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Impact of Humic Acid and some Pre and Post-Harvest Treatments in Improving Storage Behaviour of Hot Pepper Fruits (*Capsicum annuum* L.) Hybrid Barbarian F1

Laila Turki Fadala[1], Dhia Ahmed Taain[2] and Fatima Ali Hassan[3]

[1-3] Department of Horticulture and Landscape, College of Agriculture, University of Basra, Basra, Iraq.

[2]E-mail: golden_fruitb@yahoo.com

Abstract. The experiment was carried out during the 2020-2022 growing seasons in one of the unheated greenhouses at Dhi Qar University, south of Iraq, in order to investigate the impact of adding humic acid , pre and post-harvest treatments and their interaction in the storage behavior of hot pepper fruits hybrid Barbarian F1. Factorial experiment consisted of three factors which were the possible combinations of three concentrations of humic acid 0, 1, 2 g. l^{-1} and five pre and post-harvest treatments which were aqueous extract of jujube leaves at a concentration of (75) g. l^{-1}, aqueous extract of pomegranate peels at a concentration of 5 ml. l^{-1}, calcium at a concentration of 1.5 ml. l^{-1}, arginine acid at a concentration of 200 mg. l^{-1} in addition to control treatment (distilled water only). Fruits packed into polyethylene bags of 1 kg capacity containing 8 holes of 5 mm diameter and stored at a temperature of 10 ° C in a refrigerated incubator for two weeks. The experiment was designed out according to C.R.D design with three replicates. The results were analyzed by the analysis of variance and mean values were compared using the Revised Least Important Difference Test at 0.05 probability. Results showed that the fruits treated with humic acid at a concentration of 1 and 2 g.l⁻¹ was superior to control in reducing the percentage of decay and retaining the highest content of vitamin C , total soluble solids, capsaicin and phenolic substances. As for the effect of the type of treatments, the fruits treated with calcium recorded the lowest percentage of decay compared to the rest of the treatments in both seasons. The soaking method outperformed compared to spraying one in retaining fruits content of vitamin C. the most interactions among studied factors were significant in their effect on the most parameters.

Keywords. Hot pepper, Humic acid, Nitrogen, Extract of pomegranate peels, Total chlorophyll, Arginine.

1. Introduction

The fruits of hot pepper (*Capsicum annuum* L.) are of high nutritional value , and this is due to the presence of many important components such as plant pigments which are lutein, B-Carotene, B-cryptoxathin, eaxanthin, violaxanthin ,capsaicin, capsanthin , capsorubin [1], capsaicin, which is responsible for the spicy taste in the [2,3] and Characterized by an enzymatic structure , anti-obesity and anti-inflammatory properties, activates the immune system and lowers blood pressure [4].

The fruits also contain vitamin C, a powerful antioxidant that strengthens the natural immunity to diseases, and vitamin A, a fat-soluble vitamin and important antioxidant that helps in reducing health risks caused by free radicals and helps in the formation of red blood cells. Green fruits are also rich in

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vitamin E, which is essential for the production of natural skin oils and prevents premature aging of the skin, in addition to their role in reducing the risk of lung cancer, stomach cancer and prostate cancer [5]. The modern trend in agriculture is to move away from the use of chemical fertilizers, chemical growth regulators and pesticides, due to their toxic effect on human and animal life [6,7] Therefore, researchers in agriculture tended to find safer and more environmentally friendly materials. The use of plant extracts as an alternative to growth regulators is a natural substance that does not leave any trace on humans and the environment [8]. Among these extracts are the extract of jujube leaves and the extract of pomegranate peels, which contain flavonoids, a natural antioxidants compounds found in many plant parts, as well as containing saponins. They also have anti-viral, anti-bacterial and anti-fungal properties [9].

Humic acid stimulates root and vegetative growth, so the main purpose of using humic acid is to improve the nutritional status of the plant and thus increase production as a natural fertilizer alternative to industrial fertilizers [10,11]. Arginine acid is one of the amino acids that play roles in many vital processes during the stages of plant growth and development, whether in its free form or as a component of proteins. It is also included in the synthesis of nucleotides and many coenzymes [12].

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 [13]. So, to find out the effect of treatment with humic acid, spraying and soaking with aqueous extract of jujube leaves, aqueous extract of pomegranate peels, arginine and calcium on storage ability of hot pepper fruits hybrid Barbarian F1 , this study was conducted.

2. Materials and Methods

The seedlings of hot pepper , hybrid Barbarian F1, were planted in the plastic house on and all the processes using in the production of this crop grown were conducted. A humic acid fertilizer was add at three levels 0, 1 and 2 g l^{-1} . aqueous extract of jujube leaves at 75 g l^{-1} , aqueous extract of pomegranate peel at 5 g l^{-1} , calcium solution at 1.5 ml. l^{-1} , arginine acid at 200 mg l^{-1} in addition to control treatment (distilled water only) were sprayed three times, with an interval of 15 days between spray and another.

