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ORIGINAL ARTICLE

EFFECT OF COATING BY CHITOSAN POLYMER WHICH PREPARED IN THE LABORATORY AND THE TYPE PACKING ON SOME PHYSICAL AND CHEMICAL PROPERTIES AND STORAGE CAPACITY OF SIDR FRUITS OF RED MALASI VARIETY

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Abstract: The experiment was carried out in the Laboratory of Storage Technologies, Department of Horticulture and Landscape Engineering, University of Basra during the growing season 2020-2021 on Sider fruits of red Malasi variety, which was brought from one of the private orchards in Al-Houta area of Shatt Al-Arab district in Basra Governorate. To improve the storage capacity of Sider fruits and study some physical and chemical properties in them, the experiment was carried out according to a Complete randomized design (CRD), with three replications and three factors. The results showed that the treatment with chitosan coating at a concentration of 2% led to an improvement in the storage capacity of Sidr fruits by reducing the percentage of total spoilage, weight loss, and the percentage of total soluble solids (15.9, 3.78, 6.33%), respectively, and an increase in the water content and vitamin C, which amounted to (177.60, 66.86%), respectively and packing with polyethene bags succeeded in reducing the percentage of total spoilage, weight loss and total soluble solids, which were recorded (14.19, 4.56, 8.06%), respectively and the storage period of 8 weeks recorded the lowest percentage of water content, total acidity and vitamin C, which amounted to (146.0, 0.61, 62.18%), respectively. The difference between the averages was tested with the LSD test using the statistical program GenStat 2007 to analyze the data.

***Key words*:** *Ziziphus mauritiana*, Chitosan coating, Sidr red Malasi variety, Type of packing, Storage period.

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1. Introduction

Sidr *Ziziphus mauritiana* Lam is one of the oldest types of fruits whose fruits are eaten and mentioned in the Holy Quran and holy books. It is one of the plants of paradise that belongs to the family Rhamnaceae, and it is one of the evergreen fruit trees. The Sidra family is a huge plant family with 55 genera and 950 species. The genus Ziziphus is one of the most prominent genera of the Sidra family, as the total number of species belonging to this genus comprises 170 species, which are widespread in the warm temperate, tropical and subtropical regions of the world, including the red Malassi variety [Hauenschild *et al.* (2016), Christenhusz and Byng (2016)]. The Sidr tree has recently received great attention due to its high adaptability to different soils and drought conditions [Marwat *et al*. (2009)]. Sidr cultivation is spread in southern and central Iraq. Many economic varieties have early productivity and good quality, including Al-Armouti, Al-Tuffahi and Al-Malassi Al-Ahmar [Al-Asadi (2018), Noaema *et al*. (2020a)].

The cultivars of pempanese and Malass belong to the types *Z. Spina-Christi* and *Z. mauritiana*. It is one of the important varieties in Iraq, which is spread mainly in the central and southern regions of Iraq [Al-Hasany *et al*. (2020)]. Sidr trees are used for medicinal purposes, as previous studies showed that some species of the genus Ziziphus are beneficial for controlling liver and intestinal disorders and treating skin diseases. They

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are also used as antiseptics [AL-Marzooq (2014), Bukar *et al*. (2015)]. During the stage of full maturity, the period of their stay in the markets is concise, as the fruits after picking suffer from a rise in breathing speed and rapid entry into the ageing stage, which leads to the loss of their distinctive properties. The irregular shape of the fruit and its small size has a significant impact on the properties of the quality of the fruits, which negatively affects Producer income [Al Asadi (2018)].

Therefore, extending the life of fruits is one of the essential steps and positively impacts the productive reality. Recently, many chemicals have been discovered that can regulate plant growth by slowing down the metabolic activity of fruits, including chitosan, a biopolymer and the second-largest biological substance, in nature, cellulose, which is found in the exoskeleton of crustaceans, insects, and the cell walls of fungi. It is characterized by its non-toxicity and biodegradability and has no local or general effects on living tissues. It is a biofunctional compound, so it has recently attracted researchers' attention for its commercial uses in the food, chemical, medical and pharmaceutical industries. One of the defense enzymes, chitosan can inhibit the growth of fungi because it stimulates the enzyme chitinase and it was noted that the fruits treated with chitosan had decreased respiration and ethylene production.

Fruits in cold stores have living organs that carry out their vital functions such as breathing and others, and transformations accompany this in food compounds and changes in the proportion of these compounds, which affects the chemical, physical and physiological characteristics of fruits [Hamza (2010)]. Several changes occur in the fruits inside the refrigerated stores, including pathological and non-pathological, where fresh fruits are exposed to attacking microorganisms such as bacteria, fungi and yeasts through wounds, cracks and natural openings in the walls of the fruits, causing various injuries and then leading to damage to the stored fruits [Tain (2005)]. Storing the fruits at low temperatures helps to discourage chemical and physiological changes and prolong the life of the fruits. Fruits differ in their behavior during storage as they are affected by the variety, agricultural transactions before and after harvest and climatic conditions. All these factors are reflected in affecting the longevity of the fruits in storage and the physical characteristics of the fruits in terms of shape, size, color and their internal contents. Storage at low temperatures is one of the methods used to reduce or delay spoilage in fruits during the storage period, as spoilage cannot be controlled with anti-material sometimes, as fruits become more susceptible to damage, when they progress to maturity until they reach the ageing stage, so the process of storing fruits at low temperatures helps to delay the ripening of these fruits, which gives them the sufficient ability to disrupt the growth of microorganisms on the one hand and resist spoilage on the other [Benjamin *et al*. (1985)]. The type of packaging is also one of the important factors in storing fruits, as studies have indicated a close relationship between the type of packaging and the pattern of changes in the qualitative characteristics of fruits during storage [Noaema *et al*. (2020b)].

