Effect of pre and post-harvest treatment with plant extracts and calcium chloride on storage ability of tomato *Lycopersicon esculentum* Mill. fruits grown in plastic greenhouse

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Abstract. The experiment was conducted in one of the greenhouses of the Agricultural Research Station, College of Agriculture, University of Basrah, Karmat Ali site during the growing season of 2015-2016 in order to improve the storage behavior of tomato fruits hybrid Wegdan. The seedlings were planted in the plastic house on 20/10/2015 and all the processes using in the production of this crop were conducted. Water extract of licorice (*Glycyrrhiza glabra* L.) at three concentrations (zero, 2, 4 g L^{-1}) was prepared and the plants were sprayed in the early morning three times starting from 5/11/2015 with a time interval of two weeks from the date of planting for the first spray and the operation returned after 10 days. Fruits were harvested at mature green stage in the early morning and brought to the laboratory of storage technology, then cleaned and soaked in water extract of garlic with concentration of 4%, calcium chloride solution with concentration of 4% in addition to control treatment (distilled water only) for a period of 10 minutes and left to dry at room temperature. A portion of harvested fruits that was sprayed with the water extract of *G. glabra* at the concentrations of (zero, 2, 4 g L^{-1}) were left without soaking. All the fruits were packed in perforated polyethylene bags (16 hole with a diameter of 5 mm per bag and weighed 2 kg per bag). Then the samples were stored at the temperature of 13°C for four weeks. Results indicated that the decay percentage, the percentage of weight loss and the percentage of total soluble solids increased while the amount of vitamin C decreased with an increment of storage periods. The lowest percentages of the decay and weight loss and the highest percentage of total soluble solids were in fruits treated with *G. glabra* extract as compared with untreated fruits. Fruits treated with garlic extract recorded the lowest percentage of decay and lowest percentage weight loss, while fruits soaked in 4% calcium chloride solution gave the highest percentage of total soluble solids. The interaction among spray treatments with *G. glabra* extract, post-harvest soaked treatments with garlic extract and calcium chloride and the storage period was significant. Fruits sprayed with 4 g L^{-1} *G. glabra* extract, soaked in 4% garlic extract, were undamaged up to the end of the third week of storage.

Key Words: weight loss, decay percentage, vitamin C, total soluble solids.

Introduction. Tomato (*Lycopersicon esculentum* Mill.) is considered as one of the most important vegetable crops in the world due to the highest nutritive value of fruits such as vitamins (as each 100 g containing 900 IU of vitamin A, 0.06 mg vitamin B 1, 0.04 mg vitamin B2, 0 0.7 mg vitamin B3 and 10-26 mg of vitamin C) also contains lycopene pigment, protein, carbohydrates, calcium, phosphorus, potassium and iron in addition to 22 calories (Watt & Merrill 1963).

The new orientation in agriculture is to move away from the use of chemical fertilizers, chemical growth regulators and pesticides of different kinds and composition, because of their toxic effects on human and animal organisms. Therefore, researchers in agriculture have tended to find safer materials such as plant and herb extracts (Taain 2014).

The water extract of licorice (*Glycyrrhiza glabra* L.) is composed of the roots and dried rhizomes of the plant. The most important components of the roots are glycyrrhizin, a sweet-tasting substance found in the form of calcium and potassium salts for glycyrrhizic acid, which is 19.08%. The roots contain glucose by 2.8%, sucrose 3-6% and unrefined sugar 10.71% (Abu Zeid 1986). The water extract of *G. glabra* is similar to that of the gibberellin in stimulating the flowering as a result of containing the mevalonic

acid compound and also improves the vegetative growth as a result of stimulating the enzymes needed to convert the complex compounds into simple compounds and to use them in processing the energy necessary for the plant growth (Almarsumi 1999).

Al-Jawari (2002) mentioned that spraying with *G. glabra* extract with a concentration of 2.5 g L^{-1} on pepper plants, led to the superiority of all vegetative parameters (plant length, number of branches, leaf area), flowering parameters (number of flowers $plant^{-1}$, fruits $plant^{-1}$, percentage of fruit loss $plant^{-1}$) and increase yield components (fruit size, number of fruits, fruit weight, plant yield, early yield, total yield).

