.453 H	0.485 B	0.520 u	0.561 p	0.605 j	0.629 g	**0.526 e**
Moringa stenopetala oil + 5% Arabic gum	0.435 J	0.465 F	0.493 A	0.510 w	0.540 r	0.573 n	0.615 i	**0.518 f**
Moringa stenopetala oil + 10% Arabic gum	0.435 J	0.458 G	0.483 C	0.509 w	0.530 s	0.567 o	0.594 l	**0.510 g**
Moringa oleifera oil + 5% Arabic gum	0.435 J	0.452 HI	0.475 D	0.493 A	0.510 w	0.527 t	0.540 r	**0.490 h**
Moringa oleifera oil + 10% Arabic gum	0.435 J	0.451 I	0.473 E	0.493 A	0.503 x	0.521 u	0.541 r	**0.488 i**
Control	0.435 J	0.496 z	0.553 q	0.624 h	0.695 c	0.713 b	0.780 a	**0.613 a**
Mean	**0.435 g**	**0.467 f**	**0.498 e**	**0.534d**	**0.568 c**	**0.595 b**	**0.626 a**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Concerning fruit physical properties, the results are in similar to those obtained by El-Anany **[30]**, Shirzadeh **[31]** on apple fruit and Hassan **[32]** on tangerine citrus fruits who found that the fruits treated with examined materials showed a significant delay in weight loss (%) during the cold storage compared to the untreated fruits (control). Pear fruits cv. Le Conte coated with moringa oil (MO) progress in reducing the weight loss during cold storage periods for 105 day **[33].** It is possible that the reason that the treatments kept their firmness better than the untreated fruits was due to a reduction in moisture loss. This notion is supported by Aguirre **[34]**, who found that moisture loss not only correlates with mass loss, but also with fruit softening. Avocado softening is caused by a loss of membrane integrity due to mass loss and enzymatic activity, which hydrolyzes the cell wall structure and causes solute leakage **[35].** Avocado membranes are mostly made up of cellulose and hemicellulose, as well as pectins; hydrolysis and depolymerization of these structures by enzymes including polygalacturonase and pectin methylesterase causes fruit softening **[36].**

Regarding fruit chemical properties, the TSS findings are consistent with Liu **[37],** who found that ripening avocados at 20°C resulted in a significant decrease in TSS in the peel and flesh, particularly the C7 sugars, and that the decrease in TSS was accompanied by an increase in oil content. A decrease in TSS was found during storage at 1 and 5°C, but at a slower pace. Similarly, Liu **[38]** discovered a drop in C7 sugars as the ripening process progressed. Avocado fruits treated with moringa had the highest soluble solid content, according to Yousef **[23]**. They went on to say that essential oils had a beneficial impact on postharvest quality variables like total soluble solids. Avocados require carbohydrates as a source of energy for growth, development, and maintenance **[37, 39]**. The avocado has five primary soluble sugars, including the unusual seven-carbon sugar (C7), it lowered mannoheptulose sugar, polyol form, perseitol, common disaccharide sucrose, and its constituent's hexoses, fructose, and glucose **[37]**. These accounted for roughly 98 percent of the total soluble sugars (TSS). Carbohydrates were saved during avocado growth, but once the fruit was harvested, they were utilized for postharvest physiological functions like respiration via enzymatic systems that metabolize the C7 sugars **[37].** This shows that the C7 sugars play a key part in the avocado respiration during ripening.

The aforesaid acidity results are consistent with those obtained by Holcroft **[40],** who found that strawberries subjected to higher carbon dioxide concentrations at 5°C had higher pH and lower levels of titratable acidity. Tefera **[41]** found that mangoes subjected to postharvest treatments, packaging, and storage for 28 days had a decrease in titratable acidity from 3.42 to 0.2 percent, which was consistent with results obtained by Mehdi **[42]** on banana and papaya fruits, Shirzadeh **[31]** on apple fruits and Cruz **[43]** on pear fruits. According to Abdel-Moniem **[44]**, edible coating fruits such as Arabic gum and moringa enhanced fruit quality.

Over the course of 20 days, the amount of ascorbic acid in both treated and untreated fruits fluctuated, with the latter tending to decrease. Biosynthesis and breakdown reactions both affect ascorbic acid concentration, according to Del Aguila **[45].** In many vegetables, ascorbic acid levels decrease during ripening and storage, however, ascorbic acid oxidase or other oxidising enzymes, such as peroxidase, are frequently responsible for this effect **[46]**. Other elements, including as storage temperature, application, and coatings, might cause stress in the fruit, affecting its decomposition **[47]**. According to Ramful **[48]**, fruit is divided into three groups based on its ascorbic acid content: low (300 mg kg^{-1}), medium (300–500 mg kg^{-1}), and high (<500 mg kg^{-1}). Avocados are classed as fruits with low ascorbic acid content and a high concentration of liposoluble vitamins, according to this categorization. The findings obtained are identical to those obtained by El-Sharony **[11]** and Abd el-Moneim **[44].**

Results of chlorophyll and carotenoids are matched with those obtained by Sherif **[49]** who found that edible-coating treatments included Arabic gum at 10% and moringa at 10% recorded higher chlorophyll content than the uncoated guava fruits. Edible coatings are able to delay ripening and inhibit color change. Moreover, the degradation of chlorophyll and the increase in carotenoids content are related to ethylene production which causes a natural ripening process. The role of coating treatments in fruit is through delaying metabolic processes which accelerate color change **[50].**

The changes in total phenolic content are correlated to the activity of polyphenol oxidase enzymes **[51, 52, 53].** In this concern, Ali **[14]**, Addai [**15]** and Ali **[54]** found that Arabic gum as edible coatings maintain the antioxidative polyphenols of tomatoes and papayas. Chrysargyris **[55]** noticed that the increase in total phenols with 20% Aloe-coated fruits after 14 days of storage correlated to the increase of ethylene emission rates. Changes in total phenolic compounds of tomato fruits during storage are depending on the cultivar, species and temperature **[56]**. Coating guava fruits with 10% Arabic gum combined with moringa (10%) reduced the total phenol contents at the 7^{th} day, which increased at the 14^{th} day of storage **[49].**

Polyphenol oxidase (PPO) activity increases during ripening in stored avocado due to the darkening of the fruits **[57]**. Our results are in agreement with those found by Tesfay **[21]** who found that applying moringa leaf extract as avocado edible coating decreased PPO activity in avocado mesocarp. Edible films as any thin material used to wrap fruits and vegetables to extend their shelf life, can protect them from enzymatic browning reactions and fat oxidation **[58]**. Aloe-vera gel has been shown to delay oxidative browning and increasing storage shelf-life in pomegranate arils **[59].**

5. Conclusion

The presented results suggest that the physical and chemical properties of Hass avocado fruits during cold storage at 5±1˚C and 85-90% RH were affected by all treatments under the study compared to the untreated fruits where the results clear the following observations:

i) *Moringa oleifera* seed oil at 1000 ppm+10% Arabic gum was the most effective treatment and showed better properties for avocado fruits such as fruit firmness, titratable acidity and the activity of polyphenol oxidase (PPO) throughout storage period. Also, the same treatment improved the total phenol content, chlorophyll a, b and total carotenoids. On the other side, fruit weight loss, titratable acidity and PPO activity had gradual increment.

ii) Untreated avocado fruits (control) showed gradual decrease in fruit firmness, TSS, ascorbic acid, total phenol and carotenoids values during cold storage at 5±1˚C and 85-90% RH.

6. Conflicts of interest

The authors declare that they have no conflict of interest.

7. Formatting of funding sources

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