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Effect of some postharvest treatments on quality and storability of Iceberg lettuce

Huda A. Ibrahim[1], M.A.A. Abdullah[2], M. EL-Desuki[1] and M.O. Bakry[1]

[1]*Vegetable Research Dept., National Research Centre, 33 El-Buhouth St., (former El- Tahrir St.,) Dokki, Giza, Egypt. Postal Code: 12622.*
[2]*Vegetable Handling Dept., Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.*

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ABSTRACT

This study was carried out on Lettuce (*Lactuca sativa* L. cv Iceberg) obtained from a private farm at Kerdasa city in Giza Governorate, Egypt. During two successive winter seasons, harvested on December 18th and 15th in 2016 and 2017, respectively. Uncompact and non-uniform heads were eliminated and healthy heads with undamaged darker green outer leaves were chosen. The head lettuce stems and outer leaves were removed using a sharp knife to study the effect of dipping the head of lettuce in solution of citric acid at 3%, ascorbic acid at 3%, 1-Methylcyclopropene (1-MCP) at 1.5%and distillate water (untreated control) on maintaining quality and storability of lettuce heads during storage at 0°C and 95% relative humidity for 20 days. Results showed that all postharvest treatments (citric acid at 3%, ascorbic acid at 3%, 1-Methylcyclopropene (1-MCP at 1.5%) maintained fruit quality compared to untreated control during storage; however, citric acid at 3%, was the most effective in this concern. Dipping lettuce heads in a solution of 3% citric acid significantly reduced the weight loss percentage and decay score. Also maintained visual quality, ascorbic acid content. Furthermore, it was most effective treatment in delaying polyphenol oxidase activity and decrease total microbial count in lettuce and gave good appearance after 20 days of storage compared with other treatments. On the other side for color measurement (L*, a* and b* value), all treatments maintained the color compared with control treatment.

Keywords: Citric acid, Ascorbic acid, 1-Methylcyclopropene, Polyphenol oxidase, Total microbial count.

Introduction

Iceberg lettuce (*Lactuca sativa* L.) is a one of important fresh vegetable in many countries. It is most often grown as a nutritious leafy vegetable, rich in minerals and vitamins. Lettuce is easily cultivated because it has short vegetation period, so several production cycles can be achieved during the year. It requires relatively low temperatures to remain in vegetative phase (to prevent flowering) (Bahri *et al.,* 2012).

For lettuce, storage after harvest it's very important practice to maintain its quality, and the use of some postharvest treatments that inhibit ethylene action in the storage can extend the storage period of lettuce.

Citric acid is used as antioxidant effect due to their tissues activity (Gordon, 1990 and Wong *et al.,* 1971). Also, citric acid has been used for inhibit activity on polyphenol oxidase and its anti-browning activity in minimally processed lettuce (Ahvenaien, 1996). Citric acid could have effect on polyphenol oxidase activity by decreasing tissue pH. The optimal pH range of lettuce polyphenol oxidase is between 6.5 and 8 (Fujita *et al.,* 1991) and the decrease in PH value would decrease polyphenol oxidase activity (Altunkaya and Gokmen, 2008).

1-Methylcyclopropene has been used to inhibit the action of ethylene and extend the storability and quality of lettuce (Wills *et al.,* 2002) also extends the storage life of fruits and vegetables (Ku *et al.,* 1999). (Fan and Mattheis, 2000) reported that exposed iceberg lettuce leaves to 1-MCP at 42µmol m^{-3} for 4 hours at 6°C was delayed russet spotting .

Ascorbic acid is a small water soluble antioxidant molecule (Shalata and Neumann 2001) which contributes to the detoxification of reactive oxygen spices (ROS) and therefore the usage of

Corresponding Author: Huda A. Ibrahim, Vegetable Research Dept., National Research Center, Dokki, Giza, Egypt. E-mail: hadhuda1980@yahoo.com

ascorbic acid is associated with resistance plants to oxidative stress and delayed senescence (Farouk 2011). Dipping salad cut lettuce in 0.5% ascorbic acid increased and improved storability of salad cut lettuce compared to 10% ascorbic acid (Bolin and Huxsoll 1991). Beneficial effect of the ascorbic acid is attributed to several aspects, such as capturing of oxygen and tissue protection through forming a barrier that prevents oxygen diffusion toward the product, thus, reducing the production of o-quinones and inhibiting the polyphenol oxidase (PPO) (Hodges 2003).