A part of the fruits of the plants that were treated with ground addition of humic acid at the concentrations of (0 ,1,2) g.l^{-1} and sprayed with 1.5 ml. .l^{-1} calcium , 200 mg. .l^{-1} arginine acid , jujube leaves extract at a concentration of 75 g. .l^{-1} and pomegranate peels extract at a concentration of 5 g. .l^{-1} . A part of fruits of the control plants , that was not treated with ground addition of humic acid (0 g.l^{-1}), and was sprayed with distilled water only was taken, and after cleaning, the following treatments were performed on them for a period of 5 minutes:-

- Soaking in jujube leaves extract at a concentration of 75 g.l^{-1}.
- Soaking in pomegranate peels extract at a concentration of 5 g.l^{-1} .
- Soaking in calcium solution at a concentration of 1.5 ml. l^{-1}.
- Soaking in arginine at a concentration of 200 mg. l^{-1}.
- Soaking in distilled water only (control).

These two parts were packed into polyethylene bags of 1 kg capacity containing 8 holes of 5 mm diameter and stored at a temperature of 10 ° C in a refrigerated incubator for two weeks. The following characteristics were studied: Percentage of decay

$$\text{Percentage of decay}=(\text{Weight of damaged fruits per package})/(\text{Weight of total package of fruits})\times 100$$

Total soluble solids (T.S.S.) were measured by hand refractometer and the results were corrected to 20ºC. Vitamin C (mg.100 g^{-1}) determined according to [14]. Phenolic substances were determined by using Folin-Denis method mentioned [15] .The capsaicin content of the fruits was determined by a spectrophotometer and according to the method described by [16].

The experiment was designed using a Complete Randomized Design (C.R.D) with three replications for a factorial experiment of three factors,. The mean values were compared using the least significant difference test under the 0.05 probability level [17].

3. Results and Discussion

3.1. Decay Percentage

It is evident from table 1, that the addition of humic acid, the method of addition and the type of treatment had a significant effect on the percentage of decay of the fruits of the hybrid Barbarian F1 stored at a temperature of 10 ° C. The results showed that the lowest percentage of decay was recorded in the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ compared to the fruits of plants treated with a concentration of 1 $g.l^{-1}$ and control fruits (0 $g.l^{-1}$) , with a decrease percentages of (6.82, 40.72)% and (41.92 , 7.38)%, respectively, in both seasons. The percentage of decay was less in plants treated with a concentration of 1 $g.l^{-1}$ compared to control fruits, with a decrease of 36.38 and 73.29 %, respectively, in both seasons, whereas fruits treated with concentrations 1 and 2 $g.l^{-1}$ did not differ in the second season. It appears from the same table that there are significant differences in the method of addition, as it is noted that the percentage of decay decreased by the soaking method, and the lowest percentage was 16.74 and 17.53 % sequentially and in both seasons compared to the spraying method.

As for the effect of the type of treatments, it was significant in this trait, as the fruits treated with calcium recorded the lowest percentage of decay with a decrease percentages of (28.77, 19.72, 7.69)% and (27.4 , 19.45,6.67)%, respectively, in both seasons. compared to the rest of the treatments .In addition, fruits of plants treated with extract of pomegranate peel did not differ from plants treated with arginine acid, and the percentage of decay in their fruits decreased compared to control plants and plants treated with jujube extract. The interactions between humic acid and the treatment method showed a significant effect. Fruits treated with 2 $g.l^{-1}$ humic acid and Post-harvest socked with studied treatments gave the lowest percentage of decay in both seasons (5.18 and 5.31)% compared to the highest one of (11.40 and 12.12)% recorded in fruits of 0 $g.l^{-1}$ humic acid and the spray method .The interaction between humic acid and the type of treatment had a significant effect, the fruits of 2 $g.l^{-1}$ humic acid and the calcium treatment gave the lowest percentage of decay in both seasons 5.06 and 5.28% compared to the highest percentage of decay of 12.81 and 13.85% recorded in fruits of 0 $g.l^{-1}$ humic acid and post-treated with distilled water only.

The interaction between the method of addition and the type of treatment had a significant effect, as the fruits soaked with arginine acid showed the lowest percentage of decay in both seasons amounting to 5.97 and 6.30 % compared to the highest percentage of decay 10.11% in fruits sprayed with jujube leaf extract in the first season and fruits sprayed with distilled water in the second season, which was 10.73% .

As for the triple interaction, it had a significant effect, as the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ and soaked with arginine acid gave the lowest percentage of decay in both seasons (4.13 and 4.22)% compared to the highest percentage of decay of 13.13% and 14.00% recorded in fruits of 0 $g.l^{-1}$ humic acid and soaked with distilled water only in the first season and in fruits of 0 $g.l^{-1}$ humic acid sprayed with distilled water in the second season. Fruits during handling and storage are exposed to damage that varies according to the cause, as the damage may also occur as a result of infections with pathogens such as bacteria, fungi and yeasts [18].

