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A study of storage behavior of okra fruits (*Abelmoschus esculuntus* L. Moenth cv. Khnesri)

Dhia Ahmed Taain*, Abbas M.Jasim and Mr. Jameel Hassan H. Al-Hij

Department of horticulture and landscape design, college of agriculture, university of Basrah, Iraq

Corresponding author: Dhia Ahmed Taain

ABSTRACT: This study was conducted during 2009-2010 season to investigate the effect of some antioxidants on storage behavior of okra fruits (*Abelmoschus esculuntus* L. Moenth cv. Mahaly). Okra seeds were planted under plastic tunnels in winter season at Abu-Al-Khaseb ,south of Basrah, Iraq. Fruits were soaked in ascorbic and citric acids at three concentrations for each of them (0,50,100) mg/l and a mixture of both of them (50+50),(50+100),(100+50),(100+100) mg/l for 5 minutes. Fruits were packed in perforated polyethylene bags (1 kg weight, 16 holes ,6.2 mm diameter for each of them) and stored at (10°C ± 1) for 12 days. The experimental results showed that Fruits treated with ascorbic acid and citric acids in the concentration of (100 mg/l) for both of them were the best in retaining the fresh weight of fruits. Treating with citric acid in the concentration of 100 mg/l was the best in reducing the loss of total chlorophyll, protein and phenolic substances. The interaction between ascorbic acid (100 mg/l) and citric acid (50 mg/l) significantly decreased the loss of vitamin C. The results also indicated to the reduction of vitamin C , total chlorophyll, protein ,phenolic substances and fresh weight of fruits with the continuation of storage period.

***Keywords*:** Okra, storage ability, antioxidants, loss of weight

INTRODUCTION

Okra "*Abelmoschus esculuntus* L. Moenth" belongs to family Malvaceae and considers one of favorite summer vegetable crops in Iraq and other countries due to the highest nutritive value of fruits such as carbohydrates , Oils , calcium and phosphorus in addition to thiamine, niacin, vitamin C. (Hammadi and Al-Meshal, 1987; Matlob,1989; Dagawi, 1996).

Okra picked before it reaches the physiological maturity (2-3 days of age and 2.5-3.5 cm in length) in which it has low fiber . It considers as postharvest perishable fruits due to the high rate of respiration in addition to the high moisture content (Kader,1993).

Consuming large quantities of fresh green okra after cooking, as canning, freezing and drying them for consumption in winter also using as a raw material in some industries (Basco, 1995; Dagawi, 1996)..The temperature is the most important factor affecting the shelf life of okra in addition to the relative humidity. The high-temperature leads to rapid deterioration of the fruit and reduce the period of storage, while the low temperature leads to reduce the rate of respiration and evaporation of water and the production of ethylene (Abd Al-Hadi, 1989).

The fact that okra is consumed throughout the year, so it became necessary to search for ways to supply in the market, such as growing in the protected environment, freezing and drying fruits (Dagawi, 1996). It has been found that the weight loss of okra stored at a temperature 10 ± 2 °C and 100% relative humidity for 10 days decreased from 88.73% to 84.62% (Adetuyi, 2008) .

Joyce (2009) mentioned that the weight loss of okra stored at 13 °C for a period of 21 days was (79%).

Antioxidants used for the purpose to stop or delay the oxidation processes that cause undesirable changes in flavor, color and aroma, or nutritive value. The vitamin C considers as one of the most important antioxidants in

large amounts of foods widely used in the manufacture of food and to prevent brown color in the fruits and vegetables products, or as anti-oxidant in oils (Dalali and Al - Hakim, 1987 ;Smith, 1993). It has been found during the storage of okra at 96% relative humidity and the temperatures 12 °C and 25 °C that fruits stored at 25 °C colored brown and rotten as compared with fruits stored at 12 °C.(Gilmer, 2007).

Due to the lack of studies on storage ability of okra fruits, the current study was conducted to improve the storage behavior of okra fruits cv. Khnesri after treated them with some concentrations of ascorbic acid and citric acid.

Reprint of the master's thesis for the third Researcher.

