

Effect of temperature and modified atmosphere packaging on globe artichoke (*Cynara scolymus* L.) quality during storage

Abstract

Two experiments were carried out on globe artichoke cultivar “French Hyrious” in the winter seasons of 2013/2014 and 2014/2015 in private farm at Behiera Governorate and in Horticulture Research Institute, Agricultural research Center postharvest laboratory to study the physical and chemical changes in the heads. To improve the storage ability of the heads, two kinds of cold storage, two types of packages were examined. Stored heads under cold storage conditions of 0°C and 95% R.H. were much better than those stored at 5°C and 95% R.H. as it possessed the lower loss in weight and unmarketable percentage beside maintained the higher visual quality and colour in addition to contain more concentrations of T.S.S., total sugars, inulin, ascorbic acid and lower respiration rate. On the other hand, the heads stored in plastic boxes either lined with perforated polypropylene or unlined under 0°C or 5°C and 95% R.H. exhibited that lined plastic boxes existed lower loss in weight, unmarketable percentage, higher visual quality, greater colour retention and kept more concentrations of T.S.S., total sugars, inulin, ascorbic acid beside lower respiration rate comparatively to those heads stored in the unlined ones.

Keywords: globe artichoke, polypropylene, TSS, total sugars, inulin, ascorbic acid

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Introduction

Globe artichoke (*Cynara scolymus*, L.) is a perennial plant which belong to the Asteraceae family, originating from the Mediterranean region where it is traditionally cultivated and commonly consumed as an important vegetable.¹⁻³ Artichoke flower heads (or capitula) are immature composite inflorescences, including the edible part of the plant used worldwide as a fresh, frozen, or canned foodstuff. Moreover, artichoke industrial by-products (stems, outer bracts, leaves) represent about 80% of the biomass and may be used as raw material for the extraction of food additives and antioxidants.^{4,5} In addition, leaves, stems and industry residues are used for cattle feed. This vegetable crop possess an important nutrition value and medicinal uses due to its high contents of phenolic compounds, flavonoids, inulin, heparaxal, fibers and many minerals beside it contain cynarin which has effects on hepatobiliary diseases, hyperlipidaemia, dropsy, rheumatism and cholesterol metabolism.⁶⁻⁸

Optimum temperature of storage was mainly the major factor for extending the storage ability of vegetables by minimizing both the physical, chemical and biochemical changes. Hence, it was shown from the studies done on the heads of globe artichoke during cold storage that the heads stored at 0°C lost 0.8% after 16days of cold storage while those stored at 6 and 9°C lost 1.3 and 2.9% respectively whereas the heads stored at 17°C could not be prolonged for more than 10days of storage.⁹ The same conclusion was observed on, broccoli, as the spears stored at 20°C reflected rapid decrease in weight comparatively to those stored at 0°C which exhibited less decrease.¹⁰ It was noticed cauliflower that the curds stored at 0°C were much better in visual quality and marketable curds than those stored at 0°C+10°C for 2days.¹¹ From the other point of view, the other experiment on broccoli revealed that the content of T.S.S in the spears stored for 3weeks at 2±1°C was more than those stored at 12±1°C.¹² In the same subject, it was noticed on globe artichoke that heads stored

at 0,2,5,7 and 10°C for 14days showed decreases in ascorbic acid content with the progress of the storage period with the superiority of 0°C in keeping the highest concentrations of ascorbic acid during storage.¹³ Extending of experiments on globe artichoke indicated that total sugars and inulin contents decreased continuously during 28days of storage at 4°C and 8°C and those heads stored at 4°C kept more sugars and inulin contents than the ones stored at 8°C.¹⁴

