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INFLUENCE OF UV TREATMENT ON SOME PROPERTIES AND BIOACTIVE COMPOUNDS IN ONION BULBS (*ALLIUM CEPA L.*) DURRING STORAGE

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ABSTRACT

Due to the importance of food and health benefits, onions are used and stored in large quantities. One of the problems encountered during onion storage is besides maintaining the chemical components at optimal values, the losses recorded by sprouting and stripping the bulbs. Physical and chemical properties as well as bioactive compounds and weight loss of the onion bulbs were determined during storage under the influence of an UV-C treatment with doses of 2 $kJ \cdot m^{-2}$. The results showed that UV-C illumination treatment do not lead to significant differences concerning the size of onion during storage. Weight losses of onion were lower in onions treated by UV-C illumination during storage. Dry matter, the soluble solids and total phenolic contents remained higher in treated onions. Treatment of onions by UV-C illumination determines the suppression of bulb sprouting. These findings demonstrate that the application of UV-C illumination to onions can be a method of extending their shelf life.

1.Introduction

Preservation of vegetables is done in order to extend their shelf life by stopping the growth of microorganisms, including a series of processes that inhibit quality deterioration due to enzymatic processes (Maskepatil et al., 2019).

Onion (*Allium cepa L.),* originating in Asia Minor, is among the healthiest foods being found in the same family with garlic, shallots, Egyptian onions and leeks. The interest in onion bulbs worldwide has determined the growers to find new postharvest techniques to extend the storage life of this crop while maintaining their nutritional and organoleptic characteristics (Zudaire et al., 2017).

Due to the importance of food and health benefits, onions are stored in large quantities. Due to its characteristics of preservation and durability of transport, onions have al-ways been marketed more widely than most vegetables (Griffiths et al., 2002).

Onions have a high content of beneficial phenols with high antioxidant capacity, with an important role in preventing and reducing the progression of different types of diseases (Pérez-Gregorio et al., 2010).

Onions are also rich in vitamins, minerals and antioxidants, with a low energy value (Abdelrasheed et al., 2021). Onion wasted peels are rich in free fat (0.31%) and reducing sugars (Zhivkova, 2021).

Phenols also play an important role as a prebiotic (Yang et al., 2004), being a source of food for beneficial bacteria in the stomach, which is important for health, weight maintenance and dis-ease prevention.

Onion contains more phenolic compounds than garlic (Nuutila et al., 2003) or leeks and is one of the best dietary sources of flavonoids, especially quercetin.

Due to its nutritional importance and health benefits, onions are stored by refrigeration in large quantities. Some of the most important conditions in terms of maintaining the quality of the onion for as long as possible are in addition to harvesting at the optimum time, the ventilation operations during storage, especially the compliance with the periods and parameters of ventilation and care for bulbs.

The biggest problem that appears during the storage of onion bulbs is due to the germination process and microbiological changes, especially their rot.

Irradiation of vegetables is an important method to reduce the load of microorganisms on their surface and extend their shelf life (Cueva et al., 2010).

UV radiation is electromagnetic radiation with a wavelength shorter than the light radiation perceived by the human eye (Zamanian and Hardiman, 2005).

The spectrum of UV radiation is between wavelengths 10 - 380 nm (1 nanometer = 10-9 m), with a frequency of 750 THz (380 nm) to 30 PHz (10 nm). UV radiation with a maximum germicidal effect is UV-C in the wavelength spectrum of 254 nm (the point at which the nucleic acids of microorganisms have the maximum absorption) (Tran et al., 2022).

These radiations are surface sterilizers with an effect on microorganisms, especially bacteria and viruses. UV-C radiation has a disinfectant effect, as it affects the DNA structures of microorganisms, causing a photochemical effect on thymine (Kalisvaart, 2004). They dimerize, which means that two adjacent information carriers are improperly linked (Schreier et al., 2007).

This molecular change means that DNA cannot be used for the essential process of transcription (metabolism) and replication (cell division). As a result, the microorganism is inactivated and dies.

Exposure to UV-C radiation has been used as a post-harvest treatment of fruits and vegetables and is useful in delaying fruit senescence and reducing fruit decay (Wang, Chen and Wang, 2009). These, modifies the expression of genes involved in cell wall degradation delaying the softening of fruits and vegetables (Pombo et al., 2011).

