

IMPACT OF HIGH-INTENSITY PULSED ELECTRIC FIELDS OR THERMAL TREATMENT ON THE QUALITY ATTRIBUTES OF DATE JUICE THROUGH STORAGE

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ABSTRACT

The effects of high-intensity pulsed electric fields (HIPEF) processing (35 kV/cm for 1,000 μ s using pulses of 4 μ s pulses at 100 Hz in bipolar mode) or thermal treatment (90C for 60 s) on total phenols composition, color parameters, 5-(Hydroxymethyl)furfural (HMF), pH, soluble solids and turbidity were assessed in date juice for five weeks under refrigeration storage (4–5C), having as reference the untreated date juice. After processing, HIPEF treated date juice exhibited lower HMF concentration than pasteurized one. HIPEF treatment did not affect color parameters with respect to other date juices after treatments. Turbidity, soluble solids and pH were more preserved in HIPEF treated date juice compared to heated one after processing and along storage. The content of total phenols increased after HIPEF compared to untreated juice.

The HIPEF contributed to the maintain of quality attributes of date juice along refrigeration storage. This process was much better than heat.

PRACTICAL APPLICATIONS

The preservation of foods such as fruit juices, is a primarily interest of food industry. The nonthermal processes of food preservation as HIPEF become more appreciated. HIPEF technology is an innovation because the majority of foods are thermally processed between 60C and 140C, during a time varying from some seconds to some minutes. These types of processing (pasteurization, sterilization, flash pasteurization) cause alterations of the food quality (loss of taste, color and nutriment). But, the demand of consumer is to have a food of high quality. Thus, the use of HIPEF as alternative to thermal process could preserve quality attributes of juice after treatment and through storage.

INTRODUCTION

The dates are typical Tunisian fruits, which have been used for nutritional and medicinal purposes (Alkaabi *et al.* 2011). Dates are high energy foods because of their exceptional richness in sugar, vitamins, minerals and others interesting component such as polyphenols (Al-Farsi *et al.* 2007). In Tunisia, coastal dates are known as secondary or common varieties despite their nutritional value (Rhouma, 1987).

Nonetheless, date juice could be an alternative to avoid the big loss of these fruits. However, the problem in the conservation of date by-products, including juice, is their

quickly deterioration due to the high content of reducing sugars (Chaira *et al.* 2007). To prolong the date juice shelf-life, pasteurization could be a solution, but the presence of reducing sugars, amino acids and high temperature could lead to the Maillard reaction. Such reaction produces compounds such as furfurals that are able to deteriorate the quality of beverages.

The presence of furfural and 5-(Hydroxymethyl)furfural (HMF) in stored products is an indicator of their quality loss. These compounds are related with the browning of the

juice and are also good indicators of the excess of temperature and storage time in some foods (Rodrigo *et al.* 2007; Cortés *et al.* 2008). Consequently, the analysis of these compounds has special importance in food industry.

Conventional thermal processing ensures safety and extends the shelf-life of juices, but it leads to detrimental changes in their sensorial and nutritional quality (Garza *et al.* 1999; Rattanathanalerk *et al.* 2005). On the other hand, consumers desire high quality foods that are nutritious, with freshly prepared flavor, texture and color, with minimal or no chemical preservatives, and above all safe (Ayhan *et al.* 2001; Bull *et al.* 2004; Rivas *et al.* 2006).

In addition, fruit juices, especially date juice, are naturally rich in phenolic compounds (Chaira *et al.* 2007; Kelebek *et al.* 2008; Agcam *et al.* 2014). These molecules, due to their potential for neutralizing free radicals, exhibit many beneficial effects for the human body, either as preventive or even as curing agents for many diseases, such as degenerative diseases and cancer (Flores *et al.* 2013; Kim *et al.* 2013; Agcam *et al.* 2014). In some studies it has been reported that heat processing may partially destroy the phenolic compounds or significantly reduce their bioavailability, thus reducing their beneficial health effects (Turkman *et al.* 2005; Guiné and Barroca 2014). To overcome these shortcomings of heat processing, different processing technologies have been developed as nonthermal emerging technologies for juice processing (Episard 2002; Agcam *et al.* 2014).

