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EFFECT OF SOME POST HARVEST TREATMENTS ON QUALITY OF FRESH GARLIC

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Abstract

This investigation was carried out to evaluate the effect of different wrapping with LifeSpan sheet lining and Polypropylene sheet lining and coating with Chitosan at 0.5% as a post-harvest treatments at 3 plant ages (18, 20 and 22 weeks from planting date) on keeping quality of minimally processed green garlic during cold storage at 0±1 ºC. The used cultivar is "Balady" which favorite for exporting at immature stages. Weight loss of minimally processed green garlic bulbs, visual quality, TSS (%), total sugars content and total pungency content increased significantly with the progress of plant age, independently from the different post-harvest treatments. Garlic bulb at the age of 20 and 22 weeks in LifeSpan sheet lining can be stored at 0±1 ºC and 90-95 % RH for 4 weeks, with reduce weight loss, hold more TSS, total sugar and total pungency and maintained high visual quality.

Key words : Green garlic, minimally processed, Wrapping, Coating, LifeSpan sheet, Polypropylene sheet, Chitosan, Cold storage.

Introduction

Garlic (*Allium sativum* L.) is one of the oldest known plants in Egypt where, it was found on Pharaonic temples. Garlic is a bulb crop belonging to the family *Alliaceae*. It is the second most widely cultivated crop in the family after onion (*Allium cepa*) (Hamma *et al.,* 2013).

Strong flavored, garlic cloves contain many useful and unique phytonutrients, minerals, vitamins, and antioxidants to health. Studies revealed that consumption of garlic decreases incidence of cancer stomach. Allicin and other essential volatile compounds also found to have antibacterial, antiviral, and anti-fungal activities (Borek, 2006). Garlic is an excellent source of minerals e.g. potassium, iron, calcium, magnesium, manganese, zinc, and selenium. Selenium and manganese are essential cofactors for antioxidant enzymes. It contains many flavonoid antioxidants e.g. β - carotene and vitamins e.g. vitamin-C (Chiavarini *et al.,* 2016).

Egypt ranks the fifth leading country in the world for garlic production (263.167 MT) after China, India, Korea and Bangladesh (FAO, 2014). The governorate of Minya (El Adwa, Magagah and Beni-Mazar) in Egypt is one of the most important export areas of green garlic. Some Arab and European countries import garlic "Balady" cultivar (white crust) from Egypt which is immature (green) during February and early March (the head diameter should be >4 cm with no punctuation marks on the outer surface of the head and 12-14 cm for neck length) to be exported in the appropriate packaging. Farmers select the large plants for export in Feb; however, there is a risk as it is not suitable for storage leading to a great loss.

There are a great interest in marketing value-added, minimally processed vegetables, where there are many limitations to shelf life of these products due to undesirable physiological changes caused by the minimal processing (Ohlsson, 1994).

An interesting challenge facing green garlic when minimally process, where green garlic are comprised of roots and stem. Leaves, which consist of a white leaf sheath and the upper green tissues. Minimal processing includes the trimming of the leaves, the cutting of the

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roots, and remove a part of the compressed stem. Discoloration, dehydration, and decay are common defects of the cut surfaces. Additional defects, due to growth or extension of the white inner leaf bases may occur, and can cause a rapid loss garlic quality during marketing (Ahvenainen, 1996). Another defect particular to green garlics is leaf curvature due to negative geotropism, which occurs when the plants are placed horizontally. At 0°C, modified atmospheres are needed to extend the shelf life of green garlics and reduce yellowing, curvature and decay incidence (Hong *et al*, 2000).

The balance concentrations of O_2 and CO_2 in modified atmosphere packaging (MAP) including LifeSpan sheet are a function of the plant weight and its respiration rate, which is affected by temperature and the surface area, perforations, thickness and permeability to gases of films used in packaging. The correct balance of the atmosphere inside the packaging can lead to delay respiration, senescence, and slow down the rate of deterioration, thereby extending plant storage life (Caleb, 2013).

The application of edible coatings on fresh products provides a partial barrier to the movement of moisture on the surface of fresh products, thereby minimizing loss during storage after harvest. It also provides a gas barrier and thus creates a modified atmosphere around the product, which slows down respiration, senescence and enzymatic oxidation. Moreover, it preserves color and texture, helps to retain volatile compounds contributing to produce a natural aroma and restrict foreign odours; maintain plant freshness, and protects against mechanical damage, and acts as a carrier of active compounds, such as nutrients, flavouring and coloring agents, antioxidants and antimicrobial agents, leading to improved plant safety and quality (Dhall, 2013).

This study was carried out to evaluate the effect of different wrapping with Life Span sheet lining and Polypropylene sheet lining and edible coating with Chitosan at 0.5% as a post harvest treatments at 3 plant ages (18, 20 and 22 weeks from planting date) on keeping quality of minimally processed green garlic during cold storage at 0±1ºC. The used cultivar is "Balady" which favorite for exporting at immature stages.

