

# UTILIZATION OF MODIFIED ATMOSPHERE PACKAGING TO EXTEND SHELF LIFE OF ARTICHOKE HEADS DURING STORAGE

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**Abstract**-Experiment was carried out on artichoke flower heads of Balady cultivar “Cynara scolymus L.” in Sakha Research Station, Kafr El- Sheikh Governorate, Egypt during the season 2017 to study the influence of modified atmosphere packaging on the physical and chemical changes in the artichoke heads. Two treatments were studied to improve the quality and storability of the artichoke heads, the first treatment was packing artichoke heads in low density polyethylene (LDPE) and Polyester/ Polyethylene (PET/PE) and control samples without packaging, the second treatment, was packing under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub> and 5% O<sub>2</sub>+10% CO<sub>2</sub>) and control samples packaged without modified atmosphere using the same packaging materials as the first treatment All artichoke heads packaged stored in refrigerator at 4±1°C and 90- 95% relative humidity for 5 weeks. Loss in weight, decay percentage, visual quality, T.S.S., ascorbic acid, total sugars and inulin were followed during storage. The results showed that the packaging materials, modified atmosphere, storage (Days), the two-way interactions and the three-way interactions were highly significant for all characteristics tested. Stored heads packaged in PET/PE were much better than those packaged in LDPE with all characteristics tested throughout the storage period as it possessed the lower loss in weight and decay percentage beside maintained the higher visual quality. In addition to contain more concentrations of T.S.S., ascorbic acid, total sugars, inulin compared with unpackaged heads (control). On the other hand, the heads stored in modified atmosphere either (5% O<sub>2</sub>+5% CO<sub>2</sub> or 5% O<sub>2</sub>+10% CO<sub>2</sub>) exhibited that modified atmosphere existed lower loss in weight, decay percentage, higher visual quality, greater ascorbic acid and kept more concentrations of T.S.S., total sugars and inulin, comparatively to those heads packaged in without modified ambient environment. The heads stored in modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>) showed less value in weight loss, decay percentage followed by heads stored in (5% O<sub>2</sub>+5% CO<sub>2</sub>) compared with heads packaged without modified. In addition the mean values of ascorbic acid, T.S.S., total sugars and inulin with modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>) showed high values followed by modified (5%O<sub>2</sub>+5%CO<sub>2</sub>) compared with that without modified (control). Generally, this study suggests storage artichoke heads in PET/PE package with modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>) at 4°C and 90-95 % RH where this method significantly reduced the weight loss, decay percentage and maintaining the good overall appearance and most Physical and chemical properties for 5 weeks storage.

**Keywords:** Globe Artichoke, Packaging materials, modified atmosphere, physical and chemical changes

## 1. INTRODUCTION

Quality maintenance of perishable fruits and vegetables during storage is strictly connected to prevention of loss of their nutritional and organoleptic properties. The use of different types of packaging, Modified atmosphere packaging and low storage temperatures might help to realize this goal.

Artichoke (Cynara scolymus L.) is a perennial plant, one of the most typical vegetable from the family Asteraceae, originating from the Mediterranean region where it is traditionally cultivated and commonly consumed as an important vegetable [Forney1989; Sonnan te et al., 2007 and Haggag2016]. 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 [Ceccarelli et al., 2010 and Haggag et al., 2016], which health protective potential due to the antioxidant properties of its phenolic fraction is known [Gebhardt, 1997]. In addition, artichoke nutritional properties are increased by its high content of inulin [Di Venere et al., 2003a]. 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 contains cynarin which has effects on hepatobiliary diseases, hyperlipidaemia, dropsy, rheumatism and cholesterol metabolism [Adzet et al.,1987;Hammouda et al.,1993 and Helaly et al., 2016 ].Low temperature (between 0°C and5°C) and high humidity (90% RH) are recommended to store artichokes with maximum quality [Mencarelli et al., 1993].

There is an increase in artichoke demand due to a reputation for nutritional benefits and its culinary properties [Englisch et al., 2000] and this demand requires a distribution over longer distances.

Optimum temperature of storage was mainly the major factor for prolonging 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 16 days 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 10 days of storage [Artes et al., 2001]. 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 [Balouchi et al., 2011].

It was noticed that 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 2 days [Awad, 2014]. From the other point of view, the other experiment on broccoli revealed that the content of T.S.S in the spears stored for 3 weeks at 2±1°C was more than those stored at 12±1°C [Raja et al., 2011]. In the same subject, it was noticed on globe artichoke that heads stored at 0,2,5,7 and 10°C for 14 days 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 [Gil-Izquierdo et al., 2001]. Extending of experiments on globe artichoke indicated that total sugars and inulin contents decreased continuously during 28 days 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 [Raccuia and Melilli, 2007].