The treatment with humic acid worked to reduce the percentage of decay, perhaps this is due to the fact that the effectiveness of humic acid is similar to the activities of natural hormones inside the plant, and this is reflected on the physiological and biological activities in the fruits, reducing the percentage of decay [19, 20] .The percentage of decay in fruits treated with calcium decreased, which is one of the important macro nutrients that play a major role in the formation of cell walls and cell membranes, the growth and development of fruits, as well as the quality of those fruits [21,22]. Calcium plays a role in thickening the fruit wall because it enters the formation of calcium pectate, thus increasing the firmness of fruits, increasing their resistance to pathogens, delaying their ripening and reducing their damage. Calcium also has a role in regulating plant hormones, especially IAA, and works to increase the plant's efficiency in representing carbon dioxide [23]. Calcium has a role in the construction of phosphatidic acid, which enters the building of cell membranes [24], binds to pectins, and thus increases the resistance of cells to decomposition by pectin enzymes, pectin methylesterase and poly-galactosones, which are active in fruits during ripening, so the deficiency of this element leads to the decomposition of cell walls and membranes [25]. Fruits with a high content of calcium are resistant to

microorganisms during storage, as the middle lamella prevent the entry of wall-dissolving enzymes resulting from pathogens [26]. Post-harvest research revealed that the application of arginine can extend the shelf life of horticultural crops by delaying the ripening process. In addition, arginine protects plant cells from oxidative stress by biosynthesis of nitric oxide and reduces the accumulation of ROS [27]. Arginine works to increase the tolerance of fruits to chilling injury and plays a major role in activating many enzymes in fruits such as catalase enzyme, as amino acids are linked with phospholipids in the membranes and work to increase the effectiveness of these enzymes, but amino acids inhibit the enzymes responsible for the production of ethylene [28], and this confirms its role in delaying ripening and reducing fruit decay, as many studies indicated the role of arginine treatment in reducing decay to tomatoes [29], pomegranate [30] and Pistachio [31].

Table 1. Effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine on the percentage of decay of hot pepper, hybrid Barbarian F1 fruits stored at 10°C.

2022 -2021						2021 -2020						Add method M	Humic acid H
H × M	Treatment type S					H × M	Treatment type S						
	S_4	S_3	S_2	S_1	S_0		S_4	S_3	S_2	S_1	S_0		
12.12	11.13	10.83	13.13	11.50	14.00	11.40	10.93	10.23	12.50	10.83	12.50	M_1	H_0
10.79	8.83	10.20	10.30	10.92	13.70	7.28	8.30	9.63	10.00	10.23	13.13	M_2	
7.61	7.93	6.03	6.56	8.53	9.00	7.66	7.73	5.50	6.26	8.16	8.76	M_1	H_1
6.75	5.86	6.38	6.43	6.79	8.31	10.26	5.50	6.26	6.10	6.56	8.10	M_2	
8.00	7.23	5.87	5.82	11.86	9.20	6.50	7.03	5.50	5.60	11.33	8.83	M_1	H_2
5.31	4.22	4.68	4.86	5.00	7.78	5.18	4.13	4.63	4.80	4.90	7.46	M_2	
0.53			1.20			0.49			1.10			L.S.D. (0.05)	
	7.53	7.33	7.85	9.10	10.33		7.27	6.96	7.54	8.67	9.80	Mean values of treatment type	
			0.49						0.45			L.S.D. (0.05)	
Mean values of humic acid						Mean values of humic acid							
11.45	9.98	10.51	11.71	11.21	13.85	10.83	9.61	9.93	11.25	10.53	12.81	H_0	
7.18	6.90	6.20	6.50	7.66	8.65	6.89	6.61	5.88	6.18	7.36	8.43	H_1	H× S
6.65	5.72	5.28	5.34	8.43	8.49	6.42	5.58	5.06	5.20	8.11	8.15	H_2	
0.85			0.34			0.34			0.77			L.S.D. (0.05)	
Mean values of add. method						Mean values of add. method							
9.24	8.76	7.58	8.50	10.63	10.73	8.78	8.56	7.07	8.12	10.11	10.03	M_1	M×
7.62	6.30	7.08	7.19	7.57	9.93	7.31	5.97	6.84	6.96	7.23	9.56	M_2	S
0.31			0.69			0.28			0.63			L.S.D. (0.05)	

3.2. Vitamin C

Table 2 showed the effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine, and their interactions on the amount of vitamin C (mg.100 gm^{-1} fresh weight) of the fruits of the hybrid Barbarian F1 stored at a temperature of 10 ° C.

