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FOOD COMPOSITION AND ANALYSIS

Study on combined effects of blanching and sonication on different quality parameters of carrot juice

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Abstract

This study was conducted to evaluate the combined effects of blanching and sonication on carrot juice quality. Carrots were blanched at 100 °C for 4 min in normal and acidified water. Juice was extracted and sonicated at 15 °C for 2 min keeping pulse duration 5 s on and 5 s off (70% amplitude level and 20 kHz frequency). No significant effect of blanching and sonication was observed on Brix, pH and titratable acidity except acidified blanching that decreased pH and increased acidity significantly. Peroxidase was inactivated after blanching that also significantly decreased total phenol, flavonoids, tannins, free radical scavenging activity, antioxidant capacity and ascorbic acid and increased cloud and color values. Sonication could improve all these parameters significantly. The present results suggest that combination of blanching and sonication may be employed in food industry to produce high-quality carrot juice with reduced enzyme activity and improved nutrition.

Keywords

Ascorbic acid, bioactive compounds, blanching, carrot juice, cloud value, sonication

History

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Introduction

At present, use of fruits and vegetables in the human diet is increasing day by day because of their high nutritional profile and health benefits. They are important and economical sources of balanced diet which provide the required micronutrients to the body and protect it from risk of many diseases. It is fact that the juices of fruits and vegetables play a considerable role in the human health by supplying vitamins, minerals, organic acids, salts and fibers (Branco, 2001). Among vegetables, carrot is the most important root crop grown throughout the world. Its fleshy edible root is consumed by human as well as animals. Carrots provide great health benefits to the human body as they are good source of carotenoids, bioactive compounds, vitamins and minerals (Qin et al., 2005). Due to its good flavor and nutrition, carrot is regarded as very important vegetable with properties like anticancer, anti-anemic, antioxidant, sedative and healing which are directly related to human health (Shivhare et al., 2009; Speizer et al., 1999).

Phenolic compounds are the important components of vegetables. In addition to the powerful antioxidant behavior of phenolics, their presence in carrots plays a role in sensory characteristics such as color (Zhang et al., 2005), flavor (Naczk & Shahidi, 2003) and bitterness (Kreutzmann et al., 2008). In this way, the phenolics could be the indicators to assess the quality of processed and stored vegetables. Enzymes like peroxidase (POD) and catalase commonly cause various deteriorative changes in carrots. Generally, POD is known to be one of the most heat-stable enzymes present in plants. It is considered as an index of blanching, so as a general rule in the food industry if POD is inactivated it means the other enzymes are also inactivated. Because of perishable food mostly, carrots are used as fresh vegetables, their shelf life is improved by using various techniques like canning, dehydration and freezing as well. Hot water or steam is used for blanching of carrots, prior to these techniques. Enzyme inactivation, reducing infection and removal of intracellular air are the beneficial aspects of blanching, but it also adversely affects the nutritional quality of food (Ramesh et al., 2002).

Benefits of blanching depend on the intensity of heat supplied. Traditionally, these heat treatments are used to inactivate the enzymes and microorganisms for the improvement of shelf life in vegetable juices (Adekunte et al., 2010). But these thermal techniques cause adverse changes in nutrients, color and sensory characteristics of product. To minimize the negative changes in flavor and nutrients, ultrasound technique has been used instead of thermal processing (Adekunte et al., 2010; Gomez-Lopez et al., 2010). Furthermore, consumers are now more conscious about health and diet and their demands for wholesome quality food, with natural freshness and taste, preserved without chemical preservatives, are increasing day by day. That is why food industry is now searching for such innovative techniques that could meet the needs of consumer by providing the product with improved quality characteristics. Use of ultrasound for processing in the food industry has been reviewed recently (Soria & Villamiel, 2010). It could improve the quality of fruit juices by increasing amount of nutrients in them (Bhat et al., 2011; Rawson et al., 2011). It is a more suitable food processing technique due to less processing time, energy inputs and

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being environmental friendly (Mason et al., 2005; Tiwari et al., 2008a).

As blanching is the necessary step for the processing of carrots to inactivate the deteriorative enzymes and color preservation, it also causes loss in the most desirable nutrients, whereas ultrasound technique offers improvements in these nutrients. Therefore, by combining blanching and ultrasound technique for processing of carrot juice we may get the benefits of both techniques in terms of inactivation of enzymes, color preservation and recovery or improvement of nutrients lost during blanching.

