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Sonication enhances quality and antioxidant activity of blueberry juice

Yu ZOU^{1*}, Xiyan HOU¹

Abstract

Effect of sonication on the blueberry juice was studied by evaluating the pH, viscosity, electric conductivity, color, total sugars, soluble solids, polyphenol, anthocyanidin, and radical scavenging activities. There were not any remarkable ($p > 0.05$) change in pH and electric conductivity. However, viscosity and color of blueberry juice markedly ($p < 0.05$) enhanced with the extension of sonication time. Meanwhile, total sugars, soluble solids, polyphenol, and anthocyanidin were obviously enhanced ($p < 0.05$). Moreover, prominent increase ($p < 0.05$) was observed on DPPH, superoxide, and hydroxyl radicals scavenging activities of sonicated blueberry juice. The current results exhibited sonication effectively improved blueberry juice quality and enhanced its antioxidant activity.

Keywords: sonication; quality; radical scavenging activity; blueberry juice.

Practical Application: Sonication can be used potentially for juice processing and enhance quality and antioxidant activity of juice.

1 Introduction

Blueberry, a small fleshy berry, is one of the most popular and nutritious fruits. Blueberry and blueberry juice not only contain main dietary nutrients including minerals, sugars, and vitamins, but also are regarded as one of the most abundant and accessible sources of the bioactive components that are beneficial to the human health (Hwang et al., 2014; Seeram, 2008). There are some researches display that dietary intake of blueberry and its derived products can protect our body from various diseases including cancer, ageing, urinary disease, heart disease, memory loss, and vision problems (Pertuzatti et al., 2014; Shi et al., 2008).

In recent years, for purpose of meeting consumer demand of more safe, healthy, and nutritious foodstuff, many studies of food processing field have moved from the conventional thermal processing technology to the innovative non-thermal treatment technologies (Zou & Jiang, 2016). Thermal processing of food product can lead to some adverse organoleptic and nutritional losses (Gómez et al., 2011). However, innovative emerging non-thermal treatment approaches can be used to enhance food quality and ensure its security without any damage or adverse impact to food nutrients (Caminiti et al., 2011).

Sonication is one of non-thermal treatment approaches, which may observably enhance food quality and avoid nutrient damage (Cheok et al., 2013). In the last few years, impact of sonication on raw juices from fruits and vegetables such as kasturi lime, cantaloupe melon, apple, orange, and carrot (Abid et al., 2013; Bhat et al., 2011; Fonteles et al., 2012; Jabbar et al., 2014; Tiwari et al., 2008) has been investigated and proved to an appropriate processing method of the juice. Sonication can effectively retain the most beneficial nutrients

and decrease microbial load in the juice (Zou & Jiang, 2016). Moreover, sonication can shorten processing time and reduce energy consumption (Abid et al., 2014). However, until now there is still little report available in literatures about impact of sonication on the processing of blueberry juice.

This research explored impact of sonication on physicochemical parameters of blueberry juices by evaluating the pH, viscosity, electric conductivity, color, total sugars, soluble solids, polyphenol, and anthocyanidin. Moreover, the scavenging activities of sonicated blueberry juice on DPPH, superoxide, and hydroxyl radicals were investigated.

2 Materials and methods

2.1 Materials

Blueberry (*Vaccinium uliginosum* L.) was grown in Zhuanghe City (Liaoning, China) and harvested in August 2015. Fresh blueberry fruit was preserved at -20°C . DPPH and gallic acid were obtained from Sigma Chemicals Co., USA.

2.2 Preparation and sonication treatment of blueberry juice

Cleaned blueberry fruits were cracked using a BL25C46 electrical juice extractor (Midea, China). Then, solid particles were removed from crude juice by filtration. The conical flask containing the prepared juice sample was put into a KQ250-DB sonication cleaning bath (Kunshan, China) working at a sonication intensity of 0.5 W/cm^2 and a frequency of 40 kHz. Sonication treatment was performed in darkness for 20, 40, or 60 min. Similarly, samples without sonication were served as control.

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2.3 Measurement of pH

Measurement of pH was carried out with a FE20-FiveEasy pH meter (Mettler Toledo, Switzerland).

2.4 Measurement of viscosity

Measurement of viscosity was carried out with a DNJ-8S rotary viscometer (Jingmi, China) with S-4 spindle at 60 rpm.

2.5 Measurement of electric conductivity

Measurement of electric conductivity was carried out with a FE30-FiveEasy digital conductivity meter (Mettler Toledo, Switzerland).

