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Effect of Hydro-Cooling and Modified Atmosphere Packaging on Quality Attributes of Green Onion During Cold Storage.

Safaa Zakaria and Amira A. Abo Elmakarm

Postharvest and Handling of Vegetable Crops Dept., Horticulture Research Institute, Agriculture Research Center, Giza, Egypt.

ABSTRACT

Green onions (*Allium cepa* L.) plants Photon cv. were harvested when the bulb diameter exceeded 12-16 mm during 2024 and 2025 seasons to study the effect of hydro-cooling and packaging in active modified atmosphere (MAP) at (5%O_2 + 5%CO_2 or 5%O_2 + 7.5%CO_2 or 5%O_2 + 10%CO_2) or in passive MAP beside unpacked plants (control) on quality attributes and storability of green onions during storage at 0°C and 95% relative humidity (RH) for 20 days. The results indicated that the O_2 levels decreased, and CO_2 levels increased inside the packages during storage. The hydrocooling, or MAP significantly reduced weight loss and maintained visual quality, compared to uncooled or unpacked. The results indicated that O_2% and CO_2% inside the package of active and passive MAP had been differed significantly. Results indicated that green onion plants treated with combination between hydro-cooling and active MAP at (5%O_2 + 5%CO_2) or passive gave the most effective treatment in preserving all the quality attributes during storage. Moreover, the combination of hydro-cooling with active MAP at (5%O_2 + 5%CO_2) gave the best results which controlled root growth and leaf curvature, reduced leaf extending growth (less than 5 mm), and maintaining the chlorophyll and phenolic contents and gave excellent appearance without any visible injuries after 20 days of storage at 0°C. while, passive MAP treatment gave a good appearance at the same period.

Keywords: Green- Onion- Packaging- Hydro cooling- Cold storage.

INTRODUCTION

Green onion (*Allium cepa* L.) is one of the most important crops in Egypt, used for local consumption and as exportation commodity. Green onion, a highly perishable crop due to high moisture content, high respiration rate, produces large amount of respiration heat and short life, it needs minimal processing for ready to use. 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 (Frezza et al., 2011). 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 may occur (Hong and Kim, 2004) described postharvest leaf extension growth of fresh cut green onions. This extension also referred to telescoping (Cantwell et al., 2001). Extension growth causes 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 (Viskelais et al., 2012). Therefore, it is important to choose the optimal storage conditions for green onions to provide a high-quality product for fresh market, export and processing, such as precooling and use modified atmosphere packaging (MAP) (Baskran et al., 2015).

The primary purpose of precooling is to slow down the physiological and biochemical activities of fruit and vegetables and prevent fruit and vegetables from developing physiological disorders, delay aging or ripening, reduce postharvest decay, and maintain fruit quality (Kader, 2002), and prepare for the following storage period or shelf-life time. Hydro-cooling is preferable for green onion because cold water cools plants rapidly and the moisture helps to prevent witting or shriveling, an older and effective cooling technique because of the high heat transfer coefficient of water this process involves spraying cold water on fruit and vegetables with a shower system or by immersing fruit and vegetables directly in an agitated bath of cold water or ice water mixture (Liang et al., 2013).

Modified atmosphere can be used to supply the maintenance of optimum temperature and relative humidity for preserving quality and reducing postharvest losses of fruits and vegetables during transportation and storage (Kader, 1996). Modified atmosphere packaging (passive) has been successful in maintaining quality of fruits and vegetables is commonly achieved by packing them in plastic films polyethylene bags which in turn create modified atmosphere to reduce respiration and transpiration rate and reduce water loss, maintain quality and extend shelf life of produce Charles et al. (2008). Modified atmosphere packaging has been used to reduce respiration, delay ripening, decrease ethylene production, retard textural softening, slowdown compositional changes associated with ripening, and associated with biochemical and physiological changes by favorably altering the O_2 and CO_2 levels around the products. Thereby resulting an extension in shelf life (Daş et al., 2006). MAP has a critical role in reducing leaf extension growth and root growth of green onion (Li, 2001), delaying leaf curvature and reduced chlorophyll content loss in green onion (shehata et al., 2017). Omaima and Atress (2016) found that the combination of hydro-cooling with packaging reduces leaf extension growth, root growth and leaf curvature of green onion during storage. Also, the combination of hydro-cooling with MAP is effective in preserving the quality of asparagus during storage (Yoon et al., 2017).

Therefore, this work was conducted to study the effect of combination of hydro-cooling with active and passive modified atmosphere packaging (MAP) on quality attributes of green onion during cold storage at 0°C and 95% RH for 20 days.

MATERIALS AND METHODS

Green onions (*Allium cepa L.*) Photon cv. produced under usual cultivation practices in private farm at Abu Rewash District, Giza Governorate, Egypt. Plants were harvested when bulb diameter exceeded 12-16 mm on the 19th and 22nd of January during 2024 and 2025 seasons respectively. Plants were transferred directly under cooling to the laboratory of postharvest, Handling Research Department, Giza Governorate. Defect free plants were trimmed (leaf tips and root cut) and sorted in uniform size (12-16 mm bulb diameter and 28 cm length by a sharp knife. Defect free plants were bunched (10 plants/bunch) and tied using rubber bands. Then divided into two groups, the first group, green onions plants were hydrocooled after 2 hours from harvest (the temperature of plants before hydro-cooling was 26°C). Hydrocooling was done by dipping the plants in cold water (0-1°C) until the internal temperature of plants reached 2°C which was determined by type-T-thermocouples inserted into the plants and then placed on absorbent paper to remove the excess surface water. The second group was uncooled. Both two groups were treated with modified Atmosphere Packaging (MAP) (active and passive), as follows: Every bunch of green onions (10 plants) was packed in polyethylene bags 30×15 cm in size, 20 μm thickness and heat sealed which represented as one replicate, the bags were flushed with different gas mixtures (active

MAP at: $5\%O_2+5\%CO_2$, $5\%O_2+7.5\%CO_2$ and $5\%O_2+10\%CO_2$), and without flushing (Passive-MAP) beside with unpacked plants (control). Twelve replicates were prepared for each treatment and placed inside carton box (35×22×7cm), the samples were arranged in complete randomized design in three replicates and stored at 0°C and 95% relative humidity (RH) for 20 days and samples were taken every 5 days from the initial time of storage till 20 days. The following quality measurements were recorded:

- **Weight loss:** loss in weight percentage was calculated by the following equation: Loss in weight % = Initial weight of head – weight of head at sampling date / the initial weight of the head×100.
- **General appearance:** The appearance was evaluated using a scale from (1:9) where 9 = excellent, 7 = good, 5 = fair and 3= poor, heads rating (5) or below was considered unmarketable. The general appearance assessment includes symptoms of deterioration (leaf dryness, leaf wilt and yellowing, browning in the cut stem surface and decay).
- **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.
- **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 and 5 =11-15mm
- **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).
- **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.
- **Leaf Chlorophyll Pigmentation (mg/gm of fresh matter):** The contents of chlorophyll were determined spectro-photometrically according to Mitic et al., (2013).
- **Total phenolic content (mg/100g fresh weight):** was measured by the Folin-Ciocalteu method, according to Lee et al. (2015).

Statistical analysis: Experiments were performed in completely randomized factorial design with three replicates. All data were subjected to statistical analysis as described by Snedecor and Cochran (1980) the method of Duncan's multiple range tests was applied for the comparison between means.