It was noticed from the same table that there were significant differences when adding humic acid in the amount of vitamin C, as the fruits of the hybrid Barbarian F1 treated with humic acid at a concentration of 1 $g.l^{-1}$ were superior in that trait compared to the control fruits and fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ with an increment percentage of up to (13.49 and 5.69)% and (12.68 and 5.74%) sequentially in both seasons. Fruits treated with humic acid at a concentration of 2

$g.l^{-1}$ were superior to the control fruits with an increment percentage of (7.53 and 6.56)%, respectively, in both seasons.

As for the effect of the addition method on the amount of vitamin C, it was significant, as the fruits treated by soaking outperformed compared to spraying method, with an increment percentage of (6.75 and 6.23) %, respectively, in both seasons. The type of treatment had a significant effect, as the fruits treated with calcium outperformed compared to the rest of the treatments with an increment percentage of (9.40, 3.95 and 1.94)%, respectively. Those fruits did not differ from the fruits treated with arginine acid, which was superior compared to the control fruits and the fruits treated with jujube leaves extract with an increment percentage of (8.62 and 3.21)%,and these fruits did not differ from those that treated with pomegranate peel extract, which also outperformed compared to the control fruits and the fruits treated with jujube leaves extract with an increment percentage of (7.31 and 1.97%) respectively. Also, the fruits treated with jujube leaves extract outperformed compared to the control fruits with an increment percentage of 5.23% in the first season (2020-2021). In the second season (2021-2022), the fruits treated with pomegranate peel extract, calcium and arginine did not differ from each other, and they all excelled compared to the control fruits and the fruits treated with jujube leaves extract, with an increment percentages of (7.96 and 2.46%), (9.30 and 3.73)% and (8.87 and 3.32)%, respectively.

The interaction between humic acid and the method of addition had a significant effect on this trait in the season 2021-2022 only, as the fruits of plants treated with humic acid at a concentration of 1 $g.l^{-1}$ and the spray method outperformed and gave the largest amount of vitamin C in the fruits amounted to 218.76 $mg.100\ g^{-1}$ fresh weight ,while the lowest amount was in the fruits of plants treated with 0 $g.l^{-1}$ humic acid and treated with distilled water only, which was 184.53 $mg.100\ g^{-1}$ fresh weight, while the interaction between humic acid and the type of treatment showed a significant effect, as the fruits treated with $g.l^{-1}$ humic acid and calcium gave the highest amount of vitamin C amounted to (222.83 and 219.25) $mg.100\ g^{-1}$ compared to the lowest amount (178.67 and 177.58) $mg.100\ g^{-1}$ produced from fruits treated with 0 $g.l^{-1}$ humic acid and treated with distilled water only in both seasons.

The interaction between the method of addition and the type of treatment had a significant effect, as the fruits soaked with arginine had a superiority in retaining the amount of vitamin C that amounted to (218.3 and 214.48) $mg.100\ g^{-1}$ compared to the lowest amount of (1190.1 and 187.46) $mg.100\ g^{-1}$ in the fruits sprayed with distilled water only.

The triple interaction had a significant effect in the first season only, as the fruits treated with humic acid at a concentration of 1 $g.l^{-1}$ and soaked with arginine acid outperformed and gave the highest amount of 231.0 $mg.100\ g^{-1}$ compared to the lowest amount of 175.6 $mg.100\ g^{-1}$ of the treatment with humic acid sprayed with distilled water only.

Vitamin C is highly sensitive to temperature and light, so high temperature leads to oxidation of this vitamin and converting it to dehydro ascorbic acid by the action of the enzyme oxidase and ascorbase [32]. The ground addition of humic acid led to the preservation of the amount of vitamin C in the fruits compared to the lack of addition, and this may be due to the role of humic acid in increasing carbohydrates that turn into vitamin C [33]. Fruits are rich in vitamin C, and this may be due to the fact that calcium works to maintain cellular membranes by preventing their decomposition and thus reduces their permeability and reduces the entry of oxygen into cells through these membranes, thus reducing the oxidation of vitamin C [25].

Results are agreed with [34] that the addition of 2%calcium chloride delayed the oxidation processes of ascorbic acid, which resulted in the preservation of its content in apple fruits during storage. Reducing the gas exchange process because it reduces the permeability of cell membranes and thus reduces the consumption of organic acids in fruits [35]. As for the effect of arginine, the results showed that spraying it on the plant worked to maintain the amount of vitamin C.

Table 2. Effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine on vitamin C mg.100g^{-1} fresh weight of hot pepper, hybrid Barbarian F1 fruits stored at 10°C.

