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Nutrimental composition and physicochemical parameters of thermosonicated soursop nectar

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Abstract

Effect of thermosonication (TS) at two different experimental conditions [TS1 = 24 kHz, 1.3 W/mL of acoustic energy density (AED), 51 °C for 8 min and TS2 = 24 kHz, 1.4 W/mL AED, 54 °C for 10 min] on the nutrimental composition and physicochemical parameters of soursop nectar stored at 4 °C were evaluated. Fresh (untreated) and traditionally pasteurized (65 °C, 30 min) soursop nectars were used as controls. TS did not cause changes in the most nutrients and physicochemical parameters evaluated. However, it was measured a highest dietary fiber content (33 %), turbidity (30%) and viscosity (5%), when TS2 was applied. The soluble dietary fiber is one of the functional compounds with demonstrated potential effects on the health; therefore TS could increase the functional quality of soursop nectar. Also, the changes in some physicochemical characteristics improved its physical appearance. TS can be considered an excellent alternative to process soursop beverages.

Key Words: nutrimental composition, physicochemical parameters, soursop nectar, thermosonication.

Composición nutrimental y parámetros fisicoquímicos de néctar de guanábana termosonicado

Resumen

Se evaluó el efecto de la termosonicación (TS) a dos diferentes condiciones experimentales [TS1 = 24 kHz, 1,3 W/mL de densidad de energía acústica (AED), 51 °C durante 8 min y TS2 = 24 kHz, 1,4 W/mL AED, 54 °C durante 10 min] sobre la composición nutrimental y parámetros fisicoquímicos de néctar de guanábana almacenado a 4ºC. Como testigos se emplearon un néctar sin tratar y otro pasteurizado tradicionalmente (65 °C, 30 min). La TS no causó cambios en la mayoría de nutrientes y parámetros fisicoquímicos evaluados. Sin embargo, fue medido un mayor contenido de fibra dietética soluble (33%), turbidez (30%) y viscosidad (5%), en particular cuando el TS2 fue aplicado. La fibra dietética soluble es uno de los compuestos funcionales con efectos potenciales demostrados en la salud; por lo tanto, la TS podría incrementar la calidad funcional del néctar de guanábana. Así mismo, los cambios en algunos parámetros fisicoquímicos mejoraron su apariencia física. La TS puede ser considerada una excelente alternativa para procesar bebidas a base de guanábana.

Palabras Clave: composición nutrimental, parámetros fisicoquímicos, néctar de guanábana, termosonicación.

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Introduction

The consumption of fruit and vegetables beverages is highly recommended mainly for its nutritional content and healthy benefits (Carrillo *et al*., 2014). The fruit beverages as juices or nectars are subject to rapid deterioration if they are not properly processed (Nwachukwu & Ezeigdo, 2013; Giner *et al*., 2013). The thermal pasteurization is the most common heat treatment applied for fruit beverages preservation to date. It assures good shelf-life and stability of these products; however, this process may affect the beverages quality in terms of nutritional and physicochemical parameters (Santhirasegaram *et al*., 2013; Cruz-Cansino *et al*., 2016). Thermosonication (TS) is an emerging technology that is described as a complete or partial alternative to thermal processing for preservation of fruit juices or nectars (Anaya-Esparza *et al*., 2017c). TS is a technology that combines cavitation (ultrasound) with heat producing an additive effect that greatly increases bacterial and enzymatic inactivation compared to thermal pasteurization without changes in physicochemical and sensory attributes in fruit-based beverages. Several studies have been done on the application of TS on fruit juices focusing on meeting FDA-HACCP (FDA, 2004) stipulations to reduce at least five log cycles of spoilage and pathogenic microorganisms (Ferrairo *et al*., 2015; Garud *et al*., 2017; Sánchez-Rubio *et al*., 2016). The effect of TS on enzymatic inactivation has also been studied (Aadil *et al*., 2015b; Cruz-Cansino *et al*, 2015; Jabbar *et al*., 2015), and has been found to increase or retain of bioactive compounds (Martínez-Flores *et al*., 2015; Shaheer *et al*., 2014; Proestos & Komaitis, 2006), and changes on physicochemical properties of some fruit juices (Dinçer & Topuz, 2015; Ertugay & Baslar, 2014; Nafar *et al*., 2013). Recently, we have reported that TS treatment (1.4 W/mL of acoustic energy density) of soursop nectar at 54°C for 10 min resulted in 91 to 99% decreases in polyphenol oxidase (PPO) activity (Anaya-Esparza *et al*., 2017b) and is effective on the inactivation of *Escherichia coli* and *Staphylococcus aureus* (5 log CFU/mL), without affecting quality parameters such as pH, titratable acidity, total soluble solids, color, ascorbic acid content and sensory attributes at the time of TS application and during cold storage at 4°C after 30 days (Anaya-Esparza *et al*., 2017a).