RESULTS AND DSCUSSSION

Weight loss:

Results in **Table (1)** show that there was a significant increase in the percentage loss in weight with the prolongation during storage of green onion. These results agreed with Shehata et al. (2017), on fresh cut green onion and may be due to respiration, transpiration and other senescence related to metabolic process during storage (Frezza et al., 2011). Hydro-cooled treatment significantly declined the weight loss percentage as compared to the un-hydrocooled plants these results agree with those obtained by Omaima and Atres (2016). Precooling reduces respiration rate and metabolic activity and slows loss of moisture, which in turn decreases weight loss% during storage (Wijewardane and Guleria, 2013). Active and passive modified atmosphere packaging treatments significantly reduced the weight loss% of plants as compared to the control (unpacked). However, active MAP at 5%O_2+5%CO_2 was the best treatment for significantly reducing weight loss, followed by passive-MAP with no significant difference between them. While unpacked (control) recorded the greatest percentage of weight loss. These results agree with Viškelis et al. (2012) on green onion and may be due to the MAP confinement of moisture around the produce, this increases the relative humidity and reduces vapor-pressure deficit and transpiration. In addition to modified atmosphere packaging, actively or passively, reduces oxygen (O_2) and/or elevates carbon dioxide (CO_2) concentrations and around the produce which slows down metabolic processes and respirating which diminishes the weight loss percentage during storage. The interaction between hydro-cooling, MAP, and storage periods was significant. After 20 days of storage, the lowest value of weight loss was recorded from the combination of hydro-cooling with active MAP at 5%O_2+5%CO_2, followed by hydro-cooling with passive MAP, with no significant differences between them, while the highest value was obtained from uncooled and unpacked plants (control), these results were true in the two seasons.

General appearance

Table (2) Reveals that as expected, the general appearance of green onion plants gradually decreased by prolonging storage period in all treatments. Similar results were reported by Shehata et al. (2017). Frezza et al. (2011) found that the main cause of general appearance loss in green onions was the deterioration (discoloration) of outer oldest leaf decay, leaf curvature, leaf growth extension and yellowing. Hydro-cooled treatment had a significantly higher score of general appearance as compared to the un-hydrocooled plants. These results agree with those obtained by Omaima and Atres (2016). The process of precooling is the removal of field heat which arrests the deteriorative and senescence processes to maintain a high level of quality that ensures customer satisfaction, the quality of fruit and vegetables has become another critical indicator of the effect of precooling with advances in research techniques, since all efforts are aimed at obtaining a good quality of fruit and vegetables with a long shelf life (Duan et al., 2020). All MAP (active and passive) treatments improved the general appearance of green onions compared to unpacked plants, however, GA of green onions stored in active MAP at 5%O_2+5%CO_2 or passive MAP were the most effective treatments for preserving overall plants appearance and gave the highest score with no significant difference between them, while active MAP at 5%O_2 + 7.5%CO_2 or 5%O_2 + 10%CO_2 were less effective in this concern. On the other hand, unpacked control gave the lowest score of GA. These results agree with Fan et al. (2003) also mentioned that MAP maintained GA in green onions. Viskelis et al. (2012) found that modified atmosphere storage helps to preserve quality green onions, delays the senescence and extended the shelf life of green onion (Frezza et al., 2011). Depleted O_2 and/or enriched CO_2 levels can reduce respiration, delay ripening, decrease ethylene production, retard textural softening, slowdown compositional changes associated with ripening, thereby resulting an extension in shelf life of products (Das et al., 2006). The interaction among hydro-cooling, MAP and storage period was significant. After 20 days of storage, the combination of hydro-cooling with active MAP at (5%O_2+5%CO_2), showed excellent appearance and did not exhibit any change in GA, while the combination of hydro-cooling with passive MAP rated good appearance. On the other hand, uncooled and unpacked (control) had an unsalable appearance at the same period. The results were true in the two seasons and in agreement with Yoon et al. (2017) who found that the combination of hydro-cooling with the MAP is effective in preserving quality of asparagus.

Table (1). Effect of hydro-cooling and MAP on weight loss percentage of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	0.00o	0.11no	0.30k-o	0.40j-o	0.70i-o	**0.30EF**
	Active (5%O_2+5%CO_2)	0.00o	0.07no	0.11no	0.17m-o	0.22l-o	**0.11F**
	Active (5%O_2+7.5%CO_2)	0.00o	0.30k-o	0.52j-o	0.81h-o	1.16g-l	**0.56DE**
	Active (5%O_2+10%CO_2)	0.00o	0.36j-o	0.66j-o	1.00g-n	1.21g-k	**0.64C-E**
	Control-Unpacked	0.00o	3.37f	8.76d	10.56c	13.41b	**7.22B**
	Mean	**0.00F**	**0.84E**	**2.07D**	**2.59C**	**3.34B**	**1.77B**
NON-Cooling	**Passive**	0.00o	0.22l-o	0.61j-o	0.78h-o	1.00g-n	**0.52D-F**
	Active (5%O_2+5%CO_2)	0.00o	0.15m-o	0.30k-o	0.42j-o	0.61j-o	**0.30EF**
	Active (5%O_2+7.5%CO_2)	0.00o	0.52j-o	0.99g-n	1.30g-j	1.67gh	**0.90CD**
	Active (5%O_2+10%CO_2)	0.00o	0.74h-o	1.10g-m	1.65g-i	1.80g	**1.06C**
	Control-Unpacked	0.00o	4.58e	10.97c	12.77b	15.61a	**8.79A**
	Mean	**0.00F**	**1.24E**	**2.79C**	**3.38B**	**4.14A**	**2.31A**
MEAN	**Passive**	0.00j	0.17ij	0.46g-j	0.59g-j	0.85e-h	**0.41C**
	Active (5%O_2+5%CO_2)	0.00j	0.11ij	0.21h-j	0.30h-j	0.42g-j	**0.21C**
	Active (5%O_2+7.5%CO_2)	0.00j	0.41g-j	0.75f-i	1.06e-g	1.42ef	**0.73B**
	Active (5%O_2+10%CO_2)	0.00j	0.55g-j	0.88e-h	1.33ef	1.50e	**0.85B**
	Control-Unpacked	0.00j	3.97d	9.87c	11.67b	14.51a	**8.00A**
	Mean	**0.00E**	**1.04D**	**2.43C**	**2.99B**	**3.74A**	
		2025season					
PRE-Cooling	**Passive**	0.00n	0.10mn	0.29k-n	0.38j-n	0.69i-n	**0.29FG**
	Active (5%O_2+5%CO_2)	0.00n	0.06mn	0.10mn	0.15l-n	0.21l-n	**0.10G**
	Active (5%O_2+7.5%CO_2)	0.00n	0.28k-n	0.53i-n	0.86h-m	1.15g-j	**0.56D-F**
	Active (5%O_2+10%CO_2)	0.00n	0.36j-n	0.65i-n	1.16g-j	1.20g-j	**0.67C-E**
	Control-Unpacked	0.00n	3.69f	8.75d	10.78c	13.40b	**7.33B**
	Mean	**0.00G**	**0.90 F**	**2.06D**	**2.67C**	**3.33B**	**1.79B**
NON-Cooling	**Passive**	0.00n	0.21l-n	0.60i-n	0.77i-n	0.99g-l	**0.51EF**
	Active (5%O_2+5%CO_2)	0.00n	0.14mn	0.29k-n	0.41j-n	0.60i-n	**0.29FG**
	Active (5%O_2+7.5%CO_2)	0.00n	0.55i-n	1.16g-j	1.29g-i	1.66gh	**0.93CD**
	Active (5%O_2+10%CO_2)	0.00n	0.74i-n	1.09g-k	1.64gh	1.79g	**1.05C**
	Control-Unpacked	0.00n	4.89e	10.96c	12.83b	15.67a	**8.87A**
	Mean	**0.00G**	**1.31E**	**2.82C**	**3.39B**	**4.14A**	**2.33A**
MEAN	**Passive**	0.00i	0.15i	0.44hi	0.58g-i	0.84f-h	**0.40C**
	Active (5%O_2+5%CO_2)	0.00i	0.10i	0.19i	0.28hi	0.41hi	**0.20C**
	Active (5%O_2+7.5%CO_2)	0.00i	0.42hi	0.84f-h	1.08e-g	1.41ef	**0.75B**
	Active (5%O_2+10%CO_2)	0.00i	0.55g-i	0.87f-h	1.40ef	1.49e	**0.86B**
	Control-Unpacked	0.00i	4.29d	9.86c	11.81b	14.54a	**8.10A**
	Mean	**0.00E**	**1.10D**	**2.44C**	**3.03B**	**3.74A**	