2.6 Measurement of color

Measurement of color was carried out with a CR-400 colorimeter (Minolta, Japan). The levels of a^* value represented visually from redness to greenness. The levels of b^* value represented visually from yellowness to blueness. The levels of L^* value represented visually from whiteness or brightness to darkness.

2.7 Measurement of total sugars

The total sugars of juice sample were determined using phenol-sulfuric acid method (Zou & Jiang, 2016). The screw cap tube containing 0.6 mL juice sample and 0.3 mL phenol solution was capped and blended. The sulfuric acid (1.5 mL) was directly added to the liquid surface in tube, followed by incubation at 20 °C for 0.5 h. Then, optical density of reaction solution at 490 nm was determined in the UV-2600 spectrophotometer (Unico, USA) and the distilled water was used as blank.

2.8 Measurement of soluble solids

Measurement of soluble solids was carried out with a Master-20M hand held refractometer (Atago, Japan) and the results were expressed as °Brix.

2.9 Measurement of polyphenol

Measurement of polyphenol was carried out according to Folin-Ciocalteu colorimetric method of Singleton et al. (1999). Briefly, 2 mL juice sample was adequately blended with 10% sodium carbonate solution (5 mL) and 10% Folin-Ciocalteu reagent (10 mL). Then, mixture was kept at 20 °C for 2 h in darkness. Optical density of the reaction solution at 765 nm was determined and the result was presented as mg/L of gallic acid equivalents (GAE).

2.10 Measurement of anthocyanidin

Measurement of anthocyanidin was carried out using Lambert-Beer law (Fan et al., 2008). Briefly, 0.5 mL juice sample was adequately blended with 4.5 mL acid-ethanol solution (1.5 M HCl) and then optical density of mixture at 530 nm was accurately detected. Equation 1 was employed to calculate anthocyanins content.

$$Y(\text{mg/L}) = X \times K_1 / K_2 \quad (1)$$

where Y was the anthocyanins content, X was optical density of mixture, K_1 was dilution factor of sample solution, and K_2 was the molar absorptive factor (98.2) for acid-ethanol solvent.

2.11 Measurement of DPPH radicals scavenging activities

Measurement of DPPH radicals scavenging activities was carried out according to method of Tu et al. (2009). Briefly, 4 mL sample solution was adequately blended with 4 mL DPPH ethanol solution (0.2 mM), and then the mixture was kept away from light for 1 h. Optical density of mixture at 517 nm was detected against blank (ethanol solution). Equation 2 was employed to calculate DPPH radicals scavenging activities.

$$Y(\%) = [1 - (X_1 - X_2) / X_3] \times 100 \quad (2)$$

where Y were DPPH radicals scavenging activity, X_1 was optical density of reaction mixture, X_2 was optical density of sample solution, and X_3 was optical density of DPPH solution.

2.12 Measurement of superoxide radicals scavenging activities

Measurement of superoxide radicals scavenging activities was carried out according to method of Martinez et al. (2001). In short, sample solution (1 mL) was adequately blended with mixture solution (3 mL) containing methionine (13 mM), EDTA (100 μM), phosphate buffer (50 mM, pH 7.8), nitroblue tetrazolium (75 μM), and riboflavin (2 μM). After 15 min light treatment, optical density of reaction mixture at 560 nm was detected. Similarly, reaction solution kept away from light was used as blank. The distilled water was used to replace the sample as control. Equation 3 was employed to calculate superoxide radicals scavenging activities.

$$Y(\%) = (1 - X_1 / X_2) \times 100 \quad (3)$$

where Y was superoxide radicals scavenging activity, X_1 was optical density of sample solution, and X_2 was optical density of control.

2.13 Measurement of hydroxyl radicals scavenging activities

Measurement of superoxide radicals scavenging activities was carried out according to method of Zou et al. (2015). Sample solution (1 mL) was adequately blended with mixture solution (3 mL) containing ferric trichloride (100 μM), phosphate buffer (20 mM, pH 7.4), H_2O_2 (1 mM), deoxyribose (60 mM), and EDTA (100 μM). Mixture was kept at 37 °C for 40 min, and then blended with 20% HCl (1 mL) and 1% thiobarbituric acid (1 mL). The reaction was terminated by incubation in the boiling water for 20 min. Optical density of reaction solution at 532 nm was detected and distilled water was used to replace the sample as control. Equation 4 was employed to calculate hydroxyl radicals scavenging activities.

$$Y(\%) = (1 - X_1 / X_2) \times 100 \quad (4)$$

where Y was hydroxyl radicals scavenging activity, X_1 was optical density of sample solution, and X_2 was optical density of control.