2022 -2021							2021 -2020						Add. method M	Humic acid H
H ×M	Treatment type S					H × M	Treatment type S							
	S_4	S_3	S_2	S_1	S_0		S_4	S_3	S_2	S_1	S_0			
184.53	192.33	195.33	184.00	174.67	176.33	185.20	193.33	198.67	184.33	174.00	175.67	M_1	H_0	
192.70	200.00	196.67	197.67	190.33	178.83	209.80	204.00	200.33	201.00	193.00	181.67	M_2		
206.33	204.33	213.33	206.67	204.33	203.00	196.87	208.33	216.00	210.33	208.00	206.33	M_1	H_1	
218.76	226.80	225.17	218.83	221.00	202.00	196.00	231.00	229.67	221.67	225.33	206.67	M_2		
193.09	193.40	195.17	199.07	194.77	183.03	222.87	195.33	199.67	202.00	199.00	188.33	M_1	H_2	
208.91	216.63	212.67	216.90	208.67	189.70	213.07	220.00	216.67	221.00	213.67	194.00	M_2		
3.49			N.S			N.S			7.40			L.S.D. (0.05)		
	205.58	206.39	203.86	198.96	188.82		208.67	210.17	206.17	202.17	192.11	Mean values of treatment type		
			3.18						3.021			L.S.D. (0.05)		
Mean value of humic acid						Mean values of humic acid								
188.62	196.17	196.00	190.83	182.50	177.58	190.60	198.67	199.50	192.67	183.50	178.67	H_0		
212.55	215.57	219.25	212.75	212.67	202.50	216.33	219.67	222.83	216.00	216.67	206.50	H_1	H× S	
201.00	205.02	203.92	207.98	201.72	186.37	204.97	207.67	208.17	211.50	206.33	191.17	H_2		
2.46			5.52			2.34			5.23			L.S.D. (0.05)		
Mean values of add. method						Mean values of add. method								
194.65	196.69	201.28	196.58	191.26	187.46	197.29	199.00	204.78	198.89	193.67	190.11	M_1	M× S	
206.79	214.48	211.50	211.13	206.67	190.18	210.64	218.33	215.56	214.56	210.67	194.11	M_2		
2.01			4.50			1.91			4.27			L.S.D. (0.05)		

3.3. The Percentage of Total Soluble Solids

Table 3 showed that there were significant differences when adding humic acid in the percentage of total soluble solids which gave the highest value at a concentration of 2 g.l^{-1} compared to the control fruits and the fruits treated with humic acid at a concentration of 1 g.l^{-1} with an increment percentage of 6.48 , 4.22% and 6.84 , 6.54 % respectively in both seasons .

It appears from the same table that there are significant differences in the method of addition, as the soaking method outperformed the spraying one, with an increment percentage of 17.20 and 6.72%, respectively, in both seasons. It is noted from the same table that the type of treatment had a significant effect on the percentage of total soluble solids, as the fruits treated with arginine outperformed compared to the rest of the treatments with an increment percentages of 5.69, 13.34, 8.95 and 2.37%, respectively, followed by the fruits treated with calcium in the superiority compared to the rest of the other treatments with an increment percentage of 3.23, 10.70 and 6.42%, respectively. The fruits treated with arginine did not differ significantly from those treated with calcium, and both

of them were superior compared to the other treatments with an increment percentage of 4.19, 12.38 and 7.59% and 4.00, 12.17 and 7.38%, respectively. The interaction between humic acid and the method of addition had a significant effect ,as the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ and soaked in the postharvest treatments gave the highest total soluble solids in both seasons amounted to 38.39 and 8.233% compared to the lowest one amounted to 6.327 and 6.127 % that recorded in fruits treated with 0 $g.l^{-1}$ humic acid and by spraying method , while the interaction between humic acid and the type of treatment had a significant effect ,as the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ and arginine acid gave the highest percentage of total soluble solids in both seasons, which amounted to 8.317 and 8.167 % compared to the lowest percentage 6.417 , 6.233% recorded in fruits treated with 0 $g.l^{-1}$ humic acid and sprayed with distilled water only.

The interaction between the method of addition and the type of treatment was significant ,as the fruits soaked with arginine gave the highest percentage of total soluble solids in both seasons that were 9.033 and 8.556% compared to the lowest percentage recorded in fruits sprayed with jujube leaves extract amounted to 6.867 and 6.700 %. The triple interaction had a significant effect ,as the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ and soaked with arginine acid gave the highest percentage in both seasons amounting to 9.433 and 9.100 % compared to the lowest percentage of 35.83 and 5.600% recorded in the fruits treated with 0 $g.l^{-1}$ humic acid and sprayed With distilled water only.

The results in tables (41, 42, 43, 44) explain the role of humic acid, especially the concentration of 2 $g.l^{-1}$, in increasing the percentage of total soluble solids in the fruits and this may be due to the role of organic fertilizers in encouraging good plant growth [36] and this result is in agreement with what was found by [37] by using 250 $mg.kg^{-1}$ humic acid caused an incrment in the percentage of total soluble solids in the hot pepper fruits .

The reason for the superiority of the fruits treated with arginine acid with a high percentage of total soluble solids may be due to the fact that the addition of amino acids and their absorption by the plants led to an increase in the protein content and dry matter, thus increasing the content of fruits of total soluble solids . The superiority of the fruits treated with calcium maybe due to the fact that spraying plants in the field with calcium increased free calcium concentration in the cells and worked to maintain the integrity of their membranes [24,38], and the application of post-harvest calcium preserved the dry matter content of the fruits , as well as the role of calcium in reducing the breakdown of pectic soluble materials, which are part of the total soluble solids . These results agreed with [39].

