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EFFECT OF HOT WATER DIPS AND MODIFIED ATMOSPHERE PACKAGING ON QUALITY AND STORABILITY OF FRESH-CUT GREEN ONION DURING COLD STORAGE

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ABSTRACT: Green onions (*Allium cepa* L.) plants Photon cv. produced under usual cultivation practices in a private farm at Fayed District, Ismalia Governorate, Egypt. Plants were harvested when bulb diameter exceeded 12- 16 mm on February during 2015 and 2016 seasons. This investigation aims to study the effect of hot water dips (50°C for 2 min or 55°C for 1 min) and storing in active modified atmosphere packages (MAP) at 5% O_2 + 5% CO_2 or 7.5% O_2 + 10% CO_2) or in passive MAP beside unpacked plants (control) on leaf extension growth, root growth and leaf curvature and quality attributes of fresh- cut green onions during storage at 0°C and 95% relative humidity (RH) for 20 days plus 2 days at 10°C and 70% RH. Results indicated that green onion plants dipped in hot water at 50°C for 2 min. gave the lowest weight loss as compared with 55°C for 1 min, also hot water treatment at 55°C for 1 min. or storing in active MAP at 5% O_2 + 5% CO_2 were the most effective treatments in reducing decay percentage during storage + shelf life. Hot water treatment at 50°C for 2 min. or active MAP at 7.5% O_2 + 10% CO_2 were less effective in this concern. Moreover, no decay was observed in green onion plants dipped in hot water at 55°C for 1 min. followed by active MAP at 5% O_2+ 5% CO_2 during all storage period + shelf life. Furthermore, it is also controlled root growth and leaf curvature and reduced leaf extension growth (less than 5 mm), maintained chlorophyll readings and gave excellent appearance without any visible injuries after 20 days at 0°C + 2 days (at 10°C shelf life).

Key words: Onion, hot water, modified atmosphere, storability, cold storage, fresh-cut green onion.

INTRODUCTION

Green onions are highly valued for their flavor and international value in supplying minor constituents, such as macro and micro minerals (potassium, calcium, magnesium, iron, selenium) and also vitamins (B- carotene, Folate, vitamin A and C) USDA national nutrient data base for standard reference, 2011.

The increasing popularity of minimally processed fruits and vegetables has been attributed to the increasingly recognized health benefits associated with the consumption of fresh produces, combined with the propensity of consumer to eat out or buy ready to-eat and convenience (Neeto *et al*., 2011). Green onions provide an interesting challenge as a minimally processed product. Green onions are comprised of roots, a compressed stem (sometimes called stem plate), and leaves, which consist of lower white leaf sheath and hollow upper green tissues. Minimal processing includes trimming of the leaves, cutting of the roots and removal of all or part of the compressed stem. Also there are important additional defects due to lack of precision in the cutting process and frequent complete removal of the compressed stem, growth or extension of the white inner leaf bases many occur. Hong *et al*. (2000) described postharvest leaf extension growth of fresh cut green onions. This extension also referred as telescoping (Cantwell *et al.,* 2001). Leaf

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extension grow cause a rapid deterioration of the overall market quality of the product, reducing its appearance (Ragaret *et al*., 2004). Another defect particular to green onions is leaf curvature due to the negative geotropism, which occurs when the product is placed horizontally.

Therefore, several strategies are employed to achieve high quality minimally processed. For example use of good quality raw material, following strict hygienic procedures, lowering the temperature preventing mechanical damage, use modified atmosphere packaging (MAP) (Baskran *et al*., 2015) hot water dipes (Kasim 2009).

Hot water has been used as effective alternative treatment for decay and maintenance of several quality trials (Fallik, 2004) heat shock treatments prevented browning of minimally processed lettuce (Loiza-Velarde *et al*., 1997) reducing extension leaf growth of green onion (Emam, 2009 ; Shehata *et al*., 2010). Growth retarded phenomena can also be affected by heat treatments. (Hong *et al*., 2000) short hot water dips controlled geotropic curvature in asparagus (Paull and Chen, 1999) and green onions (Shehata *et al*., 2010).

Modified atmosphere packaging (MAP) is an atmosphere created around a produce that is different from that of air, which brings beneficial effect like extension of shelf life of fresh produce. MAP can be passively created by the commodity itself by the respiration process wherein oxygen is consumed and carbon dioxide is evolved or actively by flushing in gases of known composition (Kader *et al*., 1989). Depleted O_2 and/or enriched CO_2 levels can reduce respiration, delay ripening, decrease ethylene production, retard textural softening, slow down compositional changes associated with ripening, thereby resulting an extension in shelf life (Das *et al*., 2005). Reduced leaf extension growth and root growth (Li, 2001), retarded leaf curvature (Hong *et al*., 2000) and reduced chlorophyll content loss (Frezza *et al*., 2011)

Therefore, the aim of the present work is to study the effect of hot water treatments followed by modified atmosphere packaging on leaf extension growth, root growth curvature and quality attributes of minimally processed green onions during cold storage.

MATRIALS AND METHODS

Green onions (*Allium cepa* L.) Photon cv. produced under usual cultivation practices in private farm at Fayed District, Ismalia Governorate, Egypt. Plants were harvested when bulb diameter exceeded 12- 16 mm on the second week of February during 2015 and 2016 seasons. Plants were transferred directly under cooling to laboratory of postharvest, Handling Research Department, Giza Governorate. Plants were trimmed (leaf tips and root cut) and sorted in uniform size (12- 16 mm bulb diameter and 25 cm length and washed with tap water were chosen

Hot Water Treatments

Defect free plants were bunched (10 plants/ bunch) and tied using rubber bands, green onion plants were dipped in hot water, the lower 5 cm of the white stem as follows:

1. Dipping in hot water at 50°C for 2 min.
2. Dipping in hot water at 55°C for 1 min.
3. Unheated plants (control) dipping in tap water.

Modified Atmosphere Packaging (MAP)

After hot water treatments, onions were immediately cooled in water at ambient temperature for 10 minutes and then placed on absorbent paper to remove the excess surface water.

Every bunch of green onions (10 plants) which obtained from the previous hot water treatments was packed into polypropylene bags 30 × 15 cm in size, 20 μm thickness and heat sealed which represented as one replicate and treated as follows:

1. Passive MAP: respiration activity of green onion plants is allowed to change the atmosphere as O_2 is used up and CO_2 is produced.
2. Flushed with a gas mixture (active MAP) of 5% O_2 + 5% CO_2.
3. Flushed with a gas mixture (active MAP) of 7.5 % O_2 + 10% CO_2.

4. Unpacked plants (control)

Fifteen replicates were prepared for each treatment and placed inside carton box (35 × 22 × 7 cm), the samples were arranged in complete randomized design in three replicates and stored at 0°C and 95% relative humidity (RH) for 20 days at 0°C plus 2 days at 10°C and 70% RH and samples were taken every 5 days from the initial time of storage till 20 days plus 2 days shelf life.

The following quality measurements were recorded:

1. Weight loss percent
2. Decay percent
3. General appearance was evaluated using a scale from (1 to 9) where 9 = excellent, 7 = good, 5 = fair, 3 = poor and 1 = unusable. The general appearance assessment included symptoms of deterioration (leaf tip dryness, leaf wilt and yellowing, decay, deterioration of outer oldest leaf and leaf curvature defects (Hong *et al*., 2000).
4. Leaf extension growth was measured during storage with a Vernier caliper to the nearest 0.1 mm as the length from the cut surface of the green leaf base to the end of the most extension portion.
5. Root re-growth was measured with a Verner caliper in intact green onions previously trimmed of roots, as a score of 1- 5 was used where, 1= none, 2 = 1- 2 mm, 3 = 3 – 5 mm, 4 = 6 – 10 mm, 5 = 11- 15mm.
6. Leaf curvature A score of 1 – 5 was used where 1 = none , 2 = curvature of stem or leaf up to 15° from the horizontal , 3 = 15 - 30° , 4 = 30 - 45° and 5 > 45° from the horizontal (Hong *et al*., 2000).
7. Total Chlorophyll was measured using Minolta Chlorophyll Meter Spad, 502.
8. Gas composition inside the packages: the concentrations of O_2 and CO_2 inside the packages were monitored using Dual Trak model 902 D gas analyzer. By inserting the best probe through a rubber seal attached to the outside of the packaging.

All the data were subjected to the statistical analysis according to the method described by Snedecor and Cochran (1980).

RESULTES AND DISSCUTION

Weight Loss (%)

Results in Table 1 show that a progressive increase in the percentage of loss in weight of green onion during storage + shelf life. These results were in agreement with Frezza *et al*. (2011) on fresh cut green onion and may be due to respiration, transpiration and other senescence related metabolic process during storage (Shehata *et al*., 2010).

