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Respiration Rate and Some Physicochemical Characteristics of *Salicornia bigelovii* as a Leafy Green Vegetable

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ABSTRACT: *Salicornia* is a valuable halophyte annual plant in the most species. This salinity tolerance plant that grows in salt water marshes are found all over the world. Since salinity is a major stress factor, Salicornia is a priceless edible vegetable, considered to be a favourable resource for cultivation in arid and semiarid coastal zones. However, the important thing is that its properties should be well known especially as a leafy vegetable. On the other hand, *Salicornia bigelovii* is a perishable vegetable, with short storage life under ambient conditions. Thus, knowing its characteristics can be a great help to preserve it longer. Accordingly, the physicochemical properties, chemical composition and respiration rate of Salicornia biglovii grown in Aq-Qalla Salinity Research Station, Golestan Agricultural and Natural Resources Research and Education Center, Iran were investigated in this paper. The results showed that the moisture content, total soluble solids content, pH, titratable acidity, ascorbic acid content, salinity content, respiration rate, maximum force, displacement, and color indices (L*, a*, b*) of *S. bigelovii* are 89.67%, 15.83%, 6.11, 0.05%, 0.03%, 56ds/m, 26.80 mgCO_2/kg.hr, 1.4 N, 1.47 mm, and 23.69, -6.77, 15.73, respectively. With respect to *S.bigelovii* plant as a leafy green vegetable, this plant is considered as a high respiration vegetable group.

Keywords: *Quality Characteristics, Respiration Rate, Salicornia bigelovii.*

Introduction

As the world's population grows and freshwater stores become more precious, researchers are looking to the elected crops like *Salicorni*a that do not need fresh water to irrigate (Glenn *et al.*, 1998). *Salicornia* is a wild and annual (biennial, in some species) halophytic plant from Chenopodiaceae family that grows near salt marshes and salted wetlands or the vicinity of coastal areas in Asia, North America, and the Middle East. It is also grown in semi-arid areas of Iran such as Isfahan, Fars, and Yazd provinces (Akhani, 2003). *Salicornia* varieties are often multipurpose (Al-Oudat and Qadir, 2011) and it is very rich in vitamins, minerals and highly unsaturated oils (Raposo *et al.*, 2009). *Salicornioideae* species are also rich in dietary fiber and many bioactive substances, such as phytosterols, polysaccharides, and phenolic compounds mainly flavonoids and phenolic acids (Choi *et al.*, 2014). *Salicornia* is a great greenhouse crop for niche markets as well (Schalke, 2015) and its young leaves and stems are cooked or pickled (Tanaka, 1976). However, there are considerable studies on the *Salicornia*'s seed. Some of these valuable articles are summarized in the

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papers of Glenn *et al.* (1991), Clark (1994), Hassan El-Mallah *et al.* (1994), Bashan *et al.* (2000), Anwar *et al.* (2002), Grattan *et al.* (2008), Kang *et al.* (2011), Choi *et al.* (2014), and Isca *et al.* (2014). Ahmadi *et al.* (2016) also evaluated the extracted oil from *Salicornia persica* Akani plant using gas chromatography. They suggested that this oil is suitable to use in the food industry due to its proper oxidative stability. Furtheremore, there are other sporadic studies on salicornia. For example, Zerai *et al.* (2010) compared *S. bigelovii* lines produced in two breeding programs with wild germplasm in greenhouse trials on brackish water (10 ppt NaCl) irrigation. They concluded that *S. bigelovii* has sufficient genetic diversity among wild accessions and cultivars to support a crop improvement program. In addition, the effects of adding glasswort (*Salicornia herbacea* L.) hydrate containing a non-meat ingredient (carboxymethyl cellulose, carrageenan, isolated soy protein, sodium caseinate) on the quality characteristics of reduced-salt, reduced-fat frankfurters were evaluated by Lim *et al.* (2015). They indicated that the use of the above substance improves the quality characteristics of reduced-salt, reduced-fat frankfurters.

