Effect of Ohmic Heating on Quality Parameters of Sapota Juice

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Abstract: ***Sapota fruit is a good source of sugars, ascorbic acid, iron and calcium but due to high moisture (72-75%) and TSS content (12-20 ˚Brix), the fruit gets spoiled fast and need to be processed into value added product to extend the shelf life. Experiments were conducted to study the effect of ohmic heating on quality parameters of sapota juice and to extend its shelf life. The study was designed using response surface methodology employing the rotatable central composite design which generated 13 experiments. The independent variables were: electric field strength (15 V/cm – 30 V/cm) and processing time (30 s – 120 s). The responses were pH, titratable acidity, total soluble solids, ascorbic acid, reducing sugars, total colour change. The pH and titratable acidity were significantly (p<0.05) affected by ohmic heating, whereas there was no significant effect of ohmic heating on ascorbic acid, reducing sugars, total soluble solids and total colour change of sapota juice. The sapota juice processed with optimum parameters had a shelf life of 10 days whereas fresh unpasteurized juice stored at refrigerated conditions deteriorated within 5 days.***

Keywords: Sapota juice, Ohmic heating, Rotatable central composite design, Ascorbic acid.

I. INTRODUCTION

Sapota is tropical fruit which is consumed all over the world. It is believed to be native to Yucatan and possibly other nearby parts of southern Mexico, north Belize and central America. Sapota contains ascorbic acid content about 10.52 mg/100g of fruit, carotenoid content of 0.92 mg/100g, total phenolic content 134.6 mg/100g, iron content about 0.11 ppm, calcium 20.67 ppm, zinc 0.50 ppm, potassium 6.15 ppm. The medicinal properties of sapota are due to chemical constituents such as polyphenols, ascorbic acid, glycoside etc. It is an excellent source of nutrients that are useful in management of many diseases viz., inflammation, pain, diarrhoea etc. Traditionally it was used as diuretic, expectorant and in opthalmology [1]. Due to its health benefits, sapota is consumed either fresh or in form of juice. Shelf life of the sapota juice is limited by its high moisture and sugar level and hence it is also processed into value added products viz., sapota powder, nectar, jam, jelly, milkshake and osmo-dehydrated slices.

Over past decade the novel technologies are explored as an option for processing of fruit and vegetables as there is more loss of nutrients by conventional method of processing. One such technology is ohmic heating which is a thermal processing method in which an alternating electrical current is passed through food products to generate heat internally. Due to volumetric heating and shorter processing time there is retention of more nutrients by ohmic heating compared to conventional heating method. Ohmic heating has been studied for a variety of applications like preheating, blanching, pasteurization and enzyme inactivation in various food products [2, 3, 4]. However, no work has been published for its application on sapota juice. Therefore, present study aimed to study the effect of ohmic heating on quality parameters of sapota juice and its shelf life extension.

II. MATERIALS & METHODS

A. Materials

Matured and firm sapota was procured from Azadpur mandi, Delhi (India). All the chemicals and reagents ued during the research work of analytical grade procured from Sisco Research Laboratories Pvt. Ltd. (Mumbai, India) and Fisher Scientific (Mumbai, India).

B. Sapota juice extraction

The sapota fruit was kept overnight for ripening so that maximum amount of juice can be extracted. Ripened fruit was subjected to blanching at 60 ˚C for 10 minutes [5], cooled immediately under running tap water. Then process of peeling and pulping was done, thereafter juice was extracted through the screw expeller. The extracted juice was filtered through four layered muslin cloth to remove pulp or any other impurities that escaped through expeller.

C. Ohmic heating treatment

Laboratory scale ohmic heating setup was developed as described by Sagong et al. [4] with modifications of using stainless steel electrodes of grade SS 304 (Fig. 1). The ohmic heating chamber comprised of 250 ml borosilicate glass beaker and electrodes of cross sectional area of 4 cm ×3 cm ×0.2 cm. The gap maintained between electrodes was 4 cm. A digital thermometer with a probe was used to measure the temperature, inserted at center of the chamber to a depth that it is immersed into the juice. An alternating current of 50 Hz was supplied through a dimmerstat which can vary the applied voltage. The multi-meter was connected across the electrode to measure the voltage. An ammeter was connected in series with dimmerstat to electrode to measure the current flowing through the circuit. The ohmic heating setup was arranged and about 150ml of extracted sapota juice was loaded in the heating chamber, the electrodes and thermometer probe were inserted in juice and the juice was stirred slowly to ensure uniform temperature over the juice using a magnetic stirrer, the electric field applied across the juice was controlled using dimmerstat and the times period of processing are monitored as per design of experiment. The temperature, voltage and current data was recorded in every 10 second interval. Juice after heating was cooled immediately to arrest the thermal degradation using chilled water bath.