In addition, packaging is one of the important supplemental tools for cold storage to keep more good qualities for better marketing. Thus, it was found on globe artichoke that the stored heads at 4°C in polyethylene bags showed minimum loss in weight, unmarketable heads and maximum visual quality than the unpacked ones.¹⁵ This view was assured on cauliflower as the stored curds at 0°C in polypropylene or polyvinyl chloride bags Kept more T.S.S. and total sugars than those unpacked ones.^{16,17} Further study on another crop, globe artichoke, indicated that the heads stored at 5°C in perforated polypropylene bags kept comparatively the highest content of ascorbic acid than those stored in polyvinyl chloride, polyethylene or micro perforated polypropylene bags after 8days of storage.¹⁸ Concerning the respiration rate, it was noticed on broccoli that the spears packed in polypropylene and stored at 4°C and 13°C depressed O₂ and increased CO₂ inside the bags which depends to great extent on respiration rate, permeability of the used films and storage temperature.¹⁹ Thus, the present work gave spot light on the extend of storage ability and improve of quality by some postharvest tools such as cold storage and packing types.

Materials and methods

Artichoke heads of the cultivar “French Hyrious” were used in this investigation where the plants grown in private farm located at Kom EL-Farag village near Abu EL-Matameer, Behiera Governorate during the two successive winter seasons of 2013-2014 and 2014-2015. This

work was carried out to study the effect of cold storage and type of packages upon the quality of stored head. The head samples were harvested and transported within 3 hours from harvest to the laboratory of the Vegetables Department, Agriculture Research center, Ministry of Agriculture. They were cooled at 5°C and 95%RH for 24 hours after which the heads were packed in plastic boxes (40x28x15cm) either lined with perforated polypropylene (4 holes in cm with 0.5mm in diameter) or unlined, weighted then stored at 0 or 5°C and 95%RH for 1,2,3 and 4 weeks respectively. All artichoke samples of the two seasons were represented in three replicates comprised 4 heads each. Three randomly selected boxes of each treatment were devoted to the following characteristics before and after storage:

- i. **Physical changes:** Loss in weight percentage, unmarketable head percentage, visual quality and colour.
- ii. **Chemical and biochemical changes:** Total soluble solids, total sugars, inulin, ascorbic acid and the ratio between oxygen and carbon dioxide.

Determination procedures

The average changes of the heads were determined by the following procedures:

loss in weight percentage: The percentage of loss in weight was calculated by the following equation: $\text{Loss in weight \%} = \frac{\text{Loss in weight at the sampling date}}{\text{The initial weight of the heads}} \times 100$

Unmarketable percentage: The percentage of unmarketable examined heads was determined from the following equation: $\text{Unmarketable heads (\%)} = \frac{\text{Total number of unmarketable at the sampling date}}{\text{The initial number of heads}} \times 100$

Visual quality

The visual quality was determined according to the scale of scoring system as explained after Able et al., [20]. They were: 9: excellent, 7: good, 5: fair, 3: poor and 1: unsuitable. This scale depends on the morphological defects such as shriveling, loss of compactness and presence of physiological and pathological defects.

Colour

The colour of the examined part was determined by Minolta (CR-400, Minolta, Japan), according to the International commission of Illumination: (L*) Lightness, (a*) Red/Green, (b*) Yellow/Blue, (C*) Chroma and (h*) Hue angle were recorded for three pieces per sample.²¹

Total soluble solids (T.S.S)

The T.S.S content were determined by abbe refractometer as a percentage as reported in A.O.A.C., (1990).²²

Total sugars: The total sugars content was determined as g/100g dry weight according to Smith et al., (1956).²³

Inulin: The inulin content was determined after the method of Winton and Winton, (1958).²⁴

Ascorbic acid: The ascorbic acid content was determined as mg/100g fresh weight using 2,6 dichlorophenol indophenol method described in A.O.A.C.(1980).

Results

Physical changes

Loss in weight percentage: The effect of cold storage temperatures

and types of packing on the artichoke head loss in weight percentage in the two seasons of 2013-2014 and 2014-2015 are presented in Table 1. It is clear that a continuous gradual loss in weight happened in heads with the extend of the storage periods in all the treatments. The resulted data of cold storage proved that the low temperature of 0°C was much better in lessening this percentage than the other one either in lined or unlined boxes. On the other hand, evidences show that heads stored in lined boxes loss less weight as compared with those stored in the unlined ones under both the two degrees of cold storage. In other words, the heads stored under 0°C in lined boxes kept the lowest loss in weight percentage and the longest storage periods.

