ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Effect of thermosonication (TS) and Pulsed Electric Field (PEF) processing on quality characteristics of mango nectar (*Mangifera indica*)

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Manuscript Info

Manuscript History:

Received: 16 September 2013
Final Accepted: 24 September 2013
Published Online: October 2013

Key words:
Thermosonication, Pulsed Electric Field (PEF) processing, Color, Ascorbic acid

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Abstract

Thermosonication and Pulsed Electric Field (PEF) processing techniques are emerging non thermal technologies for liquid food preservation. Combination of thermosonication (TS) followed by pulsed electric field (PEF) was employed to improve the mango nectar quality and acceptability. Mango nectar was exposed to batch thermosonication at 70^0 C for 90 seconds followed by continuous PEF process at the flow rate 42.5 l/h, pulse field intensity 33.2 kV/cm, frequency 100 Hz, pulse width 20 µs and 10 mm electrode gap. Conventional thermal pasteurization (Control) at 96^0 C for 600 seconds was used as control. Maximum retention of total carotenoid, ascorbic acid and flavour retention were observed in Thermosonication + PEF (TSPEF) when compared to conventional thermal pasteurized (Control) samples. Results indicated that the application of thermosonication with pulsed electric field treatment as combination nonthermal techniques can be used to extend the shelf life of mango nectar with better quality.

Introduction

In current era, the requirement from the end user for fresh-like, minimally processed food products has been swiftly growing. At present, heat pasteurization is largely used to inactivating microorganisms and enzymes, thus extending product shelf life. However, this process may have adverse effects on sensory and nutritional qualities of foods (Braddock, 1999). In this perspective, non-thermal technologies (e.g. PEF, Sonication and Thermosonication) have received increasing attention in recent years for preservation of juices and nectars, due to their impending for inactivating spoilage and pathogenic microorganisms. In addition, they can help minimise the quality loss in terms of flavour, colour and nutritional value (Mertens and Knorr, 1992).

In the food industry, the use of ultrasounds has been a subject of research and development for many years and as is the case of other areas. The sound ranges employed can be divided basically into; (1) high frequency, low energy, diagnostic ultrasound in the MHz range; and (2) low frequency and high energy, power ultrasound in the kHz range (Mason, and Lorimer, 2002). The application of ultrasound waves generating cavitation in suspensions, which contain microorganisms and enzymes often, has a lethal result and deactivating action. When high power ultrasound propagates into a liquid, the micro bubbles, which are commonly present in it or that may form from the presence of suspended particles, will oscillate according to the pressure wave. High acoustic pressure will determine their growth and violent collapse, which is accompanied by a sudden increase of the temperature and the pressure in the surrounding area.

The influence of ultrasounds on cells and tissues is caused by the appearance of local pressures and on local accelerations. According to the frequency of the ultrasound, alternating positive and negative pressures appear locally, leading to stretch or compression of the material and causing cell disrupture. Homogenous liquids have a considerable resistance to the disruption effect (Glaser, 2001). Sonication also promotes chemical reactions involving H^+ and OH^- free radicals formed by the decomposition of water inside the oscillating bubbles. Free

radicals so produced could be scavenged by some amino acid residues of the enzymes participating in structure stability, substrate binding, or catalytic functions (Lopez, *et al.*, 2005).

Pulsed electric field is an emerging electro-technology that has become a suitable method for food preservation, therefore receiving worldwide attention from universities, research institutes and private food industries. The main advantage of this emerging technology, the retention of fresh quality attributes, is well proven in the preservation of fruit juices, purees and sauces, as well as dairy and poultry liquid products, in which pathogenic and spoilage flora, as well as some enzymes are inactivated (Jeyamkondan, *et al.*, 1999). Furthermore, PEF seems to be a good alternative for increasing the yield of juice extraction, conducting liquid waste treatment and controlling biofouling in cooling water systems.

PEF processing of food involves the application of short pulses of high electric fields for micro to milliseconds at intensities between 15-80 kv/cm. The high electric pulses are generated when a pair of high voltage electrodes are charged and discharged in fractions of a second (Qin, *et al.*, 1995). The processing time is calculated as the number of pulses times its duration, while the lethality of the process is proportional to the treatment or residence time of the food in the processing equipment or high electric field treatment zone of a high voltage chamber (Heinz, *et al.*, 2002). The existing treatment chamber designs basically involve a par of electrodes, one connected to a high voltage source and the other to the ground. Parallel plates and wires, concentric (coaxial) cylinders, rod plates, and co-fields, are some of the possible electrode configurations for such treatment chambers (Mason, *et al.*,1996). The objectives of this work were firstly to investigate the combination of Thermosonication and Pulsed Electric field to achieve similar microbial inactivation to conventional thermal pasteurisation (at 96^0 C for 600 seconds) and secondly to compare selected quality attributes (Ascorbic acid, Carotenoids, Colour, pH, Acidity and Sensory of the resultant product.