Although some research has been reported on TS processing of fruit juices, there have been no reports on the effect of TS on nutrimental components (proteins, fats, carbohydrates, dietary fiber, moisture and ash contents) in soursop beverages. The objective this work was to evaluate the effect of TS in changes of some nutrients and physicochemical parameters in soursop nectar.

Materials and methods

Samples and treatments

Mature soursop fruits were obtained from an orchard located in the village El Tonino, near Tepic, Nayarit, Mexico. For making soursop nectar, soursop pulp was diluted with purified water (350 g/L), and the mixture was homogenized, and then adjusted with sucrose (50 g/L), according to the requirements of the "*Codex Alimentarius* for Fruit Juices and Nectars" (CODEX STAN 247-2005) Nectar samples were treated with ultrasound (Hielsher UP400S, Teltow, Germany) at 270 W, with constant frequency of 24 ± 1 kHz. A shaking water bath (Thermo Scientific 2870, Ohio, USA) was used to maintain a constant temperature. Experimental TS conditions (Table I) were 1.3 W/mL of acoustic energy density (AED) at 51 °C during 8 min and 1.4 W/mL of AED at 54°C during 10 min. This combination of AED, time and temperature were established according to results from a previous study (Anaya-Esparza *et al*., 2017ab). For each treatment, 200 mL of soursop nectar were placed in a 250 mL beaker. Two control soursop nectars were considered; one fresh unpasteurized nectar (without treatment, UPN) and a thermally pasteurized at 65 ± 1 ºC for 30 min (TPN). This particular temperature and time were chosen to simulate the conventional batch pasteurization process as mentioned by Bermúdez-Aguirre *et al*. (2011). UPN nectar was analized inmediatly; while TPN and thermosonicated (TSN) nectars were stored at 4 ºC during 15 and 30 days, respectively, and analysed at the end of the storage period.

Nutrimental composition

Moisture (Method 925.09), protein (Method 920.152), and ash (Method 940.26) contents were determined following the official AOAC methods (AOAC, 2005). Soluble sugars were

Treatments	Time (min)	AED (W/mL)	Temperature (°C)	pH	TA (g MAE/L)	TSS (°Brix)
UPN	-	-	-	3.70 ± 0.01[a]	3.5 ± 0.03[a]	14.48 ± 0.03[a]
TPN	30	-	65	3.71 ± 0.01[a]	3.8 ± 0.02[a]	15.01 ± 0.09[b]
TSN 1	8	1.3	51	3.71 ± 0.01[a]	3.6 ± 0.01[a]	14.46 ± 0.03[a]
TSN 2	10	1.4	54	3.70 ± 0.01[a]	3.5 ± 0.01[a]	14.43 ± 0.03[a]

Values in final temperature are the average of triplicate determination from three different experiments (n = 9). **AED** = Acoustic energy density; **MAE** = Malic acid equivalent.

