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Effect of Hot Water Treatment with Organic Additives in Fresh Cut Carrot

Taslima Ayesha Aktar Nasrin*, Latifa Yasmin, Most Sadia Arfin, Mohammad Mainuddin Molla and Md. Nazim Uddin

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Bangladesh Agricultural Research Institute (BARI), Bangladesh.

ABSTRACT

Fresh cut carrot (Daucus carota *L*.) slices were treated with hot (60°C) water and hot aqueous solution (2% sodium chloride, 2% citric acid and 10% lime juice) for 1 min and then surface water was removed. Following treatment, fresh-cut carrot slices were kept in a polypropylene (PP) box and stored in a refrigerator (4±1°C and 50±5% RH) for 12 days. The effectiveness of the treatments in extending shelf life was evaluated by determining respiration rate, firmness, weight loss, external colour, whiteness index (WI), some chemical parameters (ascorbic acid content, TSS, acidity, pH, total sugar, reducing sugar and beta carotene), total bacterial count (TBC) and sensory quality. The highest increment of WI (48.4%) was observed without heat-treated carrot slices. On the other hand, WI was increased by 12.1% and 21.7% in carrot slices treated with hot aqueous solution of 2% citric acid and with hot aqueous solution of 2% sodium chloride respectively at 12 days of storage. On the 12th day of storage, fresh-cut carrot treated with hot aqueous solution of 2% citric acid scored 7.3 and the rest of the sample scored less than 4.5 (indicate as unacceptable) in overall acceptability. Carrot slices treated with hot aqueous solution of 2% citric acid and 2% sodium chloride retained a minimum number of TBC and delayed changes in WI, external colour and beta carotene content compared to without heat-treated carrot slices.

Keywords: Citric acid, respiration rate, sensory quality, sodium chloride, total bacterial count, whiteness index
Corresponding author. Email: taanasrin@gmail.com; st111058@alumni.ait.asia. Tel. +88 01751904470

INTRODUCTION

Carrot (Daucus carota *L*.) is an important vegetable because of its large yield per unit area throughout the world and its increasing importance as human food. It is orange-yellow in color, which adds attractiveness to foods on a plate and makes them rich in carotene, a precursor of vitamin A. It is eaten raw as well as cooked in curries and is used for pickles and sweetmeats. Carrot stands as one of the most consumed vegetables in fresh-cut form (sliced, diced, grated) due to its versatility (Alasalvar et al., 2005). The main problems limiting the shelf life of minimally processed carrots were reported as white blush discoloration (lignin formation) and microbial spoilage (Emmambux and Minaar, 2003). Lignin formation, as measured by the “whiteness index” (WI) and by peroxidase (POD) activity has been used as an indicator of fresh-cut carrots storability, as it results in an irreversible change of surface color (Izumi et al., 1996). The most commonly used method for reducing initial contamination is washing the cut vegetables in chlorinated water. In fresh-cut carrot, heat as an alternative decontamination treatment demonstrated high efficacy when compared to chlorinated water treatments (Alegria et al.,2009). On the other hand, organic acids such as citric acid and ascorbic acid have been applied for preserving physicochemical qualities (Rosen and Kader, 1989) and preventing microbial growth at levels that did not adversely affect taste and flavour (Yildiz, 1994). Sodium chloride (NaCl) is an ionic compound and assists in both preserving the fresh fruits and vegetables, through its hygroscopic properties, and

enhancing the flavour of the food preservative mixture of the present invention. Essentially, the salt draws water out of bacteria through osmotic pressure preventing the bacteria from reproducing which will otherwise cause food spoilage.

Therefore, this study aimed to evaluate the effect of hot aqueous solution of 2% NaCl, 2% citric acid and 10% lime juice for extending the postharvest quality of fresh-cut carrot during refrigerated storage. For this purpose, the physical, chemical, microbiological, and sensory quality of freshly cut treated carrots, packed in PP box and kept at refrigerator (4±1°C and 50±5% RH) were examined.