The values that contain the same capital or small letters in the same columns and rows indicate that there are no significant variations between each other at level 0.05. (**THE SAME ALL Tables)**

Table (2). Effect of hydro-cooling and MAP on General Appearance (score) of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	9.00a	9.00a	9.00a	8.33ab	7.00b-d	**8.47A**
	Active (5%O_2+5%CO_2)	9.00a	9.00a	9.00a	9.00a	8.33ab	**8.87A**
	Active (5%O_2+7.5%CO_2)	9.00a	7.00b-d	6.33c-e	4.33f-h	2.33i-k	**5.80DE**
	Active (5%O_2+10%CO_2)	9.00a	9.00a	7.00b-d	5.67d-f	4.33f-h	**7.00BC**
	Control-Unpacked	9.00a	7.00b-d	6.33c-e	4.33f-h	1.67jk	**5.67D-F**
	Mean	**9.00A**	**8.20B**	**7.53C**	**6.33D**	**4.73E**	**7.16A**
NON-Cooling	**Passive**	9.00a	9.00a	8.33ab	6.33c-e	5.00e-g	**7.53B**
	Active (5%O_2+5%CO_2)	9.00a	7.67a-c	7.00b-d	6.33c-e	4.33f-h	**6.87C**
	Active (5%O_2+7.5%CO_2)	9.00a	6.33c-e	5.00e-g	4.33f-h	3.00h-j	**5.53EF**
	Active (5%O_2+10%CO_2)	9.00a	7.67a-c	7.00b-d	5.00e-g	2.33i-k	**6.20D**
	Control-Unpacked	9.00a	6.33c-e	5.67d-f	3.67g-i	1.00 k	**5.13F**
	Mean	**9.00A**	**7.40C**	**6.60D**	**5.13E**	**3.13F**	**6.25B**
MEAN	**Passive**	9.00a	8.33a-c	8.00b-d	7.33d-f	5.67h	**7.67B**
	Active (5%O_2+5%CO_2)	9.00a	9.00a	8.67ab	7.67c-e	6.67fg	**8.20A**
	Active (5%O_2+7.5%CO_2)	9.00a	6.67fg	5.67h	4.33i	2.67k	**5.67D**
	Active (5%O_2+10%CO_2)	9.00a	8.33a-c	7.00ef	5.33h	3.33jk	**6.60C**
	Control-Unpacked	9.00a	6.67fg	6.00gh	4.00ij	1.33l	**5.40D**
	Mean	**9.00A**	**7.80B**	**7.07C**	**5.73D**	**3.93E**	
		2025season					
PRE-Cooling	**Passive**	9.00a	9.00a	9.00a	8.33ab	7.00b-d	**8.47A**
	Active (5%O_2+5%CO_2)	9.00a	9.00a	9.00a	9.00a	8.33ab	**8.87A**
	Active (5%O_2+7.5%CO_2)	9.00a	7.67a-c	5.67d-f	3.67g-i	2.33i-k	**5.67D**
	Active (5%O_2+10%CO_2)	9.00a	9.00a	6.33c-e	5.67d-f	3.67g-i	**6.73C**
	Control-Unpacked	9.00a	7.00b-d	5.67d-f	3.67g-i	1.00k	**5.27D**
	Mean	**9.00A**	**8.33B**	**7.13C**	**6.07D**	**4.47E**	**7.00A**
NON-Cooling	**Passive**	9.00a	9.00a	7.67a-c	7.00b-d	5.67d-f	**7.67B**
	Active (5%O_2+5%CO_2)	9.00a	7.67a-c	7.00b-d	6.33c-e	5.00e-g	**7.00C**
	Active (5%O_2+7.5%CO_2)	9.00a	7.00b-d	4.33f-h	3.67g-i	3.00h-j	**5.40D**
	Active (5%O_2+10%CO_2)	9.00a	7.00b-d	6.33c-e	4.33f-h	2.33i-k	**5.80D**
	Control-Unpacked	9.00a	5.67d-f	5.00e-g	1.67jk	1.00k	**4.47E**
	Mean	**9.00A**	**7.27C**	**6.07D**	**4.60E**	**3.40F**	**6.07B**
MEAN	**Passive**	9.00a	8.33ab	8.00bc	7.33cd	6.00fg	**7.73B**
	Active (5%O_2+5%CO_2)	9.00a	9.00a	8.33ab	8.00bc	7.00de	**8.27A**
	Active (5%O_2+7.5%CO_2)	9.00a	7.33cd	5.00h	3.67i	2.67j	**5.53D**
	Active (5%O_2+10%CO_2)	9.00a	8.00bc	6.33ef	5.00h	3.00ij	**6.27C**
	Control-Unpacked	9.00a	6.33ef	5.33gh	2.67j	1.00k	**4.87E**
	Mean	**9.00A**	**7.80B**	**6.60C**	**5.33D**	**3.93E**	

Leaf extension and root growth:

The results in **Tables (3 and 4)** reveal an increase in the leaf extension and root growth extension of green onion, with increasing storage durations. Such an increase in leaf extension and root growth affected negatively the market quality (Hong et al., 2000). These results were correct in the two seasons and agree with Shehata et al. (2017). Hydro-cooling treatment was much better in reducing leaf extension growth and root growth compared to un-cooling treatment with significant difference between them. These results were true in the two seasons and agree with Omaima and Atres (2016). Green onions stored in active MAP at (5%O_2+5%CO_2) was the most effective treatments in reducing leaf extension growth and root growth during storage without causing visible injury to fresh cut green onion followed by passive MAP with significant difference between them in first season, while the active MAP 5%O_2+7.5%CO_2 or 5%O_2+10%CO_2 treatments were less effective in this regard and unpack (control). These results were true in both seasons and in agreement with Shehata et al. (2017). 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. Growth phenomena such as sprouting root development of onion bulbs are inhibited by low O_2 and/or high atmosphere (Kader, 1996). 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. The interaction among hydro-cooling, MAP and storage periods on the leaf extension and growth of roots were significant. After 20 days, the most successful treatment for inhibiting the growth of roots and leaf extension were combination of hydro-cooling with active MAP at ($5\%O_2$+$5\%CO_2$) which had the lowest values of leaf extension and did not show any rooting followed by hydro-cooling with passive MAP, while the highest value was recorded with uncooled and unpacked plants stored at 0°C during the same period.

Table (3). Effect of hydro-cooling and MAP on Leaf extension growth (mm) of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

