Iran Agricultural Research (2019) **38**(**2**) 111-118

Role of seaweed (*Ulva flexuosa* Wulfen) extract in improvement of postharvest quality of Washington navel orange fruits

M. Rezaei[1], F. Abdollahi[1*], A. Mirzaalian Dastjerdi[1], M. Yousefzadi[2]

[1]Department of Horticultural Science, Faculty of Agriculture and Natural Resource, University of Hormozgan, Bandar Abbas, Iran, I. R. Iran
[2]Department of Marine Biology, Faculty of Marine Sciences and Technology, University of Hormozgan, Bandar Abbas, Iran, I. R. Iran

* Corresponding Author: fabdollahi@hormozgan.ac.ir
DOI: 10.22099/iar.2020.35017.1366

ARTICLE INFO
***Article history*:**
Received **8 October 2019**
Accepted **10 May 2020**
Available online **17 May 2020**

Keywords:
Ascorbic acid
Free radical scavenging capacity (FRSA)
Fruit storage
Total soluble solids (TSS)

ABSTRACT- Seaweeds are rich sources of bioactive natural products, which have been considered as potential biotic agents. *Ulva flexuosa* Wulfen is a species of seaweed which is endemic to the Persian Gulf. In this study, the effect of different concentrations of *U. flexuosa* extract on the antioxidant activity of Washington Navel orange (*Citrus sinensis* L. cv. Washington Navel) fruits (measured as free radical scavenging activity; FRSA) and postharvest quality of the fruits were evaluated under cold storage (5±1°C) conditions and 85-90% relative humidity up to 60 days. Results indicated that prolonging the storage time increased fruit weight loss, fruit decay and total soluble solids (TSS) contents of the fruits, while prolonging the storage time reduced the percentage of juice and ascorbic acid contents of the fruits. Postharvest quality and antioxidant activity of Washington Navel orange fruit improved significantly when they were immersed in seaweed extracts. The most effective treatment was 3.76 g L^{-1} concentration of *Ulva flexuosa* extract, which maximized the improvement of antioxidant capacity, ascorbic acid content and TSS during days of storage (DS). The results of this study indicated that the seaweed extract could be used as a new bioactive agent for maintaining the postharvest quality of orange fruit through enhancing the antioxidant activity.

INTRODUCTION

The postharvest loss of fruits occurs due to pests and diseases and increased through processes such as storage, transit and marketing. Citrus fruits suffer from relatively higher losses during harvesting and handling chain, due to unideal postharvest handling such as inappropriate storage conditions, coating materials and mechanical damages. Furthermore, pathological infections play a major role in increasing crop loss following harvest. Fruit quality and shelf life can be extended via ameliorating environmental conditions (Nunes, 2008), and minimizing mechanical damages (Cantwell and Suslow, 2002), irradiation (Fan et al., 2008), cold storage (Wiley, 1994) and application of chemical sprays or dips (Martin-Diana et al., 2007).

Changes in the quality of citrus fruits are directly associated with fruit antioxidant activity at the ripening stage (Xu et al., 2008). Fruits antioxidant capacities essentially depend on ripening duration, genetic characteristics, cultivation management and the meteorological events that occur during fruit growth and development. Antioxidant capacities of fruits, during postharvest storage, is affected on the one hand by harvest time traits including fruit TSS and phenolic compounds contents and on the other hand by storage temperature and ambient O_2 and CO_2 contents (Tavarini et al., 2008; Martin-Belloso and Soliva-Fortuny, 2006).

By the mid-1990s, awareness of increasing amount of fruit losses due to fruit decays prompted researchers to evaluate more eco-friendly natural products (Udagawa, 2005). Over the recent years, new techniques have been developed to preserve postharvest citrus fruit quality and increase storability, thereby maintaining the marketability, enhancing the economic value of the fruits, and providing high-quality products for consumers (Nunes, 2008). Most of novel approaches have focused on the identification of effective bioactive compounds (Lanciotti et al., 2004).

Seaweeds are rich and varied sources of bioactive natural products, which have been considered as potential biotical and pharmaceutical agents (Ito and Hori, 1989; Kamel, 2014; Omar, 2014; Nabti et al., 2017). They contain macro- and micro-elements, plant hormones, vitamins, enzymes and polyamines. Seaweed extracts are further known to enhance the growth of vegetables and fruits, and protect them from different pathogens either on the plant or during storage

(Washington et al., 1999). In the late 1970s, it was indicated that the natural seaweed extract could improve fruit quality and shelf life of avocado and pear fruits (Blunden et al., 1978). Meanwhile, recent studies have shown that seaweed extracts can improve postharvest qualities of orange fruit (Kamel, 2014; Omar 2014). The beneficial impact of such extracts is thought to be associated with compounds that may include, but are not limited, to betaines, oligosaccharides, polyamines, cytokinins and/or other hormones (Norrie and Keathley, 2006; Nabti et al., 2017).

