MAINTENANCE OF POMEGRANATE FRUIT QUALITY BY COATING WITH FLAXSEED, BLACK SEED OILS, AND CHITOSAN DURING DIFFERENT STORAGE PERIODS

Heshw wafa Rashid Ali[1], Researcher
Ali Muhi Aldeen Omar Aljabary[2] Assist. Prof.
[1]Dept. Horticulture -Coll. Agric. Engine. Sci. University of Kirkuk
[2]Technical Coll. of App. Sci. - Sulaimani Polytechnic University
heshw-wafa@uokirkuk.edu.iq, ali.omar@spu.edu.iq

ABSTRACT

This study was conducted on the Salakhani pomegranate fruit, to study the impact of coating with (0.5 and 1) % flaxseed, (0.5 and 1)% black seed oil, and (0.5 and 1)% chitosan plus control treatment and with five storage periods. The fruits were harvested at full ripening stage on 2/11/2020 from a private orchard. The fruits were divided into groups according to the concentrations of flaxseed oil, black seed oil, and chitosan, as well as the control treatment and storage periods. Fruits were dried well after the coating process and placed in special boxes (carton boxes), the fruits were stored for five storage periods at a temperature of 5±1°C and with 85-90% relative humidity. The factorial experiment within the complete randomized design was used with three replicates. Coating fruits with flaxseed oil at 0.5% and 1% while black seed oil and chitosan at 1% had an effect in reducing the weight loss of fruits during storage. All coated treatments caused to significantly maintain the visual evaluation quality, and decrease the chilling injury of fruits, also increased the total soluble solid, total sugars and anthocyanin in juice content than the control except for coating 0.5% flaxseed oil. The storage for 4 months was significantly superior to the percentage of total sugars, the content of anthocyanin, maintained the visual evaluation quality and decreased the chilling injury of fruits.

Keywords: cold storage, treatments coating, weight loss, chilling injury.

مجلة العلوم الزراعية العراقية -2023 :54(6):1689-1702 علي والجباري

المحافظة على جودة ثمار الرمان بتغليفها بزيتي بذور الكتان والحبة السوداء والجيتوسان أثناء فترات التخزين المختلفة

هيشو وفا رشيدعلي[1] باحثة
علي محي الدين عمر الجباري[2] أستاذ مساعد
[1]قسم البستنة – كلية علوم الهندسة الزراعية – جامعة كركوك، [2]الكلية التقنية للعلوم التطبيقية – جامعة السليمانية التقنية

المستخلص

أجريت هذه الدراسة على ثمار الرمان صنف Salakhani، لدراسة تأثير التغليف بزيت بذور الكتان بتراكيز (0.5 و1)٪ وزيت الحبة السوداء بتراكيز (0.5 و1)٪ و بتراكيز (0.5 و1)٪ من الجيتوسان بالإضافة إلى معاملة المقارنة ومع خمس فترات تخزين. قطفت الثمار في مرحلة النضج الكامل بتاريخ 2020/11/2 من بستان خاص. تم تقسيم الثمار إلى مجموعات حسب تراكيز زيتي بذور الكتان والحبة السوداء والجيتوسان بالإضافة إلى معاملة المقارنة وفترات التخزين. حيث تم تجفيف الثمار جيدًا بعد عملية التغليف، ووضعت الثمار في صناديق خاصة، وخزنت الثمار حسب فترات تخزين عند درجة حرارة 5±1°م ورطوبة نسبية 85–90٪. استخدمت التجربة العاملية ضمن ضمن التصميم العشوائي الكامل بثلاث مكررات. بينت النتائج بانه كان لتغليف الثمار بزيت بذور الكتان بتركيز 0.5٪ و 1٪ بينما زيت حبة السوداء والجيتوسان بتركيز 1٪ كان له تأثير في تقليل فقدان الوزن في الثمار. تسبب جميع معاملات التغليف في الحافظ معنويا على جودة التقييم البصري وقلل من نسبة الإصابة بأضرار البرودة، وكذلك في زيادة المواد الصلبة الذائبة الكلية والسكريات الكلية والأنثوسيانين في محتوى عصير مقارنةً بمعاملة المقارنة باستثناء التغليف بتركيز 0.5٪ من زيت بذور الكتان. كان التخزين لمدة 4 أشهر متفوقًا بشكل كبير على النسبة المئوية للسكريات الكلية ومحتوى الأنثوسيانين وحافظ على جودة التقييم البصري وقلل من نسبة الإصابة بأضرار البرودة.

الكلمات المفتاحية: التخزين البارد، معاملات التغليف، الفقد في الوزن، أضرار البرودة.

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INTRODUCTION

Pomegranate (*Punica granatum* L.) is an economically important crop with great nutritional value (22). Considering its importance many researchers focused on improving its productivity and quality, the pomegranate fruits are considered non-climacteric (16,20). It is necessary to harvest fully ripened fruits; pomegranate fruits are very sensitive to storage conditions, as this causes fruit spoilage, weight loss and chilling injury (29). The peel hardens, stains brown, and reduces the attractiveness of the fruit (10). Chilling injury (CI) is a major problem after harvest, which reduces the marketability of the fruit. CI is induced in inner tissues after a short time of cold storage (2 weeks) at 1 °C, and symptoms like browning appear when fruits transfer to 20 °C as shelf-life conditions (9). Losses due to rotting may be up to 30% of the pomegranate yield if no control measure is taken (38). Flaxseed appears as a significant functional food component because of its high content of α-linolenic acid (ALA), omega-3 fatty acid, lignans, and fiber (15). The ALA bioavailability is greater in oil compared to milled seed and has maximal bioavailability in both than in whole seed (8). Therefore, flaxseed oil may possess some advantages to be applied as an additional ingredient in the coating of foods and fruits. Recent studies have shown that the use of flaxseed oil has a big role in an extended storage period of pomegranate fruits which causes reduced weight loss and cold damage and prolongs the storage period (3). Several studies have indicated that the use of black seed oil to the extent the storage period of pomegranate fruits caused reduced weight loss and cold damage and prolonged storage period, as well as reduced the percentage of microbial damage and maintaining the quality and marketability of pomegranate fruit (3,21), and in banana fruits (24). Chitosan is a positively charged, high molecular weight polysaccharide that is soluble in dilute organic acids and can extend shelf life by controlling spoilage of many fruits such as pears, longan, and strawberries (19,18). The fruits of the Salakhani cultivar have been described as medium to large in size and have a thick reddish-yellow peel saturated with pink. Moreover, the arils are red to pink and juicy, it taste sour-sweet with good flavor, and the fruits of this cultivar are the most important for export in Kurdistan Iraq (4,1). Therefore, the present study aimed to evaluate the effect of coating with flaxseed, black seed oil, and chitosan in maintaining the storage quality characteristics and prolong the storage period and shelf life of the "Salakhani" pomegranate fruits

MATERIALS AND METHODS

This study was carried out on the “Salakhani” pomegranate fruits, which harvested manually from fifteen years old trees at full ripening stage (2 November 2020), from the private orchard in the Sazan village of Halabja Governorate in the Iraqi Kurdistan region. Pomegranate fruits were harvested early in the morning using shears. The fruits were selected that were uniform as possible in maturity, size, and color, also free from phenotypic defects such as cuts, bruises, and diseases at harvest. The harvested fruits were transferred to the laboratory of the Technical College of Applied Sciences in Halabja Governorate during same day. The fruits were divided into groups according to the storage period and the concentrations of flaxseed oil, black seed oil and chitosan plus control treatment as mentioned below:

First Factor: Immersing treatments

(T1) Fruits immersed in distilled water for one minute as control treatment.