				2024season			
	TREATMENTS	**During storage (days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	0.00r	0.00r	0.80o-r	1.20l-p	2.00h-l	**0.80E**
	Active ($5\%O_2$+$5\%CO_2$)	0.00r	0.00r	0.20qr	0.40p-r	0.45o-r	**0.21F**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00r	0.00r	1.33k-o	2.60hi	3.83d-f	**1.55CD**
	Active ($5\%O_2$+$10\%CO_2$)	0.00r	0.00r	1.67j-n	2.70gh	4.40c-e	**1.75C**
	Control-Unpacked	0.00r	1.20l-p	2.10h-k	3.67ef	5.60ab	**2.51B**
	Mean	**0.00F**	**0.24F**	**1.22D**	**2.11C**	**3.26B**	**1.36B**
NON-Cooling	**Passive**	0.00r	0.60o-r	1.20l-p	1.83i-m	2.40h-j	**1.21D**
	Active ($5\%O_2$+$5\%CO_2$)	0.00r	0.00r	0.82n-r	1.33k-o	1.67j-n	**0.76E**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00r	1.00m-q	2.03h-l	3.50fg	4.30c-f	**2.17B**
	Active ($5\%O_2$+$10\%CO_2$)	0.00r	0.82n-r	2.40h-j	3.90d-f	4.94bc	**2.41B**
	Control-Unpacked	0.00r	1.67j-m	2.70gh	4.60cd	6.00a	**2.99A**
	Mean	**0.00F**	**0.82E**	**1.83C**	**3.03B**	**3.86A**	**1.91A**
MEAN	**Passive**	0.00m	0.30lm	1.00i-k	1.52g-i	2.20ef	**1.00C**
	Active ($5\%O_2$+$5\%CO_2$)	0.00m	0.00m	0.51k-m	0.87j-l	1.06h-j	**0.50D**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00m	0.50k-m	1.68f-h	3.05d	4.07c	**1.86B**
	Active ($5\%O_2$+$10\%CO_2$)	0.00m	0.41k-m	2.03e-g	3.30d	4.67b	**2.08B**
	Control-Unpacked	0.00m	1.44g-j	2.40e	4.13bc	5.80a	**2.75A**
	Mean	**0.00E**	**0.53D**	**1.53C**	**2.57B**	**3.57A**	
				2025season			
PRE-Cooling	**Passive**	0.00q	0.00q	0.26o-q	1.07m-p	1.00m-p	**0.47GH**
	Active ($5\%O_2$+$5\%CO_2$)	0.00q	0.00q	0.20pq	0.27o-q	0.33n-q	**0.16H**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00q	0.00q	1.67j-m	2.52ij	3.50e-h	**1.54E**
	Active ($5\%O_2$+$10\%CO_2$)	0.00q	0.00q	1.67j-m	2.70hi	4.40c-e	**1.75DE**
	Control-Unpacked	0.00q	1.13m-o	2.37i-k	3.67e-g	5.37ab	**2.51B**
	Mean	**0.00F**	**0.23F**	**1.23D**	**2.04C**	**2.92B**	**1.28B**
NON-Cooling	**Passive**	0.00q	0.33n-q	1.20l-n	1.50k-m	2.12i-l	**1.03F**
	Active ($5\%O_2$+$5\%CO_2$)	0.00q	0.00q	0.86m-q	1.21l-n	1.67j-m	**0.75FG**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00q	1.03m-p	2.13i-k	2.98f-i	3.85d-f	**2.00CD**
	Active ($5\%O_2$+$10\%CO_2$)	0.00q	0.87m-q	2.22i-k	3.92de	4.95bc	**2.39BC**
	Control-Unpacked	0.00q	1.76j-m	2.77g-i	4.72b-d	6.17a	**3.08A**
	Mean	**0.00F**	**0.80E**	**1.84C**	**2.87B**	**3.75A**	**1.85A**
MEAN	**Passive**	0.00n	0.17mn	0.73k-m	1.28i-k	1.56h-j	**0.75D**
	Active ($5\%O_2$+$5\%CO_2$)	0.00n	0.00n	0.53l-n	0.74k-m	1.00j-l	**0.45E**
	Active ($5\%O_2$+$7.5\%CO_2$)	0.00n	0.52l-n	1.90hi	2.75ef	3.68cd	**1.77C**
	Active ($5\%O_2$+$10\%CO_2$)	0.00n	0.44l-n	1.94gh	3.31de	4.67b	**2.07B**
	Control-Unpacked	0.00n	1.45h-j	2.5fg	4.19bc	5.77a	**2.79A**
	Mean	**0.00E**	**0.51D**	**1.53C**	**2.45B**	**3.34A**	

Table (4). Effect of hydro-cooling and MAP on Root Growth (score) of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	1.00j	1.00j	1.00j	2.00g-i	2.33f-h	**1.47E**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.G00j	1.00j	1.00j	**1.00F**
	Active (5%O_2+7.5%CO_2)	1.00j	1.33ij	1.67h-j	2.67e-g	3.00d-f	**1.93CD**
	Active (5%O_2+10%CO_2)	1.00j	1.00j	1.67h-j	3.00d-f	3.33c-e	**2.00CD**
	Control-Unpacked	1.00j	1.00j	2.00g-i	3.33c-e	4.00bc	**2.27BC**
	Mean	**1.00F**	**1.07F**	**1.47E**	**2.40CD**	**2.73BC**	**1.73B**
NON-Cooling	**Passive**	1.00j	1.00j	1.33ij	2.33f-h	2.67e-g	**1.67DE**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.33ij	1.67h-j	2.00g-i	**1.40E**
	Active (5%O_2+7.5%CO_2)	1.00j	1.00j	2.33f-h	3.00d-f	3.67b-d	**2.20BC**
	Active (5%O_2+10%CO_2)	1.00j	1.00j	2.67e-g	3.33c-e	4.33ab	**2.47B**
	Control-Unpacked	1.00j	1.33ij	3.00d-f	4.00bc	5.00a	**2.87A**
	Mean	**1.00F**	**1.07F**	**2.13D**	**2.87B**	**3.53A**	**2.12A**
MEAN	**Passive**	1.00h	1.00h	1.17h	2.17f	2.50ef	**1.57C**
	Active (5%O_2+5%CO_2)	1.00h	1.00h	1.17h	1.33h	1.50gh	**1.20D**
	Active (5%O_2+7.5%CO_2)	1.00h	1.17h	2.00fg	2.83de	3.33b-d	**2.07B**
	Active (5%O_2+10%CO_2)	1.00h	1.00h	2.17f	3.17cd	3.83b	**2.23B**
	Control-Unpacked	1.00h	1.17h	2.50ef	3.67bc	4.50a	**2.57A**
	Mean	**1.00D**	**1.07D**	**1.80C**	**2.63B**	**3.13A**	
		2025season					
PRE-Cooling	**Passive**	1.00j	1.00j	1.00j	1.67h-j	1.67h-j	**1.27D**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.00j	1.33ij	1.33ij	**1.13D**
	Active (5%O_2+7.5%CO_2)	1.00j	1.33ij	1.67h-j	2.67e-g	2.67e-g	**1.87C**
	Active (5%O_2+10%CO_2)	1.00j	1.00j	1.67h-j	3.00d-f	4.00bc	**2.13BC**
	Control-Unpacked	1.00j	1.33ij	2.00g-i	3.00d-f	4.00bc	**2.27B**
	Mean	**1.00E**	**1.13DE**	**1.47D**	**2.33C**	**2.73B**	**1.73B**
NON-Cooling	**Passive**	1.00j	1.00j	1.33ij	2.00g-i	1.67h-j	**1.40D**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.33ij	1.67h-j	1.67h-j	**1.33D**
	Active (5%O_2+7.5%CO_2)	1.00j	1.00j	2.33f-h	3.00d-f	3.67b-d	**2.20BC**
	Active (5%O_2+10%CO_2)	1.00j	1.00j	2.33f-h	3.33c-e	4.33ab	**2.40B**
	Control-Unpacked	1.00j	1.67h-j	3.00d-f	3.67b-d	5.00a	**2.87A**
	Mean	**1.00E**	**1.13DE**	**2.07C**	**2.73B**	**3.27A**	**2.04A**
MEAN	**Passive**	1.00g	1.00g	1.17fg	1.83e	1.67ef	**1.33C**
	Active (5%O_2+5%CO_2)	1.00g	1.00g	1.17fg	1.50e-g	1.50e-g	**1.23C**
	Active (5%O_2+7.5%CO_2)	1.00g	1.17fg	2.00de	2.83bc	3.17b	**2.03B**
	Active (5%O_2+10%CO_2)	1.00g	1.00g	2.00de	3.17b	4.17a	**2.27B**
	Control-Unpacked	1.00g	1.50e-g	2.50cd	3.33b	4.50a	**2.57A**
	Mean	**1.00D**	**1.13D**	**1.77C**	**2.53B**	**3.00A**	

Leaf curvature:

Curvature was a common defect in the commercial green onion product. This curvature is due to the negative geotropism, which occurs when the product is placed horizontally (Shehata et al., 2010). As shown in **Table (5)**. There is a considerable increase in the Leaf Curvature (score) of green onion with the extension of the storage duration. These results were true in the two seasons of study and agree with Emam (2009) green onions during storage. However, hydro-cooling treatments reduce significantly the incidence of Leaf Curvature when compared to un-cooling treatment. Also, MAP was the most effective treatment in decrease Leaf Curvature in green onion compared control (unpacked). These results were true in the two seasons and agree with Hong et al. (2000) who found that packaging in nonperforated bags creates a modified atmosphere with higher concentration of CO_2 and reduced O_2 around the produce which slows down the metabolic processes and inhibition ethylene production, with a reduction of respiration rate. The interaction among hydro-cooling, MAP and storage period was significant during storage, however, the combination between hydro-cooling with active MAP at (5%O_2+5%CO_2) did not observe any signs of leaf curvature till 20 days of storage at 0°C, followed by hydro-cooling with passive MAP which gave a slight score of leaf curvature at the same period. On the other hand, uncooled and unpacked plants gave the highest score (extra sever of leaf curvature) at the same period in the two seasons.