Environmental pollution during the use of hazardous chemicals to protect crops and fruit postharvest management has led scientists to use bioactive materials in postharvest techniques. The main objective of the present research was to evaluate the effects of *Ulva flexuosa* Wulfen seaweed extract, as a bioactive compound, on various postharvest characteristics of Washington Navel orange fruit under cold storage conditions.

MATERIALS AND METHODS

Experimental Design and Study Site

In order to assess the effects of different concentrations (0.94, 1.88, 3.76, 7.52 g L^{-1}) of *U. flexuosa* (a seaweed species endemic to the Persian Gulf) extracts on antioxidant activity and postharvest quality of Washington Navel fruit during 60 days of storage (DS), a factorial experiment with three replications was carried out as a complete randomized design during 2015 and 2016 in the research laboratory of the Faculty of Agriculture and Natural Resources in University of Hormozgan, Bandar Abbas, Iran.

Seaweed Extract Preparation

In late December 2015, *U. flexuosa* samples were hand-picked from the coastal areas of the Persian Gulf, and thoroughly washed with seawater to remove undesirable contaminations, inert matters, sand particles and epiphytes. In the laboratory, after washing fresh seaweed samples with distilled water, they were air-dried for three days. The methanol extract was obtained by macerating 500 g of the air-dried powdered plant material with 200 ml methanol for 30 min using a method described by Salehi et al. (2005). They were then kept at room temperature for 24 h. The extract was then filtered and concentrated on a rotary evaporator bath with at a temperature less than 50 °C .The methanol extract was suspended in water and partitioned with ethyl acetate to obtain water soluble and water insoluble (methanol extract) sub-fractions. The water insoluble methanol extract was separated thereafter.

Fruit Preparation

Mature fruit of Washington Navel orange were harvested from a commercial orchard in December 2015, according to Kader (2002). Fruit is harvested when the appropriate TSS/acid ratio (7-9) is reached and the fruit is orange on its entire surface. For this purpose, from late November until harvest time, randomly 20 fruits from 10 trees were picked and TSS/acid ratio was measured. The fruit were directly transferred to the research laboratory of the Faculty of Agriculture and Natural Resources in University of Hormozgan, Bandar Abbas, Iran. Wounded fruit or those with other disorders were excluded. Fruit were picked, disinfected by immersion in sodium hypochlorite 1% for 3 minutes, washed with distilled water, and air-dried in the laboratory. A total of 300 healthy and uniform fruit were selected and divided into five groups, each of which received a different treatment. Each treatment was applied on 20 fruit in a plastic box, replicated three times, making 60 fruit per treatment. Fruits were dipped in solutions of seaweed extract or in distilled water as the control for 15 minutes. After that, fruit were kept under cold storage (5±1 °C) conditions at 85-90% relative humidity for 60 days.

Antioxidant Activity Measurement

Antioxidant activity, mentioned as free radical scavenging activity (FRSA), was measured at 0, 15, 30 and 45 days post-storage time, based on the scavenging of the stable free radical using 1,1-diphenyl-2-picrylhydrazyl (DPPH), according to the method used by Dambolena et al., (2010). Each sample (10 µL of plant material extract) was mixed with 900 µL of 100 mM Tris-HCl buffer (pH 7.4), 40 µL of ethanol and 50 µL of 0.5% (w/w) Tween 20 solution. They were then added to 1 mL of 0.5 mM DPPH in ethanol (250 µM in the reaction mixture). The control sample was prepared through the use of water instead of plant extract. The mixture was shaken with a mechanical shaker and was left to stand in a dark room at room temperature for 30 min. After 30 min, the absorbance was measured at a wavelength of 517 nm. The free radical scavenging activity was expressed as follows: DPPH scavenging activity (%) = [(Ac – As/Ac)] × 100, where 'Ac' is the absorbance of the control sample and 'As' is the absorbance of the test sample.

Postharvest Characteristics of Orange Fruit

To evaluate the qualitative characteristics of Washington Navel orange fruit, fruit weight loss, fruit juice, fruit decay and total soluble solids (TSS) were measured as percentage units. Ascorbic acid (Vitamin C) content was further determined. The measurements were taken five times, at 15 days intervals, at 0, 15, 30, 45 and 60 days post- storage time.

Fruit weight loss (percentage) was calculated by measuring the difference between the initial (0 DS time) and the final weight (60 DS time), whereby on the first day of the experiment, fresh weight percentage was expressed as zero (Kamel, 2014; Fisk et al., 2008). Fruit decay was specified by counting the number of fruits with signs of decay (having either pathological or physiological disorders) and was expressed as a percentage of the initial number of fruit, per each replicate for each treatment (Kamel, 2014).