Studies on the use of UV-C illumination on fresh horticultural produce have focused on the selection of appropriate doses for different species, but less attention has been paid to the effect of radiation intensity (Lin et al., 2017).

Previous studies have shown that the use of UV-C illumination of plant products combined with fresh storage has led to an extension of their shelf life (Cote et al., 2013). The duration of UV-C illumination varies, previous research indicating 30 minutes (to obtain a dose of 2.0 kJ·m-2) (Nour, Plesoianu and Ionica, 2021).

The present study was conducted to investigate the effect of UV-C illumination on some properties and bioactive compounds in onion during storage. Weight and sprouting losses during storage as a result of treatment were also investigated.

2. Materials and methods

2.1. Plant material

Daytona F1 hybrid onion bulbs purchased from local producers in Dolj County, Romania were used as plant material. Daytona F1 is a semi-early hybrid of onion, a standard variety in onion culture that offers stable and quality yields year after year. The bulb has a golden color, an attractive shape and a good storage capacity even in unarranged spaces. It has a very well-developed root system, which gives it resistance to drought-induced stress. Daytona F1 has medium resistance to *Fusarium oxysporum* and pink root rot *(Pyrenocheta terrestris*), yielding 55-60 tons/hectare.

2.1.1. Sampling

The effect of UV-C illumination treatments on the physicochemical characteristics of onion, as well as weight loss during their long-term storage, was studied.

The onion was sorted and packed in plastic net bags with a capacity of 15 kg. Two working options have been established, namely:

- Control variant (C) was to store the onion bulbs in refrigerated conditions: 4°C temperature and 75% relative air humidity
- the bulbs of the second variant (V1) were subjected to a treatment with UV illumination using a UV LED lamp for 30 minutes, equivalent to a dose of 2.0 kJ·m^{-2} measured by a UVC portable digital radiometer (TN-2254, Taine Co., Ltd., Taiwan, China). The UV lamp was placed 30 cm away from the onion.

The onion bulbs were placed in an insulated enclosure on a single layer and after 15 minutes, they were turned over and the treatment was continued for another 15 minutes. After that, they were packed and stored under the same conditions of temperature (4°C) and relative humidity (75%).

For each variant, the amount of onion studied was 75 kg (5 bags). During storage, onion samples were taken in order to highlight the changes that occurred as well as the effect of UV-C illumination. The onion was stored for 4 months, experiments were executed in five repetitions, and the results were expressed as average ± standard error of average repetitions.

2.2. Analytical methods

Dimensions, average bulb weight, volume, size index, shape index, total dry matter, soluble solids content, titratable acidity, total phenolic content as well as antioxidant capacity and weight loss of the onion bulbs were determined during storage.

Onion linear dimensions (length, L; width, W; thickness, T) were determined with a Luthier digital caliper manufactured by Stewart MacDonald (USA) and the results were expressed as mm.

Average onion weight (g) was determined by individual weighing on an analytical scale model ABT-320-4M manufactured by Kern (Balingen, Germany. The volume of the fruit was determined by a cylinder of volume on the principle of Archimedes, the results being expressed in cm3. Size index was calculated using the formula: (L+T+W)/3. Weight loss during storage was measured by monthly weighing of a predetermined lot of onion the results being expressed as a percentage.

Dry matter (%) was determined by drying 5 g of fresh onion sample to a constant weight at 105°C and soluble solids content (TSS%) was determined of onion juice was measured with a digital refractometer (Hanna Instruments, Woonsocket, USA).

The titratable acidity was determined by titration of a known amount of water extract of onion with 0.1N NaOH using phenolphthalein as indicator and is expressed as g malic acid/ 100 g fresh weight (fw).

2.2.1. Total phenolic content

The total phenolic content was assessed according to the Folin-Ciocalteu procedure (Singleton and Rossi, 1965). Briefly, a 100 µl aliquot of the extract was mixed with 5 ml of distilled water and 500 µL of Folin-Ciocalteu reagent. After 3 min, 1.5 mL (20% w / v) sodium carbonate solution was added and the reaction mixture was diluted with distilled water to a final volume of 10 mL.