Table (5). Effect of hydro-cooling and MAP on Leaf Curvature (score) of green onion during cold storage at 0°C and RH 90-95% during 2024and2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	1.00h	1.00h	1.00h	1.67f-h	2.00e-h	**1.33EF**
	Active (5%O_2+5%CO_2)	1.00h	1.00h	1.00h	1.00h	1.33gh	**1.07F**
	Active (5%O_2+7.5%CO_2)	1.00h	1.33gh	1.67f-h	2.67c-f	3.00b-e	**1.93CD**
	Active (5%O_2+10%CO_2)	1.00h	1.00h	1.67f-h	2.00e-h	3.33b-d	**1.80D**
	Control-Unpacked	1.00h	1.67f-h	2.67c-f	3.67bc	4.00ab	**2.60AB**
	Mean	**1.00F**	**1.20EF**	**1.60DE**	**2.20C**	**2.73B**	**1.75B**
NON-Cooling	**Passive**	1.00h	1.00h	1.00h	2.67c-f	2.67c-f	**1.67DE**
	Active (5%O_2+5%CO_2)	1.00h	1.00h	1.00h	1.33gh	1.67f-h	**1.20F**
	Active (5%O_2+7.5%CO_2)	1.00h	1.33gh	2.00e-h	3.33b-d	3.67bc	**2.27BC**
	Active (5%O_2+10%CO_2)	1.00h	1.67f-h	2.33d-g	3.67bc	4.00ab	**2.53B**
	Control-Unpacked	1.00h	2.00e-h	3.00b-e	4.00ab	5.00a	**3.00A**
	Mean	**1.00F**	**1.40EF**	**1.87CD**	**3.00AB**	**3.40A**	**2.13A**
MEAN	**Passive**	1.00k	1.00k	1.00k	2.17f-h	2.33e-g	**1.50C**
	Active (5%O_2+5%CO_2)	1.00k	1.00k	1.00k	1.17jk	1.50h-k	**1.13D**
	Active (5%O_2+7.5%CO_2)	1.0k	1.33i-k	1.83g-j	3.00c-e	3.33b-d	**2.10B**
	Active (5%O_2+10%CO_2)	1.00k	1.33i-k	2.00g-i	2.83d-f	3.67bc	**2.17B**
	Control-Unpacked	1.00k	1.83g-j	2.83d-f	3.83ab	4.50a	**2.80A**
	Mean	**1.00D**	**1.30D**	**1.73C**	**2.60B**	**3.07A**	
		2025season					
PRE-Cooling	**Passive**	1.00j	1.00j	1.00j	1.00j	1.33ij	**1.07E**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.00j	1.00j	1.00j	**1.00E**
	Active (5%O_2+7.5%CO_2)	1.00j	1.33ij	1.67h-j	3.00d-g	4.00a-d	**2.20CD**
	Active (5%O_2+10%CO_2)	1.00j	1.00j	2.00g-j	2.33f-i	3.67b-e	**2.00D**
	Control-Unpacked	1.00j	1.67h-j	2.67e-h	4.00a-d	4.67ab	**2.80AB**
	Mean	**1.00E**	**1.13E**	**1.67CD**	**2.00D**	**2.80AB**	**1.83B**
NON-Cooling	**Passive**	1.00j	1.00j	1.00j	1.67h-j	2.33f-i	**1.40E**
	Active (5%O_2+5%CO_2)	1.00j	1.00j	1.00j	1.33ij	2.00g-j	**1.27E**
	Active (5%O_2+7.5%CO_2)	1.00j	1.33ij	2.67e-h	3.33c-f	4.00a-d	**2.47BC**
	Active (5%O_2+10%CO_2)	1.00j	1.67h-j	2.33f-i	3.67b-e	4.33a-c	**2.60BC**
	Control-Unpacked	1.00j	2.00g-j	3.33c-f	4.00a-d	5.00a	**3.07A**
	Mean	**1.40E**	**1.27E**	**2.47BC**	**2.60BC**	**3.07A**	**2.16A**
MEAN	**Passive**	1.00f	1.00f	1.00f	1.33ef	1.67d-f	**1.20C**
	Active (5%O_2+5%CO_2)	1.00f	1.00f	1.17ef	1.17ef	1.67d-f	**1.20C**
	Active (5%O_2+7.5%CO_2)	1.00f	1.33ef	2.17d	3.17c	4.00b	**2.33B**
	Active (5%O_2+10%CO_2)	1.00f	1.33ef	2.17d	3.00c	4.00b	**2.30B**
	Control-Unpacked	1.00f	1.83de	3.00c	4.00b	4.83a	**2.93A**
	Mean	**1.00D**	**1.30D**	**1.90C**	**2.53B**	**3.23A**	

Gas composition in the package:

Data in **Tables (6 and 7)** Show that there was a significant decrease in O_2% and an increase in CO_2% in the packages during storage periods, due to the continuous process of respiration after harvest. These results were true in the two seasons and in agreement with Hong and Kim (2004) on green onion and maybe the consumption of O_2 and production of CO_2 during respiration of green onion. The CO_2 released during respiration proportionally reduces the respiration rate of green onions (Viškelis et al., 2012) and may be due to consummation of O_2 and production of CO_2 inside the package (Duan et al., 2020).

The atmosphere analysis showed that in active and passive MAP, the atmosphere had been modified **(Tables 6 and7).** However, the lowest consumption of O_2 and production of CO_2 were recorded with plant stored in active MAP at 5%O_2+5%CO_2**.** In contrast, unpacked plants showed no changes in O_2, and CO_2 concentrations thought the storage period. Due to O_2 partial pressure decreased whereas CO_2 partial pressure increased, during a transient period, to reach a steady state different from air, a so-called equilibrium modified atmosphere (MAP). O_2 consumption and CO_2 production) was balanced by O_2 and CO_2 diffusion through the polyethylene film (packaging) compared control (Charles et al., 2008). The O_2 and CO_2 inside the package of active and passive MAP had been differed significantly. However, O_2 levels in active MAP were lower than those of passive MAP as shown in **Table (6)**, while value of CO_2 was higher in **Table (7)**. Respiration rate decreased with a decreasing O_2 concentration and increasing CO_2 concentration (Kasim, 2009).