Table I. Experimental conditions and values of pH, titratable acidity (TA) and total soluble solids (TSS) of unpasteurized (UPN), traditionally pasteurized (TPN) and thermosonicated (TSN) soursop nectars stored at 4 ºC during 30 days.

quantified by the phenol-sulphuric method (Dubois *et al.*, 1956). Total dietary fiber (TDF) is the sum of soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Dietary fiber content was analysed by the AOAC enzymatic-gravimetric method (Method 991.42) modified by Mañas & Saura-Calixto (1995). Samples were treated with heat stable α-amylase, protease, and amyloglucosidase to remove protein and starch. The remaining residues were separated by centrifugation (15 min, 25 °C, 3,000 g) to separate soluble and insoluble fractions. The supernatants were dialyzed with water to avoid losses of SDF. The dialysates (containing SDF) and residues (non-starch polysaccharides, NSP) obtained from centrifugation were submitted to acid hydrolysis with sulphuric acid (12 M). To calculate SDF and NSP the amount of glucose obtained by hydrolysis was measured using the method of Englyst & Cummings (1988).

Fat content was measured according to the method of Bligh & Dyer (1959). For lipid extraction, the sample (5 mL) was homogenized with a mixture of distilled water (10 mL), methanol (20 mL), chloroform (10 mL), and then centrifuged (Hermle Z306, Wehingen, Germany) at 4,000 g for 10 min. Percentage of lipid content (using 12.5 mL of lipid extract) was quantified gravimetrically and calculated using equation (1).

$$\text{Total lipid} = \frac{\dfrac{\text{Dry weight of lipid in aliquot*}}{\text{Volume of chloroform layer}}}{\dfrac{\text{Volume of lipid extract*}}{\text{volume of sample}}} * 100 \quad \text{.......... (1)}$$

All results of proximate analyses were expressed as g/L of soursop nectar.

Turbidity, viscosity and electrical conductivity

The turbidity of soursop nectar was measured with a turbidimeter (HACH 2,100N Turbidimeter, Loveland, Colorado, USA) using sample cells (95 mm high * 25 mm diameter) at room temperature according to the manufacturer instructions. Results are expressed as Nephelometric Turbidity Unit (NTU). Viscosity was measured using a Digital Viscometer (Brookfield DV2T HB, Middleboro, USA) with a precision cylindrical (spindle HA #02) using 200 mL of sample at 25 °C, and viscosity was determined at 30 rpm as mentioned by Yusof & Ibrahim (1994), and results expressed as Centipoise (cp). Electrical conductivity (EC) was determined using a portable conductivity meter (Hanna instruments HI 8733, Bedford, United Kingdom) and results were expressed as mS/cm.

Other analysis

Total soluble solids (TSS), titratable acidity (TA) and pH were measured as reference before and after each treatment as per the methods reported by Anaya-Esparza *et al*. (2017b).

Statistical analyses

All values were obtained from three independent experiments and each sample was performed in triplicate (n = 9). Results were expressed as means ± standard deviation (SD). The one-way analysis of variance (ANOVA) test was used to analyse the data, and differences among means were compared by a Tukey test with a level of significance of $p < 0.05$, using the Statistica software (v.10 Statsoft®, Tulsa, USA).

Results and discussion

According to the "Requisite scientific parameters for establishing the equivalence of alternative methods of pasteurization" issued by the National Advisory Committee on Microbiological Criteria for Foods (NACMCF, 2006), the purpose of the emerging technologies such as thermosonication is to retain or enhance the original properties of fruit beverages after preservation treatment. Total soluble solids (TSS), titratable acidity (TA) and pH for fresh (UPN), pasteurized (TPN) and thermosonicated soursop nectar are given in Table I. The values in control (fresh and pasteurized) nectars were similar to those reported for fresh soursop nectar (Falguera *et al*., 2012) and pasteurized soursop nectar (Peters *et al*., 2000). Thermosonication processing (TS1 and TS2) did not promote significant changes ($p < 0.05$) in TSS, TA and pH compared with fresh control (Anaya-Esparza *et al*., 2017b). These results were in accordance to those reported by Tiwari *et al*. (2008). They reported no significant changes in TSS, TA and pH in orange juice treated by ultrasound independently of AED or treatment time; probably because the initial preparation of nectar (homogenization of pulp) to liberate simple sugars and organic acids in all treatments before of TS as was mentioned by Zou & Jiang (2016) after application of ultrasound treatment in carrot juice.