The aims of this study is to evaluate some postharvest treatments on keeping postharvest quality of head lettuce. And to determine the most effective treatment in the prevention of lettuce heads deterioration during storage.

Materials and Methods

Seeds of lettuce (*Lactuca sativa* L. cv Iceberg), were sown in the nursery on September 15th 2016 and 22th 2017 under plastic low tunnel protection and seedling were transplanted on October 26th and 29th in the first and second seasons, respectively, at Kerdasa city in Giza Governorate, Egypt, during the winter season of 2016/2017 and 2017/2018 seasons.

Heads of lettuce were harvested on December 18th and 15th in 2016 and 2017, respectively. Uncompact and non-uniform heads were eliminated and only healthy, undamaged darker green outer leaves, symmetrical in shape, compact and firm were choosen and transported immediately to the laboratory of Postharvest and Handling of Vegetable Crops Department, ARC, Giza, Egypt within two hours after harvesting, the dry and damage outer leaves were remove and the stem of head lettuce were cut by a sharp knife (1cm in length). Lettuce cut stem of all the previous field experiments were treated with the following treatments:

1- Dipping in the solution of citric acid at 3% (30 g/L) for 5 min.
2- Dipping in the solution of ascorbic acid at 3% (30 g/L) for 5 min.
3- Dipping in the solution of 1-Methylcyclopropene (1-MCP) at 1.5% (15 g/L) for 5 min.
4- Dipping in tap water for 5 minutes which served as untreated control.

Then, all samples were air dried, and every head served as a replicate was wrapped individually in polypropylene bag (30µm thickness). Eighteen heads of each treatment were placed in carton boxes (30×20×15cm), and the treatments were stored at 0°C and 95% RH for 20days. The treatments were arranged in complete randomized design with three replicates.

Measurements were recorded immediately after harvest and every 4 day's interval to determine the following parameters:

Weight loss percentage: lettuce heads was estimated according to the following equation: Weight loss% = [(Initial weight - weight of fruits at sampling date)/Initial weight of fruits] x 100.

Decay: it was determined as score system of 1= none, 2= slight, 3= moderate, 4= moderately severe, 5= severe. This depends on decay percentage on fruits (Watada and Morris, 1996; Jimenez *et al.,* 1998).

Visual quality: was evaluated using a scale from (1 to 9) where 9 = excellent, 7 = good, 5 = fair and 3= poor, heads rating (5) or below was considered unmarketable the general appearance assessment includes symptoms of deterioration (leaf dryness, leaf wilt and yellowing, browning in the cut stem surface and decay).

Ascorbic acid content: was determined using 2, 6-dichloro-phenol indophenols method (A.O.A.C., 2000).

Total microbial count: each sample was prepared by homogenizing 10 gm of sliced lettuce with 100 ml sterile 0.1 peptone water for 2 min. Dilution by 0.1pepton water was made as needed in Plate Count Agar (PCA) and incubated for 24 hr at 37°C for the determination of mesophilic aerobicmicroorganisms. Viable counts were determined by counting the number of colonies and reported as colony forming units per gram, CFU/g (Anese and Nicoli, 1997).

Polyphenol oxidase (PPO) assay*:*

PPO was extracted by each sample with 1.5-fold their weight sodium phosphate buffer (0.1M, pH 6.5) containing 30mM sodium ascorbate and 0.4M sucrose at 25ºC. The crude extraction was filtered and refrigerated till used within 24h. Catechol as a substrate (3mL, 10.0mM) dissolved in the phosphate buffer was mixed with 1.0mL of enzyme extract. All the enzymatic reactions were kept at the optimum condition (substrate saturation, pH 6.5 and 25ºC). The increase in absorbance of 0.01 per min. at 495 nm at the specified condition was defined as one unit of PPO activity. The results were expressed as percentage of the activity of the respective zero experiment (Dogan *et al.,* 2002).