The *Salicornioideae* family includes almost 15 genera and 80 species. The commonly found *Salicornia* species are *S. ramosissima*, *S. indica*, *S. brachiata*, *S. bigelovii*, *S. herbacea*, *S. perenis*, *S. fragilis*, *S. nitens*, *S. pusilla*, and *S. disarticulate* (Choi *et al.*, 2014; Isca *et al.*, 2014). However, there are not many studies on salicornia plant as an edible vegetable.

Salicornia bigelovii Torr., an annual salt marsh plant is a species from *Salicornia* genus, *Salicornioideae* subfamily, *Chenopodiaceae* (*Amaranthaceae*) family, and *Caryophyllales* order, in the scientific classification. The taxonomic classification of this genus is extremely difficult and may impossible for non-specialists. However, the taxonomic key for identification of the species of *Salicornia* is based on molecular genetic research (Kadereit *et al.*, 2007; Kadereit *et al.*, 2012).

Salicornia bigelovii produces seed oils, protein meal, fresh salad greens and forages on seawater irrigation (Lu *et al.*, 2010; Zerai *et al.*, 2010). It is growing to 0.3 m and is in flower from August to September. The seeds then ripen from September to October. The flowers are hermaphrodite and are pollinated by wind. It cannot grow in the shade and prefers moist soil (Anon, 2012). It is considered to be the best prospect of development and utilization of halophytes, has been successfully cultivated at home and abroad, and begin large-scale production (Lu, 2009). Nutrients and toxic trace element content of *S. bigelovii* Torr. was measured by Lu *et al.* (2010). The results showed that it has a higher nutritional value in terms of amino acid composition, vitamins, some functional ingredients and a wealth of mineral elements, which made it an ideal nutritional and diet supplement.

Since, *S. bigelovii* is perishable with a short shelf life of only about 6 days at ambient temperature (Lu *et al.*, 2009; Lu *et al.*, 2010), it is necessary to know its physiological characteristics like respiration rate as well as physicochemical properties. Thus, this paper may be an interesting article on the use of *Salicornia bigelovii* as a fresh leafy vegetable grown in Iran as commercial food crops due to the plants' native habitat will give some idea about its application needs.

Materials and Methods

- *Plant material*

Fresh samples of *Salicornia bigelovii* were supplied from Aq-Qalla Salinity Research Station, Golestan Agricultural and Natural Resources Research and Education Center, Iran (Figure 1). As is shown in Figure 1, the *Salicornia bigelovii* has stem and leaves, as the same other leafy vegetables. Thus, it was harvested and transported to the laboratory less than one day after harvesting in the cool of the night. The samples had the offshoots in 13–15 cm long. About 5–6 cm of youngest fully expanded branch tips were selected to be used in all the experimentation. These fresh samples were first washed and subjected to analyses for their characterization.

Fig. 1. A whole plant of *Salicornia bigelovii* from Aq-Qalla Salinity Research Station

- *Proximate analyses*

All the experiments for analyses were conducted in triplicate order.

- *Moisture content*

The moisture content was determined by drying the sample in an oven at 105± 5°C for about three hours until a constant weight was obtained (AOAC, 2005a). It was then calculated using Equation 1.

$$\text{Moisture content} = [(M_2-M_1)/ M_0] \times 100 \quad (1)$$

Where:

M_0 = sample mass inside the plate (g)

M_1 = mass of plate and sample (g)

M_2 = mass of plate and sample after incubation (oven) and mass stabilization (g)

- *Total soluble solids (TSS)*

The total soluble solids (TSS) were measured by a refractometer (Atago model, Japan). In this test, the device was first calibrated using distilled water (set to zero). A few drops of *Salicornia* leaves solution (20 g of salicornia leaves with 40 ml of distilled water, mixed in a blender and then filtered) was placed on the charter of the refractometer at 20°C. Then, the TSS content was expressed as a percentage (AOAC, 2005a).

- *pH*

The pH of the samples was determined with a pH meter (Metrohm- model 691, Switzerland), and the value was recorded (Maftoonazad *et al*., 2008).