MATERIALS AND METHODS

Materials

Fresh carrot (*Daucus carota* L.) and lime which were free from any mechanical damage and diseases were purchased from a local market at Gazipur. Thereafter, the carrot and lime were immediately brought to the laboratory. Selected carrots, knives, utensils to be used were washed with sanitizers (0.1% calcinated calcium). Sanitized carrots were peeled with sharp peeler and simultaneously trimmed of taproot and stem plate and cut into 0.5 cm thick round shape with sharp knives. All chemicals used in this study were of analytical grade.

Sample preparation, packaging and storage

Carrot slices were treated for 1 min using the following solutions i. normal tap water (without heat treatment) ii. hot (60°C) water iii. hot (60°C) aqueous solution of 2% NaCl iv. hot (60°C) aqueous solution of 10% lime juice v. hot (60°C) aqueous solution of 2% citric acid. Surface water of carrot slices was removed by using a fan. Three hundred grams of sliced carrot was kept in each PP box, closed and then put into a refrigerator at 4±1°C temperature. There were 5 treatments in this study and each treatment had 3 replications and each replication had 8 PP box with fresh-cut carrot.

Respiration rate measurement

The respiration rate of the freshly cut carrot was assayed for each treatment during storage. 150 g from each replication were placed in 500 ml airtight plastic containers equipped with septa and sealed for 2 h (incubation time) at ambient condition (25±2°C). 1 ml of gas was withdrawn from the headspace of the container by a gaslight hypodermic syringe and analysed using a gas analyser (CO_2/O_2 gas analyser, Quantek Instrument, Model No. 902D, USA). The percentage of CO_2 gas in the container was recorded. Thereafter, the respiration rate was calculated using total gas volume, carrot volume and carrot weight in the container and incubation time (Nasrin et al., 2017).

Measurement of firmness

Firmness was analyzed using Fruit Texture Analyzer (GUSS, Model No. GS25, SA). An 8 mm diameter stainless steel cylindrical probe with a flat end was used for this measurement. The probe was pushed to a depth of 3 mm into carrot slices (same position of each sample) at a speed of 5 mm s^{-1}. The maximum penetration force (N) was used as the firmness value of carrot slices (Nasrin et al., 2018).

Measurements of surface color

External color hue angle (H), Chroma (C), lightness (L*), a* and b* values of fresh-cut carrot was evaluated with a Chroma Meter (Model CR-400, Minolta Corp, Japan). Whiteness index (WI) was calculated using measured L*, a* and b* values as follows and was used to determine the color changes of freshly cut carrot slices (Sarıçoban and Yilmaz, 2010).

$$WI = 100 - \sqrt{[(100 - L*)^2 + a*^2 + b*^2]}$$

Ascorbic acid, beta carotene, total sugar, reducing sugar, pH and TSS determination

The ascorbic acid content, beta carotene, total sugar and reducing sugar of carrot slices were analyzed according to AOAC (1994). 10g of ground carrot was suspended in 100 ml of distilled water and then filtered. The pH of the sample (carrot juice) was assessed using a pH meter (HANNA Instrument Inc, pH -211; Microprocessor, pH Meter, Italy). The TSS of the carrot juice was determined using a refractometer.

Microbiological analysis

10 g freshly cut carrots were blended and mixed properly with 90 ml of sterile 0.9% sodium chloride (NaCl) solution. 1 ml of each homogenate sample was added into appropriate dilutions (10^{-1} to 10^{-6}) using 0.9% NaCl solution. Nutrient agar (Difco TM, USA, pH 7.0-7.4) was used to determine Total Bacterial Count (TBC) and potato dextrose agar (PDA, Hi Media, India) was used to enumerate yeast and molds. Media were prepared according to the manufacturer's instructions. Media was sterilized by autoclave at 121° C for 15 minutes. From appropriate dilution, 100 µl homogenate of each sample was inoculated in respective culture media by using a sterile pipette and was spread using sterile glass spreader. Inoculated nutrient agar plates were then kept in an incubator at 37°C for 24 to 28 hours whereas PDA plates were incubated at ambient temperature (26 ± 2°C) for 5 days. Following incubation, plates exhibiting colonies were counted. The average number of colonies