Color measurements:

Color measurements (L*, a* and b* values) were performed using a Chroma meter CR-400 (Konica Minolta Inc. Osaka, Japan) with illuminant D65 with 8 mm aperture. The instrument was calibrated with a white reference tile (L*=97.52, a*=–5.06, b*=3.57) prior to measurements. The L* (0=black, 100=white), a* (+red, –green) and b* (+yellow, –blue) color coordinates were determined according to the CIELAB coordinate color space system (Guerrero *et al.,* 1996).

Statistical analysis:

Data of the two seasons were arranged and statistically analyzed using Mstatic. The comparison among means of the different treatments was determined by using Duncan's test (Duncan, 1955). The data were tabulated and statistically analyzed according to a factorial complete randomized design (Snedecor and Cochran 1982).

Results and Discussion

Weight loss:

Data in Table (1) indicated that, there was considerable increase in weight loss percentage as the storage period was extended. These might be due to the loss in moisture and loss in dry matter content through respiration process (Shehata *et al.,* 2012) and (Atress, 2006). Concerning postharvest treatments, data show that dipping cut stem lettuce in citric acid proved to be superior in reducing weight loss percentage followed by dipping cut stem lettuce in1-Methylcyclopropene significantly as compared with control. These results are in agreement with the finding of (Shehata *et al.,* 2012) they found that dipping a head lettuce in a solution of citric acid reduced weight loss percentage. Regarding the interaction between postharvest treatments and storage periods data revealed that the lowest value of weight loss at the end of storage period (20 days) was noted in heads which dipped in citric acid, these results hold true in the two seasons.

Regarding the interaction between storage period and different treatments on the loss in weight, it was observed that weight loss percentage increased in untreated heads during storage period and reaches its maximum lost at end of storage (20 days). The percentage of weight loss was inhibited more in lettuce dipped in 3% of citric acid followed by dipping in the solution of 1.5% in 1-Methylcyclopropene and stored for 4days than other treatments in both seasons.

Decay:

Data in Table (1) revealed that, increase in the decay score during storage period (20 days).The decay started slowly in all treatments and successively increased till the end of storage. This was a result of the changes which occurred in fruits during storage, these results are in agreement with those obtained by (Shehata *et al.,* 2012) and (Atress, 2006).

Data also showed that significant differences among all treatments during storage period in both seasons. Heads lettuce dipping in citric acid at 3% gave the lowest decay score followed by dipping heads in the solution of 1-Methylcyclopropene (1-MCP) at 1.5% in both season. These results agree with Ihl *et al*. (2003) and (Ahvenaien, 1996) who reported that citric acid can be used as antimicrobial to prevent some of the microorganisms growth and browning of minimally processed lettuce.

With respect to the effect of the interaction between treatments and storage period on the decay score, data show that no decay was noticed in lettuce treated with citric acid at 3% till 12 days of storage and gave slight score or moderate score at the end of storage period (20 days) during both seasons.

Table 1: Effect of citric acid, ascorbic acid and 1-Methylcyclopropene on weight loss %, decay and visual quality of iceberg lettuce (*Lactuca sativa* L.) during cold storage at 0ºC in 2016/2017 and 2017/2018 seasons.