- *Titratable acidity*

Titratable acidity was calculated using Equation 2 (AOAC, 2005a). In order to calculate the titratable acidity in each product, the dominant acid of the product should be known that showed the equivalent factor (E) in Equation 2. Equivalent factor for a number of organic acids such as malic, citric, tartaric, oxalic, acetic, and lactic are 67, 70, 75, 45, 60, and 90, respectively (Toivonen, 2016). Patel (2016), in the evaluation of *Salicornia* as a food and medicine, pointed to the presence of oxalate. Therefore, oxalic acid was considered the dominant acid when the acidity of *Salicornia* was calculated.

$$\text{Acid (\%)} = (N \times E \times V \times 100)/\text{grams of sample} \quad (2)$$

Where:

N= Normality of NaOH (0.1 N)

E= Equivalent factor of the dominant acid

V= mls NaOH used

- *Ascorbic acid content*

Ascorbic acid was determined by the indophenol titration method (AOAC, 2005b). A 10 g sample was grounded in a mortar with 20 g L^{-1} oxalic acid solution. The 10 g L^{-1} oxalic acid solution was used to wash the paste into a 100 ml volumetric flask. About 10 ml filtered solutions were titrated with 2, 6-dichlorophenol indophenols solution until the faint pink color persisted for more than 5 s. Finally, the ascorbic acid content was calculated using Equation 3.

$$\text{Ascorbic acid} = [(V_0 - V_1) \times m_1]/m_0 \times 100 \quad (3)$$

Where:

V_0 = The volume of colored solution used for sample titration (ml)

V_1 = The volume of colored solution used in the control test (ml)

M_0 = Sample mass used in the titration test (g)

M_1 = The mass of ascorbic acid which is equivalent to one milliliter of colored solution (mg)

- *Salinity content*

The salinity content was measured by an electrical conductivity meter (Jenway model 4510, UK). In order to carry out this, 20 grams of *Salicornia* leaves were mixed with 40 milliliters of water and then filtered. The salinity content of the filtered samples was reported in dS/m.

- *Respiration rate*

Salicornia leaves with known weights were placed in an airtight plastic container (10 × 20 × 20 cm^3) to measure their respiration rate using a CO_2-sensitive sensor (Testo AG-435-2, Germany). The CO_2 sensor of the instrument was placed inside the container to measure the CO_2 concentration. The device was programmed to measure the concentration of CO_2 for each sample at 1 minute intervals for 30 minutes. The respiration rate was calculated based on the regression slope of CO_2 concentration versus time and reported in $mgCO_2$/Kg.hr (Sahraei Khosh Gardesh *et al*., 2016).

- *Texture analysis*

The resistance of the *Salicornia* plant to the sheared force (i.e. firmness) was measured using an Instron Universal Testing Machine (Hounsfield, H5KS model, UK) with the following requirements:

Shear blade specifications; length: 87.88mm, width: 69.85 mm, thickness: 3.16mm

Load cell= 500 N

Test speed= 5 mm/min

End point= 2.5 mm

A test was replicated five times. The maximum force (F_{max}) and the displacement were obtained from force-deformation curves and the results were expressed in Newton and millimeter, respectively (Konopacka and Plocharski, 2004).

- *Color measurement*

The L* (lightness), a* (green–red) and b* (blue–yellowness) color indices were measured numerically for Salicornia leaves using a portable colorimeter (Konica Minolta, CR-400 model, Japan). The instrument was first standardized using a white ceramic plate (Lu *et al*., 2010). Samples test was replicated three times.

- *Statistical analysis*

The average and standard deviation values were calculated for three replicates (five for texture analysis) of all variables by excel software.

Results and Discussion

Some of the physicochemical properties of *Salicornia bigelovii* including moisture content, total soluble solids, pH, titratable acidity, Ascorbic acid, salinity content, respiration rate, maximum force and displacement, and color (L^*, a^*, b^*) were measured in this study. The results of the above variables are shown in Table 1.