Fruit juice was extracted by the Hamilton juice extractor (model JH-149), and subsequently weighed. Then % fruit juice for each treatment was calculated by dividing the fruit juice weight to the fruit weight for that treatment. In order to measuring the TSS contents, after extracting fruit juice, the TSS of fresh fruit juice was analyzed by a digital refractometer (model DBR95, Huixia® Taiwan) and was expressed as a percentage.

In order to measure the ascorbic acid (Vitamin C) content, undiluted extracts were used for iodometric titration, according to Spínola et al. 2013. Briefly, 1 mL of 10 g L^{-1} starch solution and 1 mL of 100 g L^{-1} potassium iodide solution were added to accurately-weighed amounts of fruit extracts. Then, the samples were titrated with 0.002 mol L^{-1} previously-standardized potassium iodate solution ,until the mixture became dark blue and the color persisted for more than 60 seconds. Next, the amounts of potassium iodate and ascorbic acid contents were determined and expressed as milligrams via Eq. (1). (Suntornsuk et al., 2002).

Ascorbic acid (mg100 ml^{-1} juice) = mg iodine per potassium iodate × 8.806 (1)

Statistical Analysis

This study was carried out as a factorial experiment, based on completely randomized design. Data were analyzed using SAS program (v. 9.2, SAS Institute, Cary, NC). The mean values were compared via the least significant difference (LSD) at 5% level.

RESULTS AND DISCUSSION

Fruit Weight Loss

Washington Navel orange fruit weight loss was significantly affected by storage duration (Table 1). In each extract concentration, the weight loss was significantly increased with prolonging the storage period.

After treating fruits by different seaweed extract concentrations, no significant difference was observed among samples in 0 day storage time (Data not shown). However, in 15 DS, fruit weight loss was significantly higher at 0 and 0.94 seaweed extract concentrations than other concentrations (Table 1). During all storage period, treating fruit with 0.94 g L^{-1} concentration of seaweed extract did not significantly affect fruit weight loss compared to the controls, however, all other concentrations of seaweed extract significantly reduced this trait when compared to the controls. Throughout the storage period, the most effective concentration of seaweed extract in reducing fruit weight loss was 3.76 g L^{-1}. Accordingly, during the 60 DS, this concentration reduced fruit weight by 3.26% compared to 4.77 % fruit weight loss in control treatment (Table 1).

Fruit Juice Content

Fruit juice content decreased significantly with prolonging storage period, and the minimum percentage of fruit juice (30.3%) was observed in the control treatment during 60 DS time. Dipping the fruit in seaweed extracts did not significantly preserve the percentage of fruit juice during 15 and 30 DS times. However, dipping the fruit in 7.52 and 3.76 g L^{-1} seaweed extracts during 45 and 60 DS times preserved more juice than to the control. The lowest percentage reduction in fruit juice content was observed in samples treated with 3.76 g L^{-1} and the 7.52 g L^{-1} extracts during 45 and 60 DS times which did not significantly differ (Table 2).

Table 1. Fruit weight loss (%) of Washington Navel orange fruit treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1 °C at 85-90% RH).

Extract concentration (g L^{-1})	Fruit weight loss (%) DS time †			
	15	30	45	60
7.52	0.76 k	2.11 h	2.94 f	3.82 c
3.76	0.71 k	1.87 i	2.82 f	3.26 e
1.88	0.74 k	2.14 h	3.20 e	4.03 b
0.94	0.96 j	2.36 g	3.68 d	4.68 a
Control	1.06 j	2.38 g	3.62 d	4.77 a

Means with different letters are statistically different (LSD, $P \leq 0.05$). † DS = Days of storage

Fruit Decay

In all seaweed extract concentrations, with increasing the storage duration up to 60 DS, fruit decay increased significantly (Table 3). Fruit decay did not change significantly among samples stored for 30 days; despite treated with the different seaweed extract concentrations. Furthermore, prolonging the storage duration resulted in significant reductions in fruit decay in the seaweed extract treatments compared to control. However, no significant difference was observed when the concentration of seaweed extract increased from 0.94 to 7.52 g L^{-1}. In 60 DS duration, the minimum and maximum fruit decays were observed in samples treated with 0.94 g L^{-1} seaweed extract and control samples, respectively, although in 45 DS duration there was not significant difference between 0.94 and 1.88 g L^{-1} seaweed extract for minimum fruit decay (Table 3).

TSS

During the experiment and from Day 15 to 60, TSS did not change significantly in the control treatment (Table 4), while dipping Washington Navel orange fruit in all concentrations of seaweed extract (with the exception of 1.88 g L^{-1}) caused a significant increase in TSS content throughout the storage period (Table 4). By 15 and 30 DS, samples treated with 1.88 g L^{-1} had significantly higher TSS content than the control treatment; however, by 45 and 60 DS, no significant increase was observed in samples treated with higher extract concentrations. At the end of the experiment (60 DS), by dipping fruit in 3.76 g L^{-1}, TSS content (11.6%) was maximized.