Unmarketable percentage: The data of the effect of cold storage temperatures and types of packing on the artichoke head unmarketable percentage in the two seasons of 2013-2014 and 2014-2015 are shown in Table 2. The general view of cold storage and packing reflect an increase trend in the unmarketable percentage of the heads with the prolongation of the storage periods in all the tested experiments. The data of cold storage showed that the low temperature of 0°C kept more preferable values in this percentage by lowering the unmarketable heads than the other degree of temperature either in lined or unlined boxes. Dealing with packing, evidences caught from the trails showed that the heads stored in lined boxes exerted lower unmarketable percentage during storage at both 0°C and 5°C than those stored in the unlined ones. From these results, it is evident that the storage under 0°C in lined boxes was the best in lowering the percentage of unmarketable heads and extending the storage periods.

Visual quality

The effect of cold storage temperatures and types of packing on the artichoke head visual quality in the two seasons of 2013-2014 and 2014-2015 are clarified in Table 3. Generally speaking, the head visual quality put forth a picture of a gradual deteriorations in this characteristic with the extend of storage periods. Considerable attention to the data of cold storage presented that the temperature of 0°C reserved better visual qualities during storage than the other one of 5°C either in lined or unlined boxes. From another point of view, the results of packing reflected that the heads stored in lined boxes maintained better visual quality than those stored in the unlined ones under the two temperatures of cold storage. Noteworthy to say that the heads stored under 0°C in lined boxes kept better visual qualities and hold more storage periods in comparison with those stored under 5°C in the unlined ones.

Colour

The effect of cold storage temperatures and types of packing on the artichoke head colour in the two seasons of 2013-2014 and 2014-2015 are presented in Table 4. As a whole, in all the treatments a gradual deterioration occurred in the head colour with the extension of storage periods. It is clear that cold storage at 0°C was the most effective in minimizing the drop of this characteristic comparatively to cold storage at 5°C either in lined or unlined boxes. From another aspect, the heads stored in lined boxes reflect the least degradation of colour than those stored in the unlined ones under the two temperatures of cold storage. Thus, heads stored under 0°C in lined boxes showed more colour appearance and extended the storage periods than those kept under 5°C in unlined ones.

Chemical and biochemical changes:

Total soluble solids: The effect of cold storage temperatures and types of packing on the content of artichoke head T.S.S. during storage in the two seasons of 2013-2014 and 2014-2015 are illustrated

in Table 5. A general gradual decline trend occurred in these contents due to the applications of both cold storage temperatures and types of packing materials with the elapse of storage periods. The results were in favor of using the low temperature of 0°C which hold more higher concentrations of T.S.S. in the heads than the other kind of cold storage of 5°C in each lined or unlined boxes. On the other hand, it is clear that the heads stored in lined boxes kept more high concentrations of T.S.S. comparatively with those stored in the unlined ones under the two temperatures of cold storage. In other words, heads stored under 0°C in lined boxes contained higher concentrations of T.S.S. and showed more storage periods than those stored under 5°C in unlined boxes.

Total sugars: The result of the effect of cold storage temperatures and types of packing on the total sugars content in the artichoke heads during storage in the two seasons of 2013-2014 and 2014-2015 are shown in Table 6. The study of the view of the obtained data reflect general increases in these contents with the elongation of the storage periods in all the treatments till 14days which was followed by decreases till the last storage period at 28days. However, the resulted figures of cold storage exhibited more total sugars concentration in the heads stored at low temperature of 0°C in comparison with those stored at 5°C either in lined or unlined boxes. Dealing with packing, the obtained data indicate that the heads stored in lined boxes kept more total sugars than those stored in the unlined ones during cold storage under the two examined temperatures.