Table 1. Some of the physicochemical properties of *Salicornia bigelovii*

Factor		Mean ± SD
Moisture (%)		89.67 ± 0.01
Total soluble solids (%)		15.83 ± 0.15
pH		6.11 ± 0.0
Titratable acidity (%)		0.05 ± 0.01
Ascorbic acid (%)		- 0.025 ± 0.0
Salinity (ds/m)		56 ± 0.17
Respiration rate ($mgCO_2$/Kg.hr)		26.80 ± 10.09
Maximum force (N)		1.4 ± 0.20
Displacement (mm)		1.47 ± 0.27
	L*	23.69 ± 0.85
Color	a*	-6.77 ± 0.41
	b*	15.73 ± 0.09

- *Biochemical compositions*

Several physiological variables are associated to the quality of leafy vegetables. According to Table 1, the results of the composition analyses of *Salicornia bigelovii* grown in north of Iran (Aq-Qalla Salinity Research Station) shows a considerable characteristics as a leafy green vegetable. These results are in good agreement with the results of Lu *et al.* (2010) for some nutritional analyses of *S. bigelovii*. They reported that it contains high vitamins and minerals, which made it an ideal nutritional and diet supplement. Therefore, the detailed results are discusted below point by point.

- *Moisture content*

The Moisture content of *Salicornia bigelovii* was reported 88.42% ± 1.36 by Lu *et al.* (2010) and it was 89.67% ± 0.01 in this study. In addition, the moisture content of the leaf, stem, and root of *Salicornia herbacea* is respectively reported as 90.9, 73.9, and 66.2% by Rhee *et al.* (2009). In general, the moisture content determines the crispness and juiciness of the leaves (Kader and Barrett, 2004) .

- *Total soluble solids*

The total soluble solids (TSS) of *Salicornia bigelovii* was measured about 15.83%. Since the TSS content is directly correlated with the preservation of a pleasant taste over time (Varoquaux *et al.*, 1996; Martinez, 2010 as cited in Vargas-Arcila *et al.*, 2017), this high quality attribute in *Salicornia bigelovii* might be contributed to good taste preservation.

- *pH and titratable acidity*

The pH and the titratable acidity of *Salicornia bigelovii* plant was obtained 6.11 and 0.05%, respectively. It is worth to note that vegetable taste depends on the content and combination of sugars, organic acids, etc (Vargas-Arcila *et al.*, 2017).

- *Ascorbic acid content*

Biochemical compositions of the *S. bigelovii* tissue showed 0.025% ± 0.0 for the ascorbic acid that is a little lower than what lu *et al.* (2010) found (i.e. 58.4 ±1.39 mg/100g fresh weight). Incidentally, the negative sign for ascorbic acid in Table 1 indicates that ascorbic acid of *Salicornia* is less than the standard solution in the test. Although ascorbic acid presents in low concentrations, the nutritional quality of the product might be regarded quite standard as it is consumed fresh (Acamovic-Djokovic *et al.*, 2011).

- *Salinity content*

As cited in Grattan *et al.* (2008) work and Weeks (1986), it has been reported that the amount of salt for optimal growth of *Salicornia bigelovii Torr.* is about 170-200 mol/m^3 with an electrical conductivity of 15-17 ds/m. The salinity of *Salicornia europaea* L. (syn. *S. herbacea* L.) is stated over than 56 ds/m by Al-Oudat and Qadir (2011). In addition, the amount of salt is reported 3.3% for *Salicornia herbacea* by Rhee *et al.* (2009). However, the salinity content of *Salicornia bigelovii* plant obtained 56 ds/m in this study. High salinity content in this plant may be used as an additive in some products as a substitute for common salt.

