

## Effect of Chemical Materials Application and Storage Periods on Water Content and Total Soluble Solids of Lettuce During Ambient Storage

<sup>1</sup>Mahdi Hosseini Bahri, <sup>2</sup>Shahram Mohseni Niari and <sup>3</sup>Majid Rashidi

<sup>1</sup>Department of Agricultural Engineering Research,  
Tehran Province Agricultural and Natural Resources Research Center, Tehran, Iran

<sup>2</sup>Ardabil Province Jihad-e-Keshavarzi Education Center, Ardabil, Iran

<sup>3</sup>Department of Agricultural Machinery, Takestan Branch, Islamic Azad University, Takestan, Iran

**Abstract:** This study was conducted on the effect of chemical materials application (CMA) and storage periods (STP) on quality of Iranian white lettuce during ambient storage at temperature of 25°C and 65% relative humidity. Four CMA (calcium chloride, citric acid, acetic acid and no chemical material application as control) and five STP (0, 2, 5, 7 and 10 days) were investigated for two quality characteristics including water content and total soluble solids (TSS). The statistical results of the study indicated that CMA and STP significantly ( $P \leq 0.01$ ) affected both quality characteristics. Interaction of CMA  $\times$  STP for both studied quality characteristics was also significant ( $P \leq 0.01$ ). Results of the study indicated that calcium chloride was the best CMA for preserving water content and TSS of lettuce during ambient storage. In addition, water content and TSS decreased by increasing STP for ambient stored lettuce.

**Key words:** Lettuce • Water content • Total soluble solids • Ambient storage • Calcium chloride • Citric acid • Acetic acid • Storage period

### INTRODUCTION

The lettuce (*Lactuca sativa*) is an annual plant of the aster or sunflower family Asteraceae. It is most often grown as a leaf vegetable, but also sometimes for its stem and seeds. Lettuce was first cultivated by the ancient Egyptians, who turned it from a weed whose seeds were used to make oil into a plant grown for its leaves. Lettuce is easily cultivated, although it requires relatively low temperatures to prevent it from quickly flowering. It can be plagued with numerous nutrient deficiencies, as well as insect and mammal pests and fungal and bacterial diseases [1]. Lettuce is most often used for salads, although it is also seen in other kinds of food, such as soups, sandwiches and wraps. One type is grown for its stems, which are eaten either raw or cooked. Lettuce is a good source of vitamin A and potassium, as well as a minor source for several other vitamins and nutrients and 100 g of lettuce contains 13 cal energy, 2.2 g carbohydrates, 1.1 g dietary fiber, 0.2 g fat, 1.4 g protein, 96 g water, 166  $\mu$ g vitamin A, 73  $\mu$ g folate

(vitamin B<sub>9</sub>), 4 mg vitamin C, 102  $\mu$ g vitamin K, 1.2 mg iron and 238 mg potassium [2, 3]. World production of lettuce for calendar year 2010 stood at 23,620,000 tons, over half of which came from China. Although Iran produces 402,800 tons lettuce and is ranked 7<sup>th</sup> in the world, Iranian lettuce are not exported due to the product's short shelf life and quality decline [4].

The best methods that are being used to preserve fruits and vegetables during storage and marketing are generally based on refrigeration with or without control of composition of the atmosphere [5, 6]. However, temperature, atmosphere, relative humidity and sanitation must be regulated to maintain quality of them [7, 8]. In this direction, several methods that have been used are refrigeration, controlled atmosphere packaging, modified atmosphere packaging and chemical preservatives [9-11]. The most prevalent method is rapid cooling at a low temperature with high relative humidity [12]. However, low temperature storage is not economically feasible in most developing countries [6, 13]. To ensure high quality of freshly cut vegetables, preserving the correct coloring

and preventing the browning of tissues, a variety of processes are employed. The plants are subjected to various treatments during their growth or after harvest. Such processes comprise mainly biochemical transformations related with the occurrence of plant browning [14, 15]. One of the causes for leaf browning is a deficit of calcium ions. The most effective method is foliar supplementation of this element. Among the calcium compounds that are used for plant spraying, calcium chloride ( $\text{CaCl}_2$ ) is absorbed the best [16].