Inulin: The inulin content of the artichoke heads as affected by cold storage temperatures and types of packing in the two seasons of 2013-2014 and 2014-2015 is exhibited in Table 7. The figures indicate that there was a progressive increase in the head insulin content in all the tested treatments during the first 14days of storage after which

a drop happened till the last 28days of storage. However, the results of cold storage show that storage under the temperature of 0°C was more pronounced in retarding the degradation of inulin content than the other one of 5°C in both lined or unlined boxes. Another picture caught from the obtained results cleared that the heads stored in lined boxes reserved more inulin content comparatively to those stored in the unlined ones under the two used temperatures in cold storage.

Ascorbic acid: The figures resulted from the effect of cold storage temperatures and types of packing on the ascorbic acid content of artichoke head in the two seasons of 2013-2014 and 2014-2015 are shown in Table 8. The general sight of the figures reflects a direction of decreases in this content with the elapse of storage periods. The vision of cold storages exhibit that the heads stored at 0°C hold higher concentrations of ascorbic acid than those stored under 5°C in the lined or the unlined boxes. On the other hand, the heads stored in lined boxes kept more higher ascorbic acid content in heads during the various storage periods than those stored in the unlined ones under the two kinds of cold storage.

Ratio of oxygen and carbon dioxide: The effect of cold storage temperatures and types of packing on the levels of O₂ and CO₂ gases around artichoke heads in the two seasons of 2013/2014 and 2014/2015 are tabulated in Table 9. As a general trend, it is obvious that the levels of oxygen around the heads decreased meanwhile those of carbon dioxide increased with the extension of storage periods. However, the figures of cold storage reflect that the heads stored at 0°C showed more oxygen levels and less carbon dioxide than those stored at 5°C during all the storage periods either in lined or unlined boxes. From another point of view, the heads stored in lined boxes kept less O₂ and more CO₂ in the around atmosphere than those stored in the unlined ones.

Table 1 The effect of cold storage temperatures and types of packing on the loss in weight percentage of globe artichoke head in the two seasons of 2013-2014 and 2014-2015

Storage Periods in Days								
Treatments	2013-2014 season				2014-2015 season			
	7	14	21	28	7	14	21	28
Cold storage at 0°C								
Lined boxes	1.2	3.24	5.01	7.02	1.7	3.86	5.42	7.35
Unlined boxes	3.89	7.69	12.69	27.97	4.51	7.89	13.22	28.72
Cold storage at 5°C								
Lined boxes	2.55	7.22	7.67	9.25	3.45	7.13	7.86	9.77
Unlined boxes	7.3	13.76	20.61	-----	8.78	13.87	20.1	-----

Table 2 The effect of cold storage temperatures and types of packing on the unmarketable percentage of globe artichoke head in the two seasons of 2013-2014 and 2014-2015

Storage periods in days								
Treatments	2013-2014 season				2014-2015 season			
	7	14	21	28	7	14	21	28
Cold storage at 0°C								
Lined boxes	0	0	0	20	0	0	0	20
Unlined boxes	0	0	20	75	0	0	20	70
Cold Storage at 5°C								
Lined boxes	0	0	20	60	0	0	25	60
Unlined boxes	0	20	65	100	0	20	70	100

Table 3 The effect of cold storage temperatures and types of packing on the visual quality of globe artichoke head in the two seasons of 2013-2014 and 2014-2015

Treatments	Storage periods in days									
	2013-2014 season					2014-2015 season				
	0	7	14	21	28	0	7	14	21	28
	Cold storage at 0°C									
Lined boxes	9	9	9	9	7	9	9	9	9	7
Unlined boxes	9	9	7	5	3	9	9	7	5	3
	Cold storage at 5°C									
Lined boxes	9	9	9	7	5	9	9	9	7	5
Unlined boxes	9	7	5	3	-----	9	7	5	3	-----

Visual quality was determined using the following rating score system: Excellent=9, Good=7, Fair=5, Poor=3 and Unstable =1 (Able et al., 2002).