Treatments	Days after storage	First season (2016/2017)			Second season (2017/2018)		
		Weight loss %	Decay	Visual quality	Weight loss %	Decay	Visual quality
Citric acid 3%	0		1.00 e	9.00 a		1.00 f	9.00 a
	4	0.31 p	1.00 e	9.00 a	0.34 r	1.00 f	9.00 a
	8	0.72 n	1.00 e	9.00 a	0.75 n	1.00 f	9.00 a
	12	1.05 k	1.00 e	8.33 ab	1.17 k	1.00 f	7.00 bc
	16	1.62 h	1.33 de	7.67 bc	1.71 h	1.67 e	6.33 cd
	20	2.34 e	1.67 cd	6.33 de	2.47 e	2.00 de	5.67 de
Ascorbic acid 3%	0		1.00 e	9.00 a		1.00 f	9.00 a
	4	0.35 p	1.00 e	9.00 a	0.45 p	1.00 f	9.00 a
	8	0.91 l	1.00 e	7.67 bc	0.97 l	1.00 f	7.67 b
	12	1.23 i	1.33 de	7.00 cd	1.43 i	1.67 e	6.33 cd
	16	1.92 f	2.00 c	5.67 ef	2.03 f	2.33 cd	5.00 e
	20	2.81 b	2.67 b	4.33 g	2.96 b	2.67 bc	5.00 e
1-MCP 1.5 %	0		1.00 e	9.00 a		1.00 f	9.00 a
	4	0.32 p	1.00 e	9.00 a	0.40 q	1.00 f	9.00 a
	8	0.77 m	1.00 e	7.67 bc	0.82 m	1.00 f	7.67 b
	12	1.14 j	1.33 de	7.00 cd	1.28 j	1.67 e	7.00 bc
	16	1.76 g	1.67 cd	6.33 de	1.86 g	2.00 de	5.67 de
	20	2.50 c	2.00 c	4.33 g	2.61 c	2.33 cd	5.67 de
Control	0		1.00 e	9.00 a		1.00 f	9.00 a
	4	0.51 o	1.00 e	7.67 bc	0.58 o	1.00 f	7.00 bc
	8	1.15 j	1.33 de	7.00 cd	1.19 k	1.67 e	5.67 de
	12	1.64 h	2.00 c	5.00 fg	1.71 h	2.33 cd	5.00 e
	16	2.42 d	3.00 b	4.33 g	2.51 d	3.00 b	3.67 f
	20	3.33 a	4.00 a	3.00 h	3.53 a	4.00 a	3.00 f
Citric acid 3%		1.21 D	1.17 C	8.22 A	1.29 D	1.28 C	7.67 A
Ascorbic acid 3%		1.45 B	1.50 B	7.11 B	1.57 B	1.61 B	7.00 B
1-MCP 1.5 %		1.30 C	1.33 BC	7.22 B	1.39 C	1.50 BC	7.33 AB
Control		1.81 A	2.06 A	6.00 C	1.90 A	2.17 A	5.56 C
	0		1.00 D	9.00 A		1.00 D	9.00 A
	4	0.37 E	1.00 D	8.67 A	0.44 E	1.00 D	8.50 A
	8	0.89 D	1.08 D	7.83 B	0.93 D	1.17 D	7.50 B
	12	1.27 C	1.42 C	6.83 C	1.40 C	1.67 C	6.33 C
	16	1.93 B	2.00 B	6.00 D	2.03 B	2.25 B	5.17 D
	20	2.75 A	2.58 A	4.50 E	2.89 A	2.75 A	4.83 D

Values followed by the same letter (s) in each group are not significantly different at 5%

Visual quality:

Data in Table (1) showed that visual quality of lettuce cut stem was deteriorated during storage and the visual quality score dropped from excellent (score of 9) to good, fair or poor (7 or 5 or 3) after 16 days of storage. The decrease of visual quality during the storage period might be due to morphological defects, such as dryness of cut surface (Shehata *et al.,* 2012). General appearance of minimally processed lettuce treated with citric acid at 3% exhibited changes in their visual quality at the end of the storage (20 days) compared with other treatments. These results were agreement with those obtained by Gordon (1990) who found that dipping minimally processed lettuce in citric acid improved quality by reducing the butt discoloration.

The interaction between postharvest treatments and storage period on visual quality showed that citric acid at 3% recorded the highest visual quality till 8 days, and then dropped to fair after 20 days, of storage, in both seasons.

Ascorbic acid content (mg /100g FW):-

Data in Table (2) show that there were significant reduction in ascorbic acid content with the increase of storage period for some all treatments. These results agree with Wills *et al.* (1981) they reported that attributed the reduction of vit. C during storage as it is respired.

It was also obvious that significant differences among treatments during storage period in both seasons. Heads lettuce dipping in citric acid at 3%, exhibited highest ascorbic acid content and the most effective treatment compared with other treatments and untreated heads these results were agreement with those obtained by Ihl *et al.* (2003).