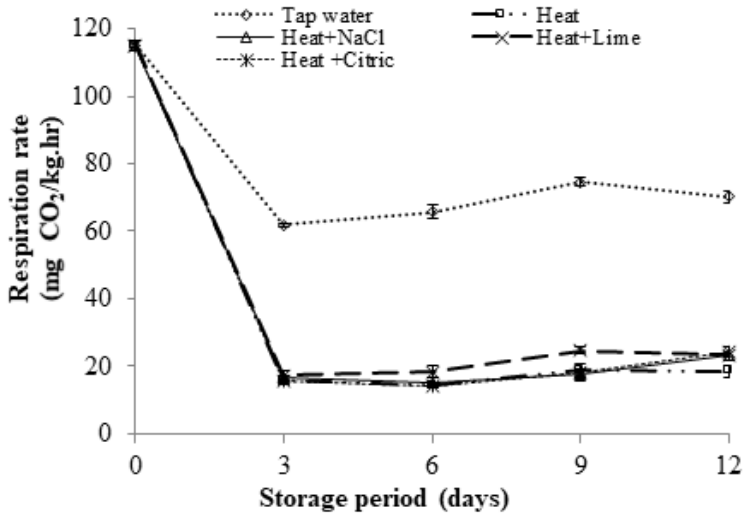


Figure 1. Respiration rate of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator. Tap water = Wash with normal tap water (without heat treatment); Heat = Treated with hot (60°C) water; Heat+NaCl = Treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = Treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime = Treated with hot (60°C) *aqueous* solution of 10% lime juice; Vertical bars indicate standard deviation.

in a particular dilution was multiplied by the dilution factor to obtained TBC. Microorganisms associated with samples were expressed as colony-forming units per gram (cfu/g). Cell counts (cfu/g) were the average of at least 3 independent experiments (Mahfuza et al., 2016).

Sensory quality analysis

The sensory quality of freshly cut carrots was evaluated at 4, 8 and 10 days of storage. The stored freshly cut carrot was kept at ambient temperature for 1 h before sensory quality evaluation. The sensorial attributes of the freshly cut carrot (color, flavour, texture and overall acceptability) were evaluated by a panel of judges consisting of 15 scientific personnel and consumers including both male and female members. Nine-point unstructured scale ranging from 1 (dislike extremely) to 9 (like extremely) was used to evaluate these sensory parameters (Nasrin and Anal, 2015). An average score of 4.5 was considered the limit for acceptability.

Statistical analysis

All the experiments were conducted in triplicate and mean ± standard deviations were reported. Analysis of variance was done by one way ANOVA procedures of MSTAT-C software. Comparisons among samples were done by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Respiration rate

Figure 1 illustrates the effect of heat treatment with additives on the respiration rate of freshly cut carrot stored in the refrigerator (4±1°C) for 12 days. The initial respiration rate of freshly cut sliced carrot was 115.15 mg $kg^{-1}h^{-1}$. The respiration rate of all fresh cut carrot after storage in the refrigerator was reduced significantly. On the 3rd day of storage, the respiration rate was 61.77 mg $kg^{-1}h^{-1}$ without heat-treatment while it was around 17 mg $kg^{-1}h^{-1}$ for all heat-treated carrot slices which did not change significantly throughout the storage period. Kato-Noguchi and Watada (1997) reported that the respiration rate of shredded carrots was around 153 mg $kg^{-1}h^{-1}$ and after dipping in citric acid, the respiration rate of shredded carrots reduced by 50% or more. Reduced respiration rates due to heat shock pre-treatments have already been reported by other studies in several fruits and vegetables, namely shredded carrot (Klaiber et al., 2005; Alegria et al., 2009).

Firmness

Firmness or texture is a critical quality attribute in the consumer acceptability of freshly cut fruits and vegetables. Degradation of insoluble protopectin to the more soluble pectic acid and pectin contributes to a decrease of firmness in fresh fruits and vegetables (Nasrin et al., 2020). Figure 2 represents the changes in the firmness without heat treatment and heat treatment with additives of freshly cut carrots during storage at refrigerator (4 ± 1°C). Initially, the firmness value of sliced carrot was 4.38 N and it was decreased gradually with time. Control (without heat-treated) freshly cut carrot lost around 9% firmness whereas carrot treated with a