3.4. Capsaicin ($mg.kg^{-1}$)

It is noted from table 4 that there are significant differences between the concentrations of humic acid, as the fruits stored at a temperature of 10 ° C treated with humic acid at concentrations (1 and 2) $g.l^{-1}$ were significantly superior to the control fruits with an increment percentage of (18.39 , 46.91)% and (8.79 , 17.79)%, respectively, in both seasons, and the fruits treated with humic acid at a concentration of 2 $g.l^{-1}$ outperformed the fruits treated with a concentration of 1 $g.l^{-1}$ with an increment percentage of 12.09 and 8.43% respectively in both seasons. It appears from the same table that there are significant differences between the treatments of the addition method in the first season only, where the soaked fruits outperformed compared to the sprayed fruits, with an increment percentage of 9.74%. The fruits treated with pomegranate peel extract outperformed compared to the rest of the treatments in the first season only, with an increment percentage of 6.79, 5.34 and 7.81%, respectively. Those fruits did not differ from the fruits treated with calcium, and there was no significant difference between the fruits treated with calcium, jujube leaves extract and the control fruits. The fruits treated with calcium outperformed compared to the fruits treated with arginine, with an an increment percentage of 4.51%. The interaction between humic acid and the method of addition had a significant effect, as the fruits treated with humic acid at a concentration of 1 $g.l^{-1}$ and treated by soaking method had the highest capsaicin content of 83.73 $mg.kg^{-1}$ in the first season compared to the lowest percentage of 51.40 $mg.kg^{-1}$ recorded in fruits of 0 $g.l^{-1}$ humic acid and treated by spraying method in both seasons, while the interaction between humic acid and the type of treatment showed significant superiority. The fruits treated with humic acid at a concentration of 1 $g.l^{-1}$ and pomegranate peel extract had the highest content of capsaicin in both seasons, reached 80.83 and 72.17 $mg.kg^{-1}$

compared to the lowest percentage of 42.00 and 52.33mg.kg^{-1} recorded in fruits of 0 g.l^{-1} humic acid and treated with distilled water only.

The interaction between the addition method and the type of treatment had a significant effect on this trait in both seasons, as the fruits soaked with pomegranate peel extract outperformed and gave the highest content of capsaicin reached 74.78 and 66.84 mg.kg^{-1}, while the lowest content was 54.11 and 59.83 mg.kg^{-1} recorded in fruits sprayed with distilled water only. The triple interaction had a significant effect on the content of the stored fruits at 10 °C, as the fruits treated with humic acid at a concentration of 1 g.l^{-1} and with distilled water in both seasons gave the highest content of capsaicin in the fruits reached 92.00 and 90.33 mg.kg^{-1} compared to the lowest percentage recorded in fruits of 0 g.l^{-1} humic acid and sprayed with distilled water only in the first season and in fruits treated with humic acid at a concentration of 1 g.l^{-1} and sprayed with distilled water only in the second season that reached 43.17 and 43.17 mg.kg^{-1}.

Table 3. Effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine on total soluble solids % in fruits of hot pepper, hybrid Barbarian F1 stored at 10°C.

2022 -2021						**2021 -2020**						**Add. method M**	**Humic acid H**
H × M	**Treatment type S**					**H × M**	**Treatment type S**						
	S_4	**S_3**	**S_2**	**S_1**	**S_0**		**S_4**	**S_3**	**S_2**	**S_1**	**S_0**		
6.127	5.667	6.500	6.433	6.433	5.600	6.327	5.900	6.600	6.733	6.567	5.833	M_1	H_0
7.855	9.110	8.567	7.833	6.900	6.867	8.080	9.333	8.900	8.000	7.167	7.000	M_2	
6.987	6.580	6.573	6.447	6.000	9.333	7.167	6.800	6.733	6.600	6.100	9.600	M_1	H_1
7.049	7.300	7.700	7.100	7.067	6.077	7.481	8.333	7.940	7.400	7.367	6.367	M_2	
6.720	7.067	6.467	5.933	5.433	8.700	6.947	7.200	6.633	6.133	5.900	8.867	M_1	H_2
8.233	9.267	9.100	8.067	8.133	6.600	8.393	9.433	9.100	8.267	8.367	6.800	M_2	
0.2317			0.5181			0.1799			0.4024			L.S.D. (0.05)	
	7.498	7.484	6.969	6.661	7.196		7.833	7.651	7.189	6.911	7.411	Mean values of treatment type	
			0.2115						0.1643			L.S.D. (0.05)	
Mean values of humic acid						Mean values of humic acid							
6.991	7.388	7.533	7.133	6.667	6.233	7.203	7.617	7.750	7.367	6.867	6.417	H_0	
7.018	6.940	7.137	6.773	6.533	7.705	7.324	7.567	7.337	7.000	6.733	7.983	H_1	H× S
7.477	8.167	7.783	7.000	6.783	7.650	7.670	8.317	7.867	7.200	7.133	7.833	H_2	
0.1638			0.3664			0.1272			0.2845			L.S.D. (0.05)	
Mean values of add. method						Mean values of add. method							
6.611	6.438	6.513	6.271	5.956	7.878	6.813	6.633	6.656	6.489	6.189	8.100	M_1	M× S
7.712	8.559	8.456	7.667	7.367	6.514	7.985	9.033	8.647	7.889	7.633	6.722	M_2	
0.1338			0.2991			0.1039			0.2323			L.S.D. (0.05)	