2.14 Statistical analysis

The data obtained from the study were indicated as means \pm standard deviation. The significance difference ($p < 0.05$) among means was measured with Fisher's F -test.

3 Results and discussion

3.1 Impact of sonication on pH, viscosity, electric conductivity, and color

It was observed from Table 1 that during sonication there was no prominent ($p > 0.05$) variation in pH of blueberry juice. However, there was an obvious ($p < 0.05$) enhancement in viscosity of sonicated blueberry juice compared to control. It is possibly caused by sonication which accelerated macromolecules, especially sugar compounds, to permeate cell membranes and go into solution. In the colloidal solution, the sugar concentration was connected with the viscosity (Suárez-Jacobo et al., 2011). Therefore, the release of sugar compounds caused by sonication resulted in the increase in viscosity of blueberry juice.

As shown in Table 1, the negligible enhancement was found in electric conductivity of blueberry juices treated with sonication. Generally, juices could conduct electricity due to the existence of water, minerals, and vitamins as conductors (Zou & Jiang, 2016). Sonication facilitated release of mineral substance and vitamins came from colloidal particles or cells in blueberry fruit and enhanced their contents in the colloidal solution. Thus, there was a negligible enhancement in electric conductivity of blueberry juices treated with sonication.

Impact of sonication on color of blueberry juice is presented in Table 2. It was observed sonication observably ($p < 0.05$) influence color attributes (a^* , b^* and L^*). With the extension of sonication time, color values gradually enhanced. Zou & Jiang (2016) investigated influence of sonication on color of carrot juice and observed the variation of color values during sonication.

Table 1. Influence of sonication on pH, viscosity, and electric conductivity.

Sonication time (min)	pH	Viscosity (mPa·s)	Electric conductivity (ms/cm)
0	3.12 \pm 0.02 ^a	2.28 \pm 0.04 ^c	10.65 \pm 0.06 ^a
20	3.13 \pm 0.03 ^a	2.41 \pm 0.05 ^b	10.73 \pm 0.05 ^a
40	3.11 \pm 0.03 ^a	2.53 \pm 0.08 ^a	10.71 \pm 0.07 ^a
60	3.09 \pm 0.01 ^a	2.64 \pm 0.08 ^a	10.74 \pm 0.04 ^a

Means in same column with different lower-case letter are markedly different at $p < 0.05$.

Table 2. Influence of sonication on color attributes.

Sonication time (min)	Color attributes		
	a^*	b^*	L^*
0	0.91 \pm 0.05 ^b	1.87 \pm 0.01 ^c	22.96 \pm 0.04 ^b
20	0.98 \pm 0.02 ^b	1.98 \pm 0.02 ^b	23.06 \pm 0.03 ^a
40	1.08 \pm 0.03 ^a	2.09 \pm 0.02 ^a	23.08 \pm 0.02 ^a
60	1.12 \pm 0.04 ^a	2.13 \pm 0.04 ^a	23.09 \pm 0.04 ^a

Means in same column with different lower-case letter are markedly different at $p < 0.05$.

It was well-known that pigment could be affected by cavitations produced from sonication (Zou et al., 2010). At present study, the variation of color values in sonicated blueberry juice was connected with pigment content. On the one hand, sonication could accelerate release of pigment from the blueberry tissues. On the other hand, sonication might damage pigment structure and affect its light absorption.

3.2 Impact of sonication on total sugars, soluble solids, polyphenol, and anthocyanidin

The content of carbohydrates was main quality parameter of blueberry juice which markedly influenced the organoleptic properties of juice. As shown in Table 3, experimental result exhibited sonication led to remarkable ($p < 0.05$) changes in total sugars and soluble solids. Total sugars enhanced from 34.1 to 35.0 g/L and soluble solids enhanced from 5.0 to 5.3 °Brix, respectively. The enhancement of total sugars and soluble solids was possibly due to the enhancement in extraction efficacy. Sonication destroyed fruit tissues and cell walls, resulting in more water might enter into fruit cells and more soluble solids might across cell membranes (Zou et al., 2010).