Regarding the interaction between the treatments and storage period, data revealed that heads were treated for citric acid at 3% exhibited the highest ascorbic acid content during all storage period compared to all other tested treatments**.**

Total microbial count:

As shown in Table (2), results indicate that there was a linear relation between the microbial load and storage period, where it was found that the increase in storage period was accompanied by an increase in microbial load. These results agree with Ihl *et al.* (2003). On the other side, the most effective antimicrobial treatment which diminishes the microbial load was dipping citric acid at 3% followed by dipping heads in the solution of 1-Methylcyclopropene (1-MCP) at 1.5% in both season. Same result was obtained by (Ahvenaien,1996) who reported that low-acid and high-humidity tissues like lettuce, can provide ideal conditions for the growth of microorganisms, the use of citric acid could not only prevent browning, but also lower the pH enough to prevent some of the microorganisms growth.

Concerning the interaction between different treatments and storage period, there was a significant difference between them, where it was noticed that all treatments affected the microbial load and decrease it until the first 4 days compared with untreated treatment especially heads dipped in the solution of 3% citric acid. Then after this storage period a remarkable increase in microbial load was observed with the increase in storage period in both seasons.

Polyphenol oxidase (PPO) activity:

Data in Table (2) show that there was considerable increase in polyphenol oxidase activity as the storage period was extended. These results are in agreement with those obtained by (Shehata *et al.,* 2012). The increase of polyphenol oxidase activity in control treatment is mainly due to activation process from latent to fully active form. In fact, as previously reported by Cantos *et al.* (2001) tissue wounding involves the decompart metallization of cellular components with the subsequent release of proteases involving a cascade of reactions leading to the activation of latent PPO. For the tested treatments, data showed that citric acid significantly reduced the activity of polyphenol oxidase activity during storage if compared with other treatments. Citric acid was effective in delaying polyphenol oxidase activity in lettuce during storage. These results agree with findings of Ihl *et al.* (2003) they reported that citric acid prevent enzymatic browning of minimally processed lettuce.

Color measurements:

L* value

Data presented in Table (3) show that L*value of lettuce heads decreased gradually with increasing storage period and reach its maximum depression at the end of storage period. This result agrees with that obtained by Martin-Diana *et al.* (2008).

Castaner *et al.* (1999) showed that color parameter L*better represented the changes in color of enzymatic browning in minimally processed lettuce.

As for the effect of postharvest treatments on L* value data show that it was observed that dipping heads lettuce in ascorbic acid at 3% or citric acid at 3% (high L value) followed by dipping heads in the solution of 1-Methylcyclopropene (1-MCP) at 1.5% in the first season, while all treatments showed no significant in the second season compared with untreated control This result might be attributed to the effect of ascorbic acid, citric acid and 1-Methylcyclopropene (1-MCP) in delaying fresh cut lettuce senescence through its effect on metabolic activities and inhibit chlorophyll degradation through the chlorophyllase enzyme (Shehata *et al.,* 2012) and (Hodges 2003).

Table 2: Effect of citric acid, ascorbic acid and 1-methylcyclopropene on ascorbic acid content, total microbial count and polyphenol oxidase activity of iceberg lettuce (*Lactuca sativa* L.) during cold storage at 0ºC in 2016/2017 and 2017/2018 seasons.

