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ORIGINAL ARTICLE

Comparison of high temperature-short time and sonication on selected parameters of strawberry juice during room temperature storage

Gulcin Yildiz[1] · **Rana Muhammad Aadil**[2]

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Abstract The purpose of current research was to explore the effect of high temperature-short time (HTST) and different ultrasound times intervals on the strawberry juice for a period of 14 days. Strawberry fruits were treated at 72 °C for 15 s by HTST and also sonicated at 20 kHz and 100% amplitude for 5, 10, and 15 min. The main objective is to evaluate the effect of treatments and storage time on color, total antioxidants, total phenolics, ascorbic acid and microbial content of strawberry juice. Results showed that the increase in the sonication treatment time (from 5 to 15 min) showed a higher total phenolics, antioxidant capacity and ascorbic acid content. In addition, 15 min sonicated-strawberry juices showed a higher lightness values as compared to HTST treated strawberry juice. Sonication treatment showed a potential as a method to preserve and improve the phytochemical quality of strawberry juice during room temperature storage.

Keywords Ultrasound · Strawberry juice · High temperature-short time · Ascorbic acid · Total phenolic content

Introduction

In the processing of fruit and vegetable juices, a thermal pasteurization technology, especially high temperature-short time (HTST) treatment is mostly used for the safety of foods. Even though HTST inactivates the pathogens in an effective way, it mostly causes some undesirable quality losses including nutrient, color, and sensory property changes in the juice samples due to high temperature (Nadeem et al. 2018). Igual et al. (2010) reported the reduction of citric and ascorbic acids in HTST treated grapefruit juice. Similarly, HTST treatment was also reported to decrease the amount of ascorbic acid in lemon/pomegranate juice blend (Mena et al. 2013). To overcome or minimize the food safety and quality problem, non-thermal technologies such as ultrasound (US), high pressure homogenization (HPH), and pulsed electric field (PEF) have been suggested as promising methods than thermal pasteurization process in fruit juice processing (Chemat and Khan 2011; Aadil et al. 2015; Khandpur and Gogate 2015; 2016). It was believed that these novel techniques caused less changes in nutritional value of juices (Jiménez-Sánchez et al. 2017). In recent years, US treatment has been recognized as promising technology for the inactivation of microorganisms and enzymes in the processing of fruit juices in a short time as compared to thermal process (Yildiz et al. 2017). Several physical and chemical changes caused by acoustic cavitation occurred during US treatment. This cavitation includes the formation, growth, and implosive collapse of small bubbles in liquid (Knorr et al. 2004). US technology has been used in the processing of various fruits and vegetables juices such as blueberry juice (Mohideen et al. 2015), orange juice (Guerrouj et al. 2016), strawberry juice (Bhat and Goh 2017), apple juice (Tremarin et al. 2017), carrot juice (Martínez-Flores et al. 2015) and pear juice (Saeeduddin et al. 2016). The aim of present research work was to explore the effects of different sonication times (5, 10 and 15 min) and HTST treatments and their comparison on color, antioxidant capacity, total phenolic and ascorbic acid

✉ Gulcin Yildiz
gulcn86@gmail.com

[1] Faculty of Engineering, Food Engineering Department, Igdir University, Iğdır, Turkey

[2] National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

contents of strawberry juices stored at room temperature for 14 days. Even though the main focus was to analyze the effect of the different sonication times and HTST treatments on the nutrient quality, preliminary studies for the microbial growth were performed at different sonication time to examine whether this emerging process can be applied as alternative to HTST. It is the study to determine the effect of HTST and different sonication treatments to investigate quality parameters and bioactive compounds on the storage stability of strawberry juice.

Materials and methods

Processing of raw material

Fresh strawberry fruits (Sweet Charlie strawberries) were purchased from a supermarket in Champaign, IL, USA. The fruits were selected on the basis of uniform size and color and sorted by eliminating injured or immature. Washing of strawberry fruits was done with tap water to remove dust and dirt. Strawberry Juice was extracted by using a juice extractor (Bullet Express Multifunction Food Processor, CA, USA). The juice was filtered by using filter paper (Tri Clover Compatible Filter, CA, U.S.A) to get rid of the pulp and foreign matter.

