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Research Article

APPLICATION OF PREDICTIVE MODELING TO ASSESS THE SHELF LIFE OF FUNCTIONAL ENRICHED SUGARCANE JUICE

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Abstract: Consumers demand for fresh and safe food with favourable sensory and nutritional properties with an adequate shelf life. Currently, ready to drink functional enriched sugarcane juice with extended shelf life is not available in markets. Functional enriched sugarcane juice blended with amla and lemon juice was developed with extended shelf life processed without/minimal heat treatment by utilizing novel food processing technologies *viz*., Pulsed Electric Field (PEF), Ultraviolet C (UV-C) treatment and Ohmic Heating (OH). Response Surface Methodology (RSM) was used to determine the combinations of experiment. The optimum levels of sugarcane juice, amla juice and lemon juice extracts were found to be 91.998 mL, 4.720 mL, 3.282 mL respectively. The standardized juice was processed using different novel food processing technologies. Multiple linear regression analysis was conducted to model the relationship between the dependent variable towards predictor variables *viz*., pH, total soluble solids (TSS), vitamin C, antioxidant activity and total plate count (TPC). From the analysis of PEF treated juice, the predicted data showed that the variables pH, Vitamin C and TPC were found to be significantly associated at 1 per cent level ($p<0.01$) with the age of the product. The Antioxidant activity was statistically significant at 5 per cent level ($p<0.05$) and TSS had no significant ($p>0.05$) difference with the age of the product. It was observed that the variables pH, VC AA and TPC were found to be significantly associated at 1 per cent level ($p<0.01$) and the TSS was statistically significant at 5 per cent level ($p<0.05$) with the age of the product in UV treated juice. From the analysis of OH treated juice the variables TSS, Vitamin C and Antioxidant activity were found to be significantly associated at 1 per cent level ($p<0.01$) with the age of the product. The TPC was statistically significant at 5 per cent level ($p<0.05$) and pH had no significant ($p>0.05$) difference with the age of the product. Hence, the regression equation obtained can be selected to be the mathematical model for prediction of age of the juice based on independent variables.

Keywords: *Sugarcane juice, Response surface methodology, Novel food processing technologies, Predictive model, Shelf life*

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Introduction

Sugarcane (*Saccharum officinarum*) is widely cultivated all over the world and India is the second largest producer of sugarcane. Sugarcane juice is mostly consumed in India as it is highly nutritious and delicious drink. The preservation of raw sugarcane juice is challenging as it gets spoiled within hours of extraction. For the purpose of preservation, sugarcane juice is blended with different proportions of amla and lemon juice extracts. Lemon is a flavor enhancer and is a source of citric acid (antioxidant). The addition of amla juice extract with sugarcane juice results in increased acidity level with antioxidant enrichment. This preservative action inhibits the growth of microorganisms during storage [1]. Response Surface Methodology (RSM) was used to standardize sugarcane juice combined with amla and lemon juice extract as a ready to drink beverage. Currently, ready to drink processed sugarcane juice and functional enriched sugarcane juice with extended shelf life is not available in markets. As conventional heat processing methods will deteriorate/reduce the taste, color and flavor of juices. To overcome these disadvantages, some of the novel food processing technologies such as pulsed electric field (PEF), ultraviolet -C (UV-C) treatment and ohmic heating (OH) are widely used to develop the functionally enriched sugarcane juice that can be processed with minimal heat treatment.

PEF is used as an alternative method for pasteurizing liquid foods. This involves the application of electric pulses of high voltage to liquid foods placed in a treatment chamber between two electrodes which inhibits the microorganism growth and increases the shelf life of food without any heat and chemical effects [2]. Ultraviolet-C is germicidal against bacteria, viruses, protozoa, yeasts, moulds, and algae with the maximum germicidal effect at wavelengths between 250 and 270 nm. Various fruit juices are disinfected using a wavelength of 254nm [3]. Ohmic Heating (OH) is an alternative thermal treatment as it causes volumetric heating of the sample which leads 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. These features make 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 [4]. using modeling under real world conditions. Kinetic equations are employed to create mathematical models for predicting the shelf life of products. The characteristics of shelf life are estimated using shelf life testing experimental data in the statistical analysis of prediction. After estimating the parameters of a shelf-life model, it can be used to predict the likelihood of various events, such as future failures. The results of the experiments are statistically independent [5].