(T2) Fruits immersed in 0.5% of flaxseed oil for one minute.

(T3) Fruits immersed in 1% of flaxseed oil for one minute.

(T4) Fruits immersed in 0.5% of black seed oil for one minute.

(T5) Fruits immersed in 1% of black seed oil for one minute.

(T6) Fruits immersed in 0.5% of chitosan for one minute.

(T7) Fruits immersed in 1% of chitosan for one minute.

Second Factor: Storage periods, the fruits were stored for one to five months as storage periods.====Fruits were dried well after immersing process and placed in special boxes (carton box), then fruits were stored according to their treatments and replications in a cold room at 5ºC with a relative humidity of 85-90%.

Solutions preparation methods

Flaxseed oil is obtained by cold pressing flax seeds to obtain 100% pure oil, and then 10 ml of flaxseed oil dissolved in ethanol by adding 90 ml of ethanol (70%) to it, and stirring for one day and then filtered and diluted the final solution with distilled water to prepare the required concentrations of the treatments (0.5% and 1%) as mentioned by (21). The same method was used to extract black seed oil and prepare the required concentrations of 0.5% and 1%. Chitosan coating was prepared according to Han's method (17), Chitosan was dissolved in distilled water Containing 0.2% glacial acetic acid with 0.1% Tween 20, then the mixture was mixed to homogeneity and the pH of the solution was maintained at (10) by adding 0.5 with 1 M sodium hydroxide.

Design and Statistical Analysis

The factorial experiment (7 x 5) within a complete randomized design (CRD) was used with three replicates and 15 fruits for each experimental unit. Collected data were analyzed by using SAS 9.1 software and the Duncan comparison method at the level of 5% was utilized for comparing the mean of treatments.

Characteristics of storage fruits quality

At the end of each storage period, the following characteristics of pomegranate fruits were determined:

Weight loss (%)

It was estimated by taking the weight of the fruits at the beginning of storage and at the end of each storage period.

Chemical juice parameters

A compound juice sample (250 ml) was prepared by collecting 50 ml of juice from five fruits in each replicate. Then sample was filtered by filter paper and 50 ml of obtained juice was placed in a plastic bottle with a tight lid and kept in the freezer until the juices of all samples were completed (23,2). Eventually, the various chemical properties of the juice were studied as follows:

Total soluble solids (TSS) % was measured by Hand Refractometer as ^{o}Brix. While Titratable Acidity (TA) % fruit juices were titrated with NaOH using phenolphthalein indicator and the acidity was determined as citric acid content followed by the method of (30). According to (5), total sugars were determined by using phenol 5% and H2SO4 (97%). Finally, total sugars were estimated by spectrophotometer at 490 nm. Anthocyanin (mg.100 ml^{-1} juice) was estimated according to (30) by using the solution (95% ethanol and 1.5 N hydrochloric acid (HCl) at 85:15 each respectively). Then anthocyanin was measured by using a spectrophotometer at the wavelength of 535 nm.

Visual evaluation (%)

This evaluation was carried out at the end of each storage period, by taking 3 fruits randomly (from each replication) after removing them from the cold storage conditions and keeping them at room temperature for 4 days, It was analyzed according to the measures that were suggested by (21, 35) as follows; 0, stained dried fruits have a lot of defects and/or a lot of microorganisms; 1, 51-60 percent fruit dryness, significant defects, and/or bacterial attack; 2, fruit dryness by 31-50% and/or moderate defects; 3, fruit dryness of 11-30% and/or the presence of slight defects; 4, 1-10% dryness and/or the presence of defects on the fruit; 5 fruits have less than 1% scratches, no defects, and no attacks by microorganisms.

Chilling injury (%)

To calculate the cold damage of the fruits as in the visual evaluation, at the end of each storage period, by taking 3 fruits randomly (from each replication) after they were removed from the cold storage conditions and kept at room temperature for 4 days, the chilling injury of the pomegranate is calculated According to previously proposed scales (21,35) put the measurements 0-3, as follows: 0, none visible; 1, slight (≤25%); 2, average (26-50%); and 3 severe (>51%).

RESULTS AND DISCUSSION

Weight loss (%):

The results in **Fig. 1.** show the effect of immersion in oils (flaxseed, black seed) and chitosan on fruit weight loss. The results indicated that most of the fruit coating treatments were significantly superior to the control treatment for reducing weight loss, especially, the fruits coated with (T2, T3, T5, and T7), and the lowest weight loss (8.33%) among all treatments was recorded from fruits coated with 0.5% of the oil Flaxseeds. This result is in agreement with the results of (14)

in their study, it was concluded that fruits immersed in 1% chitosan reduced the weight loss of fruits compared to fruits in the control treatment. (21) Studied the effect of black seed oil use on the post-harvest quality of the exquisite pomegranate cultivar. These researchers reported that black seed oil was a good protection against weight loss in pomegranate. The results of the current study also agreed with the results of the study (35) where it was mentioned that the use of black seed at a concentration of 200 ppm reduced the weight loss of pomegranate fruits compared to the control treatment fruits. The results of the current study agree with the result of a study conducted on the positive effect of oils (black seed and flaxseed) in reducing the weight loss of Salakhani pomegranate fruits during the cold storage compared to the control treatments, where it was stated that it may be due to the formation of a thin layer of oil around the peel of the fruit (3). On the other hand, (43) the effect of flaxseed gum as an edible active topping for quality ready-to-eat pomegranate was examined. The results indicated that flaxseed gum was somehow effective in reducing weight loss from pomegranate arils. In a study carried out on the post-harvest quality of the (Hicaznar) cultivar of pomegranate fruit, Candir et al (11) showed that fruits immersed in 1% chitosan for one minute were significantly superior on the control treatment in weight loss, which was close to the results of the present study. Molaei et al (28) studied the effect of chitosan treatment on cooling injuries and quality characteristics of pomegranate fruits during cold storage and reported that fruits treated with 1% and 2% chitosan lost about 8% and 6% of their weight, respectively, which was significantly less weight loss form fruits in the control group (25). It was revealed in his study that the fruits immersed in a concentration of 1% chitosan significantly reduced weight loss compared to the control fruits. The positive effect of the edible coating on reducing weight loss is due to the thin layer of oil around the fruit, where the oil treatment methods act as a barrier to permeable of moisture, CO_2, O_2, and reduce respiratory rates and water loss (32). In this study, an increased reduction in weight loss when using flaxseed and black seed oils could be due to the fact that the oil has good water vapor barrier properties (31). Using the oil coating to form a thin layer around the fruit, lead to a lower rate of water loss, which leads to reduced weight loss.