Bang (1997) used the extract of garlic (*Allium sativum* L.) at a concentration of 77 ppm that reduced fungal infections significantly on potato yields. Garlic extract contains a high percentage of amino acids containing sulfur such as cystein and methionin. Alliin is responsible for the release of active compounds in garlic. Alliin is converted to Allicin by the enzyme Alliinase, then transformed into other compounds such as Diallyl disulphide (Krest & Keusgen 1999).

Calcium salts are used to increase the firmness of fruits and to treat many of the physiological disorders by controlling decay because the role of calcium in building the cell wall, activating the process of cell division and enzymes (Taain 2011).

In a study conducted by Taain et al (2007) on the storage of tomato fruits cv. Super Maramond packed with polyethylene bags for 21 days at 5°C, the results showed that decay percentage increased with the continuation of the storage periods. The fruits also showed a gradual increment in total soluble solids with decreasing in weight loss, vitamin C and the content of organic acids.

The present study was conducted due to the lack of studies on using water extract of *G. glabra*, as well as the post-harvest treatment of the water extract of garlic and calcium chloride on storage ability of tomato fruits cv. Wegdan.

Material and Method. The experiment was conducted in one of the greenhouses of the Agricultural Research Station, College of Agriculture, University of Basrah, Karmat Ali site during the growing season of 2015-2016.

The soil was prepared by planting with a deep plowing of two times perpendicularly. NPK fertilizer was added at a rate of 50 kg/dunum.

The seedlings were planted in the plastic house on 20/10/2015 and all the processes using in the production of this crop were conducted. Water extract of *G. glabra* at three concentrations (0, 2, 4 g L^{-1}) was prepared and the plants were sprayed in the early morning three times starting from 5/11 /2015, with a time interval of two weeks from the date of planting for the first spray and the operation returned after 10 days.

Fruits were harvested at mature green stage in the early morning and brought to the laboratory of storage technology, then cleaned and soaked in the following solutions for a period of ten minutes and left to dry at room temperature:

1. Water extract of garlic with concentration of 4%;
2. Calcium chloride solution with concentration of 4%;
3. Distilled water only (control);
4. A portion of harvested fruits was sprayed with the water extract of *G. glabra* at the concentrations of 0, 2, 4 g L^{-1} was left without soaking.

A portion of harvested fruits was sprayed with the water extract of *G. glabra* at the concentrations of 0, 2, 4 g L^{-1} was left without soaking. All the fruits were packed in perforated polyethylene bags (16 hole with a diameter of 5 mm per bag and weighed 2 kg per bag), and then stored at the temperature of (13°C) for four weeks.

The following parameters were studied weekly:

1. Percentage of decay:

$$\text{Decay}(\%) = \frac{\text{Weight of damaged fruits in the package}}{\text{Total weight of fruits in the package}} x100$$

2. Percentage of weight loss:

$$\text{Weight loss}(\%) = \frac{\text{Weight of the fruits before storage - Weight of the fruits at the end of storage}}{\text{The weight of fruits before storage}} x100$$

3. Vitamin C (mg/100 g) determined according to A.O.A.C. (1990).
4. Total soluble solids (T.S.S.) were measured by hand refractometer and the results were corrected to 20ºC.

The experiment included six treatments came from the interaction among pre harvest spraying of *G. glabra* water extract at the concentrations of 0, 2, 4 g L^{-1}, post harvest soaking with (4% w/v) water extract of garlic and calcium chloride for both of them in addition to control treatment (distill water only). Complete Randomized Design was used with three replicates. The results were analyzed by the analysis of variance and mean values were compared using the Revised Least Significant Difference Test at 0.05 probability level (Al-Rawi & Khalf Allah 1980).