Materials and methods

Mango Nectar production and processing

Fresh ripe Mallika variety (hybridization of the Indian mango varieties Neelum and Dasheri) mango (*Mangifera indica)* purchased from Mysore India local market the day before juicing and stored at 4^0C until juice extraction. The fruits washed with tap water and then with sterile water. Mango skin was peeled manually and deskinned and then cut into small piece then pulped by pulper and then diluted to required viscous then filtered through double layered muslin cloth and poured into sterile stainless steel vessel prior to processing. The juice was processed by the following treatments: (1) Conventional high temperature heat pasteurization (Control) at 96^0 C for 600 seconds. (2) Batch thermosonication at 80% amplitude at 70^0 C for 90 seconds followed by continuous PEF (TSPEF) at pulse field intensity 33.2 kV/cm, 20µ pulse width, 100Hz frequency and 10 mm electrode gap.

Thermosonication Conditions

Ultrasonic processor UP 400S, 400 w, with working frequency of 24 kHz (Model: Hielscher Ultrasonics GmbH, Germany) was used. The efficiency of the processor is of > 90, control range of ± 1 kHz, output control of 20 %.... 100 %, steplessely adjusted, pulse – pulse mode with a factor of 10 % ….. 100% per second, steplessely adjusted, maximum energy density of 12…600 w/$Cm^{2,}$ maximum amplitude of 12… 260 µm, sonotrode: H3, maximum submerged depth (90 mm), tip dia 3 mm, maximum amplitude (210µm) and acoustic power density of 460 w/Cm^2. The ultrasonic processor generates longitudinal mechanical vibrations by means of electrical excitation (reversed piezoelectric effect) with a frequency of 24 kHz. The vibrations are amplified by the sonotrode fitted to the horn and formed as a λ / 2 vibrators and transformed via its end face to the medium to be sonically irradiated. Mango nectar was treated with batch thermosonication at 80% amplitude for 90 seconds maintained at 70^0 C followed by continuous PEF treatment.

PEF Processing Conditions

A continuous PEF system (Model: Elcrack® HVP5 manufactured by German Institute of Food Technologies, Quakenboruck) was used in this study. Pulse waveform, voltage, and intensity in the treatment chambers were recorded with a digital oscilloscope (Digital touch screen oscilloscope Siemens, Made in Denmark). The treatment chamber of the PEF was tube having diameter of 10 mm. The in-put process parameters such as output voltage, pulse width, frequency, and flow rate and electrode gap are set to suit to process mango nectar. Samples were collected after each PEF treatment, and filled in sterile pouches at sterile conditions. Then the samples were stored for further analysis. The experiments were preformed in triplicate.

Thermal Pasteurization

Mango Nectar (200mL) was poured into Pre-fabricated multilayer laminated pouches consisting of 12 µm Polyethylene terephthalate / 15µm Nylon / 9µm Aluminum foil / 80µm Cast. Polypropylenes (Total thickness 116µm) of 200 ml capacity with a dimension of 15 X 20 cm and sealed using impulse sealing machine (Model: HP Impulse Sealer, M/s. Sunray Industries Mysore, India) followed by thermal pasteurized at at 96^0 C for 600 seconds (Hsua, *et al.*, 2008) Afterward, the nectar pouch was immediately cooled in ice water for 2 min.

Methods of analysis

Parameters of the samples were analyzed as described below and all the experiments were carried out in triplicate;

Physical properties

The pH was determined with a model pH 700 Digital pH meter at 23^0C (Eutech Instruments, Made in Singapore). The pH meter was standardized using pH buffer of 4.0, 7.0 and 10.2.

The *Hunter Color (L* a* b*)* was measured using a Hunter Lab Scan Spectrophotometric colorimeter controlled by a computer that calculates color ordinates from the reflectance spectrum. (Hunter Lab Color Flex EZ $45/0^0$ color spectrophotometer, Made in USA). The results were expressed in accordance with the CIELAB system with reference to illuminate D65 and with a visual angle of 10^0. The samples were placed in an optical glass tray, using the white plate of the colorimeter as the background (Standard white plate no. CFEZ0503 X=79.05, Y=84.00, Z=87.76). This background was used to standardize the measurements. The measurements were made through a diaphragm 30 mm.

