Impact of Ultraviolet radiation and 1-methylcyclopropane treatments on maintain quality and storability of Iceberg lettuce head during cold storage.

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ABSTRACT

This study was carried out on head Lettuce (*Lactuca sativa* L. cv Iceberg) during two seasons, in 2020 and 2021, to study the effect of exposed head lettuce to ultraviolet radiation (UV-C) doses (200 and 250 nm for 5 min) and 1-Methylcyclopropene sheet (1-MCP) 1.5 and 5% alone and combination between them beside untreated control on maintaining quality and storability of lettuce heads during storage at 0°C and 95% relative humidity for 20 days. Results showed that all postharvest treatments-maintained head lettuce quality compared to untreated control during storage; however, exposed head lettuce to ultraviolet radiation 250 nm + 5% 1-Methylcyclopropene for 5 minutes and 200 nm + 5% 1-Methylcyclopropene for 5 minutes, were the most effective in reducing the weight loss percentage, decay score and total microbial count and incidence of discoloration. Also, maintained general appearance, ascorbic acid and total phenolic compound content. Furthermore, delaying polyphenol oxidase activity compared with other treatments.

Lettuce heads treated with ultraviolet radiation 250 nm + 5% 1-Methylcyclopropene showed the best appearance and maintaining postharvest quality and didn't exhibit any changes in their appearance and gave excellent appearance at the end of storage period (20 days at 0 °C) while 200 nm + 5% 1-Methylcyclopropene treatment gave good appearance at the same period.

Key words: Ultraviolet - Polyphenol oxidase - Total microbial count – head lettuce-postharvest.

INTRODUCTION

Iceberg lettuce (*Lactuca sativa*) is one of the most highly favorable fresh vegetables, being a traditional ingredient in salad vegetable in many countries, because of the increased consumption of the fast food and prepared salads. Edible quality both sensorial and nutritional of iceberg lettuce declines rapidly after harvest and considerable losses may occur during storage wilting and discoloration (Wills et al., 2002and Chandra et al., 2010).

Major problems of leaves and cut stem lettuce during storage are highly susceptible to enzymatic browning, thereby causing economic loss to the producer and generally results in loss of nutritional, functional and organoleptic qualities and reduces their marketability, increase in respiration rates, biochemical changes and microbial spoilage, which often result in degradation in color, texture and flavor of the produce (Martin-Diana et al., 2005). Lettuce is highly susceptible to enzymatic browning. Enzymatic browning (EB) does not occur in intact plant cells since phenolic compounds in cell vacuoles are separated from the PPO which is present in the cytoplasm. Once tissue is damaged by slicing, cutting or pulping, however, the formation of brown pigments occurs. The main step in enzymatic browning is the oxidation of phenolic compounds by PPO in the presence of oxygen (Karrayan and Aydemir, 2001). Therefore, it is very important to prevent these reactions. Some postharvest treatments can be used for maintaining quality and inhibiting browning control in head lettuce such as ultraviolet (UV-C) and 1-Methylcyclopropene (1-MCP).

Effective ultraviolet (UV) irradiation has been used as a postharvest technology to reduce decay, delay ripening, and delay senescence in crop products, Ultraviolet irradiation in postharvest as a nonchemical, innovative light treatment is a promising illumination to extend the shelf life and improve the nutritional quality of vegetables. In general, there are many results using UV-C. (Sonntage et al., 2023). The application of ultraviolet light (UV-C 200-280 nm) on fruits and vegetables to stimulate beneficial responses is a new method for o delay fungal growth and senescence (softening, color change) and extending the shelf-life of fruits and vegetables (Mercier et al., 2000 and El-Ghaouth et al., 2003).

UV-C treatment effectively retarded the occurrence of surface green fading and browning, thus, maintaining a good visual appearance in fresh-cut stem lettuce. Furthermore, the degradation of chlorophyll, loss of ascorbic acid and accumulation of phenolic compounds were restrained with the application of UV-C. According to the changes in browning-related enzymes activities, UV-C treatment did not show a distinct effect on activities of PPO and POD, but pronouncedly inhibited the activity of PAL. Based on this, the inhibited tissue browning upon application of UV-C should be mainly attributed to suppressed PAL activity. These findings suggested that UV-C treatment has a potential practical application in preserving fresh-cut stem lettuce (Han et al., 2021). In addition, the application of UV-C radiation has been reported to inhibit tissue browning in several fruits and vegetables. The advantages of UV radiation include that it does not leave a residue, does not change sensory characteristics, and does not involve high cost (Wang et al., 2019).

1-Methylcyclopropene (1-MCP) has been used to inhibit the action of ethylene and extend the storability and quality of lettuce, owing to the delayed development of browning on cut surfaces (Wills et al., 2002). The mode of action of 1-MCP in inhibiting browning on the cut lettuce surface is probably due to blocks ethylene binding to its receptor, as ethylene increases the activity of polyphenol oxidase and phenylalanine ammonialyase, which are key enzymes in the induction of surface browning in fruits and vegetables.