Concerning the effect of hot water treatments, results revealed that there were significant differences between treatments in weight loss percentage during storage, however, all hot water treatments led to increases the percentage of weight loss during storage as compared with untreated control. Moreover, green onion plants dipped in hot water at 55°C for 1 min. or 50°C for 2 min. increased weight loss percentage with no significant differences between them in the two seasons. The lowest value in weight loss percentage was obtained from unheated plants (control). Heat treatments of green onions resulted in a significant increase in respiration rates (Cantwell *et al*., 2001) which in turn increase weight loss percentage However, when hot water treatments were put in comparison, it was concluded that green onion treated with hot water at 50°C for 2 min. gave the lowest weight loss as compared with 55°C for 1 min. in the two seasons. These results were in agreement with those obtained by (Hong *et al*., 2000) who found that the rate of fresh weight loss of heated green onion plants was as much as 1% per day more in heated green onion than in the control.

Regarding the effect of MAP on weight loss percentage, data showed that all treatments retained their weight loss during storage as compared with unpacked (control). Green onion plants stored in active MAP or passive MAP resulted in prominent reduction in weight loss percentage. Active MAP at 5% O_2 + 5% CO_2 or 7.5% O_2 + 10 CO_2 was the most effective treatments in reducing the loss in weight percentage during storage + shelf life with no significant difference between them in the first season. The highest value of weight loss percentage was obtained from unpacked plants (control). These results were true in the two seasons

Table 1. Effect of hot water and modefied atmosphere packaging (MAP) on weight loss percentage of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage peiod + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	0.00 Z	0.45 UV	0.67 Q	0.89 O	0.96 N	0.60 E
	B	0.00 Z	0.30 WX	0.50 U	0.64 Q-S	0.78 P	0.44 G
	C	0.00 Z	0.34 W	0.49 U	0.60 ST	0.76 P	0.43 GH
	D	0.00 Z	1.25 L	2.41 H	3.00 E	3.60 B	2.05 B
	Mean	0.00K	0.59 I	1.02 F	1.28 C	1.53 B	0.88 B
55°C	**A**	0.00 Z	0.58 T	0.90 O	1.20 L	1.40 K	0.82 D
	B	0.00 Z	0.42 V	0.63 Q-ST	0.78 P	0.91 NO	0.55 F
	C	0.00 Z	0.40 V	0.66 QR	0.80 P	0.96 N	0.56 F
	D	0.00 Z	1.64 J	2.72 G	3.40 C	3.96 A	2.34 A
	Mean	0.00 K	0.76 H	1.23 D	1.55 B	1.81 A	1.07 A
Unheated (control)	**A**	0.00 Z	0.28 X	0.40 V	0.61 R-T	0.81 P	0.42 H
	B	0.00 Z	0.14 Y	0.32 WX	0.48 U	0.64 Q-S	0.32 I
	C	0.00 Z	0.16 Y	0.30 WX	0.45 UV	0.60 ST	0.30 I
	D	0.00 Z	1.06 M	2.20 I	2.80 F	3.16 D	1.84 C
	Mean	0.00 K	0.41 J	0.81 G	1.09 E	1.30 C	0.72 C
				Interaction MAP × storage period			
Mean	**A**	0.00 M	0.44 K	0.66 H	0.90 F	1.06 E	0.61 B
	B	0.00 M	0.29 L	0.48 J	0.63 HI	0.78 G	0.44 C
	C	0.00 M	0.30 L	0.48 J	0.62 I	0.77 G	0.44 C
	D	0.00 M	1.32 D	2.44 C	3.07 B	3.57 A	2.08 A
	Mean	0.00 E	0.59 D	1.02 C	1.30 B	1.55 A	
				Season (2016)			
50°C	**A**	0.00 J	0.66 UV	0.78 Q	0.98 O	1.04 N	0.69 E
	B	0.00 J	0.51 Z	0.61 VW	0.74 Q-S	0.86 P	0.54 G
	C	0.00 J	0.55 X-Z	0.60 WX	0.69 S-U	0.84 P	0.54 G
	D	0.00 J	1.46 K	2.52 H	3.09 E	3.68 B	2.15 B
	Mean	0.00 K	0.795 I	1.128 G	1.375 D	1.605 C	0.98 B
55°C	**A**	0.00]	0.71 S-U	1.01 NO	1.29 L	1.48 K	0.90 D
	B	0.00]	0.55 X-Z	0.74 Q-S	0.87 P	0.99 NO	0.63 F
	C	0.00]	0.53 YZ	0.77 QR	0.89 P	1.04 N	0.65 F
	D	0.00]	1.77J	2.83 G	3.49 C	4.04 A	2.43 A
	Mean	0.00 K	0.89 H	1.34 E	1.635 B	1.888 A	1.15 A
Unheated (Control)	**A**	0.00]	0.39 [	0.51 Z	0.70 S-U	0.89 P	0.50 H
	B	0.000]	0.25 \	0.43 [	0.57 W-Y	0.72 R-T	0.39 I
	C	0.000]	0.27 \	0.41 [	0.54 YZ	0.68 TU	0.38 I
	D	0.000]	1.17 M	2.31 I	2.89 F	3.24 D	1.92 C
	Mean	0.00 K	0.52 J	0.92 H	1.18 F	1.39 D	0.80 C
				Interaction MAP × storage period			
Mean	**A**	0.00 L	0.59 J	0.77 H	0.99 F	1.14 E	0.70 B
	B	0.00 L	0.44 K	0.59 J	0.73 I	0.86 G	0.52 C
	C	0.00 L	0.45 K	0.59 J	0.71 I	0.85 G	0.52 D
	D	0.00 L	1.47 D	2.55 C	3.16 B	3.65 A	2.17 A
	mean	0.00 E	0.74 D	1.13 C	1.40 B	1.63 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

and in agreement with Frezza *et al*. (2011) who stated that modified atmosphere packaging acts like a water vapor barrier reducing weight loss percentage of the green onion during storage.

A combination between unheated onion plants and active MAP at 5% O_2 +5% CO_2 or 7.5% O_2 + 10% CO_2 was the most effective treatments in reducing the weight loss percentage of green onions during storage + shelf life with no significant differences between them in two seasons

Concerning the interaction among hot water treatments, MAP and storage period, results revealed that unheated green onion plant in combination with stored in active MAP at 5% O_2 + 5% CO_2 or at 7.5% O_2 + 10 CO_2 was the most effective treatment in reducing weight loss percentage with no significant differences between them at the end of storage period (20 days at 0°C + 2 days at 10°C in the two seasons.

Decay (%)

Results in Table 2 show that decay percentage stated slowly and increased gradually up to the end of storage period. These results were in agreement with (Hong *et al*., 2000) and may be due to the continuous chemical and biochemical changes happened in fruits such as respiration of complex compounds to simple forms of more liability to fungal infection (Wills *et al.,* 1998**)**.

However, fresh cut green onion dipped in hot water at 50°C for 2 min. or 55°C for 1 min. were effective in reducing decay percentage during storage period + shelf life. Hot water dips at 55°C for 1 min. was the most effective treatment in this concern. These results were in agreement with (Shehata *et al*., 2010) which might be related to washing of the natural pathogenic spores populations from the surface of the fruit (Kasim, 2009) on green onion. On the contrary the highest value of decay was obtained from untreated control.

Concerning the effect of MAP, results showed that there were significant differences among treatments in decay percentage during storage + shelf life. However, green onion plants stored in active MAP significantly decreased the percentage of decay in plants compared with passive MAP or untreated MAP (control) with significant differences between them in the two seasons. Green onion plants stored in active MAP at 5% O_2 + 5% CO_2 was the most effective treatment in reducing decay percentage during storage + shelf life. These results were in agreement with Hong *et al*. (2000) and Frezza *et al*. (2011), who found that MAP significantly prevent green onion plants decay and improved the shelf life when compared with unpacked plants.

The reduction in decay and fungal development may be due to the active MAP apparently delayed fruits senescence and inhibited microbial growth (Nielsen and Leufven, 2008) and controlled the exponential growth of microbial microorganisms (Allende *et al*., 2007). Also, Farber (1991) found that CO_2 inhibits microbial activity in two ways, it dissolve in water in the product, and it has negative effect on enzymic and biochemical activities in cells of both product and microorganisms.