High-intensity pulsed electric fields (HIPEF) is a non-thermal technology for liquid foods preservation that leads to high retention or enhancement of the concentration of some bioactive compounds especially phenols in fruit juices (Cortés *et al.* 2008; Odriozola-Serrano *et al.* 2009; Sanchez-Moreno *et al.* 2009; Morales de la Peña *et al.* 2011; Agcam *et al.* 2014). Moreover, it has been reported that HIPEF processing has shown promising results on microbial reduction, enzymatic inactivation (Aguilo-Aguayo *et al.* 2009; Aguiló-Aguayo *et al.*, 2010) and prolonging the shelf-life of liquid foods (Elez-Martinez *et al.* 2006).

Diverse studies have been focused on the effect of HIPEF treatment on the quality parameters and phenolic composition of many fruit juices in comparison with heat treatment (Min *et al.* 2003; Martín-Belloso 2009; Aguiló-Aguayo *et al.* 2010; Morales-de la Peña *et al.* 2010; Sanchez-vega *et al.* 2014; Sanchez-vega *et al.* 2015). However, to the best of our knowledge, there are no studies about the effects of HIPEF processing on the quality attributes and the phenolic composition of date juice. Therefore, the purpose of this study was to evaluate and compare the effects of HIPEF processing and traditional pasteurization (90 °C/60 s) on the content of total phenolic compounds, the color, the HMF concentration and physicochemical parameters of Tunisian date juice. Furthermore, the influence of refrigeration storage (4°C for 5 weeks) on the aforementioned parameters was investigated.

MATERIALS AND METHODS

Date Juice Preparation

The dates (variety Bou-Hattem) were collected from the coastal oasis of Gabes (Tunisia). Dates were washed and seeds removed. Then, the pulp was drained and crushed and water was added in a proportion 1:3 (dates: water) in terms of weight. After that, the mix was filtered through a cheese-cloth. Finally, the filtrate was centrifuged at 8,000 rpm for 20 min at 4°C and the obtained supernatant was considered as the clarified juice (Chaira *et al.* 2007).

HIPEF Treatment

HIPEF treatments were carried out using a continuous-flow bench scale system (OSU-4F, Ohio State University, Columbus, OH), that held monopolar or bipolar square wave pulses located in the University of Lleida, Spain. The treatment system consisted of eight co-field flow chambers in series, each one containing two stainless steel electrodes separated by a gap of 2.92 mm. The treatment flow was controlled by a variable-speed pump (model 75210-25, Cole Parmer Instruments Company, Vernon Hills, IL). The inlet and outlet temperatures of each pair of chambers were monitored during HIPEF treatment and never exceeded 35°C. The temperature was controlled by using a cooling coil connected between each pair of chambers and submerged in an ice-water shaking bath. The date juice was treated by HIPEF treatment applying bipolar square wave pulses of 4 µs, at 35 kV/cm of field strength and a frequency of 100 Hz for 1,000 µs.

Thermal Treatment

Date juice was thermally processed at 90°C for 60 s in a tubular heat exchanger with 2.16 mm inner diameter and 1.10 m length (University of Lleida, Spain). A gear pump was used to maintain the beverage flow rate of 40.5 mL/min. After heating, the beverage was immediately cooled (down to 5 ± 1°C) in a heat exchange coil immersed in an ice water-bath.

Packaging and Storage

Polypropylene sterile bottles of 100 mL were used to store the date juice. The containers were tightly closed and stored at 4 ± 1°C in darkness up to five weeks. The samples were taken for analysis every week.