Previously, some reports are available on separate effects of blanching and sonication on the quality of carrots and carrots juice blended with other fruit juices (Gao & Rupasinghe, 2012; Sharma et al., 2009). But to our knowledge, there is no report on combined effects of blanching and sonicatoin on the quality of carrot juice. Therefore, this study was first conducted with the specific object of evaluating the combined effects of blanching and sonicatoin on the quality attributes such as pH, acidity, Brix, color, cloud value, tannins, total phenol, total flavonoids, antioxidant capacity, ascorbic acid and POD activity of carrot juice.

Materials and methods

Chemicals

DPPH (2, 2-diphenyl-1-picrylhydrazyl) and gallic acid were purchased from Sigma Chemical Co. (St. Louis, MO). Folin–Ciocalteu reagent was purchased from Fluka (Buchs, Swiltzerland). Catechin was purchased from Funakoshi Co., Ltd (Tokyo, Japan). HPLC grade methanol was purchased from Hanbon Science and Technology (Jiangsu, China). Sulfuric acid, sodium nitrite, sodium phosphate, sodium carbonate, sodium hydroxide, citric acid, ammonium molybdate, aluminum trichloride ($AlCl_3$), ascorbic acid, vanillin, hydrochloric acid, diabasic potassium phosphate (K_2HPO_4), monobasic potassium phosphate (KH_2PO_4), hydrogen peroxide (H_2O_2) and pyrogallol were obtained from Sinopharm Chemical Regent Co., Ltd (Shanghai, China). All other chemicals were of analytical grade.

Preparation of carrot juice

Fresh carrots were purchased from a local vegetable market of Nanjing, China. Good quality carrots were washed using tap water, peeled and then sliced manually to a thickness of 2 cm. The sliced carrots were divided into three parts. First part was selected as control without any pretreatment of blanching, second part was blanched in hot water and third part was blanched in acidified water (citric acid of 45 g/L) at 100 °C for 4 min and then cooled down to a room temperature by dipping in cold water. Juice was then extracted by using domestic juice extractor (MJ-M176P, Panasonic Manufacturing, Berhad, Malaysia). The juice was filtered through four layered cheese cloth and then subjected to sonication treatments.

Ultrasound treatment

Ultrasonic processor of 750 W (VC 750, Sonics and Materials Inc., Newtown, CT) with 0.5-inch probe was used for sonication. Juice samples were sonicated (250 mL in a 500-mL jacketed vessel) for 2 min with pulse duration of 5 s on and 5 s off at a frequency of 20 kHz and constant temperature of 15 °C with amplitude level of 70% in darkness to avoid any interference of light with samples. All the treatments were performed in triplicate. Fresh untreated juice was selected as control. All the juice samples were then stored in air tight sterilized 250 mL media bottles at 4 °C until further analysis.

Determination of Brix, pH and color

Brix of all the samples were determined by using hand refractometer (WYT-80, Quanzhou Wander Experimental Instrument Co., Ltd, China) at 20 ± 0.5 °C. After each analysis, prism of refractometer was washed with distilled water. All the measurements were done in triplicate.

A total of 10 mL of sample was taken in a beaker and stirred continuously with magnetic stirrer and the pH of sample was determined at 20 ± 0.5 °C by digital pH meter (Delta 320 pH meter, Metller Toledo Instruments Co., Ltd, Shanghai, China). Calibration of pH meter was done using buffer solutions of pH 7.0 and 4.0.

Color of the sample was determined by using Minolta Colorimeter (Chroma Meter CR-400, Konica Minolta Sensing, Inc., Osaka, Japan). White reference tile was used to calibrate the instrument. Color values were expressed as CIE L* (whiteness or brightness/darkness), a* (redness/greenness) and b* (yellowness/blueness) system. All measurements were taken in triplicate.

Determination of titratable acidity

AOAC method (AOAC International, 1999) was used to measure the titratable acidity. In total 10 mL juice sample was taken in 250 mL beaker and 90 mL distilled water was added in it. Solution was stirred continuously using magnetic stirrer and titrated to the end point (pH 8.2 ± 0.1) using standard solution of 0.1 N NaOH. The following equation was used to calculate the titratable acidity.

$$\text{Titratable acidity } (\%) = \frac{V \times 0.1\text{N NaOH} \times 0.067 \times 100}{m}.$$

where V is the titer volume of NaOH and m is the volume of carrot juice (mL).