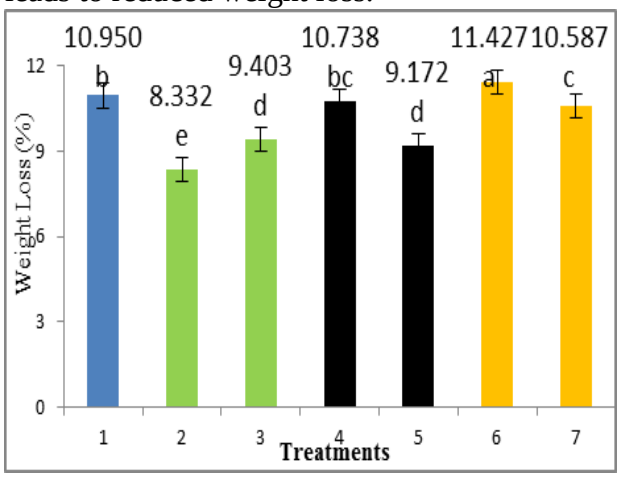

Fig. 1. Effect of flaxseed oil, black seed oil and chitosan concentrations on weight loss of the Salakhani pomegranate fruits.

Usually, weight loss increases with increasing the storage periods, as expected, the results showed that weight loss percentage increased gradually and significantly with increasing the storage periods, the fruits lost 4.20% of their weight in the first month of storage and this percentage reached 15.02% after five months of storage Fig. 2. This decrease of the weight loss may be due to the decreasing peel moisture with increasing the storage periods (Fig. 3). Pomegranate fruit weight loss is one of the most common postharvest issues. Long and inefficient storage results in significant losses in weight, as well as fruit quality and farmer revenue. Weight loss also causes the husk to harden and the rind to darken), weight loss can be seen as a sign of agricultural produce's freshness. The findings of the present study were also supported by the results reported by Varasteh et al (41). Similar results were found by Kahramanoğlu et al (21) indicated that the weight of pomegranate fruits was higher at the end of the experiment period compared to the beginning of the study who found an increasing trend of loss of pomegranate fruits weight during the storage period. Pomegranate fruit is very sensitive to storage conditions, and it loses weight and quality over time. Pomegranate fruit suppliers and marketers face a major problem in maintaining the quality post-harvest. The results of the current research are close to the

results of the study (6) on the pomegranate fruits cv. (Armishty), where the rate of weight loss increased with the prolonged storage period.

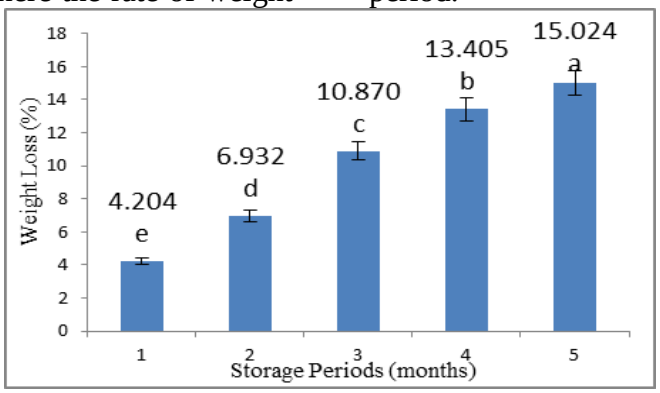

Fig. 2. Effect of storage periods on weight loss of Salakhani pomegranate fruits

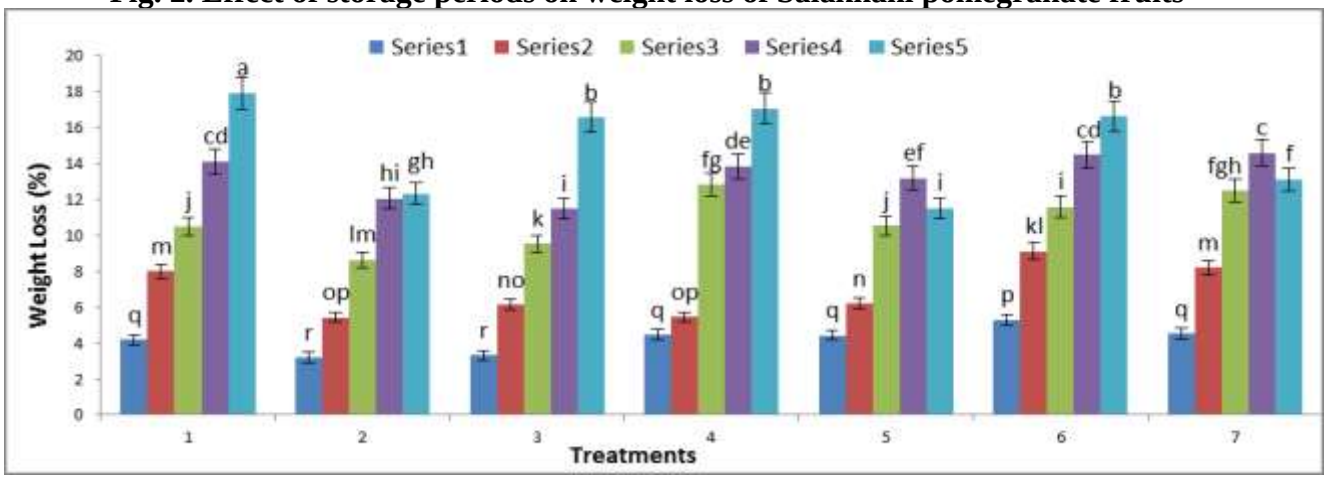

Fig. 3. The effect of interaction between the treatments and the storage periods on weight loss.

The effect of the interaction between treatments and storage times on weight loss. Through Fig. 3. it was found that the highest fruit weight loss in the untreated fruits (control) was nested with the fifth month of storage which reached (17.92). The best interaction treatment for reducing weight loss to (3.20) was coating fruits with 0.5% flaxseed oil nested with two months of storage.

Total soluble solids (TSS)%

The results in Fig.3 indicate that there are significant differences among treatments in the total soluble solids of pomegranate fruit juice, the fruits coated with 0.5%chitosan gave a higher percentage of total soluble solids which was significantly superior to the fruits in the control treatment. The lowest total soluble solids content was observed in fruits coated with 0.5% flaxseed oil. Interestingly, pomegranate fruits treated with (0.5) chitosan gave a higher TSS content than those treated with 1% chitosan. TSS is defined as the measurement of the carbohydrates, organic acids, proteins, fats, and minerals in the fruit, when fruit grows it becomes less acidic and sweeter. It is critical that the grower strives to achieve a satisfactory balance between TSS and fruit acidity (7). This increase of TSS in fruits treated with T6 may be due to the increase of water loss in this fruit (Fig.1). This result coincides with the studies conducted on the effect of chitosan coating on pomegranate fruit (12) and of mango (13) Chitosan coating application has shown effects on total solubility dissolved solids content

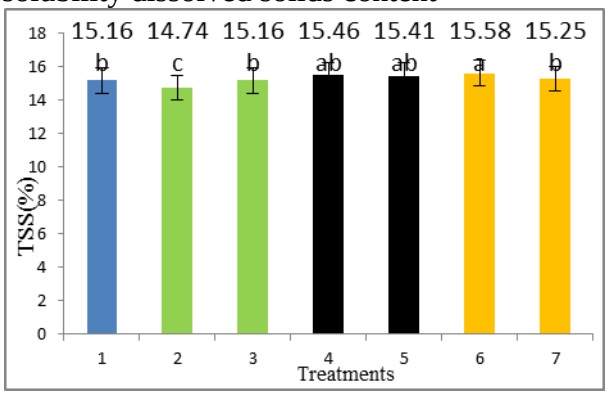

Fig. 4. Effect of flaxseed oil, black seed oil and chitosan concentrations on TSS% of the Salakhani pomegranate fruits

In this study, the effect of storage duration was highly significant on the TSS ratio (fig.5). In the second month of the storage the highest TSS content (16.20%) was observed, it may be due to a decrease in the rate of respiration in the second month which cause to lack of consumption of the reserved dry matters in the fruits, while the lowest amount of TSS (14.84%) was observed in the third month of the storage. Varasteh et al (41) revealed that the TSS of fruits was increased, but did not significant, from 1 to 45 days of the storage, and then, a slight decrease was observed from 45 to 135 days of the storage, in a study by Candir et al (11), a slight decrease in the TSS content of pomegranate fruit juice was observed during the storage period; However, its effect did not statistically significant. In another study with similar results, Malekshahi et al (25) indicated that storage duration had no significant effect on the TSS ratio of pomegranate juice.