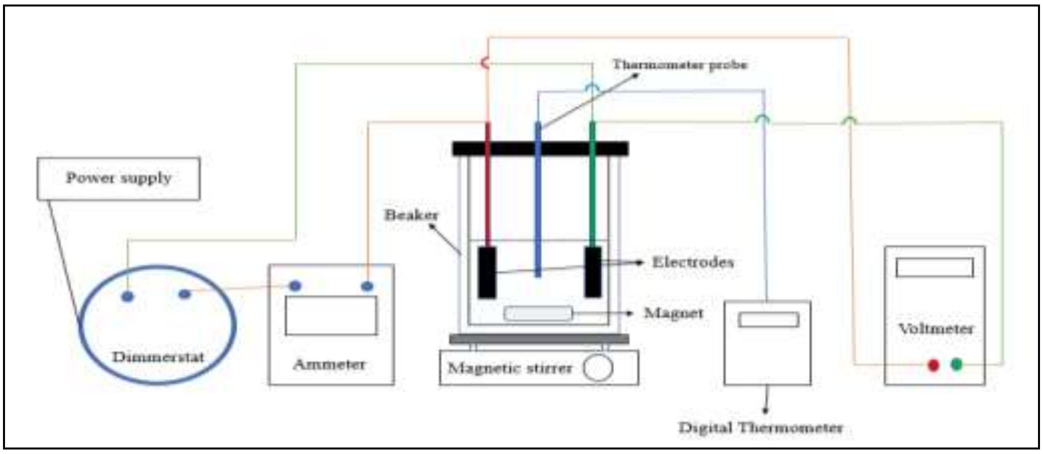

Figure 1 Ohmic heating setup

D. Design of experiment

The experiments were designed as per rotatable central composite design (RCCD) and effects of the independent variables on the responses were analysed using response surface methodology (RSM). RSM is a collection of statistical and mathematical techniques for building of empirical model, with objective to optimize the influence of independent variables (input variables) on a response (output variable). The RSM provides a relation between independent variable and one or more dependent variables (responses) in form of a following quadratic equation;

$$Y = a_0 + a_1X_1 + a_2X_2 + a_{11}X_1^2 + a_{22}X_2^2 + a_{12}X_1X_2 \quad (1)$$

Where Y is dependent variable or responses, a_n are the Model constants, X_1 and X_2 are the independent variables. The independent variables were; Electric field strength and processing time and dependent variables were quality parameters of sapota juice *viz.*, titratable acidity, pH, total soluble solids, ascorbic acid, reducing sugar and total colour change. The coded and real values of independent variables are shown in Table 1 and the rotatable central composite design matrix with studied responses is shown in Table 2.

Table 1 Coded and real values of independent variables for Rotatable central composite design

Independent variables	**Coded Symbols**	**Coded levels**				
		$+\alpha_m$	+1	0	-1	$-\alpha_m$
Electric Field strength (V/m)	*X*1	30	27.8	22.5	17.2	15
Time (seconds)	*X*2	120	106.8	75	43.2	30

Table 2 Rotatable central composite designs with independent variables and studied response

Treatment	**Independent variables**		**Studied responses**					
	*X*1	*X*2	TA	pH	TSS	Ascorbic acid (mg/100 ml)	Reducing sugar (%)	ΔE^*
T0	-	-	0.205	5.38	21	26.93	10.17	-
T1	27 (+1)	107 (+1)	0.179	5.62	22	24.10	9.42	5.63
T2	27 (+1)	43 (-1)	0.198	5.49	22	24.27	9.82	6.42
T3	17 (-1)	107 (+1)	0.180	5.65	22	23.27	9.13	7.58
T4	17 (-1)	43(-1)	0.199	5.47	22	23.77	9.71	5.68
T5	23 (0)	75 (0)	0.194	5.49	21	23.60	9.52	5.93
T6	23 (0)	75 (0)	0.194	5.54	22	23.43	8.96	6.00
T7	22 (0)	75 (0)	0.195	5.56	22	23.77	9.43	5.99
T8	23 (0)	75 (0)	0.195	5.51	22	23.93	9.86	6.03
T9	23 (0)	75 (0)	0.196	5.45	21	23.77	9.38	6.05
T10	30 ($+\alpha_m$)	75 (0)	0.193	5.48	22	23.13	9.07	5.06
T11	15 ($-\alpha_m$)	75 (0)	0.192	5.48	22	23.69	9.28	5.07
T12	23 (0)	120 ($+\alpha_m$)	0.175	5.70	22	23.77	9.16	4.59
T13	23 (0)	30 ($-\alpha_m$)	0.202	5.40	22	24.93	9.64	4.84