Strawberry juice processing treatments

Strawberry juice was subjected to pasteurization by using a HTST/UHT system (Armfield company, FT74XTS, Hampshire, England) and the juice sample were cooled at room temperature. The pasteurization conditions were chosen with respect to the industrial processing of juices at 72 °C for 15 s to achieve the 5-log reduction of Escherichia coli O157:H7. The US treatment was done using a VC-750 US unit (Sonics & Materials, Inc., Newtown, CT, USA) at 20 kHz for 5, 10 and 15 min. A total of 200 mL of freshly squeezed strawberry juices were put into a beaker, and the acoustic energy was transferred to the sample by a probe (12.5 mm diameter). The beaker was put in an ice bath at the time of sonication to control the temperature of the sample. All US treatments were carried out in dark to avoid any light interference. For control samples, no treatment was applied.

Sampling procedure

After HTST and US treatments, the juice samples were stored at room temperature for 2-weeks, and evaluation of each sample was conducted at 0, 2, 5, 7, and 14 days of storage.

Preparation of inoculum

A frozen stock culture of non-pathogenic *E. coli* O157:H7 was used. The bacterial strain was previously prepared by repeated sub-culturing on plate containing 50 mg/L of nalidixic acid (Sigma Aldrich, St. Louis, MO). The cell culture was inoculated to tryptic soy agar (TSA) plates. A loop of cell culture was delivered to 250 mL of tryptic soy broth (TSB) and incubated at 37 °C for 24 h in order to achieve a cell density of 10^8 CFU (Colony-forming unit) per mL (CFU/mL). The cell cultures were centrifuged at 10,000 g for 10 min at 4 °C and washed with a water (Yildiz 2019). Plate counting method was performed to determine the log reduction of *E. coli* O157:H7 population.

Color measurement

Color of each strawberry juice sample was analyzed by Hunter colorimeter (Hunter Associates Laboratories, Reston, Va, USA) depending on the *L**, *a* and b** values. Strawberry juices (10 mL) were poured into a plastic dish (35 mm, Corning tissue culture dish, NY, USA) and subjected to colorimeter. The blank measurements were made by running distilled water (DW) against a reference white pressed plate on colorimeter.

Ascorbic acid content (AAC)

AAC of strawberry juice was determined by following the method stated by Yildiz and Feng (2019) with little modification. 10 mL of strawberry juices were added into 10 mL of 3% (v/v) metaphosphoric acid. The concentrate was completed to a volume of 100 mL and centrifuged at room temperature (3000 g, 15 min). The supernatant (10 mL) was titrated against standard 2,6-dichloro-indophenol, which previously standardized against standard ascorbic acid and the result was report-ed as mg 100 mL-1 fresh weight (FW).

Antioxidant capacity (AOC)

1,1-diphenyl-2picryl hydrazyl radical (DPPH) was used to estimate the antioxidant capacity of control, US and HTST-treated strawberry juice samples (Ebrahimzadeh et al. 2009). The several concentrations of sample concentrates at the rates of 0.02%, 0.04%, 0.06%, 0.08%, and 0.1% were prepared. DPPH compound was mixed with the sample concentrate, and then placed on vortexed for vigorous mixing. The mixture was incubated for an hour at ambient temperature in the dark. The solution was centrifuged (3000 g, 10 min) and the absorbance of each sample was measured at 517 nm with a spectrophotometer (Lamda 1050 UV/VIS/NIR Spectromter, PerkinElmer, Waltham,

MA, USA). Methanol solutions known as Trolox (the amount of 0.1 to 1.0 mM) were used for the calibration curve and the findings were expressed as μmol of Trolox equivalents per liter of juice sample (μmol TE/L).

Total phenolic content (TPC)

TPC of Control, US, and HTST-treated strawberry juices was measured by a colorimetric method (Igual et al. 2012). The method includes the degradation of Folin–Ciocalteau indicator (Sigma Chemical, St. Louis, Missouri, USA) by phenolic ingredients, with the formation of an blue compound. The juice extract (0.25 mL) was added into 15 mL of DW and 1.25 mL of Folin–Ciocalteau testing agent and kept in dark place for 8 min. 3.75 mL of saturated sodium carbonate was added into the mixture and diluted up to 25 mL with DW. The testing mixture was kept at 25 °C for an hour and the absorbance was measured at 765 nm on a spectrophotometer. Gallic acid was used as a reference standard and the results for TPC were expressed as mg gallic acid equivalents per liter of juice sample (mg GAE/L).