In addition, packaging is one of the important supplemental tools for cold storage to keep more good qualities for most 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 [Del-Nobile et al., 2009]. 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 [Schonhof et al., 2004 and Simon, et al., 2008]. 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 8 days of storage [Gil-Izquierdo et al., 2002]. And other 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. [Haggag et al., 2017].

Modified atmosphere packaging reduces excessive water loss in artichoke heads during conventional cold storage and shelf life. Most of the available films modify extremely the atmosphere inside the package, due to the high artichoke respiration rate and low gas permeability's of films. In addition, low O<sub>2</sub> combined to high CO<sub>2</sub> levels promote internal blackening. [Gilet et al., 2003]. Concerning the respiration rate, it was noticed on broccoli that the spears packed in polypropylene and stored at 4°C and 13°C depressed O<sub>2</sub> and increased CO<sub>2</sub> inside the bags which depends to great extent on respiration rate, permeability of the used films and storage temperature [Tano et al., 2007].

Controlled atmosphere (CA) in artichokes has contributed positively to preserving the quality properties [Isemberg, 1979]. Atmospheres of 3–5% CO<sub>2</sub> may stimulate the growth of pappus on the receptacle, whereas treatments excluding carbon dioxide may increase internal violet coloration [Miccolis and Saltveit 1988]. Recently, artichokes have been packed in trays for protection of the heads from sensory quality deterioration. Water loss was dramatically reduced in artichokes kept in modified atmosphere packaging (MAP) compared to Control samples [Mencarelli et al., 1993]. Thus, MAP could be an efficient mean of extending the shelf life of artichokes and protecting the heads from mechanical damage. However, little is known about the effect of film selection on artichoke quality and the changes in its nutrient content. It has been reported that storage conditions and technological treatments applied to vegetables

During postharvest life lead to a marked effect on nutritional content and quality [Tomás- Barberán et al., 2000]. The protective effects of diets are rich in fruit and vegetables against cardiovascular diseases and certain cancers have been attributed partly to antioxidant vitamins such as vitamin E, C and carotenoids [Hirvonen et al., 2000 and Wargovich, 2000].

Thus, the aim of this work is to give spot light on the prolonging of storage ability and improve of quality by some postharvest tools such as plastic packaging and modified atmosphere packaging (MAP) on artichoke quality during storage at 4°C for five weeks.

## 2. MATERIALS AND METHODS

Artichoke flower heads of Balady cultivar “Cynara scolymus L.” were used in this investigation obtained from the plants were grown in Sakha Horticultural Research Station, Kafr El- Sheikh Governorate, Egypt during the season 2017. This work was performed to investigate the effect of packaging materials and modified atmosphere to improve storability of those heads during storage at 4°C. The head samples were harvested and transported within 2 hours from harvest to the food technology laboratory of Sakha Research Station, Kafr El-Sheikh Governorate, Egypt. They were cooled at 5°C for 24 hours after which the heads were placed in foil

dish (five per dish) and packed in two different packing film, (45x35cm) low density polyethylene (LDPE) and Polyester/ Polyethylene (PET/PE). Some foil dish were left without film and served as control treatment.

Then, the packed artichoke heads were randomly divided into three treatments. The first treatment saved as control samples without modified atmosphere. In the second treatment, samples were packaged in modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>) and the third treatments included samples packaged in modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>). Then the all stored at 4°C for 1, 2, 3, 4 and 5 weeks. All artichoke samples were represented in three replicates comprised 5 heads each. Three randomly selected packing of each treatment were devoted to study physical, chemical and bio changes before and after storage.

## 2.1 Packaging Sources

The used packing film samples were low density polyethylene (LDPE) and Polyester/ Polyethylene (PET/PE) packages. They were obtained from the Arabic medical packaging company (flex pack) Cairo, Egypt. Characteristic of different packing materials, physical and permeability properties are shown in (Table 1). Physical and chemical analyses were recorded at harvesting date (zero time) and after 1, 2, 3, 4 and 5 weeks.

### 2.1.1 Physical Changes included

Loss in weight percentage, unmarketable head percentage (decay) and visual quality.

### 2.1.2 Chemical and Biochemical Changes Comprised

Total soluble solids (TSS), ascorbic acid, total sugars and inulin.

## 3. DETERMINATION PROCEDURES

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

### 3.1 Weight Loss

The percentage of loss in weight was measured from the initial weight of fruits **A.O.A.C. (2000)**.