- *Respiration rate*

The initial respiration rate of *S. bigelovii* was about 26.80mgCO_2/Kg.hr. In the classification of vegetables and fruits based on their relative respiration rate, they are divided into six categories: very low (less than 5), low (5-10), medium (11-20), high (21-40), very high (41-60) and extremely high (more than 60) at 5^{o}C. Leafy vegetables such as spinach and parsley with 45 and 60 mgCO_2/kg.hr respiration rate respectively is placed in the very high category (Mangaraj and Goswami, 2009; Gross *et al*., 2016). Since respiration rate of *Salicornia bigelovii* was measured about 26.80mgCO_2/Kg.hr, it is placed in the category with a high respiration rate. The higher respiration rate results in the less durability and shelf life. In fact, the two main goals of post-harvest technologies for fruits and vegetables are to preserve their quality in the production chain. In general, respiration is one of the most important metabolic activities of plants that breaks complex molecules such as starches, sugars and organic acids in cells and converts them into simple molecules such as H_2O, CO_2, and energy (Sharon and Martha, 2010). Upon completion of these resources, the product enters the senescence stage. Therefore, respiratory rate determines the amount of using organic matter, as a result, the shelf life of the product.

- *Texture analysis*

From the force-displacement curve in the shear test for shearing the leaves of *Salicornia bigelovii*, the maximum force was obtained 1.4 N ± 0.20 at a displacement of 1.47mm ± 0.27. It should be noted that postharvest changes in texture of *S. bigelovii* strongly require basic information like the obtained results for many of the future applications.

- *Color analysis*

In addition, the general color scores (mean ± S.D. for three replicates) for *S. bigelovii* as a leafy green vegetable in terms of L*, a*, and b* values were obtained 23.69 ± 0.85, -6.77 ± 0.41, 15.73 ± 0.09, respectively as is presented in Table 1. In general, variations in the color of the leaves is mainly resulting from chlorophyll degradation (Vargas-Arcila *et al*., 2017). Therefore, the color information of the *S. bigelovii* may help to its better applications such as packaging, storage, etc.

Conclusion

S. bigelovii is one of the most promising halophytes and is likely to provide human foods supplement. It was perishable with a shelf life of only about 6 days at ambient temperature (25^{o}C). Thus, knowing its characteristics could be a very useful and practical information in deciding how to increase the shelf life or processing of *Salicornia* as an edible vegetable. Therefore, the current results are potential beneficiaries for *Salicornia* growers, horticultural specialists, consumers and all actors of the production-distribution-sales chain of *Salicornia*.

References

Acamovic-Djokovic, G., Pavlovic, G.R., Mladenovic, J. & Djuric, M. (2011). Vitamin C content of different types of lettuce varieties. Acta agriculturae serbica, 16 (32), 83-89.

Ahmadi, H., Noroozy J., Farhoodi, M., Rahimi, M. R. & Rahmatzadeh, B. (2016). Extraction and physicochemical properties of Salicornia (*Salicornia perssica* Akhani sub sp. rudshurensis Akhani) oil. Iranian Journal of Nutrition Science & Food Technology, 11(1), 67-74.

Akhani, H. (2003). *Salicornia persica* Akhani (Chenopodiaceae) a remarkable new species from Central Iran. Linzer Biologische Beiträge, 35, 607–612.

Al-Oudat, M. & Qadir, M. (2011). The halophytic flora of Syria. International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.

Anon. (2012). *Salicornia bigelovii* Torr. Plants for a future, registered company No.

3204567 in England and Wales. https://pfaf.org/user/Plant.aspx?LatinName=Salicornia+bigelovii.

Anwar, F., Bhanger, M., Nasir, M. K. A. & Ismail, S. (2002). Analytical characterization of *Salicornia bigelovii* seed oil cultivated in Pakistan. Journal of Agricultural and Food Chemistry, 50(15), 4210-4214.

Association of Analytical Communities (AOAC). 2005a. Method 923.03. In: Official Methods of Analysis, 21st Edition, AOAC International Publisher, Gaithersburg.

Association of Analytical Communities (AOAC). 2005b. Method 967.21. In: Official Methods of Analysis, 18th Edition, AOAC International Publisher, Gaithersburg

Bashan, Y., Moreno, M. & Troyo, E. (2000). Growth promotion of the seawater-irrigated oilseed halophyte *Salicornia bigelovii* inoculated with mangrove rhizosphere bacteria and halotolerant *Azospirillum* spp. Biology and Fertility of Soils, 32, 265-272.