Determination of cloud value

Cloud values of all the juice samples were measured using a method stated by Versteeg et al. (1980) with little modifications. A total of 5 mL carrot juice sample was centrifuged at 6000 rpm for 15 min by Anke TGL-16 G centrifuge (Shanghai Anting Scientific Instrument Factory, Shanghai, China). The absorbance of supernatant was measured at 660 nm using 722 S Visible Spectrophotometer (Shanghai Jinghua Science & Technology Instruments Co., Ltd, Shanghai, China) with distilled water as blank.

Determination of ascorbic acid

Ascorbic acid was determined using a method stated by Lee & Coates (1999) with some modifications. Agilent 1100 series HPLC (Agilent Technologies, Santa Clara, CA) consisted of a model G1379A degasser, a model G1311A pump, a model G1316A column oven and model G1315B diode array detector (DAD) with Tskgel ODS-100 Z column (4.6×15 mm, 5 µm, Tosoh, Japan). Methanol (30%) was used as mobile phase with a flow rate of 1.0 mL/min and wavelength of detector was set at 280 nm. Sample was filtered through a syringe filter of 0.45 µm diameter and 20 µL of sample was injected. Standard solution of ascorbic acid was used to make a suitable calibration curve and results were expressed as mg ascorbic acid/100 mL of carrot juice.

Determination of contents of total phenol, total flavonoids and tannins

Total phenol was measured spectrophotometrically by using Folin–Ciocalteu colorimetric method (Singleton et al., 1999) with slight modifications. Juice sample (0.5 mL) was taken in a vial and 1.0 mL of 10% Folin–Ciocalteu reagent was added in it.

Then, 2.0 mL of a 20% Na_2CO_3 solution was added in it after 6 min. The mixture was placed in water bath for 60 min at 30 °C and then absorbance was determined at 760 nm. Gallic acid was used as standard and the total phenol content was expressed as μg GAE/g of sample.

The total flavonoids content was measured by the procedure reported by Jia et al. (1999) with some modification. Briefly, 1.25 mL deionized water was added to 0.25 mL of juice sample. Then, 75 μL of a 5% $NaNO_2$ solution was added. Then, 150 μL of a 10% $AlCl_3$ solution was added after 6 min and 0.50 mL of 1.0 M NaOH was added after 5 min. The final volume was made to 2.50 mL by adding distilled water. Absorbance was measured by spectrophotometer at 510 nm. The results were expressed as μg of (+)-catechin equivalent per gram of sample.

Tannins content was determined by the method described by Broadhurst & Jones (1978). In briefly, centrifuge 10 mL of sample at 6000 rpm for 15 min using Anke TGL-16 G centrifuge to separate the haze sediments. The supernatant was analyzed using the Vanillin–HCl assay to measure the tannins. The absorbance was measured at 720 nm using a spectrophotometer. Catechin was used as standard to make a suitable calibration curve. The results were expressed as mg catechin/100 mL of sample.

Determination of antioxidant capacity of carrot juice

Assay of antioxidant capacity

Antioxidant capacity of carrot juice was determined using a method stated by Prieto et al. (1999). A known aliquot (0.4 mL, 250 μg/mL in methanol) of juice sample was taken in a vial, and then 4.0 mL of reagent solution containing 0.6 M sulfuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate was added in it. The mixture was then placed in a water bath of 95 °C for 90 min. A total of 4 mL reagent solution and 0.4 mL methanol was taken in a vial to run a blank. After cooling to a room temperature, the absorbance of mixture was measured against blank at 695 nm using a spectrophotometer. Ascorbic acid was used as a standard and antioxidant capacity was expressed as μg ascorbic acid/g of sample.

Assay of DPPH free radical scavenging activity

DPPH free radical scavenging activity was measured according to the method reported by Yi et al. (2008) with some modifications. Briefly, 2.0 mL of 0.2 mM ethanolic DPPH solution was added in 2.0 mL juice sample. This mixture was placed in dark at room temperature for 30 min. The absorbance was determined with spectrophotometer at 517 nm. The same procedure was revised for control by using ethanol instead of sample solution. Following equation was used to calculate the percent DPPH free radical scavenging activity:

$$\text{DPPH free radical scavenging activity } (\%) = (A_0 - A_1/A_0) \times 100$$

where A_0 is the absorbance of the control and A_1 is the absorbance of the juice sample.