Hence, the research work was proposed to develop a predictive model to assess the shelf life of functional enriched sugarcane juice blended with amla and lemon using novel food processing technologies.

Material and Methods

Design of experiment

D-optimal mixture design was chosen to determine the combinations of experiment where, sugarcane, amla and lemon juice extracts were considered as independent variables. The number of runs created in RSM software was 16. The sensory attributes *viz*., colour, flavor, taste and overall acceptability were considered as responses. The optimized levels of juices were chosen based on the desirability of the design and range assigned to each of the responses. The optimum levels of sugarcane juice, amla juice and lemon juice extracts were found to be 91.998 mL, 4.720 mL, 3.282 mL respectively. The optimum levels were blended for the development of functional enriched sugarcane juice for further processing.

Processing of standardized juice

The standardized functional enriched sugarcane juice was processed using novel food processing technologies *viz*, Pulsed Electric Field (PEF), Ultraviolet C (UV-C) treatment and Ohmic Heating (OH). Two different treatments (T_1 and T_2) were selected in each novel food processing technology as shown below. The processed juice samples were collected in sterile glass containers and stored at 5˚C for conducting storage studies at regular intervals. The processed juice samples were compared with control (pasteurized) samples. One way analysis of variance (ANOVA) was carried out to find the efficacy of treatments in each of the novel food processing technologies *viz*., PEF, UV, OH.

Novel Technology	Treatment 1	Treatment 2
Pulsed Electric Field (PEF)	25kV, 2.5µs pulse width for 150s	25kV, 2.5µs pulse width for 300s
UV-C treatment (UV-C)	5 L/h for single circulation and double circulation	10L/h for single circulation and double circulation
Ohmic Heating (OH)	25 V/cm, 50˚C for 3min	25V/cm, 60 ˚C for 3min

Predictive modeling

The predictive model was developed for the selected treatment using multiple linear regression model using IBM SPSS Version 20.0. Kinetic equations were used to setup mathematical models to predict the shelf life of the functional enriched sugarcane juice. Minimum sample size of 30 samples was required to develop a predictive model. For developing a predictive model to assess the shelf life of the developed functional enriched sugarcane juice, pH, total soluble solids, vitamin C, antioxidant activity, total plate count were considered as independent parameters and shelf life (in days) was considered as a dependent parameter.

Relationship between age of the product (sugarcane juice) and their physicochemical, nutritional and microbiological properties

In order to model the relationships between the age of the product and their physico chemical, nutritional and microbiological properties of functional enriched sugarcane juice, a multiple linear regression model was fitted.

The functional form of predictive model is as below:

$$Y= \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \mu$$

Where,

Dependent variable:

Y-Age of the product in days

Independent Variables:

X_1-pH

X_2-Total soluble solids (TSS)

X_3-Vitamin C

X_4-Antioxidant activity

X_5-Total plate count (TPC)

A-Intercept

βi-Regression coefficients to be estimated

µ-Error term

Results

Relationship between age of the product (sugarcane juice) and their physico-chemical, nutritional and microbiological properties of PEF, UV and OH treated juice. The results of the multiple linear regression model fitted to find the relationship between age of the product and their physico-chemical, nutritional and microbiological properties of PEF, UV and OH treated juice [Table-1, 2 and 3]. The model showed a good fit with the adjusted R2values of 0.921,0.942and 0.997indicating that 92.1, 94.2 and 99.7 per cent of variation in shelf life (days)for PEF, UV and OH treated juice respectively. The result showed that independent variables were well explained the dependent variable used in fitting the model. The ANOVA also showed that the model was statistically significant with a 'F' value of 201.573, 212.674 and 2658.046 for PEF, UV and OH respectively. Among the five variables chosen for model definition in PEF, the variables *viz*., pH, vitamin C, antioxidant activity and TPC were found to have statistically significant association with the age of the product whereas the TSS had no significant difference with the age of the product. Among these properties, all the variables were found to be positively associated with the age of the product except pH and antioxidant activity. The variables pH, vitamin C and TPC were found to be significantly associated at 1 per cent level ($p<0.01$) with the age of the product. Antioxidant activity was statistically significant at 5 per cent level ($p<0.05$) and TSS had no significant ($p>0.05$) difference with the age of the product [Table-1]. Among the five variables chosen for model definition in UV, all the variables *viz*., pH, TSS, vitamin C, antioxidant activity and TPC were found to have statistically significant association with the age of the product. Among these properties, all the variables were found to be negatively associated with the age of the product except vitamin C and TPC.