### 3.2 Unmarketable Percentage (Decay %)

The percentage of unmarketable examined heads were calculated from the following equation: Unmarketable heads (%) = Total number of unmarketable at the sampling date / the initial number of heads \*100

### 3.3 Visual Quality

The visual quality was determined according to the scale of scoring system (**Able et al., 2002**) as explained 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.

### 3.4 Total Soluble Solids (TSS)

The total soluble solids content of the fresh heads was measured according to the method outlined in **A.O.A.C. (2005)**.

### 3.5 Ascorbic acid (V.C)

The ascorbic acid was determined using 2, 6 dichlorophenol indophenoltitrimetic method as described in **A.O.A.C., (2000)**. The results were expressed in milligrams ascorbic acid per 100 ml of fresh heads juice.

### 3.6 Total Sugars

The total sugars content was determined at harvesting date (zero time) and after 1, 2, 3, 4 and 5 weeks from storage as g/100g dry weight, as reported by **Dubois et al. (1956)**.

### 3.7 Inulin Concentration

The inulin content was determined at harvesting date (zero time) and after 1, 2, 3, 4 and 5 weeks from storage according to **Winton and Winton, (1958)**.

### 3.8 Statistical Analysis

Data obtained from experimental treatments were subjected to the analysis of variance using the Costat Statistical and treatments means were compared using L.S.D. range test at 5 % level according to **Gomez and Gomez (1984)**.

**Table-3.1 Characteristics Of The Used Packaging Materials**

Packaging Materials	Thickness (um)	Heat sealing tem. (°C)	Printability	Permeability		
				Water vapor g/m <sup>2</sup> d	O <sub>2</sub> CC/m <sup>2</sup> d	CO <sub>2</sub> CC/m <sup>2</sup> d
LDPE	50	130	Poor	2.4	2110	4600
PET/PE	85	140	medium	1.8	97	494

LDPE: Low density poly ethylene, PET/PE: Polyester/Polyethylene

DOI Number: 10.30780/IJTRS.V3.I10.2018.013

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Paper Id: IJTRS-V3-I10-013

Volume 3 Issue X, November 2018

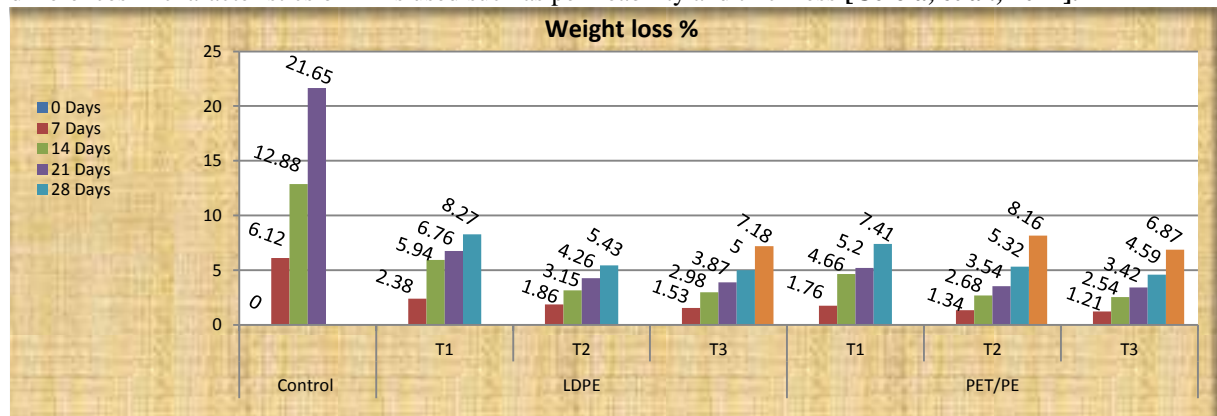
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## 4. RESULTS AND DISCUSSION

### 4.1 Physical Changes

#### 4.1.1 Weight Loss

The effect of types of packaging materials and modified atmosphere (MAP) on the heads weight loss percentage is presented in Fig. [4.1]. The results observed that a gradual loss in weight happened in heads with during storage periods up to 5 weeks in all treatments. The resulted data of different packaging materials were effective in reducing weight loss. Samples packed in LDPE and PET/PE had low weight loss as compared with those stored in the unpackaged ones (control). Such that samples stored in PET/PE had the lowest weight loss percentage with the longest storage period compared to those stored in LDPE. Those results may be due to differences in characteristics of films used such as permeability and thickness [Cefola, et al., 2012].