MATERIALS AND METHODS

Experiment was carried out during the winter season 2009-2010 under plastic tunnels in Abu-Al-Khaseb, southern Basrah Governorate . Agricultural processes included cultivation, adding animal manure (1 ton / acre) and superphosphate fertilizer (25 kg / acre) . Seeds were sown on 1/12/2009 and after germination , all the processes using in the production of this crop were conducted.

Solutions of ascorbic acid and citric acid at three concentrations for each of them (zero, 50, 100 mg / l) and mixture of both of them (50 +50 mg / l) , (100 +50 mg / l) , (50 + 100 mg / l) and (100 +100 mg / l) were prepared and the solutions preserved in a place far from the light while in use . Fruits were selected by a length of 2.5-3.5 cm and completely soaked in the solutions for a period of five minutes and left to dry at room temperature while the fruits of the control soaked in water only. Fruits of Each treatment were divided into three replicates and packed in perforated polyethylene bags (16 hole with a diameter of 6.2 mm per bag and weighed 1 kg per bag).Then stored at the temperature of (10 ± 1°C) .

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Figure 1. Okra plant cv. Mahaly

The weight loss was calculated as a percentage, as in the following equation: -

$$\text{The percentage of weight loss} = \frac{\text{Weight of the sample before storage} - \text{Weight of the sample after storage}}{\text{Weight of the sample before storage}} \times 100$$

Vitamin C (mg / 100 g) determined according to A.O.A.C.(1990). Total chlorophyll in fruits (mg / 100 g) determined according to the method of Zaehringer and his colleagues described in (Goodwin, 1976). the total protein content was determined using the micro-kjeldhal method (Nx6.25). (A.O.A.C. 1990). Phenolic substances were determined by using Folin-Denis method mentioned in Dalali and Al-Hakim(1987).

Randomized complete block design in factorial experiment was used with three replicates per treatment and 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 and Khalaf Allah, 1980).

RESULTS AND DISCUSSION

1. Weight loss(%)

Results presented in Table (1) indicated that ascorbic acid significantly influenced the percentage of weight loss, which was the highest in control fruits (8.98%) with no significant difference with ascorbic acid treatment at the

concentration of 50 mg / l. Treated fruits with ascorbic acid at the concentration of 100 mg/l gave the lowest percentage of weight loss (7.74%).

The citric acid significantly affected the percentage of weight loss.The untreated fruit gave the highest percentage of loss of weight, While the lowest percentage was in fruits treated with 100 mg / l citric acid. As can be showed in the same table, The weight loss increased with the continuation of storage period reached to the highest percentage after 12 days of storage (13.76). The interaction between ascorbic acid and storage period had a significant effect on weight loss. The lowest percentage of weight loss was in fruit treated with ascorbic acid at the concentration of 100 mg / l after 3 days of storage. The interaction between citric acid and storage period had significant effect on weight loss. Treating fruit with 100 mg / l of citric acid and storage for 12 days gave the highest percentage of weight loss with no significant difference with control fruits and citric acid concentration of 50 mg / l after 3 days of storage. The triple interaction had no significant effect in weight loss of okra fruits.

Weight loss occurs as a result of loss of water through the transpiration from the surface of fruits or as a result of consumption of food in the process of respiration or both (Kays ,1991; Dessouki, 2001) .The water content of the fruits is one of the most important factor affecting the fruit quality during storage because of the loss of water leads to reduce the turgor pressure of fruit tissues and wilting of fruit . Shirokov (1988) recorded that if the fruit cells lost turgid state, the water content, in which can be reached to the less than 5-7% of fresh weight. The role of ascorbic acid in reducing the percentage of the weight loss may be due to its role in reducing the vital process particularly respiration rate . Results are in the same line with those obtained by Singh and Dankhar(1980) which refered to the reducing of weight loss of okra fruits by treating them with ascorbic acids.