Viscosity was measured from approximately 100 mL of Mango nectar juice using a rotatory viscometer (Model Rheotech GmbH, Viscosmeter RC 01/02 Made in Germany) with a precision cylindrical spindle (R_2) rotating (UL) adapter. Mango nectar was placed in the UL adapter and viscosity was determined at 100 rpm. The viscosity was expressed as cP unit.

Sensory quality was determined using 9 point Hedonic scale rating method followed by Ranganna 1999. For sensory taste and odor evaluation, 20 untrained volunteers were selected. The samples (Treated juices without storage and with storage) were presented in a glass with a capacity of 100 ml. For characteristics, (Odor, Taste and Over all Acceptability) the judge rated the preferred samples in comparison with heat pasteurized and Thermosonication + PEF.

Chemical analysis

The tritatable acidity (TA) was determined by titrating 1 mL of each sample (diluted to 20 mL final volume with deionized water) with 0.1 mol L^{-1} NaOH. Results were expressed as g citric acid 100 mL^{-1} sample. (Araujo, *et al.*, 2011)

Ascorbic acid in mango nectar was estimated by following method Ranganna 1999. A sample of 10 mL of mango nectar was mixed with 20% Meta phosphoric acid in a mortar and pestle, then transferred into a 100 ml volumetric flask by decantation re extract 3 times with few ml each time of Meta phosphoric acid and made up to volume with distilled water. Then 10ml of vitamin C extract titrated against the standard 2, 6 dichlorophenol indophenol dye. The Ascorbic acid content of each sample was estimated according to the following equation: Ascorbic acid mg/100ml = T.V x dye factor x volume made up x 100 / volume taken for titration x sample weight. The Ascorbic acid was expressed as mg /100 ml

Carotenoids was determined by spectrophotometrically (UV- Spectrophotometer, Spectronic® Genesys™ 2 Instruments, Made in USA) followed Ranganna 1999 method. A 5g nectar sample was mixed with 20mL of Acetone and kept for dark for 10-15min, then content were filtered through sintered funnel under suction and 20 ml of acetone was added twice to extract the pigments then 20ml of hexane was added to extract the pigment completely. The combined extract was added to transfer the pigment to hexane layer after 5 min the aqueous layer was completely discarded. Transferred hexane layer into 250ml volumetric flask and volume was made up to the mark with hexane. A pinch of anhydrous sodium sulphate was added and absorbance was read at 450nm against hexane as blank. The carotenoid content of each sample was estimated according to the following equation: Absorbance x 250 x1000/250 x Wt of sample. The carotene was expressed as µg /ml.

The total and reducing sugar was determined by titration method followed by method Ranganna 1999.

Microbial analysis

Microbial analysis was followed by Rivas, *et al.,* 2006. For the microbial counts, samples were serially diluted, plated in total count agar (PCA) for total plate (aerobic) counts, and in acidified Potato dextrose agar (PDA) for mold and yeast counts. Plates were incubated at 30^0C for 48h or 5 days for Total Plate Counts and Molds and Yeast respectively. Violet Red Bile Agar for Coliforms used.

Data analysis

All the analysis was carried out in triplicate. The data were analysed statistically to find out standard deviations and significance (Snedecor and Cochran, 1988).

Results and Discussion

PEF treatment

The PEF main operational process parameters are continuously monitored .The flow rate was set at 45.0 l/h with a peristaltic pump. Treatment conditions for mango nectar were 33.2 kV/cm pulse field intensity, 100 Hz frequency, and 20 µs pulse with at a maximum temperature of 45.3^0 C. Samples were collected after treatment, cooled and stored until analysis. The experiments were performed in duplicate.

Physical properties

The effects of the different processing conditions on pH, values are shown in Table 1 whereas results of the colour and viscosity were given in Table 2 & 3.

The initial pH of the sample after processed was 4.32 ± 0.020 and 4.30 ± 0.010 for Conventional thermal pasteurized (Control) and Thermosonication and PEF treated (TSPEF) samples respectively. The pH of the Conventional thermal pasteurized sample was increased after processing than Thermosonication and PEF treated samples, it is due to higher temperature processing in higher temperature degradation of ascorbic acid will starts.Not much significant change in pH was noticed in 5^0 C stored samples. A slight increase in pH was found during ambient condition (27-30^0 C) storage. It may happen due to the degradation of ascorbic acid. Kaanane, *et al.,* (1988) also studied the storage effect on the pH of fruit juices; he did not observe significant variations in pH during storage of pasteurized juices. Yeom, *et al.,* (2000b) also did not find pH changes in the orange juice treated by PEF.