This study aims to improve the storage capacity of Sidr fruits of the red Malasi variety in the maturity stage, after treating the fruits with chitosan polymer and testing the extent of its effect on:

A- Storage temperature.

b- The type of packing.

C- Storage period.

2. Materials and Methods

This study was conducted during the season 2021-2020 on the fruits of Sidr, red Malasi variety, which were brought from one of the private orchards in the Al-Houta area of the Shatt Al-Arab district, on 03.04.2021 in the stage of complete physiological maturity, after that the fruits were transferred to the laboratory of storage technologies in Department of Horticulture and Garden Engineering was washed with distilled water to remove dirt and dust from it, and small, infected and mechanically damaged fruits were excluded. Then the fruits were sorted in preparation for coating them with three concentrations of the locally manufactured chitosan polymer. Then, they were packed in 250 gm containers, wrapped and stored in a refrigerated incubator at a temperature of 4°C for a period of eight weeks to study the effect of coating with a polymer.

The experiment included three factors:

The first factor: chitosan polymer coating

1- T_1 symbolizes the control treatment %0.

2- Chitosan polymer coating with a concentration of 1%, symbolized by T_2.

3- Chitosan polymer coating with a concentration of 2%, symbolized by T_3.

The second factor: the type of packaging

1- Packaging with polyethylene bags, symbolized by P1.

2- Packing in cartons, symbolized by P2.

3- Packing with plastic boxes, symbolized by P3.

The third factor: the storage period

The fruits are stored in a refrigerated incubator at 4°C for eight weeks

1- The second week, symbolized by W2

2- The fourth week, symbolized by W4

3- The sixth week, symbolized by W6

4- The eighth week, symbolized by W8

Studied characteristics

2.1 Firstly: the physical characteristics

2.1.1 Percentage of damaged fruits

The percentage of damaged fruits that were infected with pathogens or that have entered the stage of full maturity was calculated as follows:

$$\text{Percentage of damaged fruits} = \frac{\text{The number of affected fruits}}{\text{Total number of fruits}} \times 100$$

2.1.2 Percentage of weight loss

According to the weight loss of fruits as a percentage at a rate once every two weeks for 8 weeks, an electronic scale was used to estimate the percentage of weight loss according to the following equation:

Weight loss percentage = (Sample weight before storage - Sample weight after storage) / (Sample weight before storage) × 100

2.2 Secondly: the chemical properties

2.2.1 Percentage of water content

The water content of the fruits was estimated as a weight of 10 g of sliced fruit flesh and placed in an Oven Vacuum oven to 70°C for 72 hours. The water content was estimated according to the following equation:

$$\text{Water content \%} = \frac{\text{Sample fresh weight (g)} - \text{Sample dry weight (g)}}{\text{Sample fresh weight (g)}} \times 100$$

2.2.2 Total dissolved solids (TSS)

The percentage of total soluble solids in the fruits was calculated according to a method [AOAC (1980)] by mashing 5 g of fresh fruit pulp for each repeater with 5 ml of distilled water, then filtering the juice and placing one or two drops of the clear juice of the fruits (after filtering) on a scale surface.hand refractometer (2WAJ-china made) and after each The reading was adjusted under a temperature of 23°C according to the tables described by Horwitz (1975).

2.2.3 Percentage of neutralizable total acidity

The total acidity of Sidr fruits was estimated as a percentage according to the method of Ranganna (1977) by mashing 5 g of soft fruits for each repeater with 20 ml of distilled water, then mixed with an electric mixer for five minutes and then filtered by a piece of gauze, 10 ml of the filtrate was used. The phenolphthalein index was used, then it was neutralized with (0.1 p) sodium hydroxide until the equilibrium point was reached and the pink color appeared, which does not disappear with shaking.

The percentage of total acidity was calculated on the basis of citric acid in fruit juice [AOAC (1980)] using the following equation:

$$\text{Total acidity} = \frac{\text{Base standardization} \times \text{its quantity} \times 0.064 \times \text{Final volume of solution}}{\text{Swab volume x sample weight}} \times 100$$

2.2.4 Percentage of vitamin C

Vitamin C was estimated by direct scaling method using 2,6-dichlorophenol indophenol dye according to the method of AOAC (1980) by mashing 50 g of fresh fruit pulp for each sample using an electric blender with 50 ml of oxalic acid 6% concentration (dissolving 60 g of Oxalic acid in a liter of distilled water) for five minutes until the solution became homogeneous, then the juice is extracted using a piece of gauze and took 10 ml of juice and placed in a 50 ml beaker and completed the volume to the mark with 3% oxalic acid (dissolving 30 g of oxalic acid in a liter distilled water), then 10 ml was taken from it and placed in a beaker, and it was smeared with dye 2,6-dichlorophenol indophenol its strength (0,1 mg), and vitamin C was estimated according to the following equation:

Vitamin C = (Volume of dye solution used for dilutions × Dye strength × Dilutions)/ (Sample weight)

× 100

2.3 Experimental design and analysis

The experiment was carried out as a factorial experiment according to a Complete randomized design (CRD) with three replications, had three factors included, the first factor, chitosan polymer coating with three concentrations (0, 1, 2%), second factor, the type of packaging, as three types of packaging were used (polyethylene bags, cartons, plastic containers). The third factor was the storage period, represented by four storage periods (after two weeks, four weeks, six weeks, eight weeks). The difference between averages was tested by testing the least significant difference (LSD) at probability level of 5% using Gestate data analysis software.

3. Result and Discussion

3.1 Physical characteristics

3.1.1 Percentage of damaged fruits

Table 1 shows the effect of treatment with chitosan, type of packing, storage period and the interaction between them on the percentage of total spoilage of Sidr fruits, cultivar Malasi red %. The highest percentage of total spoilage was 24.33% for the fruits of the control treatment. This result is consistent with El-Badawy (2012) findings that all chitosan treatments succeeded in reducing the percentage of spoilage in peach fruits during the storage period compared to untreated fruits. As for the effect of the type of packaging, it was found that the lowest percentage of total spoilage was 8.06% for fruits packed with polyethylene bags, with a significant difference from the rest of the treatments. In comparison, the highest percentage of total spoilage was 21.72% for fruits packed with cartons. The low percentage of spoilage for fruits packed with airless polyethylene bags may be due to the attack of fungi in the stored air of fruits packed with plastic and cardboard packages because they allow air to enter, unlike airtight polyethylene bags. This result is consistent with Hamza (2010), where it was found. The type of packing had a significant effect in reducing the percentage of damaged fruits, as the lowest percentage of spoilage was (10.28, 5.83%) for the fruits of the Halawi and Al-Sayer cultivars that were filled with air-tight polyethylene bags, while the highest percentage of spoilage for fruits packed with plastic boxes was (16.39, 14.17%) for the fruits of the two cultivars. It also agrees with the study of Waheed (2008), where the percentage of total spoilage in polyethylene bags was low compared to fruits filled with cartons. The results of this study did not agree with Jassim *et al*. (1999) and Ta'in (2005) and it may be due to the lack of air discharge in polyethylene bags.

The storage period had an apparent effect, as it was noted from the mentioned table that the percentage of total spoilage increases the longer the storage period, as the highest percentage of total spoilage reached 33.11% for Sidr fruits after 8 weeks of storage, while the percentage of damaged fruits was 3.63% after the first and second weeks of storage. This may be due to the rapid progression of maturity and the attack of some fungi on it. This study also agrees with Hamza (2010). As for the effect of the interaction between the treatment with chitosan and the type of packing, the results indicate that the fruits treated with chitosan at a concentration of 2% and filled with airless polyethylene bags excelled in reducing the percentage of total spoilage and recorded 4.08%, while the highest percentage of spoilage was 37.25% for fruits treated with 0% concentration and packed with chitosan with cardboard boxes.

The results also showed that the interaction between chitosan treatment and storage period had a significant effect, as the lowest spoilage rate was 15.22% for fruits treated with chitosan 2% concentration at the end of the fermentation period of 8 weeks, while the highest percentage of total spoilage was 51.22% for fruits treated with chitosan 0% concentration after 8 weeks from storage. As for the interaction between the type of packing and the duration of storage, it had a significant effect on the percentage of total spoilage, as the lowest percentage of damaged fruits was 20.78% for fruits packed with airless polyethylene bags at the end of the storage period of 8 weeks, while the highest percentage of damaged fruits was 44.78% for fruits packed with boxes Cardboard at the end of the 8-week storage period (Table 1).

The effect of the interaction between the three factors treated with chitosan, the type of packing and the storage period was significant, as the lowest percentage of total spoilage was 11.67% for the fruits treated with chitosan concentration 2%, which were filled with airless polyethylene bags at the end of the storage period of 8 weeks, while the highest percentage of total spoilage was 75.00% for the fruits-treatment

Table 1: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on the percentage of spoilage.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1	0.00	3.33	5.67	12.67	35.33	14.25
	P2	0.00	10.67	25.00	38.33	75.00	37.25
	P3	0.00	5.67	12.33	24.67	43.33	21.50
1%	P1	0.00	0.33	2.00	5.67	15.33	5.83
	P2	0.000	5.33	11.67	21.67	46.67	21.33
	P3	0.00	2.33	5.33	14.00	36.67	14.58
2%	P1	0.00	0.33	1.33	3.00	11.67	4.08
	P2	0.00	3.33	5.67	5.67	12.67	6.58
	P3	0.00	1.33	3.33	7.33	21.33	8.33
							Average (T)
T*W	0%	0.00	6.56	14.33	25.22	51.22	24.33
	1%	0.00	2.67	6.33	13.78	32.89	13.92
	2%	0.00	1.67	3.44	5.00	15.22	6.33
							Average (P)
W*P	P1	0.00	1.33	3.00	7.11	20.78	8.06
	P2	0.00	6.44	14.11	21.56	44.78	21.72
	P3	0.00	3.11	7.00	15.33	33.78	14.81
Average (W)			3.63	8.04	14.67	33.11	
$LSD_{0.05}$							
T	P	W	T*P	T*W	P*W	T*P*W	
0.82	0.82	0.95	1.43	1.65	1.65	2.86	

with 0% chitosan, packed in cartons, at the end of the 8-week storage period.