Table 1. The effect of ascorbic acid, citric acid , storage period and the interaction among them on weight loss (%) of okra fruits stored at (10 ± 1°C)

Ascorbic acid mg/l	Citric acid mg/l	Storage period (day)				Ascorbic acid x citric acid
		3	6	9	12	
	0	2,94	6,84	12,09	14,29	9,04
0	50	2,39	6,79	12,72	14,55	9,11
	100	1,97	5,35	12,46	15,45	8,80
	0	2,23	5,74	11,30	13,07	8,09
50	50	2,30	5,41	11,13	13,19	8,00
	100	2,18	5,48	11,62	14,52	8,45
	0	2,02	5,90	10,21	11,58	7,43
100	50	2,82	5,02	11,23	14,05	8,28
	100	1,77	3,48	11,29	13,15	7,51
						Means of ascorbic acid
Ascorbic acid x storage periods	0	2,43	6,32	12,42	14,76	8,98
	50	2,24	5,54	11,34	13,59	8,18
	100	2,20	4,92	10,91	12,92	7,74
						Means of citric acid
Citric acid x storage periods	0	2,38	6,16	11,20	12,98	8,89
	50	2,50	5,74	11,69	13,93	8,46
	100	1,97	4,88	11,79	14,37	8,25
Means of storage periods		2,29	5,59	11,56	13,76	
RLSD 0.05						
Ascorbic acid	Citric acid	Storage periods	Ascorbic acid x citric acid	Ascorbic acid x storage periods	Citric acid x storage periods	Ascorbic acid x citric acid x storage periods
0.41	0.41	0,47	N.S	0.82	0,82	N.S

2. Vitamin C (mg / 100 g)

As is clear from the table (2) ,fruits treated with 100 mg / l ascorbic acid gave the highest amount of vitamin C , While the control fruits gave the lowest amount of vitamin C with no significant difference for the treatment of ascorbic acid (50mg/l).

Treating with citric acid at the concentration of 50 mg / l gave the highest amount of vitamin C with no significant difference for the treatment of citric acid (100 mg / l), while untreated fruits gave the lowest amount of vitamin C . As presented in table (4), it is clear that the amount of vitamin C decreased with increase a storage period reached to the lowest amount after 12 days of storage .

The interaction between ascorbic acid of 100 mg / l and citric acid of 50 mg / l was superior to other treatments in retaining the highest value of vitamin C.

Treating with ascorbic acid 100 mg /l gave the highest amount of vitamin C after three days of storage, while the treatment of 50 mg / l citric acid gave the highest amount of vitamin C after three days of storage. The triple interaction had also significant effect on vitamin C. It is clear that the highest amount of vitamin C was in fruits treated with 100 mg / l ascorbic acid and 50 mg / l citric acid after three days of storage .

The reason for retaining the fruits treated with ascorbic acid and citric acid with the highest amount of vitamin C compared to untreated one may be due to the role of these acids in reducing vital processes occurred inside fruit cells and thus reduce the demolition of the vitamin, as well as to the role of ascorbic acid in reducing some of vital processes, such as Oxidation .This is in agreement with Richard and Gauillard (1997) who mentioned that the ascorbic acid prevented some processes,, such as oxidation that occurred in the stored apples and with Hall (2001) who found that ascorbic acid and citric acid reinforce the effectiveness of primary antioxidants (phenolic material), thus reducing the activity of enzymes as a result of its reaction with the free radicals and the formation of stable products and ineffective. 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 dehydro ascorbic acid. This is in agreement with Tamura and Minimide (1983) who noted that vitamin C reduced by 50% when okra stored for 10 days at 12 °C and with Adetuyi *et al.* (2008) whom reported that the vitamin C in okra reduced to (16.58 mg / 100g) when fruits stored at 10±2°C for10 days.