After stirring vigorously and incubating in the dark at 40 ° C for 30 minutes, the absorbance was measured at 765 nm on a Varian Cary 50 UV spectrophotometer (Varian Co., USA).

A calibration curve was prepared using standard gallic acid solutions. The results were expressed in milligrams of gallic acid equivalents (GAE)/ 100 g fresh weight.

2.2.2. Antioxidant activity

Antioxidant activity was measured in methanolic extract using the DPPH test (2,2-diphenyl-1-picrylhydrazyl).

Sampling was performed according to the same protocol described for the total phenolic content. The free radical scavenging capacity of DPPH free radical extracts was evaluated as described by Oliveira et al. (2008), with some modifications.

Each ethanolic onion extract (50 µl) was mixed with 3 mL of 0.004% (v / v) DPPH methanolic solution. The mixture was incubated for 30 minutes at room temperature in the dark and the absorbance was measured at 517 nm on a Varian Cary 50 UV-VIS spectrophotometer. DPPH free radical scavenging capacity was calculated with reference to Trolox (6-hydroxy2,3,7,8-tetramethylchroman-2-carboxylic acid), which was used as a standard reference.

A methanol/water control was used in each analysis. All tests were performed in triplicate and the results were expressed in mmol Trolox / 100 g fresh weight (fw).

2.2.3. Statistical analysis

Results were expressed as means ± standard deviation. Effect of storage time was analyzed using the least significant difference (LSD) test and differences at $p < 0.05$ were considered to be significant. The statistical analysis was carried out using Statgraphics Centurion XVI software (StatPoint Technologies, VA, USA).

3. Results and discussions

3.1. Physical properties and weight loss of onions during storage

Table 1. The variation of the dimensions, size index and shape index of the onion

Variant/Storage period (months)	**Control (C)**	**UV-C treatment (V1)**
Length (L) (mm)		
Beginning of storage	63.05±5.66	63.05±5.66
1	60.88±7.67	58.89±8.79
2	60.49±8.11	61.14±8.78
3	60.08±8.28	60.96±8.40
4	60.08±7.90	50.20±8.50
Width, (W) **(mm)**		
Beginning of storage	60.52±6.41	60.52±6.41
1	60.35±7.45	57.87±9.41
2	59.33±8.00	58.42±8.76
3	59.33±8.30	59.14±9.10
4	58.87±8.21	46.50±8.74
Thickness, (T) (mm)		
Beginning of storage	62.17±6.50	62.17±6.50
1	63.16±7.27	59.97±10.16
2	60.81±7.23	62.47±8.25
3	61.46±7.52	61.75±7.29
4	61.24±7.45	53.10±7.85
Size index		
Beginning of storage	61.88±5.02	61.88±5.02
1	61.46±7.39	59.24±8.62
2	60.21±7.49	60.67±7.91
3	60.27±7.64	60.61±7.56
4	60.06±7.51	60.09±7.71
Shape index		
Beginning of storage	0.99±0.11	0.99±0.11
1	1.04±0.04	1.00±0.14
2	1.01±0.08	1.02±0.12
3	1.02±0.09	1.02±0.12
4	1.01±0.08	1.02±0.12

*Means followed by different superscript letter in a column are significantly different (LSD test, P<0.05).

Size and shape are needed to describe a product defined with some dimensional parameters (Devojee et al., 2021). The size of the onion decreased constantly during storage (Table 1). It is also seen that the largest decrease in size is recorded in onion bulbs treated by UV-C illumination.

However, no significant differences were recorded between the two variants in terms of dimensions, size index and shape index of the onion.

Another trend is observed in terms of the weight and the volume of the onion (Table 2). The weight and volume of onion bulbs are a characteristic of the variety and there is a correlation between these and some chemical components such as flavonoids (Pérez-Gregorio et al., 2014; Riggi et al., 2019). Although these characteristics evolved negatively during storage, with weight and volume losses, it was found that they were higher in control (C) variant. No significant differences were found in terms of variations in onion bulb volume.