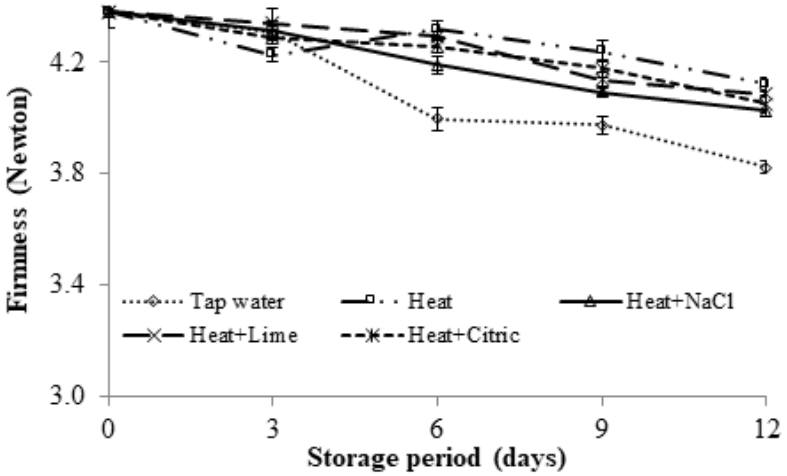


Figure 2. Firmness of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator. Tap water= Wash with normal tap water (without heat treatment); Heat= Treated with hot (60°C) water; Heat+NaCl= Treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = Treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime= Treated with hot (60°C) *aqueous* solution of 10% lime juice; Vertical bars indicate standard deviation.

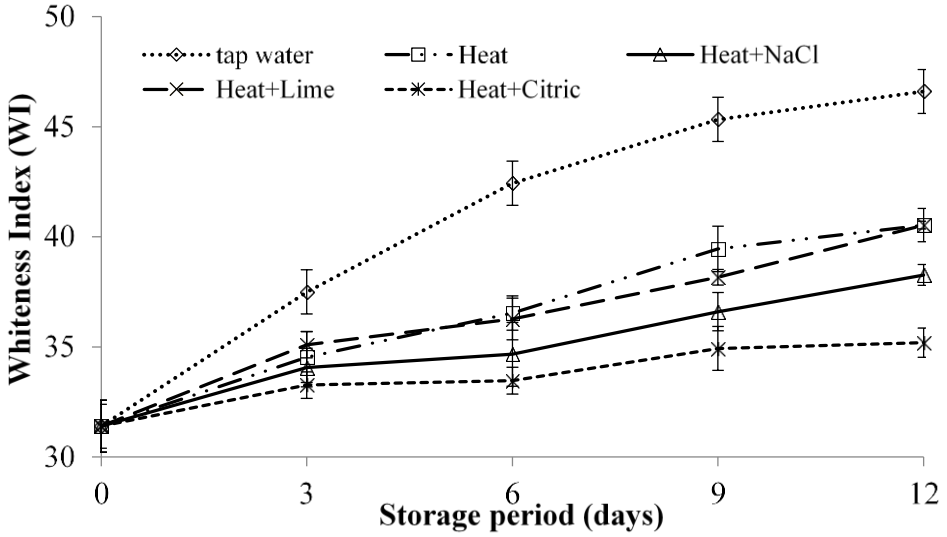


Figure 3. Whiteness index of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator. Tap water= Wash with normal tap water (without heat treatment); Heat= Treated with hot (60°C) water; Heat+NaCl= Treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = Treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime= Treated with hot (60°C) *aqueous* solution of 10% lime juice; Vertical bars indicate standard deviation.

hot aqueous solution of 2% citric acid had lost around 5% firmness at the 9th day of storage period.

Whiteness index (WI)

Discoloration of freshly cut carrots' surface during storage is considered to be an unfavorable quality defect since consumers relate white discoloration with loss of freshness (Howard et al., 1994). A mechanism proposed for white discoloration on minimally processed carrots is correlated to both physical and physiological responses to wounding (peeling and slicing). Surface dehydration (physical response) induces a reversible color change, while the activation of the phenolic metabolism and production of lignin (physiological response) results in an irreversible color change (Emmambux and Minnaar, 2003). In Figure 3, the whiteness index (WI) values of freshly cut sliced carrot as affected by the heat