3.1.2 Percentage of weight loss

The results of Table 2 shows the effect of treatment with chitosan, type of packing, storage period and the interaction between them on the percentage of weight loss in Sidr fruits, cultivar Malasi red, stored at a temperature of 4°C. for fruits treated with a chitosan concentration of 2%,while the highest percentage of weight loss was 6.70% for fruits treated with chitosan concentration of 0%. Perhaps the low percentage of weight loss is that the application of chitosan on the peel of fresh fruits reduces weight loss by reducing transpiration. The weight loss of the fruit is due to water loss as a result of evaporation and transpiration. Chitosan acts as a barrier, thus restricting water transport and protecting the outer surface of the fruits from mechanical injury, in addition to closing small wounds, thus delaying drying [Ribeiro *et al*. (2007)].

As for the effect of the type of packing, it was noted that the highest percentage of balloon loss was 5.75% for fruits filled with carton boxes, while the lowest percentage of weight loss for fruits packed with air-tight and sealed polyethylene bags was 4.56%. Perhaps the reason is that the process of losing weight for fruits occurs as a result of water loss through transpiration from the surface of the fruits or as a result of the consumption of food stored in the breathing process. And the water content of the fruits is one of the essential storage qualities that must be preserved during storage, as the water loss of the fruits occurs as a result of a decrease in the pressure of filling. Then the fruits lose

Table 2: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on Percentage of weight loss %.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1	0.00	2.72	4.34	7.43	10.54	6.26
	P2	0.00	3.21	5.66	8.95	12.44	7.56
	P3	0.00	2.33	4.41	7.30	11.14	6.29
1%	P1	0.00	1.48	3.39	5.18	7.54	4.40
	P2	0.00	2.75	4.29	6.43	8.26	5.43
	P3	0.00	1.74	3.85	5.85	7.73	4.79
2%	P1	0.00	1.04	2.51	3.20	5.35	3.03
	P2	0.00	2.23	3.74	4.62	6.43	4.25
	P3	0.00	1.65	3.50	4.80	6.30	4.06
							Average (T)
T*W	0%	0.00	2.75	4.80	7.89	11.37	6.70
	1%	0.00	1.99	3.84	5.82	7.84	4.87
	2%	0.00	1.64	3.25	4.21	6.02	3.78
							Average (P)
W*P	P1	0.00	1.75	3.41	5.27	7.81	4.56
	P2	0.00	2.73	4.56	6.66	9.04	5.75
	P3	0.00	1.91	3.92	5.98	8.39	5.05
Average (W)			2.13	3.97	5.97	8.41	
$LSD_{0.05}$							
T	P	W	T*P	T*W	P*W	T*P*W	
0.07	0.07	0.08	0.13	0.15	0.15	0.26	

part of their weight and luster. Consequently, they show symptoms of wilting and wrinkling, as well as the reason for the loss due to the presence of a difference in vapour pressure between the amount of water in the fruits and the surrounding atmosphere, where an increase in moisture in the atmosphere surrounding the fruits is reported to reduce the percentage of loss. The weight loss of the fruits decreases as a result of the increase in CO_2 concentration and the low concentration of O_2 that works to create the modified atmosphere, which leads to a reduction in the breathing process as a result of the lack of combustion of materials carbohydrates and stored organics [Hassan (2004)]. The storage period had an apparent effect, as it was noted from the mentioned table that the balloon loss rate increased the more extended the storage period, as the highest percentage of weight loss reached 8.41% after 8 weeks of storage, while the weight loss rate was 2.13% after the first and second week of storage. The reason may be attributed to the fact that the weight loss increases the longer the storage period as a result of the loss of the nutritional stock of the fruits due to the vital processes inside the fruit, such as respiration, as well as the loss of water from the surface of the fruit through transpiration [Pareek (2001)]. This result is consistent with the findings of Tembo *et al*. (2008) that weight loss increases with increasing storage period when Sidr fruits are stored at a temperature of 5°C for 12 weeks and it is in line with what Shahi *et al.* (2015) discovered when Sidr fruits were stored for 25 days at a temperature of 4°C, as the weight loss of the fruits increased when the storage period was increased, as I agreed with what Sahala (2015) indicated that storing Sidr fruits for 5 weeks and at a temperature of 5°C, where the weight loss of the fruits increased when the storage period increased.

As for the interaction effect between treatment with chitosan and the type of packing, the lowest percentage of weight loss was 3.03% for fruits treated with chitosan concentration of 2% and packed with polyethylene bags, while the highest percentage of weight loss was 7.56% for fruits treated with chitosan concentration of 0% and packed in cartons. The results also showed that the interaction effect between chitosan treatment and storage period had a significant effect, as the lowest percentage of weight loss was 6.02% for fruits treated with chitosan concentration 2% at the end of the storage period of 8 weeks, while the highest percentage of weight loss was 11.37% for fruits treated with chitosan concentration 0% after 8 weeks of storage.