Storage of onions involves many pre-harvest and postharvest factors which determine weight losses (Petropoulos, Ntatsi and Ferreira, 2017).

The weight loss of onions (table 3) has steadily increased during storage, which has been more pronounced in the last two months, being higher in the variant treated by UV-C illumination compared to the control (C).

Table 2. The variation of the dimensions, size index and shape index of the onion during the storage

Variant/Storage period (months)	Control (C)	UV-C treatment (V1)
Weight (w) (g)		
Beginning of storage	$121.1±5.57^{c}$	$121.1±5.57^{b}$
1	$115±5.60^{bc}$	$105.3±5.16^{a}$
2	$110.6±5.49^{b}$	$110.7±5.42^{a}$
3	$107.7±5.36^{b}$	$108.7±5.39^{a}$
4	$97.38±4.81^{a}$	$107.4±5.22^{a}$
Volume (V) (cm^3)		
Beginning of storage	126.1±6.19	126.1±6.19
1	124.8±6.09	116.5±6.10
2	121.5±5.97	120.5±5.69
3	117.4±5.49	124.3±6.11
4	116.8±5.85	118.6±5.82

*Means followed by different superscript letter in a column are significantly different (LSD test, P<0.05).

Table 3. Weight loss of onion during storage

Variant/Storage period (months)	Control (C)	UV-C treatment (V1)
Weight loss (%)		
Beginning of storage	-	-
1	$1.52±0.06^{a}$	$2.17±0.99^{a}$
2	$2.67±0.13^{b}$	$3.71±0,19^{b}$
3	$4.08±0.20^{c}$	$5.46±0.26^{c}$
4	$5.47±0.27^{d}$	$7.00±0.32^{d}$

*Means followed by different superscript letter in a column are significantly different (LSD test, P<0.05).

3.2. Variation of the chemical properties of onions during storage

The dry matter in onions consists mainly of fiber, starch and sugars; these include non-structural carbohydrates such as fructose and glucose, non-reducing sugars such as glucose, and fructans (Ríos-González et al., 2018). The dry matter content in onion decreased steadily in the first two months of storage and then increased in the third month of storage, returning to a downward trend in the last month of storage (Table 4).

The soluble solids content is an important quality parameter and is related to the degree of preservation of the onion (Mallor et al., 2011). Onion at harvest maturity (Table 4) had a soluble solids content of 7.75%, which decreased steadily during their storage, which is consistent with data obtained by Saeed, and Mohsen (2015) and Chávez-Mendoza et al. (2016). The largest decrease in the soluble solids content is observed in the control variant (6.98%).

In both variants, in the second and third months of storage is a sharp increase followed by a sharp decrease in the last month of storage. Soluble solids content reduction during storage is due to the increase of the carbohydrate metabolism through respiration (Mota et al., 2019).

The titratable acidity values increased continuously until the third month of storage, when, in the illuminated variant, there was a decrease of it. However, the increases in titratable acidity did not have a specific trend in both variants studied, which is consistent with the data presented by Zudaire et al. (2020).

This can be attributed to the fact that during storage at low temperatures, respiratory intensity decreases as well as metabolic activities (do Nascimento Nunes and Emond, 2002).

Table 4. The dry matter content (DW %), soluble solids content (TSS%) and titratable acidity in the onion during storage

Variant/Storage period (months)	**Control (C)**	**UV-C treatment (V1)**
Dry matter (DW%)		
Beginning of storage	9.52±0.63^{c}	9.52±0.63^{b}
1	8.51±0.12^{b}	8.17±0.16^{a}
2	8.35±0.30^{b}	7.24±0.48^{a}
3	8.82±0.21^{b}	7.77±0.38^{a}
4	7.01±0.18^{a}	7.45±0.46^{a}
Soluble solids content (TSS%)		
Beginning of storage	7.80±1.18^{ab}	7.80±1.18
1	7.47±0.69^{ab}	7.20±0.91
2	7.86±0.65^{ab}	7.64±0.76
3	8.03±0.70^{b}	7.27±0.47
4	7.02±0.59^{a}	7.12±0.35
Titratable acidity (g malic acid/100 g fw)		
Beginning of storage	1.68±0.08^{a}	1.68±0.08^{b}
1	2.01±0.13^{b}	1.34±0.06^{a}
2	1.67±0.09^{a}	1.34±0.07^{a}
3	2.01±0.09^{b}	2.01±0.09^{c}
4	2.01±0.10^{b}	1.67±0.09^{b}

*Means followed by different superscript letter in a column are significantly different (LSD test, $P<0.05$).