Chlorophyll contents:

Data presented in **Table (8)** shows that chlorophyll content in green onion plants a progressive and a significant decrease happened in chlorophyll content as the storage period was prolonged. 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 agree with Shehata et al. (2017**)** on green onion. Regarding treatments, it is clear from the results that Hydro-cooling green onion plants significantly reduced chlorophyll degradation of green onion leaves compared with un-cooling treatments. These results agreed with the findings of (Omaima and Atres, 2016) green onion. Rapid fruit cooling after harvest reduces metabolism and the degradation of chlorophyll because of the reduction in ethylene production. This is combined with the action of chlorophylls and oxidative systems, because the color change of the stem is suppressed in the water-cooled system, which affects the green appearance quality on precooling fruit (Yoon et al., 2017). Concerning the effect of MAP, results revealed that green onions stored in active and passive MAP reduced the loss of chlorophyll content during storage compared control, however, active MAP at 5%O2+5%CO2 followed by passive MAP were the most effective treatments in maintaining chlorophyll content with no significant differences between them. On the other hand, unpacked plants (control) gave the lowest value of chlorophyll content during storage. These results were true in the two seasons and agree with **Frezza *et al.* *(*2011),** who found that MAP reduced the respiration process resulting in decreased activity of chlorophylls enzyme and decreased chlorophyll. The interaction between hydro-cooling, MAP and storage period on chlorophyll content was significant during storage. However, after 20 days of storage, the combination of hydrocooling with active MAP at 5%O_2+5%CO_2 was the most effective in reducing chlorophyll loss.

Table (6). Effect of hydro-cooling and MAP on O_2 concentration of green onion during cold storage at 0°C and RH 90-95% during 2024 and2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	21.00a	20.92a	20.25ab	18.00c	15.96d	**19.23B**
	Active(5%O_2+5%CO_2)	5.00f	4.75fg	4.40f-i	4.22f-j	4.08g-l	**4.49D**
	Active(5%O_2+7.5%CO_2)	5.00f	4.75fg	4.22f-j	3.37k-o	3.00m-o	**4.07E**
	Active(5%O_2+10%CO_2)	5.00f	4.43f-h	4.00g-l	3.67h-m	3.03m-o	**4.03E**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00A**
	Mean	**11.40A**	**11.17A**	**10.77B**	**10.05C**	**9.42D**	**10.56A**
NON-Cooling	**Passive**	21.00a	19.53b	19.57b	16.42d	14.61e	**18.22C**
	Active(5%O_2+5%CO_2)	5.00 f	4.35f-i	4.10g-k	3.50j-o	3.13m-o	**4.02E**
	Active(5%O_2+7.5%CO_2)	5.00 f	4.39f-i	3.62i-n	3.00m-o	2.77op	**3.76EF**
	Active(5%O_2+10%CO_2)	5.00 f	4.30f-i	3.30l-o	2.87no	2.01p	**3.50F**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00A**
	Mean	**11.40A**	**10.71B**	**10.32C**	**9.36D**	**8.70E**	**10.10B**
MEAN	**Passive**	21.00a	20.22b	19.91b	17.21c	15.28d	**18.73B**
	Active(5%O_2+5%CO_2)	5.00e	4.55ef	4.25fg	3.86gh	3.61hi	**4.25C**
	Active(5%O_2+7.5%CO_2)	5.00e	4.57ef	3.92gh	3.18ij	2.88jk	**3.91D**
	Active(5%O_2+10%CO_2)	5.00e	4.37fg	3.65hi	3.27ij	2.52k	**3.76D**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00A**
	Mean	**11.40A**	**10.94B**	**10.55C**	**9.70D**	**9.06E**	
		2025season					
PRE-Cooling	**Passive**	21.00a	20.87a	20.31ab	18.13d	15.98e	**19.26B**
	Active(5%O_2+5%CO_2)	5.00g	4.78gh	4.45g-i	4.26g-k	4.11h-l	**4.52D**
	Active(5%O_2+7.5%CO_2)	5.00g	4.71gh	4.24g-k	3.44l-p	3.10n-p	**4.10E**
	Active(5%O_2+10%CO_2)	5.00g	4.54gh	4.07h-m	3.69i-n	3.06n-p	**4.07E**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00A**
	Mean	**11.40A**	**11.18A**	**10.81B**	**10.10C**	**9.45D**	**10.59A**
NON-Cooling	**Passive**	15.98e	21.00a	19.50c	19.57bc	16.43e	**18.28C**
	Active(5%O_2+5%CO_2)	4.11h-l	5.00g	4.46g-i	4.10h-m	3.53k-p	**4.05E**
	Active(5%O_2+7.5%CO_2)	3.10n-p	5.00g	4.47gh	3.62j-o	3.00n-p	**3.80EF**
	Active(5%O_2+10%CO_2)	3.06n-p	5.00g	4.33g-j	3.34m-p	2.80pq	**3.52F**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00A**
	Mean	**11.40A**	**10.75B**	**10.32C**	**9.35D**	**8.82E**	**10.13B**
MEAN	**Passive**	21.00a	20.18b	19.94b	17.28c	15.44d	**18.77 B**
	Active(5%O_2+5%CO_2)	5.00e	4.62ef	4.28fg	3.90gh	3.65hi	**4.29 C**
	Active(5%O_2+7.5%CO_2)	5.00e	4.59ef	3.93gh	3.22ij	3.00jk	**3.95 D**
	Active(5%O_2+10%CO_2)	5.00e	4.44fg	3.70hi	3.24ij	2.59k	**3.79 D**
	Control-Unpacked	21.00a	21.00a	21.00a	21.00a	21.00a	**21.00 A**
	Mean	**11.40A**	**10.97B**	**10.57C**	**9.73D**	**9.14E**	

Table (7). Effect of hydro-cooling and MAP on CO_2 concentration of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	0.03p	0.38p	0.59p	1.41o	1.61o	**0.80H**
	Active (5%O_2+5%CO_2)	5.00m	5.15lm	5.32lm	5.71kl	6.07k	**5.45F**
	Active (5%O_2+7.5%CO_2)	7.5 j	7.83ij	9.43h	10.27fg	10.83ef	**9.17D**
	Active (5%O_2+10%CO_2)	10.00gh	10.70f	10.89ef	11.70d	14.41b	**11.54B**
	Control-Unpacked	0.03p	0.03p	0.03p	0.03p	0.03p	**0.03I**
	Mean	**4.51G**	**4.82FG**	**5.25E**	**5.82D**	**6.59C**	**5.40B**
NON-Cooling	**Passive**	0.03p	0.48p	0.50p	3.27n	4.80m	**1.82G**
	Active (5%O_2+5%CO_2)	5.00m	5.70kl	6.10k	8.28i	9.87gh	**6.99E**
	Active (5%O_2+7.5%CO_2)	7.50j	7.96ij	9.43h	11.47de	11.63d	**9.60C**
	Active (5%O_2+10%CO_2)	10.00gh	10.83ef	12.90c	13.15c	15.62a	**12.50A**
	Control-Unpacked	0.03p	0.03p	0.03p	0.03p	0.03p	**0.03I**
	Mean	**4.51G**	**5.00EF**	**5.79D**	**7.24B**	**8.39A**	**6.19A**
MEAN	**Passive**	0.03n	0.43mn	0.55m	2.34l	3.21k	**1.31D**
	Active (5%O_2+5%CO_2)	5.00j	5.42ij	5.71i	7.00h	7.97g	**6.22C**
	Active (5%O_2+7.5%CO_2)	7.50g	7.90g	9.43f	10.87d	11.23d	**9.39B**
	Active (5%O_2+10%CO_2)	10.00e	10.77d	11.89c	12.43b	15.01a	**12.02A**
	Control-Unpacked	0.03n	0.03n	0.03n	0.03n	0.03n	**0.03E**
	Mean	**4.51E**	**4.91D**	**5.52C**	**6.53B**	**7.49A**	
		2025season					
PRE-Cooling	**Passive**	0.03p	0.22p	0.57p	1.37o	1.56o	**0.75H**
	Active (5%O_2+5%CO_2)	5.00m	5.15lm	5.29lm	5.67kl	6.00k	**5.42F**
	Active (5%O_2+7.5%CO_2)	7.50j	7.69j	8.96i	10.00gh	10.63e-g	**8.96D**
	Active (5%O_2+10%CO_2)	10.00gh	10.48fg	10.89ef	11.63d	14.11b	**11.42B**
	Control-Unpacked	0.03p	0.03p	0.03p	0.03p	0.03p	**0.03I**
	Mean	**4.51G**	**4.72FG**	**5.15E**	**5.74D**	**6.47C**	**5.32B**
NON-Cooling	**Passive**	0.03p	0.33p	0.49p	2.83n	4.73m	**1.68G**
	Active (5%O_2+5%CO_2)	5.00m	5.66kl	5.97k	8.08j	9.53hi	**6.85E**
	Active (5%O_2+7.5%CO_2)	7.50j	7.99j	9.40hi	11.25de	11.80d	**9.59C**
	Active (5%O_2+10%CO_2)	10.00gh	10.87ef	13.23c	12.98c	15.02a	**12.42A**
	Control-Unpacked	0.03p	0.03p	0.03p	0.03p	0.03p	**0.03I**
	Mean	**4.51G**	**4.98EF**	**5.82D**	**7.04B**	**8.22A**	**6.11A**
MEAN	**Passive**	0.03n	0.27mn	0.53m	2.10l	3.15k	**1.22D**
	Active (5%O_2+5%CO_2)	5.00j	5.41ij	5.63i	6.88h	7.77g	**6.14C**
	Active (5%O_2+7.5%CO_2)	7.50g	7.84g	9.18f	10.63d	11.22c	**9.27B**
	Active (5%O_2+10%CO_2)	10.00e	10.68d	12.06b	12.31b	14.57a	**11.92A**
	Control-Unpacked	0.03n	0.03n	0.03n	0.03n	0.03n	**0.03E**
	Mean	**4.51E**	**4.85D**	**5.49C**	**6.39B**	**7.35A**	

