RESEARCH ARTICLE

Shelf Life Extension of Functional Enriched Sugarcane Juice using Ohmic Heating

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ABSTRACT

The present study investigates the development of functional enriched sugarcane juice processed through ohmic heating. Currently, ready to drink functional enriched sugarcane juice with extended shelf life is not available in markets. As conventional heat processing methods reduce the taste, color, and flavor of juices, functional enriched sugarcane juice blended with amla and lemon juice extracts was developed with extended shelf life processed with minimal heat treatment by utilizing ohmic heating - a novel food processing technology. Ohmic Heating (OH) is an alternative thermal treatment as it causes volumetric heating of the sample with a short processing time and it causes minimum discoloration and maintains the nutritive value of the food. The preliminary trials were carried out to optimize the levels of sugarcane juice, amla juice and lemon juice for

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acceptable sensory attributes on 9 point hedonic scale. Response Surface Methodology (RSM) was used to determine the combinations of the experiment. The independent variables considered were sugarcane juice, amla juice and lemon juice. The responses considered were sensory attributes such as color, flavor, taste and overall acceptability. The optimum levels of sugarcane juice, amla juice and lemon juice were 91.998 mL, 4.720 mL, and 3.282 mL, respectively. The optimum levels were blended for the development of functionally enriched sugarcane juice. The standardized juice was processed using ohmic heating with two different treatments, *viz*., 50 °C (T_1) and 60 °C (T_2), for 3 minutes at 25 V/cm. The processed juice was collected in sterile glass bottles and stored at 5 ˚C for conducting storage studies at regular intervals. Microbial and sensory parameters of the untreated, control (pasteurized), and ohmic heated juice were analyzed using one-way analysis of variance (ANOVA). No significant difference ($p>0.05$) was observed in sensory immediately after ohmic processing when compared to control samples but showed a highly significant difference ($p<0.01$) in sensory during the storage period. There was a high significant difference ($p<0.01$) in the total plate count of ohmic heated samples compared to control and during the storage period. No coliform was found in all ohmic heated and control samples. Yeast and mold were present in the untreated sample, but after ohmic heating, no growth was observed. Hence highest microbial reduction was observed in ohmic heating treatment T_2 than T_1 and control, and the shelf life also extended up to 4 weeks.

Keywords: *Sugarcane juice; Response surface methodology; Ohmic Heating; Microbial reduction; Shelf life*

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is widely cultivated worldwide, and India is the second-largest producer of sugarcane. Sugarcane juice is mostly consumed in India as it is a highly nutritious and delicious drink. The preservation of raw sugarcane juice is challenging as it gets spoiled within hours of extraction. For preservation, sugarcane juice may be blended with different proportions of amla and lemon juice. Lemon is a flavor enhancer and citric acid (antioxidant) source. The addition of amla juice with sugarcane will result in an increased acidity level with antioxidant enrichment. This preservative action will inhibit the growth of microorganisms during storage (Sangeeta *et al*., 2013).

Currently, ready-to-drink (RTD) processed sugarcane juice and functionally enriched sugarcane juice with an extended shelf life are not available in markets. As conventional heat processing methods will deteriorate/reduce the taste, color, and flavor of juices, the development of functionally enriched sugarcane juice can be processed with minimal heat treatment by utilizing novel food processing technology.

Ohmic Heating (OH) has gained wide popularity as an alternative thermal treatment as it causes volumetric heating of the sample, leading to consistent and rapid heat generation, especially in liquid foods. Due to short processing times, OH causes minimum discoloration and maintains the nutritive value of the food. This feature makes it one of the most desirable treatments, particularly for sugarcane juice, as it contains sensitive flavor components that are easily destroyed at longer treatment times (Leizerson and Shimoni, 2005).

Response surface methodology (RSM) is a technique to optimize responses and it is a mathematical tool for the design of experiments. It also aids in optimizing the ingredient levels with desirable qualities. RSM is utilized by researchers for product development, and it is particularly promising due to the limited number of experiments required and the absence of human bias. RSM was proven to be useful in maximizing the sensory response by optimizing the ingredient amounts with high desirability (Wadikar *et al.,* 2010).

Hence, the research work aimed to extend the shelf life of the developed functional enriched sugarcane juice blended with amla and lemon using ohmic heating - a novel food processing technology.

MATERIAL AND METHODS

Raw materials

1) Sugarcane juice of 'Mandya' variety Co 62175 was procured from the local market.
2) Amla and lemon juice extract was prepared as per FSSAI from the fruits procured from the local market.

Equipment

Lab model ohmic heating equipment

a) Stainless steel chamber and titanium electrode
b) 1 – Φ variac (0 – 230 V) with temperature measurement probes and indicators.

Preliminary trials

The preliminary trials were carried out to optimize the levels of sugarcane juice, amla juice, and lemon juice for acceptable sensory attributes on 9 points hedonic scale.