Here, *X*1 = Electric field strength (V/m), *X*2 = Time (seconds), TA = Titratable acidity, TSS = total soluble solids.

E. Analysis of total soluble solid, pH and colour score of the sapota juice

Sapota juice after treating with ohmic heating was analysed for total soluble solids using hand refractometer (Model ATAGO, 0-32 BRIX IP65). The pH was measured using pH meter (Systronics Digital pH meter 335) as per the protocol given by Makroo et al. [6]. The juice was filled in glass bottle, sealed and colour of sapota juice was measured using CR-400 Chroma meter. The colour values were expressed ΔE^* score, which represents the overall colour change.

F. Analysis of titratable acidity, ascorbic acid and reducing sugar

Titratable acidity and ascorbic acid content were measured as per the protocol given by Ranganna [7]. The reducing sugar was analyzed as explained by Miller [8].

G. Optimisation of ohmic heating parameters

The processing parameters were optimised using design expert version-11 software. During the optimization certain constraints were fixed for independent variables and responses. The best solution generated by the software is near to set constraints. The solution with highest desirability score is chosen as optimised solution.

H. Changes in the sensory attributes of untreated and treated sapota juice during storage

The juice was analysed for sensory score using 9-point hedonic scale (where, 9 = like extremely and 1 = dislike extremely). The evaluation was done by 25 semi-trained panelist comprising faculty and PhD scholars of National Institute of Food Technology Entrepreneurship and Management (NIFTEM), India. During evaluation it was ensured that there was enough lighting and comfort zone for sensory panel and water was kept as neutral food to clean mouth before tasting each sample.

I. Microbial enumeration of untreated and treated sapota juice during storage

Sapota juice after the treatment packed in glass bottles, sealed with crown cap and stored in refrigerator. The shelf life of sapota juice was estimated in terms of its sensory attributes and microbial enumeration in each 5 days interval for 15 days. The microbial enumeration was done by serial dilution method followed by pour plate method using nutrient agar for total plate count, potato dextrose agar for yeast and mould count. The sample was diluted to 10^{-3} dilution using maximum recovery diluent. Before starting the enumeration, all required material like petri plates, marker, micropipette, cotton, alcohol, spirit lamp, all pre-sterilised media and diluent along test tube are placed in laminar air flow chamber for UV sterilisation for 15 minutes. After sterilisation the sample is diluted using recovery diluent and 1ml of diluted sample from required dilution is transferred to petri plate and the required media is poured and care is taken that media is not too hot that it will kill the microbes. After pouring allow the media to solidify and incubate at 37˚C for total plate count agar and 32˚C for yeast and mould colonies. After incubation of 48 hours, the colonies are counted using colony counter and results were expressed as cfu/ml of the sample.

J. Statistical analysis

Experimental designing and optimization was carried out using RRCD design of Design-Expert version.11 (Stat-Ease, Inc., Minneapolis, MN, USA). Data of triplicate readings were analysed using Analysis of variance (ANOVA) at 95% confidence level.

III. RESULTS & DISCUSSION

A. Effect of independent factors on pH and titratable acidity

There was significant effect of electric field strength and processing time on pH and titratable acidity of sapota juice ($p < 0.05$) as shown in Table 2. The quadratic equations for pH and titratable acidity are shown below;

$$\text{pH} = 5.49 - 0.0013X_1 + 0.0918X_2 + 0.0056X_1^2 + 0.0406X_2^2 - 0.0125X_1X_2 \quad (2)$$

$$\text{Titratable acidity} = 0.1948 - 0.0001X_1 - 0.0095X_2 - 0.0015X_1^2 - 0.0035X_2^2 + 0X_1X_2 \quad (3)$$