POD residual activity

POD activity was measured by the procedure reported by Kwak et al. (1995) using pyrogallol as the substrate. The reaction mixture contained (total volume of 3.0 mL) 2.2 mL centrifuge juice sample (10 000 rpm for 10 min at 4 °C with Avanti J-E Centrifuge, Beckman Coulter, Inc., Brea, CA), 100 mM potassium-phosphate buffer (pH 6, 0.32 mL), 5% pyrogallol (0.32 mL, w/v) and 0.147 M H_2O_2 (0.16 mL). The reaction was started by the addition of H_2O_2, and the increase in absorbance at 420 was noted in 3 min. The percentage of POD residual activity was calculated by the following equation:

$$\text{POD residual activity} = 100 \times \frac{A_t}{A_0}$$

where A_t and A_0 are the enzyme activity of the treated and untreated samples, respectively.

Statistical analysis

Data obtained in the study (physico-chemical, bioactive compounds and enzyme activity) were represented as mean value ± SD. Completely randomized design (CRD) was conducted with one-way ANOVA at a significance level of $p < 0.05$, and significant differences between mean values were determined by LSD pair-wise comparison test. Statistical analyses were determined by using Statistix 9.0 software (Analytical Software, Tallahassee, FL).

Results and discussion

Effect of blanching and sonication on titratable acidity, pH, Brix, color and cloud value

Results regarding the effects of blanching and sonicatoin on the acidity, pH and Brix of carrot juice are mentioned in the Table 1. We observed no significant changes in acidity, pH and Brix in the sonicated, WB (water blanched) and WBS (water blanched and sonicated) treatments when compared with control (untreated). But significant decrease in pH that was 3.92 and 3.94 and increase in acidity that was 0.26 and 0.26 occurred in the AB (acidified blanched) and ABS (acidified blanched and sonicated) treatments respectively when compared with control, sonicated, WB and WBS. The changes in pH and acidity in AB and ABS treatments might be due to the blanching treatment of carrots in acidified water.

Results regarding the effects of blanching and sonication on color values of carrot juice are shown in Table 1. In our study, we observed significant increases in L*, a* and b* values in all the treatments when compared with control juice sample which showed low lightness (L_0), yellowness (a_0), redness (b_0) values. Both blanching and sonicatoin significantly improved all the color values. Particularly, acid blanching showed more impact on improvement in all the color values. The changes in juice color values can be ascribed to the cavitations produced during sonication (Tiwari et al., 2008b). The increases in Hunter redness and yellowness color values of carrot juice due to blanching of carrots have already been reported (Bao & Chang, 1994; Sim et al., 1993). Acidification could improve the extraction and/or retention of carotenoids. It has already been observed that on pH 4, acidification was more effective than on pH 5 (Sim et al., 1993). The increase in carotenoids during blanching may cause color improvement in carrot juice. Higher amount of β-carotene has already been reported in blanched carrots than un-blanched (Negi & Roy, 2001). This discussion may justify our results regarding color improvement in carrot juice.

Results regarding the effects of blanching and sonicatoin on the cloud value of carrot juice are mentioned in the Table 2. Our study showed that the cloud values of all the blanched and sonicated treatments significantly increased when compared with that of control. Additionally, acidic blanching of carrots showed more improvement of cloud value of juice as shown in the Table 2. The increase in cloud value of carrot juice due to blanching has previously been reported that heating of carrots may extract and stabilize more clouds in the juice (Beveridge, 2002; Genovese et al., 1997). Another reason is that blanching

Table 1. Combined effects of blanching and sonication on Brix, pH, acidity and color attributes in carrot juice ($n = 3$).