Browning of the lettuce leaves was significantly inhibited by the storage at low temperature and by treatment with1-MCP. The biochemical analysis further indicated that the reduction of soluble protein and sugar, decrease in activity of polyphenol oxidase (PPO) and peroxidase (POD) and accumulation of free amino acids in the lettuce leaves during storage could be remarkably prevented by low temperature, treatment with1-MCP. Our result suggested that 1-MCP treatment would provide a potential way for controlling quality of the lettuce under suboptimal postharvest temperature conditions, they suggested PPO and POD may also play important roles in the developing russet spot on iceberg lettuce leaves during storage. Our study showed that both PPO and POD activity in the lettuce leaves were suppressed by 1-MCP. These changes were negatively correlated ($P<0.05$) to the development of russet spot in the heads treated by 1-MCP. It has been found that reducing the ethylene level can delay leaf browning of lettuce stored at 20 °C or 0 °C (Tian et al., 2011).

The aim of this study is to evaluate some postharvest treatments on keeping postharvest quality of head lettuce. And to determine the most effective treatment in the prevention of lettuce heads deterioration during cold storage.

MATERIALS AND METHODS

Heads of lettuce (*Lactuca sativa* L. cv Iceberg) were harvested at the proper stage of maturity from private farm Giza gov., Egypt, in 2020 and 2021 seasons.

Uncompact and non-uniform heads were eliminated and only healthy, undamaged darker green outer leaves, symmetrical in shape, compact and firm were chosen good ones were transported immediately to the Great foods company, remove the dry and damage outer leaves and the stem of head lettuce were cut by a sharp knife (1cm in length), exposed some heads to two levels for ultraviolet radiation doses (200 and 250 nm for 5 min). Then, after that all heads either exposed to UV radiation or non-exposed transported immediately to the laboratory of Postharvest and Handling of Vegetable Crops Department, ARC, Giza, Egypt. three Lettuce heads were placed in carton both boxes (30×20×15cm), each box represented as one experimented unit (EU) randomly distributed into nine group 1-MCP (sheet) contained 1.5% and 5%, exposed head to UV 200 and 250 nm, exposed head to UV 200 nm plus 1.5% 1-MCP, Exposed head to UV 200 nm plus 5% 1-MCP, Exposed head to UV 250 nm plus 1.5% 1-MCP, Exposed head to UV 250 nm plus 5% 1-MCP and untreated control. Eighteen EU from each treatment were prepared and stored at 0°C and 95% RH for 20 days. The treatments were arranged in a completely randomized design with three replicates.

Measurements were recorded immediately after harvest and every 4 day's intervals to determine the following parameters:

1. **Weight loss percentage:** Lettuce heads was estimated according to the following equation: Weight loss% = [(Initial weight - weight of fruits at sampling date)/Initial weight of fruits] x 100.
2. **Decay score:** it was determined as score system of 1= none, 2= slight, 3= moderate, 4= moderately severe, 5= severe. This depends on the decay percentage of fruits (Jimenez et al., 1998).
3. **General appearance score:** was evaluated using a scale from (1 to 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).
4. **Discoloration score:** Discoloration was evaluated on a scale of 1 to 5 where 1 = none, 2 = slight, 3 = moderate, 4 = severe and 5 = extra sever
5. **Ascorbic acid content (mg/100g fruit fresh weight)**: was determined using 2, 6-dichloro-phenol indophenols method (A.O.A.C., 2000).
6. **Total microbial count: was** measured by Anese and Nicoli, 1997).
7. **Polyphenol oxidase activity percentage (PPO %) assays:** PPO was extracted by (Dogan et al., 2002).
8. **Total phenolic compound (mg/100g fresh weight):** was **calculated** by using the Folin–Ciocalteu reagent with some alteration by using gallic acid as a standard curve (El-Mogy et al., 2020).

Statistical analysis: Data of the two seasons were arranged and statistically analyzed using M-static. The comparison among means of the different treatments was determined by using Duncan's test. The data were tabulated and statistically analyzed according to a factorial complete randomized design (Snedecor and Cochran 1982).

RESULTS AND DISCUSSION

1. Weight loss:

Data in **Table (1)** showed that when the storage period was increased, the weight loss % increased noticeably. The Increased weight loss during storage is a consequence of physiological processes such as respiration and transpiration rates. (Abdullah et al., 2023).

Concerning postharvest treatments, data show that exposed head lettuce to ultraviolet radiation 250 nm + 5% 1-MCP proved to be superior in reducing weight loss percentage followed by UV 200 nm and 5% 1-MCP treatment significantly as compared with the other treatments and control. The reducing weight loss% of head lettuce during storage by using UV-C radiation or 1-MCP treatments may be due to these treatments decreased respiration rate, delayed fruit ripening, and consequently retarded fresh weight loss (Manganaris et al., 2008 and Daiuto et al., 2013).