Thermal pasteurized (Control) samples luminosity (l*) was found to be higher than Thermosonication and PEF (TSPEF) treated samples, and yellowness (b*) was reduced more compared to TSPEF treated samples. It is clearly shows the degradation of carotenoids in the mango nectar. During the 90 days storage 5^0 C control samples was found to be increase in luminosity (l*) from 28.52 ± 0.01 to 31.24 ± 0.005 and yellowness (b*) was reduced from 15.61 ± 0.005 to 13.38 ± 0.050. Thermosonication and PEF treated (TSPEF) samples was also found to be increase in luminosity (l*) from 25.53 ± 0.090 to 27.38 ± 0.057 and yellowness (b*) was reduced from 19.66 ± 0.034 to 15.65 ± 0.057 at 5^0 C storage. There is not much change in redness (a*) during storage, the same trend was repeated at the ambient condition (27-30^0 C) storage. Zhang, *et al.,* (1997) also found a better color preservation in the PEF treated samples when compared to heat pasteurized samples.

The reliability of mango nectar expressed in viscosity is essential part for the quality of mango nectar. The viscosity of Conventional thermal pasteurized (control) and Thermosonication and PEF (TSPEF) treated samples was 104 ± 0.00 cP and 103 ± 0.00 cP respectively and shown in Table 3. The mango nectar by TSPEF treated had a significantly lower viscosity than that by conventionally thermal pasteurized. During storage at 5^0C for 90^{th} day, the viscosity values of the nectar by conventional thermal treated increased up to 119 ± 0.00 cP and TSPEF treated up to 106 ± 0.00cp. It is due to the water loss during high temperature processing and the same trend was repeated at the ambient condition (27-30^0 C) storage.

On the basis of the average rating given by the panelist, the overall acceptability (OAA) of the TSPEF treated samples were most acceptable (8.6 ± 0.1) than treated by (7.7 ± 0.2) Conventional thermal pasteurized (Control). TSPEF treated samples showed (8.4 ± 0.1) and (8.0 ± 0.1) for 5^0 C and ambient condition (27-30^0 C)

storage respectively. But it is higher than control sample (7.0 ± 0.1) and (6.8 ± 0.1) for 5^0 C and ambient condition (27-30^0 C) storage respectively. Min, *et al.,* (2003); Dunn and Pearlman (1987) confirmed the high sensory quality of PEF treated juice when compared with thermally processed juice.

Chemical analysis

The initial total tritatable acidity of the sample after processed was 0.23 ± 0.005 0.24 ± 0.005 for Conventional thermal pasteurized (Control) and Thermosonication and PEF treated (TSPEF) samples respectively. During storage in both temperatures samples showed a slight increase in total acidity in 90^{th} and 60^{th} day of storage, it related to the decrease found in pH (Table 1). Rivas, *et al.,* (2006) did not found much variation in total acidity of PEF treated juice when compared with an untreated sample.

The results illustrated in Figure 1 and 2 revealed that there was significant decrease in ascorbic acid values of mango nectar upon Conventional thermal pasteurized (Control) and along the storage period. However, the rate of decrease in vitamin C was significantly higher in Control samples than Thermosonication and PEF treated (TSPEF) samples. Analysis showed that thermal pasteurization significantly lowered the destruction that happened to ascorbic acid during storage which may be due to the inactivation of ascorbic acid oxidase. Elez-Martinez, and Martin-Belloso, (2007) and Odriozola-Serrano, *et al.,* (2009) also found 20 % losses in PEF treated orange and strawberry juice respectively.

Total carotenoids significantly decreased in Conventional thermal pasteurized (Control) samples than TSPEF treated samples (Figure 3 & 4). During the 90 days storage at 5^0 C control samples was found to be decreased 16.43 ± 0.057µg/g to 11.77 ± 0.011µg/g. Thermosonication and PEF treated (TSPEF) samples were also found to be slightly decreased from 21.16 ± 0.288 to 18.82 ± 0.040µg/g. However, the rate of decrease in carotenoids content was significantly higher in control samples than TSPEF treated samples.

The Reducing sugar and Total sugars results were presented in the Table 4. At the initial stage of storage reducing sugar was 6.7 ± 0.1 % which decreased to 6.41 ± 0.01 % at 90^{th} day storage at 5^0C for Conventional thermal pasteurized (Control) samples. Thermosonication and PEF treated (TSPEF) treated samples reducing sugar was 6.8 ± 0.1% which decreased to 6.73 ± 0.057%. Total sugar was 17.53 ± 0.05% which decreased to 17.70 ± 0.011% at 90^{th} day storage at 5^0 C for Conventional thermal pasteurized (Control) samples. Thermosonication and PEF treated (TSPEF) treated samples reducing sugar was 17.36 ± 0.05% which decreased to 17.46 ± 0.09% and the same trend was repeated at the ambient condition (27-30^0 C) storage.