The interaction between hot water treatments, and MAP on decay percentage was significant, however, no decay was observed in green onion dipped in hot water at 55°C for 1 min., followed by stored in active MAP at 5% O_2 + 5%CO_2 during storage + shelf life, while the highest value was observed in combination between unheated+ unpacked plants. These results were true in the two seasons and in agreement with Hong *et al*. (2000).

The interaction among hot water treatment, MAP and storage period was significant, however green onion plants dipped in hot water at 55°C for 1 min. followed by MAP at 5% O_2 + 5% CO_2 did not show any decay till the end of storage period + shelf life. On the other hand, decay (%) was observed after 10 days at 0°C + 2 days (at 10°C) of storage for unheated treatment combined with unpacked plants.

General Appearance (GA)

Results in Table 3 reveal that as expected, general appearance of green onion plants was decreased with the prolonging of storage period + shelfe life and GA score dropped gradually from excellent to good, fair, poor and unsalable (9,7,5,3,1) respectively. Similar results were reported by (Shehata *et al.,* 2010 ; Frezza *et al*., 2011) found that the main cause of general appearance loss in green onions were the deterioration (discoloration) of outer oldest leaf,

Table 2. Effect of hot water and modefied atmosphere packaging (MAP) on decay percentage of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	0.00 M	0.00 M	0.00 M	0.00 M	8.41 E	1.68 F
	B	0.00 M	0.00 M	0.00 M	0.00 M	4.33 IJ	0.87 H
	C	0.00 M	0.00 M	0.00 M	0.00 M	6.11 F	1.22 G
	D	0.00 M	0.00 M	0.00 M	5.40 G	10.14 C	3.11 C
	Mean	0.00 H	0.00 H	0.00 H	1.35 E	7.25 B	1.72 B
55°C	**A**	0.00 M	0.00 M	0.00 M	0.00 M	4.00 IJ	0.80 H
	B	0.00 M	0.00 M	0.00 M	0.00 M	0.00 M	0.00 J
	C	0.00 M	0.00 M	0.00 M	0.00 M	2.10 L	0.42 I
	D	0.00 M	0.00 M	0.00 M	2.33 L	9.12 D	2.29 E
	Mean	0.00 H	0.00 H	0.00 H	0.58 G	3.81 D	0.88 C
Unheated (Control)	**A**	0.00 M	0.00 M	0.00 M	4.81 H	13.17 B	3.60 B
	B	0.00 M	0.00 M	0.00 M	0.00 M	6.00 F	1.20 G
	C	0.00 M	0.00 M	0.00 M	3.80 K	8.92 D	2.54 D
	D	0.00 M	0.00 M	4.62 HI	10.13 C	16.17 A	6.18 A
	Mean	0.00 H	0.00 H	1.16 F	4.69 C	11.06 A	3.38 A
				Interaction MAP × storage period			
Mean	**A**	0.00 H	0.00 H	0.00 H	1.61 F	8.53 B	2.03 B
	B	0.00 H	0.00 H	0.00 H	0.00 H	3.44 E	0.69 D
	C	0.00 H	0.00 H	0.00 H	1.27 G	5.71 D	1.40 C
	D	0.00 H	0.00 H	1.54 F	5.95 C	11.81 A	3.86 A
	Mean	0.00 D	0.00 D	0.39 C	2.21 B	7.37 A	
				Season (2016)			
50°C	**A**	0.00 N	0.00 N	0.00 N	0.00 N	8.20 G	1.64 F
	B	0.00 N	0.00 N	0.00 N	0.00 N	4.57 K	0.91 H
	C	0.00 N	0.00 N	0.00 N	0.00 N	5.90 I	1.18 G
	D	0.00 N	0.00 N	0.00 N	5.10 J	9.90 C	3.00 C
	Mean	0.00 H	0.00 H	0.00 H	1.28 E	7.14 B	1.68 B
55°C	**A**	0.00 N	0.00 N	0.00 N	0.00 N	3.67 L	0.73 I
	B	0.00 N	0.00 N	0.00 N	0.00 N	0.00 N	0.00 K
	C	0.00 N	0.00 N	0.00 N	0.00 N	2.00 M	0.40 J
	D	0.00 N	0.00 N	0.00 N	1.86 M	8.87 E	2.15 E
	Mean	0.00 H	0.00 H	0.00 H	0.47 G	3.63 D	0.82 C
Unheated (Control)	**A**	0.00 N	0.00 N	0.00 N	4.38 K	13.14 B	3.51 B
	B	0.00 N	0.00 N	0.00 N	0.00 N	6.20 H	1.24 G
	C	0.00 N	0.00 N	0.00 N	3.60 L	8.53 F	2.43 D
	D	0.00 N	0.00 N	4.40 K	9.53 D	16.11 A	6.01 A
	Mean	0.00 H	0.00 H	1.10 F	4.38 C	10.99 A	3.30 A
				Interaction MAP × storage period			
Mean	**A**	0.00 G	0.00 G	0.00 G	1.46 E	8.34 B	1.96 B
	B	0.00 G	0.00 G	0.00 G	0.00 G	3.59 D	0.72 D
	C	0.00 G	0.00 G	0.00 G	1.20 F	5.48 C	1.34 C
	D	0.00 G	0.00 G	1.47 E	5.49 C	11.62 A	3.72 A
	Mean	0.00 D	0.00 D	0.37 C	2.04 B	7.26 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

Table 3. Effect of hot water and modefied atmosphere packaging (MAP) on general appearance (score) of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	9.00 A	9.00 A	9.00 A	7.00 CD	5.67 EF	7.93 C
	B	9.00 A	9.00 A	9.00 A	8.33 AB	7.00 CD	8.47 AB
	C	9.00 A	9.00 A	9.00 A	7.67 BC	5.67 EF	8.07 BC
	D	9.00 A	9.00 A	7.00 CD	5.00 FG	3.00 H	6.60 F
	Mean	9.00 A	9.00 A	8.50 A	7.00 CD	5.33 E	7.77 B
55°C	**A**	9.00 A	9.00 A	9.00 A	7.67 BC	6.33 DE	8.20 BC
	B	9.00 A	9.00 A	9.00 A	9.00 A	8.33 AB	8.87 A
	C	9.00 A	9.00 A	9.00 A	9.00 A	7.67 BC	8.73 A
	D	9.00 A	9.00 A	7.67 BC	5.67 EF	4.33 G	7.13 E
	Mean	9.00 A	9.00 A	8.67 A	7.83 B	6.67 D	8.23 A
Unheated (Control)	**A**	9.00 A	9.00 A	8.33 AB	5.67 EF	4.33 G	7.27 E
	B	9.00 A	9.00 A	9.00 A	7.00 CD	5.00 FG	7.80 CD
	C	9.00 A	9.00 A	8.33 AB	6.33 DE	4.33 G	7.40 DE
	D	9.00 A	7.00 CD	4.33 G	3.00 H	1.00 I	4.87 G
	Mean	9.00 A	8.50 A	7.50 BC	5.50 E	3.67 F	6.83 C
				Interaction MAP × storage period			
Mean	**A**	9.00 A	9.00 A	8.78 AB	6.78 E	5.44 G	7.80 C
	B	9.00 A	9.00 A	0.00 A	8.11 CD	6.78 E	8.38 A
	C	9.00 A	9.00 A	8.78 AB	7.67 D	5.89 FG	8.07 B
	D	9.00 A	8.33 BC	6.33 EF	4.556 H	2.78 I	6.20 D
	Mean	9.00 A	8.83 A	8.22 B	6.78 C	5.22 D	
				Season (2016)			
50°C	**A**	9.00 A	9.00 A	9.00 A	7.67 BC	5.67 EF	8.07 BC
	B	9.00 A	9.00 A	9.00 A	9.00 A	6.33 DE	8.47 AB
	C	9.00 A	9.00 A	9.00 A	8.33 AB	6.33 DE	8.33 AB
	D	9.00 A	7.000 CD	7.00 CD	5.00 FG	3.00 H	6.20 E
	Mean	9.000 A	8.500 A	8.50 A	7.50 B	5.33 D	7.77 B
55°C	**A**	9.00 A	9.00 A	9.00 A	7.67 BC	7.00 CD	8.33 AB
	B	9.00 A	9.00 A	9.00 A	8.33 AB	8.33 AB	8.73 A
	C	9.00 A	9.00 A	9.00 A	8.33 AB	7.00 CD	8.47 AB
	D	9.00 A	9.00 A	7.00 CD	5.67 EF	5.00 FG	7.13 D
	Mean	9.000 A	9.00 A	8.50 A	7.50 B	6.83 C	8.17 A
Unheated (Control)	**A**	9.00 A	9.00 A	7.67 BC	4.33 G	4.33 G	6.87 D
	B	9.00 A	9.00 A	9.00 A	7.00 CD	5.00 FG	7.80 C
	C	9.00 A	9.00 A	8.33 AB	6.33 DE	3.00 H	7.13 D
	D	9.00 A	9.00 A	4.33 G	4.33 G	1.00 I	5.53 F
	Mean	9.00 A	9.000 A	7.33 BC	5.50 D	3.33 E	6.83 C
				Interaction MAP × storage period			
Mean	**A**	9.00 A	9.00 A	8.56 A-C	6.56 E	5.67 FG	7.76 B
	B	9.00 A	9.00 A	9.00 A	8.11 CD	6.56 E	8.33 A
	C	9.00 A	9.00 A	8.78 AB	7.67 D	5.44 GH	7.98 B
	D	9.00 A	8.33 BC	6.11 EF	5.00 H	3.00 I	6.29 C
	Mean	9.00 A	8.83 A	8.11 B	6.83 C	5.17 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

decay, leaf curvature, leaf growth extension and yellowing.