Total Phenolic Compounds Determination

Total phenolic compounds were determined by the colorimetric method proposed using the Folin-Ciocalteu reagent. A portion of 0.5 mL of date juice was mixed with 0.5 mL of

Folin-Ciocalteu reagent and 10 mL of saturated Na_2CO_3 (for an alkaline environment which triggers the redox reaction). Samples were kept at room temperature in darkness for 1 h. Afterwards, the absorbance was measured at 725 nm using a CECIL 2021 spectrophotometer (Cecil Instruments Ltd., Cambridge, U.K.). Concentrations were determined by comparing the absorbance of the samples with a calibration curve built generated with gallic acid (0–500 mg/L). Results were expressed as mg Gallic Acid Equivalent (EGA) per one liter of juice (mg/L EGA).

Color Measurement

The color parameters L^* (luminosity), a^* (variation between red and green color) and b^* (variation between yellow and blue color) of the date juice was measured using a colorimeter (Minolta CR-400, Konica Minolta Sensing, Inc., Osaka, Japan) at room temperature.

These values were then used to obtain the hue angle (h°) through the Equation 1:

$$h^\circ = \tan^{-1} b^* / a^* \quad (\text{Eq. 1})$$

5-(Hydroxymethyl)Furfural Measurement

The 5-HMF concentration was determined by the method described by Cohen *et al.* (1998). Briefly, 5 mL of ethyl alcohol (950g/L) was added to 5 mL of date juice and centrifuged for 10 min at 5,000 rpm. Then 2 mL of the supernatant, 2 mL of trichloroacetic acid (120 g/L) and 2 mL of thiobarbituric acid (3.60 g/L) solutions were mixed in a 16 mL screw-cap test tube. The tube was heated for 50 min in a water bath at $40 \pm 0.5^\circ\text{C}$. Finally absorbance was measured at 443 nm (Cecil Instruments Ltd.), and a calibration curve at different concentrations of HMF (0–10 mg/L) was used to calculate the HMF concentration.

Turbidity Evaluation

To determinate the turbidity, the technique described by Rivas *et al.* (2006) was followed. The date juice was centrifuged at 1,500 rpm for 10 min at room temperature, and then the absorbance of the supernatant was measured at 660 nm using a CECIL 2021 spectrophotometer (Cecil Instruments Ltd.). The distilled water is used as a blank.

pH and Soluble Solids Determination

The pH was measured by a pH-meter (InoLab, Germany). The soluble solids were measured using a digital refractometer (BRAND, Model 10430, 0–30°Brix, Cambridge Instruments Inc., U.S.A.).

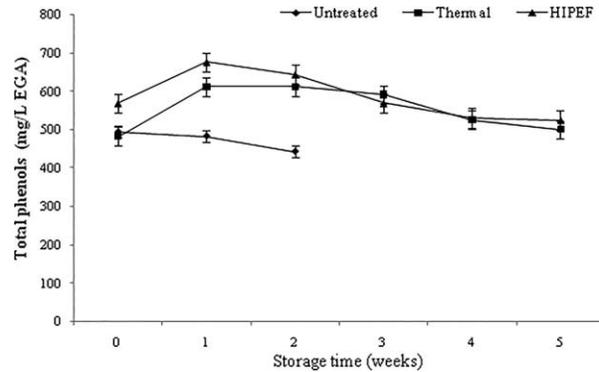


FIG. 1. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON THE CONCENTRATION OF TOTAL PHENOLS OF DATE JUICE DURING REFRIGERATION STORAGE. ERROR BARS REPRESENT MEANS \pm 5D (N = 3)

Statistics

Triplicate measurements were performed for each sample. Differences among treatments ($P < 0.05$) throughout the storage time were evaluated using an analysis of variance procedure and the Tukey method was used to determine differences between means. The statistical procedures were conducted with SPSS (Statistical Package for the Social Sciences) 16.0 for Windows.