Microbial analysis

The combinations of Thermosonication and PEF treatment effect on Micro floras are shown in Table: 4. Mango nectar had an initial microbial of 4.877121 ± 0.65, 4.1 ± 0.60 and 3.861 ± 0.60 log cfu/mL for total plate count, coliforms and yeast and molds respectively. When the two hurdles were combined [Thermosonication + PEF (TSPEF)] the overall microbial reduction was 4.877121 ± 0.65, 4.1 ± 0.60 and 3.861 ± 0.60 log cfu/mL for total plate count, coliforms and yeast and molds respectively, that is all the microbial load was inactivated.

Thermal pasteurization of mango nectar is generally coupled with a loss of organoleptic qualities (Liang, *et al.,* 2006). The application of a hurdle approach of TSPEF, to fresh mango nectar resulted in a similar microbial inactivation to Thermal Pasteurization (Control). In a similar study conducted by Liang, *et al.,* (2006) apple cider was processed by PEF alone at 33 kV/ cm for 58.7 square pulses of 1µs resulting in a 3.1 log cycles reduction of native flora. Cserhalmi, Vidacs, Beczner, and Czukor (2002) reported a 3.4 log cycle inactivation in apple juice inoculated with *Saccharomyces cerevisiae* when treated with 8.3 pulses of 2 µs in 6 consecutive treatment chambers (total treatment time being kept constant at 100 µs) at 28 kV/cm. Reference to above study PEF alone inactivated around 3.0 log cycle reduction of native flora, in this study Thermosonication combined with PEF (TSPEF) inactivated all the native micro flora was totally justified.

Table 1: pH and acidity of processed samples during 5^0C and ambient condition (27-30^0 C)

	Storage time (days)	Heat Pasteurization (Control)		Thermosonication + PEF (TSPEF)	
		5^0C	**27-30^0C**	**5^0C**	**27-30^0C**
pH	0	4.32 ± 0.020	4.32 ± 0.011	4.30 ± 0.010	4.30 ± 0.010
	15	4.32 ± 0.000	4.32 ± 0.010	4.30 ± 0.005	4.31 ± 0.010
	30	4.31 ± 0.010	4.33 ± 0.010	4.30 ± 0.000	4.31 ± 0.000
	45	4.31 ± 0.005	4.33 ±0.005	4.31 ± 0.010	4.32 ± 0.005
	60	4.32 ± 0.010	4.34 ±0.005	4.31 ± 0.000	4.33 ± 0.005
	75	4.32 ± 0.005	ND	4.31 ± 0.010	ND
	90	4.33 ±0.005	ND	4.32 ± 0.010	ND
Acidity (Citric acid)	0	0.23 ± 0.005	0.23 ± 0.005	0.24 ± 0.005	0.24 ± 0.005
	15	0.23 ± 0.000	0.23 ± 0.000	0.24 ± 0.000	0.24 ± 0.000
	30	0.23 ± 0.005	0.21 ± 0.005	0.24 ± 0.010	0.24 ± 0.010
	45	0.22 ± 0.005	0.21 ± 0.005	0.24 ± 0.005	0.22 ± 0.000
	60	0.22 ± 0.000	0.20 ± 0.000	0.23 ± 0.005	0.21 ± 0.005
	75	0.22 ± 0.000	ND	0.23 ± 0.005	ND
	90	0.21 ± 0.005	ND	0.23 ± 0.010	ND

Mean ± SD

Table 2: Hunter color values of processed samples during 5^0C and ambient condition (27-30^0 C)