Nutritional composition of soursop nectar

Nutritional analyses were performed in thermosonicated nectar (TSN) to evaluate the possible change in nectar composition (protein, fat, carbohydrates, dietary fiber, moisture and ash) after treatment, because of studies about the effect of thermosonication on nutrimental content in fruit juice and nectars are scarce. Results of nutritional analyses in soursop nectar are shown in Table II.

No differences in the protein content were detected between TS1 and TS2 (3 g/L and 2.9 g/L respectively) compared with thermal pasteurized (TPN) (2.9 g/L) and unpasteurized (UPN) (2.9 g/L) nectars. According to Tian *et al*. (2004) this is attributable to the presence of sucrose in soursop nectar; which is used as an additive to stabilize proteins and avoiding them from unfolding. Also, minimal differences in protein content (less than 1%) in thermosonicated milk samples were reported after processing compared with raw milk (Bermúdez-Aguirre *et al*., 2009ab). It has previously been shown that application of ultrasound can break some aggregates of whey protein without causing denaturation of individual protein molecules

Treatment	Protein (g/L)	Fat (g/L)	Soluble sugars (g/L)	Moisture (g/L)	Ash (g/L)
UPN	2.9 ± 0.01[a]	3.5 ± 0.07[a]	97.5 ± 0.31[a]	894.9 ± 0.37[a]	0.9 ± 0.01[a]
TPN	2.9 ± 0.01[a]	3.6 ± 0.01[a]	97.4 ± 0.38[a]	894.9 ± 0.28[a]	0.9 ± 0.01[a]
TSN 1	3.0 ± 0.03[a]	3.3 ± 0.04[a]	101.0 ± 0.30[a]	891.9 ± 0.32[a]	0.9 ± 0.01[a]
TSN 2	2.9 ± 0.01[a]	3.6 ± 0.03[a]	100.3 ± 0.23[a]	892.1 ± 0.26[a]	0.9 ± 0.01[a]

Values are the average of triplicate determination from three different experiments (n = 9) ± standard deviation (SD). Means in a column with different letters are significantly different ($p < 0.05$). **TS1-TS2** = the key to the samples numbers can see in Table I.

Table II. Nutritional composition of unpasteurized (UPN) traditionally pasteurized (TPN) and thermosonicated (TSN) soursop nectars stored at 4 °C during 30 days.

(Chandrapala *et al*., 2012). This assumption implies possible enhancement of protein functionality (e.g. emulsions-viscosity) in the soursop nectar (Kentish *et al*., 2008; Güzey *et al*., 2006).

Thermosonication did not promote changes ($p > 0.05$) in the fat content in soursop nectars. UPN and TPN nectars had a fat content of 3.5 g/L and 3.6 g/L, respectively, and no differences were observed after TS1 (3.3 g/L) and TS2 (3.6 g/L). According to Suzuki *et al*. (2010) the application of ultrasound (US) in fat samples did not increase the fat content, but, there was a reduction on fat globules size as evidenced during the evaluation of functional properties of anhydrous milk fat after US treatment. Nonetheless, the disruption of fat globules increased the homogenization of the samples (Bermúdez-Aguirre *et al*., 2009b). Our results are in agreement with Bermúdez-Aguirre & Barbosa-Cánovas (2008) who reported no changes in fat content after applying TS in milk.