Table 4. Effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine on capsaicin mg.kg in fruits of hot pepper, hybrid Barbarian F1 stored at 10°C.

2022 -2021						2021 -2020							
H × M	Treatment type S					H × M	Treatment type S					Add. method M	Humic acid H
	S_4	S_3	S_2	S_1	S_0		S_4	S_3	S_2	S_1	S_0		
61.00	68.00	59.67	66.67	59.33	51.33	51.40	53.00	53.00	55.67	55.33	40.00	M_1	H_0
55.16	58.13	57.67	57.00	49.67	53.33	57.00	58.00	61.67	63.33	58.00	44.00	M_2	
51.70	55.00	54.00	51.00	55.33	43.17	53.27	57.00	56.67	54.67	57.33	40.67	M_1	H_1
74.68	67.33	69.20	75.87	70.07	90.93	75.07	61.00	71.67	78.67	72.00	92.00	M_2	
73.31	60.53	70.33	76.67	74.00	85.00	75.53	70.00	74.67	79.33	72.00	81.67	M_1	H_2
63.73	62.00	68.33	67.67	69.00	51.67	83.73	85.00	83.67	82.33	78.33	89.33	M_2	
6.35			14.20						6.75			L.S.D. (0.05)	
	61.83	63.20	65.81	62.90	62.57		64.00	66.89	69.00	65.50	64.61	Mean values of treatment type	
			Ns						2.75			L.S.D. (0.05)	
Mean values of humic acid						Mean values of humic acid							
58.08	63.07	58.67	61.83	54.50	52.33	54.20	55.50	57.33	59.50	56.67	42.00	H_0	
63.19	61.17	61.60	63.43	62.70	67.05	64.17	59.00	64.17	66.67	64.67	66.33	H_1	H× S
68.52	61.27	69.33	72.17	71.50	68.33	79.63	77.50	79.17	80.83	75.17	85.50	H_2	
4.49			10.04			2.13			4.77			L.S.D. (0.05)	
Mean values of addition mthod						Mean values of addition mthod							
62.00	61.18	61.33	64.78	62.89	59.83	60.07	60.00	61.44	63.22	61.56	54.11	M_1	M× S
64.52	62.49	65.07	66.84	62.91	65.31	71.93	68.00	72.33	74.78	69.44	75.11	M_2	
N.S			8.20			1.74			3.89			L.S.D. (0.05)	

3.5. The Percentage of Phenolic Substances

Table 5 showed the effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peel, calcium and arginine on the percentage of phenolic substances in the fruits stored at a temperature of 10 ° C. It is noted from the table that there are significant differences between the concentrations of humic acid in the percentage of phenolic substances. The fruits treated with 1 and 2 $g.l^{-1}$ humic acid significantly outperformed compared to the control plants with an increment percentage of (4.79,13.17) and (4.21,11.44)% respectively in both seasons, and the fruits treated with 2 $g.l^{-1}$ humic acid outperformed compared to the fruits treated with a concentration of 1 $g.l^{-1}$ with an increase of (8.00 , 6.93)% respectively in both seasons. It appears from the same table that there are significant differences between the treatments of the addition method, as the spraying method is superior compared to the soaking method, with an increment percentage of (2.28 and 2.90)%, respectively, in both seasons. As for the type of treatment, in the first season, there was no significant difference between the fruits treated with arginine and the control fruits and also it was noted that there was no significant difference between the control fruits and the fruits treated with jujube extract and pomegranate peels, and all of them were superior compared to the fruits treated with calcium, with an increment percentage of (5.91, 4.73 and 54.32) % respectively, while in the second season, no significant difference was observed between the fruits treated with arginine, control fruits, and fruits treated with pomegranate peel extract, all outperformed compared to the fruits treated with jujube extract and calcium, with an increment percentage of (2.90 , 3.50%), (2.90 , 3.50%) and (2.90 ,3.50%) %, respectively.