Materials and Methods

This investigation was carried out during the two successive seasons of 2015-16 and 2016-17 on green garlic cultivar in the private farm at El-Burg Village, Naser (Bush), Beni-Suef Governorate, and Horticulture Research Institute, Vegetable Handling Research Department, Giza, Egypt.

Post harvest treatments

At ages of 18, 20 and 22 weeks from planting, after trimming (Roots cut off, no punctuation marks on the outer surface of the head and cut of the garlic with a neck length of 12-14 cm), only healthy bulbs (uniform in size, weight, color) and free from any visible defects were selected. The experiment included four treatments as follow:

- LifeSpan sheet lining.
- Polypropylene lining
- Chitosan 0.5%
- Control.

Bulbs were packed in carton boxes and lined with LifeSpan or Polypropylene sheet (50±5 μ m. in thickness), in a single layer, then stored at 0±1 °C and 90:95% RH up to 4 weeks.

Polypropylene lining sheet

Sheet material was coated with a natural mineral which was impregnated into low density polypropylene resin to produce a packaging film. The impregnated mineral is hydroscopic and has known absorptive characteristics *e.g.* remove ethylene gas as well as anti-fog treatment to reduce water formation.

LifeSpan lining sheet

Sheet material (polyamide materials) are blends of polyamide and grafted polyethylene. LifeSpan sheet technology can manipulate perm selectivity, which is the selective permeation of sheet materials to various gases. Through coating, micro perforation, or polymer blending, perm selectivity can be manipulated to modify the atmospheric concentration of gaseous compounds inside a package, relative to the oxidation or respiration kinetics of plant material and complies with food contact EC regulation No. 10/2011.

Garlic bulbs quality parameters

Three replicates were taken for each treatment weekly and examined as the following:

1. Physical characteristics

a. Weight loss percentage: It was expressed as percentage of weight loss relative to the initial weight as described by Lemoine *et al*., (2009).

Weight loss % = [(A – B) / A]*100

Where: A = the initial weight

B = Weight at inspect date

[1]Source. Food Processing and Packaging Research Department, Food Technology Research Institute (FTRI),

ARC, Egypt.

[2] Source. Amcor Flexibles (Australia) Pty Ltd, Australia.

b. Visual quality (Score): Overall visual quality was scored on a 9–1 scale, with reference points of 9, excellent; 7, good; 5, fair; 3, poor; and 1, unusable as described by Hong *et al.,* (2000). A score of 6 was regarded as the limit of marketability. The visual quality assessment included discoloration and curvature defects and extension defects in the minimally processed garlics.

2. Chemical characteristics

a. Total soluble solids percentage (TSS %): It was estimated by a'bbe digital refractometer, according to A.O.A.C., 1990.

c. Total sugars content (g/100 g dry weight): In ethanol, determination of total sugars was carried out by using the sulphuric acid method according to Dubois *et al*., (1956).

A standard curve was carried out using pure glucose with a suitable concentration. The total sugars was calculated and expressed as g / 100 g dry weight.

d. Total pungency (µ mol pyruvic acid/ 100 gm fresh weight): Total pungency determined by measuring of pyruvate concentration according to the method of described by Schwimmer and Weston (1961), and Wall and Corgan (1992). The total pungency was calculated and expressed as µ mol pyruvic acid/ 100 gm fresh weight.

3. Statistical analysis procedure: The experiment was conducted using a completely randomized design with three replicates. Data from the analytical determinations were subjected to analysis of variance (ANOVA) (Snedecor and Cochran, 1989) using MSTAT-C statistical software, Michigan State University. Mean comparisons were performed by Duncan's multiple range test at $p \geq 0.05$ level (Duncan, 1955).

Results and Discussion

Physical characteristics

Weight loss percentage (%)

As shown in Table 1, weight loss percentage of garlic bulbs was significantly affected by the post harvest treatments and storage period. The highest weight loss percentage was recorded by control treatment during all storage period in both studied seasons. The lowest significant weight loss values were recorded with LifeSpan sheet lining and Polypropylene lining, in comparison to coating treatment with 0.5% chitosan. This effect of wrapping and coating treatments started to be already evident after 1 week of cold storage. Untreated bulbs recorded the highest loss of weight after 4 weeks of storage in both seasons.

Weight loss of garlic bulbs during storage decreased with the advancing plant age. Garlic bulbs at age of 22 weeks after planting exhibited the least significant loss during the various storage period. Weight loss after harvesting time is caused by physiological process like respiration and transpiration process.

Regarding the interaction between the used post harvest treatments and plant age of green garlic cv. "Balady" data indicated that, LifeSpan sheet lining was the best treatment for maintaining weight loss for all plant age of green garlic during all storage period. Garlic bulb of age 22 weeks after planting date with LifeSpan sheet lining recorded the lowest significant weight loss values followed by Polypropylene lining and coating treatment with 0.5% chitosan during all storage period in both studied seasons.