Table 4 The effect of cold storage temperatures and types of packing on the colour of globe artichoke head in the two seasons of 2013- 2014 and 2014-2015

Treatments	Storage periods in days	2013-2014 season			2014-2015 season		
		(L*)	(C*)	(h*)	(L*)	(C*)	(h*)
	Cold storage at 0°C						
	0	37.22	18.23	87.28	37.62	20.99	85.9
	7	37.1	17.83	86.85	34.2	19.76	84.33
Lined boxes	14	36.81	16.68	86.1	34.12	18.87	82.55
	21	36.76	16.61	82.03	33.35	16.56	79.81
	28	33.38	16.54	80.39	32.85	16.5	79.58
	0	38.57	19.82	89.04	40.81	25.3	91.15
	7	34.44	16.07	75.64	34.21	20.61	82.85
Unlined boxes	14	32.67	15.97	74	33.14	18.46	75.57
	21	31.9	15.16	72.57	32.88	18.1	75.37
	28	30.93	15.12	64.56	31.04	17.14	63.71
	Cold storage at 5°C						
	0	41.1	19.49	93.31	36.67	22.98	93.19
	7	40.63	19.03	88.63	35.87	17.66	80
Lined boxes	14	38.48	18.47	84.14	35.4	17.57	74.53
	21	37.61	17.01	83.55	35.27	16.23	68.78
	28	37.13	16.6	83.51	31.3	15.85	61.02
	0	37.55	17.86	88.1	37.6	21.55	84.76
	7	36.2	17.57	77.84	34.8	18.85	78.95
Unlined boxes	14	36	15.54	77.59	33.49	17.57	74.49
	21	33.41	14.81	71.14	33.12	17.45	72.15
	28	-----	-----	-----	-----	-----	-----

Color was quantified using a chromameter (CR-400 , Minolta, Japan). (L*) lightness, (C*) Chroma, (h*) Hue angle

Table 5 The effect of cold storage temperatures and types of packing on the total soluble solids percentage of globe artichoke head in the two seasons of 2013-2014 and 2014-2015

Storage periods in days											
Treatments	2013-2014 season					2014-2015 season					
	0	7	14	21	28	0	7	14	21	28	
Cold storage at 0°C											
Lined boxes	13.2		12.8	12.4	11.9	11	13.5	13.1	12.6	12.4	11.5
Unlined boxes	13.2		12.3	11.8	10.9	9.8	13.5	12.7	12.2	11.3	10.2
Cold storage at 5°C											
Lined boxes	13.2	12.7		12.2	11.5	10.3	13.5	13	12.4	11.6	10.5
Unlined boxes	13.2	11.7		11.1	10	-----	13.5	12	11.3	10.2	-----

Table 6 The effect of cold storage temperatures and types of packing on the total sugars (g/100g.d.w) of globe artichoke head in the two seasons of 2013-2014 and 2014-2015

Storage periods in days										
Treatments	2013-2014 season					2014-2015 season				
	0	7	14	21	28	0	7	14	21	28
Cold storage at 0°C										
Lined boxes	27.34	29.94	30.11	26.29	22.08	26.15	28.81	29.77	25.87	21.37
Unlined boxes	27.34	27.7	29.37	25.18	19.67	26.15	26.43	28.76	24.77	18.64
Cold storage at 5°C										
Lined boxes	27.34	28.85	29.87	25.34	20.31	26.15	26.51	28.89	24.83	19.94
Unlined boxes	27.34	27.42	28.54	20.21	-----	26.15	26.31	26.88	18.89	-----

Table 7 The effect of cold storage temperatures and types of packing on the inulin(g/100g.d.w) of globe artichoke head in the two seasons of 2013-2014 and 2014- 2015