Table (1). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on weight loss percentage of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5%	0.00 i	0.29 g	0.73 a	1.75 o	2.23 k	3.46 c	**1.41C**
MCP 5%	0.00 i	0.28 gh	0.69 b	1.66 q	2.06 i	3.33 d	**1.34D**
UV 200 nm	0.00 i	0.31 f	0.78 z	1.83 n	2.36 j	3.63 b	**1.49B**
UV 250 nm	0.00 i	0.28 gh	0.69 b	1.66 q	2.05 l	3.32 d	**1.33D**
UV 250 + MCP 1.5	0.00 i	0.25 ig	0.63 c	1.32 v	1.59 r	2.98 f	**1.13F**
UV 250 + MCP 5	0.00 i	0.21 k	0.53 e	0.93 x	1.39 u	2.71 h	**0.96H**
UV 200 + MCP 1.5	0.00 i	0.26 hi	0.68 b	1.52 s	1.71 p	3.12 e	**1.21E**
UV 200 + MCP 5	0.00 i	0.23 j	0.59 d	1.17 w	1.49 t	2.89 g	**1.06G**
Control	0.00 i	0.33 f	0.86 y	1.98 m	2.63 i	3.96 a	**1.63A**
Mean	**0.00F**	**0.27E**	**0.69D**	**1.54C**	**1.94B**	**3.27A**	
	2021						
MCP 1.5%	0.00 n	0.34 h	0.78 a	1.79 o	2.28 k	3.50 c	**1.45C**
MCP 5%	0.00 n	0.32 i	0.73 b	1.70 q	2.10 l	3.37 d	**1.37D**
UV 200 nm	0.00 n	0.36 g	0.84 z	1.91 n	2.40 j	3.65 b	**1.53B**
UV 250 nm	0.00 n	0.32 i	0.73 b	1.69 q	2.10 l	3.37 d	**1.37D**
UV 250 + MCP 1.5	0.00 n	0.27 k	0.64 d	1.36 v	1.63 r	3.03 f	**1.15F**
UV 250 + MCP 5	0.00 n	0.23 m	0.56 e	0.98 x	1.41 u	2.76 h	**0.99H**
UV 200 + MCP 1.5	0.00 n	0.29 j	0.72 b	1.57 s	1.77 p	3.14 e	**1.25E**
UV 200 + MCP 5	0.00 n	0.25 i	0.66 c	1.21 w	1.52 t	2.93 g	**1.10G**
Control	0.00 n	0.40 f	0.95 y	2.06 m	2.69 i	4.04 a	**1.69A**
Mean	**0.00F**	**0.31E**	**0.73D**	**1.59C**	**1.99B**	**3.31A**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

2. Decay score:

Data in **Table (2)** indicated a rise in the degradation decay score during storage period (20 days). In every treatment, the deterioration began gradually and grew till the end of storage. This resulted from alterations that happened to the heads while they were being stored, and it matches the findings of (Ibrahim and Abdullah, 2018).

Data also showed significant differences among all treatments during storage period in both seasons. All treatments were much better in reducing decay score and so longer storage period than control. After 20 days of storage, heads exposed to UV 250 nm + 5% 1-MCP and UV 200 nm + 5% 1-MCP treatments gave the lowest decay score in both seasons. These results agree with Wiseman et al. (2023) and Watkins, (2008) who reported that 1-MCP can be used as antimicrobial to prevent some of the microorganism's growth and browning of minimally processed lettuce.

Also, use of high dosages of UV-C delaying senescence, inhibited microbial growth and decay, reduces microbial activity during storage and delayed yellowing and chlorophyll degradation (Jiayi and Zhaoxia, 2023). Also, Garzon-Garcia et al. (2020) reported that UV-C might stimulate the activity of lignifying enzymes and enhance the protection against pathogenic invasion.

Table (2). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on decay score of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	**4**	**8**	**12**	**16**	**20**	**Mean**
MCP 1.5	1.00 g	1.00 g	1.00 g	1.00 g	1.33 fg	2.00 de	**1.22C**
MCP 5	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.33 fg	**1.06D**
UV 200	1.00 g	1.00 g	1.00 g	1.33 fg	2.00 de	2.67 bc	**1.50B**
UV 250	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.33 fg	**1.06D**
UV 250 + MCP 1.5	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	**1.00D**
UV 250 + MCP 5	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	**1.00D**
UV 200 + MCP 1.5	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.33 fg	**1.06D**
UV 200 + MCP 5	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	1.00 g	**1.00D**
Control	1.00 g	1.67 ef	2.33 cd	2.33 cd	3.00 b	4.00 a	**2.39A**
Mean	**1.00D**	**1.07CD**	**1.15C**	**1.19C**	**1.37B**	**1.74A**	
	2021						
MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	2.00 cd	**1.22C**
MCP 5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	**1.06CD**
UV 200	1.00 f	1.00 f	1.00 f	1.33 ef	2.00 cd	2.33 bc	**1.44B**
UV 250	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	1.33 ef	**1.11CD**
UV 250 + MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	1.67 de	**1.17CD**
UV 250 + MCP 5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	**1.00D**
UV 200 + MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	**1.06CD**
UV 200 + MCP 5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	**1.00D**
Control	1.00 f	1.33 ef	2.33 bc	2.67 b	3.67 a	4.00 a	**2.50A**
Mean	**1.00D**	**1.04D**	**1.15CD**	**1.22C**	**1.52B**	**1.78A**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

3. General appearance score (GA):

Data in **Table (3)** revealed that after 16 days of storage, the general appearance score fell from exceptional (score 9) to good (score 7), fair (score 5), or bad (score 3). The overall look (score) of the chopped lettuce stem also declined during storage. The decrease in GA of head lettuce during storage may be due to morphological defects, such as dryness of the cut surface, butt discoloration or macroscopic decay (Shehata et al., 2012)

All postharvest treatments had significantly the highest score of appearance as compared with untreated control. However, head lettuce exposed to UV-C 250 nm + 5% 1-MCP and UV-C 200 nm + 5% 1-MCP were the most effective treatments for maintaining GA with no significant differences between them. In general, the interaction between postharvest treatments and storage period was significant in the two seasons. However, UV-C 250 nm + 5% 1-MCP showed the best appearance and gave an excellent appearance at the end of storage. While UV-C 200 nm + 5% 1-MCP gave good appearance at the same period. On the other hand, control had an unusable appearance at the end of storage.