However, general appearance of green onions dipped in hot water at 50°C for 2 min. or 55°C for 1 min. had the best appearance during storage + shelf life with significant difference between them when compared with unheated control. Hot water at 55°C for 1 min. treatment was the most effective treatment in maintaining GA plants. These results were in agreement with Shehata *et al.* (2010) and Kasim (2009) on green onion who found that hot water treatment provided the best overall visual quality and this may be due to hot water treatments effectively controlled leaf extension, curvature, root growth and reducing the color development during storage (Kasim, 2009).

There were significant differences between MAP treatments and the control in general appearance score. Moreover, green onion plants stored in active MAP at 5% O_2 + 5% CO_2 or 7.5% O_2 + CO_2 or passive MAP were better with significant differences between them in the two seasons than those stored in air (control). These results were in agreement with Viskelis *et al*. (2012) who found that modified atmosphere storage helps to preserve quality of green onions, thus extending, their shelf life. Previous studies showed that MAP delay senescence of green onion (Frezza *et al*., 2011). MAP made a significant contribution on extending the postharvest longevity of green onion plants having a high rate of postharvest water loss (Hong and Kim, 2004). Water saturated atmosphere within the package controlled water loss and delay senescence in the absence of water stress and thereby green onion plants (Frezza *et al*., 2011).

In general, the interaction between hot water treatment and MAP was significant, However, in green onion plants treated with hot water at 55°C for 1 min. followed by storage in active MAP at 5% O_2 + 5% CO_2 or 7.5% O_2 + 10% CO_2 were the most effective combination treatments in maintaining GA during storage + shelf life followed by 50°C for 2 min. in combination with the two tested concentrations active MAP. The lowest values of GA score were recorded with unheated treatment in combination with unpacked. These results were true in the two seasons and were in agreement with Hong and Kim (2004).

The interaction among hot water treatments, MAP and storage period was significant however, green onion plants treated with hot water at 55 °C for1 min followed by MAP at 5% O_2 + 5% CO_2 showed the best appearance, and they did not exhibit any changes in their appearance till the end of storage period + shelf life, while using hot water at 50°C for 2 min. and then stored in MAP at 7.5 O_2 + 10% CO_2 rated good appearance after 15 days at 0°C + 2 days at 10 °C. On the other hand unheated treatment followed by stored in unpacked plants resulted in unusable appearance after 20 days of storage at 0°C + 2 days at 10°C. These results were true in the two seasons and were in agreement with Hong *et al*. (2000).

Leaf Extension Growth and Root Growth

Results in Tables 4 and 5 show that fresh-cut green onions were continuous increase in leaf extension growth and root growth during cold storage + shelf life, leaf growth and root growth reached 11.20 mm and 2.88 (score) (average of the two seasons), respectively after 20 days at 0°C + 2 days at 10°C. Such increase in leaf extension and root growth affected negatively the market quality (Hong *et al*., 2000). These results were true in the two seasons and were in agreement with Kasim (2009).

However, fresh cut green onions dipped in hot water at 50°C for 2 min. or 55°C for 1 min. were the most effective treatments in reducing leaf extension growth and root growth less than 5 mm during storage + shelf life without cause visible injury to fresh cut green onion. Cantwell *et al*. (2001) showed that leaf extension growth of 5 mm for leaf extension growth was not significantly noticeable to make green onions unmarketable unless they also had other defects. These results were true in the two seasons and were in agreement with Shehata *et al.* (2010) who found that heat treatment had passive affect on controlling leaf extension growth and root growth of green onions compared with non heated onions during storage. Various metabolic reactions (Loiza-Velarde *et al.*, 1997) and growth phenomena can be controlled by short heat shock treatments (Hong *et al.,* 2000). The heat treatment 55°C for 2 min effectively controlled extension of the cut onion plants (Cantwell *et al*., 2001).

Table 4. Effect of hot water and modefied atmosphere packaging (MAP) on leaf extention growth (mm) of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	0.00 [	1.72 W-Y	2.94 ST	4.12 M	7.22 I	3.20 F
	B	0.00 [	1.35 YZ	2.35 UV	3.75 M-O	4.92 L	2.47 H
	C	0.00 [	1.68 W-Y	2.70 TU	3.92 MN	5.35 K	2.73 G
	D	0.00 [	2.35 UV	10.62 G	15.22 E	28.31 B	11.3 B
	Mean	0.000 L	1.78 J	4.65 G	6.75 E	11.45 B	4.93 B
55°C	**A**	0.00 [	1.40 X-Z	2.75 TU	3.84 MN	5.22 KL	2.64 GH
	B	0.00 [	1.10 Z	2.10 VW	3.00 R-T	3.60 N-Q	1.96 J
	C	0.00 [	1.25 Z	2.40 UV	3.40 OPQR	3.90 MN	2.19 I
	D	0.00 [	1.90 W	8.24 H	12.00 F	18.36 D	8.10 C
	Mean	0.00 L	1.41 K	3.87 H	5.56 F	7.77 D	3.72 C
Unheated (Control)	**A**	0.00 [	1.90 W	3.20 Q-S	3.70 MNOP	10.32 G	3.82 D
	B	0.00 [	1.70 W-Y	2.70 TU	5.63 JK	7.57 I	3.52 E
	C	0.00 [	1.80 WX	3.30 P-S	5.90 J	8.00 H	3.80 D
	D	0.00 [	2.76 TU	12.34 F	20.18 C	31.12 A	13.28 A
	Mean	0.00 L	2.04 I	5.39 F	8.85 C	14.25 A	6.11 A
				Interaction MAP × storage period			
Mean	**A**	0.00 M	1.67 K	2.96 I	3.89 H	7.59 D	3.22 B
	B	0.00 M	1.38 L	2.38 J	4.13 H	5.36 F	2.65 D
	C	0.00 M	1.58 KL	2.80 I	4.41 G	5.75 E	2.91 C
	D	0.00 M	2.34 J	10.40 C	15.80 B	25.93 A	10.89 A
	Mean	0.00 E	1.74 D	4.64 C	7.06 B	11.16 A	
				season 2016			
50°C	**A**	0.00 [	1.83 W-Y	3.05 ST	4.21 M	7.31 I	3.28 F
	B	0.00 [	1.46 YZ	2.46 UV	3.84 M-O	5.01 L	2.55 H
	C	0.00 [	1.79 W-Y	2.81 TU	4.01 MN	5.44 K	2.81 G
	D	0.00 [	2.46 UV	10.73 G	15.31 E	28.40 B	11.38 B
	Mean	0.00 L	1.89 J	4.76 G	6.84 E	11.54 B	5.01 B
55°C	**A**	0.00 [	1.51 XYZ	2.86 TU	3.93 MN	5.31 KL	2.72 GH
	B	0.00 [	1.21 Z	2.21 VW	3.09 R-T	3.69 N-Q	2.04 J
	C	0.00 [	1.35 Z	2.51 UV	3.49 O-R	3.99 MN	2.27 I
	D	0.00 [	2.01 W	8.35 H	12.09 F	18.45 D	8.18 C
	Mean	0.00 L	1.52 K	3.98 H	5.65 F	7.86 D	3.80 C
Unheated (Control)	**A**	0.00 [	2.01 W	3.31 Q-S	3.79 M-P	10.41 G	3.90 D
	B	0.00 [	1.81 W-Y	2.81 TU	5.72 JK	7.66 I	3.60 E
	C	0.00 [	1.91 WX	3.41 P-S	5.99 J	8.090 H	3.88 D
	D	0.00 [	2.87 TU	12.45 F	20.27 C	31.21 A	13.36 A
	Mean	0.00 L	2.15 I	5.50 F	8.94 C	14.34 A	6.19 A
				Interaction MAP × storage period			
Mean	**A**	0.00 M	1.78 K	3.07 I	3.98 H	7.68 D	3.30 B
	B	0.00 M	1.49 L	2.49 J	4.22 H	5.45 F	2.73 D
	C	0.00 M	1.68 KL	2.91 I	4.50 G	5.84 E	2.99 C
	D	0.00 M	2.45 J	10.51 C	15.89 B	26.02 A	10.98 A
	Mean	0.00 E	1.85 D	4.75 C	7.15 B	11.25 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