Statistical analysis

Statistical analyses were conducted using the General Linear Models procedure in SAS (version 9.3, SAS Institute, Inc., Cary, North Carolina, USA). Fisher's least significant difference (LSD) test was conducted to compare the statistical changes among treatments at 95% confidence level ($\alpha = 0.05$). The results were expressed as mean ± standard deviation. All analysis was performed in triplicates.

Results and discussion

Microbial inactivation

US has been recognized as a potential technique in achieving a 5-log reduction in the survival count of a target human pathogen in juices to meet FDA requirements (Salleh-Mack and Roberts 2007). In the present work, it was observed that 5-log reduction of *E. coli* O157:H7 was achieved in 5 min (5.04 log CFU/mL), in 10 min (5.36 log CFU/mL) and in 15 min (6.08 log CFU/mL) by US-treatment. Similarly, D'amico et al. (2006) pointed out that a 5-log reduction of *E. coli* O157:H7 population in sonicated apple cider in 4.5 min at 57 °C.

Color measurement

Colorimetric parameters of control and treated strawberry juices are shown in Table 1. It was observed that L^* values decrease in all treatments, but the reduction was more significant in control and HTST treated strawberry juice. Similarly, Tomadoni et al. (2017) was observed the decrease in L^* value in thermally treated strawberry juice as compared to sonication during storage. The decrease in L^* value could be attributed to different factors such as thermal degradation of color pigments, Maillard reaction and enzymatic activities (Lyu et al. 2018). No significant changes were observed in a^* (redness) and b^* (yellowness) values in control, HTST and US-strawberry juice during 14 days (Table 1). Among all US treatments (US10 and US15) observed to show less changes in L^* value during storage. Similar findings has been reported by Rojas et al. (2016) where the L^* values of US treated peach juice were found as more stable. The higher retention of color attributes during US could be attributed to removal of oxygen during cavitation thus preventing the oxidative degradation of color pigments during storage (Abid et al. 2015; Yildiz et al. 2016). In this study, US treatment was found as more effective in less browning and retention of color pigments during storage.

Ascorbic acid content (AAC)

The results regarding the AAC of control, HTST and US treated strawberry juice are shown in Table 2. It was observed that AAC decreases in all treatment, but the reduction was more significant in control and HTST treatments during storage. Similar decrease in AAC was observed in control and thermally processed mango nectar during storage was observed by Kumar et al. (2018). The decrease in AAC might be due to the oxidation and anaerobic degradation of AAC in thermally preserved juice during storage (Igual et al. 2010).

Among US treatments, it was observed that US10 and US15 samples showed higher retention of AAC as compared to control during storage. Similar results have been reported by Dias et al. (2015) who observed the higher AAC in sonicated sour soup juice as compared to non-sonicated juice. This higher AAC could be attributed to the sonication in which no heat is supplied to the juice that cause the loss of ascorbic acid. The other reason could be the removal of oxygen during cavitation (Abid et al. 2015). US treatment was proved to be effective in preserving ascorbic acid content in strawberry juice in this study.

Table 1 Change of color in fresh, US and HTST-treated strawberry juices over storage at room temperature