The quality of lettuce was remarkably retained during storage at 0 °C and could be effectively delayed by treatment with 1-MCP. Therefore, commercial use of 1-MCP may enhance iceberg lettuce quality under suboptimal postharvest conditions (Tian et al., 2011). 1-Methylcyclopropene (1-MCP) has been found to inhibit the action of ethylene and thereby extend the storage life (Wills et al., 2002).

UV-C radiation is effective in delaying senescence and deterioration in fresh processed vegetables by reducing the microbial populations and thereby improving the keeping quality (Allende and Arte´s, 2003). Also, UV-C treatment at the dose of 8 kJ m− 2 effectively retarded the occurrence of surface green fading and browning thus, maintaining a good visual appearance in fresh-cut stem lettuce (Han et al., 2021).

Table (3). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on general appearance score of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and 2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5	9.00 a	9.00 a	9.00 a	7.67 bc	7.00 cd	5.00 fg	**7.78D**
MCP 5	9.00 a	9.00 a	9.00 a	7.67 bc	7.00 cd	5.00 fg	**7.78D**
UV 200	9.00 a	9.00 a	7.67 bc	6.33 de	5.00 fg	3.67 hi	**6.78E**
UV 250	9.00 a	9.00 a	8.33 ab	8.33 ab	7.00 cd	5.67 ef	**7.89CD**
UV 250 + MCP 1.5	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.00 cd	**8.56AB**
UV 250 + MCP 5	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	**8.89A**
UV 200 + MCP 1.5	9.00 a	9.00 a	9.00 a	9.00 a	7.00 cd	6.33 de	**8.22BC**
UV 200 + MCP 5	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	7.67 bc	**8.78A**
Control	9.00 a	5.67 ef	4.33 gh	4.33 gh	3.00 i	1.00 j	**4.56F**
Mean	**9.00A**	**8.63B**	**8.26C**	**7.82D**	**6.93E**	**5.52F**	
	2021						
MCP 1.5	9.00 a	9.00 a	9.00 a	7.00 cd	6.33 de	5.00 fg	**7.56C**
MCP 5	9.00 a	9.00 a	9.00 a	7.67 bc	6.33 de	5.67 ef	**7.78C**
UV 200	9.00 a	9.00 a	7.00 cd	6.33 de	5.00 fg	4.33 gh	**6.78D**
UV 250	9.00 a	9.00 a	8.33 ab	7.00 cd	6.33 de	5.00 fg	**7.44C**
UV 250 + MCP 1.5	9.00 a	9.00 a	9.00 a	9.00 a	7.67 bc	7.00 cd	**8.44B**
UV 250 + MCP 5	9.00 a	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	**8.89A**
UV 200 + MCP 1.5	9.00 a	9.00 a	9.00 a	9.00 a	7.00 cd	6.33 de	**8.22B**
UV 200 + MCP 5	9.00 a	9.00 a	9.00 a	9.00 a	8.33 ab	7.00 cd	**8.56AB**
Control	9.00 a	6.33 de	4.33 gh	3.67 h	1.67 i	1.00 i	**4.33E**
Mean	**9.00A**	**8.70A**	**8.19B**	**7.52C**	**6.41D**	**5.52E**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

4. Discoloration score:

Data presented in **Table (4)** demonstrate how the lettuce heads' discolorations score gradually dropped as the storage duration lengthened and reached its maximum depression at the conclusion of the storage period. This result agrees with that obtained by Martin-Diana et al. (2008), the brown color development is related primarily to oxidation of phenolic compounds to quoins in ones a reached catalyzed by polyphenol oxidase (PPO) quiones then polymerized to dark brown, black or red polymers.

As for the effect of postharvest treatments on discoloration, score data show that all treatments reduced the incidence of discoloration compared with control. However, UV-C 250 nm + 1.5% 1-MCP and UV-C 250 nm + 5% 1-MCP and UV-C 200 nm + 1.5% 1-MCP and UV-C 250 nm + 5% 1-MCP were the effect treatments in reducing discoloration during storage.

On day-20 in storage, heads exposed to UV 250 nm + 5% 1-MCP and UV-C 200 nm + 5% 1-MCP were the most effective treatments in preventing discoloration. This result might be attributed to the effect 1-MCP in delaying fresh cut lettuce senescence through its effect on metabolic activities and inhibit enzymatic browning (Fan and Mattheis, 2000 and Han et al., 2021) found that lettuce slices exposed to different doses of UV-C exhibited slower surface discoloration than the control during the storage period.

In addition, the application of UV-C radiation has been reported to inhibit tissue browning in several fruit and vegetables (Wang et al., 2019). Han et al. (2021) found that the inhibited tissue browning upon application of UV-C should be mainly attributed to suppressed PAL and PPO activity. According to earlier studies, the UV-C induced inhibition of tissue browning in fresh-cut produce has been correlated with a complex mechanism of these three enzymes.