Table 5. Effect of hot water and modefied atmosphere packaging (MAP) on root growth (score) of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water	MAP	Storage period + shelf life (day)					Mean
Treatment		0	5 +2	10 +2	15 +2	20 +2	
				Season (2015)			
	A	1.00 H	1.00 H	1.667 FG	2.33 DE	3.00 C	1.80 CD
	B	1.00 H	1.00 H	1.00 H	1.00 H	2.00 EF	1.20 E
50°C	**C**	1.00 H	1.00 H	1.33 GH	1.67 FG	2.67 CD	1.53 D
	D	1.00 H	1.00 H	2.00 EF	3.00 C	3.67 B	2.13 B
	Mean	1.00 E	1.00 E	1.50 D	2.00 C	2.83 B	1.67 B
	A	1.00 H	1.00 H	1.33 GH	2.00 EF	2.67 CD	1.60 D
	B	1.00 H	1.00 H	1.00 H	1.00 H	1.00 H	1.00 E
55°C	**C**	1.00 H	1.00 H	1.00 H	1.33 GH	1.67 FG	1.20 E
	D	1.00 H	1.00 H	1.00 H	2.33 DE	3.00 C	1.67 CD
	Mean	1.00 E	1.00 E	1.08 E	1.67 D	2.08 C	1.37 C
	A	1.00 H	1.00 H	2.33 DE	2.67 CD	3.67 B	2.13 B
Unheated	**B**	1.00 H	1.00 H	1.67 FG	2.33 DE	2.67 CD	1.73 CD
(Control)	**C**	1.00 H	1.00 H	2.00 EF	2.67 CD	3.00 C	1.93 BC
	D	1.00 H	1.67 FG	2.67 CD	3.67 B	4.67 A	2.73 A
	Mean	1.00 E	1.17 E	2.17 C	2.83 B	3.50 A	2.13 A
				Interaction MAP × storage period			
	A	1.00 G	1.00 G	1.78 DE	2.33 C	3.11 B	1.84 B
	B	1.00 G	1.00 G	1.22 FG	1.44 EF	1.89 D	1.31 D
Mean	**C**	1.00 G	1.00 G	1.44 EF	1.89 D	2.44 C	1.56 C
	D	1.00 G	1.22 FG	1.89 D	3.00 B	3.78 A	2.18 A
	Mean	1.00 D	1.06 D	1.58 C	2.17 B	2.81 A	
				Season (2016)			
	A	1.00 H	1.00 H	2.00 EF	2.33 E	3.33 CD	1.93 CD
	B	1.00 H	1.00 H	1.00 H	1.00 H	2.33 E	1.27 FG
50°C	**C**	1.00 H	1.00 H	1.33 GH	1.67 FG	2.33 E	1.47 EF
	D	1.00 H	1.00 H	2.00 EF	3.00 D	3.67 BC	2.13 BC
	Mean	1.000 G	1.000 G	1.58 DE	2.00 C	2.92 B	1.70 B
	A	1.00 H	1.00 H	1.33 GH	2.00 EF	2.33 E	1.53 EF
	B	1.00 H	1.00 H	1.00 H	1.00 H	1.00 H	1.00 G
55°C	**C**	1.00 H	1.00 H	1.00 H	1.33 GH	2.00 EF	1.33 F
	D	1.00 H	1.00 H	1.67 FG	2.33 E	3.00 D	1.73 DE
	Mean	1.00 G	1.00 G	1.25 FG	1.67 D	2.08 C	1.40 C
	A	1.00 H	1.00 H	1.67 FG	3.00 D	3.67 BC	2.27 B
Unheated	**B**	1.00 H	1.00 H	1.33 GH	2.33 E	3.00 D	1.93 CD
(Control)	**C**	1.00 H	1.33 GH	1.33 GH	3.33 CD	3.33 CD	2.33 B
	D	1.00 H	2.00 EF	2.33 E	4.00 B	5.33 A	3.00 A
	Mean	1.00 G	1.33 EF	1.67 D	3.17 B	3.83 A	2.20 A
				Interaction MAP × storage period			
	A	1.00 H	1.00 H	1.67 E	2.44 C	3.11 B	1.84 B
	B	1.00 H	1.00 H	1.11 GH	1.44 EF	2.11 D	1.33 D
Mean	**C**	1.00 H	1.11 GH	1.22 F-H	2.11 D	2.56 C	1.60 C
	D	1.00 H	1.33 FG	2.00 D	3.11 B	4.00 A	2.29 A
	Mean	1.00 D	1.11 D	1.50 C	2.28 B	2.94 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

Concerning the effect of MAP on leaf extension growth and root growth, results in Tables 4 and 5 reveal that, green onion stored in active and passive MAP reduced those characters during storage + shelf life. However, active MAP at 5% O_2 + 5% CO_2 was the most effective treatment in reducing leaf extension growth and root growth as compared with the other treatments or unpacked (control). These results were true in the two seasons and were in agreement with Li (2001) on green onion.

Growth phenomena such as sprouting, root development of onion bulbs and periderm formation of potatoes are inhibited by low O_2 and/or high atmosphere (Kader, 1986). The MA effect on growth phenomena may be due to the reduction of normal respiratory activities by MA which in term may limit energy supply for growth related events (Kays, 1991), additionally, some enzymatic steps in the growth process may be specially inhibited by the MA conditions.

In general, interaction between hot water treatment and MAP on leaf extension growth and root growth were significant during storage + shelf life, however green onion plants dipped in hot water at 55°C for 1 min. and then stored in active MAP at 5% O_2 + 5% CO_2 was the most effective treatments in reducing those characters during all storage period + shelf life. Combination between unheated treatment and unpacked plants (control) recorded the highest value of leaf extension growth and root growth during storage+ shelf life. These results were true in the two seasons and were in agreement with Hong *et al.* (2000).

The interaction among hot water treatment, MAP and storage period were significant, however, green onion plants dipped in hot water at 55°C for 1 min. and then stored at active MAP at 5% O_2+ 5% CO_2 controlled root growth and reduced leaf extension growth at different cold storage periods, while unheated treatment combined with unpacked plants had the highest value of leaf extension growth and root growth, these results, were true in the two seasons and were in agreement with Hong *et al.* (2000).

Leaf Curvature

Curvature was common defect in the commercial green onion product. Results in Table 6 show a progressive increase in leaf curvature score during storage + shelf life, however, the leaf curvature started to be shown after 10 days of storage. Extending the storage period up to 20 days at 0°C + 2 days at 10°C resulted in a significant higher leaf curvature score. These results were true in the two seasons of study and were in agreement with Emam (2009) and Shehata *et al*. (2010) on green onions during storage.

However, green onions dipped in hot water at 55°C for 1 min. was very effective in retarding leaf curvature. These results were true in the two seasons and were in agreement with Cantwell *et al*. (2001) who found that the pre-storage heat treatments of 52°C and 55°C for 4 and 2 min., respectively were especially effective in reducing the rate of curvature of green onions.

Concerning the effect of MAP on leaf curvature, results showed that, green onion stored in active or passive MAP reduced the leaf curvature during storage+ shelf life as compared to unheated and unpacked (control). Green onion stored in active MAP at 5% O_2 + 5% CO_2 was the most effective treatment in reducing leaf curvature as compared with the other treatments or unpacked (control). These results were true in the two seasons and were in agreement with (Hong *et al*., 2000) who found that controlled atmosphere retarded leaf curvature of green onions during storage.

In general, the interaction between hot water treatments and MAP on leaf curvature was significant during cold storage + shelf life, however, green onion plants treated with hot water at 55°C for 1 min. and then stored in active MAP at 5% O_2 + 5% CO_2 was controlled the leaf curvature, followed by the combination between hot water at 50°C for 2 min. and active MAP at 5% O_2 + 5% CO_2 with no significant difference between them. These results were true in the two seasons and were in agreement with those obtained by Hong *et al*. (2000).