Results obtained with LifeSpan sheet lining and Polypropylene lining are in accordance with those obtained by Lin (1993), Suparlan and Itoh (2003) and Pereira *et al*., (2006). They indicated that, a self-generated modified atmosphere within the sealed package could extend the storage life of green garlic. Furthermore, the use of polymeric films in MAP serves as mechanical barrier to the movement of water vapor and this helps to maintain a high level of Relative humidity within the package, and reduce weight loss. The package with plastic film favors a lower transpiration rate of garlic bulbs and consequently lower rate of water loss to the environment. A minimal loss in weight for MAP packages due to their ability to minimize weight loss by retarding respiration and transpiration rates (Singh *et al.,* 2009).

In addition, Mshraky *et al*., (2017) evaluated effects of imported smart packaging (LifeSpan™ bags) under passive modified atmosphere / modified humidity bags. They found that, LifeSpan™ was the best treatment for maintaining weight loss followed by un-perforated polypropylene bags.

Results obtained with chitosan applications are in accordance with Shehata *et al.,* (2012). They indicated that chitosan coating treatments recorded least loss of weight. The effect of chitosan on garlic bulbs storability may be due to the positive effect of chitosan coatings effect that extend the storage through the reduction of respiration rate and water loss.

A semi permeable film on the fruit surface could be formed by the chitosan, consequently modifying the internal atmosphere of the fruit with limited gas exchange due to the coating barrier, enzymatic activity and

Table 1: Effect of plant age and post harvest treatments during storage at 0±1°C and 90-95% RH on weight loss (%) of garlic bulb cv. "Balady" in 2015-2016 and 2016-2017 seasons.

Plant age (week)	Post harvest treatments	Cold storage period (week)																	
		Initial	1		2		3		4		Initial	1		2		3		4	
		2015-2016 Season									2016-2017 Season								
18	LifeSpan	0.00	1.96	e	2.29	g	3.27	e	4.84	e	0.00	1.86	e	2.35	e	3.51	e	4.79	f
	Polypropylene	0.00	2.31	d	3.06	de	4.28	c	5.04	e	0.00	2.26	d	3.20	c	4.32	cd	5.14	e
	Chitosan 0.5%	0.00	3.22	b	3.90	b	5.60	a	6.54	b	0.00	3.02	b	3.87	a	5.63	a	6.49	b
	Control	0.00	3.96	a	4.26	a	5.71	a	7.01	a	0.00	3.60	a	4.07	a	5.76	ab	7.12	a
	Mean	0.00	2.86	A	3.38	A	4.71	A	5.86	A	0.00	2.68	A	3.37	A	4.81	A	5.88	A
20	LifeSpan	0.00	1.67	f	1.95	h	2.78	f	4.11	g	0.00	1.58	f	1.99	f	2.99	ef	4.07	h
	Polypropylene	0.00	1.94	e	2.57	fg	3.59	de	4.23	g	0.00	1.90	e	2.69	d	3.63	de	4.32	gh
	Chitosan 0.5%	0.00	2.77	c	3.35	cd	4.82	b	5.62	d	0.00	2.60	c	3.33	bc	4.84	bc	5.58	d
	Control	0.00	3.40	b	3.66	bc	4.91	b	6.03	c	0.00	3.09	b	3.50	b	4.95	abc	6.12	c
	Mean	0.00	2.45	B	2.88	B	4.02	B	5.00	B	0.00	2.29	B	2.88	B	4.10	B	5.02	B
22	LifeSpan	0.00	1.22	g	1.42	i	2.03	g	3.00	h	0.00	1.15	g	1.46	g	2.18	g	2.97	i
	Polypropylene	0.00	1.44	fg	1.90	h	2.66	f	3.13	h	0.00	1.40	f	1.99	f	2.69	fg	3.20	i
	Chitosan 0.5%	0.00	2.07	e	2.51	fg	3.61	de	4.22	g	0.00	1.95	e	2.50	de	3.63	de	4.18	h
	Control	0.00	2.55	c	2.75	ef	3.68	d	4.52	f	0.00	2.32	d	2.63	d	3.71	de	4.59	fg
	Mean	0.00	1.82	C	2.15	C	3.00	C	3.72	C	0.00	1.71	C	2.14	C	3.05	C	3.74	C
Mean	LifeSpan	0.00	1.62	D	1.89	D	2.69	C	3.98	C	0.00	1.53	D	1.93	D	2.89	C	3.94	D
	Polypropylene	0.00	1.90	C	2.51	C	3.51	B	4.14	C	0.00	1.85	C	2.63	C	3.55	B	4.22	C
	Chitosan 0.5%	0.00	2.69	B	3.25	B	4.68	A	5.46	B	0.00	2.52	B	3.23	B	4.70	A	5.42	B
	Control	0.00	3.30	A	3.55	A	4.77	A	5.85	A	0.00	3.00	A	3.40	A	4.81	A	5.94	A

Values followed by the same latter (s) in each column (storage period) are not significantly different at p e" 0.05 level.

metabolism-involving respiration can be thus affected, there by resulting in lower weight loss (Raymond *et al.*, 2012).