Results and Discussion

Decay percentage. The results presented in Table 1 showed the effect of spraying *G. glabra* extract, treating with garlic extract and calcium chloride and the duration of storage in the decay percentage of tomato fruits cv. Wegdan stored at 13°C. The results indicated that the decay percentage increased with an increment of storage periods till reached (4.68%) after four weeks of storage. As for the effect of spray treatments with *G. glabra* extract, results showed that the lowest percentage of the decay (1.33%) was in fruits treated with *G. glabra* extract of 4 g L^{-1} with a significant difference in treatment with 2 g L^{-1} *G. glabra* extract and control treatment which recorded the highest percentage (3.60%). The spraying treatment of 2 g L^{-1} *G. glabra* extract was also superior to the control treatment. The effect of post-harvest treatments on the percentage of decay was significant, with the fruits treated with garlic extract in recording the lowest percentage of decay which was 1.81%, while the control fruits gave the highest percentage of decay (5.03%). Fruits soaked in 4% calcium chloride solution significantly differed on the control treatment.

The results of the Table 1 show a significant interaction between spraying with *G. glabra* extract and post-harvest treatments. The lowest percentage of decay was in the fruits sprayed with 4 g L^{-1} *G. glabra* extract and soaked in 4% garlic extract, which was 1.31% with no significant difference with the fruits sprayed with 4 g L^{-1} *G. glabra* extract and soaked in 4% calcium chloride and significant for the rest of the factorial treatments.

The Table 1 also shows significant interaction between the spraying with *G. glabra* extract and the storage period. The lowest percentage of decay was in the fruits sprayed with 2 g L^{-1} *G. glabra* extract after a week of storage which was 1.10%, with no significant difference with fruits sprayed with 4 g L^{-1} *G. glabra* extract after a week of storage and fruits sprayed with 4 g L^{-1} *G. glabra* extract after two weeks of storage. The highest percentage of decay (5.46%) was in untreated fruits after four weeks of storage.

The interaction between the post-harvest and storage period was significant. The fruits that soaked in 4% garlic extract after one week of storage and those soaked in 4% calcium chloride solution after one and two weeks of storage gave the lowest percentage of decay, while the highest percentage of decay was in untreated fruits after four weeks of storage.

The results indicate to a significant interaction between spraying with *G. glabra* extract and post-harvest treatments with garlic extract and calcium chloride and the duration of storage. Fruits sprayed with 4 g L^{-1} *G. glabra* extract, soaked in 4% garlic extract, were undamaged up to the end of the third week of storage. The highest percentage of decay (7.25%) was in the fruits sprayed with 0 g L^{-1} *G. glabra* extract and soaked in distilled water only (control fruits) after four weeks of storage with no significant difference with fruits sprayed with 0 g L^{-1} *G. glabra* extract and soaked in distilled water after three weeks of storage and significant for the rest of the factorial treatments.

Table 1

Effect of spraying with *Glycyrrhiza glabra* extract, postharvest treatments and storage period on decay percentage of tomato fruits stored at 13°C

G. glabra extract g L^{-1}	*Postharvest treatments (%)*	*Storage period (week)*				*Interaction between G. glabra and postharvest treatments*
		1	*2*	*3*	*4*	
		Decay %				
0	Control 0	5.00	5.05	6.57	7.25	5.96
	Garlic extract 4	0.00	1.06	3.70	4.15	2.22
	Calcium chloride 4	0.00	1.75	3.72	5.00	2.61
2	Control 0	3.30	4.72	5.67	5.95	4.91
	Garlic extract 4	0.00	0.50	3.10	4.02	1.90
	Calcium chloride 4	0.00	1.50	3.92	4.30	2.43
4	Control 0	3.47	3.95	4.47	5.02	4.22
	Garlic extract 4	0.00	0.00	2.20	3.07	1.31
	Calcium chloride 4	0.00	0.00	2.47	3.47	1.48
						Means of *G. glabra* extract
G. glabra × storage period	0	1.66	2.62	4.66	5.46	3.60
	2	1.10	2.24	4.23	4.75	3.08
	4	1.15	1.31	3.04	3.85	2.33
						Means of postharvest treatments
Postharvest treatments × storage period	Control 0	3.92	4.57	5.57	6.07	5.03
	Garlic extract 4	0.00	0.52	3.00	3.74	1.81
	Calcium chloride 4	0.00	1.08	3.37	4.25	2.17
Means of storage period		1.30	2.05	3.98	4.68	-
RLSD 0.05						
G. glabra extract	Postharvest treatments	Storage period	*G. glabra* × postharvest treatments	*G. glabra* × storage period	Postharvest Treatments × storage period	*G. glabra* × postharvest treatments × storage period
0.2713	0.2713	0.3132	0.4698	0.5425	0.5425	0.9396

The fruits are exposed during the process of packing and storage to the damage, which takes several forms according to its causes. It may be the result of mechanical disorders to the fruits during packing and storage, such as bruises caused by the pressure of the fruits of each other inside the package. The damage is caused as a result of the progress of fruits ripening, and also due to injuries with pathogens such as bacteria, fungi and yeast (Taain 2005, 2011).