The interaction among hot water treatment, MAP and storage period was significant during storage + shelf life, however, green onion plants treated with hot water at 55°C for 1 min. and then stored in active MAP at 5% O_2 + 5% CO_2 did not observed any signs of leaf curvature till

Table 6. Effect of hot water and modefied atmosphere packaging (MAP) on leaf curvature (score) of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	1.00 J	1.00 J	2.33 FG	2.33 FG	3.00 DE	1.93 CD
	B	1.00 J	1.00 J	1.00 J	1.00 J	1.67 HI	1.13 HI
	C	1.00 J	1.00 J	1.00 J	2.00 GH	2.33 FG	1.47 FG
	D	1.00 J	1.00 J	2.00 GH	2.67 EF	3.67 BC	2.07 BC
	Mean	1.00 H	1.00 H	1.58 FG	2.00 DE	2.67 B	1.65 B
55°C	**A**	1.00 J	1.00 J	1.67 HI	2.00 GH	2.67 EF	1.67 EF
	B	1.00 J	1.00 J	1.00 J	1.00 J	1.33 IJ	1.07 I
	C	1.00 J	1.00 J	1.00 J	1.67 HI	2.00 GH	1.33 GH
	D	1.00 J	1.00 J	1.67 HI	2.33 FG	3.33 CD	1.87 C-E
	Mean	1.000 H	1.00 H	1.33 G	1.75 EF	2.33 C	1.48 C
Unheated (Control)	**A**	1.00 J	1.00 J	2.67 EF	2.67 EF	3.67 BC	2.20 B
	B	1.00 J	1.00 J	1.67 HI	2.00 GH	2.67 EF	1.67 EF
	C	1.00 J	1.00 J	1.67 HI	2.33 FG	3.00 DE	1.80 DE
	D	1.00 J	1.00 J	3.00 DE	4.00 B	5.00 A	2.80 A
	Mean	1.00 H	1.00 H	2.25 CD	2.75 B	3.58 A	2.12 A
				Interaction MAP × storage period			
Mean	**A**	1.00 G	1.00 G	2.22 CD	2.33 C	3.11 B	1.93 B
	B	1.00 G	1.00 G	1.22 FG	1.33 F	1.89 E	1.29 D
	C	1.00 G	1.00 G	1.22 FG	2.00 DE	2.44 C	1.53 C
	D	1.00 G	1.00 G	2.22 CD	3.00 B	4.00 A	2.24 A
	Mean	1.00 D	1.00 D	1.72 C	2.17 B	2.86 A	
				Season (2016)			
50°C	**A**	1.00 I	1.00 I	2.33 E-G	3.00 C-E	3.000 C-E	2.07 BC
	B	1.00 I	1.00 I	1.00 I	1.00 I	2.000 F-H	1.20 F
	C	1.00 I	1.00 I	1.00 I	3.00 C-E	2.333 E-G	1.67 DE
	D	1.00 I	1.00 I	2.00 F-H	3.67 BC	4.000 B	2.33 B
	Mean	1.00 G	1.00 G	1.58 EF	2.67 BC	2.83 B	1.82 B
55°C	**A**	1.00 I	1.00 I	1.67 G-I	2.33 E-G	2.67 D-F	1.73 DE
	B	1.00 I	1.00 I	1.00 I	1.00 I	1.00 I	1.00 F
	C	1.00 I	1.00 I	1.00 I	2.00 F-H	2.67 D-F	1.53 E
	D	1.00 I	1.00 I	1.67 G-I	2.67 D-F	3.33 B-D	1.93 CD
	Mean	1.00 G	1.00 G	1.33 FG	2.00 D	2.42 C	1.55 C
Unheated (Control)	**A**	1.00 I	1.00 I	2.67 D-F	3.33 B-D	3.33 B-D	2.27 B
	B	1.00 I	1.00 I	1.00 I	2.00 F-H	2.67 D-F	1.53 E
	C	1.00 I	1.33 HI	1.00 I	2.67 D-F	2.67 D-F	1.73 DE
	D	1.00 I	1.67 G-I	3.00 C-E	4.00 B	5.33 A	3.00 A
	Mean	1.00 G	1.25 FG	1.92 DE	3.00 B	3.50 A	2.13 A
				Interaction MAP × storage period			
Mean	**A**	1.00 G	1.00 G	2.22 EF	2.89 CD	3.00 C	2.02 B
	B	1.00 G	1.00 G	1.00 G	1.33 G	1.89 F	1.24 D
	C	1.00 G	1.111 G	1.00 G	2.56 DE	2.56 DE	1.64 C
	D	1.00 G	1.22 G	2.22 EF	3.44 B	4.222 A	2.42 A
	Mean	1.00 D	1.08 D	1.61 C	2.56 B	2.92 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); excpt 0 time

20 days of storage at 0°C + 2 days at 10°C, while hot water at 50°C for 2 min. followed by active MAP at 5% O_2 +5% CO_2 gave a slight score of leaf curvature at the same period. On the other hand, unheated treatment followed by unpacked plants gave the highest score (extra sever of leaf curvature) at the same period.

Chlorophyll Readings

Results in Table 7 show that chlorophyll content in green onion plants decreased gradually with the prolongation of storage period. This decrement in chlorophyll content could be attributed to the gradual destruction by chlorophyllase activity and transformation of chloroplasts to chromoplasts. These results were true in the two seasons and were in agreement with Emam (2009), Shehata *et al.* (2010) and Frezza *et al*. (2011) on green onion.

However, green onion plants dipped in hot water at 50°C and 55°C for 2 and 1 min., respectively, inhibited chlorophyll loss during storage + shelf life as compared with unheated plants. Moreover, hot water at 55°C for 1 min. was the most effective treatment in reducing chlorophyll loss in the two seasons and were in agreement with Hong *et al*. (2000) and Kasim (2009). Hot water treatment maintained the bright green color of the leaves of onion plants during storage and this may be due to that hot water inhibited chlorophyllase enzyme activity (Kazami *et al*., 1991).

Concerning the effect of MAP, results revealed that green onions stored in active and passive MAP reduced the loss of chlorophyll reading during storage + shelf life, however, active MAP at 5% O_2 + 5% CO_2 followed by 7.5% O_2+ 10% CO_2 were the most effective treatments in maintaining chlorophyll readings with significant differences between them. On the other hand unpacked plants (control) gave the lowest value of chlorophyll reading during storage+ shelf life. These results were true in the two seasons and were in agreement with Frezza *et al*. (2011). Controlled atmosphere 2% O_2 with 5, 10 and 15% CO_2 reduced these color changes at 4°C of green onion (Hong *et al*., 2000).

The interaction between hot water treatments and MAP on chlorophyll reading was significant during storage+ shelf life. However, green onion plants dipped in hot water at 55 °C for 1 min. and then stored at active MAP 5% O_2 + 5% CO_2 was the most effective treatment in maintaining chlorophyll reading during storage shelf life. On the other hand, combination between unheated treatment and unpacked (control) had the lowest value of chlorophyll reading during storage+ shelf life. These results were in agreement with Hong *et al*. (2000) who found that, fresh cut green onion dipped in hot water followed by high CO_2 atmospheres was the most effective combination treatment in retarding any appearance yellowing at the cut surface.

The interaction among hot water treatment MAP and storage period was significant during storage + shelf life, however, after 20 days of storage combined with storing (at 0°C + 2 days at 10°C) green onion dipped in hot water at 55°C for 1 min. and then stored in active MAP at 5% O2+ 5% CO_2 was the most effective in reducing chlorophyll loss.

Gas Concentration Inside the Bags

Green onions are still alive after harvest and it also respires. It is necessary to achieve proper gas composition in the packages, so it is very important to study the gas changes inside the package of MAP. Moreover, the atmosphere analysis showed that, in active and passive MAP, the atmosphere had been modified (Tables 8 and 9). The O_2 and CO_2 inside the package of active and passive MAP differed significantly. However, O_2 levels in active MAP were lower than that of passive MAP as shown in Table 8, while value of CO_2 were higher in Table 9. The O_2 levels decreased and CO_2 increased continuously during storage + shelf life until reached 11.65 O2% and 4.77 CO_2 % after 20 days at 0°C + 2 days at 10°C (average of the two seasons). These results were true in the two seasons and were in agreement with Frezza *et al*. (2011) and Hong and Kim (2004) on green onion and may be due to consummation of O_2 and production of CO_2 of green onion during respiration (Kasim, 2009).

After 20 days of storage at 0°C + 2 days at 10°C, the gas concentrations were 3.92 O_2% and 6.34 CO_2 % (average of the two seasons) in active MAP at 5% O_2+ 5% CO_2. The gas composition inside the passive package 18.12% O2 and 1.11% CO_2in the same period.