Treatments	Days after storage	First season (2016/2017)			Second season (2017/2018)		
		Ascorbic acid content	Total microbial count	Polyphenol oxidase activity %	Ascorbic acid content	Total microbial count	Polyphenol oxidase activity %
Citric acid 3%	0	39.31 a	0.58 t	78.60 t	39.09 a	0.63 s	75.33 u
	4	37.52 b	1.65 s	80.96 s	37.24 b	1.73 r	77.05 t
	8	34.71 e	2.72 o	83.61 p	34.36 d	2.85 n	79.85 p
	12	30.85 h	3.43 m	86.04 m	30.46 g	3.72 k	83.41 l
	16	26.55 k	4.61 i	89.33 i	26.15 j	4.91 g	87.31 i
	20	21.92 n	5.81 e	94.04 f	21.46 l	6.13 d	90.32 e
Ascorbic acid 3%	0	39.31 a	0.58 t	78.60 t	39.09 a	0.63 s	75.33 u
	4	37.49 c	2.06 q	82.83 q	37.21 b	2.35 p	78.93 r
	8	34.67 f	3.43 m	86.22 l	34.30 e	3.65 l	81.73 n
	12	30.79 i	4.22 j	89.32 i	30.41 h	4.53 h	86.05 j
	16	26.51 l	5.43 f	94.42 e	26.12 j	5.72 e	89.82 f
	20	21.90 n	6.92 b	99.52 b	21.42 m	5.72 e	93.42 b
1-MCP 1.5 %	0	39.31 a	0.58 t	78.60 t	39.09 a	0.63 s	75.33 u
	4	37.51 bc	1.87 r	81.53 r	37.24 b	2.04 q	78.07 s
	8	34.70 ef	3.05 n	84.83 n	34.34 d	3.35 m	80.63 o
	12	30.81 i	3.93 l	88.11 j	30.44 gh	4.13 j	84.92 k
	16	26.55 k	5.02 g	93.32 g	26.14 j	5.21 f	88.14 g
	20	21.90 n	6.12 d	97.71 c	21.44 lm	6.45 c	92.15 d
Control	0	39.31 a	0.58 t	78.60 t	39.09 a	0.63 s	75.33 u
	4	37.03 d	2.54 p	83.92 o	36.73 c	2.73 o	79.75 q
	8	34.02 g	4.14 k	88.03 k	33.63 f	4.36 i	82.34 m
	12	29.93 j	4.93 h	91.33 h	29.55 i	5.21 f	87.92 h
	16	25.91 m	6.62 c	96.15 d	25.41 k	6.93 b	92.31 c
	20	20.73 o	7.51 a	102.51 a	20.32 n	7.84 a	99.52 a
Citric acid 3%		31.81 A	3.13 D	85.43 D	31.46 A	3.33 D	82.21 D
Ascorbic acid 3%		31.78 C	3.77 B	88.48 B	31.43 B	3.77 B	84.21 B
1-MCP 1.5 %		31.80 B	3.43 C	87.35 C	31.45 A	3.64 C	83.21 C
Control		31.16 D	4.39 A	90.09 A	30.79 C	4.62 A	86.19 A
	0	39.31 A	0.58 F	78.60 F	39.09 A	0.63 F	75.33 F
	4	37.39 B	2.03 E	82.31 E	37.10 B	2.21 E	78.45 E
	8	34.52 C	3.34 D	85.67 D	34.16 C	3.55 D	81.14 D
	12	30.60 D	4.13 C	88.70 C	30.21 D	4.40 C	85.58 C
	16	26.38 E	5.42 B	93.31 B	25.96 E	5.69 B	89.40 B
	20	21.61 F	6.59 A	98.45 A	21.16 F	6.54 A	93.85 A

Values followed by the same letter (s) in each group are not significantly different at 5%

a* value

As for greenness (a* value), data presented in Table (3) show that the effect of storage period and its effect on a* value, data show that the increment in storage period was accompanied by a linear decrease in a* value and a degradation in green color especially at the end of storage period (20 days).

This result agrees with that obtained by Martin-Diana *et al.* (2008) they found that the increase in storage period led to a decrease in a* value of fresh cut lettuce.

Regarding the effect of some postharvest treatments on a* value, data show that no significantly affected by different treatments compared with untreated control the all treatments scored the highest a* value compared with untreated control in both seasons.

Table 3: Effect of citric acid, ascorbic acid and 1-methylcyclopropene on L*, a* and b* value of iceberg lettuce (*Lactuca sativa* L.) during cold storage at 0ºC in 2016/2017 and 2017/2018 seasons.