As previously mentioned, spraying with *G. glabra* extract and soaking with garlic extract and calcium chloride, reduced the damage rate of tomatoes.

The effect of plant extracts in reducing the incidence of microbial infections may be due to their effect in inhibiting the growth, activity and reproduction of fungi, especially volatile oils and alkaloids that prevent the spread of pathogens and inhibit their growth (Williams & Hoagland 1986). In addition, the volatile oils and their compounds have the potential to inhibit the growth of bacteria and fungi (Kluge et al 2003).

The effect of calcium chloride treatment in reducing decay percentage due to the vital roles of calcium in plant tissues, such as increases membrane stability, and cell wall strength (Poovaiah et al 1988). As was pointed out by Taain (2011) postharvest treatment of jujube fruits with calcium chloride and calcium nitrate decreased the decay of fruits particularly caused by fungi, decreased weight loss, total soluble solids and total sugars at the end of storage at 0ºC and 5ºC.

Weight loss percentage. Table (2) showed the effect of spraying *G. glabra* extract, treating with garlic extract and calcium chloride and the duration of storage in the percentage of weight loss of tomato fruits cv. wegdan stored at 13°C. The results indicate that the percentage of weight loss increased by increasing the storage period until reached (0.650%) after four weeks of storage. As for the effect of spraying treatments with *G. glabra* extract, the least loss in weight was in fruits treated with 4 g L^{-1} *G. glabra* extract which reached (0.336%) with no significant difference compared to 2 g L^{-1} *G. glabra* extract and significant for control which recorded the highest percentage (0.450%). The effect of post-harvest treatments on the percentage of weight loss was significant. Fruits treated with 4% garlic extract recorded the lowest percentage weight loss (0.200%) with no significant difference with 4%calcium chloride.

The results of the same table showed a significant difference between the spray treatments with *G. glabra* extract and post-harvest treatments. The lowest percentage of weight loss was in fruits sprayed with *G. glabra* extract 4 g L^{-1} and treated with 4% garlic extract, which reached (0.208%) with no significant difference with fruits sprayed with 4 g L^{-1} *G. glabra* extract and soaked with 4% calcium chloride solution. The highest percentage of weight loss was in the fruits that sprayed with *G. glabra* extract 0 g L^{-1} and soaked in distilled water which was (0.910%) and significantly different from the rest of the treatments.

Regarding to the correlations between the spray treatments and storage period and the correlations between postharvest treatments and storage period, the highest weight loss percentages (0.858%, 1.277%) were in untreated fruits after four weeks of storage respectively.

The interaction between spraying with *G. glabra* extract and post-harvest treatments with garlic extract and calcium chloride and storage period was significant. The lowest percentage of weight loss was in the fruit sprayed with 4 g L^{-1} *G. glabra* extract and soaked in garlic extract 4% after a week of storage, which amounted to (0.103%) with no significant difference with fruits sprayed with 2 g L^{-1} *G. glabra* extract and soaked in 4% garlic extract after one week of storage. The highest percentage of weight loss (0.910%) was in fruits sprayed with *G. glabra* extract 0 g L^{-1} and soaked with distilled water after four weeks of storage.

The effect of calcium chloride treatment in reducing decay percentage due to the vital roles of Calcium in plant tissues, such as increases membrane stability, and cell wall strength (Poovaiah et al 1988). As pointed out by Taain (2011) postharvest treatment of jujube fruits with calcium chloride and calcium nitrate decreased the decay of fruits particularly caused by fungi, decreased weight loss , total soluble solids and total sugars at the end of storage at 0ºC and 5ºC.