The results showed that the effect of the interaction between the type of packing and storage period had a significant effect, as the lowest percentage of weight loss was 7.81% for fruits packed with polyethylene bags at the end of the storage period of 8 weeks, while the highest percentage of weight loss was 9.04% for fruits packed with carton boxes after 8 weeks of storage. As for the effect of the interaction of the three factors treated with chitosan, the type of packing and the storage period, it was noted that the lowest percentage of weight loss was 5.35% for the fruits treated with chitosan concentration of 2% and which were filled with airless polyethylene bags at the end of the storage period of 8 weeks, while the highest percentage of weight loss reached 12.44% for the fruits treatment with 0% chitosan and packed in cartons after 8 weeks of storage (Table 2).

3.2 The chemical properties

3.2.1 Percentage of water content %

The results of Table 3 shows the effect of treatment with chitosan, type of packing, storage period, and the interaction between them on the percentage of water content of Sidr fruits, cultivar Malasi red, stored at a temperature of 4°C. Sidr fruits were treated with chitosan concentration of 2%, while the lowest percentage of water content was 62.72% for Sidr fruits treated with chitosan concentration of 0%. These results are similar to those of Bautista-Banos *et al*. (2006). They found that the application of chitosan polymer works to reduce the water loss of fruits. The reason may be attributed to the fact that chitosan forms a semi-permeable membrane that regulates gas exchange and maintains its water content.

As for the effect of the type of packing, it was noted that the fruits packed with polyethylene bags had an effect in increasing the water content, which amounted to 66.14%, compared to the fruits packed with cartons, where the percentage of water content was 63.81%. This is because the air-tight polyethylene bags were sealed and did not allow the water to lose from the fruits, compared to the carton package [Tain (2005)]. This result agrees with Jassim *et al*. (1999). The reason is also that plastic and cardboard packages that are not tightly closed can gain moisture from the frozen atmosphere due to the pressure difference, unlike sealed polyethylene bags and the results of this study are in agreement with Al-Mashhadi *et al*. (1993). The storage period had an apparent effect, as it was noted from the table that the percentage of water content decreases the more extended the storage period, where the highest percentage reached 67.73% for Sidr fruits after the first and second week of storage, while the lowest percentage of water content was 62.18% for Sidr fruits at the end of the 8-week storage period. The reason may be because the percentage of the water content increases with a decrease in the percentage of total soluble solids in the fruits, or it may be due to the relatively high storage temperature and the low humidity of the storehouse atmosphere, which leads to the loss of the water content of the fruits in the form of water vapour due to the pressure difference between the water vapour between inside and outside the fruit. The result of this study agrees with Abbas *et al*. (2005) and Al-Barrak (2009). The table also shows the effect of the interaction between the treatment with chitosan and the type of packing. The results indicate that the fruits treated with chitosan concentration of 2% and packed with polyethylene bags were significantly superior in the increase in the percentage of water content, which amounted to 68.49%. In comparison, the lowest percentage of the water content of fruits treated with chitosan concentration 0% and packed in boxes cartoons amounted to 61.27%.

The results of the table also showed the effect of the interaction between chitosan treatment and the storage period, where the highest percentage of water

Table 3: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on percentage of water content %.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1	69.82	66.70	64.20	62.10	60.73	63.43
	P2	69.82	63.20	62.20	60.86	58.83	61.27
	P3	69.82	65.70	64.83	2.80	60.50	63.45
1%	P1	69.82	69.33	67.20	65.90	63.63	66.51
	P2	69.82	67.63	65.76	63.46	61.90	64.69
	P3	69.82	68.40	66.26	64.23	62.20	65.27
2%	P1	69.82	71.20	69.83	67.13	65.80	68.49
	P2	69.82	68.23	66.20	65.16	62.30	65.47
	P3	69.82	69.16	67.76	65.80	63.76	66.62
							Average (T)
T*W	0%	69.82	65.20	63.74	61.92	60.02	62.72
	1%	69.82	68.45	66.41	64.53	62.57	65.49
	2%	69.82	69.53	67.93	66.03	63.95	66.86
							Average (P)
W*P	P1	69.82	69.07	67.07	65.04	63.38	66.14
	P2	69.82	66.35	64.72	63.16	61.01	63.81
	P3	69.82	67.75	66.28	64.27	62.15	65.11
Average (W)			67.73	66.03	64.16	62.18	
$LSD_{0.05}$							
T	P	W	T*P	T*W	P*W	T*P*W	
0.20	0.20	0.23	0.35	0.41	0.41	0.71	

content reached 63.95% for Sidr fruits treated with chitosan 2% concentration at the end of the storage period of 8 weeks, while the lowest percentage of water content reached 60.02% for fruits treated with chitosan 0% concentration after 8 weeks of storage. The table also shows the interaction between the type of packing and the storage period, as the highest percentage of water content was 63.38% for fruits packed with polyethylene bags after 8 weeks of storage, while the lowest percentage of water content was 61.01% for fruits packed with cartons at the end of the storage period of 8 weeks. As for the interaction between the three factors treated with chitosan, the type of packing and the duration of storage, it was noted that the highest percentage of water content was 65.80% for fruits treated with chitosan at a concentration of 2% and the packaging with air-tight and sealed polyethylene bags at the end of the storage period of 8 weeks, while the lowest percentage of water content was 58.83% for fruits treated with 0% chitosan and packed in cartons after 8 weeks of storage (Table 3).