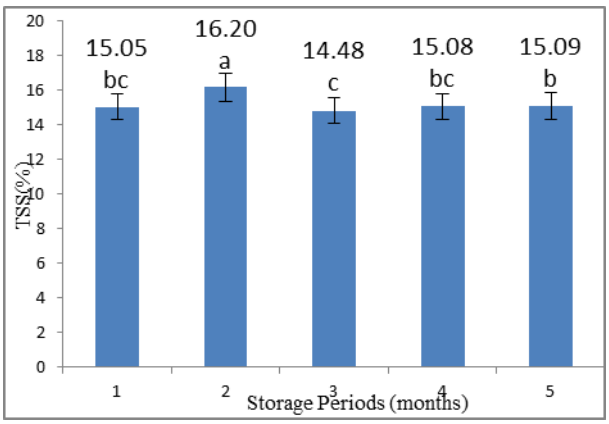

Fig. 5. Effect of storage periods on TSS% of Salakhani pomegranate fruits

As for the interactions among the treatments and the duration of storage on TSS of juice contains the highest percentage of total soluble solids was observed in the second month of the storage in the fruits coated with 0.5% black seed oil (16.73%). While recorded the lowest TSS (14.43%) in fruits coated with 0.5% flaxseed oil and stored for four months of the storage (Fig.6).

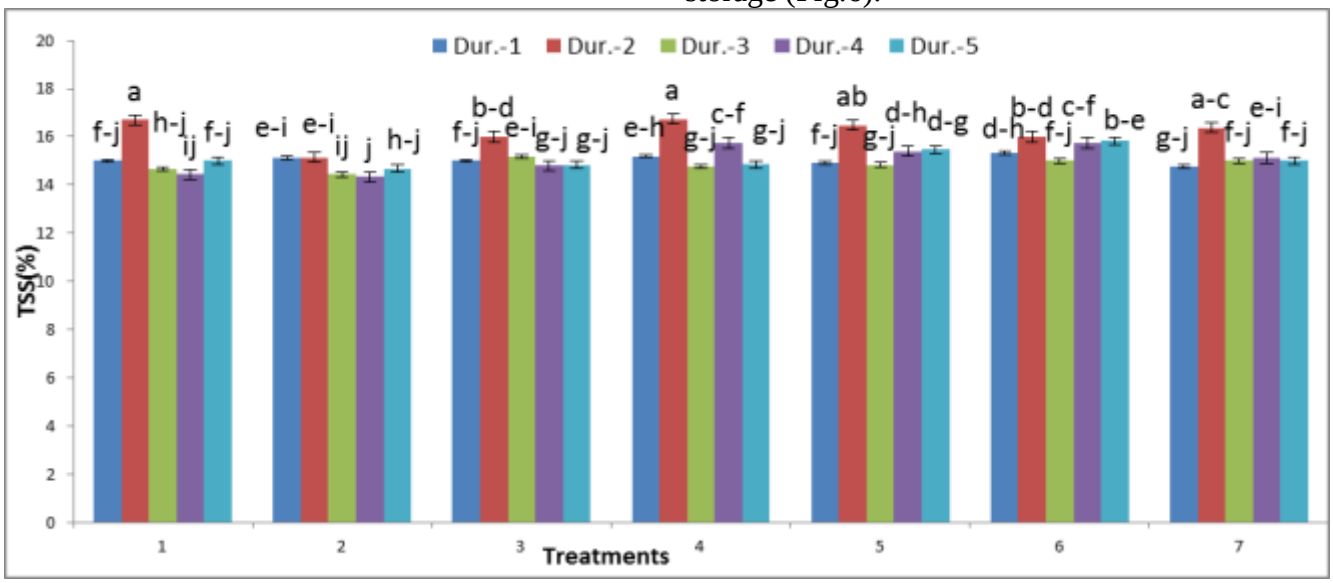

Fig. 6. The effect of interactions between the treatments and the storage periods on TSS (%)

Total acidity (TA) %:

Through **Fig.7**, the results show the positive effect on TA%, that fruits of all treatments contain a higher amount of TA% compared to the untreated fruits. The highest percentage was obtained in fruits treated with 0.5% black seed oil.

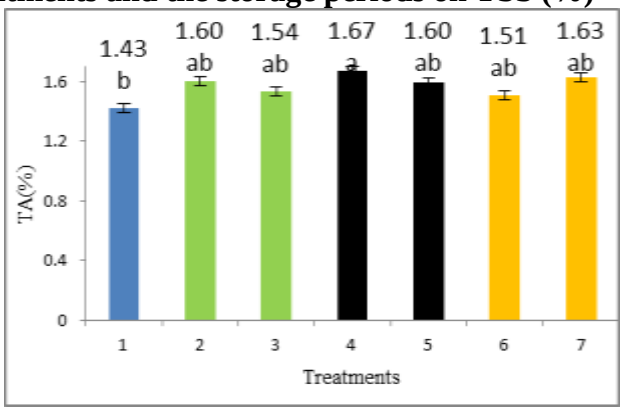

Fig. 7. Effect of flaxseed oil, black seed oil and chitosan concentrations on TA% of the Salakhani pomegranate fruits

As for the effect of the storage period on the TA%. Figure (8) shows that in contrast to the TSS content approximately, the highest percent of TA was observed in the fruits that were stored for five months, while the lowest percent of TA was obtained from the fruit juice that was stored for two months. This may be due to the conversion of organic acids into other compounds like sugars and vice versa as shown in (fig. 5) as the highest TSS in the second month had similar results with a study (37). Varasteh et al (41) reported that during the storage period, %TA content showed a decreasing rate until the end of the storage and this reversed with our results. These changes in TA% in our study may be due to the changes that occur in the stored compounds in the fruits during the respiration process as convert the carbohydrate compounds to organic acids or to phenolic compounds or to amino acids and in contrast.

