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Influence of postharvest water replacement on shelf life of parsley leaves

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Abstract

Wilting is one of the major problems of parsley leaves in Brazilian retail stores. This study was conducted to determine the effect of postharvest replacement of water by submerging the parsley leaf bunches in water for 3, 6 or 9 hours at three stages: when total weight loss reached 5 and 10% and immediately after two hours of storage. Leaves were stored at 5 or 25°C until visible wilting or yellowing was detected. Results demonstrated that water replacement resulted in gains in fresh mass, resulting in longer shelf life for leaves stored at 5 and 25°C. In general, longer recharging resulted in greater water uptake by the leaves, but at a lower rate. By recharging the leaves with water, lower rates of mass loss were observed compared to untreated leaf bunches. Regardless the storage temperature, the relative water content of leaves decreased during shelf life, which in general was less accentuated for leaves submerged in water for 6 and 9 hours. Postharvest water replacement should be considered as an option to extend the shelf life of horticultural products that are susceptible to intense moisture loss.

Key words: *Petroselinum crispum*, water uptake, relative water content, shelf life.

Introduction

Leafy greens are highly susceptible to water loss, which can be intensified by inadequate management of temperature and air humidity present in the storage facility. Even if the water content of most leafy greens is above 90%, they will show severe wilting symptoms with losses of fresh weight between 5 to 10% [3].

The rate of postharvest moisture loss varies widely among different fruits and vegetables. Major factors in the rate of water loss are the surface area of the product and the gradient of vapor pressure between the intercellular spaces of the tissue and the surrounding air in the storage room [4]. As leaves have a high surface area/volume ratio, elevated rates of water loss will take place once harvested. In many cases, excessive wilting is the main cause of poor quality of green vegetables in small retail stores in Brazil.

Several actions are used to diminish the rate of dehydration of fresh horticultural products during storage. In general, rapid reduction of temperature and increasing air humidity are efficient methods to slow down plant metabolism and to reduce water loss. Leaf dehydration at low temperatures and high humidity can be intensified due to excessive air movement in the storage facility which reduces the thickness of the boundary layer surrounding the product surface [6]. Shibairo *et al.* [5] working with carrots, proposed a method for the replacement of lost moisture. They obtained convincing data demonstrating that water can be replaced by submerging the carrot tap roots in a water bath for several hours. This technique extended the shelf life of the roots. In similar work, Almeida and Valente [1] observed that parsley leaves recovered water loss by placing the leaf petiole in water. However, it is not known if submerging the parsley leaves in water at different times during short-term storage would have a beneficial effect on the shelf life. Thus the objective of this study was to evaluate the dynamics of water uptake by using a recharge technique and to determine its potential to extend the shelf life of parsley leaves.

Material and Methods

Parsley (*Petroselinum crispum* Mill. cv. Graúda Portuguesa) was grown at the Research Farm of the Federal University of Viçosa (642 m asl, 20°45' lat. S and 42°51' long. W). The leaves were harvested 80 days after seeding by cutting them at the base of the petiole (20 cm long). Harvest took place early in the morning when the leaves appeared green and fully expanded. After selection, the leaves were tied with a rubber band in bunches of 30 g each. The leaf bunches were immediately placed at 5 or 25°C, simulating the two most common temperatures used in retail stores in Brazil. After storage for two hours at these two temperatures, the bunches were treated for a single recharge treatment as follows: recharging for 3, 6 and 9 hours immediately after storage for two hours at the two storage temperatures; recharging for 3, 6 and 9 hours after the leaves had lost 5 or 10% of fresh weight; no recharging (control). The relative humidity of the storage rooms were 66% at 5°C and 68% at 25°C. The length of time required from harvest until the leaves had lost 5 and 10% of fresh weight was 3:00 and 8:00 hours, respectively, at 5°C, and 1:00 and 2:30 hours, respectively, at 25°C.

Recharging was obtained by completely submerging the leaf bunches in water at 25°C as described by Shibairo *et al.* [5].

Water uptake was measured by the variation of fresh weight in each leaf bunch and by the relative water content (RWC) before and after recharging the leaves. The RWC was determined in the discs of leaves as previously described by Álvares *et al.* [2]. Chlorophyll content was measured using a SPAD-502 (Minolta, Japan) taken at 0, 48, 72 and 96 hours after the experiment began for the leaves stored at 5°C, and at 0 and 24 hours for the leaves stored at 25°C.

The rate and total amount of water absorbed by leaf bunches were estimated by the percentage of mass gained at the end of recharge treatment [5]. The leaf bunches were discarded when the total mass lost 20% of its initial weight at the beginning of the experiment or when the leaves turned yellow.