Storage time (days)	Heat Pasteurization (Control)			Thermosonication + PEF (TSPEF)		
				5^0C		
	L*	a*	b*	L*	a*	b*
0	28.52 ± 0.010	0.14 ± 0.005	15.61 ± 0.005	25.53 ± 0.090	0.05 ± 0.005	19.66 ± 0.034
15	28.54 ± 0.010	0.35 ± 0.005	14.84 ± 0.011	25.61 ± 0.057	0.22 ± 0.051	19.37 ± 0.063
30	29.14 ± 0.005	0.45 ± 0.005	14.57 ± 0.063	25.93 ± 0.057	0.16 ± 0.005	18.78 ± 0.057
45	29.85 ± 0.005	0.59 ± 0.005	14.20 ± 0.057	26.38 ± 0.057	0.12 ± 0.010	17.34 ± 0.005
60	30.14 ± 0.005	0.61 ± 0.005	13.94 ± 0.023	26.80 ± 0.076	0.28 ± 0.005	16.85 ± 0.060
75	31.15 ± 0.005	0.71 ± 0.005	13.55 ± 0.057	26.88 ± 0.100	0.32 ± 0.015	15.75 ± 0.057
90	31.24 ± 0.005	0.17 ± 0.005	13.38 ± 0.050	27.38 ± 0.057	0.12 ± 0.005	15.65 ± 0.057
				27-30^0C		
0	28.52 ± 0.010	0.14 ± 0.005	15.61 ± 0.005	25.53 ± 0.090	0.05 ±0.010	19.66 ± 0.034
15	28.91 ± 0.051	0.66 ± 0.011	14.20 ± 0.072	25.93 ± 0.057	0.17 ± 0.005	17.84 ± 0.005
30	29.57 ± 0.057	0.52 ± 0.023	13.28 ± 0.057	26.30 ± 0.063	0.59 ± 0.040	16.17 ± 0.057
45	29.78 ± 0.057	0.78 ± 0.005	12.27 ± 0.057	28.39 ± 0.080	1.36 ± 0.051	15.71 ± 0.057
60	31.09 ± 0.023	0.45 ± 0.011	12.12 ± 0.058	29.29 ± 0.010	1.30 ± 0.057	14.14 ± 0.010

Mean ± SD

Table 3: Viscosity of processed samples during 5^0C and ambient condition (27-30^0 C)

	Storage time (days)	Heat Pasteurization (Control)		Thermosonication + PEF (TSPEF)	
		5^0C			
		Shear Force (cp)	**Shear rate (%)**	**Shear Force (cp)**	**Shear rate (%)**
Viscosity	0	104 ± 0.00	26.0	103 ± 0.00	25.0
	15	104 ± 0.00	26.0	104 ± 0.00	26.0
	30	106 ± 0.00	26.5	104 ± 0.00	26.0
	45	106 ± 0.00	26.5	106 ± 0.00	26.5
	60	106 ± 0.00	26.5	106 ± 0.00	26.5
	75	119 ± 0.00	29.7	106 ± 0.00	26.5
	90	119 ± 0.00	19.7	106 ± 0.00	26.5
		27-30^0C			
	0	104 ± 0.00	26.0	103 ± 0.00	25.0
	15	112 ± 0.00	28.0	103 ± 0.00	25.0
	30	112 ± 0.00	28.0	103 ± 0.00	25.0
	45	119 ± 0.00	19.7	104 ± 0.00	26.0
	60	119 ± 0.00	19.7	106 ± 0.00	26.5

Mean ± SD

Table 4: Log cycle reduction of native microbial flora in Control and TSPEF processed samples

Parameter	Fresh	Heat Pasteurization (Control)	Thermosonication + PEF (TSPEF)
TPC log (cfu/mL)	4.877 ± 0.65	Nil	Nil
Coliforms log (cfu/mL)	4.100 ± 0.60	Nil	Nil
Yeast & Molds log (cfu/mL)	3.861 ± 0.60	Nil	Nil

Mean ± SD

Figure: 1 Ascorbic acid contents of Mango nectar treated by Heat Pasteurization (Control) and Thermosonication + PEF (TSPEF) of storage days at 5^0 C.