Choi, D., Lim, G. S., Piao, Y. L., Choi, O. Y., Cho, K. A., Park, C. B., Chang, Y. C., Song, Y. I., LEE, M. K. & Cho, H. (2014). Characterization, stability, and antioxidant activity of *Salicornia herbaciea* seed oil. Korean Journal of Chemical Engineering, 31, 2221-2228.

Clark, A. (1994). Samphire: from sea to shining seed. Saudi Aramco World, 45(6), 2-9.

Glenn, E. P., Brown, J. J. & O'Leary, J. W. (1998). Irrigating crops with seawater. Scientific American, 279 (2): 76-81.

Glenn, E. P., Oleary, J. W., Watson, M. C., Thompson, T. L. & Kuehl, R. O. (1991). *Salicornia bigelovii* Torr.: an oilseed halophyte for seawater irrigation. Science, 251 (4997): 1065-1067.

Grattan, S. R., Benes, S. E., Peters, D. W. & Diaz, F. (2008). Journal of Environmental Quality [Supplement], 37, 149 – 156.

Gross, K. C., Wang, C. Y. & Saltveit, M. (2016). Agriculture Handbook Number 66: The commercial storage of fruits, vegetables, and florist and nursery stocks. Agricultural Research Service, United States Department of Agriculture (USDA).

Hassan El-Mallah, M., Murui, T. & El-Shami, S. (1994). Detailed studies on seed oil of *Salicornia* SOS-7 cultivated at the egyptian border of Red Sea. Grasas y Aceites, 45(6), 385-389.

Isca, V. M. S., Seca, A. M. L., Pinto, D. C. G. A. & Silva, A. M. S. (2014). An overview of *Salicornia* genus: the phytochemical and pharmacological profile, in: "Natural roducts: Research Reviews", (Gupta, V.K., Ed.). pp. 145-176.

Kader, A. & Barrett, D. M. (2004). Classification, composition of fruits and postharvest maintenance of quality, in: "Processing fruits" (Barrett, D.M., Somogyi, L., and Ramaswamy, H., Eds.). Boca Raton, USA: CRC Press.

Kadereit, G., Ball, P., Beer, S., Mucina, L., Sokoloff, D., Teege, P., Yaprak, A. E. & Freitag, H. (2007). A taxonomic nightmare comes true: phylogeny and biogeography of glassworts (*Salicornia* L., Chenopodiaceae). Taxon, 56 (4), 1143–1170.

Kadereit, G., Piirainen, M., Lambinon, J., and Vanderpoorten, A. (2012). Cryptic taxa should have names. Reflections on the glasswort genus *Salicornia* (Amaranthaceae). Taxon, 61: 1227–1239.

Kang, S., Kim, D., Lee, B. H., Kim, M. R., Chiang, M. & Hong, J. (2011). Antioxidant properties and cytotoxic effects of fractions from glasswort (*Salicornia herbacea*) seed extracts on human intestinal cells. Food Science and Biotechnology, 20(1), 115-122.

Konopacka, D. & Plocharski, W. J. (2004). Effect of storage conditions on the relationship between apple firmness and texture acceptability. Postharvest Biology and Technology, 32, 205-211.

Lim, Y. B., Kim, H. W., Hwang, K. E., Song, D. H., Kim, Y. J., Ham, Y. K., Jang, S. J., Lee, C. H., He, F. Y., Choi, Y. S. & Kim, C. J. (2015). Effects of Glasswort (*Salicornia herbacea* L.) Hydrates on Quality Characteristics of Reduced-salt, Reduced-fat Frankfurters. Korean Journal for Food Science of Animal Resources, 35, 783-792.

Lu, D. (2009). Studies on Technology, Mechanism and Model of *Salicornia Bigelovii* Torr. MAP Storage with Silicon Gu. PhD thesis, Jiangnan University.