Table 2. Fruit juice (%) of Washington Navel orange fruit treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1 °C at 85-90% RH)

Extract concentration (g L^{-1})	Fruit juice (%)				
	DS time †				
	0	15	30	45	60
7.52	49.3 a	46.1 b	39.8 c	36.0 de	33.6 efg
3.76	49.3 a	45.5 b	40.3 c	38.0 cd	35.5 ef
1.88	49.3 a	44.8 b	39.0 c	34.7 ef	31.5 gh
0.94	49.3 a	44.7 b	39.1 c	33.9 ef	30.9 h
Control	49.3 a	44.7 b	39.2 c	33.6 fg	30.3 h

Means with different letters are statistically different (LSD, $P \leq 0.05$)

† DS = Days of storage

Table 3. Fruit decay (%) of Washington Navel orange fruits treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1°C at 85-90% RH)

Extract concentration (g L^{-1})	Fruit juice (%)				
	DS time †				
	0	15	30	45	60
7.52	0.00 h	0.33 gh	1.33 fgh	3.00 def	4.33 c-f
3.76	0.00 h	0.33 gh	2.00 e-h	3.33 de	5.33 bc
1.88	0.00 h	0.33 gh	1.33 fgh	2.66 def	4.33 bcd
0.94	0.00 h	0.33 gh	1.33 fgh	2.33 efg	3.66 cde
Control	0.00 h	0.66 gh	2.66 def	5.66 b	11.66 a

Means with different letters are statistically different (LSD, $p \leq 0.05$)

† DS = Days of storage

Table 4. Total soluble solids (TSS %) of Washington Navel orange fruit treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1 °C at 85-90% RH)

Extract concentration (g L^{-1})	Fruit decay (%)				
	DS time †				
	0	15	30	45	60
7.52	8.2i	8.5hi	8.9ghi	10.5a-e	11.2abc
3.76	8.2i	9.0f-i	9.3e-i	10.2b-f	11.6a
1.88	8.2i	11.2abc	10.8abc	9.1f-i	9.4e-i
0.94	8.2i	10.5a-e	10.7a-d	8.9ghi	11.3ab
Control	8.2i	10.4a-e	9.5d-h	10.0c-g	10.4a-e

Means with different letters are statistically different (LSD, $P \leq 0.05$).

† DS = Days of storage

Ascorbic Acid

Until day 45, the ascorbic acid content increased in all seaweed extract concentrations, but thereafter, it decreased significantly, when compared with the control (Table 5), indicating that the seaweed extracts were effective in maintaining the ascorbic acid content up to 45 DS. The most effective concentrations of the extract to increase the amount of ascorbic acid content were 3.76, 1.88 and 7.52 g L^{-1} by 30 DS. Although maximum ascorbic acid content on days 45 (73.48) and 60 (23.76 mg100 ml^{-1} juices) was observed in samples dipped in 7.52 gL^{-1} seaweed extract, but this concentration was not significantly different from 1.88 g L^{-1} and the control. No significant increase in ascorbic acid content was found in fruit dipped in seaweed extract at 60 days of storage, compared with the non-treated (control) fruits (Table 5).

Free Radical Scavenging Activity (FRSA)

The FRSA of orange fruits was significantly affected by days of storage (DS) and seaweed extract application. From the day 0 up to 30 DS, in all concentrations of seaweed extracts (with the exception of 3.76 g L^{-1}), the FRSA decreased significantly. Although these reductions were very remarkable on day 15, the increase in the FRSA was gradual thereafter. Fruit dipped in seaweed extracts showed a higher FRSA by 45 DS as compared to 15 and 30 DS. At each sampling time, orange fruits dipped in seaweed extracts had significantly higher FRSA as compared with the control, hence the maximum and minimum FRSA obtained in samples treated with 3.76 g L^{-1} of seaweed extract and control, respectively. Accordingly, maximum FRSA (84.89 %) was obtained by 45 DS in samples treated with 3.76 g L^{-1} seaweed extract, which had significant differences with other concentrations and the control (Table 6).