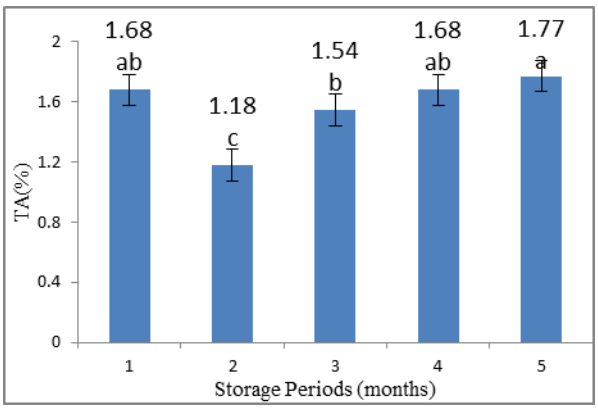

Fig. 8. Effect of storage periods on TA% of Salakhani pomegranate fruits

As for the interaction effect between immersion in (flaxseed, black seed, and chitosan oils) and storage time, when considering the TA content of fruit juice in (fig. 9) the fruits immersed in 0.5% flaxseed oil at the first month of the storage showed the highest amount of TA (2.26%). On the contrary, untreated fruit juice in the second month of storage showed the lowest amount of TA (0.94%).

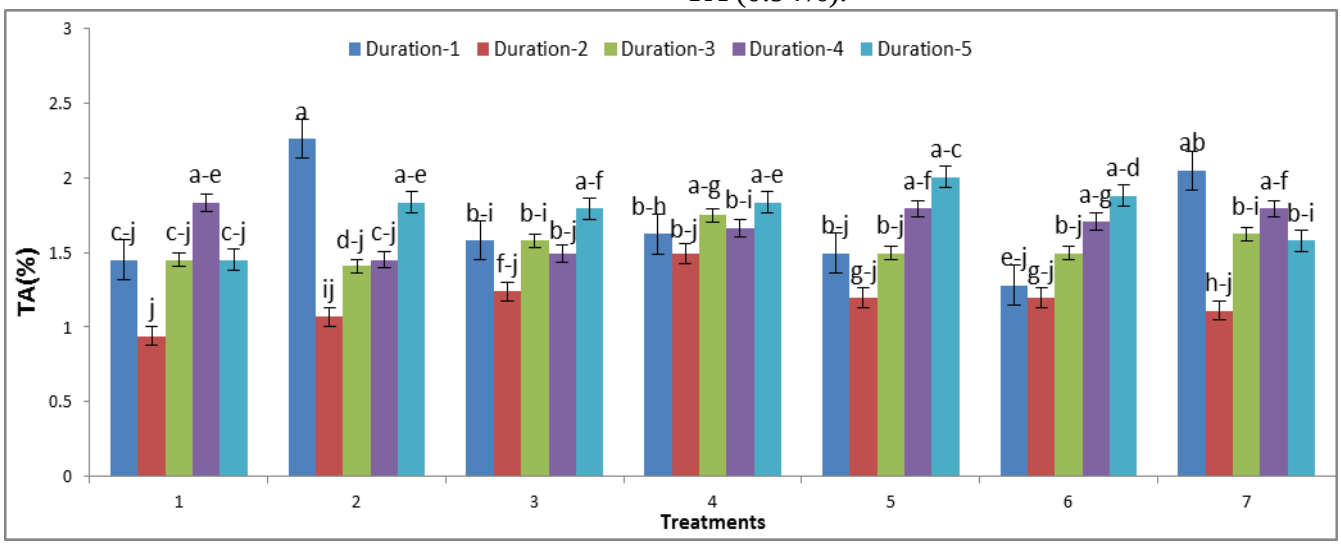

Fig. 9. The effect of interactions between the treatments and the storage periods on TA (%).

Total sugars (%): Through (Fig.10) there are significant differences between the treatments, the results of this study indicated that the fruits covered with 1% black seed oil had the highest percentage of total sugars (3.82) and were significantly superior to the control fruits. On the other hand, the lowest percentage was obtained in fruits treated with 0.5% flaxseed oil (T2). This decrease in total sugars may be due to the increment in the respiration rate in this treatment which caused to raising in the consumption of sugars during the respiration process or conversion to other compounds. In addition, the positive effect of the fruit coating reduces the weight loss of the fruit and this may be due to it making a thin layer of coating around the peel of the fruit. This layer acts as a barrier against moisture loss and air exchange, thus reducing oxidation, reactions, and water loss (25). The results of the current study are similar to the results of study (3) on flaxseed oil and black seed when the pomegranate fruits were immersed in 2% black seed oil and 1% and 2% flaxseed oil, the total sugar content in the immersed fruits was significantly superior to the fruits in the control group.

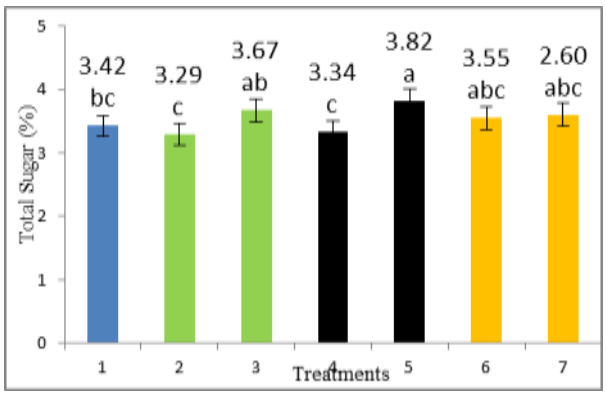

Fig. 10. Effect of flaxseed oil, black seed oil and chitosan concentrations on total sugar (%) on the Salakhani pomegranate fruits

Related to the effect of the storage period on the percentage of total sugars in Fig. 11 the minimum was in the second month (2.08%), where the higher the respiratory rate the percentage of sugars decreases, as sugars are the main subject matter that is consumed in the respiration process. Then this percentage gradually increased until the end of the study. These increases in the total sugar content in the fruit may be due to the gradually increasing water loss in the fruit during storage periods (Fig. 2), which resulted in the concentration of fruit juice and thus the increase in total sugars in it.

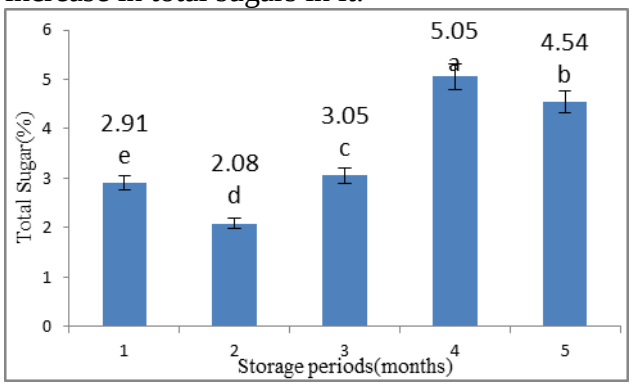

Fig. 11. Effect of storage periods on total sugar (%) of Salakhani pomegranate fruits

Regarding the effect of interactions among oil immersion (flaxseed, black seed), chitosan, and the storage period, through (fig. 12) it was found that the treatment of black seed oil at a concentration of (1%) in the fifth month significantly outperformed the comparison and other treatments (5.91%) in maintaining the total sugar content. The lowest percentage of total sugars for treatment of flaxseed oil concentration (0.5%) was in the second month (1.66%).