Sugars are the major soluble solids in fruit juices (Cheng *et al*., 2007), and are considered as a quality parameter mainly due to their contribution to the sensory characteristics of the soursop nectar (Yusof & Ibrahim, 1994). There was an apparent increase in sugar content (2%) in TS1 (101 g/L) and TS2 (103 g/L) of soursop nectar, but this increase was not significant ($p > 0.05$) compared with UPN (97.5 g/L) and TPN (97.5 g/L) nectars. Zou & Jiang (2016) reported a slight increase in the sugar content from 14.42 – 14.82 g/L in ultrasonicated carrot juice (40 kHz at 0.5 W/cm^2 of ultrasound intensity for 60 min). Also, similar trends were reported in thermosonicated jamun fruit juice (Shaheer *et al*., 2014) and milk (Bermúdez-Aguirre & Barbosa-Cánovas, 2008). Abid *et al*. (2014a) and Fonteles *et al*. (2012) reported an increase in sugar content after ultrasound treatment (US) of apple and cantaloupe melon juices, respectively. The increase in sugars content might be attributed to cell disruption (vegetable tissues) promoted by the US treatment, which promotes their release into the liquid (Lieu & Le 2010; Zou *et al*., 2010).

The moisture and ash contents were not significantly affected ($p > 0.05$). The effect of TS on moisture content in fruit juice has not been reported yet. According to Khandpur & Gogate (2016), moisture content in fruit juice could be lost by evaporation (temperature effect) and may contribute to an increase in total soluble solids. Thus, TS treatments used in this work (TS1 and TS2) not cause TSS and sugars changes. Li *et al*. (2004) reported no significant changes ($p > 0.05$) in ash content of soybeans treated with ultrasound. Abid *et al*. (2014b) and Aadil *et al*. (2015b) reported an increase in the contents of some minerals such as Ca^{2+} and Mg^{2+}, and a decrease in others such as K and Na, after application of ultrasound in apple and grape juices, respectively. They mentioned that loss of minerals is dependent on the type of mineral and type of fruit. Similar trends were reported by Ferreira *et al*. (2014) when applied ultrasound as a method for extraction of some minerals in chocolate powder.

The importance of dietary fiber (DF) content in fruit and vegetable juices and its implications in human nutrition and health as prebiotic and regulating the glucose and lipids levels (cholesterol and triacylglycerols) in blood has been reported previously (Goñi *et al*., 2009). Additionally, several authors have reported on the disruptive effect of TS on cell walls (vegetable tissues) increasing the content of several bioactive compounds (Yan *et al*., 2015; Proestos & Komaitis, 2006). However, the effect of TS on total dietary fiber content in thermosonicated soursop nectar (TSN) has not been reported yet. The soluble (SDF), insoluble (IDF) and total dietary fiber (TDF) contents in UPN, TPN, and TSN soursop nectars are listed in Table III. The SDF and TDF contents showed significant differences ($p < 0.05$) between treatments. UPN nectar had a SDF content of 1.8 g/L of nectar and similar values were obtained in TS1 (1.9 g/L). In TPN nectar was measured a 28% more (2.3 g/L); while TS2 SDF had 33% (2.7 g/L) more, compared with UPN nectar. Ultrasound is well known for extracting some components caused by its disrupting effect on cell walls (Cruz-Cansino *et al*., 2016; Lieu & Le, 2010), and precipitation and solubilization (temperature effect) of some pectin substances present in soursop nectar can explain the increase in SDF content. According to Jovanović *et al*. (2017) the combination of acustic and thermal energy improves the efficiency of extraction by disruption of cellular structures. This feature leads to increase the cell membrane permeability and breakdown of secondary metabolites-herb matrix interactions, what cause enhancement of pectin substances solubility and may contribute to the increase in viscosity (Dhingra *et al.*, 2012) of TSN nectars. Differences between TS1 and TS2 could be due to the increase in acoustic energy density (W/mL) on the treatment as mentioned by Evelyn & Silva (2016).