Table 5. Total ascorbic acid content of Washington Navel orange fruits treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1 °C at 85-90% RH)

Extract concentration (g L^{-1})	Ascorbic acid content (mg100 ml^{-1} juice)				
	DS time †				
	0	15	30	45	60
7.52	33.44f	51.04de	66.00ab	73.48a	23.76g
3.76	33.44f	45.32e	73.43a	56.76cd	22.44g
1.88	33.44f	47.08e	73.33a	66.44ab	19.36g
0.94	33.44f	44.00e	64.68b	62.92bc	21.41g
Control	33.44f	36.08f	66.00ab	69.96ab	19.87g

Means with different letters are statistically different (LSD, $P \leq 0.05$)
† DS = Days of storage

Table 6. Free radical scavenging activity (FRSA) of Washington Navel orange fruits treated with various concentrations of seaweed extract compared to control treatment in the cold storage conditions (5±1 °C at 85-90% RH)

Extract concentration (g L^{-1})	FRSA (%)			
	DS time †			
	0	15	30	45
7.52	73.95 bc	11.49 hi	36.69 f	76.88 b
3.76	73.95 bc	20.23 g	71.61 c	84.89 a
1.88	73.95 bc	15.76 h	57.72 d	56.39 d
0.94	73.95 bc	8.46 ij	51.24 e	56.30 d
Control	73.95 bc	6.28 j	22.20 g	22.06 g

Means with different letters are statistically different (LSD, $P \leq 0.05$).
† DS = Days of storage

This study indicated that weight loss of Washington Navel fruit increased significantly by increasing the storage duration up to 60 DS. It has been reported that more weight loss occurred through prolonged durations of storage due to the moisture loss and the greater vulnerability of orange fruit to water loss despite low temperatures (Rab et al., 2015). The results of this study showed that dipping Washington Navel orange fruit in all seaweed extract concentrations (except for 0.94 g L^{-1}), significantly reduced their weight loss. Parallel to our results, Omar (2014) indicated that the seaweed extract reduced the percentage of fruit weight loss significantly, possibly due to the effects of the extract as an organic permeable barrier against oxygen, carbon dioxide and moisture, which reduces respiration ,water loss and oxidation reaction rates.

In this study, it was shown that weight loss of Washington Navel orange fruit during storage was accompanied by reduction in fruit juice contents. After treating the fruit with seaweed extract, fruit weight loss decreased as compared with control. In a way that the maximum fruit juice contents were observed in samples treated with 3.76 g L^{-1} and 7.52 g L^{-1} concentrations of seaweed extract at the end of the experiment (60 DS). These results are in align with the reports by Kamel (2014) who indicated that treating orange fruit with seaweed extracts maintained higher percentages of the fruit juice. Some studies have shown that fruit coating with seaweed extract as an organic barrier prevents the loss of fruit water, resulting in fruit juice maintenance (Omar, 2014).

Regardless of the concentration of seaweed extract, increasing the duration of treatment up to 60 DS, significantly augmented fruit decay, while treatment of fruits with seaweed extracts were able to observably reduce fruit decay symptoms. The effect of all seaweed extract concentrations on the reduction of fruit decay symptoms was statistically similar. Accordingly, no significant differences on fruit decay were observed when the seaweed extract concentration increased from 0.94 to 7.52 g L^{-1}. Certain studies have indicated that seaweed extract show strong antimicrobial activities which affect postharvest quality (Nabti et al., 2017), significantly reduce fruit diseases, and prolong the shelf life of Navel orange fruit (Rizvi and Shameel 2001; Omar 2014). Nabti et al. (2017) demonstrated that strong antimicrobial activity of seaweed extract is owing to presence of terpenes compounds.

In the absence of seaweed extract, no significant trend was observed in TSS changes during 15 DS to 60 DS. This finding was in contrast with Kamel's (2014) finding who indicated that the TSS content significantly increased by up to 30 days of storage, and then decreased by the end of the storage time (60 DS). When orange fruit were dipped in 3.76 and 7.52 g L^{-1} of seaweed extract, TSS content increased significantly at 60 DS compared to other storage periods. So that, the highest amount (11.6%) of TSS content was observed at 60 DS when orange fruits were coated with 3.76 g L^{-1} seaweed extract. It has been reported that TSS depends on the maturity stage and due to the hydrolysis of polysaccharides, it tends to increase during the ripening process which happens to maintain the respiration rate of fruits (Yonemoto et al., 2002). In this study, treating fruits with seaweed extracts caused their TSS to increase. Similar to these results, Kamel (2014) and Omar (2014) also showed that exogenous use of seaweed extract prevented the reduction of TSS in

orange fruits. This is probably because the extract acted as a protective O_2 barrier on the fruit surface, which reduced the oxygen supply to the fruit, thereby inhibiting respiration (Yonemoto et al., 2002).