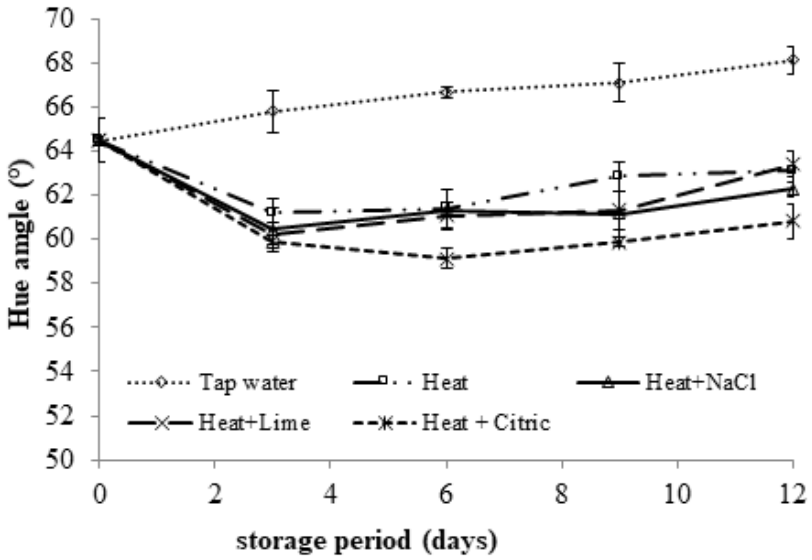


Figure 4. Color (hue angle) of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator. Tap water= Wash with normal tap water (without heat treatment); Heat= Treated with hot (60°C) water; Heat+NaCl= Treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = Treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime= Treated with hot (60°C) *aqueous* solution of 10% lime juice; Vertical bars indicate standard deviation.

treatments and storage time are shown. Just after slicing (day 0), WI value was 31.4 but it increased in all samples with storage period as shown in figure 3. The rate of increment of WI values is significantly higher in carrot slices without heat treatment than the heat-treated ones. Whiteness value of without heat-treated carrot increased by 48.4% whereas it was only 12.1% and 21.7% in carrot slices treated with a hot aqueous solution of 2% citric acid and a hot aqueous solution of 2% sodium chloride respectively. Alegria et al. (2009) found that heat treatment (before grated, whole carrot treated with hot water 100°C/ 45 s) maintained their initial WI value throughout storage. Amanatidou et al. (2000) also reported that dipping in citric acid solution prevented the whitening of the carrot.

Surface color (hue angle)

Hue angle value of freshly cut carrot was around 65 (Figure 4). After heat treatment only or with additives it was decreased. This indicates heat-treated carrot is more orange red colored than without heat treated carrot. During 12 days of storage, hue angle value peaked at 68.1 in without heat-treated carrot slices and it was 60.8 in freshly cut carrot treated with a hot aqueous solution of 2% citric acid. During the initial part of the heating, an increase in green color is observed (Tijskens et al., 2001). Similarly, Herrmann (1993) reported that green beans blanched for 30 s showed higher scores for the green color than non-blanched ones. Likewise, Lau et al. (2000) noticed an initial increase in the green color of asparagus after heat treatments.

Microbial contamination

The change in different microbial populations, namely total bacterial count (TBC), yeasts and mould over 12 days of storage in a refrigerator (4 ± 1°C) is reported in Figure 5. The lack of microbial quality standards in many countries for freshly cut vegetables makes it difficult to define a CFU number threshold beyond which the product can be considered unacceptable. However, French regulations establish a limit of 5×10^8 CFU/g (8.67 log CFU/g) as the maximum acceptable contamination values for the TBC in carrot sticks (Aked, 2002). Initial TBC of freshly cut carrot was 2.1 log CFU/g as shown in Figure 5. After heat treatment, it was lowered and then it increased slightly during storage. The highest amount (4.13 log cfu/g) of TBC was observed in without heat treated carrot while it was only 2.26 log cfu/g in freshly cut carrot treated with hot aqueous solution of 2% citric acid.