Visual quality (Score)

Visual quality score of Garlic bulb decreased as the storage period increased (Table 2). All post harvest treatments succeeded to maintain visual quality of Garlic bulb in both seasons, compared with untreated fruits. Moreover, no significant difference was observed in mean values among the various treatments until the end of the 1st week of storage period. Starting from the 2nd week of cold storage, Lifespan sheet lining treatment recorded the highest significant score values of visual quality up to the end of storage period in both seasons. Coating treatment with 0.5 % chitosan showed to be superior in maintain visual quality of Garlic bulb comparing to Polypropylene lining garlic bulbs.

Overall visual quality of garlic bulbs at the age of 18 weeks decreases significantly faster than the garlic bulbs at ages of 20 and 22 weeks from the date of cultivation during cold storage and with the advancing of storage period. Garlic bulbs at age of 22 and 20 weeks from the date of cultivation exhibited the highest significant visual quality score during the various storage period with no significant differences between them.

Regarding the interaction between the used post harvest treatments and plant age of green garlic cv. "Balady" data indicated that, LifeSpan sheet lining was the best treatment for maintaining visual quality score for all plant age of green garlic during all storage period. During all storage period in both seasons, garlic bulb of age 22 weeks after planting date with

Table 2: Effect of plant age and post harvest treatments during storage at 0°±1C and 90-95% RH on visual quality (Score) of garlic bulb cv. "Balady" in 2015-2016 and 2016-2017 seasons.

Plant age (week)	Post harvest treatments	Cold storage period (week)																	
		Initial	1		2		3		4		Initial	1		2		3		4	
		2015-2016 Season									2016-2017 Season								
18	LifeSpan	9.00	9.00	a	9.00	a	8.36	bcd	8.36	ab	9.00	9.00	a	9.00	a	8.47	abc	8.11	ab
	Polypropylene	9.00	9.00	a	8.47	c	7.95	def	7.22	c	9.00	9.00	a	8.11	d	7.92	cd	7.25	c
	Chitosan 0.5%	9.00	9.00	a	8.62	bc	8.11	cde	7.36	c	9.00	9.00	a	8.22	cd	8.11	bc	7.44	bc
	Control	9.00	7.67	c	7.11	e	6.67	G	5.11	d	9.00	7.78	c	6.92	f	6.33	f	5.44	e
	Mean	9.00	8.67	B	8.30	B	7.77	B	7.01	B	9.00	8.69	A	8.06	C	7.71	B	7.06	B
20	LifeSpan	9.00	9.00	a	9.00	a	8.92	Ab	8.55	ab	9.00	9.00	a	9.00	a	8.70	ab	8.25	ab
	Polypropylene	9.00	9.00	a	8.84	ab	8.47	a-d	8.03	b	9.00	9.00	a	8.47	bc	8.03	bcd	7.89	abc
	Chitosan 0.5%	9.00	9.00	a	8.92	a	8.62	abc	8.22	ab	9.00	9.00	a	8.76	ab	7.92	cd	7.78	abc
	Control	9.00	8.22	b	7.84	d	7.44	F	7.11	c	9.00	8.11	b	7.33	e	6.92	ef	6.11	de
	Mean	9.00	8.81	A	8.65	A	8.36	A	7.98	A	9.00	8.78	A	8.39	B	7.89	B	7.51	A
22	LifeSpan	9.00	9.00	a	9.00	a	9.00	A	8.78	a	9.00	9.00	a	9.00	a	8.92	a	8.59	a
	Polypropylene	9.00	9.00	a	8.92	a	8.62	abc	8.44	ab	9.00	9.00	a	8.76	ab	8.36	abc	8.11	ab
	Chitosan 0.5%	9.00	9.00	a	9.00	a	8.78	ab	8.25	ab	9.00	8.92	a	8.84	a	8.62	abc	7.78	abc
	Control	9.00	8.25	b	7.92	d	7.62	ef	7.22	c	9.00	8.22	b	7.92	d	7.33	de	6.33	d
	Mean	9.00	8.81	A	8.71	A	8.50	A	8.17	A	9.00	8.79	A	8.63	A	8.31	A	7.70	A
Mean	LifeSpan	9.00	9.00	A	9.00	A	8.76	A	8.56	A	9.00	9.00	A	9.00	A	8.70	A	8.32	A
	Polypropylene	9.00	9.00	A	8.74	B	8.35	B	7.90	B	9.00	9.00	A	8.45	B	8.10	B	7.75	B
	Chitosan 0.5%	9.00	9.00	A	8.85	B	8.50	AB	7.95	B	9.00	8.97	A	8.61	B	8.22	B	7.67	B
	Control	9.00	8.05	B	7.62	C	7.24	C	6.48	C	9.00	8.04	B	7.39	C	6.86	C	5.96	C

Values followed by the same latter (s) in each column (storage period) are not significantly different at p e" 0.05 level.