Design of Experiment

Response Surface Methodology (RSM) uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations that can be graphically represented as response surfaces. D-optimal mixture design was chosen to determine the combinations of the experiment where sugarcane, amla, and lemon juice extracts were considered as independent variables. The independent variables were assigned minimum, and maximum levels based on the preliminary trials carried out. The number of runs created in RSM software was 16.

These 16 combinations of juices were blended and given for sensory evaluation using 9 points hedonic scale. The sensory attributes *viz.,* color, flavor, taste, and overall acceptability were considered as responses. The averages of responses obtained from panelists were entered in RSM software. The responses of the panelists were optimized by numerical and graphical representation using Response Surface Methodology (RSM).

The optimized levels of juices were chosen based on the desirability of the design and the range assigned to each of the responses. The optimum levels of sugarcane juice, amla juice and lemon juice were found to be 91.998 mL, 4.720 mL, 3.282 mL, respectively. The optimum levels were blended to develop functionally enriched sugarcane juice for further processing.

Processing of standardized juice

The standardized functional enriched sugarcane juice samples were ohmic heated using lab model ohmic heating unit with two different treatments viz., 50 °C and 60 °C for 3 mins at 25 V/cm. The time and temperature were recorded using an inbuilt timer and temperature indicators embedded on the lab model OH equipment. One litre of juice was filled in an ohmic heating processing chamber made up of stainless steel comprisingtitanium electrodes. The voltage is gradually varied using 1 – Φ variac until the temperature reaches 50 °C and 60 °C for 3mins. After the set time, the voltage is gradually reduced to zero. The processed juice was collected in sterile glass containers for conducting storage studies. Sensory evaluation (color, flavor, taste, and overall acceptability) and microbial examination (total plate count, coliform count and yeast and mold counts) were carried out for OH processed samples immediately after processing.

Statistical analysis

Response surface methodology was used to determine the optimum levels of juice extracts to develop functionally enriched sugarcane juice. One way analysis of variance (ANOVA) was carried out to determine the shelf life of developed functional enriched sugarcane juice with acceptable sensory attributes

RESULTS AND DISCUSSION

Microbiological studies

Table 1 shows the total plate count in $\log_{10}$ cfu/mL in untreated, control, and OH processed functional enriched sugarcane juice samples. Mean values of 3.48, 1.52, 1.34, 1.23 was obtained for untreated, control, T_1 and T_2, respectively, during 0th day (immediately after processing). It was found that there was a significant difference in total plate count (p<0.01) between the untreated, control and ohmic heated samples. The total plate count increased during the storage period in all samples. The total plate count of all treated samples was found below the prescribed limit of FSSR. Table 2 shows yeast and mold count ($\log_{10}$ cfu/mL) in untreated, control and OH processed functionally enriched sugarcane juice. A mean value of 1.36 was obtained for untreated samples but no yeast and mold growth was observed in the control and ohmic-heated samples at 10^{-5} and 10^{-6} dilution. This is in accordance with the findings of Saxena *et al.,* 2016 who observed complete inactivation of yeast and mold in OH treated sugarcane juice.

Table 1. Total plate count ($\log_{10}$ cfu/mL) in untreated, control and OH processed functionally enriched sugarcane juice stored at 5˚C (Mean±SE)[@]

Treatments	**0th week**	**1st week**	**2nd week**	**3rd week**	**4th week**	**F value**
25V/cm 50°C 3 mins	1.34±0.02[a]	2.22±0.07[a]	3.61±0.12	4.99±0.10	-	343.51**
25V/cm 60°C 3 mins	1.23±0.02[aA]	2.22±0.06[aB]	2.75±0.04[C]	3.91±0.06[D]	4.94±0.11[E]	488.86**
Control	1.52±0.03[b]	2.60±0.06[b]	3.74±0.18	4.92±0.11	-	180.49**
Untreated	3.48±0.09[c]	4.76±0.18[c]	-	-	-	41.45**
F value	436.29**	142.47**	18.72**	40.96**		

@ average of six trials

** Highly significant (p<0.01)

- indicates loss of shelf life stability

Table 2 . Yeast and mould count ($\log_{10}$ cfu/mL) in untreated, control and OH processed functional enriched sugarcane juice stored at 5˚C (Mean±SE)[@]

Treatments	**0th week**	**1st week**	**2nd week**	**3rd week**	**4th week**	**F value**
25V/cm 50°C 3 mins	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00	0.00±0.00	-	
25V/cm 60°C 3 mins	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00	0.00±0.00	0.00±0.00	
Control	0.00±0.00[a]	0.00±0.00[a]	0.00±0.00	0.00±0.00	-	
Untreated	1.36±0.04[b]	3.02±0.10[b]	-	-	-	253.85**
F value	1403.81**	950.16**				

@ average of six trials

** Highly significant (P<0.01)

- indicates loss of shelf life stability

Sensory quality

Table 3 shows the sensory parameters *viz*., color, flavor, taste, and overall acceptability rated on 9 points hedonic scale for untreated, control, and OH processed sugarcane juice samples. Mean values of 8.75±0.04, 8.68±0.06, 8.75±0.04, 8.70±0.07 were obtained for overall acceptability in untreated, control, T_1, and T_2 samples. The results revealed no significant difference (P>0.05) in sensory attributes between control and immediately processed samples and during storage period. However significant difference (P<0.01) in color, flavor, taste and overall acceptability was observed in control and untreated samples during the entire storage period.