A large quantity of phenolic compounds and anthocyanidin exist in fresh fruit and juice. These compounds are surprisingly beneficial to the sensory properties and antioxidant capacity of juice products (Khanizadeh et al., 2008). Moreover, the color of anthocyanins may enhance the aesthetic perception of juice and make it more attractive and desirable for consumers. As shown in Table 3, results showed a remarkable ($p < 0.05$) enhancement in polyphenol and anthocyanidin of blueberry juice treated with sonication for 40 min as compared with juices sonicated for 20 min and the control. Abid et al. (2013) observed the identical result that sonication could enhance total phenols of apple juice. These experimental results revealed that sonication enhanced bioactive compounds content in the juice.

3.3 Impact of sonication on radical scavenging activity

Radicals scavenging activities in food were very important to stay the health of consumers because free radicals could accelerate lipids oxidation and induce serious tissue damage (Peksel et al., 2010). Determination of DPPH radical was simple and effective method to assess antioxidant ability of the food. As shown in Table 4, DPPH radicals scavenging activities respectively reached 53%, 63%, 70%, and 73% in samples sonicated for 0, 20, 40, and 60 min. The experimental result showed that the scavenging activities of blueberry juice on DPPH

Table 3. Influence of sonication on total sugars, soluble solids, polyphenol, and anthocyanidin.

Sonication time (min)	Total sugars (g/L)	Soluble solids (°Brix)	Polyphenol (GAT, mg/L)	Anthocyanidin (mg/L)
0	34.1 \pm 0.1 ^c	5.0 \pm 0.1 ^d	528 \pm 9 ^c	228 \pm 8 ^c
20	34.6 \pm 0.1 ^b	5.1 \pm 0.1 ^c	568 \pm 7 ^b	247 \pm 8 ^b
40	34.7 \pm 0.1 ^b	5.2 \pm 0.1 ^b	589 \pm 7 ^a	266 \pm 6 ^a
60	35.0 \pm 0.1 ^a	5.3 \pm 0.1 ^a	585 \pm 8 ^a	266 \pm 5 ^a

Means in same column with different lower-case letter are markedly different at $p < 0.05$.

Table 4. Influence of sonication on radical scavenging activity.

Sonication time (min)	Scavenging activity (%)		
	DPPH radical	superoxide radical	hydroxyl radical
0	53 ± 3 ^c	41 ± 2 ^d	45 ± 2 ^c
20	63 ± 2 ^b	48 ± 3 ^c	55 ± 3 ^b
40	70 ± 3 ^a	56 ± 2 ^b	63 ± 3 ^a
60	73 ± 2 ^a	62 ± 2 ^a	65 ± 2 ^a

Means in same column with different lower-case letter are markedly different at $p < 0.05$.

radicals observably ($p < 0.05$) increased with the extension of sonication time.

The superoxide could combine with other radicals, such as hydroxyl and nitric oxide, to form stronger reactive species and possess greater oxidative ability (Peksel et al., 2010). Table 4 exhibited that scavenging activities of superoxide radicals increased from 41% up to 48%, 56%, and 62% in blueberry juice sonicated for 0, 20, 40, and 60 min, respectively. The experimental results indicated that sonication markedly ($p < 0.05$) enhanced superoxide radicals scavenging activities of blueberry juice.

Hydroxyl radical was one of the strongest reactive radicals, which induced serious cell injury and caused senescence, tumour and other severe diseases (Zou et al., 2015). It was observed that there was a prominent ($p < 0.05$) increase in hydroxyl radicals scavenging activities of blueberry juice sonicated for 0, 20, 40, and 60 min ranged from 45% to 55%, 63%, and 65% (Table 4). A similar result was obtained by Zhang et al. (2015) who found, with the extension of sonication time, the scavenging abilities of Maillard reaction products on oxygen radical also increased.

The increase in radicals scavenging activity was possibly ascribed to the enhancement in polyphenolic compounds and anthocyanins in blueberry juice during sonication (Abid et al., 2013). The longer sonication time was, the more antioxidants could enter solution and the more free radicals could be scavenged. Therefore, sonication plays a main role in improving the antioxidant activity of blueberry juice. It is one of the most important advantages of sonication.

4 Conclusions

Influence of sonication on the quality and radicals scavenging activities of blueberry juice was studied. There was not obvious ($p > 0.05$) variation in pH and electric conductivity. With extension of sonication time, viscosity and color observably ($p < 0.05$) enhanced. Total sugars, soluble solids, polyphenol, and anthocyanidin were markedly ($p < 0.05$) improved during sonication. Scavenging activities of sonicated blueberry juice on DPPH, superoxide and hydroxyl radicals significantly ($p < 0.05$) increased. The present results indicated that sonication could be successfully applied to blueberry juice processing and enhanced its quality and antioxidant activity.

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