LifeSpan sheet lining recorded the highest significant visual quality score in comparing with the control treatment followed by coating treatment with 0.5% chitosan and Polypropylene lining with no significant differences between all post harvest treatments.

Results obtained with modified atmosphere (MA) are in line with Gorny (2003) and Cantwell *et al*., (2003). They reported that modified atmosphere help maintaining quality by inhibiting metabolic activity and especially, ethylene biosynthesis and action. Moreover, CO_2 containing atmospheres reduced the change in visual quality of garlic during storage, especially sprout growth and discoloration, but the low O_2 atmospheres alone generally had little benefit.

Additionally, for the minimally processed green onions, the high CO_2 atmospheres was the most effective combination in reduction of normal respiratory activities, maintaining quality and retarding any appearance of yellowing at the cut surface (Kays, 1991 and Hong *et al*., 2000).

Results obtained with chitosan applications are in accordance with Fard *et al.,* (2010) and Raymond *et al.* (2012) on sweet pepper fruits and Ahmed (2015) on garlic bulbs. They found that, chitosan treatments reduced decay and sprouting percentages of garlic bulbs during storage periods. These results may be due to the stimulatory effect of chitosan on growth parameters, which may be reflected on quality and storability of garlic bulbs during storage. Chitosan coating delayed the deterioration as judged by the external appearance.

Moreover, as chitosan can form an edible film when applied to the surface of fruit and vegetables. It

Table 3: Effect of plant age and post harvest treatments during storage at 0±1°C and 90-95% RH on TSS (%) of garlic bulb cv. "Balady" in 2015-2016 and 2016-2017 seasons.

Plant age (week)	Post harvest treatments	Cold storage period (week)									
		Initial	1	2	3	4	Initial	1	2	3	4
		2015-2016 Season					2016-2017 Season				
18	LifeSpan	16.90 c	16.73 f	16.22 g	15.97 d	15.88 e	16.95 c	16.78 e	16.27 g	16.01 d	15.93 d
	Polypropylene	16.90 c	16.64 f	16.05 g	15.71 d	15.80 e	16.95 c	16.69 e	16.10 g	15.76 d	15.85 d
	Chitosan 0.5%	16.90 c	16.39 f	15.88 g	15.63 d	15.71 e	16.95 c	16.44 e	15.93 g	15.68 d	15.76 d
	Control	16.90 c	15.21 g	14.87 h	15.12 e	16.05 e	16.95 c	15.25 f	14.91 h	15.17 e	16.10 d
	Mean	16.90 C	16.24 C	15.75 C	15.61 C	15.86 C	16.95 C	16.29 C	15.80 C	15.65 C	15.91 C
20	LifeSpan	19.59 b	19.19 bcd	18.77 bc	17.65 b	17.73 d	19.88 b	19.48 bcd	19.05 cd	18.02 b	17.99 c
	Polypropylene	19.59 b	19.00 cde	18.44 cde	17.57 b	18.02 bcd	19.88 b	19.28 cd	18.72 cde	17.93 b	18.29 bc
	Chitosan 0.5%	19.59 b	18.79 de	18.05 ef	17.55 b	18.00 bcd	19.88 b	19.07 d	18.32 e	17.91 b	18.27 bc
	Control	19.59 b	18.67 e	17.56 f	16.54 c	17.83 cd	19.88 b	18.95 d	17.82 f	16.88 c	18.09 c
	Mean	19.59 B	18.91 B	18.21 B	17.33 B	17.89 B	19.88 B	19.20 B	18.48 B	17.68 B	18.16 B
22	LifeSpan	20.27 a	19.86 A	19.42 a	18.63 a	18.34 abc	20.80 a	20.39 a	19.94 a	18.91 a	18.83 ab
	Polypropylene	20.27 a	19.66 ab	19.08 ab	18.53 a	18.65 a	20.80 a	20.18 a	19.59 ab	18.81 a	19.14 a
	Chitosan 0.5%	20.27 a	19.44 abc	18.68 bcd	18.52 a	18.63 a	20.80 a	19.96 ab	19.17 bc	18.80 a	19.12 a
	Control	20.27 a	19.32 bc	18.17 de	17.45 b	18.44 ab	20.80 a	19.83 abc	18.64 de	17.71 B	18.94 ab
	Mean	20.27 A	19.57 A	18.84 A	18.28 A	18.51 A	20.80 A	20.09 A	19.34 A	18.56 A	19.00 A
Mean	LifeSpan	18.92 A	18.59 A	18.14 A	17.41 A	17.32 A	19.21 A	18.88 A	18.42 A	17.65 A	17.58 A
	Polypropylene	18.92 A	18.43 AB	17.86 A	17.27 A	17.49 A	19.21 A	18.72 AB	18.14 B	17.50 A	17.76 A
	Chitosan 0.5%	18.92 A	18.21 B	17.54 B	17.23 A	17.45 A	19.21 A	18.49 B	17.81 C	17.46 A	17.72 A
	Control	18.92 A	17.73 C	16.86 C	16.37 B	17.44 A	19.21 A	18.01 C	17.13 D	16.59 B	17.71 A

Values followed by the same latter (s) in each column (storage period) are not significantly different at p e" 0.05 level.

is clearly effective in conferring a physical barrier to moisture loss; its coating can prolong storage life, delay the drop in sensory quality, and control the decay (Romanazzi *et al.,* 2013).