All experiments were conducted with three replicates of a single bunch per replication, arranged in a completely randomized design. Data were analyzed by analysis of variance ANOVA using the statistical software SAEG (UFV, Viçosa), and the means were separated using Scott-Knott's contrast and Tukey's test at $P=0.05$.

Results and Discussion

For leaves stored at 5°C and submerged in water at 25°C, the gain of mass increased throughout the recharging treatment, regardless if the treatment was performed immediately after harvesting or when 5 or 10% of weight loss was achieved (Table 1). The highest mass gain was obtained when the leaves were recharged for 9 hours after allowing 5 or 10% of fresh weight loss; however, the highest rate of water uptake (>7% h^{-1}) was determined for leaves that were kept in water for 3 hours after having lost 5 or 10% of fresh weight (Table 1). After removing the leaves from the water, post-treatment water loss was reduced significantly in all treatments compared to the rate loss of 1.78% h^{-1} observed on untreated leaves (Table 1). Similar treatment in carrots had no effect in reducing the subsequent rate of water loss during the storage of roots at 13°C for 21 days [5]. These apparent contradictory results may be due to the duration of time that the products were kept in storage after recharging; the carrots were kept in storage much longer than the parsley, possibly allowing the carrots to lose the beneficial post-treatment effect towards the end of the shelf life.

The longest total shelf life obtained was 84 hours for parsley stored at 5°C and recharged for 6 or 9 hours after allowing the loss of 10% fresh weight (Table 1). Independently of treatments applied, recharging resulted in the gain of mass in leaves by 4- to 7-fold compared to untreated leaves, with a positive effect on shelf life. The longest extension on shelf life after water submersion, providing an additional of 61 hours, was obtained when the leaves were recharged for 6 hours after allowing the 5% loss of fresh weight (Table 1).

Treating leaves with water at 25°C for 9 hours resulted in the largest water uptake when submerged immediately after harvest and stored at 25°C (Table 2). The highest rate of water uptake (6.18% h^{-1}) was observed when the leaves were kept in water for 3 hours while the lowest rate was observed in leaves submerged for 6 and 9 hours after loosing 5 or 10% of fresh mass (Table 2). Similarly for leaves stored at 5°C, a significant reduction in the post-treatment water loss was detected for leaves stored at 25°C, with the tendency of lower rates of water loss the longer the leaves were submerged in water. This resulted in a significant lower final mass loss of the leaves, when they were recharged for 9 hours after losing 10% of fresh weight. However, in all recharging treatments, regardless the duration or when performed, a lower rate of water loss was observed which led to a doubling of the postharvest life from 12 hours for the untreated leaves to 24 hours for the recharged leaves (Table 2).

Chlorophyll content was not affected by the recharging treatments, the two storage temperatures or by the length of storage until the leaves were completely wilted (data not shown); however, the relative water content of leaves was affected by the recharging treatments and the storage conditions (Table 3). As expected, the relative water content for the uncharged leaves was reduced significantly throughout storage at both 5 and 25°C. This reduction in water content was also observed for most recharging treatments, but it was not as extensive as the water loss determined in control leaves (Table 3). By submerging leaves in water for 6 or 9 hours after they had lost 5% of the fresh weight, or for 3, 6 or 9 hours after losing 10% of fresh weight, the recharging treatments were able to increase the water content in leaves stored at 5°C. For leaves stored at 25°C, 9 hours of recharging, regardless if performed immediately after harvest or during storage, was the most effective treatment for replacing the water content of leaves (Table 3). Shibairo *et al.* [5] measured the influence of similar treatments in carrots on the fluctuations of weight gain during recharging, but without measuring the effect on the water status of the roots after treatments. Our results showed that regardless of the storage temperature, the increase of shelf life was positively affected by the significant uptake of water by the leaves during the recharging treatment.

Conclusions

Recharging harvested parsley leaves with water extended the shelf life due to the replacement of moisture lost during storage and by reducing the post-treatment rate of water dehydration. Relative water content of leaves dropped over time, regardless of the storage temperature. Postharvest water recharging treatments should be considered as a viable technique to prolong the shelf life of horticultural products.

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Table 1. Water uptake, mass loss and shelf life of parsley leaves recharged with water at 25ºC and stored at 5ºC.