3.2.2 Total dissolved solids (TSS) %

The results of Table 4 shows the effect of treatment with chitosan, type of packing, storage period and the interaction between them on the percentage of total soluble solids of Sidr fruits, cultivar Malasi red, stored at a temperature of 4°C. The percentage of total soluble solids was 15.19% for fruits treated with chitosan concentration of 2%, while the highest percentage of total soluble solids reached 16.86% for fruits treated with chitosan concentration of 0%. The type of packing had a significant effect in reducing the percentage of

Table 4: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on total dissolved solids %.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1		12.02	12.18	16.02	16.75	18.50
	P2		12.08	16.00	16.30	20.04	16.10
	P3		12.24	16.18	16.22	16.28	15.23
1%	P1		12.13	12.26	16.05	16.13	14.14
	P2		12.25	16.06	16.25	20.25	16.20
	P3		12.24	18.29	20.13	20.32	17.74
2%	P1		12.25	12.32	16.03	16.13	14.18
	P2		16.08	16.18	20.20	20.32	18.19
	P3		16.32	20.00	16.26	20.29	18.22
							Average (T)
T*W	0%		14.88	16.16	17.50	18.91	16.86
	1%		12.20	15.54	17.48	18.90	16.03
	2%		12.11	14.78	16.18	17.69	15.19
							Average (P)
W*P	P1		12.13	12.25	16.03	16.34	14.19
	P2		13.47	16.08	17.58	20.20	16.83
	P3		13.60	18.16	17.54	18.96	17.06
Average (W)			13.07	15.50	17.05	18.50	
			$LSD_{0.05}$				
T	P	W	T*P	T*W	P*W	T*P*W	
0.09	0.09	0.10	0.15	0.18	0.18	0.31	

total soluble solids, as it reached the lowest percentage of 14.19% for Sidr fruits packed with polybags, while the highest percentage of solids reached 17.06% for fruits packed with plastic boxes. Perhaps this is due to the lack of loss in the water content of fruits packed with airless polyethylene bags compared to cartons and plastic boxes. This study agrees with Jassim *et al*. (1999) and Tain (2005). The reason may be due to the low percentage of fruit juice and the low moisture content of the fruit [Burton (1982)].

The storage period had a positive effect, as it was noticed from the mentioned table that the percentage of solid materials increases with the longer storage period, as it reached the highest percentage of 18.50% after 8 weeks of storage, while the lowest percentage reached 13.07% after the first and second weeks of storage. This may be because the percentage of total soluble solids increases by decreasing the water content in the fruits. This may be because the solids in the fruits of advanced maturity increase when they progress towards the last stages of maturity [Al-Khafaji *et al*. (1992)]. Also, Sidr fruits are considered to be chlamycotic fruits, as the accumulation of total soluble solids increases during the progression of the fruits to maturity**,** where the ripening process is accompanied by many rapid chemical changes, especially the activities that take place under the control of enzymes that end with an increase in the sugar content of fruits, which is reflected in their content of soluble solids. This study agrees with Al-Issawi (2004) and Al-Barrak (2009). These results are in agreement with the findings of Sahala (2015), when storing Sidr fruits at a temperature of 5°C for 5 weeks, where the percentage of total soluble solids of the fruits increased when the storage period progressed, as well as with the findings of Shahi *et al*. (2015), when storing Sidr fruits at a temperature of 4°C for 25 days, the percentage of total soluble solids (TDS) of the fruits increased when the storage period was increased, and with the findings of Zeraatgar *et al*. (2018), when storing Sidr fruits for 30 days, where the percentage of total soluble solids of fruits increased when the storage period is increased.

As for the effect of the interaction between the treatment with chitosan and the type of packing, the lowest percentage of solids was 14.18% for the fruits treated with chitosan concentration 2% and packed with polyethylene bags, which did not differ significantly from the fruits treated with chitosan concentration 1% and packed with polyethylene bags, which reached 14.14%, while the highest percentage of solids 18.50% for Sidr fruits treated with 0% chitosan and packed with polyethylene bags. The table also shows the effect of the interaction between chitosan treatment and the storage period, where the lowest percentage of total soluble solids reached 17.69% for Sidr fruits treated with chitosan with a concentration of 2% after 8 weeks of storage, while the highest percentage of solids reached 18.91% for Sidr fruits treated with chitosan with a concentration of 0% at the end of a Storage, which did not differ significantly from the fruits treated with chitosan concentration 1%, where the rate reached 18.90%. The interaction between the type of packing and the storage period, it had a significant effect on the percentage of solids, as the lowest percentage of solids reached 16.34% for Sidr fruits packed with polyethylene bags at the end of the storage period of 8 weeks, while the highest percentage of solids reached 20.20% for fruits packed with cartons at the end of the storage period. The results also showed the effect of the interaction between the three factors treated with chitosan, the type of packing and the storage period, where the lowest percentage of solids reached 16.13% for Sidr fruits treated with chitosan concentration 2% and packed with polyethylene bags at the end of the storage period of 8 weeks, which did not differ significantly from the fruits treated with chitosan concentration 1% and filled with polyethylene bags, while the highest percentage of solids reached 20.32% for Sidr fruits treated with 2% chitosan concentration and packed with cartons at the end of the storage period, which did not differ significantly from fruits treated with 1% chitosan concentration and packed with plastic boxes (Table 4).