Table (4). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on discoloration score of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and 2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5	1.00 h	1.00 h	1.00 h	1.67 fg	2.33 de	3.00 bc	**1.67B**
MCP 5	1.00 h	1.00 h	1.00 h	1.33 gh	2.00 ef	2.67 cd	**1.50BC**
UV 200	1.00 h	1.00 h	1.00 h	1.33 gh	2.67 cd	3.33 b	**1.72B**
UV 250	1.00 h	1.00 h	1.00 h	1.33 gh	1.67 fg	2.00 ef	**1.33CD**
UV 250 + MCP 1.5	1.00 h	1.00 h	1.00 h	1.00 h	1.33 gh	2.00 ef	**1.22DE**
UV 250 + MCP 5	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	**1.00E**
UV 200 + MCP 1.5	1.00 h	1.00 h	1.00 h	1.00 h	1.33 gh	1.67 fg	**1.17DE**
UV 200 + MCP 5	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	1.00 h	**1.00E**
Control	1.00 h	2.00 ef	3.33 b	3.33 b	4.00 a	4.00 a	**2.94A**
Mean	**1.00E**	**1.11DE**	**1.26CD**	**1.44C**	**1.93B**	**2.30A**	
	2021						
MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	2.33 cd	**1.28CD**
MCP 5	1.00 f	1.00 f	1.00 f	1.33 ef	1.67 df	2.67 bc	**1.44BC**
UV 200	1.00 f	1.00 f	1.00 f	1.33 ef	2.67 bc	2.67 bc	**1.61B**
UV 250	1.00 f	1.00 f	1.00 f	1.33 ef	2.00 ce	2.00 ce	**1.39BC**
UV 250 + MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	**1.00D**
UV 250 + MCP 5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	**1.00D**
UV 200 + MCP 1.5	1.00 f	1.00 f	1.00 f	1.00 f	1.67 df	2.00 ce	**1.28CD**
UV 200 + MCP 5	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	1.00 f	**1.00D**
Control	1.00 f	2.33 cd	3.33 ab	3.67 a	3.67 a	4.00 a	**3.00A**
Mean	**1.00E**	**1.15DE**	**1.26CD**	**1.41C**	**1.78B**	**2.07A**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

5. Ascorbic acid content (mg /100g FW):

Data in **Table (5)** demonstrate that, for several treatments, there were appreciable drops in ascorbic acid content as storage times increased. These findings concur with the findings of (Saltveit, 2004) who suggested that the respiration process reduces vitamin C during storage.

It was also obvious that significant differences among treatments during storage period in both seasons. Heads lettuce exposed to UV-C 250 nm + 5% 1-MCP exhibited highest ascorbic acid content compared with the other treatments and untreated heads. These results agreed with those obtained by Tian et al. (2011).

UV-C or 1-MCP treatments effectively retarded the occurrence of loss of ascorbic acid by reducing respiration and mirabolic process, thus maintaining ascorbic acid (Han et al., 2021).

Regarding the interaction between the treatments and storage period, data revealed that heads exposed to UV-C 250 nm + 5% 1-MCP exhibited the highest ascorbic acid content during all storage period compared to all other tested treatments.

6. Total microbial count:

As shown in **Table (6),** findings show that the microbiological load and storage period had a linear relationship, with an increase in storage duration being correlated with an increase in microbial load. These results agree with Ihl et al. (2003). On the other side, the most effective antimicrobial treatment which diminishes the microbial load was exposed to UV-C at 250 nm and 5% 1-MCP followed by heads exposed to UV-C at 200 nm + 5% 1-MCP with significant differences between them in both seasons. An important aspect of UV-C irradiation is to extend the shelf life by reducing the microbial load of food. UV-C radiation has been shown to cause DNA strand breaks and oxidative damage to lipids in microorganisms and to increase intracellular reactive oxygen species (ROS) levels in microorganisms (Sonntage et al., 2023).

Another consideration is the preservation of desirable quality characteristics, which should not be compromised. UV irradiation at postharvest has been shown to play an important role in reducing microorganisms such as Escherichia coli, Listeria pseudomonas, Salmonella typhimurium, and Listeria monocytogenes on vegetables

(Santos et al., 2013 and Huang and Chen, 2019).

On the other hand, relatively little has been researched concerning the effects of 1-MCP on disease incidence, compared to its effects on Delayed ripening due to inhibition of ethylene action may increase the resistance of the commodity to infection. However, small amounts of endogenous ethylene may be necessary to maintain basic levels of resistance to pathogens because of its involvement in regulation of plant defense genes.