Table 7. Effect of hot water and modefied atmosphere packaging (MAP) on total chlorophyll readings of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	67.82 A	62.14 F	60.17 H	58.13 K	54.30 O	60.51 E
	B	67.82 A	65.22 C	62.10 F	60.22 H	58.33 K	62.74 B
	C	67.82 A	64.11 D	61.17 G	59.34 IJ	56.41 M	61.77 C
	D	67.82 A	61.11 G	59.14 IJ	55.21 N	51.42 R	58.94 H
	Mean	67.82 A	63.15 C	60.65 E	58.22 G	55.12 I	60.99 B
55°C	**A**	67.82 A	64.14 D	60.27 H	59.11 IJ	57.94 K	61.86 C
	B	67.82 A	66.22 B	63.17 E	61.00 G	60.37 H	63.72 A
	C	67.82 A	65.64 C	61.34 G	60.23 H	58.94 J	62.79 B
	D	67.82 A	62.34 F	58.11 K	56.11 M	53.67 P	59.61 F
	Mean	67.82 A	64.58 B	60.72 E	59.11 F	57.73 H	61.99 A
Unheated (Control)	**A**	67.82 A	60.11 H	57.13 L	54.24 O	50.12 S	57.88 I
	B	67.82 A	63.23 E	60.22 H	58.22 K	54.32 O	60.76 D
	C	67.82 A	61.32 G	58.13 K	56.11 M	52.37 Q	59.15 G
	D	67.82 A	59.41 I	55.43 N	51.22 R	45.30 T	55.84 J
	Mean	67.82 A	61.02 D	57.73 H	54.95 I	50.53 J	58.41 C
				Interaction MAP × storage period			
Mean	**A**	67.82 A	62.13 D	59.19 I	57.16 L	54.12 N	60.08 C
	B	67.82 A	64.89 B	61.83 E	59.81 H	57.67 K	62.41 A
	C	67.82 A	63.69 C	60.21 G	58.56 J	55.91 M	61.24 B
	D	67.82 A	60.95 F	57.56 K	54.18 N	50.13 O	58.13 D
	Mean	67.82 A	62.92 B	59.70 C	57.43 D	54.46 E	
				Season (2016)			
50°C	**A**	68.92 A	63.24 F	61.27 H	58.22 K	54.39 N	61.21 E
	B	68.92 A	66.32 C	63.20 F	60.31 I	58.42 K	63.43 B
	C	68.92 A	65.21 D	62.27 G	59.43 J	56.50 L	62.47 C
	D	68.92 A	62.21 G	60.24 I	55.30 M	51.51 Q	59.64 H
	Mean	68.92 A	64.25 C	61.74 E	58.32 H	55.21 J	61.69 B
55°C	**A**	68.92 A	65.24 D	61.37 H	59.20 J	58.03 K	62.55 C
	B	68.92 A	67.32 B	64.27 E	61.09 H	60.46 I	64.41 A
	C	68.92 A	66.74 C	62.44 G	60.32 I	59.03 J	63.49 B
	D	68.92 A	63.44 F	59.21 J	56.20 L	53.76 O	60.31 F
	Mean	68.92 A	65.68 B	61.82 E	59.20 F	57.82 I	62.69 A
Unheated (Control)	**A**	68.92 A	61.21 H	58.23 K	54.33 N	50.21 R	58.58 I
	B	68.92 A	64.33 E	61.32 H	58.31 K	54.41 N	61.46 D
	C	68.92 A	62.42 G	59.23 J	56.20 L	52.46 P	59.85 G
	D	68.92 A	60.51 I	56.53 L	51.31 Q	45.39 S	56.53 J
	Mean	68.92 A	62.12 D	58.83 G	55.04 J	50.62 K	59.10 C
				Interaction MAP × storage period			
Mean	**A**	68.92 A	63.23 D	60.29 H	57.25 L	54.21 N	60.78 C
	B	68.92 A	65.99 B	62.93 E	59.90 I	57.76 K	63.10 A
	C	68.92 A	64.79 C	61.31 G	58.65 J	56.00 M	61.93 B
	D	68.92 A	62.05 F	58.66 J	54.27 N		58.82 D
	Mean	68.92 A	64.02 B	60.80 C	57.52 D	54.55 E	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); except 0 time

Table 8. Effect of hot water and modefied atmosphere packaging (MAP) on O_2 concentration inside the packages of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (day) 0	5 +2	10 +2	15 +2	20 +2	Mean
				2014 season			
50°C	A	20.80 A	20.10 B	19.20 EF	18.70 G	18.00 H	19.36 C
	B	5.00 K	4.63 K-N	4.20 N-R	4.20 N-R	4.00 Q-S	4.41 G
	C	7.50 J	4.52 L-P	4.10 P-R	4.00 Q-S	3.80 R-T	4.79 F
	D	20.80 A	20.50 AB	20.80 A	20.80 A	20.80 A	20.74 A
	Mean	13.52 A	12.44 BC	12.07 D	11.93 D	11.65 E	12.32 B
55°C	A	20.80 A	20.20 BC	19.60 DE	19.00 FG	18.70 G	19.66 B
	B	5.00 K	4.84 KL	4.60 K-O	4.40 L-Q	4.20 N-R	4.61 FG
	C	7.50 J	4.73 K-M	4.52 L-P	4.210 N-R	4.17 O-R	5.03 E
	D	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A
	Mean	13.52 A	12.64 B	12.38 C	12.10 D	11.97 D	12.52 A
Unheated (Control)	A	20.80 A	19.82 CD	19.00 FG	18.10 H	17.51 I	19.05 D
	B	5.00 K	4.41 L-Q	4.10 P-R	3.80 R-T	3.42 TU	4.15 H
	C	7.50 J	4.31 M-Q	4.00 Q-S	3.60 ST	3.10 U	4.51 G
	D	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A
	Mean	13.52 A	12.34 C	11.97 D	11.57 E	11.21 F	12.12 C
				Interaction MAP × storage period			
Mean	A	20.80 A	20.04 B	19.27 C	18.60 D	18.07 E	19.36 B
	B	5.00 G	4.63 H	4.30 IJ	4.13 JK	3.87 KL	4.39 D
	C	7.50 F	4.52 HI	4.21 J	3.94 KL	3.69 L	4.77 C
	D	20.80 A	20.70 A	20.80 A	20.80 A	20.80 A	20.78 A
	Mean	13.52 A	12.47 B	12.14 C	11.87 D	11.61 E	
				season 2016			
50°C	A	20.80 A	20.22 BC	19.27 EF	18.79 G	18.11 H	19.44 C
	B	5.00 K	4.75 K-M	4.27 N-R	4.29 N-R	4.11 P-S	4.48 H
	C	7.50 J	4.64 K-N	4.17 O-R	4.09 P-S	3.91 R-T	4.86 F
	D	20.80 A	20.62 AB	20.80 A	20.80 A	20.80 A	20.76 A
	Mean	13.52 A	12.56 C	12.13 D	11.99 D	11.73 E	12.39 B
55°C	A	20.80 A	20.40 A-C	19.67 DE	9.09 FG	18.81 G	19.75 B
	B	5.00 K	5.04 K	4.67 K-N	4.49 L-Q	4.31 M-R	4.71 FG
	C	7.50 J	4.93 K	4.59 K-O	4.30 M-R	4.28 N-R	5.12 E
	D	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A
	mean	13.52 A	12.79 B	12.43 C	12.17 D	12.05 D	12.59 A
Unheated (Control)	A	20.80 A	19.95 CD	19.07 FG	18.19 H	17.62 I	19.13 D
	B	5.00 K	4.54 L-P	4.17 O-R	3.89 R-T	3.53 TU	4.23 I
	C	7.50 J	4.44 M-Q	4.07 Q-S	3.69 ST	3.21 U	4.58 GH
	D	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A	20.80 A
	mean	13.52 A	12.43 C	12.03 D	11.64 E	11.29 F	12.18 C
				Interaction MAP × storage period			
Mean	A	20.80 A	20.19 B	19.34 C	18.69 D	18.18 E	19.44 B
	B	5.00 G	4.78 GH	4.37 I	4.22 I-K	3.98 KL	4.47 D
	C	7.50 F	4.67 H	4.28 IJ	4.03 J-L	3.80 L	4.86 C
	D	20.80 A	20.74 A	20.80 A	20.80 A	20.80 A	20.79 A
	mean	13.52 A	12.59 B	12.20 C	11.93 D	11.69 E	

Means in the same column having the same letter are not significsantly different at 0.05 levewl by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); excpt 0 time