Table (8). Effect of hydro-cooling and MAP on Total Chlorophyll contents (mg/g F.W.) of green onion during cold storage at 0°C and RH 90-95% during 2024 and2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	93.00a	92.96a	91.15a-c	90.51a-c	86.30a-f	**90.78A**
	Active(5%O_2+5%CO_2)	93.00a	92.91ab	91.55a-c	91.59a-c	88.29a-e	**91.47A**
	Active(5%O_2+7.5%CO_2)	93.00a	89.70a-d	86.67a-f	80.10f-h	75.30g-i	**84.95BC**
	Active(5%O_2+10%CO_2)	93.00a	90.84a-c	85.16a-f	81.85d-g	73.33hi	**84.84BC**
	Control-Unpacked	93.00a	86.03a-f	80.67e-h	73.55hi	79.47f-h	**82.54CD**
	Mean	**93.00A**	**90.49AB**	**87.04BC**	**83.52CD**	**80.54DE**	**86.92A**
NON-Cooling	**Passive**	93.00a	90.36a-c	88.45a-e	85.33a-f	84.25c-f	**88.28AB**
	Active(5%O_2+5%CO_2)	93.00a	90.54a-c	89.19a-d	84.92b-f	74.28g-i	**86.38B**
	Active(5%O_2+7.5%CO_2)	93.00a	86.62a-f	80.81e-h	74.22g-i	70.26ij	**80.98D**
	Active(5%O_2+10%CO_2)	93.00a	80.88e-h	84.55c-f	73.02hi	71.00ij	**80.49D**
	Control-Unpacked	93.00a	80.25f-h	63.33jk	68.33ij	60.06k	**72.99E**
	Mean	**93.00A**	**85.73C**	**81.27D**	**77.16E**	**71.97F**	**81.83B**
MEAN	**Passive**	93.00a	91.66a	89.80ab	87.92a-c	85.28b-d	**89.53A**
	Active(5%O_2+5%CO_2)	93.00a	91.73a	90.37ab	88.25a-c	81.29de	**88.93A**
	Active(5%O_2+7.5%CO_2)	93.00a	88.16a-c	83.74cd	77.16ef	72.78fg	**82.97B**
	Active(5%O_2+10%CO_2)	93.00a	85.86b-d	84.86b-d	77.43ef	72.17fg	**82.66B**
	Control-Unpacked	93.00a	83.14cd	72.00fg	70.94g	69.76g	**77.77C**
	Mean	**93.00A**	**88.11B**	**84.15C**	**80.34D**	**76.25E**	
		2025season					
PRE-Cooling	**Passive**	95.67a	93.67a-c	91.30a-d	90.58a-f	86.52d-i	**91.55AB**
	Active(5%O_2+5%CO_2)	95.67a	94.83ab	91.55a-d	91.69a-d	88.33c-g	**92.41A**
	Active(5%O_2+7.5%CO_2)	95.67a	90.03a-g	86.56d-h	80.13j-m	75.18l-o	**85.51DE**
	Active(5%O_2+10%CO_2)	95.67a	90.83a-e	85.03e-j	81.72h-k	73.67n-p	**85.38DE**
	Control-Unpacked	95.67a	86.29d-j	80.33i-m	73.56n-p	77.88k-n	**82.75EF**
	Mean	**95.67A**	**91.13B**	**86.95C**	**83.54DE**	**80.31F**	**87.52A**
NON-Cooling	**Passive**	95.67a	90.53a-g	88.78b-g	85.67d-j	84.59f-j	**89.05BC**
	Active(5%O_2+5%CO_2)	95.67a	90.62a-f	89.40b-g	84.89e-ij	74.59m-p	**87.03CD**
	Active(5%O_2+7.5%CO_2)	95.67a	86.46d-i	80.33i-m	74.25m-p	70.43op	**81.43F**
	Active(5%O_2+10%CO_2)	95.67a	80.89h-l	84.38g-j	73.07n-p	70.67op	**80.93F**
	Control-Unpacked	95.67a	80.33i-m	63.67qr	68.46pq	58.35r	**73.30G**
	Mean	**95.67A**	**85.77CD**	**81.31EF**	**77.27G**	**71.73H**	**82.35B**
MEAN	**Passive**	95.67a	92.10a-c	90.04b-d	88.13c-e	85.55e-g	**90.30A**
	Active(5%O_2+5%CO_2)	95.67a	92.72ab	90.48bc	88.29c-e	81.46gh	**89.72A**
	Active(5%O_2+7.5%CO_2)	95.67a	88.25c-e	83.44fg	77.19h	72.80i	**83.47B**
	Active(5%O_2+10%CO_2)	95.67a	85.86d-f	84.71e-g	77.39h	72.17ij	**83.16B**
	Control-Unpacked	95.67a	83.31fg	72.00ij	71.01ij	68.12j	**78.02C**
	Mean	**95.67A**	**88.45B**	**84.13C**	**80.40D**	**76.02E**	

Total phenolic content:

Results in **Table (9)** indicate that total phenolic content decreased with the prolongation of the storage period is most likely due to the PPO enzyme, which oxidises phenolic compounds in the presence of oxygen, which explains the parallel consumption of phenols throughout the storage period (Queiroz et al., 2008). Also, the decline in total phenols was associated with their consumption to inhibit free radicals during storage**.** Regarding treatments, it is clear from the results that Hydro-cooling green onion plants significantly reduced phenol degradation of green onion compared with un-cooling treatments. These results agreed with the findings of (Alvares et al., 2007**).** However, active MAP at 5%O_2+5%CO_2 was the most effective treatment in reducing the loss of total phenolic content during storage, followed by passive MAP with no significant differences between them. The lowest values of total phenolic content were obtained from control. Our results agree with Sakaldaş et al. (2010), who reported that modified atmosphere packaging prevented degradation of phenolic compounds in dill leaves. Modified atmospheric packaging with low O_2 and high CO_2 was the most effective for retaining total antioxidant activity and total phenols throughout the storage period (Sethi et al., 2014), and modified atmospheres had a positive effect on phenolic-related quality. After 20 days, the combination of hydrocooling with active MAP at 5%O_2+5%CO_2 and hydrocooling with passive MAP maintained their total phenolic content with no significant differences between them, while the uncooled and unpacked gave the lowest ones during the same period.

CONCLUSION

From the previous results, it could be concluded that the combination of hydro-cooling with active MAP at 5%O_2 + 5%CO_2 is effective in preserving the quality of green onion, controlling leaf extension growth, reduced leaf curvature and root growth, maintaining high chlorophyll and phenol contents, and gave an excellent general appearance for 20 days at 0°C.