According to Figuerola *et al.* (2005), IDF is related to water-insoluble compounds as cellulose, hemicellulose and lignin that are resistant to lyses. Dhingra *et al.* (2012) reported that heating generally changes the ratio of soluble to insoluble fiber. In this study no differences ($p > 0.05$) on IDF content were obtained between treatments, and TDF depended on the SDF and IDT content. Differences between treatments in TDF are due to the SDF content. Additionally, soursop nectar could be considered as a good source of dietary fiber (Olagnero *et al.*, 2007).

Treatment	SDF (g/L)	IDF (g/L)	TDF (g/L)
Fresh control	1.8 ± 0.02[a]	3.4 ± 0.05[a]	5.2 ± 0.02[a]
Pasteurized control	2.3 ± 0.01[b]	3.0 ± 0.01[a]	5.3 ± 0.02[a]
TSN 1	1.9 ± 0.01[a]	3.1 ± 0.01[a]	5.0 ± 0.01[a]
TSN 2	2.7 ± 0.01[c]	3.2 ± 0.01[a]	5.9 ± 0.02[c]

Values are the average of triplicate determination from three different experiments (n = 9) ± standard deviation (SD). Means in a column with different letters are significantly different (p < 0.05). **TS1-TS2** = the key to the samples numbers can see in Table I.

Table III. Soluble (SDF), insoluble (IDF) and total dietary fiber (TDF) of unpasteurized (UPN) traditionally pasteurized (TPN) and thermosonicated (TSN) soursop nectars stored at 4 °C during 30 days.

Turbidity, viscosity and electrical conductivity

Turbidity and viscosity are related to the suspended particles within the system, and both are considered as a quality parameter in fruit drinks (Lindsay-Rojas *et al.*, 2016). The effect of thermosonication treatment on the turbidity of soursop nectar is given in Table IV. The TPN nectar (65°C ± 1 °C) and TSN nectars show an increase in turbidity of 18% (4,786 NTU) and 30% (TS1 and TS2) in comparison with UPN nectar (3,963 NTU). No differences ($p < 0.05$) in turbidity were observed between TS1 and TS2. A decrease in turbidity and/or viscosity affects negatively the appearance of the soursop nectar due to the sedimentation of the suspended particles (Ertugay & Baslar, 2014). Quek *et al.* (2012) reported turbidity values between 703 to 913 NTU in soursop juice extracted by different hot-water methods. Differences in results are due to more solid particles in soursop nectar (14.5 °Brix) than soursop juice (4.5 – 6.7 °Brix) (Gao & Rupasinghe, 2012). Similar trends have been reported in applying TS in black mulberry juice (Dinçer & Topuz, 2015), cantaloupe melon (Fonteles *et al.*, 2012), and apple juices (Ertugay & Baslar, 2014). Authors are in agreement that during TS treatment the suspended particles are reduced by cavitation effect and at the same time are dissolved by temperature (mainly pectin particles); increasing turbidity values; which are favored by the presence of high sugar concentrations (Zou & Jiang, 2016; Dahdouh *et al.*, 2015). In addition, increase of turbidity depends on the acoustic energy density level (AED) as demonstrated by Dinçer & Topuz (2015). No differences in turbidity were detected when TS was applied at 0.86 W/mL and 1.26 W/mL of acoustic energy density (AED) in black mulberry juice compared to the increase in turbidity (40%) at 1.63 W/mL of AED in the same study.

Treatment	Turbidity (NTU)	Viscosity (cP)	EC (mS/cm)
Fresh control	3963.33 ± 25.16[a]	334.86 ± 0.45[a]	19.36 ± 0.15[a]
Pasteurized control	4786. 66 ± 37.85[b]	336.03 ± 0.70[a]	19.34 ± 0.15[a]
TS 1	5183.33 ± 15.27[c]	348.96 ± 0.32[b]	19.73 ± 0.15[a]
TS 2	5186.66 ± 15.27[c]	351.80 ± 0.45[c]	19.43 ± 0.15[a]

Values are the average of triplicate determination from three different experiments (n = 9) ± standard deviation (SD). Means in a column with different letters are significantly different (p < 0.05). **TS1-TS2** = the key to the samples numbers can see in Table I. **NTU** = Nephelometric Turbidity Unit. **cP** = Centipoise. **mS** = mili-Siemens.