3.2.3 Percentage of neutralizable total acidity

The results of Table 5 shows the effect of treatment with chitosan, type of packing, storage period and the interaction between them on the percentage of total acidity that can be neutralized on Sidr fruits, cultivar Malasi red, stored at a temperature of 4°C for the season 2020-2021 The highest percentage of the neutralized total acidity in the concentration of 2% was 1.24%, while the lowest percentage of the total acidity neutralizing in the comparison treatment was 0.90%. Pre-harvest in all treatments increased acidity compared to the control treatment, except for chitosan treatment by 1%, which decreased with no significant differences in both seasons. As for the effect of the type of packing, the highest value of the total acidity neutralization rate was 1.22% for fruits packed with plastic cans. As for fruits packed with vacuum, boxes gave the lowest total acidity neutralization rate, which amounted to 0.92 percent. The high acidity of the vacuum bags may be due to the activity of yeasts inside this container at room temperature (25 ± 2^0C). The results of this study are in agreement with Jassim *et al*. (1999) and Tain (2005).

The table also shows the moral effect of the storage period on the total neutralizable acidity, as it was noted that the percentage of total neutralizing acidity decreases the longer the storage period at a temperature of 4°C, where the lowest percentage reached 0.61% after 8 weeks of storage, while the highest percentage of total acidity reached 1.54%. The decrease in the total acidity of the fruits with the progression of the storage period may be attributed to the fact that they may be consumed by the breathing process or turn into sugars [Burton (1982)]. The results of this study agree with Ta'in (1997) and Al-Issawi (2004). The reason may also be attributed to the fact that the percentage of total acidity that can be neutralized continuously during the storage period is a result of physiological and chemical changes that occur inside the fruits, or it may be a result of the progression of the ripening of the fruits up to the stage of adulthood. Their transformation into sugars where they become fit for consumption, or their decrease may be due to their consumption in the process of breathing [Al-Ani (1985), Burton (1982)]. This result is consistent with what was found by Tembo *et al*. (2008) when storing

Table 5: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on percentage of neutralizable total acidity %.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1	1.80	1.17	0.89	0.68	0.46	0.80
	P2	1.80	1.28	1.03	0.71	0.50	0.88
	P3	1.80	1.53	1.22	0.86	0.47	1.02
1%	P1	1.80	1.33	1.06	0.73	0.46	0.89
	P2	1.80	1.57	1.18	0.97	0.64	1.09
	P2	1.80	1.77	1.41	1.03	0.72	1.23
2%	P1	1.80	1.46	1.28	0.90	0.60	1.06
	P2	1.80	1.78	1.36	1.13	0.76	1.26
	P3	1.80	1.96	1.56	1.23	0.91	1.41
							Average (T)
T*W	0%	1.80	1.32	1.05	0.75	0.48	0.90
	1%	1.80	1.56	1.21	0.91	0.61	1.07
	2%	1.80	1.73	1.40	1.09	0.75	1.24
							Average (P)
W*P	P1	1.80	1.32	1.07	0.77	0.51	0.92
	P2	1.80	1.54	1.19	0.93	0.63	1.07
	P3	1.80	1.75	1.40	1.04	0.70	1.22
Average (W)		1.80	1.54	1.22	0.91	0.61	
$LSD_{0.05}$							
T	P	W	T*P	T*W	P*W	T*P*W	
0.01	0.01	0.01	0.02	0.02	0.02	0.04	

Sidr fruits at a temperature of 5°C, where the total acidity of the fruits decreased after 12 weeks of storage. For Sidr fruits, the more advanced is the storage period when stored at a temperature of 5°C for 5 weeks, and with the findings of Zeraatgar *et al*. (2018), where the total acidity of Sidr fruits decreased, the longer the storage period when the fruits were stored for 30 days.

The interaction between the treatment with chitosan and the type of packing had a significant effect on the percentage of total acidity that can be neutralised. The fruits treated with chitosan concentration of 2% and those packed with plastic boxes recorded the highest percentage of total acidity of 1.41%, while the fruits treated with chitosan concentration of 0% and packed with polyethylene bags recorded the lowest percentage of total acidity, which amounted to 0.80%. The results also showed that the interaction effect between the treatment with chitosan and the storage period had a significant effect, as the highest percentage of total acidity that could be neutralized was 0.75% for the fruits treated with chitosan at a concentration of 2% at the end of the storage period of 8 weeks. The lowest percentage of total acidity was 0.48% for the compared-treated fruits at the end of the 8-week storage period.

As for the interaction effect between the type of packing and the storage period, it was significantly below the 5% significance level, as the highest percentage of total acidity was 0.70% for fruits packed with plastic boxes after 8 weeks of storage, while the lowest percentage of total acidity was 0.51% for fruits packed with polyethylene bags at the end of the storage period.