However, TBC in all samples was below the maximum acceptable contamination values for the TBC in freshly cut carrot slices. Besides, there were no detectable yeast and mould counts in any samples initially and during the storage life of fresh-cut carrot. Rocha et al. (2007) also stated that the total counts of microorganisms at 30°C and 7°C never exceeded the maximum acceptable limit of log CFU g^{-1} = 8 during storage (Jacxsens et al., 2002). Mahfuza et al. (2016) found that TBC in freshly cut carrots was $4.3x10^3$cfu/g. Eni et al. (2010) investigated that the total microbial count ranged from 3.8×10^6 to 2.9×10^7cfu/g in carrot and 1.3×10^7 to 4.6×10^6cfu/g in cucumber. Nwachukwu and Chukwu (2013) reported total bacterial count as 1.8×10^6cfu/g and 3.2×10^5cfu/g in

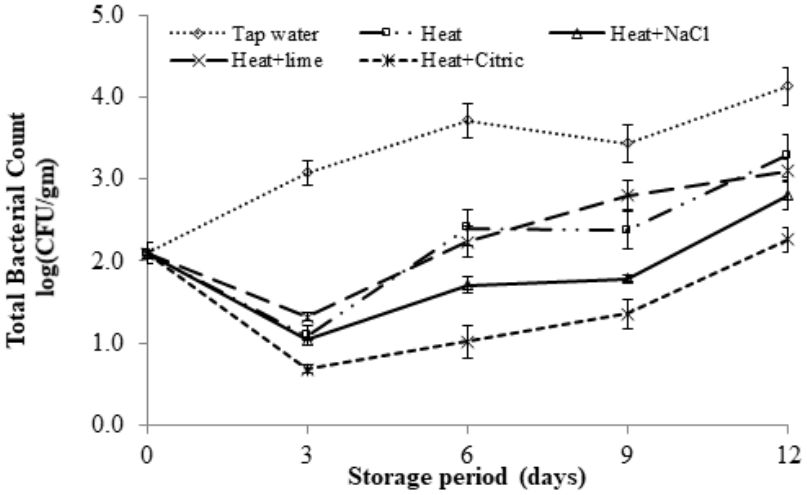


Figure 5. Total bacterial count of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator. Tap water= Wash with normal tap water (without heat treatment); Heat= Treated with hot (60°C) water; Heat+NaCl= Treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = Treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime= Treated with hot (60°C) *aqueous* solution of 10% lime juice; Vertical bars indicate standard deviation.

Table 1. Ascorbic acid content, Total Soluble Solids and pH in fresh cut carrot influenced by heat treatment with additives during storage at refrigerator.

	Total soluble solid (°Brix)			pH			Ascorbic acid (mg/100g)		
Treatment	0 day	4 day	12 day	0 day	4 day	12 day	0 day	4 day	12 day
Tap water	9.5±.06	9.4±.2	9.3±0	6.3±.01	6.2±.01	6.1±.01	15.3±.1b	11.3±.1c	9.3±.1c
Heat	9.2±.06	9.1±.2	9.1±.1	6.1±.01	6.0±.01	6.0±.01	14.8±.1b	12.3±.1b	10.8±.1b
Heat+NaCl	9.8±.06	9.8±.1	9.7±.1	6.4±.01	6.3±.01	6.2±.01	14.9±.1b	12.9±.2b	10.4±.1b
Heat+citric	9.9±.06	9.8±.1	9.7±.1	5.3±.01	5.3±.01	5.1±.01	16.3±.1a	15.3±.2a	13.8±.2a
Heat + lime	9.3±.06	9.1±.1	8.8±.2	6.1±.01	6.1±.01	6.0±.01	15.7±.1b	12.3±.1b	11.1±.2b

Tap water = washed with tap water, without heat treatment; Heat = treated with hot (60°C) water; Heat+NaCl = treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime = treated with hot (60°C) *aqueous* solution of 10% lime juice. Means with different letters within each column are significantly different ($p < 0.05$).

carrot and cucumber respectively. Alegria et al. (2009) also reported that no yeast and mould were found in heat-treated samples immediately after minimal processing or throughout storage (always less than the detection limit of 10^1cfu g^{-1}). Ayhan et al. (2008) also described that no yeast or mould growth was observed in minimally processed carrots packaged with different atmospheres during the 21 days of storage in refrigerators. This might be due to the pH of the product (6.3-4.3), which encourages bacterial growth instead of yeast and mould growth.