Treatments	Brix	pH	Titratable acidity (%)	Color attributes L*	a*	b*
Control	8.00 ± 0.10^{a}	6.04 ± 0.05^{a}	0.11 ± 0.01^{b}	45.55 ± 0.07^{f}	21.94 ± 0.04^{f}	26.61 ± 0.07^{f}
Sonicated	8.00 ± 0.10^{a}	6.08 ± 0.03^{a}	0.11 ± 0.01^{b}	45.92 ± 0.06^{e}	22.94 ± 0.05^{e}	28.79 ± 0.06^{e}
WB	8.00 ± 0.10^{a}	5.99 ± 0.01^{a}	0.11 ± 0.01^{b}	48.55 ± 0.08^{d}	25.60 ± 0.04^{d}	31.98 ± 0.08^{d}
WBS	8.00 ± 0.10^{a}	6.01 ± 0.04^{a}	0.11 ± 0.01^{b}	48.69 ± 0.05^{c}	27.10 ± 0.07^{c}	33.17 ± 0.05^{c}
AB	8.00 ± 0.10^{a}	3.92 ± 0.13^{b}	0.26 ± 0.02^{a}	50.14 ± 0.08^{b}	27.70 ± 0.05^{b}	33.57 ± 0.08^{b}
ABS	8.00 ± 0.10^{a}	3.94 ± 0.15^{b}	0.26 ± 0.02^{a}	50.39 ± 0.07^{a}	28.65 ± 0.03^{a}	35.21 ± 0.07^{a}

Values with different letters in the same column (a–f) are significantly different ($p < 0.05$) from each other. WB, water blanched; WBS, water blanched and sonicated; AB, acid blanched; ABS, acid blanched and sonicated.

Table 2. Combined effects of blanching and sonication on the cloud value, ascorbic acid and residual activity % of peroxidase in carrot juice ($n = 3$).

Treatments	Cloud value	Ascorbic acid (mg/100 ml)	Peroxidase (residual activity %)
Control	1.823 ± 0.006^{f}	6.36 ± 0.02^{b}	100 ± 0.00^{a}
Sonicated	1.844 ± 0.003^{d}	7.07 ± 0.04^{a}	99.68 ± 0.05^{a}
WB	1.835 ± 0.005^{e}	4.31 ± 0.02^{e}	2.49 ± 0.06^{c}
WBS	1.862 ± 0.003^{c}	5.37 ± 0.01^{d}	2.47 ± 0.02^{c}
AB	1.878 ± 0.002^{b}	4.27 ± 0.02^{f}	2.48 ± 0.06^{c}
ABS	1.907 ± 0.003^{a}	5.56 ± 0.03^{c}	2.47 ± 0.08^{c}

Values with different letters in the same column (a–f) are significantly different ($p < 0.05$) from each other. WB, water blanched; WBS, water blanched and sonicated; AB, acid blanched; ABS, acid blanched and sonicated.

inactivates the enzymes pectin methyl esterase and pectin esterase, which could enhance the molecular weight of suspended particles thus, causing sedimentation. Our results are in accordance with the observations of Yen & Song (1998), who reported that heat treatment and acidification could improve the stability of cloud in guava puree. Moreover, acidic blanching also plays a role in the slight improvement of clouds in the juice (Reiter et al., 2003; Sim et al., 1993). The improvement in cloud due to acidification can be attributed to the lower pH of carrot juice extraction which reduced the precipitation of pectin because of its high impact on pectin estrification (Sawayama et al., 1987). Similarly, sonication also increases the cloud value of carrot juice by breaking the macromolecules to micro molecules due to pressure gradient by cavitations, thus making the juice more consistent and homogenized. It has been previously reported that ultrasound caused breakdown of linear pectin molecules and thus lowering its molecular weight and making weaker network (Seshadri et al., 2003). Thus, combined effect of blanching and sonication in the improvement of cloud value of carrot juice is stronger than using alone technique.

Effect of blanching and sonication on ascorbic acid

The results regarding the effects of blanching and sonication of carrot juice on ascorbic acid are shown in Table 2. In this study, the significant decreases in ascorbic acid were observed in treatments WB and AB that was 4.31 and 4.27 mg/100 mL, respectively, when compared with control that was 6.36 mg/100 mL. The decrease in ascorbic acid of carrot juice due to pretreatment has already been reported by Sharma et al. (2009). The loss of ascorbic acid during blanching was due to its sensitivity to heat and solubility in water (Dewanto et al., 2002; Nagy & Smooth, 1977). In our study, we also observed significant increases in ascorbic acid in the sonicated, WBS and ABS treatments that were 7.07, 5.37 and 5.56 mg/100 mL, respectively, as compared to control, WB and AB treatments that were 6.36, 4.31 and 4.27 mg/100 mL, respectively. These results are in accordance with the observations of sonicated Kasturi lime juice, where an increase in ascorbic acid has already been observed (Bhat et al., 2011). This improvement in ascorbic acid can be ascribed to the removal of dissolved oxygen, the causative agent for degradation of ascorbic acid, due to cavitations produced during sonication (Cheng et al., 2007). Sonication could recover loss of ascorbic acid occurred during blanching which is a great merit of this non thermal technique.