RESULTS AND DISCUSSION

Total Phenolic Compounds

The effects of HIPEF and heat treatments on total phenolic compounds of date juice are shown in Fig. 1. The highest phenolic content (statistically significant) in date juice was observed after HIPEF treatment (569.552 ± 5.240 mg/L EGA) in comparison with untreated juice (483.320 ± 10.330 mg/L EGA) and thermally treated juice that increases slightly (494.350 ± 3.790 mg/L EGA). Agcam *et al.* (2014) studied the processing of orange juice by HIPEF and thermal pasteurization aiming to compare changes in total phenolic concentration before and after storage at 4°C for 180 days. Their results showed that the orange juice samples processed with the application of high energy (HIPEF) had higher phenolic content than those processed with the application of low energy (heat). The explanation laid in the fact that extraction of intracellular contents is enhanced by PEF treatment, in a way that permeabilization of plant cells can be used to increase yield in the production of fruit juices, enhance the extraction of intracellular metabolites, and increase the extraction efficiency of processes (Agcam *et al.* 2014). In general, the processed juice samples had higher

TABLE 1. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON COLOR PARAMETERS OF DATE JUICE DURING REFRIGERATION STORAGE

Storage time (weeks)	Treatments	Color parameters			
		L*	a*	b*	Hue
0	Untreated	27.380 ± 1.15b	-0.073 ± 0.015a	1.210 ± 0.104b	-86.533 ± 4.95b
	Thermal	28.563 ± 0.64c	-0.207 ± 0.023a	0.660 ± 0.26d	-72.61 ± 4.09d
	HIPEF	27.517 ± 2.13e	-0.170 ± 0.038b	1.117 ± 0.040a	-89.143 ± 1.43c
1	Untreated	26.733 ± 2.11a	-0.097 ± 0.015ab	0.913 ± 0.12a	-83.953 ± 1.95a
	Thermal	27.570 ± 1.05a	-0.340 ± 0.010ab	0.370 ± 0.15a	-47.413 ± 0.54a
	HIPEF	26.833 ± 0.60b	-0.100 ± 0.020ab	1.027 ± 0.06a	-84.438 ± 1.08ab
2	Untreated	27.957 ± 2.13c	-0.138 ± 0.028b	1.243 ± 0.12b	-83.65 ± 1.27a
	Thermal	28.283 ± 0.60b	-0.230 ± 0.020d	0.717 ± 0.12e	-72.212 ± 0.72d
	HIPEF	26.967 ± 1.20ab	-0.070 ± 0.042ab	1.163 ± 0.06b	-86.555 ± 2.10b
3	Untreated	-	-	-	-
	Thermal	28.223 ± 1.22b	-0.357 ± 0.035a	0.477 ± 0.025b	-53.205 ± 1.27b
	HIPEF	27.287 ± 0.60d	-0.133 ± 0.015a	1.033 ± 0.12a	82.646 ± 0.81b
4	Untreated	-	-	-	-
	Thermal	28.660 ± 1.75d	-0.250 ± 0.017cd	0.603 ± 0.06c	-67.481 ± 1.32c
	HIPEF	27.040 ± 1.32a	-0.130 ± 0.072a	0.803 ± 0.055a	-80.807 ± 0.59a
5	Untreated	-	-	-	-
	Thermal	28.71 ± 0.50d	-0.294 ± 0.021bc	0.608 ± 0.35c	-64.139 ± 2.01c
	HIPEF	27.108 ± 3.61c	-0.142 ± 0.020a	0.822 ± 0.06a	-80.147 ± 0.75a

Values are expressed as mean ± SD ($n = 3$). Different letters in the same column indicate significant differences ($P < 0.05$).

L*, luminosity; a*, variation between red and green color; b*, variation between yellow and blue color; and Hue, Hue angle.

phenolic acid contents than the untreated juice samples (Guiné and Barroca, 2014).