Chemical characteristics

Total soluble solids percentage (TSS %)

As shown in Table 3, The TSS percentage of the Garlic bulb significantly decreased steadily with the advance in the storage period up 3 weeks then increased after that up to the last cold storage period (4 weeks) at 0±1ºC. A similar reduction was also observed in control bulb.

The reduction in total soluble solids content in the first period of storage might owe much to the higher rate of sugar loss through respiration. The increase in this character during the storage period might be due to the higher rate of moisture loss through transpiration than the rate loss of dry matter (Stanely, 1991).

As to post harvest wrapping and coating treatments, it is clear that total soluble solids percentage in garlic bulbs showed that the highest significant values were recorded with LifeSpan sheet lining, compared to the Polypropylene lining and coating treatment with 0.5% chitosan. No significant differences were observed between Polypropylene lining and coating treatment with 0.5% chitosan during all storage period in both seasons. The control (unwrapped) garlic bulbs recorded the lowest significant values.

The obtained results were in agreement with those of Atta-Aly, (1998) on green onion. In addition, Mshraky *et al.,* (2017) found that pomegranate fruits packed in LifeSpan™ bags was the higher in total soluble solids (TSS) content than in unpackaged (control) treatment overall different cold storage periods.

Table 4: Effect of plant age and post harvest treatments during storage at 0±1°C and 90-95% RH on total sugars (g/100 gm DW.) of garlic bulb cv. "Balady" in 2015-2016 and 2016-2017 seasons.

Plant age (week)	Post harvest treatments	Cold storage period (week)																			
		Initial		1		2		3		4		Initial		1		2		3		4	
		2015-2016 Season										2016-2017 Season									
18	LifeSpan	0.583	c	0.539	i	0.512	h	0.446	I	0.373	i	0.615	c	0.569	i	0.541	g	0.471	h	0.394	i
	Polypropylene	0.583	c	0.522	k	0.475	j	0.376	K	0.316	j	0.615	c	0.552	k	0.501	j	0.397	k	0.334	j
	Chitosan 0.5%	0.583	c	0.525	j	0.465	k	0.396	J	0.309	k	0.615	c	0.554	j	0.491	k	0.418	j	0.326	k
	Control	0.583	c	0.513	l	0.412	l	0.366	L	0.236	l	0.615	c	0.542	l	0.434	l	0.386	l	0.250	l
	Mean	0.583	C	0.525	C	0.466	C	0.396	C	0.309	C	0.615	C	0.554	C	0.492	C	0.418	C	0.326	C
20	LifeSpan	0.693	b	0.672	b	0.640	b	0.577	b	0.572	b	0.704	b	0.682	c	0.650	b	0.585	b	0.580	b
	Polypropylene	0.693	b	0.646	e	0.616	d	0.514	f	0.461	f	0.704	b	0.656	e	0.626	d	0.521	f	0.468	f
	Chitosan 0.5%	0.693	b	0.635	f	0.588	f	0.516	e	0.484	d	0.704	b	0.644	f	0.596	f	0.524	e	0.491	d
	Control	0.693	b	0.573	h	0.506	i	0.459	h	0.419	h	0.704	b	0.581	h	0.514	i	0.466	i	0.425	h
	Mean	0.693	B	0.631	B	0.588	B	0.516	B	0.484	B	0.704	B	0.641	B	0.596	B	0.524	B	0.491	B
22	LifeSpan	0.717	a	0.703	a	0.663	a	0.597	a	0.585	a	0.736	a	0.721	a	0.680	a	0.612	a	0.600	a
	Polypropylene	0.717	a	0.668	c	0.623	c	0.531	c	0.477	e	0.736	a	0.686	b	0.640	c	0.545	c	0.489	e
	Chitosan 0.5%	0.717	a	0.657	d	0.608	e	0.527	b	0.501	c	0.736	a	0.674	d	0.624	e	0.541	d	0.514	c
	Control	0.717	a	0.593	g	0.524	g	0.475	g	0.434	g	0.736	a	0.608	g	0.537	h	0.487	g	0.445	g
	Mean	0.717	A	0.655	A	0.604	A	0.532	A	0.499	A	0.736	A	0.672	A	0.620	A	0.546	A	0.512	A
Mean	LifeSpan	0.664	A	0.638	A	0.605	A	0.540	A	0.510	A	0.685	A	0.657	A	0.624	A	0.556	A	0.525	A
	Polypropylene	0.664	A	0.612	B	0.572	B	0.474	B	0.418	B	0.685	A	0.631	B	0.589	B	0.488	B	0.430	B
	Chitosan 0.5%	0.664	A	0.605	C	0.554	C	0.480	C	0.431	C	0.685	A	0.624	C	0.571	C	0.494	C	0.444	C
	Control	0.664	A	0.560	D	0.480	D	0.433	D	0.363	D	0.685	A	0.577	D	0.495	D	0.446	D	0.373	D

Values followed by the same latter (s) in each column (storage period) are not significantly different at p e" 0.05 level.