Although ascorbic acid content increased over 45 days, however as storage time increased up to 60 days, the amount of ascorbic acid in all seaweed extract concentrations decreased significantly. These findings are in contrast with the results reported by Kamel (2014) and Omar (2014) which noted, prolonging the storage period up to 45 DS significantly reduced the ascorbic acid content of orange fruits when treated with seaweed extract. Similar to our results, it was reported that cold storage of some citrus fruits such as kinnow fruit (*Citrus reticulata*) increased the amount of ascorbic acid in the fruits (Shah et al., 2015). Increasing in ascorbic acid content maybe due to reduction of orange juice content under cold storage conditions (Johnson et al., 1995). All seaweed extract concentrations were able to maintain the ascorbic acid content up to 45 DS, but at 60 DS; this trait decreased significantly. Nonetheless, in agreement with our results, Kamel (2014) reported that ascorbic acid content was decreased significantly at 60 DS. In line with these results, previous studies indicated that seaweed extract contains antioxidant enzymes that prevents the breakdown of ascorbic acid in the fruit (Nabti, 2017). Therefore, it seems that *Ulva flexuosa* extracts able to maintain the orang ascorbic acid content in short time of storage.

At the beginning of the experiment, FRSA was at its maximum. While on the 15th day, a sharp decrease in this trait was observed in all extracts concentrations. This seems to be due to the decrease the total phenolic compounds and anthocyanin content in cold storage conditions (Galani et al., 2017). With a lag phase, after 15 day fruit dipping in seaweed extract gradually increased FRSA, and this trend continued until 45 DS so that the highest FRSA was observed at 3.76 g L^{-1} extract, which differed significantly with other concentrations. This lag phase seems to be due to the delay in starting the effect of the antioxidants in seaweed extract .In fact, Corsetto et al. (2020) shown that seaweed extract may act as an antioxidant either by direct scavenging ROS or by stimulating the activity of endogenous antioxidant enzyme system. Moreover, they confirmed that the antioxidant activity of seaweed extracts, related to their significant polyphenol content (Corsetto et al., 2020). Parallel with these results, Zhang and Schmidt (2000) and Kasim et al. (2015) indicated that the seaweed extract could enhance antioxidant activity in plants. It seems that by increasing FRSA, seaweed extract reduces lipid oxidation, which is one of the major causes of food deterioration during processing and storage (Thitileadecha et al., 2008). Therefore our study indicated that increasing the FRSA by the application of seaweed extract through increasing in ascorbic acid maintenance and TSS content and decreasing fruit decay and fruit weight loss could increase the postharvest quality of orange fruits under cold storage conditions.

CONCLUSION

The present study suggests that dipping Washington Navel orange fruit in seaweed extracts increases the free radical scavenging activity (FRSA) and the storage life by augmenting the ascorbic acid content and reducing the percentage of fruit decay. During the postharvest period, seaweed extracts were able to ameliorate other features such as fruit juice and TSS percentage. The most effective concentration of *Ulva flexuosa* extract was 3.76 g L^{-1} which maintained the quality characteristics of Washington Navel orange fruit during cold storage up to 60 days. The results of this study suggest that seaweed extracts can be used as a perfect natural compound, to improve fruit quality and storability of the Washington Navel orange.

ACKNOWLEDGEMENT

The authors are thankful to University of Hormozgan, Iran for providing financial assistance.

REFERENCES

Blunden, G., Jones, E. M., Passam, & H. C. (1978). Effects of postharvest treatment of fruit and vegetables with cytokinin-active seaweed extract and kinetin solutions. *Botanica Marina*, 21, 237-240.

Cantwell, M. I., & Suslow, T. V. (2002). Postharvest handling systems: fresh-cut fruits and vegetables. In: Kader, A. A. (Ed.). *Postharvest technology of horticultural crops* (pp. 315-326). Oakland: University of California Publications.

Corsetto, P. A., Montorfano, G., Zava, S., Colombo, I., Ingadottir, B., Jonsdottir, R., Sveinsdottir, K., & Rizzo, A. M. (2020). Characterization of antioxidant potential of seaweed extracts for enrichment of convenience food. *Antioxidants*, 9, 249. doi: 10.3390/antiox9030249

Dambolena, J. S., Zunino, M. P., Lucini, E. I., Olmedo, R., Banchio, E., Bima, P. J., & Zygadlo, J. A. (2010). Total phenolic content, radical scavenging properties, and essential oil composition of *Origanum* species from different populations. *Journal of Agricultural and Food Chemistry*, 58, 1115-1120.

Fan, X., Niemira, B., & Prakash, A. (2008). Irradiation of fresh fruits and vegetables. *Food Technology*, 62(3), 36-43.

Fisk, C. L., Silver, A. M., Strik, B. C., & Zhao, Y. (2008). Postharvest quality of hardy kiwifruit (*Actinidia arguta* 'Ananasnaya') associated with packaging and storage conditions. *Postharvest Biology and Technology*, 47, 338-345.

Ito, K., & Hori, K. (1989). Seaweed: Chemical composition and potential food uses. *Food Review International*, 5, 101-144.