Lu, D. H., Zhang, M., Wang, S. J., Cai, J. L., Zhu, C. P. & Zhou, X. (2009). Effects of modified atmosphere packaging with different sizes of silicon gum film windows on *Salicornia bigelovii* Torr. storage. Journal of the Science of Food and Agriculture, 89, 1559–1564.

Lu, D., Zhang, M., Wang, S., Cai, J., Zhou, X. & Zhu, C. (2010). Nutritional characterization and changes in quality of *Salicornia bigelovii* Torr. during storage. LWT-Food Science and Technology, 43, 519-524.

Maftoonazad, N., Ramaswamy, H. S. & Marcotte, M. (2008). Shelf-life extension of peaches through sodium alginate and methyl cellulose edible coatings. International Journal of Food Science and Technology, 43, 951-957.

Mangaraj, S. & Goswami, T. K. (2009). Modified atmosphere packaging of fruits and vegetables for extending shelf-life: a review. Fresh Produce, 3(1), 1-31. Global Science Books.

Martinez, J. A. (2010). Optimizacion en el envasado en atmosfera modificada de lechuga iceberg. PhD thesis, University of Murcia.

Patel, S. (2016). *Salicornia*: evaluating the halophytic extremophile as a food and a pharmaceutical candidate. 3 Biotech, 6(1), 14. Springer.

Toivonen, P. M. A. (2016). Postharvest physiology of fruits and vegetables, in: Postharvest ripening physiology of crops (Ed. Pareek, S.). CRC Press.

Raposo, M. F. D. J., DE Morais, R. M. S. C. & DE Morais, A. M. M. B. (2009). Controlled atmosphere storage for preservation of *Salicornia ramosissima*. International Journal of Postharvest Technology and Innovation, 1, 394-404.

Rhee, M. H., Park, H. J. & Cho, J. Y. (2009). *Salicornia herbacea*: Botanical, chemical and pharmacological review of halophyte marsh plant. Journal of Medicinal Plants Research, 3(8), 548-455.

Sahraei Khosh Gardesh, A., Badii, F., Hashemi, M., Yasini Ardakani, A., Maftoonazad, N. & Mousapour Gorji, A. (2016). Effect of nanochitosan based coating on climacteric behavior and postharvest shelf-life extension of apple cv. Golab Kohanz. LWT-Food Science and Technology, 70, 33-40.

Schalke, D. (2015). *Salicornia*: a great greenhouse crop for niche markets [Online]. http://www.hortidaily.com/article/20419/Salicornia-a-great-greenhouse-crop-for-niche-markets.

Sharon, P. S. & Martha, C. S. (2010). Post-harvest Technology of Horticultural Crops. Mehra Offset Press. Delhi., 315P.

Tanaka, T. (1976). Tanaka's cyclopaedia of edible plants of the world. Keigaku Publishing Co, Tokyo, 1st edition.

Vargas-Arcila, M., Cartagena-Valenzuela, J. R., Germán Franco, G., Correa-Londoño, G. A., Quintero-Vásquez, L. M. & Gaviria-Montoya, C. A. (2017). Changes in the physico-chemical properties of four lettuce (*Lactuca sativa* L.) varieties during storage. Corpoica Cienc Technol Agropecuaria, Mosquera (Colombia), 18 (2), 257-273.

Varoquaux, P., Mazollier, J. & Albagnac, G. (1996). The influence of raw material characteristics on the storage life of fresh cut butterhead lettuce. Postharvest Biology and Technology. 9(2): 127-139.

Weeks, J. R. (1986). The growth and water relations of a coastal halophyte, Salicornia bigelovii. Ph.D. Thesis. University of Arizona, Tucson, USA.

Zerai, D. B., Glenn, E. P., Chatervedi, R., Lu, Z. J., Mamood, A. N., Nelson, S. G. & Ray, D. T. (2010). Potential for the improvement of *Salicornia bigelovii* through selective breeding. Ecological Engineering, 36 (5), 730-739.