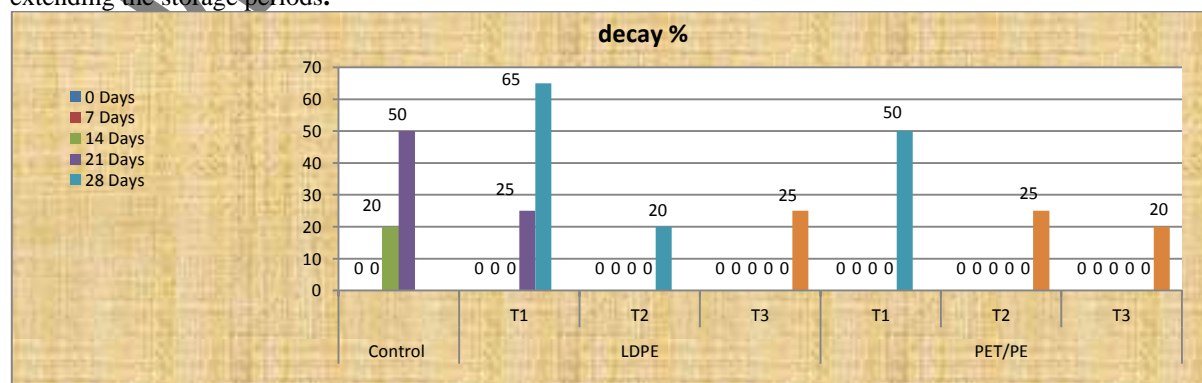
T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

**Fig. 4.1 The Effect Of Packaging Materials And Modified Atmosphere On The Loss Weight In Percentage Of Globe Artichoke Head During Storage At 4 °C**

Artichoke head packed under modified atmosphere (5%O<sub>2</sub>+10%CO<sub>2</sub>) had much better results in weight loss compared with samples packed under modified atmosphere (5%O<sub>2</sub>+5%CO<sub>2</sub>) while control samples had the highest weight loss during storage this may be related to the modification of atmosphere that reduced respiration rate which depends on the commodity. Gil, et al., (2003) showed that modified atmosphere packaging reduces excessive water loss in artichoke heads during conventional cold storage and shelf life.

#### 4.2 Decay Percentage

The effects of types of packing and modified atmosphere on the artichoke head unmarketable percentage are shown in Fig. [4.2] the general view of packing and modified atmosphere reflects an increase trend in the unmarketable percentage of the heads with the prolongation of the storage periods in all tested experiments. The results showed that artichoke head packed under modified atmosphere kept more preferable values by lowering the unmarketable heads than the other unmodified either in LDPE or PET/PE package. After 21 and 28 days of storage the % decay reached 25 and 65, respectively with T1 and 25, 20 with T2 & T3 after 35 days. Dealing packing, evidences caught from the trails showed that the heads stored in PET/PE exerted lower unmarketable percentage during storage at 4°C than those stored in the LDPE. From these results, it is evident that the heads stored in PET/PE with (5%O<sub>2</sub>+10%CO<sub>2</sub>) was the best in lowering the percentage of unmarketable heads and extending the storage periods.



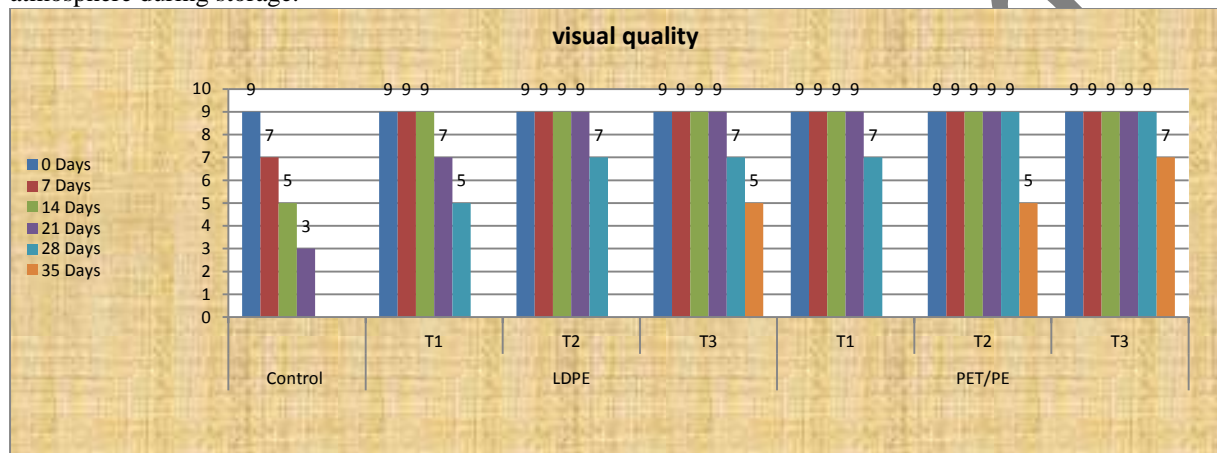
T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

**Fig. 4.2 The Effect of Packaging Materials And Modified Atmosphere On Decay Percentage Of Globe Head During Storage At 4°C**

Gil-Izquierdo et al.,[2002] showed that loss of water after harvest was the major cause for artichoke deterioration. The rate of transpiration was minimized by MAP, which reduced weight loss and avoided wilting and shriveling. Alexopoulos, [2003] showed 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 color of vegetables.