A slight loss in TSS content was obtained in MAP by the end of the storage period, which was significantly greater in the control than in packaged fruits. It can be hypothesized that the control fruits used energy for respiration (Shaarawi and Nagy, 2017).

The effect of chitosan coating on TSS was probably due to the slowing down of respiration and metabolic activity, hence retarding the ripening process. The modified atmosphere created by chitosan coating suppresses the loss of TSS (Ali *et al.,* 2011).

Concerning the garlic bulb ages, results indicated that total soluble solids percentage significantly increased with the advancing in bulb age in both seasons. Garlic bulbs at age of 18 weeks after planting exhibited the least significant TSS percentage and followed by Garlic bulbs at age of 20 weeks. The Garlic bulbs at age of 22 weeks after planting recorded the highest significant values of TSS % during the various storage period.

Regarding the interaction between plant age and post harvest treatments obviously had positive effect on total soluble solids content in both seasons. It clear that the age of 22 weeks with LifeSpan sheet lining had highest value of TSS content during the various storage period in both seasons.

Total sugars content (g/100 gm DW.)

Total sugars content of Garlic bulb decreased as the storage period increased table 4, where Garlic bulb at harvest date had the highest content of total sugars compared to those after storage period. The obtained results might be attributed to consumption sugars during respiration process and / or the conversion sugars to other forms of

Table 5: Effect of plant age and post harvest treatments during storage at 0±1°C and 90-95% RH on total pungency (µ mol pyruvic acid/ 100 gm FW.) of garlic bulb cv. "Balady" in 2015-2016 and 2016-2017 seasons.

Plant age (week)	Post harvest treatments	Cold storage period (week)									
		Initial	1	2	3	4	Initial	1	2	3	4
		2015-2016 Season					2016-2017 Season				
18	LifeSpan	328.6 c	335.2 f	333.0 d	331.7 D	341.9 d	329.7 c	333.0 d	334.1 c	334.1 c	345.0 Fg
	Polypropylene	328.6 c	330.6 f	331.1 d	331.9 D	341.7 d	329.7 c	329.7 d	329.7 c	329.7 c	342.8 G
	Chitosan 0.5%	328.6 c	332.0 f	330.6 d	331.6 D	341.9 d	329.7 c	334.1 d	331.9 c	333.0 c	345.0 Fg
	Control	328.6 c	328.8 f	329.6 d	332.9 D	342.6 d	329.7 c	329.7 d	330.8 c	334.1 c	346.1 Fg
	Mean	328.6 C	331.6 C	331.1 C	332.0 C	342.0 C	329.7 C	331.6 C	331.6 C	332.7 C	344.7 C
20	LifeSpan	360.1 b	368.4 bcd	368.4 Bc	368.4 bc	380.3 abc	362.1 b	369.5 c	370.4 b	370.9 b	382.0 bcd
	Polypropylene	360.1 b	362.4 cde	358.9 c	360.1 C	375.5 bc	362.1 b	364.0 c	360.8 b	361.6 b	377.5 de
	Chitosan 0.5%	360.1 b	360.1 de	358.9 c	360.1 C	376.7 bc	362.1 b	361.1 c	359.9 b	362.4 b	378.0 cde
	Control	360.1 b	356.5 e	358.9 c	364.8 bc	368.9 c	362.1 b	366.4 c	358.5 b	360.5 b	370.1 def
	Mean	360.1 B	361.8 B	361.3 B	363.3 B	375.3 B	362.1 B	365.3 B	362.4 B	363.8 B	376.9 B
22	LifeSpan	372.2 a	383.4 a	383.4 a	383.4 A	395.7 a	382.4 a	393.8 a	393.8 a	393.8 a	406.6 A
	Polypropylene	372.2 a	377.2 ab	373.5 ab	374.7 ab	390.8 Ab	382.4 a	387.5 ab	383.7 a	385.0 a	401.5 Abc
	Chitosan 0.5%	372.2 a	374.7 ab	373.5 ab	374.7 ab	392.0 Ab	382.4 a	385.0 ab	383.7 a	385.0 a	402.7 Ab
	Control	372.2 a	371.0 bc	373.5 ab	379.6 A	365.5 C	382.4 a	381.1 b	383.7 a	390.0 a	353.1 Efg
	Mean	372.2 A	376.6 A	375.9 A	378.1 A	386.0 A	382.4 A	386.9 A	386.2 A	388.4 A	391.0 A
Mean	LifeSpan	353.6 A	362.2 A	361.6 A	361.1 A	372.6 A	358.1 A	365.4 A	366.1 A	366.3 A	377.9 A
	Polypropylene	353.6 A	356.7 AB	354.5 B	355.5 A	369.3 AB	358.1 A	360.4 AB	358.1 B	358.8 B	373.9 A
	Chitosan 0.5%	353.6 A	355.6 B	354.3 B	355.5 A	370.2 A	358.1 A	360.0 AB	358.5 B	360.1 AB	375.3 A
	Control	353.6 A	352.1 B	354.0 B	359.1 A	359.0 B	358.1 A	359.1 B	357.7 B	361.5 AB	356.4 AB