The 3-D surface plot for pH and titratable acidity are shown in Fig. 2. Results showed that at lower applied electric field strength, there was more increase in pH compared with higher applied electric field strength. Similar findings were reported by Makro et al. [6] in case of water melon juice. Similar results were also reported by Boldaji et al. [9] in case of tomato paste processing by ohmic heating method. The change in pH is affected by the residence time of sample during ohmic heating, at higher applied electric field strength, the rate of heating is fast and need less time to heat compared to residence time at lower voltages. Electrochemical reaction takes place during ohmic heating such as electrolysis of water and corrosion of electrodes which will increase the pH of sample if residence time is higher. From Fig. 2, it can be explained that there was decrease in titratable acidity of sapota juice by ohmic heating. The change in titratable acidity can related to electrochemical reactions taking place during ohmic heating such as hydrolysis of sample and corrosion reaction at electrodes.

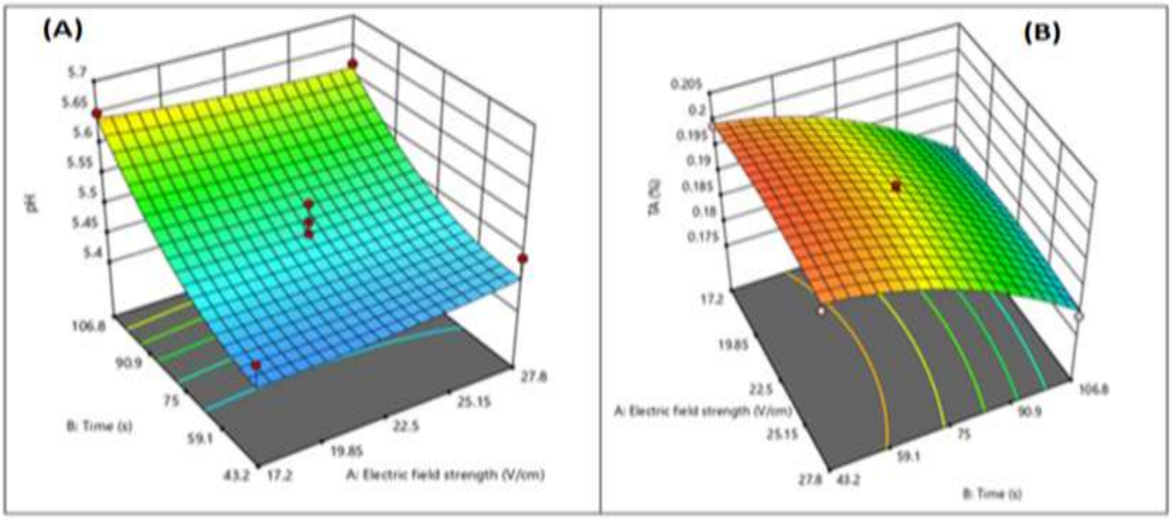

Figure 2 Effect of independent variables on pH (A) and titratable acidity (B)

B. Effect of independent factors on total soluble solids and ascorbic acid content

Table 2 showed that electric field strength and processing time had no significant effect on total soluble solids of sapota juice ($p>0.05$). The quadratic equation for the total soluble solids can be written as under;

$$TSS = 21.60 + 0X_1 + 0X_2 + 0.2X_1^2 + 0.2X_2^2 + 0X_1X_2 \quad (4)$$

The 3-D surface of total soluble solid content also revealed the same (Fig. 3). Similar findings were also observed by Makroo et al. [6] for water melon juice subjected to ohmic and conventional heat treatment.

It was also reported that electric field strength and processing time had no significant effect on ascorbic acid content of sapota juice (Fig. 3). The quadratic equation for the ascorbic acid can be written as under;

$$\text{Ascorbic acid} = 23.70 + 0.0842X_1 - 0.2896X_2 - 0.1687X_1^2 + 0.3229X_2^2 + 0.0833X_1X_2 \quad (5)$$

Results revealed that ascorbic acid content was found to be decreasing with increase in processing time at all levels of applied electric field, but the decrease in ascorbic acid content was not much significant as the temperature attained during processing was less. The ascorbic acid content has decreased to a maximum of 23.13 mg/100ml from 26.93 mg/100 ml of juice. Assiry et al. [10] reported that there was decrease in ascorbic acid content during ohmic heating they have stated that the degradation is due to electrolysis of water which generates oxygen molecules that leads to oxidation of ascorbic acid content and corrosive reactions occurring at electrodes.