Table 2. The effect of ascorbic acid, citric acid , storage period and the interaction among them on vitamin C (mg / 100 g) of okra fruits stored at (10 ± 1°C)

Ascorbic acid mg/l	Citric acid mg/l	Pre-storage	Storage period (day) 3	6	9	12	Ascorbic acid x citric acid
	0	43,50	32,75	25,56	21,75	18,78	28,46
0	50	43,50	33,17	28,75	23,00	20,48	29,78
	100	43,50	31,25	27,75	23,59	21,25	29,46
	0	43,50	31,55	25,75	22,01	18,75	28,31
50	50	43,50	33,75	27,55	24,40	20,50	29,94
	100	43,50	35,57	25,80	22,74	20,81	29,68
	0	43,50	33,04	26,70	22,00	19,60	28,96
100	50	43,50	36,25	29,82	24,55	21,82	31,19
	100	43,50	35,50	28,31	24,34	21,50	30,63
							Means of ascorbic acid
Ascorbic acid x storage periods	0	43,50	32,39	27,35	22,78	20,17	29,23
	50	43,50	33,62	26,36	23,05	20,02	29,31
	100	43,50	34,93	28,27	23,62	20,97	30,26
							Means of citric acid
Citric acid x storage periods	0	43,50	32,44	26,00	21,92	19,04	28,58
	50	43,50	34,39	28,70	23,98	20,93	30,30
	100	43,50	34,10	27,28	23,55	21,18	29,92
Means of storage periods		43,50	33,64	27,33	23,15	20,39	

RLSD 0.05

Ascorbic acid	Citric acid	Storage periods	Ascorbic acid x citric acid	Ascorbic acid x storage periods	Citric acid x storage periods	Ascorbic acid x citric acid x storage periods
0,53	0,53	0,62	0.76	0.88	0.88	1.47

3 - Total chlorophyll (mg / 100 g)

As shown in table (3) fruit treated with 100 mg / l ascorbic acid gave the highest amount of chlorophyll reached to (0261 mg / 100 g) ,while the lowest amount of Chlorophyll was in fruits treated with ascorbic acid at the concentration of 50 mg / l and untreated fruits (0257 mg / 100 g) Fruits treated with 100 mg / l citric acid gave the highest amount of total chlorophyll (0261 mg / 100 g), while the lowest amount of Chlorophyll recorded in untreated fruits. The amount of chlorophyll decreased with the increment of storage period reached to 0.229 mg / 100g after12 days of storage.

The interaction between ascorbic acid and citric acid was not significant for its impact on the character. Fruits treated with 50 mg / l ascorbic acid gave the highest amount of chlorophyll after 3 days of storage, while fruits treated with 100 mg / l citric acid recorded the highest amount of chlorophyll after 3 days of storage . Fruit treated with 100 mg / l ascorbic acid and 50 mg / l citric acid gave the highest amount of chlorophyll after3 days of storage.

Retaining the stored fruits treated with ascorbic acid and citric acid with the highest amount of chlorophyll may be due to the role of acids in reducing the activity of chlorophyllase enzyme which decomposition of chlorophyll.

This is in agreement with Blokhina (2003) who obtained that ascorbic acid (vitamin C) has a wide range of important functions as an antioxidant and reducing the loss of chlorophyll. The decrease of chlorophyll in fruits with an increasing of storage period may be due to the activity of chlorophyllase enzyme. This is in constant with Isabel (1990) who reported that the amount of chlorophyll gradually decreased as a result of pigments destroy.

Table 3. The effect of ascorbic acid, citric acid , storage period and the interaction among them on total chlorophyll (mg / 100 g) of okra fruits stored at (10 ± 1°C)

Ascorbic acid mg/l	Citric acid mg/l	Pre-storage	Storage period (day) 3	6	9	12	Ascorbic acid x citric acid
	0	0,295	0.262	0.245	0.243	0.223	0.254
0	50	0,295	0.287	0.248	0.240	0.218	0.258
	100	0,295	0.275	0.253	0.247	0.233	0.261
	0	0,295	0.256	0.254	0.244	0.229	0.256
50	50	0,295	0.259	0.254	0.245	0.229	0.256
	100	0,295	0.265	0.251	0.248	0.231	0.258
	0	0,295	0.264	0.249	0.244	0.229	0.256
100	50	0,295	0.273	0.255	0.247	0.230	0.260
	100	0,295	0.279	0.270	0.244	0.240	0.266
							Means of ascorbic acid
Ascorbic acid x storage periods	0	0,295	0.275	0.248	0.244	0.225	0.257
	50	0,295	0.260	0.253	0.246	0.236	0.257
	100	0,295	0.272	0.258	0.245	0.233	0.261
							Means of citric acid
Citric acid x storage periods	0	0,295	0.261	0.249	0.244	0.227	0.255
	50	0,295	0.273	0.252	0.244	0.225	0.258
	100	0,295	0.273	0.258	0.246	0.235	0.261
Means of storage periods		0,295	0.269	0.253	0.245	0.229	