Table 9. Effect of hot water and modefied atmosphere packaging (MAP) on Co_2 concentration inside the packages of fresh-cut green onion during storage period + shelf life in 2015 and 2016 seasons

Hot water Treatment	MAP	Storage period + shelf life (days) 0	5 +2	10 +2	15 +2	20 +2	Mean
				Season (2015)			
50°C	**A**	0.03 U	0.31 R-U	0.52 Q-S	0.74 Q	1.10 P	0.54 G
	B	5.00 O	5.30 M-O	5.60 LM	6.00 JK	6.32 IJ	5.64 E
	C	10.00 H	10.40 FG	10.82 DE	11.20 B	11.46 AB	10.78 B
	D	0.03 U	0.03 U	0.03 U	0.03 U	0.03	0.03 I
	Mean	3.77 H	4.01 FG	4.24 DE	4.49 C	4.73 B	4.25 B
55°C	**A**	0.03 U	0.20 STU	0.34 R-U	0.50 Q-S	0.72 Q	0.36 H
	B	5.00 O	5.10 NO	5.40 MN	5.80 KL	6.00 JK	5.46 F
	C	10.00 H	10.20 GH	10.60 EF	11.00 CD	11.20 BC	10.60 C
	D	0.03 U	0.03 U	0.03 U	0.03 U	0.03 U	0.03 I
	Mean	3.77 H	3.88 GH	4.09 EF	4.33 CD	4.49 C	4.11 C
Unheated (Control)	**A**	0.03 U	0.41 Q-T	0.61 QR	0.14 TU	1.34 P	0.51 GH
	B	5.00 O	5.62 LM	5.82 KL	6.20 IJ	6.52 I	5.83 D
	C	10.00 H	10.71 DEF	11.00 CD	11.50 AB	11.80 A	11.00 A
	D	0.03 U	0.03 U	0.03 U	0.030 U	0.03 U	0.03 I
	Mean	3.77 H	4.19 DE	4.37 CD	4.47 C	4.92 A	4.34 A
				Interaction MAP × storage period			
Mean	**A**	0.03 M	0.31 L	0.49 L	0.46 L	1.05 K	0.47 C
	B	5.00 J	5.340 I	5.61 H	6.00 G	6.28 F	5.65 B
	C	10.00 E	10.44 D	10.81 C	11.23 B	11.49 A	10.79 A
	D	0.03 M	0.03 M	0.03 M	0.03 M	0.03 M	0.03 D
	Mean	3.77 E	4.03 D	4.23 C	4.43 B	4.71 A	
				season 2016			
50°C	**A**	0.03 X	0.34 T-X	0.57 S-U	0.84 S	1.23 R	0.60 G
	B	5.00 Q	5.33 O-Q	5.65 NO	6.10 LM	6.45 JK	5.71 E
	C	10.00 I	10.43 GH	10.87 D-F	11.30 BC	11.59 AB	10.84 B
	D	0.03 X	0.06 WX	0.08 WX	0.13 V-X	0.16 V-X	0.09 I
	Mean	3.77 I	4.04 GH	4.29 EF	4.59 BC	4.86 A	4.31 B
55°C	**A**	0.03 X	0.23 U-X	0.39 T-W	0.60 ST	0.85 S	0.42 H
	B	5.00 Q	5.13 PQ	5.45 OP	5.90 MN	6.13 K-M	5.52 F
	C	10.00 I	10.23 HI	10.65 FG	11.10 CD	11.33 BC	10.66 C
	D	0.03 X	0.06 WX	0.08 WX	0.13 V-X	0.16 V-X	0.09 I
	Mean	3.77 I	3.91 HI	4.14 FG	4.43 C-E	4.62 B	4.17 C
Unheated (Control)	**A**	0.03 X	0.44 T-V	0.66 ST	0.24 U-X	1.47 R	0.57 GH
	B	5.00 Q	5.65 NO	5.87 MN	6.30 KL	6.65 J	5.89 D
	C	10.00 I	10.74 E-G	11.0 C-E	11.60 AB	11.93 A	11.06 A
	D	0.03 X	0.03 X	0.03 X	0.03 X	0.03 X	0.03 I
	Mean	3.77 I	4.22 F	4.40 DE	4.54 B-D	5.02 A	4.39 A
				Interaction MAP × storage period			
Mean	**A**	0.03 N	0.34 M	0.54 L	0.56 L	1.18 K	0.53 C
	B	5.00 J	5.37 I	5.66 H	6.10 G	6.41 F	5.71 B
	C	10.00 E	10.47 D	10.86 C	11.33 B	11.62 A	10.85 A
	D	0.03 N	0.05 N	0.06 N	0.10 N	0.12 N	0.07 D
	Mean	3.77 E	4.06 D	4.28 C	4.52 B	4.83 A	

Means in the same column having the same letter are not significsantly different at 0.05 levewl by Duncan's multiple rang test.

A= Passive MAP B= Active MAP at 5% O_2+ 5% CO_2

C= Active MAP at 7.5% O_2+ 10% CO_2 D= Unpacked (control)

Each storage period followed by 2 days shelf life (at 10°C and 70% RH); excpt 0 time

Conclusion

Green onion plants dipped in hot water at 55°C for 1 min. and then stored in active MAP at 5% O_2 + 5% CO_2 were the most effective treatment for reducing decay and color change and maintaining high content of chlorophyll, controlling leaf extension growth reduced leaf curvature and root growth and gave plants with excellent appearance for 20 days at O°C + 2 days at 10°C.

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تأثير الغمس فى الماء الساخن والتعبئة فى الجو الهوائى المعدل على الجودة والقدرة التخزينية للبصل الأخضر المقطع جزئيا أثناء التخزين المبرد

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أُجريت الدراسة على نباتات البصل الأخضر الصنف فوتون فى مزرعة خاصة بمركز فايد – محافظة الإسماعيلية خلال عامى ٢٠١٥ و ٢٠١٦ وذلك بهدف دراسة تأثير غمس نباتات البصل الأخضر فى الماء الساخن (٥٠ درجة مئوية لمدة دقيقتين، ٥٥ درجة مئوية لمدة دقيقة بالإضافة إلى النباتات غير المعاملة حراريا (كنترول) ثم يتبعها التعبئة تحت ظروف الجو الهوائى المعدل الموجب (حقن الغازات) ٥% أكسيجين + ٥% ثانى أكسيد الكربون أو ٧,٥ % أكسيجين + ١٠% ثانى أكسيد الكربون إلى جانب غير المعبأة واثر هذه المعاملات على استطالة الأوراق ونمو الجذور وانحناء الأوراق وصفات الجودة لنباتات البصل الأخضر خلال فترة التخزين على درجة الصفر المئوي ورطوبة نسبية ٩٥% لمدة ٢٠ يوم متبوعة بيومين على درجة ١٠°م ورطوبة نسبية ٧٠%، تشير النتائج إلى أن غمس نباتات البصل الأخضر فى الماء الساخن على درجة حرارة ٥٥°م لمدة ٢ ق أدى إلى تقليل نسبة الفقد في الوزن مقارنة بالمعاملة ٥٥°م لمدة ١ ق، كانت المعاملة بالماء الساخن (على درجة حرارة ٥٥°م لمدة ١ ق أو ٢ ق) أو التعبئة في جو هوائى معدل موجب (بتركيز ٥% أكسيجين + ٥% ثاني أكسيد الكربون) أكثر فاعلية لتقليل التالف و تقليل استطالة الأوراق ونمو الجذور والانحناء مع المحافظة على المحتوى من الكلوروفيل خلال التخزين + فترة العرض على الرف، كانت المعاملة بالماء الساخن على درجة ٥٥°م لمدة ٢ ق ثم يتبعها التعبئة في جو هوائى معدل ٧,٥% أكسيجين + ١٠% ثاني أكسيد الكربون الأقل تأثيرا على نفس الصفات السابقة، لم يلاحظ اى تلف فى نباتات البصل الأخضر التي تم غمسها في الماء الساخن على درجة ٥٥°م لمدة ١ ق ثم يتبعها التعبئة فى جو هوائى معدل بتركيز ٥% أكسجين + ٥% ثاني أكسيد الكربون خلال مراحل التخزين المبرد + فترة الرف كما أدت أيضًا إلى التحكم فى نمو الجذور وانحناء الأوراق وتقليل استطالة الأوراق (أقل من ٥ مم) مع الحفاظ على المحتوى من الكلوروفيل كما أعطت مظهر ممتاز وبدون أى أضرار بعد ٢٠ يوم من التخزين على درجة صفر°م + ٢ يوم على ١٠°م (فترة العرض على الرف).

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