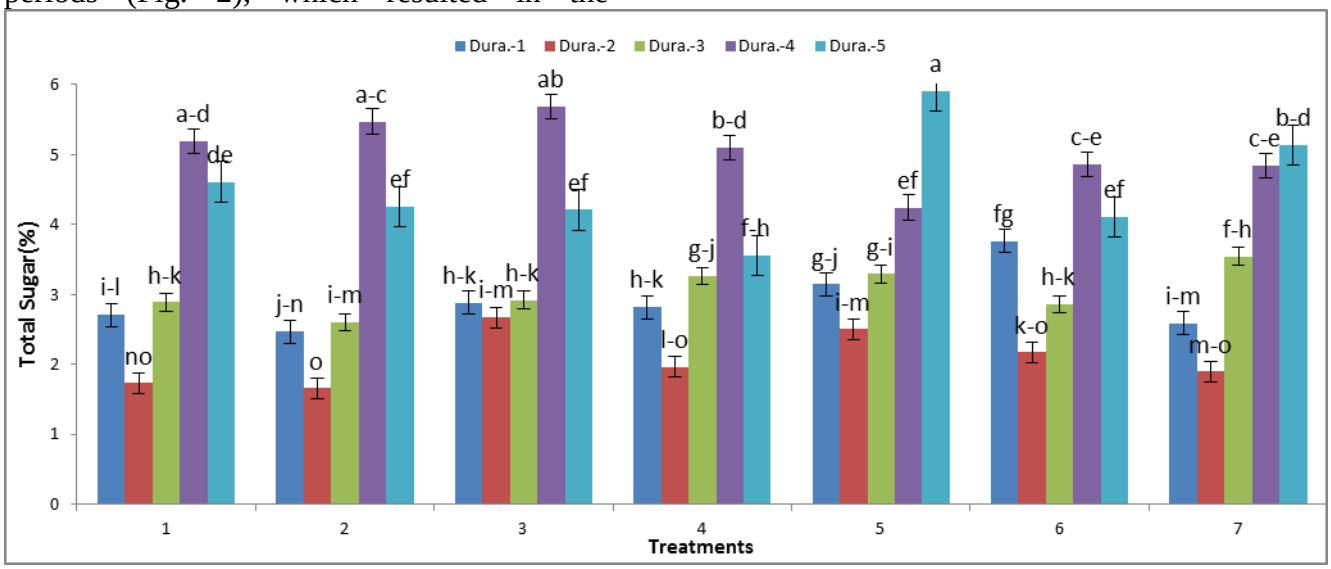

Fig. 12. The effect of interactions between the treatments and the storage periods on Total sugar (%)

Anthocyanin content (mg.100ml^{-1} juice)

The effect of treatments on anthocyanins in pomegranate juice was presented in Fig. 13. Through the results, it was found that there are significant differences among the treatments, all treatments significantly increased the anthocyanin content compared to the control except T2 (0.5% flaxseed oil) which gave the lowest value (11.46%). This may be a result of the increase in the respiratory rate of fruits in T2, as Miguel et al (26) mentioned that any increase or decrease in anthocyanin is affected by CO_2 and O_2 levels. They also showed that chitosan increased anthocyanin content compared to fruits in the control group. Similar results were found by Molaei et al (28), who reported the positive effects of 1% and 2% chitosan on increasing the total anthocyanin content in the (Malas e Saveh) pomegranate cultivar. Furthermore, our

findings revealed that coating treatments reduced anthocyanin degradation over time. This was likely due to the fact that coating treatment reduces the activity of polyphenol oxidase and peroxidase enzymes in response to changes in the internal environment of the coated fruit (42). The results of this study agree with the results of the study (3) by increasing anthocyanins in oil-coated fruits of flaxseed and black seed oil compared to uncoated fruits.

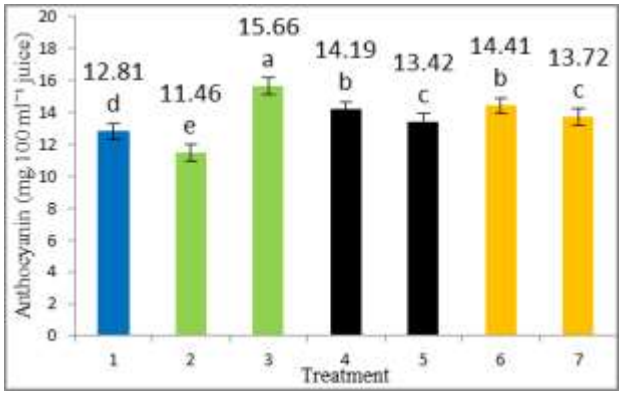

Fig. 13. Effect of flaxseed oil, black seed oil, and chitosan concentrations on Anthocyanin content (mg.100ml⁻¹ juice) of the Salakhani pomegranate fruits

A non-uniform trend of changes in the anthocyanin content of pomegranate fruits during the storage period was observed. Most of the amounts of anthocyanins belong to fruit juice stored for four months (15.65) the anthocyanins may be reverted to sugars (fig. 11), while the lowest amounts were observed in fruit juice stored for three months (11.07) (Figure 14). Candir et al (11) noticed that the color of the Hicanzar pomegranate fruit was redder in the first four months of cold storage as a result of the increase in its contents of anthocyanins, and then there was a loss of anthocyanin contents and a decrease in the red color of the arils at the end of the storage period and the duration of the marketing life.

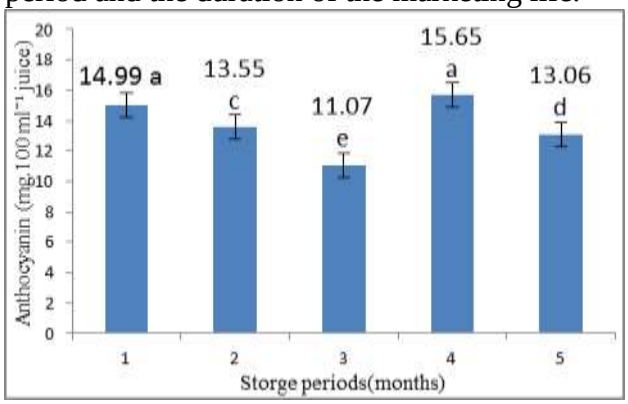

Fig.14. Effect of storage periods on Anthocyanin content (mg.100ml⁻¹ juice) of Salakhani pomegranate fruits