During refrigeration storage (Fig. 1), an increment in the content of total phenolic compounds both in thermally (612.537 ± 10.330 mg/L EGA) and HIPEF-processed (677.014 ± 3.070 mg/L EGA) date juices was observed after one week (Fig. 1). The same conclusions were achieved by Piljac-Zegarac *et al.* (2009) whom observed that thermally treated juices (cranberry, strawberry, cherry and blueberry) presented an increment of total phenols at two weeks of refrigeration storage. Phenolic compounds are chemically diverse and found in different locations and forms in plant tissue and cells (Kalt, 2005). The stress conditions, such as processing and overheating can provoke changes and reactions on the fruit phenolic content (Joslyn 1957; Agcam *et al.* 2014).

In fact, the biochemical reactions that occur as consequence of food processing and storage could lead to the formation of new compounds, this could be explained by the fact that phenolic compounds (usually stored in vegetables pectin or cellulose) may be released during processing (Patras *et al.* 2009; Piljac-Zegarac *et al.* 2009) and/or by partial degradation of the combined forms during extraction or processing (Guiné and Barroca, 2014).

In addition, the concentration of phenolic compounds can be affected by the presence of some enzymes, such as polyphenol oxidase (PPO) and phenylalanine ammonialyase (PAL), this is the enzyme responsible for phenolic biosynthesis. The induction of PAL activity by process could increase the accumulation of phenolic compounds (Aguilo-Aguayo *et al.* 2009).

From the second week of storage, the concentration of phenols decreased, but it remained at superior levels in comparison with the untreated juice.

Color

The effects of processing and storage on color parameters L^* , a^* , b^* and h° of date juice are shown in Table 1. HIPEF processing of date juice had negligible effects on these parameters ($L^* = 27.517 \pm 2.130$, $a^* = -0.170 \pm 0.038$, $b^* = 1.117 \pm 0.040$, $h^\circ = -89.143 \pm 1.430$) compared to thermally processed and unprocessed juices.

Right after HIPEF processing, lightness (L^*) of date juice increased slightly (27.517 ± 2.130) (nonstatistically significant) compared to untreated one (27.380 ± 1.150), whereas, heat treated juice showed a significant increase in the parameter L^* (28.563 ± 0.64) compared to other juices. Our results agreed with the results obtained by Rivas *et al.* (2006) who did not obtain significant variations in the luminosity after applying HIPEF (25 kV/cm, 280 μ s) to orange-carrot juice.

Cortés *et al.* (2008) observed that the parameter L^* also increased in the juice treated by HIPEF (52.230) and in thermally treated juice (52.410) compared with untreated orange juice (51.360). Cserhalmi *et al.* (2006) reported the same results with the HIPEF processed and pasteurized orange juices in that CIE L^* increases after treatments compared to control. Similar results were described by Aguilo-Aguayo *et al.* (2010), who processed watermelon juice by

HIPEF and thermal treatment and observed a significant difference in L^* .

During storage (Table 1), lightness decrease significantly in untreated juice and thermally processed one. The HIPEF processed juice showed less variation. The decrease in L^* could be explained by the formation of dark compounds from Maillard reaction such as HMF that enhanced over time (Yeom *et al.* 2000). This decrease can also be attributed to partial precipitation of unstable suspended particles in date juices.

The mean CIE a^* , that indicates the variation between red and green color, is significantly higher in untreated juice (-0.073 ± 0.015) than in processed juices. The value of this parameter for the HIPEF date juice is -0.170 ± 0.038 and -0.207 ± 0.023 for pasteurized juice, observing significant differences ($P \leq 0.05$) between them. Similar results were obtained by Cortés *et al.* (2008) for orange juice, in with this parameter decreased after HIPEF processing.

The color shift toward negative a^* and positive b^* directions indicates less red and more yellow in date juices. CIE a^* values decrease significantly ($P \leq 0.005$) during refrigeration storage for untreated and pasteurized date juice. For HIPEF processed juice, it increases and it was more preserved during storage compared to other juices. Otherwise, the existence of an initial period, in which red pigments are probably liberated in the juice, would explain the trend observed in color of treated juices over time (Aguiló-Aguayo *et al.* 2010). Nevertheless, the increase in redness was appreciated in HIPEF processed juice. As a result of the HIPEF treatment at temperature lower than 35°C, cell membrane and protein-carotenoids complex may be disrupted, providing more red pigments in the juice (Aguiló-Aguayo *et al.* 2010).