Storage periods in days										
Treatments	2013-2014 season					2014-2015 season				
	0	7	14	21	28	0	7	14	21	28
Cold storage at 0°C										
Lined boxes	15.53	16.57	17.54	14.98	11.97	14.86	15.89	16.75	13.51	11.16
Unlined boxes	15.53	15.83	16.36	13.21	8.93	14.86	15.16	15.91	12.81	8.04
Cold storage at 5°C										
Lined boxes	15.53	15.95	16.61	13.89	9.65	14.86	15.21	15.98	12.93	8.87
Unlined boxes	15.53	15.62	16.05	12.52	-----	14.86	14.98	15.23	11.78	-----

Table 8 The effect of cold storage temperatures and types of Packing on the ascorbic acid(mg/100g.f.w) of globe artichoke head in the two seasons of 2013-2014 and 2014- 2015

Storage Periods in Days										
Treatments	2013-2014 season					2014-2015 season				
	0	7	14	21	28	0	7	14	21	28
Cold storage at 0°C										
Lined boxes	16.35	14.4	12.67	11	8.2	18.4	16	14.11	12.32	9.17
Unlined boxes	16.35	12.1	10	8.59	6	18.4	14.62	11.73	9.52	6.4
Cold storage at 5°C										
Lined boxes	16.35	12.21	10.02	8.81	5.53	18.4	14	11.78	9.87	6.65
Unlined boxes	16.35	10.4	7.83	5.72	-----	18.4	12	9.03	6.83	-----

Table 9 The effect of cold storage temperatures and types of packing on the ratio of O₂ and CO₂ (%) around globe artichoke head in the two seasons of 2013/2014 and 2014/2015

Treatments		2014 – 2015 season					2013 – 2014 season				
		0	7	14	21	28	0	7	14	21	28
Cold storage at 0°C											
Lined boxes	O ₂	20.9	14.2	12.73	10	8	20.9	14.65	13.96	10.39	8.13
	CO ₂	0.03	3.51	4.25	5.81	6.68	0.03	3.36	4.2	5.7	6.53
Unlined boxes	O ₂	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
	CO ₂	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cold storage at 5°C											
Lined boxes	O ₂	20.9	13	11.93	8.78	5.68	20.9	13.11	12.17	8.99	6
	CO ₂	0.03	4.31	5.17	6.66	8.13	0.03	4.2	5.09	6.41	7.81
Unlined boxes	O ₂	20.9	20.9	20.9	20.9	-----	20.9	20.9	20.9	-----	20.9
	CO ₂	0.03	0.03	0.03	0.03	-----	0.03	0.03	0.03	-----	0.03

Discussion

The prime consideration in this part of the experiment is the use of the best storage temperature, relative humidity and atmospheric conditions for maintaining the highest quality of globe artichoke heads. However, refrigeration has long been recognized as the first factor for reserving the quality. Proper use of low temperature will retard respiration, other metabolic activities, aging, softening, colour changes, moisture loss, spoilage, undesirable growth and flavor changes. As the requirements of different vegetables vary widely, it is also vary among the various varieties which belong to one crop. So, it is necessary to establish this experiment to have knowledge about the most suitable cold storage temperature for globe artichoke variety "French Hyrious". Thus, maintaining the proper environment around the commodity during storage will prolongs their usefulness and may improve their quality.

As a general trend during cold storage either at 0°C or 5°C, there was continuous increase in loss in weight, more appearance of unmarketable heads, reduction in the visual qualities and more degradation in colour with the prolongation of the storage periods. Moreover, it is well known that all the fresh vegetable crops including globe artichoke are consist of high water content which during storage are subjected to desiccation that lead to wilting and shriveling.²⁵ The loss of the stored food reserves during respiration, hastening senescence, increase loss of visual quality, loss of soluble dry weight and reduction of food value.^{1,26,27} It is clear from the obtained results of cold storage that the heads stored at 0°C exhibited better results regarding the physical and chemical characteristics during all the storage periods than those stored at 5°C. Thus, the view existed from using cold storage at 0°C was the best in minimizing head loss in weight, unmarketable percentage, changes in the visual qualities and colour deterioration at all the storage periods than storing at 5°C. These results may be attributed to more reduction in respiration rate combined with lower ethylene production that led to better retention of the marketable and visual qualities²⁸⁻³⁰ in addition to more inhibition of a wide range of plant pathogens.³¹⁻³³