Table (9). Effect of hydro-cooling and MAP on Total phenolic content (mg /100g F.W.) of green onion during cold storage at 0°C and RH 90-95% during 2024 and 2025 seasons.

		2024season					
	TREATMENTS	**During storage(days)**					
		INTIAL	**5**	**10**	**15**	**20**	**Mean**
PRE-Cooling	**Passive**	51.87a	51.49a	50.91ab	50.30a-d	45.80a-k	**50.07A**
	Active(5%O_2+5%CO_2)	51.87a	51.40a	50.62a-c	50.73a-c	47.63a-i	**50.45A**
	Active(5%O_2+7.5%CO_2)	51.87a	47.97a-h	45.50a-k	43.39c-n	40.42i-o	**45.83B-D**
	Active(5%O_2+10%CO_2)	51.87a	51.77a	48.70a-g	44.79a-l	39.56k-p	**47.34A-C**
	Control-Unpacked	51.87a	45.80a-k	44.47a-l	42.77e-o	36.31n-p	**44.24CD**
	Mean	**51.87A**	**49.68AB**	**48.04B**	**46.40BC**	**41.94DE**	**47.59A**
NON-Cooling	**Passive**	51.87a	50.47a-c	48.53a-g	47.37a-j	43.92b-m	**48.43AB**
	Active(5%O_2+5%CO_2)	51.87a	49.67a-e	49.10a-f	47.20a-j	45.69a-k	**48.70AB**
	Active(5%O_2+7.5%CO_2)	51.87a	47.23a-j	41.30g-o	41.87f-o	37.73l-p	**44.00DE**
	Active(5%O_2+10%CO_2)	51.87a	48.20a-h	42.93d-o	40.80h-o	36.96m-p	**44.15CD**
	Control-Unpacked	51.87a	43.80b-m	40.00j-o	35.53op	32.55p	**40.75E**
	Mean	**51.87A**	**47.87B**	**44.37CD**	**42.55DE**	**39.37E**	**45.21B**
MEAN	**Passive**	51.87a	50.98ab	49.72a-c	48.83a-c	44.86c-e	**49.25A**
	Active(5%O_2+5%CO_2)	51.87a	50.53ab	49.86a-c	48.97a-c	46.66a-e	**49.58A**
	Active(5%O_2+7.5%CO_2)	51.87a	47.60a-d	43.40d-f	42.63d-f	39.08fg	**44.91B**
	Active(5%O_2+10%CO_2)	51.87a	49.98a-c	45.82b-e	42.80d-f	38.26fg	**45.74B**
	Control-Unpacked	51.87a	44.80c-e	42.23ef	39.15fg	34.43g	**42.50C**
	Mean	**51.87A**	**48.78B**	**46.21C**	**44.47C**	**40.66D**	
		2025season					
PRE-Cooling	**Passive**	56.87a	56.05ab	54.72a-e	53.87a-f	49.86a-j	**55.05A**
	Active(5%O_2+5%CO_2)	56.87a	55.87ab	54.93a-e	54.03a-f	51.83a-h	**55.49A**
	Active(5%O_2+7.5%CO_2)	56.87a	52.65a-g	48.48c-j	47.59e-k	44.08i-l	**50.79BC**
	Active(5%O_2+10%CO_2)	56.87a	55.07a-d	50.60a-j	47.80d-k	43.33j-l	**52.22A-C**
	Control-Unpacked	56.87a	49.57a-j	47.27f-k	43.98i-l	39.13l	**49.11C**
	Mean	**56.87A**	**54.51AB**	**52.96B**	**51.37BC**	**46.95DE**	**52.53A**
NON-Cooling	**Passive**	1.86m	56.36ab	55.91ab	55.30a-c	50.80a-i	**53.50AB**
	Active(5%O_2+5%CO_2)	56.87a	56.40ab	55.63a-c	55.60a-c	52.96a-f	**53.92AB**
	Active(5%O_2+7.5%CO_2)	56.87a	52.83a-f	50.43a-j	48.39c-k	45.42g-l	**49.08C**
	Active(5%O_2+10%CO_2)	56.87a	56.43ab	53.47a-f	49.79a-j	44.56h-l	**49.24C**
	Control-Unpacked	56.87a	50.53a-j	49.37b-j	47.77d-k	41.01kl	**45.62D**
	Mean	**56.87A**	**53.17B**	**49.44CD**	**47.54DE**	**44.34E**	**50.27B**
MEAN	**Passive**	56.87a	56.05a	54.72a-c	53.87a-c	49.86b-e	**54.27A**
	Active(5%O_2+5%CO_2)	56.87a	55.87a	54.93ab	54.03a-c	51.83a-e	**54.70A**
	Active(5%O_2+7.5%CO_2)	56.87a	52.65a-d	48.48d-f	47.59d-f	44.08fg	**49.93B**
	Active(5%O_2+10%CO_2)	56.87a	55.07ab	50.60b-e	47.80d-f	43.33fg	**50.73B**
	Control-Unpacked	56.87a	49.57c-e	47.27ef	43.98fg	39.13g	**47.36C**
	Mean	**56.87A**	**53.84B**	**51.20C**	**49.45C**	**45.65D**	

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الملخص العربي

تأثير التبريد المائي والجو الهوائي المعدل على صفات الجودة للبصل الأخضر أثناء التخزين المبرد

صفاء زكريا وأميرة عبد البديع أبو المكارم

قسم بحوث تداول الخضر- معهد بحوث البساتين- مركز البحوث الزراعية-الجيزه-مصر

تم حصاد نباتات البصل الأخضر (*Allium cepa* L.) صنف فوتون عند وصول قطر البصلة 12-16 مم خلال موسمي 2024 و2025، لدراسة تأثير التبريد المائي والتعبئة تحت ظروف الجو الهوائي المعدل الموجب بنسبة 5% أكسجين + 5% ثاني أكسيد الكربون، أو 5% أكسجين + 7.5% ثاني أكسيد الكربون، أو 5% أكسجين + 10% ثاني أكسيد الكربون، أو في ظروف الجو الهوائي المعدل السالب بجانب النباتات غير المعبأة (كنترول)، على خصائص الجودة والقدرة التخزينية للبصل الأخضر خلال فترة التخزين على درجة حرارة صفر مئوية ورطوبة نسبية 95% لمدة 20 يومًا .

تشير النتائج الي انخفاض مستوي الأكسجين، وزيادة مستوي ثاني أكسيد الكربون داخل العبوات اثناء التخزين، وساهم التبريد المائي أو الجو الهوائي المعدل بشكل ملحوظ في تقليل الفقد في الوزن والحفاظ على الجودة المظهرية، مقارنةً بالبصل غير المبرد أو غير المعبأ. نسبة الأكسجين وثاني أكسيد الكربون داخل عبوات الجو الهوائي المعدل الموجب والسالب اختلفت معنويا، كما وجد أن نباتات البصل الأخضر المعامل بالتبريد المائي مع الجو الهوائي المعدل الموجب بتركيز ($5\%O_2 + 5\%CO_2$) أو السالب كانت الأكثر فعالية في الحفاظ على جميع خصائص الجودة أثناء التخزين. ومع ذلك، فإن المعاملة بالتبريد المائي مع الجو الهوائي المعدل الموجب بتركيز ($5\%O_2 + 5\%CO_2$) قد أعطت أفضل النتائج حيث تحكمت في نمو الجذور وانحناء الأوراق كما قللت من استطالة الأوراق (أقل من 5 مم)، وحافظت على محتوى الكلوروفيل والفينول، وأعطت مظهرًا ممتازًا وبدون أي أضرار بعد 20 يومًا من التخزين عند درجة حرارة صفر مئوية .بينما أعطت معاملة الجو الهوائي المعدل السالب مظهرًا جيدًا خلال نفس الفترة.