Concerning CIE b^* , it decreased significantly after pasteurization by comparison to untreated date juice and HIPEF processed one in which b^* was better preserved immediately after processing and during refrigeration storage.

The parameter b^* decreases considerably during storage in the untreated and heat processed juices. This parameter was unstable for these juices compared to HIPEF treated date juice in which the decrease of b^* was lower. Rodrigo (2007) describe a significant decrease of the parameter b^* when they analyze pasteurized orange-carrot juices.

The h° value is related to the intensity of the red chromaticity. After HIPEF processing, h° decreases (-89.143 ± 1.430) compared to thermally treated date juice (-72.610 ± 4.090) that increases significantly by comparison to untreated juice (-86.533 ± 4.950). This color index showed a statistically significant increase in heat processed date juice during refrigeration storage and it was unstable compared to HIPEF processed juice in which color parameters were better preserved during storage.

In the same way, Cortés *et al.* (2008) observed a higher change in the color of a heat pasteurized orange juice

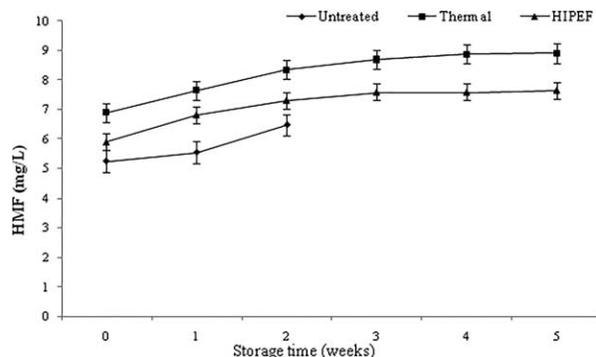


FIG. 2. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON 5-(HYDROXYMETHYL) FURFURAL (HMF) CONTENT OF DATE JUICE DURING REFRIGERATION STORAGE. ERROR BARS REPRESENT MEANS \pm SD (N = 3)

through refrigerated storage compared to a HIPEF processed juice.

5-(Hydroxymethyl)–2-Furfural

The values of HMF content are 5.250 ± 1.260 mg/L, 6.900 ± 0.500 mg/L and 5.899 ± 1.150 mg/L for untreated, heated and HIPEF treated date juices, respectively (Fig. 2). There were statistically significant variations ($p = 0.000$) between all date juices immediately after processing. Aguiló-Aguayo *et al.* (2009) reported lower HMF concentration in strawberry juice after HIPEF processing (35 kV/cm for 1,700 μ s using squared-wave pulses of 4 μ s and a pulse frequency of 100 Hz) than those processed by heat. Similarly, Cortés *et al.* (2008) reported different HMF values after processing (Untreated = 0.088 mg/L, thermal = 0.115 mg/L, HIPEF = 0.089 mg/L) of orange juice. The increase of HMF content in thermally treated juice could be due to the accelerator effect of temperature on Maillard reaction in the presence of reducer sugar (glucose and fructose) and acids in date juice. The slow browning rates observed in the HIPEF-processed date juice by comparison to heated juice could be related to the high retention of acid in the juice. In fact, when the ascorbic acid is not oxidized it does not provide reactive carbonyl group. These compounds could be precursors of nonenzymatic browning reaction that lead to the formation of furfurals such as HMF (Aguiló-Aguayo *et al.* 2009).