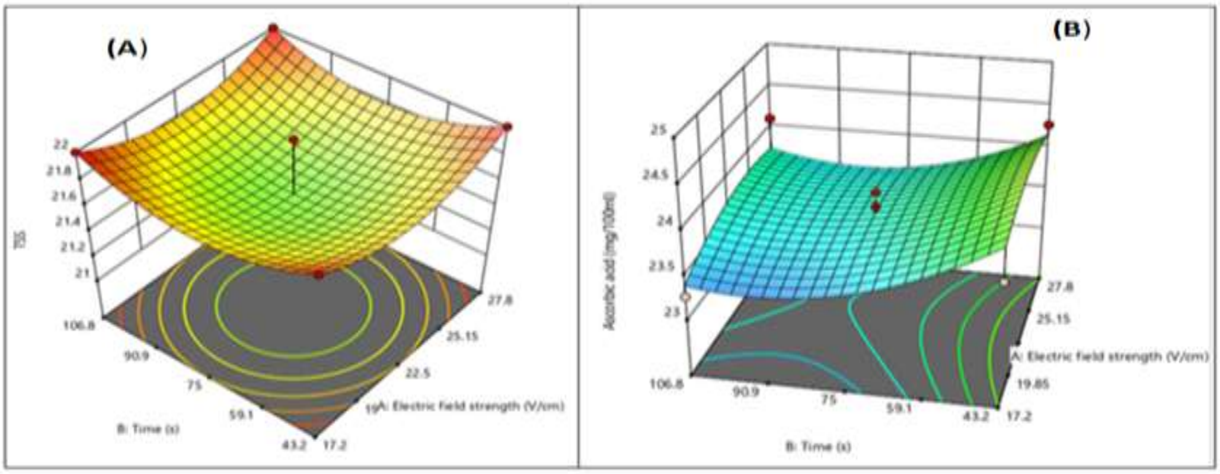

Figure 3 Effect of independent factors on total soluble solids (A) and ascorbic acid content (B)

C. Effect of independent factors on reducing sugars and overall colour difference

Table 2 showed that there was no significant effect of electric field strength and processing time on reducing sugar content of sapota juice (p>0.05). Results showed that reducing sugar content was not much affected by ohmic heating at all the levels of applied electric field strength (Figure 4). The maximum decrease of 8.96% from 10.17% in reducing sugars was observed at treatment 6 of electric field strength 22.5V/cm and treatment period of 75 s. The average reducing sugar content after all treatments was 9.413±0.289%. The quadratic equation for the reducing sugar is given below;

$$\text{Reducing sugar} = 9.43 + 0.0132X_1 - 0.2085X_2 - 0.0687X_1^2 + 0.0434X_2^2 + 0.0439X_1X_2 \quad (6)$$

There was no significant effect of electric field strength and time on total colour change of sapota juice (p>0.05). The 3-D surface (Fig. 4) showed that at lower levels of applied electric field strength, the total colour change is less when compared to that of total colour change at higher levels of applied electric field strength. There was more degradation of sapota juice at higher electric field strength this is due to the temperature attained at higher electric field compared to temperature attained at lower levels of electric field strength at same period of processing time. Thus, there was more change in total colour of sapota juice at higher levels of applied electric field strength.

$$\Delta E^* = 6.00 + 0.1530X_1 + 0.3804X_2 - 0.1081X_1^2 - 0.2831X_2^2 + 0.2775X_1X_2 \quad (7)$$