Chemical parameters

Total soluble solids (TSS) and pH found for fresh-cut carrot was 9.5° Brix and 6.3 respectively (Table 1). During storage, slight decreased in TSS and pH were found in all samples but there was no significant difference among the samples ($p<0.05$). Fresh cut carrot retained ascorbic acid around 15.3 (mg/100g) initially as shown in Table 1. It was reduced during storage in all samples but the reduction rate was different. The lowest value of ascorbic acid (9.3 mg/100g) was observed without heat-treated carrot whereas carrot treated with hot aqueous solution of 2% citric acid retained the highest (13.8 mg/100g) at 12 days of storage.

Total and reducing sugar content in fresh-cut carrot was 6.75% and 2.78% respectively. During storage, both sugar content was reduced slightly and there was no significant difference among the treatment. Kaur et al. (1976) reported that percentages of 1.67–3.35% reducing sugars, 1.02–1.18% non-reducing sugars and 2.71–4.53% total sugars were found in 6 cultivars of carrot. Lee et al. (2011) reported that during storage, the total sugar content, glucose and fructose all slightly decreased after 2 weeks at 2°C. The beta carotene

Table 2. Total sugar, reducing sugar and beta carotene content in fresh cut carrot influenced by heat treatment with additives during storage at refrigerator

	Total sugar			Reducing sugar			Beta carotene (µg/ g)		
Treatment	0 day	4 day	12 day	0 day	4 day	12 day	0 day	4 day	12 day
Tap water	6.7±.02	5.9±.04	4.8±.04	2.7±.09	2.3±.03	2.2±.02	44.7±.2b	42.8±.3b	41.9±.2b
Heat	6.2±.02	5.5±.02	4.8±.03	2.3±.09	2.4±.06	2.3±.02	48.4±.3a	47.6±.2a	46.6±.3a
Heat+NaCl	6.3±.02	5.7±.03	4.6±.02	2.4±.09	2.4±.03	2.4±.01	48.4±.2a	48.1±.4a	45.4±.2a
Heat+ citric	6.1±.02	5.7±.02	4.7±.04	2.3±.09	2.5±.02	2.4±.02	48.3±.3a	47.9±.4a	46.3±.1a
Heat + lime	6.0±.02	5.4±.03	4.4±.04	2.2±.09	2.4±.02	2.4±.03	48.4±.3a	47.7±.3a	45.8±.1a

Tap water = washed with tap water, without heat treatment; Heat = treated with hot (60°C) water; Heat+NaCl = treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime = treated with hot (60°C) *aqueous* solution of 10% lime juice. Means with different letters within each column are significantly different ($p < 0.05$).

Table 3. Sensory quality of fresh cut carrot during storage at refrigerator based on fresh like appearance, color and flavour.

	Colour			flavour			texture			Overall acceptability		
Treatment	4day	8day	12day	4day	8day	12 day	4day	8day	12 day	4day	8 day	12 day
Tap water	4.5±.2 c	3.2±.2 d	2.7±.2 c	4.3±.6 c	3.1±.7 d	2.3±.1 c	5.1±.1 c	4.1±.3 b	3.1±.3 d	4.5±.3 c	3.1±.3 d	2.3±.1 c
Heat	6.8±.3 b	4.2±.3 c	3.4±.3 c	6.8±.7 b	4.2±.2 c	3.2±.1 c	6.1±.1 b	4.9±.1 b	4.2±.1 c	5.3±.2 b	4.3±.2 c	3.8±.1 b
Heat+NaCl	8.1±.1 a	5.5±.1 b	4.4±.1 b	8.3±.1 a	5.1±.3 b	4.3±.1 b	8.2±.1 a	6.8±.2 a	5.2±.2 b	7.8±.1 a	5.8±.1 b	4.4±.1 b
Heat+CA	8.5±.1 a	6.7±.1 a	6.3±.1 a	8.8±.1 a	6.9±.1 a	5.8±.1 a	8.6±.1 a	7.5±.1 a	6.6±.1 a	8.4±.2 a	7.3±.2 a	6.3±.1 a
Heat+lime	6.9±.2 b	4.3±.2 c	3.3±.2 c	7.2±.6 b	4.4±.4 c	3.1±.1 c	6.3±.1 b	5.1±.5 b	4.4±.5 c	5.3±.3 b	4.3±.3 c	3.9±.1 b