### 4.3 Visual Quality

The effects of packages types and modified atmosphere on the quality of artichoke head are clarified in Fig. [4.3]. Considerable attention to the data of packing presented that the packaging materials reserved better visual qualities during storage than the other one of unpackaged (control) either under modified atmosphere or unmodified. Samples packed in PET/PE had high quality than those packed in LDPE under modified atmosphere (5%O<sub>2</sub>+10%CO<sub>2</sub>). Poor visual quality 3 was observed after 28 days with T1 (without modified atmosphere) of LDPE and T2 (under modified atmosphere 5% O<sub>2</sub>+ 5% CO<sub>2</sub>) of PET/PE, except that the all treatments achieved visual quality between 5-9. From another point of view, the results observed that samples packed under modified atmosphere and stored had better visual quality than those stored without modified atmosphere during storage.



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).T1:control samples without modified atmosphere,T2:samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

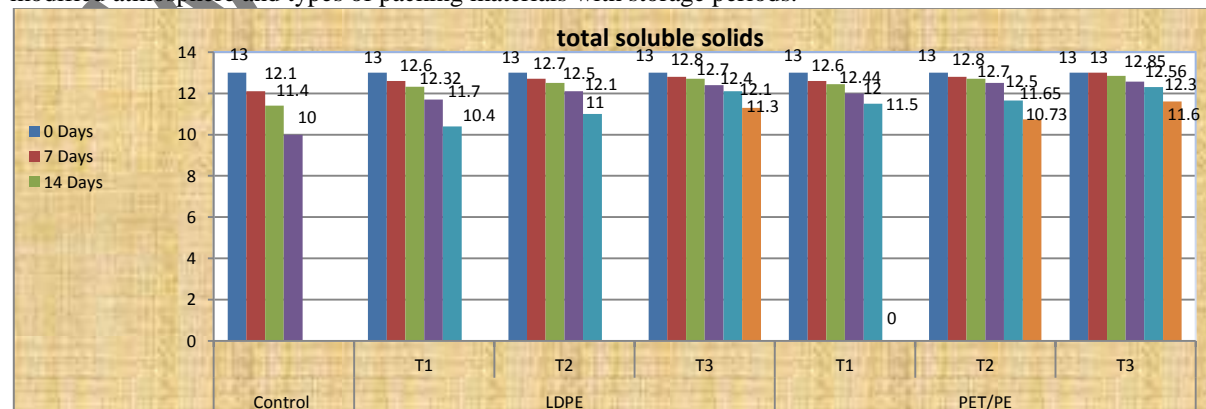
**Fig. 4.3 The Effect Of Packaging Materials And Modified Atmosphere On The Visual Quality Of Globe Artichoke Head During Storage At 4°C.**

Gil-Izquierdo et al., (2002) showed that the higher water losses were detected of artichoke packed in PVC samples due to the higher water vapor permeability of these films and found that external visual quality of artichoke decreased considerably throughout the storage period.

## 5. CHEMICAL AND BIOCHEMICAL CHANGES

### 5.1 Total Soluble Solids

The effect of types of packaging materials and modified atmosphere (MAP) on the T.S.S. artichoke head is illustrated in Figure [5.1]. A general gradual decline trend occurred in these contents due to package under modified atmosphere and types of packing materials with storage periods.



T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

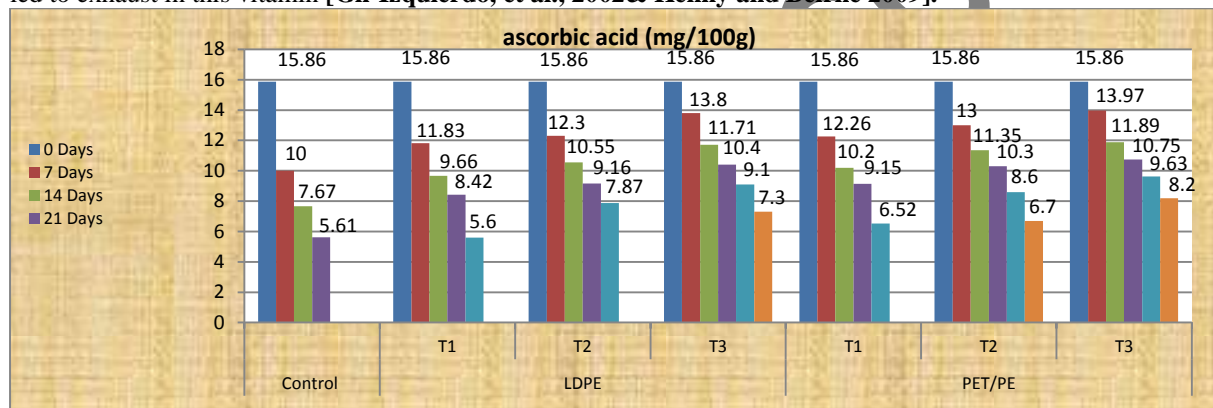
**Fig. 5.1The Effect Of Packaging Materials And Modified Atmosphere On The Total Soluble Solids Percentage Of Globe Artichoke Head During Storage At 4°C.**