Table (5). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on Ascorbic acid content of Iceberg head lettuce during storage at 0°C and RH 95 % in 2020 and 2021seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5	41.66 a	40.73 ef	39.31 m	38.20 s	37.84 v	37.63 wx	**39.23G**
MCP 5	41.66 a	40.82 e	39.60 kl	38.51 r	38.03 tu	37.80 v	**39.40F**
UV 200	41.66 a	40.62 fg	39.13 no	38.02 u	37.51 x	37.21 y	**39.03H**
UV 250	41.66 a	40.81 e	39.64 k	38.86 p	38.15 st	37.82 v	**39.49E**
UV 250 + MCP 1.5	41.66 a	41.03 d	40.31 h	39.54 kl	39.03 o	38.21 s	**39.96C**
UV 250 + MCP 5	41.66 a	41.30 b	40.81 e	40.13 i	39.52 l	38.82 pq	**40.38A**
UV 200 + MCP 1.5	41.66 a	41.01 d	39.82 j	39.05 o	38.71 q	38.04 tu	**39.72D**
UV 200 + MCP 5	41.66 a	41.16 c	40.65 f	39.51 l	39.21 mn	38.51 r	**40.12B**
Control	41.66 a	40.50 g	38.82 pq	37.75 vw	37.13 y	36.81 z	**38.78I**
Mean	**41.66A**	**40.89B**	**39.79C**	**38.84D**	**38.35E**	**37.87F**	
	2021						
MCP 1.5	41.21 a	39.90 g	39.35 l	38.83 o	38.11 s	37.62 v	**39.17F**
MCP 5	41.21 a	40.05 f	39.53 j	39.03 n	38.43 q	37.90 tu	**39.36E**
UV 200	41.21 a	39.63 i	39.02 n	38.51 p	37.85 u	37.32 x	**38.93G**
UV 250	41.21 a	40.02 f	39.52 j	39.03 n	38.44 q	37.92 t	**39.35E**
UV 250 + MCP 1.5	41.21 a	40.41 d	40.04 f	39.62 i	39.11 m	38.51 p	**39.82C**
UV 250 + MCP 5	41.21 a	40.87 b	40.46 d	40.03 f	39.53 j	39.05 n	**40.19A**
UV 200 + MCP 1.5	41.21 a	40.23 e	39.71 h	39.34 l	38.82 o	38.21 r	**39.59D**
UV 200 + MCP 5	41.21 a	40.63 c	40.23 e	39.87 g	39.33 l	38.81 o	**40.01B**
Control	41.21 a	39.42 k	38.80 o	38.22 r	37.45 w	37.02 y	**38.69H**
Mean	**41.21A**	**40.13B**	**39.63C**	**39.16D**	**38.57E**	**38.04F**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

Table (6). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on Total microbial count of Iceberg head lettuce during storage at 0°C and RH 95 % in 2020 and 2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5	0.12 r	0.14 q	0.20 no	0.27 jl	0.32 eg	0.37 bc	**0.24B**
MCP 5	0.12 r	0.14 q	0.19 no	0.26 jl	0.31 fh	0.36 cd	**0.23C**
UV 200	0.12 r	0.15 q	0.20 n	0.27 jk	0.31 eg	0.39 b	**0.24B**
UV 250	0.12 r	0.14 q	0.19 no	0.25 kl	0.30 gh	0.36 cd	**0.23CD**
UV 250 + MCP 1.5	0.12 r	0.14 q	0.18 op	0.25 l	0.29 h	0.32 ef	**0.22E**
UV 250 + MCP 5	0.12 r	0.13 qr	0.17 p	0.23 m	0.26 j-l	0.26 jl	**0.19G**
UV 200 + MCP 1.5	0.12 r	0.14 q	0.18 op	0.25 kl	0.29 hi	0.35 d	**0.22DE**
UV 200 + MCP 5	0.12 r	0.13 qr	0.17 p	0.23 m	0.26 jl	0.29 hi	**0.20F**
Control	0.12 r	0.15 q	0.20 n	0.27 ij	0.33 e	0.45 a	**0.25A**
Mean	**0.12F**	**0.14E**	**0.19D**	**0.25C**	**0.30B**	**0.35A**	
	2021						
MCP 1.5	0.14 v	0.21 pq	0.26 km	0.32 i	0.38 d	0.44 b	**0.29B**
MCP 5	0.14 v	0.19 os	0.23 no	0.27 jk	0.32 hi	0.38 d	**0.26C**
UV 200	0.14 v	0.22 op	0.28 jk	0.32 hi	0.37 de	0.43 b	**0.29B**
UV 250	0.14 v	0.18 st	0.19 os	0.28 jk	0.32 hi	0.37 de	**0.25D**
UV 250 + MCP 1.5	0.14 v	0.17 tu	0.19 rs	0.25 mn	0.28 jk	0.34 gh	**0.23E**
UV 250 + MCP 5	0.14 v	0.15 uv	0.18 st	0.22 op	0.25 mn	0.27 kl	**0.20F**
UV 200 + MCP 1.5	0.14 v	0.20pr	0.22 op	0.26 km	0.31 i	0.36 ef	**0.25D**
UV 200 + MCP 5	0.14 v	0.15 uv	0.18 st	0.22 op	0.25 lm	0.29 j	**0.21F**
Control	0.14 v	0.22 op	0.29 j	0.35 fg	0.41 c	0.47 a	**0.31A**
Mean	**0.14F**	**0.19E**	**0.22D**	**0.28C**	**0.32B**	**0.37A**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

7. Polyphenol oxidase (PPO) activity:

Data in **Table (7)** demonstrate that when the storage period was increased, there was a noticeable rise in polyphenol oxidase activity. These results agree with those obtained by (Shehata et al., 2012). The increase of polyphenol oxidase activity in control treatment is mainly due to activation process from latent to fully active form. In fact, as previously reported by Cantos et al. (2001) tissue wounding involves the decompart metallization of cellular components with the subsequent release of proteases involving a cascade of reactions leading to the activation of latent PPO. For the tested treatments, data showed that lettuce heads exposed to UV-C 250 nm + 5% 1-MCP significantly reduced the activity of polyphenol oxidase activity during storage if compared with other treatments and untreated control.