Calcium chloride is a salt of calcium and chloride. It behaves as a typical ionic halide and is solid at room temperature. Calcium chloride can serve as a source of calcium ions in a solution, as it is soluble. Calcium chloride can be produced directly from limestone, but large amount are also produced as a byproduct of the Solvay process. As an ingredient, it is listed as a permitted food additive in the European Union for use as a sequestrant and firming agent with the E number E509 and considered as generally recognized as safe (GRAS) by the U.S. Food and Drug Administration. As a firming agent, calcium chloride is used in canned vegetables, in firming soybean curds into tofu and in producing a caviar substitute from vegetable or fruit juices. It is commonly used as an electrolyte in sport drinks and other beverages, including bottle water. The extremely salty taste of calcium chloride is used to flavor pickles while not increasing the food's sodium content. Also, it is frequently added to sliced apples to maintain texture [1]. It has been found that a high content of calcium in fruits reduces the rate of respiration and delays ageing [17]. Earlier studies showed that foliar application of calcium chloride solution on plants of sweet and hot peppers at the seedling stage caused accelerated ripening of the fruits [16].

Citric acid is a weak organic acid with the chemical formula  $\text{C}_3\text{H}_4\text{OH}(\text{COOH})_3$ . It is a natural preservative/conservative and is also used to add an acidic, or sour, taste to foods and soft drinks. Citric acid is used mainly as an acidifier, as a flavoring and as a chelating agent. The dominant use of citric acid is as a flavoring and preservative in food and beverages, especially soft drinks. Within the European Union it denoted by E number E330 [1]. Acetic acid is another organic compound with the chemical formula  $\text{CH}_3\text{COOH}$ . It is a colorless liquid that when undiluted is also called glacial acetic acid. Acetic acid is the main component of vinegar (apart from water; vinegar is roughly 8% acetic acid by volume) and has a distinctive sour taste and pungent smell. Although it is classified as a weak acid,

concentrated acetic acid is corrosive to skin and must, therefore, be handled with appropriate care, since it can cause burns, permanent eye damage and irritation to the mucous membranes. These burns or blisters may not appear until hours after exposure [1].

In this paper, the effects of chemical materials application (CMA) and storage periods (STP) on two quality characteristics of Iranian white lettuce including water content and total soluble solids (TSS) during ambient storage at temperature of 25°C and 65% relative humidity are reported.

## MATERIALS AND METHODS

**Experimental Material:** The experimental material was Iranian white lettuce. Lettuces were purchased from a green house in Varamin, Iran.

**Experimental Method:** A split plot experiment was laid out in a randomized complete block design (RCBD) with three replications to randomize the chemical materials application (CMA) and storage periods (STP) in the main and sub-plots, respectively. The experiment comprised of four CMA (calcium chloride, citric acid, acetic acid and no chemical material as control) and five STP (0, 2, 5, 7 and 10 days) at temperature of 25°C and 65% relative humidity.

**Calcium Chloride Application:** Lettuces were sprayed with aqueous solution of calcium chloride ( $10 \text{ g L}^{-1}$ ) after three and five weeks from planting in the green houses. After harvesting, they were visually inspected for freedom of defects and blemishes. Lettuces were then washed with tap water and then air dried for approximately 15 minutes. After that, they were individually wrapped with cellophane film and stored at temperature of 25°C and 65% relative humidity.

**Citric Acid Application:** Lettuces were visually inspected for freedom of defects and blemishes after harvesting. They were then washed with tap water, placed in a 50-liter plastic bucket and soaked for 5 minutes at 20°C in  $10 \text{ g L}^{-1}$  aqueous solution of citric acid. After that, lettuces were air dried for approximately 15 minutes, individually wrapped with cellophane film and stored at temperature of 25°C and 65% relative humidity.