The results were in favor of packaging materials which hold higher concentrations of T.S.S. in the heads than the other unpacked (control) with modified or unmodified. The highest value of T.S.S was observed in artichoke head packed in PET/PE. On the other hand, artichoke head stored without package (control) showed the lowest value of T.S.S throughout the storage period. Furthermore, it is clear that the heads stored under modified atmosphere had more high concentrations of T.S.S. comparatively with those stored without modified during storage. The data showed that a continuous gradual decrease happened in heads T.S.S. with extend of the storage periods to 5 weeks in all the treatments.

The view of the data of modified atmosphere and packing types reflected that the heads stored in LDPE or PET/PE surpassed those stored without packing ones in retention the maximum concentrations of T.S.S 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 [Cefola, et al., 2012].

### 5.2 Ascorbic Acid

Fig. [5.2] shows the effect of packing under modified atmosphere and types of packing on ascorbic acid content of artichoke head during storage at 4°C. The results observed that samples packed in LDPE and PET/PE hold higher concentrations of ascorbic acid in comparison with control ones. On the other hand, samples stored under modified atmosphere had higher ascorbic acid content than control ones (without modified) during storage periods. Nevertheless, the degradation in artichoke head ascorbic acid content during storage may be due to the fact 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 [Gil-Izquierdo, et al., 2002& Kenny and Beirne 2009].

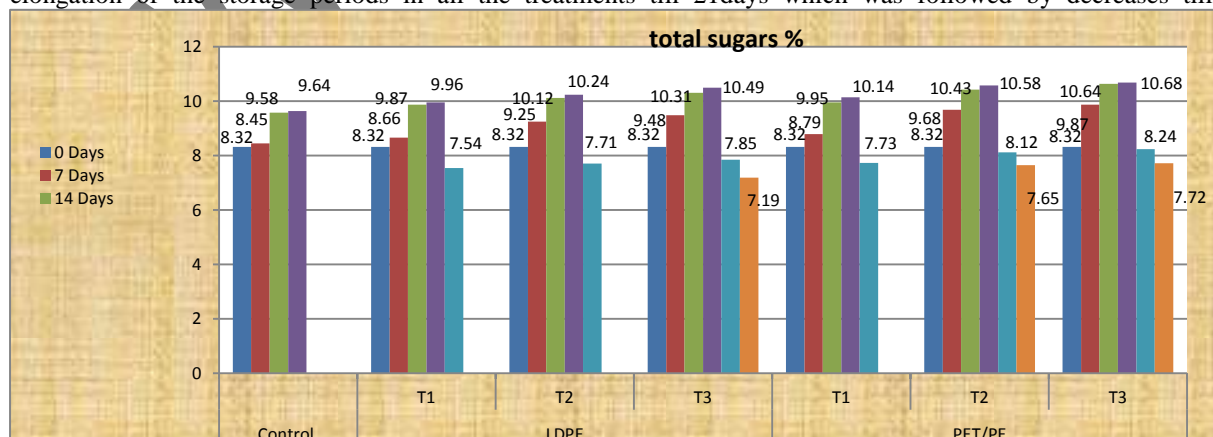


T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

**Fig. 5.2 The Effect Of Packaging Materials And Modified Atmosphere On The Ascorbic Acid (Mg/100g) Of Globe Artichoke Head During Storage At 4°C.**

### 5.3 Total Sugars

Fig. [5.3] shows the effect of packing under modified atmosphere and types of packing on total sugars content of artichoke heads during storage at 4°C. The results observed that total sugars content increased with the elongation of the storage periods in all the treatments till 21 days which was followed by decreases till