Treatments	Storage (days)	L_*	a^*	b^*
FRESH	0	36.12 ± 0.48[a]	23.8 ± 0.28[a]	18.1 ± 0.41[a]
	2	32.25 ± 0.16[b]	23.2 ± 0.12[a]	18.7 ± 0.15[a]
	5	29.70 ± 0.27[c]	24.8 ± 0.65[a]	18.3 ± 0.24[a]
	7	25.93 ± 0.13[d]	23.5 ± 0.77[a]	18.4 ± 0.39[a]
	14	20.36 ± 0.22[e]	23.2 ± 0.14[a]	18.3 ± 0.44[a]
HTST	0	36.23 ± 0.25[a]	24.3 ± 0.13[a]	18.3 ± 0.12[a]
	2	31.48 ± 0.31[b]	24.2 ± 0.23[a]	18.5 ± 0.34[a]
	5	28.89 ± 0.17[c]	23.5 ± 0.37[a]	18.1 ± 0.57[a]
	7	24.15 ± 0.22[d]	23.1 ± 0.31[a]	18.7 ± 0.97[a]
	14	20.19 ± 0.15[e]	23.7 ± 0.14[a]	18.8 ± 0.33[a]
US5	0	36.14 ± 0.13[a]	23.4 ± 0.14[a]	18.5 ± 0.25[a]
	2	36.09 ± 0.46[a]	24.4 ± 0.25[a]	18.2 ± 0.08[a]
	5	31.81 ± 0.55[b]	23.5 ± 0.68[a]	18.2 ± 0.95[a]
	7	28.63 ± 0.19[c]	23.8 ± 0.19[a]	18.5 ± 0.74[a]
	14	25.87 ± 0.25[d]	23.1 ± 0.83[a]	18.6 ± 0.19[a]
US10	0	36.76 ± 0.33[a]	24.1 ± 0.72[a]	18.3 ± 0.35[a]
	2	36.22 ± 0.14[a]	23.5 ± 0.16[a]	18.7 ± 0.42[a]
	5	31.69 ± 0.87[b]	23.6 ± 0.93[a]	18.4 ± 0.19[a]
	7	28.34 ± 0.15[c]	23.6 ± 0.79[a]	18.5 ± 0.24[a]
	14	28.19 ± 0.63[c]	23.4 ± 0.72[a]	18.1 ± 0.11[a]
US15	0	36.81 ± 0.16[a]	23.3 ± 0.18[a]	18.5 ± 0.86[a]
	2	36.25 ± 0.92[a]	23.4 ± 0.20[a]	18.1 ± 0.68[a]
	5	31.72 ± 0.13[b]	23.5 ± 0.14[a]	18.8 ± 0.13[a]
	7	28.87 ± 0.24[c]	23.8 ± 0.43[a]	18.4 ± 0.27[a]
	14	28.45 ± 0.41[c]	23.5 ± 0.35[a]	18.2 ± 0.39[a]

[a–e]The same letters in each treatment show that treatment means for different storage times are not significantly different ($p > 0.05$)

Antioxidant capacity (AOC)

The results regarding the effect of HTST and US on AOC of strawberry juices are presented in Table 2. The antioxidant capacity decrease in all samples, irrespective of treatments, throughout the storage period of 14 days. This decrease was more significant in control and HSTS treatment as compared to US. Similar results has been reported by Igual et al. (2010) who observed that pasteurization provoked a significant decrease in AOC of grapefruit juice. This decrease in AOC could be related to the phenolic content that was degraded due to high temperature during thermal treatment (Kumar et al. 2018). In US, it was observed that AOC of strawberry juice increase with the increase in treatment time of sonication. This increase in AOC could be attributed to the enhanced extraction of antioxidant compounds such as ascorbic acid and phenolic compounds due to the mechanical effect of cavitation and bubble implosions during sonication (Abid et al. 2015). Among all US treatments, US15 juices showed the highest AOC during the storage. Similarly, Jabbar et al. (2014) has reported the higher AOC in sonicated carrot juices as compared to the untreated sample. This higher AOC could be attributed to the effective inactivation of polyphenol oxidase and peroxidase enzymes during US treatment (Aadil et al. 2018; Yildiz and Izli 2019a). In this present study, it was found that US treatment was more effective at preserving the nutritional properties that lead to higher AOC.

Total phenolic content (TPC)

The effect on TPC in control, HTST and US-treated strawberry juice samples during 21 days of storage are presented in Table 2. All the sample showed decrease in TPC during 14 days of storage. It was observed that decrease was more significant in control and HTST treated samples as compared to US treated sample. Similar results were reported in sonicated and pasteurized pear juice during storage (Saeeduddin et al. 2016). Decrease in TPC could be attributed to the oxidative degradation of phenolic compounds and their polymerization with protein during

Table 2 Changes of ascorbic acid, antioxidant capacity, and total phenolic content in fresh, US HTST-treated strawberry juices over storage at room temperature