RLSD 0.05

Ascorbic acid	Citric acid	Storage periods	Ascorbic acid x citric acid	Ascorbic acid x storage periods	Citric acid x storage periods	Ascorbic acid x citric acid x storage periods
0.0019	0.0019	0.0022	N.S	0.0038	0.0038	0.0067

4- Total Protein (%)

As is clear from the table (4) , treating of okra fruits with 100 mg / l ascorbic acid recorded the highest percentage of total protein , while fruits treated with citric acid at the concentration of 100 mg / l gave the highest percentage of total protein with no significant difference for the untreated fruit. Protein content of fruits reduced with the continuation of storage periods reached to 13.25% after 12 days of storage.

The interaction between ascorbic acid at the concentration of 100 mg / l and citric acid at the concentration of zero gave the highest percentage of protein with significant difference for the treatment of the interaction between ascorbic acid at the concentration of 100 mg / l and citric acid at the concentration of 100 mg / l,. The interaction between ascorbic acid and storage period significantly influenced total protein. Treating with ascorbic acid at the concentration of 100 mg / l gave the highest percentage of protein after three days of storage, while fruits treated with citric acid 100 mg / l gave the highest percentage of protein after three days of storage. The triple interaction had no significant effect on the percentage of total protein.

Retaining the stored fruits treated with ascorbic acid and citric acid with the highest amount of total protein may be due to their role to install the protein within the cells of fruit in addition to the role of the ascorbic acid in capturing hydrogen peroxide and protection of enzymes and proteins from oxidation (Foyer, 1993). The reason for reducing the percentage of protein with the continuation of storage period maybe due to the biological processes that occur within the cells of okra, which lead to the decomposition of protein and this is consistent with what was reported by Mohamed (1985) who mentioned that the protein decreased in most stored fruits with the continuation of storage period. Results are in agreement with Adetuyi (2008) who reported that the percentage of protein decreased from 14.87 to 12.87 during the storage of okra at 10 ± 2°C for 10 days.

Table 4. The effect of ascorbic acid, citric acid , storage period and the interaction among them on total protein (%) of okra fruits stored at (10 ± 1°C)

Ascorbic acid mg/l	Citric acid mg/l	Pre-storage	Storage period (day) 3	6	9	12	Ascorbic acid x citric acid
	0	16,40	15,25	14,10	13,50	13,10	14,47
0	50	16,40	14,85	14,05	13,20	12,25	14,15
	100	16,40	15,90	14,85	13,50	13,05	14,47
	0	16,40	15,45	14,45	13,45	13,10	14,57
50	50	16,40	15,70	14,20	13,55	13,00	14,57
	100	16,40	15,85	14,75	13,95	13,50	14,89
	0	16,40	16,00	15,45	14,45	14,05	15,27
100	50	16,40	15,75	15,00	13,75	13,40	14,87
	100	16,40	15,70	14,80	14,20	13,85	14,99
							Means of ascorbic acid
Ascorbic acid x storage periods	0	16,40	15,33	14,33	13,40	12,80	14,45
	50	16,40	15,66	14,46	13,65	13,20	14,67
	100	16,40	15,81	15,08	14,13	13,76	15,04
							Means of citric acid
Citric acid x storage periods	0	16,40	15,43	14,66	13,80	13,41	14,77
	50	16,40	15,43	14,41	13,50	12,88	14,52
	100	16,40	15,81	14,80	13,88	13,46	14,87
Means of storage periods		16,40	15,60	14,62	13,72	13,25	