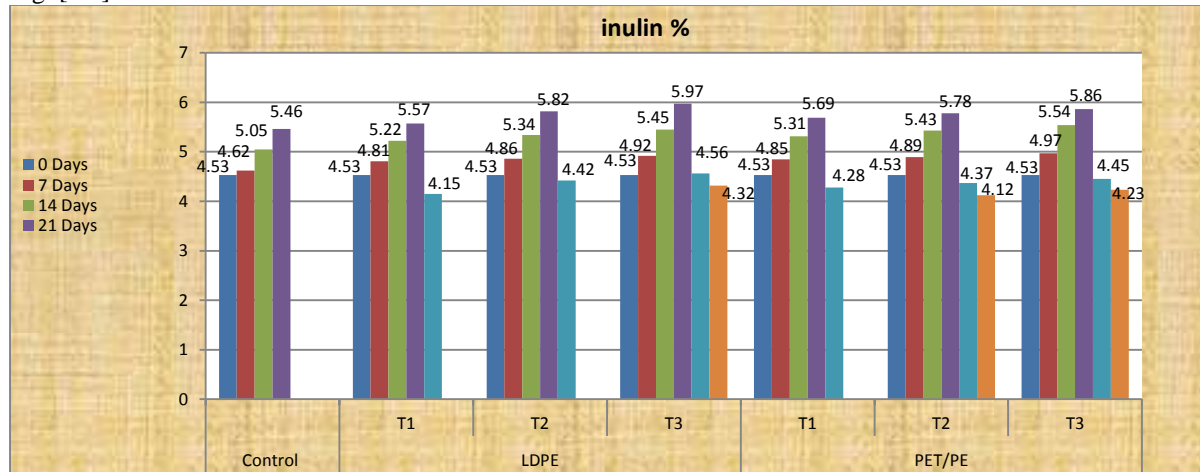
T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

**Fig. 5.3 The Effect Of Packaging Materials And Modified Atmosphere On The Total Sugar (%) Of Globe Artichoke Head During Storage At 4°C.**

the last storage period at 35 days. However, the resulted figures of cold storage exhibited more total sugars concentration in the heads packed in LDPE and PET/PE in comparison with those unpacked (control) either in modified atmosphere or unmodified. Dealing with modified atmosphere, the obtained data indicate that the heads stored in modified atmosphere kept more total sugars than those stored in the unmodified ones during storage.

#### 5.4 Inulin

The inulin content of the artichoke heads as affected by types of packages and modified atmosphere is shown in Fig. [5.4].



T1: control samples without modified atmosphere, T2: samples packaged under modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged under modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>).

**Fig. 5.4 The Effect Of Packaging Materials And Modified Atmosphere On The Inulin (%) Of Globe Artichoke Head During Storage At 4 °C.**

The results indicate that there was a progressive increase in the head inulin content in all tested treatments during the first 21 days storage after which a drop happened till the last 35days of storage. However, the results observed that modified atmosphere packaging show that packed artichoke heads were more pronounced in retarding the degradation of inulin content than heads packed without modified atmosphere in both LDPE and PET/PE packing. Also, inulin content of samples packed was higher than without packed samples. The view of the data of modified atmosphere and packing types reflected that the heads stored in LDPE or PET/PE surpassed those stored without packing ones in retention the maximum concentrations of the contents of T.S.S, total sugars, inulin, 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 [Cefola, et al., 2012]. On the other hand, [Pramanik, et al., 2004] showed that total sugars and inulin 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.

#### 5.5 Analysis Of Variance:

Summarization the results of the analysis of variance and mean values of loss in weight, decay, total soluble solids, ascorbic acid, visual quality, total sugars and inulin of globe artichoke head during storage at 4°C as affected by packaging materials, modified atmosphere and period of storage are shown in Table [5.1].

**Table-5.1 Effect Of Packaging Materials And Modified Atmosphere On The Loss In Weight, Decay, Total Soluble Solids, Ascorbic Acid, Visual Quality, Total Sugars And Inulin Of Globe Artichoke Head During Storage At 4°C.**

Characteristics Treatment	Weight Loss (%)	Decay (%)	TSS (%)	V.C (mg/100 g sample)	visual quality	Total sugar (%)	Inulin (g/100g)
packaging materials (P)	3.95	12.26	12.11	10.49	7.11	8.83	4.86
LDPE	3.68	8.04	12.34	10.92	7.89	9.10	4.87
PET/PE	**	**	**	**	**	**	**
Sig	0.1543	0.1216	0.0066	0.0074	0.0036	0.0063	0.0010
L S D (0.05)							