Table 6: Effect of treatment with chitosan, type of packing and storage period on Sidr fruits, cultivar Malasi red, on percentage of vitamin C.

Chitosan polymer coating (T)	Type of packaging (P)	Storage period (W)					T*P
		Before storage	W2	W4	W6	W8	
0%	P1	198.5	162.3	153.3	143.6	134.0	148.3
	P2	198.5	153.6	146.6	141.0	126.6	142.0
	P2	198.5	145.0	141.0	132.0	121.6	134.9
1%	P1	198.5	180.0	172.3	165.6	151.3	167.3
	P2	198.5	171.0	161.6	151.6	141.0	156.3
	P3	198.5	166.6	162.0	154.6	145.0	157.0
2%	P1	198.5	196.3	187.0	180.0	172.3	183.9
	P2	198.5	183.6	181.0	173.3	163.0	175.2
	P3	198.5	190.3	177.0	168.3	159.0	173.6
							Average (T)
T*W	0%	198.5	153.6	147.0	138.8	127.4	141.7
	1%	198.5	172.5	165.3	157.3	145.7	160.2
	2%	198.5	190.1	181.6	173.8	164	177.6
							Average (P)
W*P	P1	198.5	179.5	170.8	163.1	152.5	166.5
	P2	198.5	169.4	163.1	155.3	143.5	157.8
	P3	198.5	167.3	160.0	151.6	141.8	155.2
Average (W)			172.1	164.6	156.7	146.0	
LSD 0.05							
T	P	W	T*P	T*W	P*W	T*P*W	
0.79	0.79	0.91	1.37	1.58	1.58	2.74	

The table indicates the effect of the interaction between three factors (treatment with chitosan, type of packing and storage period) on the total acidity that can be neutralized, where the highest acidity rate was 0.91 for fruits treated with chitosan concentration of 2% and packed with plastic boxes after 8 weeks of storage, while the lowest acidity percentage reached 0.46% for the fruits treated with chitosan 0% concentration for the control treatment and packed with polyethylene bags after 8 weeks of storage (Table 5).

3.2.4 Percentage of vitamin C

The results of Table 6 shows the effect of chitosan treatment, type of packing, storage period, and the interaction between them on the percentage of vitamin C for Sidr fruits, cultivar Malasi red, stored at a temperature of 4°C. Treatment with chitosan concentration of 2%, while the lowest percentage was 141.7% for Sidr fruits treated with chitosan concentration of 0%. As for the type of packing, the highest percentage of vitamin C was 166.5% for Sidr fruits packed with polyethylene bags, while the lowest percentage was 155.2% for Sidr fruits packed with plastic boxes. The storage period had a significant effect on the percentage of vitamin C. The longer the storage period, the lower the percentage of vitamin C. The lowest percentage reached 146.0% for Sidr fruits after 8 weeks of storage, while the highest percentage reached 172.1% after the first and second week of storage. The reason for this may be due to the increased percentage of weight loss as well as the increase in breathing speed and exposure to light that leads to the oxidation of vitamin C and its transformation into dehydro ascorbic acid by the action of the enzyme Ascorbase and Oxidase and thus the oxidation of vitamin C. This study agrees with what was found by Tembo *et al*. (2008) when storing Sidr fruits at a temperature of 5°C for 12 weeks, as the vitamin C content of the fruits decreased when the storage period progressed. The study also agrees with the findings of Aboutalebi,and Mehdi (2014), when storing Sidr fruits for 20 days, where the content of the fruits of vitamin C decreased when the storage period progressed. These results also agreed with the findings of Mani *et al*. (2017) when storing Sidr fruits for 15 days, as it was observed a decrease in the amount of vitamin C in the fruits when the storage period was advanced and with what Zeraatgar *et al*. (2018) indicated when storing Sidr fruits for 30 days, where the amount of vitamin C decreased when the storage period was increased.

The interaction between the treatment with chitosan and the type of packing had a significant effect on the percentage of vitamin C, as it reached the highest percentage of 183.9% for Sidr fruits treated with chitosan concentration 2% and packed with polyethylene bags, while the lowest percentage of vitamin C reached 134.9% for Sidr fruits treated with chitosan concentration 0% and packed with plastic boxes. As for the interaction effect between chitosan treatment and the storage period, the highest percentage of vitamin C reached 164.7% for Sidr fruits treated with chitosan at a concentration of 2% after 8 weeks of storage, while the lowest percentage reached 127.4% for Sidr fruits treated with chitosan with a concentration of 0% at the end of the storage period.

The results also showed in the mentioned table the effect of the interaction of the three factors treated with chitosan, the type of packing and the storage period. The table shows the effect of the type of packing and storage period, where the highest percentage of vitamin C reached 152.5% for Sidr fruits packed with polyethylene bags and the lowest percentage was 141.8% for Sidr fruits packed with plastic boxes at the end of the storage period. The highest percentage of vitamin C reached 172.3% for Sidr fruits treated with chitosan at a concentration of 2% and packed with polyethylene bags after 8 weeks of storage, while the lowest percentage of vitamin C reached 121.6% Sidr fruits treated with 0% chitosan and filled with plastic cans have the end of storage period (Table 6).

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