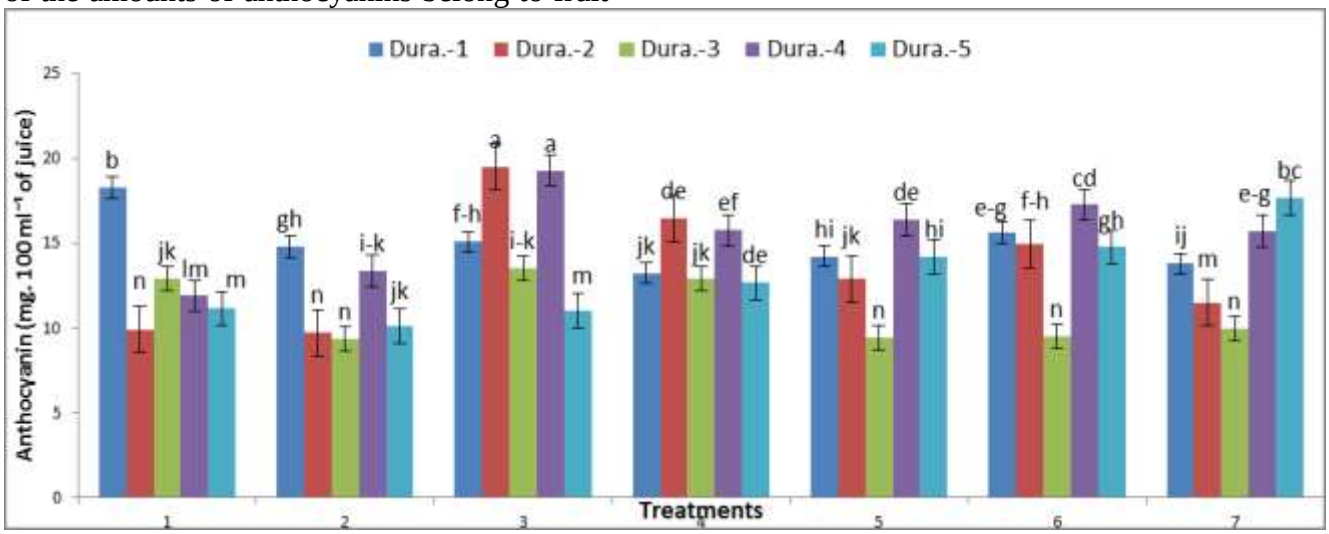

Fig. 15. The effect of interactions between the treatments and the storage periods on Anthocyanin content (mg.100ml⁻¹juice)

The results in **Fig. 15** show the effect of the interactions between treatments and storage period, the significant differences were observed among them, also found that the highest value (19.52%) of anthocyanin content in fruits immersed in 1% flaxseed oil which stored for the two months, while the lowest value (9.36%) was found from fruits treated with 0.5% flaxseed oil which stored for the three months

Visual evaluation (%): From the **Fig. 16** the results indicated that all treatments were significantly superior to maintaining the quality of the fruits than uncoated fruits and

0.5% flaxseed oil, the fruits coated with 1% chitosan were significantly superior to the other treatments, which got the highest percentage (3.99%). While the lowest percentage was recorded in uncoated fruits. This indicated that treatments coating helped preserve the freshness of the pomegranate fruits and their arils until the end of storage. (14) also indicated in their study on pomegranate (cv. Tarom) that chitosan can directly inhibit spore germination and fungal growth on the fruit peel and prolong the fruit storage period, which may be related to its ability to form a film on the surface of the fruit. indicated in their (21) indicated in study on (Wonderful) pomegranate fruits that black seed oil helps to protect the visual quality by weighting the fruits by preventing their drying and preventing the occurrence of mold, and also proved that the black seed oil-coated fruits obtained a higher score than the uncoated fruits with respect to visual quality. Our results were similar to the results of (3) indicating that the oils (black seed and flaxseed) have the ability to reduce the physiological disorders of the Salakhani pomegranate fruits compared to the uncoated fruits.

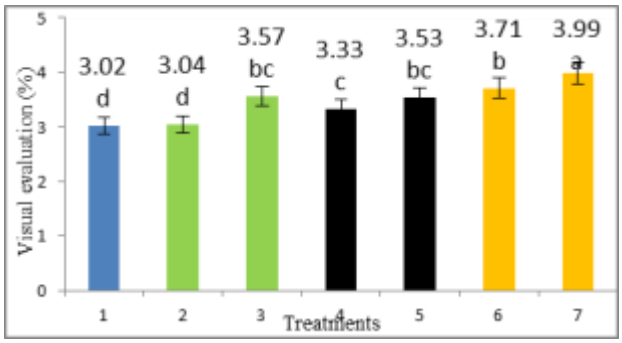

Fig. 16. Effect of flaxseed oil, black seed oil and chitosan concentrations on visual evaluation (%) of the Salakhani pomegranate fruits during 5 months of storage and 4 days at room temperature

Visual quality scores: 5=less than 1% of dents, absence of blemishes, and absence of microorganism attack; 4=1–10% of the fruit was blemished or dry; 3=11–30% of the fruit was dry or showed minor blemishes; 2=31–50% of the fruit was dry or had moderate blemishes; and 1=51–60% of the fruit was dry and had severe blemishes or microorganism attack; 0, dry with very severe blemishes or widespread microorganism attack

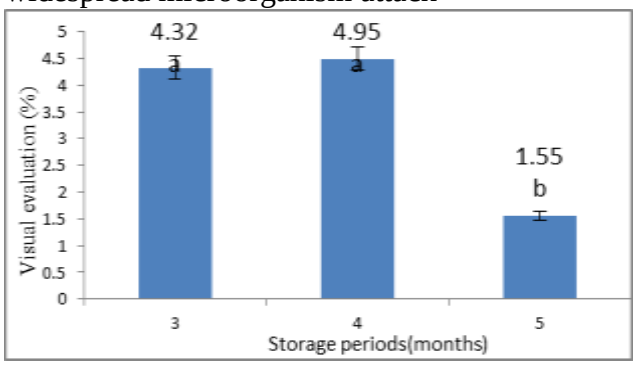

Fig. 17. Effect of storage periods on visual evaluation of Salakhani pomegranate fruits during 5 months of storage and 4 days at room temperature

As for the effect of storage periods studied in the last three months, it was shown in (Fig. 17) that the third and fourth months of cold storage significantly outperformed the preservation of the fruit's quality compared to the fifth month. It is explained by the decrease in the respiratory rate in the third and fourth months, which helped to preserve the quality of the fruit. The visual quality of the studied pomegranate fruits was affected by the interaction of treatments and storage duration, and the best performance was observed of in the fruits coated with 1% flaxseed oil when stored for the four month (4.73), while the fruits coated with 0.5% flaxseed oil at the fifth month of the study showed the lowest visual quality grade (fig. 18).

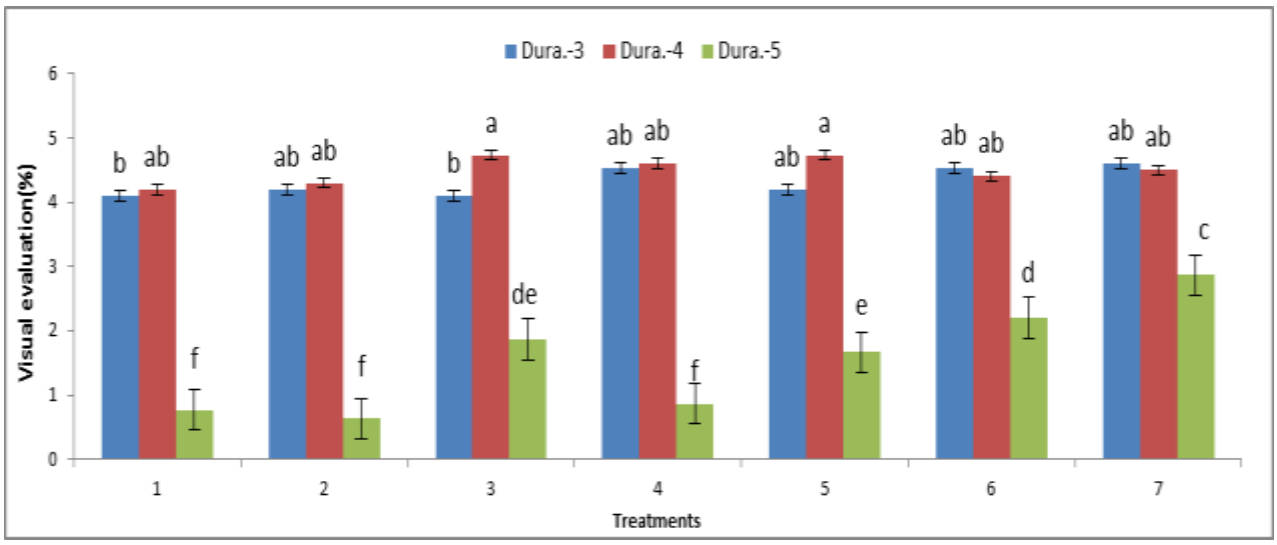

Fig. 18. The effect of interactions between the treatments and the storage periods on visual evaluation (%) during 5 months of storage and 4 days at room temperature