Table 2

Effect of spraying with *Glycyrrhiza glabra* extract, postharvest treatments and storage period on weight loss percentage of tomato fruits stored at 13°C

G. glabra extract g L^{-1}	*Postharvest treatments (%)*	*Storage period (week)*				*Interaction between G. glabra and postharvest treatments*
		1	*2*	*3*	*4*	
		Decay %				
0	Control 0	0.377	0.533	0.767	1.965	0.910
	Garlic extract 4	0.128	0.145	0.165	0.200	0.159
	Calcium chloride 4	0.165	0.255	0.293	0.411	0.281
2	Control 0	0.342	0.488	0.613	0.960	0.600
	Garlic extract 4	0.103	0.198	0.267	0.375	0.235
	Calcium chloride 4	0.185	0.228	0.273	0.381	0.266
4	Control 0	0.322	0.457	0.602	0.907	0.572
	Garlic extract 4	0.103	0.188	0.242	0.300	0.208
	Calcium chloride 4	0.105	0.215	0.245	0.357	0.230
						Means of *G. glabra* extract
G. glabra × storage period	0	0.223	0.311	0.409	0.858	0.450
	2	0.210	0.304	0.384	0.572	0.367
	4	0.176	0.286	0.363	0.521	0.336
						Means of postharvest treatments
Postharvest treatments× storage period	Control 0	0.347	0.492	0.660	1.277	0.694
	Garlic extract 4	0.111	0.177	0.224	0.291	0.200
	Calcium chloride 4	0.151	0.232	0.270	0.383	0.259
Means of storage period		0.203	0.300	0.384	0.650	-
			RLSD 0.05			
G. glabra extract	Postharvest treatments	Storage period	*G. glabra* × postharvest treatments	*G. glabra* × storage period	Postharvest Treatments × storage period	*G. glabra* × postharvest treatments × storage period
0.0828	0.0828	0.0956	0.0433	0.0655	0.0455	0.2267

As previously mentioned, spraying with *G. glabra* extract and soaking with garlic extract and calcium chloride, reduced the weight loss percentage of tomatoes. The effect of plant extracts on the reduction of weight loss may be due to the fact that plant extracts have formed a layer of insulation covering stomata and act as anti-transpirations because they contain substances of a similar effect to wax or vegetable oils (Rizk et al 1985).

It is noted that the fruits soaked with calcium chloride solution decreased the percentage of loss in weight because of calcium increases cell wall strength and reduces the decomposition of pectin and wax layer surrounding the fruit epidermis, which leads to reduce the evaporation of water content of fruits (Conway & Sams 1983).

As for the effect of the storage period, the results indicate to an increase in the percentage of weight loss by increasing storage period. This is due to the reduction of weight of the fruits as the storage period progresses, resulting in loss of the water content of the fruits while the storage period continues, as well as the consumption of the food stored in the fruit as a result of breathing. These finding are in the accordence with those previously reported by Taain et al (2007) for Super Maramond tomato cultivar.

Vitamin C (mg 100 g^{-1}). The results of the Table 3 showed the effect of spraying treatments of *G. glabra* extract and treatment with garlic extract and calcium chloride and their interaction in the amount of vitamin C for tomato fruits stored at 13°C. The results indicate that the amount of vitamin C decreased with the continuation of storage period reached to 15.45 mg 100 g^{-1} after four weeks of storage. As for the effect of spraying treatments with *G. glabra* extract, the highest value of vitamin C was in fruits sprayed with 0 g L^{-1} *G. glabra* extract, which amounted 18.76 mg 100 g^{-1}. As for the postharvest treatments, the highest value of vitamin C (18.00 mg 100 g^{-1}) was in fruits soaked in 4% garlic extract with no significant differences with 4% calcium chloride and a significant from the control (soaking in distilled water only) that gave the lowest value of vitamin C amounting 14.56 mg 100 g^{-1}.