However, an enlightenment on this result put forth a fact that with

every 10°C increase in temperature during storage an acceleration of deterioration took place by two to three folds.²⁴ From another point of view, the results obtained on the changes in the head chemical contents during cold storage under the two examined temperatures put spot light on a continuous loss of T.S.S. and ascorbic acid and at the same time reduction in the level of O₂ and elevation of CO₂ with the prolongation of the storage periods. On the other hand, total sugars and inulin contents showed gradual increases till 14days of cold storage that was followed by a decrease drop up to the end of storage periods. However, the decrease in TSS is mainly a resultant to conversion of insoluble compounds to simpler soluble forms on one side, moisture loss by transpiration or respiration on the other side.³⁴⁻³⁶

To have a look at the changes in total sugars and inulin contents during storage, it is clear that these contents increased during cold storage at first and decreased at the end. This result may be related to the use of these contents as respiration substrate at late storage periods.³⁷⁻³⁹ Nevertheless, the degradation in head ascorbic acid content during storage may be due to the fact that this vitamin was known as a catalyst in respiration and has an important role in the biological and biochemical oxidation-reduction reactions during the various vital processes occurring in the stored fruits which led to exhaust in this vitamin.^{18,40} The findings resulted for O₂ and CO₂ which show decreases in O₂ and increases in CO₂ during cold storage of the heads may be due to the continuous respiration process which use up O₂ and produce CO₂.⁴¹⁻⁴³

Concerning the packing treatment which held as a cold storage supplemental aid is one of the keys associated with the extension of the storage ability of the fresh product. The obtained results of packing manifested that the heads stored in lined boxes revealed preferable results of physical and chemical characteristics at all the storage periods comparatively to those stored in the unlined ones. The view of the packing data reflected that the heads stored in lined boxes transcended those stored in the unlined ones by decreasing the loss in weight, the unmarketable percentage, the changes in the visual quality and the colour degradation at all the storage periods. On the whole, the potential benefits of packing depends on the commodity, variety, physiological age, atmospheric composition around the commodity,

temperature, duration of storage and film permeability.⁴⁴ The obtained results may refer to some reasons mainly the following three ones. The first point show that the limitation of water vapor diffusion by the film increased the general water vapor pressure inside it and correlated with the decrease of the film permeability.^{45,46} The second point exhibit that the reduction in respiration rate combined with the lower of ethylene production by packing film during storage condition led to better in the unmarketable percentage, visual quality and green colour of vegetables.³⁰ The third point implied that packing film inhibit a wide range of plant pathogens during storage and significantly improved the appearance of the stored commodity.⁴⁷⁻⁵⁰ The view of the data of packing types reflected that the heads stored in lined boxes surpassed those stored in the unlined ones in retention the maximum concentrations of the contents of T.S.S, total sugars, insulin, ascorbic acid and lessening of respiration rate in all the storage periods. These results may be related to the modification of atmosphere that reduced respiration rate which depends on the commodity, variety beside the type of film used such as permeability and thickness.⁴³

Conclusion

In seeking to follow the results in this experiment, two points can be put in mind as recommendations for practical work. The first point recommend that cold storage at 0°C is the most suitable and effective for maintaining the quality during storage than that at 5°C. The second point, suggest statement in favor of the perforated polypropylene lining boxes which were the most effective in extending the shelf life of globe artichoke and maintaining the highest nutritional contents. Thus, the best storability for globe artichoke is storing the heads under the conditions of cold storage at 0°C and 95% R.H in lined boxes with perforated polypropylene sheets.

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Conflict of interest

The author declares no conflict of interest.

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