Chilling injury (%): Chilling injury in pomegranate fruits in the form of darkening and pecking in the peel of the fruit, which is very sensitive to damage Sayyari et al (33), most of these symptoms may reach arils, which leads to a decrease in the internal quality of the fruits and leads to an effect on the hardness, color of arils and the content of ascorbic acid in the fruits (40). Color changes in fruits as a result of enzymatic activity are one of the main problems that occur during the processes of harvesting, transportation, and storage of fruits, and the deterioration of qualities is not acceptable by the consumer (39). As for the effect of treatments on the chilling injury of fruits, Figure (20) shows that all coating treatments are significantly superior on the uncoated fruits for reducing the chilling injury of fruits. In a study with similar results, Kahramanoğlu et al (21) found that using 0.1% and 0.5% black seed oil for coating had a positive effect on reducing cold damage in pomegranate fruits. Also, to support our findings, Molaei et al (28) reported that the use of chitosan for coating has a significant effect on reducing cooling damage compared to uncoated fruits. The reason may be attributed to reduces the dryness of the peel cells, which leads to the cells maintaining their stability, and thus reducing the oxidation of anthocyanin (Fig. 13), which is the main cause of the brown color of fruits affected by chilling injury.

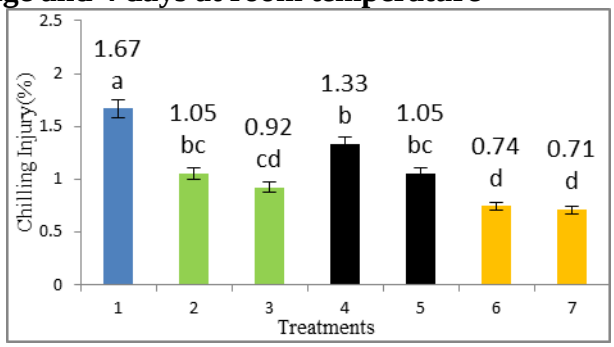

Fig. 19. Effect of flaxseed oil, black seed oil and chitosan concentrations on chilling injury (%) of the fruits of Salakhani pomegranate during 5 months of storage and 4 days at room temperature

Chilling injury scores were given according to the following scale: (0) none visible; (1) slight (25%); (2) moderate (26-50%) and (3) severe (>51%). Related to the effect of the storage period on chilling injury of the fruits, as shown in (fig. 20), it was found that there are significant differences among them, with increasing the storage periods gradually increasing the infection of fruits with chilling injury. In a similar way, Mirdehghan et al (27) mentioned that chilling injury expanded in pomegranate fruit starting from the first testing time, increased with storage time, and it could be found by rind browning, and ion leakage. Serry (34) reported that chilling injury in 'Succary' pomegranates increased with prolonged storage at 5 °C.

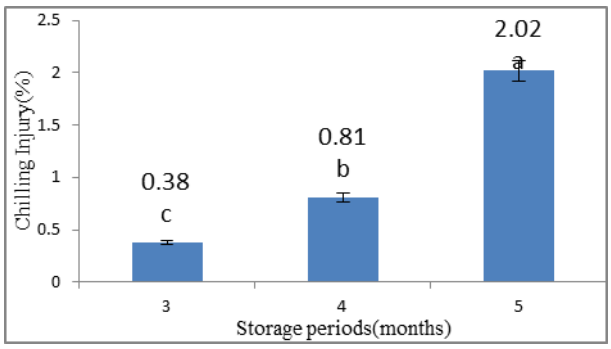

Fig. 20. Effect of storage periods on chilling injury (%) of the Salakhani pomegranate fruits during 5 months of storage and 4 days at room temperature

The effect of the interactions between immersion treatments (flaxseed oil, black seed oil, chitosan) and the storage periods. Noticed from (Fig. 21) that there are significant differences among the interaction treatments, that the control fruits in the fifth month were more affected by chilling injury compared to most of the other interaction treatments, however, fruits coated with (flaxseed oil, black seed oil, and chitosan) at the third month of storage period were the most efficient in preserving the fruits from the chilling injury.

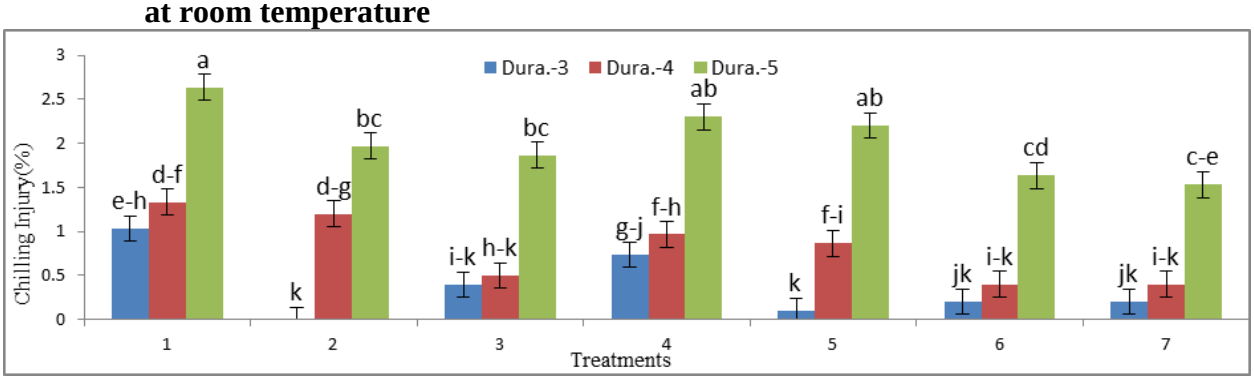

Fig. 21. The effect of interactions between the treatments and the storage periods on chilling injury (%) during 5 months of storage and 4 days at room temperature

Conclusions: Based on the results of the current study, can be concluded that the flaxseed oil at 0.5% and 1% concentrations as well as black seed oil at 1% concentration had a higher effect on reducing weight loss of pomegranate fruits. All coating treatments significantly reduced the infections by chilling injury and also preserved the quality of the visual fruits, hence they can be used for coating pomegranate and even other fruits because of their safety for humans and the environment. On the other hand, all coating treatments maintain the chemical properties of pomegranate juice than the control treatment except 0.5% of flaxseed oil. Storing "Salakhani" pomegranate fruits for five months at 5˚C causes to reduction in the visual evaluation and increases the infection of fruits with chilling injury, thus prefer not to store fruits of this cultivar at this temperature for more than 4 months.

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