In regard to Binary interactions, there were significant differences between factorial treatments, the highest value of vitamin C was in the fruits sprayed with 0 g. L^{-1} *G. glabra* extract and soaked in 4% garlic extract (18.98 mg 100 g-¹) with no significant differences with fruits sprayed with 0 g L^{-1} and soaked in 4% calcium chloride solution, and fruits sprayed with 0 g L^{-1} and soaked in distilled water only. The lowest amount of vitamin C was in fruits sprayed with 2 g L^{-1} *G. glabra* extract and soaked in 4% calcium chloride solution, which reached to 14.08 mg 100 g^{-1}. The Table 3 also showed the significance of the interaction between the spray treatments with the *G. glabra* extract and the storage period. The highest vitamin C value was in the fruits of the 0 g L^{-1} *G. glabra* extract spray after a week of storage, which was 19.29 mg 100 g^{-1} and the same treatment after three weeks of storage with significant difference with the rest of the treatments. The lowest value of vitamin C was in fruits of 4 g L-¹ *G. glabra* extract spray after four weeks of storage, which was 14.25 mg 100 g^{-1}. The highest value of vitamin C in the fruits of 4% garlic extract soaking after a week of storage which was 19.51 mg 100 g^{-1} with no significant differences with 4% calcium chloride after a week of storage and 4% garlic extract after 2 weeks of storage. The lowest value of vitamin C was in comparison treatment (soaking in distilled water only) after four weeks of storage, which amounted to 13.54 mg 100 g^{-1}.

In regard to triple interaction, the highest value of vitamin C was in fruits sprayed with 0 g L^{-1} *G. glabra* extract and soaked in 4% garlic extract after a week of storage, which amounted to 20.65 mg 100 g^{-1} with no significant differences with fruits sprayed with 0 g L^{-1} *G. glabra* extract and soaked in 4% calcium chloride or in distilled water only after one and two weeks of storage and with fruits sprayed with 4 g L^{-1} *G. glabra* extract and soaked in 4% calcium chloride or in 4% garlic extract after a week of storage.

The reason for decreasing the vitamin C with the continuation of storage period may be due to the continuation of vital processes and increased the activity of ascorbase and oxidase with the continuation of storage period and exposure to light which caused the oxidation of vitamin C to dehydroascorbic acid. This is in agreement with Taain (2011) for jujube fruits cv. Tufahi.

Table 3

Effect of spraying with *Glycyrrhiza glabra* extract, postharvest treatments and storage period on vitamin C (mg 100 g^{-1}) of tomato fruits stored at 13°C

G. glabra extract g L^{-1}	*Postharvest treatments (%)*	*Storage period (week)*				*Interaction between G. glabra and postharvest treatments*
		1	*2*	*3*	*4*	
		Decay %				
0	Control 0	19.65	19.17	18.25	17.54	18.65
	Garlic extract 4	20.65	19.33	18.45	17.49	18.98
	Calcium chloride 4	19.22	19.38	18.48	17.51	18.64
2	Control 0	15.64	15.33	14.49	13.79	14.81
	Garlic extract 4	18.39	17.50	16.89	16.37	17.28
	Calcium chloride 4	16.06	15.16	14.39	13.59	14.8
4	Control 0	11.09	10.40	10.05	9.30	10.21
	Garlic extract 4	19.51	18.01	17.23	16.17	17.73
	Calcium chloride 4	19.09	18.64	18.05	17.28	18.26
						Means of *G. glabra* extract
G.glabra × storage period	0	19.84	19.29	18.39	17.52	18.76
	2	16.70	16.00	15.26	14.58	15.63
	4	16.56	15.68	15.11	14.25	15.40
						Means of postharvest treatments
Postharvest treatments × storage period	Control 0	15.46	14.96	14.26	13.54	14.56
	Garlic extract 4	19.51	18.28	17.53	16.68	18.00
	Calcium chloride 4	18.12	17.73	16.97	16.13	17.24
Means of storage period		17.70	16.99	16.25	15.45	-
		RLSD 0.05				
G. glabra extract	Postharvest treatments	Storage period	*G. glabra* × postharvest treatments	*G. glabra* × storage period	Postharvest treatments × storage period	*G. glabra* × postharvest treatments × storage period
0.880	0.880	1.016	1.523	1.759	1.759	3.047

Percentage of total soluble solids (TSS). Results presented in Table 4 showed the effect of spray treatment with *G. glabra* extract, garlic extract, calcium chloride and storage period on total soluble solids of tomato fruits stored at 13°C. Data's showed that the percentage of total soluble solids increased up to 10.1% after four weeks of storage. The increment in the percentage of total soluble solids may be due to the reduction of moisture content of fruits with the continuation of storage period, as the storage period progresses, the lower moisture content of the fruit increases the concentration of the cell juice of the fruit and thus increases the percentage of soluble solids (Buroton 1982).