Lettuce senescence comes from our findings that 1-MCP may inhibit the oxidation of polyphenols into quinines, prevent leaf browning, and lower soluble sugar and protein levels in lettuce. (Tay and Perera, 2004). Han et al. (2021) found That UV-C light treatment significantly reduced PPO activity of lettuce during storage.

Table (7). Effect of ultraviolet radiation and 1-methylcyclopropane treatments on Polyphenol oxidase (PPO) activity of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and 2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	4	8	12	16	20	Mean
MCP 1.5	0.32 w	0.37 qw	0.44 ko	0.52 hi	0.58 fg	0.72 c	**0.49C**
MCP 5	0.32 w	0.36 rw	0.42 lq	0.47 ik	0.54 gh	0.67 de	**0.46D**
UV 200	0.32 w	0.38 pu	0.46 jl	0.58 fg	0.62 ef	0.78 b	**0.52B**
UV 250	0.32 w	0.36 rw	0.42 lp	0.48 ik	0.54 gh	0.67 d	**0.46D**
UV 250 + MCP 1.5	0.32 w	0.34 tw	0.39 ot	0.42 lp	0.48 ik	0.58 fg	**0.42E**
UV 250 + MCP 5	0.32 w	0.32 vw	0.35 sw	0.37 pv	0.41 lq	0.48 ik	**0.38G**
UV 200 + MCP 1.5	0.32 w	0.35 sw	0.40 mr	0.45 km	0.50 hj	0.63 df	**0.44E**
UV 200 + MCP 5	0.32 w	0.33 uw	0.37 qw	0.39 ns	0.44 kn	0.53 gh	**0.40F**
Control	0.32 w	0.40 ms	0.51 hj	0.65 de	0.77 bc	0.89 a	**0.59A**
Mean	**0.32F**	**0.36E**	**0.42D**	**0.48C**	**0.54B**	**0.66A**	
	2021						
MCP 1.5	0.34 w	0.43 ps	0.54 lm	0.63 hj	0.72 ef	0.78 cd	**0.57C**
MCP 5	0.34 w	0.42 qu	0.50 mo	0.57 kl	0.65 gh	0.69 fg	**0.53D**
UV 200	0.34 w	0.46 oq	0.58 jl	0.67 gh	0.78 cd	0.83 bc	**0.61B**
UV 250	0.34 w	0.42 qt	0.51 mo	0.57 kl	0.65 gh	0.68 fg	**0.53D**
UV 250 + MCP 1.5	0.34 w	0.38 sw	0.43 ps	0.48 np	0.50 mo	0.57 kl	**0.45F**
UV 250 + MCP 5	0.34 w	0.35 vw	0.37 tw	0.41 ru	0.44 pr	0.47 op	**0.40H**
UV 200 + MCP 1.5	0.34 w	0.40 rv	0.46 oq	0.53 ln	0.59 ik	0.64 gi	**0.49E**
UV 200 + MCP 5	0.34 w	0.37 uw	0.40 ru	0.45 pr	0.46 oq	0.51 mo	**0.42G**
Control	0.34 w	0.48 np	0.63 hj	0.74 de	0.84 b	0.97 a	**0.67A**
Mean	**0.34F**	**0.41E**	**0.49D**	**0.56C**	**0.63B**	**0.68A**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

8. Total phenolic compound:

Data in **Table (8)** showed that total phenolic compound of lettuce heads decreased with the prolongation of storage till the end of storage period in both seasons; these results are similar with (Abdullah et al., 2023).

Concerning the effect of postharvest treatments, data indicated that there were significant differences between all treatments and clear observed that all treatments maintained phenolic compounds during storage period with little changes in their contents, especially for heads exposed to UV-C 250 nm + 5% 1-MCP which show the lowest decreasing rates followed by heads exposed to UV-C 200 nm + 5% 1-MCP with significant differences between them. While untreated control lettuce heads had a significantly greater decrease. The same results agreed with (Tedeschi et al., 2023 and Tian et al., 2011) these results may be due 1-Methylcyclopropene reduce the oxygen supply for enzymatic oxidation of phenols.

Saltveit (2004) found that the effectiveness of 1-MCP in inhibiting ethylene-induced accumulation of phenolic compounds in mid-rib lettuce tissue does not extend to the wound-induced accumulation of phenolic compounds in similar tissue. Furthermore, many studies have indicated that UV-C treatment can act independently or synergistically to induce the biosynthesis and accumulation of health-promoting compounds (phenolic compounds, carotenoids and fatty acids) and trigger the enhancement of enzymatic antioxidant defense system in fresh-cut produce (Surjadinata et al., 2017).

Table (8). Effect of Ultraviolet radiation and 1-methylcyclopropane treatments on Total phenolic compound of Iceberg head lettuce during storage at 0̊C and RH 95 % in 2020 and 2021 seasons.