Johnson, J., Braddock, R., & Chen, C. (1995). Kinetics of ascorbic acid loss and nonenzymatic browning in orange juice serum: Experimental rate constants. *Journal of Food Science*, 60(3), 502-505.

Galani, J. H. Y., Patel, J. S., Patel N. J., & Talati, J. G. (2017). Storage of fruits and vegetables in refrigerator increases their phenolic acids but decreases the total phenolics, anthocyanins and vitamin C with subsequent loss of their antioxidant capacity. *Antioxidants*, 6, 59. doi: 10.3390/antiox6030059

Kader, A. A. (2002). Standardization and inspection of fresh fruits and vegetables. In: Kader, A. A. (Ed.). *Postharvest technology of horticultural crops* (pp. 287-300). Oakland: University of California Publications.

Kamel, H. M. (2014). Impact of garlic oil, seaweed extract and imazalil on keeping quality of Valencia orange fruits during cold storage. *Journal of Horticultural Science and Ornamental Plants*, 6, 116-125.

Kasim, W. A. Hamada, E. A. M., Nahal, G., Shams, El-Din., N. G., & Eskander, S. K. (2015). Influence of seaweed extracts on the growth, some metabolic activities and yield of wheat grown under drought stress. *International Journal of Agronomy and Agricultural Research*, 7(2), 173-189.

Lanciotti, R., Gianotti, A., Patrignani, F., Belleti, N., Guerzoni, M. E., & Gardini, F. (2004). Use of natural aroma compounds to improve shelf-life and safety of minimally processed fruits. *Trends in Food Science and Technology*, 15, 201-208.

Martin-Belloso, O., & Soliva-Fortuny, R. (2006). Effect of modified atmosphere packaging on the quality of fresh-cut fruits. *Stewart Postharvest Review*, 2, 1-8.

Martin-Diana, A. B., Rico, D., Frias, J. M., Barat, J. M., Henehan, G. T. M., & Barry-Ryan., C. (2007). Calcium for extending the shelf-life of fresh whole and minimally processed fruits and vegetables: A review .*Trends in Food Science and Technology*, 18, 210-218.

Nabti, E., Jha, B., & Hartman, A. (2017). Impact of seaweeds on agricultural crop production as biofertilizer. *International Journal of Environmental Science and Technology*, 14, 1119-1134.

Norrie, J., & Keathley, J. P. (2006). Benefits of *Ascophyllum nodosum* marine plant extract application to Thompson seedless grape production. *Acta Horticulturae*, 727, 243-248.

Nunes, M. C. N. (2008). Impact of environmental conditions on fruit and vegetable quality. *Stewart Postharvest Review*, 4(4), 1-14.

Omar, A. E. K. (2014). Use of seaweed extract as a promising post-harvest treatment on Washington Navel orange (*Citrus sinensis* Osbeck). *Biological Agriculture and Horticulture*, 30, 198-210.

Rab, A., Najia, M., Sajid, F., Bibi, I. Jan, G., & Nawab, K. (2015). Quality changes in heat treated sweet orange fruit during storage at low temperature. *Journal of Animal and Plant Sciences*, 25(3), 661-668.

Rizvi, M. A., & Shameel, M. (2001). Distribution of elements in marine algae of Karachi coast. *Pakistan Journal of Botany*, 33(4), 357-363.

Salehi, P., Sonboli, A., Eftekhar, F., Nejad-Ebrahimi, S., & Yousefzadi, M. (2005). Essential oil composition, antibacterial and antioxidant activity of the oil and various extracts of *Ziziphora clinopodioides* subsp. rigida (BOISS.) RECH. f. from Iran. *Biological and Pharmaceutical Bulletin*, 28(10),1892-1896.

Shah, S., Jahangir, M., Qaisar, M., Khan, S., Mahmood, T., Saeed, M., & Liaquat, M. (2015). Storage stability of kinnow fruit (Citrus reticulata) as affected by CMC and guar gum-based silver nanoparticle coatings. *Molecules*, 20(12), 22645-22661.

Suntornsuk, L., Gritsanapun, W., Nilkamhank, S., & Paochom, A. (2002). Quantitation of vitamin C content in herbal juice using direct titration. *Journal of Pharmaceutical and Biomedical Analysis*, 28(5), 849-855.

Spínola, V., Mendes, B., Câmara, J. C., & Castilho, P. C. (2013). Effect of time and temperature on vitamin C stability in horticultural extracts. UHPLC-PDA vs iodometric titration as analytical methods. *LWT - Food Science and Technology*, 50(2), 489-495.

Tavarini, S., Degl Innocenti, E., Remorini, D., Massai, R., & Guidi, L. (2008). Antioxidant capacity, ascorbic acid, total phenols and carotenoids changes during harvest and after storage of Hayward kiwifruit. *Food Chemistry*, 107(1), 282-288.