**Acetic Acid Application:** Lettuces were visually inspected for freedom of defects and blemishes after harvesting. After that, they were washed with tap water, placed in a 50-liter plastic bucket and soaked for 5 minutes at 20°C

in 10 g L<sup>-1</sup> aqueous solution of acetic acid. Then, lettuces were air dried for approximately 15 minutes, separately wrapped with cellophane film and stored at temperature of 25°C and 65% relative humidity.

**No Chemical Material Application:** Lettuces were visually inspected for freedom of defects and blemishes after harvesting. They were only washed with tap water and then air dried for approximately 15 minutes. After that, lettuces were placed in the polyethylene boxes and stored at temperature of 25°C and 65% relative humidity.

**Water Content:** The water content of lettuces was determined using the equation 1:

$$\text{Water content (\%)} = 100 \times (M_1 - M_2) / M_1 \quad (1)$$

where:

M<sub>1</sub> = Mass of sample before drying, g

M<sub>2</sub> = Mass of sample after drying, g

**Total Soluble Solids (TSS):** The total soluble solids of lettuces (TSS) was measured using an ATC-1E hand-held refractometer (ATAGO, Japan) at temperature of 20°C.

**Data Analysis:** The data were subjected to analysis of variance (ANOVA) using MSTAT-C statistical software. Moreover, the means of different treatments were separated by Duncan's Multiple Range Test (DMRT) at 1% probability level.

## RESULTS AND DISCUSSION

**Effect on Water Content:** CMA and STP significantly affected water content (Table 1). The highest water content of 94.32% was observed in the first CMA (calcium chloride application) and lowest (91.51%) in the no chemical material application and CMA affected water content in the order of calcium chloride > citric acid > acetic acid > no chemical material application (Table 2). Moreover, the highest water content of 96.15% was observed in 0 days STP and lowest (90.67%) in 10 days STP and water content decreased by increasing STP (Table 2). Furthermore, interaction of CMA × STP showed significant effect (P ≤ 0.01) on water content (Table 1). The study of CMA and STP combinations on water content showed that in each CMA, water content had the highest value in 0 days STP and lowest value in 10 days STP. The maximum mean value for water content (96.15%) was observed in 0 days STP of all CMA and minimum

Table 1: Analysis of variance for two quality characteristics of ambient stored lettuce

Source of variation	Df	Mean square	
		Water content	TSS
Chemical Materials Application (CMA)	3	28.33 **	0.534 **
Storage Period (STP)	4	57.10 **	1.231 **
CMA × STP	12	4.450 **	0.134 **
Error	32	0.028	0.000
C.V. (%)	---	0.18	0.56

\*\* = Significant at 0.01 probability level

Table 2: Means comparison for two quality characteristics of ambient stored lettuce under different treatments using DMRT at 1% probability level

	Treatment	Water content (%)	TSS (%)
CMA	Calcium chloride	94.32 a	4.037 a
	Citric acid	94.29 a	3.902 b
	Acetic acid	94.14 a	3.883 b
	No chemical material	91.51 b	3.589 c
STP	0 days	96.15 a	4.107 b
	2 days	95.09 b	4.173 a
	5 days	93.63 c	3.903 c
	7 days	92.28 d	3.688 d
	10 days	90.67 e	3.391 e

Means in the same column with different letters differ significantly at 0.01 probability level according to DMRT

mean value for water content (86.17%) was observed in 10 days STP of no chemical material application. Also, in each STP, CMA affected water content in the same order as mentioned before, i.e. calcium chloride > citric acid > acetic acid > no chemical material application (Table 3). These results are in agreement with those of Izumi and Watada [18] who concluded that water loss of carrots substantially decreased when they were treated with calcium chloride solution and the differential between control and the treated carrots was greater at the extended STP. These results are also in line with the results reported by El-Hammady *et al.* [19] that application of calcium chloride reduced water loss of citrus fruits. This might be due to the fact that the anhydrous hygroscopic CaCl<sub>2</sub> salt, in atmosphere of high relative humidity, has the ability of absorbing water. These results are also in agreement with those of Smith and Stow [5], Baldwin *et al.* [10], El Ghaouth *et al.* [20], Bahri and Rashidi [21], Rashidi and Bahri [22] and Rashidi *et al.* [23] who concluded that water loss significantly increased by increasing STP.