Table IV. Turbidity, viscosity and electrical conductivity (EC) of unpasteurized (UPN), traditionally pasteurized (TPN) and thermosonicated (TSN) soursop nectars stored at 4 °C during 30 days.

UPN nectar had a viscosity value of 334 cP and TPN nectar of 336 cP (Table IV). These viscosity values are lower than reported in previous study (Ikegwu & Ekwu, 2009) in soursop juice (1,236 cP) and are similar to those reported in banana juice (395 cP) after enzyme treatment (0.1% enzyme concentration, 40 °C, 120 min) by Tapre & Jain (2014). Samples treated by TS showed an increase of 4% (TS1 – 349 cP) and 5% (TS2 – 352 cP) compared with UPN nectar. These results were similar to those previously reported by Wu *et al.* (2008). Their studies showed that the viscosity of tomato juice also significantly increased after TS treatment and they mentioned that viscosity can be influenced by AED and temperature. They explained that during TS, particle sizes are divided into fine particles (cavitation effect) and raise the solubilisation (temperature effect) of solid responsible for increasing viscosity. Also, results are in accordance to those of Aadil *et al.* (2015b) and Martínez-Flores *et al.* (2015) who reported an increase in viscosity up to 28% after TS treatment in grape and carrot juices. Conversely, Cruz-Cansino *et al.* (2015) reported a reduction of viscosity in purple cactus juice after TS

(20 kHz; 50°C; 25 min); which might be attributable to a partial enzymatic inactivation (Engmann *et al*., 2014). According to Soria & Villamiel (2010), the effect of AED on viscosity can be temporary or permanent. In addition, the presence of some ions (*e.g.* Ca^{2+} and Mg^{2+}) and high sugars concentration may contribute to maintaining viscosity (Dahdouh *et al*., 2015). Thermosonication enhances the viscosity and consistency in milk and yoghurt (Riener *et al*., 2009; 2010).

Electrical conductivity (EC) is related to soluble solids content and especially with the presence of ions (Palaniappan & Sastry, 1991). Results regarding the effect of TS treatments on the EC of soursop nectar are listed in Table IV. In this study, a slight increase in EC of TS1 and TS2 (19.73 and 19.43 mS/cm) soursop nectar compared with UPN (19.36 mS/cm) and TPN (19.34 mS/cm) nectars was observed, but this increase was not significant ($p > 0.05$). Similar trends were reported in carrots (Zou & Jiang, 2016) and apple (Abid *et al*., 2014a) juices, or sweet whey (Barukčić *et al*., 2015) after sonication treatment, but differ from that mentioned by Aadil *et al*. (2015a) who reported a decrease in EC after TS in grape juice. Authors are in agreement that during sonication or TS treatment EC increase might be attributed to the increase in mineral elements or vitamin retention after treatment or the possible deterioration of ultrasound probe tip and small release of particles into model system (Jambrak *et al*., 2009). According to Moura *et al*. (1999) a decrease in EC can result in an increase in viscosity due to a decrease in the mobility of the ions.

Conclusions

The TS (1.4 W/mL and 54°C for 10 min) did not cause changes in the most of nutrients of soursop nectar, which it is important of the point of view nutritional. However, TS improved the nutritional quality with the bioaccessibility of SDF due to this compound is considered highly functional on the health. In the same way the changes in the viscosity and turbidity showed a better visual appearance of nectar. This work is important due to the fact that it is the first study that evaluated the effect of thermosonication on nutrimental content of soursop beverages.

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Conflict of interest

The authors have declared that no conflict of interest exists.

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