As for the interaction between humic and the method of addition, the effect was significant in the first season only, as fruits treated with humic acid at a concentration of 2 g.l⁻¹ and sprayed with the treatments gave the highest percentage of phenolic substances amounted to 0.191%, while the lowest percentage in the fruits of 0 g.l⁻¹ humic acid and soaked in the post-harvest treatments amounted to 0.165% . As for the interaction between humic and the type of treatment, it was significant, as the fruits treated with humic acid at a concentration of 2 g.l-1 and treated with calcium and arginine outperformed and gave the highest percentage of phenolic substances in the first season amounting to 0.190 and 0.190 %, while in the second season the fruits of 0 g.l-1 humic acid and calcium treatment gave the highest percentage amounted to 0.190% compared to the lowest percentage of phenolic substances recorded in fruits treated with humic acid at a concentration of 1 g.l⁻¹ and calcium treatment (0.163 and 0.162)% in both season respectively.

Table 5. Effect of adding humic acid, spraying and soaking with jujube extract, pomegranate peels, calcium and arginine on phenolic substances % in fruits of hot pepper, hybrid Barbarian F1 stored at 10°C.

2022 -2021						2021 -2020						Add. method M	Humic acid H
H × M	Treatment type S					H × M	Treatment type S						
	S_4	S_3	S_2	S_1	S_0		S_4	S_3	S_2	S_1	S_0		
0.188	0.189	0.190	0.186	0.192	0.183	0.169	0.164	0.167	0.167	0.175	0.173	M_1	H_0
0.182	0.188	0.190	0.183	0.170	0.178	0.165	0.180	0.141	0.176	0.162	0.167	M_2	
0.174	0.1807	0.154	0.172	0.169	0.190	0.178	0.191	0.153	0.180	0.174	0.192	M_1	H_1
0.171	0.175	0.169	0.172	0.164	0.177	0.172	0.174	0.173	0.173	0.170	0.172	M_2	
0.169	0.163	0.169	0.167	0.175	0.172	0.191	0.191	0.190	0.189	0.196	0.188	M_1	H_2
0.164	0.175	0.143	0.177	0.159	0.166	0.187	0.188	0.190	0.186	0.186	0.186	M_2	
N.S			0.010			0.003			0.007			L.S.D. (0.05)	
	0.177	0.171	0.177	0.172	0.177		0.181	0.169	0.178	0.177	.0179	Mean values of treatment type	
			0.004						0.003			L.S.D. (0.05)	
Mean values of humic acid						Mean values of humic acid							
0.166	0.189	0.190	0.184	0.181	0.180	0.167	0.172	0.154	0.171	0.168	0.170	H_0	
0.173	0.181	0.162	0.172	0.167	0.183	0.175	0.182	0.163	0.176	0.172	0.182	H_1	H× S
0.185	0.169	0.156	0.172	0.167	0.169	0.189	0.190	0.190	0.188	0.191	0.187	H_2	
0.003			0.007			0.002			0.005			L.S.D. (0.05)	
Mean values of add. method						Mean values of add. method							
0.177	0.179	0.171	0.175	0.179	0.182	0.179	0.182	0.170	0.179	\ \ 0.1=2	0.184	M_1	M× S
0.172	0.179	0.167	0.177	0.164	0.173	0.175	0.180	0.168	0.178	0.173	0.175	M_2	
0.002			0.006			0.002				0.004			

The interaction between the method of addition and the type of treatment showed a significant superiority as the fruits sprayed with distilled water in both seasons, outperformed the highest percentage was (0.184 and 0.182)%, compared to the lowest percentage recorded in fruits soaked with calcium, which was 0.168% in the first season and soaked in jujube leaves extract in the second season amounted to 0.164%. The triple interaction was significant, as the fruits treated with humic acid at a concentration of 1 g.l⁻¹ and sprayed with distilled water recorded the highest percentage of phenolic substances in both seasons amounting to (0.192 and 0.190)%, compared to the lowest percentage of

0.141% in the fruits of 0 g.l⁻¹ humic acid, soaked in calcium in the first season. Storage temperature has a significant impact on the content of phenolic substances in fruits, as high temperatures and exposure of fruits to light as well as the enzymatic activity of polyphenol oxidase and peroxidase that work on the oxidation of phenolic substances and their transformation into Quinone's, which enters a series of reactions that eventually lead to the formation of the brown pigment of melanin [40]. These results are in agreement with what [41] concluded that the highest percentage of phenolic compounds in okra fruits were when stored at a temperature of 10°C ±2. [42] showed that the dried chili fruits had a decrease in the percentage of phenolic substances when stored at a temperature of 30 ° C for a period of five months, and at a higher rate than when they were reduced at a temperature of 25 ° C, and the lowest decrease was at a temperature of 20 ° C.

Conclusions

It is clear from the current study that adding humic acid at concentrations of (1 and 2) g. l^{-1} had an important role in improving the most of studied characteristics and the shelf life of hot pepper fruits during the storage at 10°C by reducing the percentage of decay and retaining the highest content of vitamin C , total soluble solids, capsaicin and phenolic substances**.** fruits soaked with arginine had a superiority in retaining the amount of vitamin C**.**

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