<b>modified atmosphere (M)</b>	4.74	21.25	12.04	9.79	6.67	8.71	4.78
<b>T1</b>	3.44	5.44	12.14	10.78	7.50	9.01	4.78
<b>T2</b>	3.27	3.75	12.48	11.54	8.33	9.10	4.94
<b>T3</b>	**	**	**	**	**	**	**
<b>Sig</b>	0.1788	0.0668	0.0098	0.0109	0.0166	0.0113	0.0182
<b>L S D (0.05)</b>							
<b>storage period (days) (S)</b>	0.00	0.00	13.00	15.86	9.00	8.32	4.53
<b>0</b>	1.68	0.00	12.75	12.87	9.00	9.28	4.88
<b>7</b>	3.66	0.00	12.58	10.89	8.67	10.22	5.38
<b>14</b>	4.51	4.17	12.21	9.70	7.66	10.35	5.78
<b>21</b>	6.00	22.5	11.49	7.89	6.00	7.87	4.37
<b>28</b>	7.02	34.22	11.25	7.03	4.68	7.59	4.25
<b>35</b>	**	**	**	**	**	**	**
<b>Sig</b>	0.271	0.0842	0.0323	0.0365	0.0449	0.0371	0.0515
<b>L S D (0.05)</b>							
<b>Interaction between treatments</b>							
<b>M*P</b>	**	**	**	**	**	**	**
<b>M*S</b>	**	**	**	**	**	**	**
<b>P*S</b>	**	**	**	**	**	**	**
<b>M*P*S</b>	**	**	**	**	**	**	**

P > 0.05 non-significant, P < 0.05 Significant, T1: control samples without modified atmosphere, T2: samples packaged in modified atmosphere (5% O<sub>2</sub>+5% CO<sub>2</sub>), T3: samples packaged in modified atmosphere (5% O<sub>2</sub>+10% CO<sub>2</sub>)

It is cleared that the period of storage had the highest significant effects on the percentage of weight loss, decay, total soluble solids, ascorbic acid, visual quality, total sugars and inulin of globe artichoke head stored in 4°C. Meanwhile, Gradual continuous loss in weight happened in artichoke head with extend of the storage periods to 5 weeks in all treatments, it was noted that there was a sharp increase in the following 3 weeks (from 3 to 5 weeks). Interestingly, it was noted that there was none increase in decay % from 0 to 14 days, but happened sharp increase in the following 3 weeks (from 21 to 35 days). Also, it is noticed that total soluble solids, ascorbic acid and visual quality of globe artichoke head decreased by increasing storage periods to the end of storage period. On the other hand, total sugars and inulin of globe artichoke head increased by increasing storage periods even 3 weeks and gradually decreased to the end of storage period in all treatment.

As a general trend during cold storage at 4°C, there was continuous increase in loss in weight, more appearance of unmarketable heads, reduction in the visual qualities and more degradation in Total soluble solids, ascorbic acid with the prolongation of the storage periods. Moreover, it is well known that all the fresh vegetable crops including globe artichoke consist of high water content which during storage are subjected to desiccation that lead to wilting and shriveling [Kader AA (2011)].

It is clear from the obtained results of cold storage that the heads stored in different packages and modified atmosphere at 4°C exhibited better results regarding the physical and chemical characteristics during all the storage periods than those stored without packaging materials (control). Thus, using different packages and modified atmosphere was the best in minimizing head loss in weight, unmarketable percentage, changes in the visual qualities, Total soluble solids (T.S.S), ascorbic acid, total sugars and inulin at all the storage periods than control.

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 qualities [Kader, 1992; Passam et al., 1999 and Alexopoulos, et al., 2003]. In addition to more inhibition of a wide range of plant pathogens [Yahia 2007]. 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 [Vallejo et al., 2003].

For the packaging materials effect, data in table [2] included that the packaging type had the highest significant effects for weight loss, decay, total soluble solids, ascorbic acid, visual quality, total sugars and inulin of globe artichoke head stored in 4°C. Low density polyethylene recorded the highest value for weight loss and decay percentage (3.95 and 12.26), respectively. While, artichoke head packaged in PET/PE recorded highest for total soluble solids, ascorbic acid, visual quality, total sugars and inulin.

The two – way interactions of (M\*P), (M\*S), (P\*S) and the three- way interactions of (M\*P\*S) were highly significant for weight loss, decay, total soluble solids, ascorbic acid, visual quality, total sugars and inulin of globe artichoke head. This indicated that the effect of modified atmosphere depends on type of packaging material and also on the period of storage.



## CONCLUSION

As recommendations for the present work there are two points.

- Recommended on using PET/PE package which the most suitable and effective is for enhance the quality of globe artichoke head during storage than LDPE package.
- Packaging under modified atmosphere especially (5% O<sub>2</sub>+10%CO<sub>2</sub>) in PET/PE package was the most effective in extending the shelf life of globe artichoke and maintaining the highest nutritional contents.

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