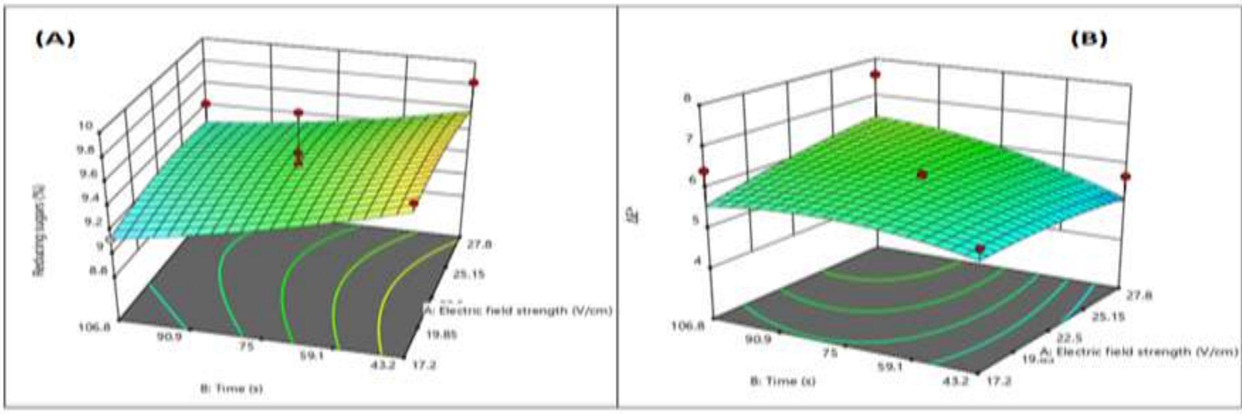

Figure 4 Effect of independent factors on reducing sugar (A) and overall colour difference (B)

D. Optimization of processing parameters

Design expert 11 statistical software was used for numerical optimization. The optimum processing parameters resulting for maximum recovery of quality parameters of sapota juice by ohmic heating process are;

$X1$ = 21.116 V/cm $X2$ = 43.2 seconds

E. Shelf life

The sapota juice after processing at optimum electric field strength and processing time is packed in glass bottles and sealed and stored at refrigerated conditions for shelf life study of 15 days by microbial enumeration and sensory evaluation each in 5 days interval. The results of microbial enumeration are shown in Table 3 and the results of sensory analysis of untreated sapota juice and treated sapota juice are shown in Table 4. It was observed that the untreated sapota juice had a shelf life less than 5 days as the microbial load In terms of its total plate count, crossed the safe consumption level. But the untreated juice was still acceptable with respect to sensory parameters till day 5. The treated juice had a shelf life of 10 days as it has crossed the safe consumption level on 15 day. However, no growth of yeast and mould count was observed in treated as well as untreated samples. The results of sensory attributes showed that the juice was acceptable till day 10 after which the sensory scores show that it was less acceptable.

Table 3 Microbial results of sapota juice over a storage period of 15 days

Days	**Total plate count (cfu/ml)**		**Yeast (cfu/ml)**	
	Untreated	Treated	Untreated	Treated
0	20	4	$<1\times10^1$	$<1\times10^1$
5	55	12	$<1\times10^1$	$<1\times10^1$
10	ND	40	$<1\times10^1$	$<1\times10^1$
15	ND	70	$<1\times10^1$	$<1\times10^1$

ND= Not detected

Table 4 Sensory results of untreated and treated sapota juice

Sensory parameters of untreated sapota juice					
Days	Colour	Taste	Aroma	Mouthfeel	Overall acceptability
0	7.64±0.76	8.16±0.25	8.1±0.47	7.62±0.67	8.1±0.29
5	7.5±0.45	7.23±0.38	7.44±0.59	7.21±0.47	7.4±0.31
Sensory parameters of treated sapota juice					
0	7.46±0.88	7.35±0.25	7.87±0.57	7.39±0.54	7.42±0.56
5	7.27±0.54	7.06±0.22	7.01±0.78	6.8±0.31	7.09±0.23
10	6.88±0.41	6.8±0.38	7.0±0.35	6.6±0.24	6.91±0.21
15	6.42 ±0.25	6.1±0.34	6.4±0.41	6.1±0.26	6.44±0.24

Values are the means ± standard deviation of three independent readings.

IV. CONCLUSION

The under lying motive of this study was to generate sufficient scientific information and foundation for application of ohmic heating to food products and its utilisation by industries. The experimental part of research work was conducted on a NIFTEM developed laboratory scale ohmic heater. It was observed that the pH and titratable acidity had significantly affected by ohmic heating, the pH has increased to a maximum of 5.70 from 5.38 (5.95 % change in pH with respect to untreated sapota juice) during ohmic heating and titratable acidity as decreased to maximum of 0.175 from 0.205 (14.63 % change in titratable acidity with respect to untreated sapota juice).The ascorbic acid, reducing sugars, total soluble solids and total colour change of sapota juice were not significantly affected by ohmic heating. The total change in colour of sapota juice was found to be increasing with increase in electric field strength and processing time. The shelf life of sapota juice processed with ohmic heating had a shelf life of 10 days compared to less than 5 days shelf life of untreated sapota juice.

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