Treatments	Days after storage	First season (2016/2017)			Second season (2017/2018)		
		L* Value	a* Value	b* Value	L* Value	a* Value	b* Value
Citric acid 3%	0	54.58 a	-8.42 k	23.87 a	53.13 a	-8.33 h	23.53 a
	4	53.17 b	-8.03 j	23.63 b	52.45 abc	-8.04 gh	23.22 b
	8	52.72 c	-7.63 h	23.22 d	51.71 bcd	-7.51 fg	22.84 d
	12	52.03 d	-6.92 f	22.82 e	50.83 d	-6.81 de	22.44 ef
	16	51.52 f	-6.11 d	22.06 f	49.74 e	-6.21 bc	21.93 g
	20	50.21 h	-5.71 c	21.60 h	48.52 f	-5.73 b	21.43 i
Ascorbic acid 3%	0	54.58 a	-8.42 k	23.87 a	53.13 a	-8.33 h	23.53 a
	4	53.22 b	-8.05 j	23.62 b	52.59 ab	-7.98 gh	23.18 c
	8	52.70 c	-7.61 h	23.19 d	51.73 bcd	-7.47 fg	22.83 d
	12	52.07 d	-6.93 f	22.82 e	50.81 d	-6.82 de	22.40 f
	16	51.47 f	-6.12 d	22.01 g	49.67 e	-7.19 ef	21.92 g
	20	50.27 h	-5.72 c	21.53 i	48.87 ef	-5.69 b	21.44 i
1-MCP 1.5 %	0	54.58 a	-8.42 k	23.87 a	51.57 cd	-8.33 h	23.53 a
	4	53.19 b	-8.03 j	23.64 b	52.60 ab	-8.01 gh	23.20 bc
	8	52.61 c	-7.62 h	23.20 d	51.74 bcd	-7.51 fg	22.80 d
	12	52.06 d	-6.92 f	22.83 e	50.85 d	-6.84 de	22.42 ef
	16	51.28 g	-6.12 d	22.07 f	49.74 e	-6.20 bc	21.93 g
	20	50.22 h	-5.74 c	21.59 h	48.52 f	-5.71 b	21.44 i
Control	0	54.58 a	-8.42 k	23.87 a	53.13 a	-8.33 h	23.53 a
	4	51.81 e	-7.72 i	23.32 c	50.81 d	-7.80 gh	22.82 d
	8	50.02 i	-7.03 g	22.82 e	49.81 e	-7.01 ef	22.45 e
	12	49.81 j	-6.23 e	22.04 fg	49.03 ef	-6.32 cd	21.74 h
	16	48.81 k	-5.53 b	21.11 j	48.11 fg	-5.72 b	21.02 j
	20	47.82 l	-4.81 a	20.22 k	47.52 g	-5.02 a	20.05 k
Citric acid 3%		52.37 AB	-7.14 B	22.87 A	51.13 A	-7.11 B	22.56 A
Ascorbic acid 3%		52.39 A	-7.14 B	22.84 B	51.06 A	-7.25 B	22.55 A
1-MCP 1.5 %		52.32 B	-7.14 B	22.87 A	50.84 A	-7.10 B	22.55 A
Control		50.48 C	-6.62 A	22.23 C	49.74 B	-6.70 A	21.93 B
	0	54.58 A	-8.42 F	23.87 A	52.74 A	-8.33 F	23.53 A
	4	52.85 B	-7.96 E	23.55 B	52.11 B	-7.96 E	23.11 B
	8	52.01 C	-7.47 D	23.11 C	51.25 C	-7.38 D	22.73 C
	12	51.49 D	-6.75 C	22.63 D	50.38 D	-6.70 C	22.25 D
	16	50.77 E	-5.97 B	21.81 E	49.32 E	-6.33 B	21.70 E
	20	49.63 F	-5.50 A	21.23 F	48.36 F	-5.54 A	21.09 F

Values followed by the same letter (s) in each group are not significantly different at 5%

b *value

As shown in Table (3), lettuce yellowness (b* value) of all treatments increase gradually during cold storage, the maximum sag was remarked at the end of storage period after 20 days of storage. The increase of b* value through the increase of storage period may be related to the breakdown of chlorophyll during storage period (Brown *et al.,* 1991).

Concerning the effect of postharvest treatments on b* value, results show that dipping heads lettuce in citric acid at 3% or 1-Methylcyclopropene (1-MCP) led to a slightly reduction in b* value followed by dipping heads in the solution of ascorbic acid at 3%in the first season, while all treatments showed no significant in the second season compared with untreated control. This result might be related to the inhibitory effect of treatments on polyphenol oxidase enzyme (Lai *et al*., 2006) that retard the appearance of yellow color which increase relatively with the increase of polyphenol oxidase activity.

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