RLSD 0.05

Ascorbic acid	Citric acid	Storage periods	Ascorbic acid x citric acid	Ascorbic acid x storage periods	Citric acid x storage periods	Ascorbic acid x citric acid x storage periods
0,15	0,15	0,18	0,27	0,31	0.31	N.S

5-Phenolic substances

Results presented in table(5) indicated that fruits treated with 100 mg / l ascorbic acid gave the highest percentage of total phenolic substances, while the lowest percentage of phenolic substances was in untreated fruit and fruits treated with ascorbic acid at the concentration of (50 mg / l). Fruits treated with100 mg / l citric acid gave the highest percentage of total phenolic substances and the lowest percentage of phenolic substances was in fruits treated with citric acid at the concentration of (50 mg / l) . The percentage of phenolic substances decreased with the continuation of storage period reached to 0.062 after 12 days of storage.

The interaction between ascorbic acid at mthe concentration of 100 mg / l and citric acid at the concentration of zero and the interaction between ascorbic acidat the concentration of 100 mg / l and citric acid at the concentration of 100 mg / l gave the highest percentage of phenolic substances with no significant difference with the interaction between ascorbic acid at the concentration of 50 mg / l and citric acid at the concentration of zero and the interaction between the ascorbic acid at the concentration of 50 mg / l and citric acid at the concentration of (100 mg / l) .

Treating with ascorbic acid at the concentrations of 50 mg / l and 100 mg / l gave the highest percentage of phenolic substances 0.079 after three days of storage, while the lowest percentage of phenolic substances 0.06 was in fruits treated with ascorbic acid 50 mg / l after 12 days of storage. The interaction between citric acid and storage periods and the triple interaction had no significant effects on phenolic substances.

Fruits treated with ascorbic acids and citric acids retained the highest percentage of phenolic substances which may be due to the role of both acids in reducing the activity of polyphenol oxidase and thus stop or discourage the work of the enzyme (Dalali and Al-Hakim, 1987; Hall, 2001). The reason for decreasing the phenolic substances with an increment of the storage period may be due to the oxidation processes caused by some enzymes such as poly phenol oxidase that reduced phenolic substances into quinones which were not fixed and this is in agreement with Tamura and Minimide (1983) who reported that the phenolic substances in the fruits of okra reduced with the elongation of storage period.

Table 5. The effect of ascorbic acid, citric acid , storage period and the interaction among them on phenolic substances (%) of okra fruits stored at (10 ± 1°C)

Ascorbic acid mg/l	Citric acid mg/l	Pre-storage	Storage period (day) 3	6	9	12	Ascorbic acid x citric acid
	0	0.085	0.075	0.071	0.067	0.060	0.072
0	50	0.085	0.076	0.072	0.067	0.063	0.073
	100	0.085	0.078	0.072	0.068	0.062	0.073
	0	0.085	0.079	0.074	0.069	0.062	0.074
50	50	0.085	0.077	0.072	0.063	0.058	0.071
	100	0.085	0.082	0.076	0.067	0.062	0.074
	0	0.085	0.080	0.073	0.071	0.065	0.075
100	50	0.085	0.079	0.072	0.069	0.062	0.073
	100	0.085	0.079	0.075	0.071	0.066	0.075
							Means of ascorbic acid
Ascorbic acid x	0	0.085	0.076	0.072	0.068	0.062	0.073
storage periods	50	0.085	0.079	0.074	0.066	0.060	0.073
	100	0.085	0.079	0.073	0.070	0.064	0.074
							Means of citric acid
Citric acid x storage	0	0.085	0.078	0.073	0.069	0.062	0.073
periods	50	0.085	0.077	0.072	0.066	0.061	0.072
	100	0.085	0.079	0.074	0.069	0.063	0.074
Means of storage periods		0.085	0.078	0.073	0.068	0.062	

RLSD 0.05

Ascorbic acid	Citric acid	Storage periods	Ascorbic acid x citric acid	Ascorbic acid x storage periods	Citric acid x storage periods	Ascorbic acid x citric acid x storage periods
0.0082	0.00082	0.00095	0.0016	0.00165	N.S	N.S

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