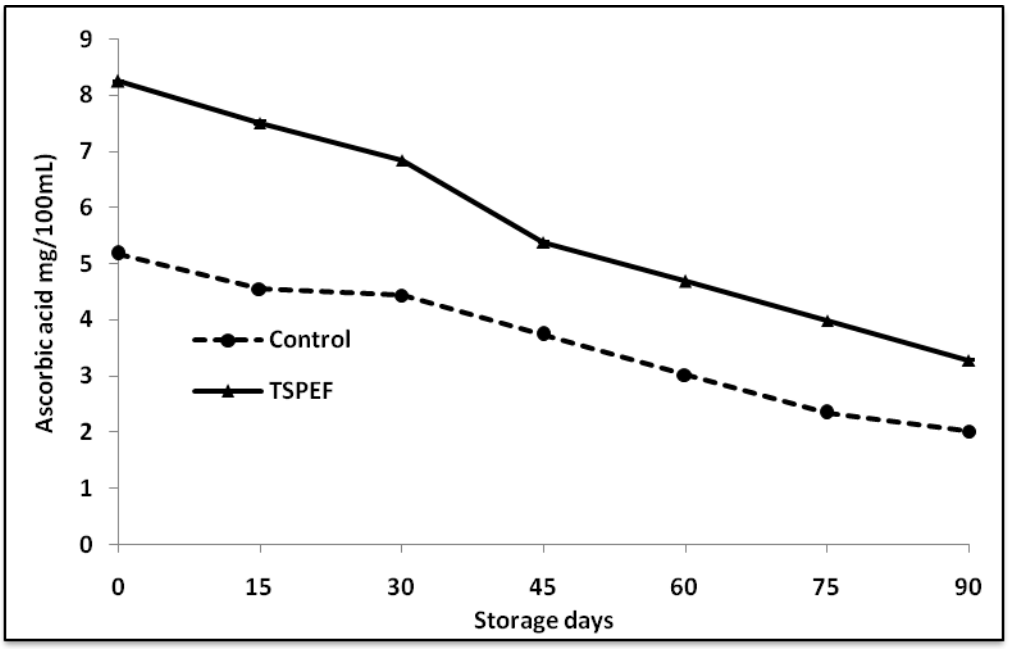


Figure: 2 Ascorbic acid contents of Mango nectar treated by Heat Pasteurization (Control) and Thermosonication + PEF (TSPEF) of storage days at ambient condition (27-30^0 C).

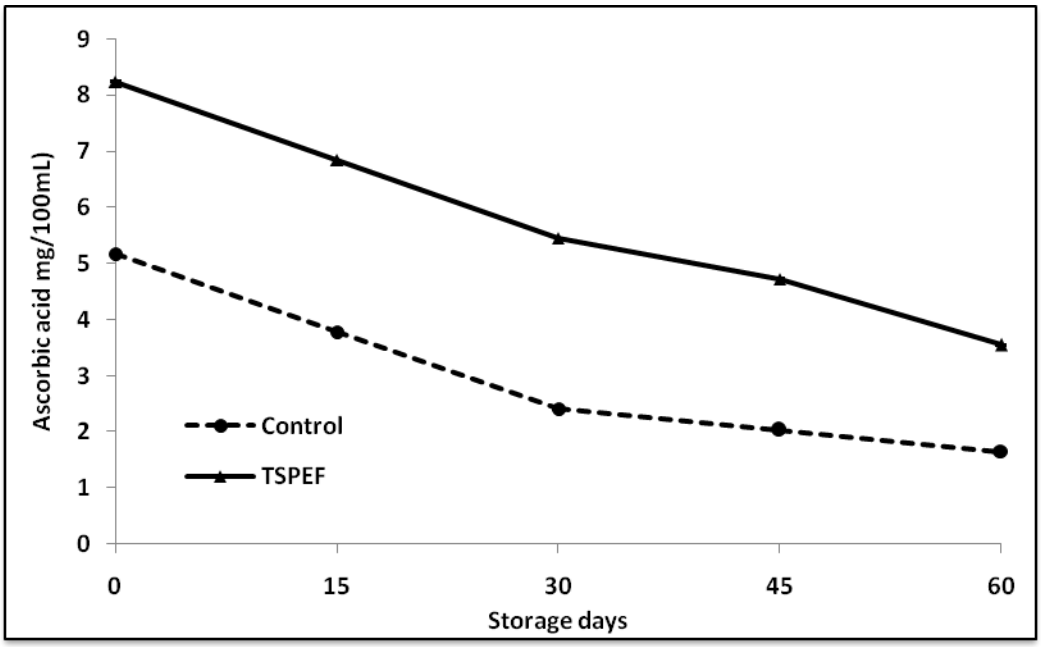


Figure: 3 Carotenoids contents of Mango nectar treated by Heat Pasteurization (Control) and Thermosonication + PEF (TSPEF) of storage days at 5^0 C.