During the storage (Fig. 2), the content of HMF increased significantly for untreated juice and thermally treated juice after one week of storage contrarily to HIPEF treated juice that increased slightly ($P < 0.05$). After two weeks of storage, the concentration of HMF in the untreated juice increased significantly. The increment of the HMF in treated juices was not significant during storage. Similarly to our findings, Rodrigo *et al.* (2007) observed a slight increase in HMF content during six weeks of refrigeration storage of orange-carrot juices treated by HIPEF.

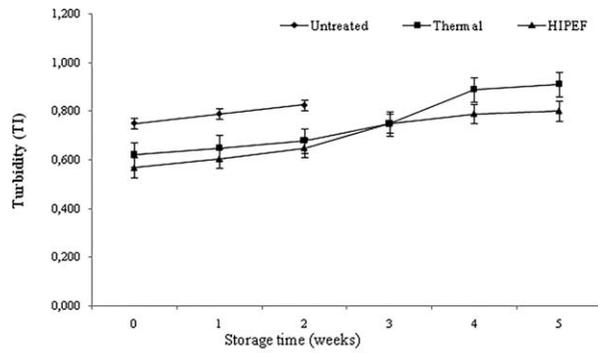


FIG. 3. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON TURBIDITY OF DATE JUICE DURING REFRIGERATION STORAGE. ERROR BARS REPRESENT MEANS \pm SD (N = 3)

The content of HMF in untreated and treated date juices was slightly higher than the maximum values allowed (5 mg/L) by the Association of the Industry of Juices and Nectars from Fruits and Vegetables.

Turbidity, pH and Soluble Solids

Figure 3 shows the difference on the turbidity index (*TI*) after processing and during storage of different date juices analysed. The turbidity is one of the most important indexes of fruit juice quality (Chandler and Robertson, 1983).

Thermally treatment and HIPEF treatment decreased the *TI* of date juice, compared to untreated one. The *TI* decreases from 0.750 ± 0.050 for untreated juice to 0.623 ± 0.030 for heated juice and 0.569 ± 0.030 for HIPEF-processed juice. This difference was statistically significant between control (untreated) juice and HIPEF treated juice, and was nonsignificant ($P = 0.005$) between the HIPEF treated juice and thermally processed juice. These values were less than those obtained by Rivas *et al.* (2006) for thermally treated carrot juice (1.310).

During storage (Fig. 3), turbidity increased with respect to the time. This variation on turbidity was not significant for processed juices until the fifth week of storage. The untreated juice had the highest value of turbidity; it spoiled after two weeks of refrigeration storage. According to Rivas *et al.* (2006), the main goal of any conservation treatment of juice is to reduce the activity of pectinmethylesterase that is an enzyme responsible for the loss of turbidity and hence the loss of the quality of the juice.

The effects of processing and storage time on the pH are shown in Fig. 4. After HIPEF treatment, pH increased slightly (3.830 ± 0.100) with regard to the untreated juice (3.780 ± 0.152) ($P < 0.005$).

For thermal treatment, there was a significant increase ($P < 0.005$) of the pH value (3.85 ± 0.250) compared to the control.

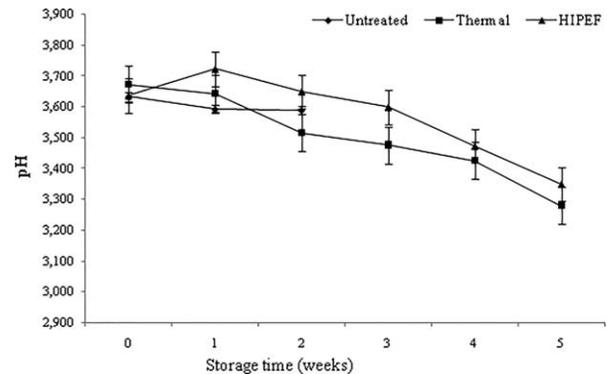


FIG. 4. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON pH OF DATE JUICE DURING REFRIGERATION STORAGE. ERROR BARS REPRESENT MEANS \pm SD (N = 3)

The pH decreased with storage time in untreated juice and processed date juices. The pH changed from 3.830 ± 0.100 to 3.590 ± 0.230 and from 3.850 ± 0.250 to 3.580 ± 0.152 for date juices processed by HIPEF and heat, correspondingly after five weeks of storage. Bull *et al.* (2004) obtain significant modification in pH of pasteurized orange juice during refrigeration storage.