Effect of blanching and sonication on total phenol, total flavonoids and tannins

Results regarding effects of blanching and sonication on total phenol and total flavonoids are mentioned in the Table 3. In our study, a significant decrease in total phenol was observed in the juice extracted from blanched carrots as compared to control juice samples extracted from un-blanched carrots. This decrease in total phenol was 300.17 and 301.10 μg GAE/g in WB and AB treatments, respectively, as compared to control that was 311.69 μg GAE/g. We also observed the same trend of significant decrease in total flavonoids in the juice extracted from blanched carrots when compared with control (un-blanched juice sample) as mentioned in the Table 3. The decrease in polyphenolic compounds might be attributed to the thermal breakdown, leaching loss and diffusion of these compounds during blanching (Lindley, 1998). Similar results were previously observed in different vegetables by Ismail et al. (2004) and Turkmen et al. (2005). In this study, we observed significant increases in total phenol in all the sonicated, WBS and ABS treatments that were 325.59, 320.99 and 321.38 μg GAE/g, respectively, as compared to non-sonicated control, WB and AB treatments that were 311.69, 300.17 and 301.10 μg GAE/g, respectively. This increase was might be due to the addition of sonochemically produced hydroxyl radicals to the aromatic ring of phenolic compounds. Our results regarding increase in total phenol are in accordance with the observations of ultrasonically treated Kasturi lime juice (Bhat et al., 2011). The breakdown of cell wall due to sonicatoin may enhance the liberation of bound phenolics and increase their availability in the carrot juice.

Similarly, significant increases in total flavonoids were observed in all the sonicated, WBS and ABS treatments that were 246.17, 226.18 and 236.09 μg catechin/g, respectively, as compared to non-sonicated control, WB and AB treatments that were 196.05, 176.10 and 186.08 μg catechin/g, respectively. Hence, increases in total phenol and flavonoids on sonication of carrot juice will be beneficial for commercial as well as consumer's health point of view.

Results regarding the effects of blanching and sonication on tannin compounds of carrot juice are shown in Table 3. In our study, we found the significant decreases in tannins in the WB and

Table 3. Combined effects of blanching and sonication on total phenolics, flavonoids, tannins, DPPH and antioxidant capacity in carrot juice ($n = 3$).

Treatments	Total phenol (gallic acid equivalent μg/g)	Total flavonoids (Catechin equivalent μg/g)	Tannins (Catechin equivalent mg/100mL)	Percentage inhibition (DPPH radical)	Antioxidant capacity (Ascorbic acid equivalent μg/g)
Control	311.69 ± 0.05^{d}	196.05 ± 0.05^{d}	11.65 ± 0.05^{d}	32.40 ± 0.48^{c}	230.62 ± 0.02^{d}
Sonicated	325.59 ± 0.03^{a}	246.17 ± 0.08^{a}	16.45 ± 0.04^{a}	39.67 ± 0.93^{a}	286.33 ± 0.04^{a}
WB	300.17 ± 0.08^{f}	176.10 ± 0.10^{f}	10.86 ± 0.03^{f}	28.80 ± 0.26^{d}	229.22 ± 0.03^{e}
WBS	320.99 ± 0.06^{c}	226.18 ± 0.16^{c}	14.08 ± 0.05^{c}	34.01 ± 0.17^{b}	284.93 ± 0.05^{b}
AB	301.10 ± 0.08^{e}	186.08 ± 0.08^{e}	10.96 ± 0.03^{e}	27.00 ± 0.17^{e}	228.32 ± 0.04^{f}
ABS	321.38 ± 0.03^{b}	236.09 ± 0.09^{b}	14.54 ± 0.05^{b}	33.28 ± 0.20^{b}	284.62 ± 0.06^{c}

Values with different letters in the same column (a–f) are significantly different ($p < 0.05$) from each other. WB, water blanched; WBS, water blanched and sonicated; AB, acid blanched; ABS, acid blanched and sonicated.