Thitileadecha, N., Teerawutgulrag, A., & Rakariyatham, N., (2008). Antioxidant and antibacterial activities of *Nephelium lappaceum* L. extracts. *LWT - Food Science and Technology*, 41(10), 2029-2035.

Toivonen, P. M. A. (2008). Application of 1-methylcyclopropene in fresh-cut/ minimal processing systems. *Horticultural Science*, 43(1), 102-105.

Udagawa, S. (2005). Fungal spoilage of foods and its risk assessment. *Nihon Ishinkin Gakkai Zasshi*, 46(1), 5-11. (In Japanese with an abstract in English).

Washington, W. S. Engleitner, S., Boontjes, G., & Shanmuganathan, N. (1999.) Effects of fungicides, seaweed extract, tea tree oil and fungal agents on fruit rot and yield in strawberry. *Australian Journal of Experimental Agriculture*, 39, 487–494.

Wiley, R. C. (1994). *Minimally processed refrigerated fruits and vegetables*. (1st ed). New York: Chapman and Hall Publisher.

Xu, G., Liu, D., Chen, J., Yea, X., Ma, Y., & Shi, J. (2008). Juice components and antioxidant capacity of citrus varieties cultivated in China. *Food Chemistry*, 106(2), 545-551.

Yonemoto, Y., Higuchi, H., & Kitano, Y., (2002). Effects of storage temperature and wax coating on ethylene production, respiration and shelf-life in cherimoya fruit. *Journal of the Japanese Society for Horticultural Science*, 71(5), 643-650.

Zhang, X. Z., & Schmidt, R. E. (2000). Hormone-containing products' impact on antioxidant status of tall fescue and creeping bentgrass subjected to drought. *Crop Science*, 40(5), 1344-1349.

تحقیقات کشاورزی ایران (۱۳۹۸) ۳۸(۲) ۱۱۱-۱۱۸

تأثیر عصاره جلبک دریاییUlva *flexuosa* Wulfenدر بهبود کیفیت پس از برداشت میوه پرتقال واشنگتن ناول

محبوبه رضایی[۱]، فرزین عبدالهی[*۲]، عبدالمجید میرزاعلیان دستجردی[۱]، مرتضی یوسف زادی[۲]

[۱]گروه باغبانی دانشکده کشاورزی و منابع طبیعی، دانشگاه هرمزگان، بندرعباس، ج. ا. ایران
[۲]گروه زیست دریا، دانشکده علوم و فنون دریایی، دانشگاه هرمزگان، بندرعباس، ج. ا. ایران

*نویسنده مسئول

اطلاعات مقاله

تاریخچه مقاله:
تاریخ دریافت: ۱۳۹۸/۷/۱۷
تاریخ پذیرش: ۱۳۹۹/۲/۲۱
تاریخ دسترسی:۲۸ /۲ /۱۳۹۹

واژه‌های کلیدی:
آسکوربیک اسید
ظرفیت حذف رادیکال‌های آزاد (FRSA)
انبارمانی میوه
کل مواد جامد محلول (TSS)

چکیده جلبک‌های دریایی حاوی یک منبع متنوع از ترکیبات غنی هستند که به عنوان ترکیبات بالقوه فعال زیستی مورد توجه قرار گرفته‌اند. این آزمایش برای بررسی اثر غلظت‌های مختلف عصاره جلبک دریایی Ulva flexuosa Wulfen (بومی خلیج فارس) بر فعالیت آنتی اکسیدانی میوه پرتقال واشنگتن ناول و ویژگی‌های کیفی پس از برداشت میوه درشرایط نگهداری در انبارسرد (۵±۱) و رطوبت نسبی ۹۰-۸۵ درصد به مدت ۶۰ روز انجام شد. نتایج این آزمایش نشان داد که با افزایش زمان انبارمانی، میزان کاهش وزن میوه، فساد میوه و کل مواد جامد محلول (TSS) افزایش در حالی که درصد آب میوه و آسکوربیک اسید میوه پرتقال کاهش یافت. با قراردادن میوه‌های پرتقال واشنگتن ناول در محلول عصاره جلبک، ویژگی‌های کیفی پس از پرداشت و فعالیت آنتی اکسیدانی بطور معنی‌دار افزایش یافت. غلظت ۳/۷۶ گرم در لیتر عصاره جلبک موثرترین غلظت در بهبود ظرفیت آنتی اکسیدانی، میزان آسکوربیک اسید و TSS در طول انبارمانی بود. در مجموع نتایج این پژوهش نشان داد که عصاره جلبک دریایی می‌تواند به عنوان یک ترکیب فعال زیستی جدید برای بهبود ویژگی‌های پس از برداشت میوه پرتقال از طریق افزایش فعالیت آنتی اکسیدان مورد استفاده قرار گیرد.