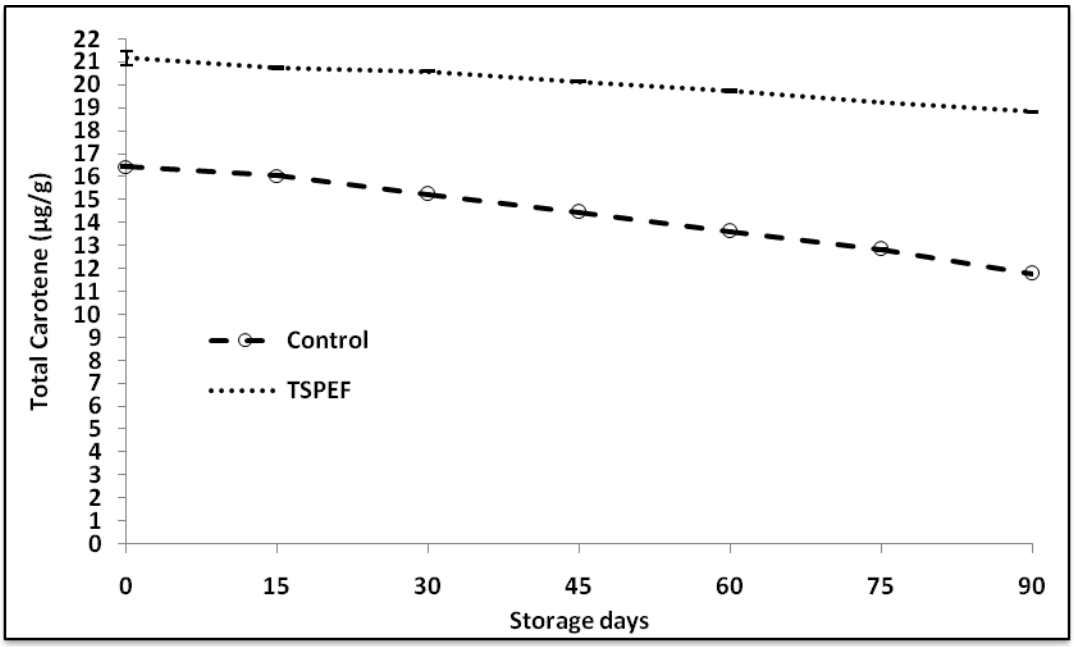
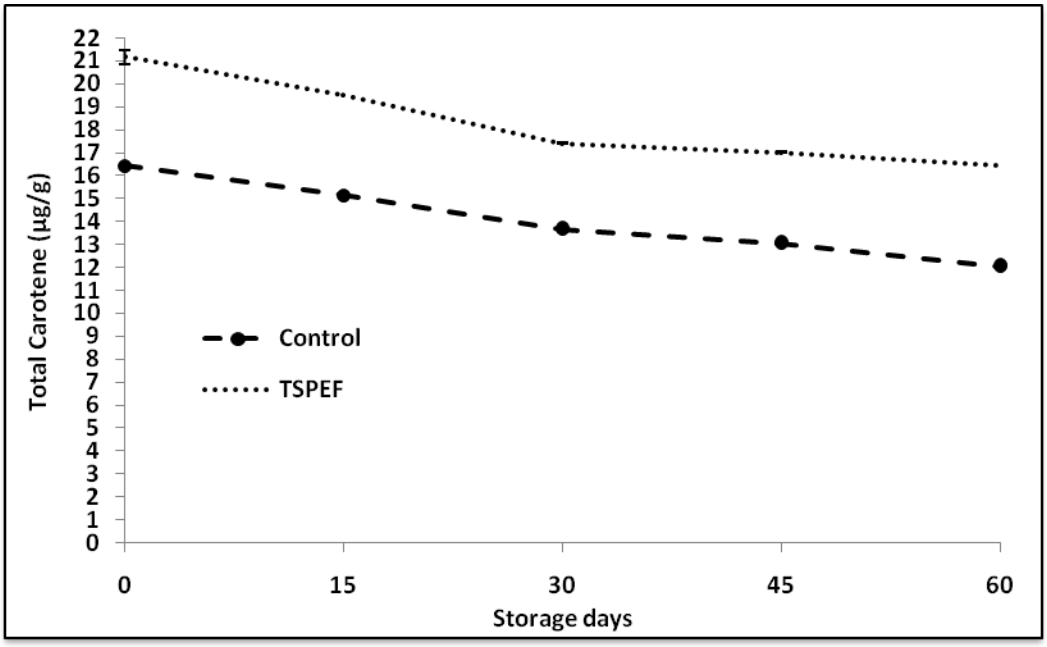


Figure: 4 Carotenoids contents of Mango nectar treated by Heat Pasteurization (Control) and Thermosonication + PEF (TSPEF) of storage days at ambient condition (27-30^0 C).



Conclusion

It was impossible to reach the same microbial and enzymatic inactivation by PEF alone or Ultrasonication technologies alone. Nevertheless, with the combination of Thermosonication the PEF treatment was applied and the acceptable levels of enzyme and microbial inactivation were achieved, and produced mango nectar with sensory properties (odor and taste) and colour more similar to that of untreated nectar than the thermally pasteurized.

Acknowledgement

The research work is in part of author R Kumar's PhD work. The author expresses deep gratitude to The Director, Defence Food Research Laboratory, Mysore for the constant support and encouragement.

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