AB treatments that were 10.86 and 10.96 mg catechin/100 mL of juice, respectively, when compared with control that was 11.65 mg catechin/100 mL. The degradation of tannin during blanching of vegetables could be ascribed to its breakdown (Akindahunsi & Oboh, 1999). During this study, we also observed the significant increases in tannin in the sonicated, WBS and ABS treatments that were 16.45, 14.08 and 14.54 mg catechin/100 mL, respectively, when compared with control, WB and AB treatments that were 11.65, 10.86 and 10.96 mg catechin/100 mL, respectively. In fact, it is due to the non-thermal behavior of sonication due to which there is no increase in macro-temperature of liquid food, which ultimately preserves most of the functional food quality parameters (Wong et al., 2010).

Effect of blanching and sonication on free radical scavenging activity and antioxidant capacity

Results regarding the effects of blanching and sonication on the antioxidant capacity and radical scavenging activity of carrot juice are shown in Table 3. In our study, we observed the significant decreases in radical scavenging activity and antioxidant capacity in all the juice samples extracted from blanched carrots as compared to control un-blanched. The decrease in radical scavenging activity was 28.80 and 27% in WB and AB, respectively, as compared to control that was 32.40%. Similarly, the decrease in antioxidant capacity was 229.22 and 228.32 μg ascorbic acid equivalent/g in WB and AB, respectively, as compared to control that was 230.62 μg ascorbic acid equivalent/g. These results are related with the observations of Puupponen-Pimiä et al. (2003), who reported 20–30% reductions in the radical scavenging activity during blanching treatment of vegetables. The decrease in radical scavenging activity and antioxidant capacity of carrot juice might be due to the decrease in phenolic compounds/antioxidants during blanching treatment of carrots because in most of the vegetables scavenging activity is directly correlated with phenolic compounds that are also connected with antioxidant capacity (Kidmose & Martens, 1999).

In this study, we also found the significant increase in radical scavenging activity and antioxidant capacity of all the sonicated samples of carrot juice when compared with non sonicated treatments. The increases in radical scavenging activity were 39.67, 34.01 and 33.28 in sonicated, WBS and ABS treatments, respectively, when compared with 32.40, 28.80 and 27.00 in control, WB and AB treatments, respectively. Similarly, the increases in antioxidant capacity were 286.33, 284.93 and 284.62 μg ascorbic acid equivalents/g in sonicated, WBS and ABS treatments, respectively, when compared with 230.62, 229.22 and 228.32 μg ascorbic acid equivalent/g in control, WB and AB treatments, respectively. These results are on par with the observations done in sonicated Kasturi lime juice (Bhat et al., 2011). The increase in radical scavenging activity and antioxidant capacity of sonicated carrot juice can be directly ascribed with cavitations produced during sonication which may increase the extraction of phenolic compounds/antioxidants. It is fact that antioxidant capacity of any product increases whenever there is increase in total phenolic compounds in that product due to any processing technique. Further, the increase in ascorbic acid may also increase the antioxidant capacity of juice.

Effect of blanching and sonication on POD residual activity

Results regarding the effect of blanching and sonication on the inactivation of POD are shown in Table 2. In our present study, we did not observe any significant effect of sonication treatment on inactivation of POD but significant effect of blanching treatment was observed on the inactivation of POD. Fresh untreated carrot juice showed 100% POD activity which was decreased significantly in all the blanched juice samples as mentioned in the Table 2. Similar observations regarding the inactivation of POD activity, due to blanching using high temperature and short time technique, were previously reported by Kidmose & Martens (1999) and Shivhare et al. (2009). Blanching severely reduced the POD activity but at the same time it also caused loss of nutrients in carrot juice which was recovered by sonication. So by using combination of blanching and sonication at same time, we can get the benefit of both techniques in terms of enzyme inactivation as well as retention and improvement of nutrients.

Conclusion

In conclusions, sonication technique has been supposed to improve the blanching technique but it could not inactivate the enzyme at low temperature. In our study, blanching could ideally inactivate POD enzyme but it also caused considerable loss to the important nutrients which are necessary for human health. In terms of enzyme inactivation, sonication is intended not to replace the blanching treatment but to produce high value addition in carrot juice. Based on the present study, we recommend that combination of blanching and sonication is highly feasible for practical use in the food industry to get the benefits of both techniques in terms of enzyme inactivation and recovery or improvement of nutrients lost during blanching.

Declaration of interest

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