Wang *et al.* (2006) observed a reduction of pH during conservation of the carrot juice. These authors assigned the reduction out of total sugars, amino acids and pH with the reaction of Maillard. They allotted the fall of pH to the formation of the 5-HMF formed in the reaction of Maillard, which needs a carbonyl function and a free amine function. Thus, during the reaction of condensation between a carbonyl function and a function amine of an amino acid there can be a reduction in the pH of the medium because the function amine disappears whereas the carboxylic acid function can be always expressed (Wang *et al.* 2006).

Contrarily, Esteve *et al.* (2005) and Rodrigo *et al.* (2007) did observe significant differences in the pH values neither

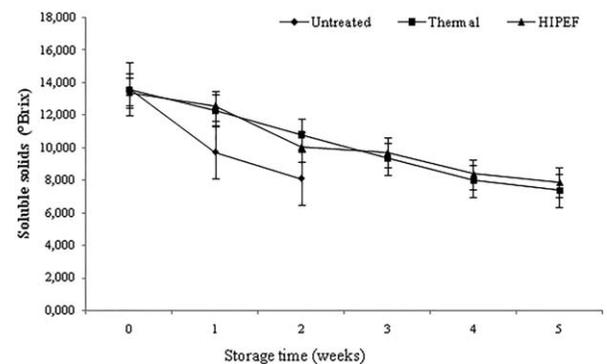


FIG. 5. EFFECTS OF HIPEF AND THERMAL TREATMENTS ON SOLUBLES SOLIDS (°Brix) OF DATE JUICE DURING REFRIGERATION STORAGE. ERROR BARS REPRESENT AVERAGE OF THREE REPLICATES \pm SD (N = 3)

after pasteurization nor during refrigeration storage of orange and orange-carrot juices.

After HIPEF, we observe a decrease on the soluble solids content (13.100 ± 2.060) in comparison with untreated juice (13.600 ± 0.500) and thermally treated juice (13.500 ± 1.410) as shown in Fig. 5. The difference was not statistically significant for heating treatment by comparison to untreated juice.

After a week of storage there was an increase of the soluble solids content, and then it decreased. In fact, the decrease of soluble solids could be related to the Maillard reaction that converts sugars into new compounds. This decrease in °Brix could be, also, due to microbial deterioration, especially, on the untreated juice that spoiled after two weeks of storage (Wang *et al.* 2006). Cortés *et al.* (2008) and Rivas *et al.* (2006) reported similar tendencies for thermally and HIPEF treated orange juice and for a pasteurised and HIPEF processed orange-carrot juice in that order.

CONCLUSION

The feasibility of HIPEF (35 kV/cm for 1,000 μ s using pulses of 4 μ s pulses at 100 Hz in bipolar mode) to preserve the nutritional and physicochemical characteristics of date juice after treatment and during five weeks of refrigeration storage (4–5°C) by comparison to untreated juice and thermally processed (90°C for 60 s) juice was demonstrated in this study. The benefits of the date juice related to phenolic composition enhanced after HIPEF processing. In fact, total phenolic compounds increased after HIPEF ($569.552 \pm$ mg/L EGA) and was better preserved through storage than that untreated and heat processed. In addition, HIPEF did not seem to greatly affect the color parameters and got reduce HMF content of date juice after processing and during storage (HMF = 5.250 ± 1.260 mg/L for HIPEF; HMF = 5.899 ± 1.150 mg/L for heat treatment). Physicochemical characteristics (pH, °Brix and turbidity) were more preserved in HIPEF by comparison to thermally treated and untreated date juices. Thus, HIPEF was the best food processing technology for preserving the date juice features.

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