Table 3. Sensory attributes in untreated, control and OH processed functionally enriched sugarcane juice stored at 5˚C (Mean±SE)

Sensory parameters	Treatments	Storage periods					F value
		0th week	1st week	2nd week	3rd week	4th week	
Colour	25V/cm 50°C 3 mins	8.52±0.07^{a}	8.18±0.07^{c}	8.70±0.11	8.11±0.19	-	1.45^{NS}
	25V/cm 60°C 3 mins	8.58±0.08^{aC}	8.30±0.06^{cC}	8.80±0.09^{B}	8.70±0.07^{B}	8.32±0.19^{A}	2.05^{NS}
	Control	8.55±0.04^{a}	7.88±0.06^{b}	7.42±0.05	6.90±0.10	-	115.37**
	Untreated	8.42±0.06^{a}	6.03±0.11^{a}	-	-	-	353.79**
F value		1.24^{NS}	189.58**	5.66*	10.22**		
Flavour	25V/cm 50°C 3 mins	8.65±0.06^{a}	8.52±0.06^{b}	8.43±0.06	8.15±0.08	-	0.69^{NS}
	25V/cm 60°C 3 mins	8.58±0.08^{aD}	8.55±0.08^{cC}	8.48±0.06^{B}	8.32±0.05^{B}	8.12±0.08^{A}	1.71^{NS}
	Control	8.58±0.06^{a}	7.73±0.05^{b}	7.30±0.06	6.97±0.07	-	141.44**
	Untreated	8.52±0.05^{a}	6.92±0.11^{a}	-	-	-	168.18**
F value		0.77^{NS}	37.63**	18.59**	40.77**		
Taste	25V/cm 50°C 3 mins	8.72±0.05^{a}	8.68±0.05^{c}	8.55±0.04	8.23±0.07	-	4.37*
	25V/cm 60°C 3 mins	8.65±0.07^{aE}	8.58±0.06^{cD}	8.42±0.07^{C}	8.35±0.07^{B}	8.20±0.07^{A}	2.41^{NS}
	Control	8.68±0.06^{a}	7.97±0.05^{b}	7.70±0.05	6.87±0.14	-	77.22**
	Untreated	8.90±0.06^{b}	6.60±0.17^{a}	-	-	-	161.94**
F value		3.47*	72.26**	1.97^{NS}	8.17**		
OAA	25V/cm 50°C 3 mins	8.75±0.04^{a}	8.60±0.06^{c}	8.55±0.04	8.20±0.06	-	1.53^{NS}
	25V/cm 60°C 3 mins	8.70±0.07 ^{aE}	8.63±0.07^{cD}	8.50±0.08^{C}	8.32±0.06^{B}	8.25±0.06^{A}	0.86^{NS}
	Control	8.68±0.06 ^{a}	7.98±0.06^{b}	7.40±0.07	6.95±0.06	-	143.15**
	Untreated	8.75±0.04 ^{a}	6.82±0.14^{a}	-	-	-	185.86**
F value		0.40^{NS}	71.09**	19.70**	15.36**		

@ average of six trials

** Highly significant (P<0.01)

* Significant (P<0.05)

NS No significant (P>0.05)

- indicates loss of shelf life stability

CONCLUSION

Thus functionally enriched sugarcane juice was developed by blending nutritious juices of amla and lemon without the external addition of sugar and acids. Sugarcane juice had sufficient sweetness and lemon juice was used as a source of citric acid and amla was used as a natural source of ascorbic acid, which helped to stabilize the juice and made it highly acceptable. It can be concluded that good quality with satisfactory storage stability with acceptable sensory attributes with an extended shelf life of 4 weeks could be achieved by ohmic heating juice at 60˚C for 3 mins at 25 kV/cm. Hence antioxidant-enriched sugarcane juice blended with natural juices would pave the way for a healthy nation and a promising sector for the soft drink industry.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Author contributions

Rajalakshmi R, Dr. G. Sujatha, Dr. V. Perasiriyan, Dr. N. Karpoora Sundara Pandian contributed to develop functional enriched sugarcane juice with extended shelf life. Dr. A. Serma Saravana Pandian contributed to design of experiment and statistical analysis.

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