Tap water = washed with tap water, without heat treatment; Heat = treated with hot (60°C) water; Heat+NaCl = treated with hot (60°C) *aqueous* solution of 2% NaCl; Heat+Citric = treated with hot (60°C) *aqueous* solution of 2% citric acid; Heat+Lime = treated with hot (60°C) *aqueous* solution of 10% lime juice. Means with different letters within each column are significantly different ($p < 0.05$).

content of fresh-cut carrot just after slicing and during their storage is shown in Table 2. Fresh carrot contained 44.7 (µg/g) beta carotene whereas after heat treatment it was increased to approximately 48 µg/g. Dutta et al. (2005) also reported that the beta carotene content has increased from 84 (fresh sample) to 100.8 µg/g (in 3 min. heat-treated sample). During storage beta carotene content was reduced in all treatments and the lowest value (41.9 µg/g) was observed in without heat-treated carrot at 12 days of storage. On the other hand, the highest (46.6 µg/g) beta carotene content was found in only heat treated fresh-cut carrots and this value was statistically similar with all other heat-treated carrots with additives at 12 days of storage.

Sensory quality

Results of the sensory quality for color, flavour, texture and overall acceptability are shown in Table 3. After processing (day 0), the scores for all attributes of heat-treated and without heat-treated samples were not significantly different. Concerning heat-treated samples during storage, color maintenance is observed ($p>0.05$) since without heat-treated carrot slices scored 4.5 while others got more than 7 (scores varied between 6.8 and 8.5) on the 4th day of storage.

Fresh cut carrot treated with a hot aqueous solution of 2% citric acid scored 6.3 while it was less than 4 in the rest of the samples recognized as unacceptable in case of overall acceptability at 12 days of storage. Sensory evaluation of the color attribute was in agreement with WI evolution during storage.

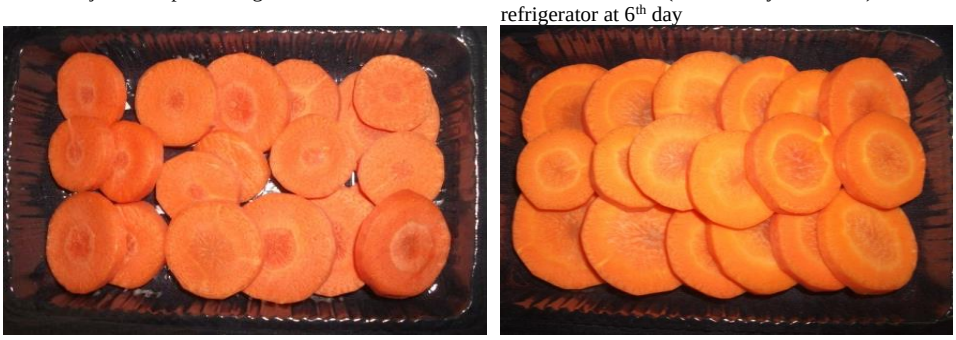
Fresh cut carrot treated with hot aqueous solution of 2% citric acid was bright orange-red color and fresh like appearance throughout the storage period as shown in Figure 6.

CONCLUSION

The results of physical, chemical, microbial and sensory parameters proved that the shelf life of fresh-cut carrots was increased during storage after treatment with a hot aqueous solution of 2% citric acid and hot aqueous solution of 2% sodium. Without heat-treated fresh-cut carrot were acceptable for up to 4 days, carrot slices treated with hot aqueous solution of 2% NaCl were acceptable up to 8 days and carrot slices treated with a hot aqueous solution of 2% citric acid were acceptable up to 12 days.

FC carrot just after processing

Control FC carrot (without any treatment) stored in refrigerator at 6th day



FC carrot treated with warm solution of 2% NaCl, stored in refrigerator at 10th day

FC carrot treated with warm solution of 2% citric acid stored in refrigerator at 12th day

Figure 6. Some pictorial views of fresh cut carrot influenced by heat treatment with additives during storage at refrigerator.

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