Treatments	Storage period (day)						
	2020						
	0	**4**	**8**	**12**	**16**	**20**	**Mean**
MCP 1.5	28.13 a	27.10 e	26.52 i	26.22 kl	25.81 n	25.54 o	**26.55E**
MCP 5	28.13 a	27.34 d	26.82 gh	26.51 i	26.12 lm	25.81 n	**26.79D**
UV 200	28.13 a	26.83 gh	26.21 l	25.87 n	25.89 n	25.21 p	**26.36F**
UV 250	28.13 a	27.35 d	26.82 gh	26.51 i	26.12 lm	25.82 n	**26.79D**
UV 250 + MCP 1.5	28.13 a	27.70 b	27.11 e	26.83 gh	26.43 ij	26.12 lm	**27.05C**
UV 250 + MCP 5	28.13 a	28.02 a	27.51 c	27.15 e	26.91 fg	26.52 i	**27.37A**
UV 200 + MCP 1.5	28.13 a	27.33 d	26.82 gh	26.52 i	26.14 lm	25.82 n	**26.79D**
UV 200 + MCP 5	28.13 a	27.83 b	27.32 d	27.03 ef	26.73 h	26.34 jk	**27.23B**
Control	28.13 a	26.55 i	26.03 m	25.65 o	25.32 p	25.00 q	**26.11G**
Mean	**28.13A**	**27.34B**	**26.79C**	**26.48D**	**26.16E**	**25.80F**	
	2021						
MCP 1.5	27.96 a	26.86 g	26.53 j	26.12 p	25.75 t	25.24 w	**26.41E**
MCP 5	27.96 a	27.12 e	26.85 g	26.42 kl	26.03 o	25.54 u	**26.65D**
UV 200	27.96 a	26.62 i	26.20 o	25.83 s	25.42 r	25.02 y	**26.17F**
UV 250	27.96 a	27.15 e	26.81 g	26.43 kl	26.05 q	25.54 u	**26.65D**
UV 250 + MCP 1.5	27.96 a	27.41 c	27.14 e	26.71 h	26.31 n	25.84 s	**26.89C**
UV 250 + MCP 5	27.96 a	27.65 b	27.35 cd	27.04 f	26.69 h	26.35 mn	**27.17A**
UV 200 + MCP 1.5	27.96 a	27.14 e	26.82 g	26.44 k	26.06 po	25.53 u	**26.66D**
UV 200 + MCP 5	27.96 a	27.62 b	27.30 d	27.01 f	26.65 hi	26.11 p	**27.11B**
Control	27.96 a	26.37 lm	25.91 r	25.54 u	25.11 x	24.74 z	**25.94G**
Mean	**27.96A**	**27.10B**	**26.77C**	**26.39D**	**26.01E**	**25.54F**	

Means values within a column or row having the same letter/s are not significantly different at 5 % level.
Storage periods and treatments refer to the specific and interaction effect between them, respectively.

CONCLUSION

From the previous results, it could be concluded that, Iceberg lettuce heads exposed to ultraviolet radiation 250 nm + 5% 1-Methylcyclopropene showed the best appearance and maintaining postharvest quality and didn't exhibit any changes in their appearance and gave excellent appearance at the end of storage period (20 days at 0 °C), while 200 nm + 5% 1-Methylcyclopropene treatment gave good appearance at the same period.

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الملخص العربى

تأثير الاشعة فوق البنفسجيه والمثيل سيكلو بروبان على الجودة والقدرة التخزينية لرؤس الخس الكابوتشا اثناء التخزين المبرد.

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أجريت هذه الدراسه على رووس الخس صنف ايس بيرج خلال موسمى 2020 و 2021 لدراسة تأثير تعرض رووس الخس للأشعة فوق البنفسجيه بتركيز200 و 250 نانوميتر و1- مثيل سيكلو بروبان بتركيز 1.5 – 5 % والتداخل بينهم بجانب الرووس الغير معامله (كنترول) على الجودة والقدرة التخزينيه لرؤوس الخس خلال التخزين على صفر° م ورطوبه نسبيه 90- 95% لمدة 20 يوم. أوضحت النتائج أن كل معاملات ما بعد الحصاد قد حافظت على جودة رؤوس الخس مقارنة بمعاملة الكنترول أثناء التخزين. مع ذلك، معاملة التعرض للاشعة فوق البنفسجية بجرعة 250 نانوميتر مع 1- الميثيل سيكلو بروبان تركيز 5 % (شيت) ومعاملة التعرض للأشعة فوق البنفسجية بجرعة 200 نانوميتر مع 1- الميثيل سيكلو بروبان تركيز 5 % (شيت) كانت الأكثر فاعلية في تقليل نسبة الفقد فى الوزن والتالف والحمل الميكروبى وتغير اللون مع الحفاظ على الجودة المظهرية ومحتوى حمض الأسكوربيك والمحتوى الفينولي الكلي علاوة على ذلك، أدت المعاملات الى تأخير نشاط انزيم البولي فينول أوكسيديز مقارنة بباقي المعاملات. كما لوحظ أن رؤوس الخس المعاملة بالتعرض للأشعة فوق البنفسجية بجرعة 250 نانوميتر مع 1- الميثيل سيكلو بروبان تركيز 5% (شيت) أعطت مظهرًاً ممتازاً والمعاملة بالتعرض للأشعة فوق البنفسجية بجرعة 200 نانوميتر مع 1- الميثيل سيكلو بروبان تركيز 5% (شيت) وأعطت مظهرًا جيداً لمدة 20 يوم من التخزين على درجة صفر °م.