Treatment[(1)]	Water uptake		Rate of	Shelf life (longevity)		
	Total (%)	Rate (% h-1)	mass loss (% h-1)	Total mass loss (%)	Hours after harvest	Hours after recharging
T1	-	-	1.78 a	21.37 a	12	-
T2	14.07 b	4.69 b	0.55 b	22.73 a	48	45
T3	18.60 b	3.10 b	0.45 b	21.30 a	48	42
T4	21.87 b	2.43 b	0.29 b	18.66 a	48	39
T5	21.12 b	7.04 a	0.35 b	18.90 a	48	40
T6	21.24 b	3.54 b	0.32 b	25.05 a	72	61
T7	31.08 a	3.45 b	0.37 b	21.79 a	72	58
T8	21.37 b	7.12 a	0.37 b	18.94 a	72	46
T9	23.31 b	3.88 b	0.42 b	25.27 a	84	55
T10	28.44 a	3.16 b	0.46 b	26.92 a	84	52

(1)T1 = no recharging, T2 = recharging for 3 hours at harvest; T3 = recharging for 6 hours at harvest; T4 = recharging for 9 hours at harvest ; T5 = recharging for 3 hours after 5% of mass loss; T6 = recharging for 6 hours after 5% of mass loss; T7 = recharging for 9 hours after 5% of mass loss; T8 = recharging for 3 hours after 10% of mass loss; T9 = recharging for 6 hours after 10% of mass loss; T10 = recharging for 9 hours after 10% of mass loss. Means within the column followed by the same letter do not differ significantly using Scott-Knott test at $P \leq 0.05$.

Table 2. Water uptake, mass loss and shelf life of parsley leaves recharged with water at 25ºC and stored at 25ºC.

Treatment[(1)]	Water uptake		Rate of	Shelf life (longevity)		
	Total (%)	Rate (% h-1)	mass loss (% h-1)	Total mass loss (%)	Hours after harvest	Hours after recharging
T1	-	-	2.46 a	29.58 a	12	-
T2	18.54 c	6.18 a	1.54 c	28.75 a	24	21
T3	20.01 b	3.33 c	1.57 c	27.42 a	24	18
T4	25.83 a	2.87 c	1.26 c	27.34 a	24	15
T5	15.39 c	5.13 b	1.72 b	28.57 a	24	20
T6	11.52 c	1.92 d	1.96 b	29.50 a	24	17
T7	16.74 c	1.86 d	1.20 c	22.87 a	24	14
T8	15.03 c	5.01 b	1.76 b	26.61 a	24	18
T9	16.50 c	2.75 c	1.36 c	28.71 a	24	15
T10	21.15 b	2.35 d	1.18 c	12.96 b	24	12

(1)T1 = no recharging, T2 = recharging for 3 hours at harvest; T3 = recharging for 6 hours at harvest; T4 = recharging for 9 hours at harvest ; T5 = recharging for 3 hours after 5% of mass loss; T6 = recharging for 6 hours after 5% of mass loss; T7 = recharging for 9 hours after 5% of mass loss; T8 = recharging for 3 hours after 10% of mass loss; T9 = recharging for 6 hours after 10% of mass loss; T10 = recharging for 9 hours after 10% of mass loss. Means within the column followed by the same letter do not differ significantly using Scott-Knott test at $P \leq 0.05$.

Table 3. Relative water content (%) of parsley after recharging the leaves with water at 25ºC and stored at 5 and 25ºC.

Treatment[(1)]	Temperature of storage (°C)					
	5 °C				25 °C	
	Hours after harvest (h)					
	0	48	72	96	0	24
T1	91.91 aA	68.99 bB	-	-	90.84 aA	71.27 bB
T2	91.91 aA	63.16 bB	-	-	90.84 aA	72.43 bB
T3	91.91 aA	54.56 bB	-	-	90.84 aA	72.49 bB
T4	91.91 aA	74.38 bB	-	-	90.84 aA	79.51 aB
T5	91.91 aA	64.98 bB	-	-	90.84 aA	70.82 bB
T6	91.91 aA	82.84 aB	66.90 aC	-	90.84 aA	78.04 aB
T7	91.91 aA	84.31 aAB	75.37 aB	-	90.84 aA	85.27 aB
T8	91.91 aA	83.32 aAB	75.94 aB	-	90.84 aA	70.48 bB
T9	91.91 aA	85.75 aAB	70.33 aBC	54.86 aC	90.84 aA	72.25 bB
T10	91.91 aA	88.61 aA	70.89 aB	65.75 aB	90.84 aA	79.77 aB

(1)T1 = no recharging, T2 = recharging for 3 hours at harvest; T3 = recharging for 6 hours at harvest; T4 = recharging for 9 hours at harvest ; T5 = recharging for 3 hours after 5% of mass loss; T6 = recharging for 6 hours after 5% of mass loss; T7 = recharging for 9 hours after 5% of mass loss; T8 = recharging for 3 hours after 10% of mass loss; T9 = recharging for 6 hours after 10% of mass loss; T10 = recharging for 9 hours after 10% of mass loss. Means followed by the same by small letter in the column do not differ significantly according to Scott-Knott test at $P \leq 0.05$. Means followed by the same by capital letter in the row do not differ significantly according to Tukey's test at $P \leq 0.05$ (-) Treatments discarded.