The phenols, have an important role from a nutritional point of view (Liguori et al., 2017). Postharvest processing and storage affect the content of phenolic acids and flavonoids in foods (Tomás-Barberán, Ferreres and Gil, 2000).

In our study onion has a high total phenolic content (Table 5) with higher values than those reported by Zudaire et al. (2019).

It steadily increased over two months of storage and then fell sharply in the third, resuming its upward trend in the last month of storage. This upward trend has also been mentioned in the literature (Zudaire et al., 2020; Juániz et al., 2016).

Table 5. Variation in total phenolic content and antioxidant activity of onion during storage

Variant/Storage period (months)	Control (C)	UV-C treatment (V1)
Total phenolic content (milliequivalent gram of gallic acid (GAE)/100 g fw)		
Beginning of storage	76.25±2.76[a]	76.25±2.76[b]
1	76.06±2.85[a]	76.88±3.11[b]
2	82.19±3.08[b]	76.25±2.80[b]
3	70.93±3.21[a]	66.87±2.81[a]
4	76.56±3.60[ab]	80.93±2.98[b]
Antioxidant activity (AOA) (mmol Trolox / 100 g fw)		
Beginning of storage	0.74±0.04[b]	0.74±0.04[b]
1	1.34±0.07[c]	0.77±0.03[b]
2	0.60±0.03[a]	0.57±0.02[a]
3	1.55±0.07[d]	0.76±0.04[b]
4	1.49±0.06[d]	1.14±0.05[c]

*Means followed by different superscript letter in a column are significantly different (LSD test, P<0.05).

Regarding the effect of UV-C illumination on the total phenolic content, there is initially a slower increase in the first 2 months of storage and a sudden increase in the last month of storage of the onion. At the end of the storage, the UV-C illuminated onion had a higher phenolic content than the control (80.93 milliequivalent gram of gallic acid /100 g fw compared to 76.56 milliequivalent gram of gallic acid /100 g fw in the control).

Juániz et al. (2016) reported that the increase in phenolic compounds in the stored onion corresponded to an increase in antioxidant activity determined by the DPPH method (Table 5), which is also confirmed by the data found in this study. Previous reserch has shown a strong correlation between antioxidant activity and total phenolic content (Shim, Yi, and Kim, 2011).

Sprouting can be prevented by different chemical treatements or an appropiate storage temperature (Suojala, 2001). It was found that the bulbs in the version treated by UV-C illumination did not show swelling and sprouting processes comparing with control (C) that registered 4% sprouted bulbs, a slight dehydration and stripping.

4. Conclusions

Storage conditions did not affect the morphological parameters of the onion and have helped to maintain a low respiration rate, weight and chemical compounds loss being relatively small.

Onions belonging to the cultivar Daytona F1 have highly characteristics in terms of natural antioxidant compounds. UV-C illumination treatments maintain at a higher level the content of onions in phenolic compounds as well as their antioxidant activity.

UV-C illumination leads to a more pronounced decrease in onion size during storage. The individual weight and volume of the onion evolves negatively during storage, the total weight loss being higher in the UV-C treated variant.

UV-C illumination treatment with doses of 2 $kJ \cdot m^{-2}$ resulted in a higher maintenance of dry matter, total soluble solids and total phenol content.

The antioxidant activity of onion evolves in accordance with the content in total phenols, still, a decrease being observed under the influence of UV-C treatment during storage.

Treatment of onions by UV-C illumination leads to the suppression of bulb dehydration and stripping. UV-C illumination treatment of onion significantly suppressed water loss, thus delaying their degradation during storage. Treating onion bulbs by UV-C illumination prevents them from sprouting.

The results suggest that UV-C illumination with doses of 2 $kJ \cdot m^{-2}$ can be a method of maintaining onion bulbs quality and extending their self-life.

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