**Effect on Total Soluble Solids (TSS):** The effect of CMA and STP on TSS was found significant (Table 1). The highest TSS of 4.037% was observed in the first

Table 3: Means comparison for two quality characteristics of ambient stored lettuce under different combinations of Chemical Materials Application (CMA) and Storage Period (STP) using DMRT at 1% probability level

	CMA × STP	Water content (%)	TSS (%)
Calcium chloride	0 days	96.15 a	4.107 b
	2 days	95.33 ab	4.173 a
	5 days	94.33 bcd	4.063 b
	7 days	93.42 cde	3.977 c
	10 days	92.38 efg	3.863 e
Citric acid	0 days	96.15 a	4.107 b
	2 days	95.35 ab	4.163 a
	5 days	94.40 bc	3.943 cd
	7 days	93.36 cdef	3.773 f
	10 days	92.20 fg	3.523 h
Acetic acid	0 days	96.15 a	4.107 b
	2 days	95.26 ab	4.163 a
	5 days	94.15 bcd	3.927 d
	7 days	93.20 def	3.750 f
	10 days	91.93 g	3.467 i
No chemical material	0 days	96.15 a	4.107 b
	2 days	94.43 bc	4.193 a
	5 days	91.64 g	3.680 g
	7 days	89.15 h	3.253 j
	10 days	86.17 i	2.710 k

Means in the same column with different letters differ significantly at 0.01 probability level according to DMRT

CMA (calcium chloride application) and lowest (3.589%) in the no chemical material application and CMA affected TSS in the order of calcium chloride > citric acid > acetic acid > no chemical material application (Table 2). Moreover, the highest TSS of 4.173% was observed in 2 days STP and lowest (3.391%) in 10 days STP and TSS decreased by increasing STP (Table 2). Furthermore, interaction of CMA × STP showed significant effect on TSS (Table 1). Mean comparison of CMA × STP combinations on TSS revealed that in each CMA, TSS had the highest value in 2 days STP and lowest value in 10 days STP. The maximum mean value for TSS (4.193%) was observed in 2 days STP and no chemical material application and the minimum mean value for TSS (2.710%) was observed in 10 days STP and no chemical material application. Also, in each STP, CMA affected TSS in the same order as mentioned before, i.e. calcium chloride > citric acid > acetic acid > no chemical material application (Table 3). These results are in agreement with those of Mahajan and Sharma [24] who concluded that application of CaCl<sub>2</sub> solutions on peach plants at pit hardening stage of the fruits significantly increased TSS of the fruits. On the other hand, these results are not in line with the results reported by Bahri and Rashidi [21], Rashidi and Bahri [22], Rashidi *et al.* [23], Park *et al.*

[25, 26] and Hussain *et al.* [27] that TSS significantly increased by increasing STP for carrot, tomato and mango, respectively. This might be due to the fact that TSS of lettuce initially increased as a result of reducing water content of lettuce during 2 days STP and subsequently decreased because of starting sugar fermentation in lettuce after 2 days STP.

## CONCLUSION

Chemical materials application (CMA) and storage periods (STP) significantly ( $P \leq 0.01$ ) affected water content and total soluble solids (TSS) of Iranian white lettuce during ambient storage at temperature of 25°C and 65% relative humidity. Results of the study indicated that calcium chloride was the best CMA for preserving water content and TSS of lettuce during ambient storage. Additionally, water content and TSS decreased by increasing STP for ambient stored lettuce.

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