Treatments	Storage (days)	Ascorbic Acid (mg/100 mL)	Antioxidant Capacity (μmol TE/L)	Total phenolic content (mg GAE/L)
FRESH	0	254.15 ± 1.54^{a}	1224.23 ± 1.89 ^{h}	326 ± 4.2^{d}
	2	223.23 ± 1.25^{b}	1221.10 ± 1.77 ^{h}	275 ± 3.3^{e}
	5	207.43 ± 2.11^{c}	998.22 ± 1.23^{i}	269 ± 1.8^{e}
	7	188.42 ± 0.93^{d}	925.35 ± 1.99^{i}	248 ± 2.3^{e}
	14	165.19 ± 1.04^{e}	897.14 ± 1.04^{i}	165 ± 3.2^{f}
HTST	0	255.65 ± 1.18^{a}	1554.73 ± 1.43 ^{g}	337 ± 6.6^{d}
	2	225.23 ± 1.13^{b}	1524.12 ± 1.28 ^{g}	282 ± 7.3^{e}
	5	205.19 ± 2.45^{c}	1234.67 ± 1.34 ^{h}	277 ± 2.6^{e}
	7	184.45 ± 1.14^{d}	1038.41 ± 1.12^{i}	246 ± 8.3^{e}
	14	163.72 ± 2.22^{e}	911.54 ± 1.43^{i}	194 ± 1.8^{f}
US5	0	254.89 ± 2.32^{a}	2480.45 ± 1.66^{d}	435 ± 4.3^{c}
	2	226.21 ± 2.17^{b}	2126.16 ± 1.64^{e}	434 ± 5.8^{c}
	5	224.25 ± 1.65^{b}	1525.12 ± 1.92 ^{g}	338 ± 6.5^{d}
	7	202.86 ± 1.09^{c}	1514.36 ± 1.98 ^{g}	325 ± 7.2^{d}
	14	183.20 ± 2.97^{d}	1224.35 ± 1.48 ^{h}	323 ± 7.6^{d}
US10	0	255.75 ± 1.34^{a}	2927.19 ± 1.64^{c}	545 ± 2.5^{b}
	2	249.43 ± 2.16^{a}	2475.24 ± 1.67^{d}	444 ± 4.1^{c}
	5	249.20 ± 2.78^{a}	2325.55 ± 1.88^{d}	437 ± 2.8^{c}
	7	225.64 ± 1.97^{b}	1984.48 ± 1.45^{f}	328 ± 1.2^{d}
	14	206.24 ± 1.58^{c}	1456.15 ± 1.23 ^{g}	325 ± 4.4^{d}
US15	0	255.97 ± 1.15^{a}	3657.18 ± 1.44^{a}	697 ± 7.7^{a}
	2	253.39 ± 2.16^{a}	3180.23 ± 1.31^{b}	646 ± 7.3^{a}
	5	255.18 ± 2.12^{a}	2913.77 ± 1.82^{c}	597 ± 8.9^{b}
	7	227.42 ± 2.14^{b}	2418.65 ± 1.44^{d}	528 ± 5.3^{b}
	14	206.60 ± 1.79^{c}	2027.72 ± 1.73^{e}	427 ± 5.5^{c}

$^{a–i}$The same letters in each treatment show that treatment means for different storage times are not significantly different ($p > 0.05$)

storage (Yildiz and Izli 2019b). Among all US treatment, decrease was observed in TPC but US15 treated strawberry juices retained higher TPC during storage. Cruz-Cansino et al. (2015) reported that US treatment shows higher TPC as compared to control and pasteurize treated cactus pear juice during storage. This higher TPC could be attributed to cavitation that caused the release of bound form of phenolic content from cell wall (Aadil et al. 2017). The present study indicates that US treatment was more effective in preserving the TPC in strawberry juice.

Conclusion

The results demonstrated that the ultrasonic treatment had significant effects on the physiological quality of the strawberry juices. Strawberry juice treated with US exhibited to be a promising alternative to HTST treatment as demonstrated by its quality retention ability during room temperature storage. When the sonication time was increased from 5 to 15 min higher levels of TPC, antioxidant capacity, and ascorbic acid were observed. A 15 min treated strawberry juices showed higher lightness (L*) values compared to the HTST-treated strawberry juice during a 2-week period. In overall, application of 15 min sonication at 20 kHz maintains overall quality better than other ultrasonic treatments. Based on the present study, we suggest that 15 min sonication may be implemented on a commercial scale for the production of strawberry juice with improved quality and stability during storage to get more benefits.

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