The highest percentage of TSS was in fruits sprayed with 4 g L^{-1} *G. glabra* extract and fruits soaked in 4% calcium chloride solution which were 9.1%, 9.5% respectively with significant difference with the rest of treatments.

In regard to Binary interactions, there were significant differences between factorial treatments, the highest percentage of TSS was in the fruits sprayed with 4 g. L^{-1} *G. glabra* extract and soaked in 4% garlic extract (10.1%) with no significant differences from 2 g L^{-1} *G. glabra* extract spraying and 4% calcium chloride solution soaking. The highest percentage of TSS was recorded in fruits of 4 g L^{-1} *G. glabra* extract spray after four weeks of storage, with no significant differences from 2 g. L^{-1} after four weeks. The highest percentage of total soluble solids was in the fruits of the treatment with calcium chloride solution 4%, which reached 11.2% after four weeks of storage with no significant differences with 4% garlic extract soaking after four weeks of storage.

In regard to triple interaction, the highest percentage of TSS was in fruits sprayed with 2 g L^{-1} *G. glabra* extract and soaked in 4% calcium chloride after four weeks of storage, which amounted to 11.7% with no significant differences with fruits sprayed with 2 g L^{-1} *G. glabra* extract and soaked in 4% garlic extract after four weeks of storage and with fruits sprayed with 4 g. L^{-1} *G. glabra* extract and soaked in 4% calcium chloride after four weeks of storage.

Table 4

Effect of spraying with *Glycyrrhiza glabra* extract, postharvest treatments and storage period on TSS percentage of tomato fruits stored at 13°C

G. glabra extract g L^{-1}	*Postharvest treatments (%)*	*Storage period (week)*				*Interaction between G. glabra and postharvest treatments*
		1	*2*	*3*	*4*	
		Decay %				
0	Control 0	4.8	6.4	7.5	8.2	6.7
	Garlic extract 4	5.5	6.7	7.4	9.2	7.2
	Calcium chloride 4	6.7	7.9	8.7	10.4	8.4
2	Control 0	5.12	6.0	7.2	8.1	6.6
	Garlic extract 4	8.8	9.1	10.4	11.1	9.8
	Calcium chloride 4	8.4	9.8	10.7	11.7	10.1
4	Control 0	6.0	6.5	7.5	9.0	7.2
	Garlic extract 4	8.8	9.5	10.2	11.7	10.0
	Calcium chloride 4	8.9	9.5	10.5	11.5	10.1
						Means of *G. glabra* extract
G. glabra × storage period	0	0.223	0.311	0.409	0.858	0.450
	2	0.210	0.304	0.384	0.572	0.367
	4	0.176	0.286	0.363	0.521	0.336
						Means of postharvest treatments
Postharvest treatments × storage period	Control 0	0.347	0.492	0.660	1.277	0.694
	Garlic extract 4	0.111	0.177	0.224	0.291	0.200
	Calcium chloride 4	0.151	0.232	0.270	0.383	0.259
Means of storage period		0.203	0.300	0.384	0.650	-
RLSD 0.05						
G. glabra extract	Postharvest treatments	Storage period	*G. glabra* × postharvest treatments	*G. glabra* × storage period	Postharvest treatments × storage period	*G. glabra* × postharvest treatments × storage period
0.0828	0.0828	0.0956	0.0433	0.0655	0.0455	0.2267

Conclusions. In conclusion, the results obtained in the present work clearly indicated the role of pre and post-harvest application of plant extracts in improving storage ability of tomato fruits cv. Wegdan stored at (13°C) for four weeks. Obtained results indicated that the lowest percentages of the decay and weight loss and the highest percentage of total soluble solids were in fruits treated with *G. glabra* extract in the concentrations of 4 g L^{-1} and 2 g L^{-1} as compared with untreated fruits. Fruits treated with 4% garlic extract recorded the lowest percentage of decay and lowest percentage weight loss, while fruits soaked in 4% calcium chloride solution gave the highest percentage of total soluble solids.

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