Values followed by the same latter (s) in each column (storage period) are not significantly different at p e" 0.05 level.

carbohydrate compounds.

Concerning to post harvest wrapping and coating treatments, it is clear that total sugars content in garlic bulbs showed that the highest significant values were recorded with LifeSpan sheet lining, compared to the Polypropylene lining and coating treatment with 0.5% chitosan. No significant differences were observed between Polypropylene lining and coating treatment with 0.5% chitosan during all storage period in the 1st season, and up to 3 weeks of storage period in the 2nd season.

The control (unwrapped) garlic bulbs recorded the lowest significant values in both seasons. As respect of garlic bulb ages, results indicated that total sugars content significantly increased with the advancing in bulb age in both seasons. Garlic bulbs at age of 22 weeks after planting exhibited the highest significant total sugars content and followed by Garlic bulbs at age of 20 weeks. The Garlic bulbs at age of 18 weeks after planting recorded the lowest significant values of total sugars content during the various storage period.

The increase for sugars with the progress of the plants towards maturity are due to the consistent translocation of these sugars between the parts of plant (Stanely, 1991).

The interaction between plant age and post harvest wrapping and coating treatments, data indicated that the highest total sugars content was detected by garlic bulb age of 22 weeks with LifeSpan sheet lining during the all storage period in both seasons. The control treatment of Garlic bulbs at age of 18 weeks after planting recorded the lowest significant values of total sugars content starting from the 2nd week

of storage period in both seasons.

Storage atmospheres did not affect sugar concentrations of the green onions (Hong *et al.*, 2000).

Total pungency (µ mol pyruvic acid/ 100 gm FW.)

(Table 5) show the total pungency content (µ mol pyruvic acid/ 100 gm FW) of green garlic bulb cv. "Balady" as affected by bulb age and pos tharvest wrapping and coating treatments, during 2015-2016 and 2016-2017 seasons.

Total pungency content of Garlic bulb increased slightly as the storage period increased, where Garlic bulb at the end of storage period (4 weeks) had the highest content of total pungency compared to those at harvest date in both seasons.

The obtained results were in agreement with those of Cantwell *et al.,* (2003) on garlic plants who stated that, pyruvate concentrations increased significantly during storage especially in the normal storage in ambient air. These increases may be due to the highest values of weight losses after the long period of storage, it might be to concentration of sulfur and pyruvate contents.

Concerning to post harvest wrapping and coating treatments, data indicated that total pungency content of Garlic bulb showed that the highest values were recorded with LifeSpan sheet lining, compared to other post harvest treatments with no significant differences were observed due to all post harvest treatments and control during all storage period in both seasons.

With respect to garlic bulb ages, results indicated that total pungency content (µ mol pyruvic acid/ 100 gm FW) significantly increased with the advancing in bulb age in both seasons. Garlic bulbs at age of 22 weeks after planting exhibited the highest significant total pungency content and followed by Garlic bulbs at age of 20 weeks. The Garlic bulbs at age of 18 weeks after planting recorded the lowest significant values of total pungency content (µ mol pyruvic acid/ 100 gm FW) during the various storage period.

The interaction between bulb age and post harvest wrapping and coating treatments, data indicated that apart from post-harvest treatments, the bulbs with the age of 22 a week from the planting date was the highest in their content of total pungency. The Garlic bulbs at age of 18 weeks after planting date recorded the lowest values of total pungency content of Garlic bulb in both seasons.

No significant differences were observed due to all post harvest treatments and control within any bulb age during all storage period in both seasons.

Block *et al*., (1992) reported that the thiosulûnates responsible for the characteristic flavor of green onions were 1-propanesulfonoth ioic acid S-(Z)-propenyl ester, 1-propanesulûnothioic acid S-1-propyl ester, and methanesulûnothioic acid S-(Z)-propenyl ester.

Thiosulûnate concentrations were determined to estimate changes in pungent ûavor of the green onions. Cut onions stored in CA had thiosulûnate concentrations similar to the control (Yoo and Pike, 1998 and Hong *et al.,* 2000).

Conclusion

Minimally processed green garlic (Balady cv.) at age of 22 and 20 weeks in LifeSpan sheet lining can be stored at 0±1ºC and 90-95 % RH for 4 weeks, with reduce weight loss, hold more TSS, total sugar and total pungency and maintained high visual quality.

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