The variables pH, vitamin C, antioxidant activity and TPC were found to be significantly associated at 1 per cent level ($p<0.01$) and TSS was statistically significant at 5 per cent level ($p<0.05$) with the age of the product [Table-2]. Among the five variables chosen for model definition in OH, the variables *viz*., TSS, vitamin C, antioxidant activity and TPC were found to have statistically significant association with the age of the product and the pH was no significant. Among these properties, all the variables were found to be negatively associated with the age of the product except TPC. The variables TSS, vitamin C and antioxidant activity were found to be significantly associated at 1 per cent level ($p<0.01$) with the age of the product. The TPC was statistically significant at 5 per cent level ($p<0.05$) and pH had no significant ($p>0.05$) difference with the age of the product [Table-3].

The functional form of predictive model for PEF is as below:

$$Y= \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \mu$$

$$Y = 99.520-65.906\ (X_1) + 1.194\ (X_2) + 15.334\ (X_3) - 2.058\ (X_4) + 16.526\ (X_5) + \mu$$

The functional form of predictive model for UV is as below:

$$Y= \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \mu$$

$$Y = 278.453-17.727\ (X_1) - 5.767\ (X_2) + 3.852\ (X_3) - 1.991\ (X_4) + 4.086\ (X_5) + \mu$$

The functional form of predictive model for OH is as below:

$$Y= \alpha + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \mu$$

$$Y = 314.610 - 1.780\ (X_1) - 2.397\ (X_2) - 10.291\ (X_3) - 1.063\ (X_4) + 2.374\ (X_5) + \mu$$

Discussion

From the analysis, the predicted data showed reasonable correlation with the observed data with improved adjusted R-Square values of 92.1%, 94.2% and 99.7% for PEF, UV and OH processed juice respectively. This is in accordance with the findings of who reported that the kinetic mathematical models were developed for the prediction of orange juice shelf life as a function of temperature and L- Ascorbic acid in the intervals of the derived shelf-life distribution at 95% confidence level [6].

Thus, functional enriched sugarcane juice was developed by blending nutritious juices of amla and lemon juice extracts. 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.

Table-1 *Results of multiple linear regression predictive model for PEF treated juice*

Variables	Unstandardized Coefficients		Standardized Coefficients	t value	p value	Significance
	B	Std. Error	Beta			
(Constant)	99.520	99.485		1.000	0.320	NS
pH	-65.906	8.848	-1.113	-7.449	0.000	**
TSS	1.194	4.770	0.029	.250	0.803	NS
Vitamin C	15.334	2.048	1.469	7.489	0.000	**
Antioxidant activity	-2.058	1.013	-0.285	-2.032	0.045	*
TPC	16.526	3.806	1.018	4.342	0.000	**
R^2	0.926					
Adjusted R^2	0.921					
F value	201.573**					

Table-2 *Results of multiple linear regression predictive model for UV treated juice*

Variables	Unstandardized Coefficients		Standardized Coefficients	t value	p value	Significance
	B	Std. Error	Beta			
(Constant)	278.453	47.881		5.816	0.000	**
pH	-17.727	6.534	-0.452	-2.713	0.009	**
TSS	-5.767	2.392	-0.216	-2.411	0.019	*
Vitamin C	3.852	0.904	0.482	4.260	0.000	**
Antioxidant activity	-1.991	0.581	-0.418	-3.427	0.001	**
TPC	4.086	1.170	0.373	3.492	0.001	**
R^2	0.947					
Adjusted R^2	0.942					
F value	212.674**					

Table-3 *Results of multiple linear regression predictive model for OH treated juice*

Variables	Unstandardized Coefficients		Standardized Coefficients	t value	p value	Significance
	B	Std. Error	Beta			
(Constant)	314.610	43.885		7.169	0.000	**
PH	-1.780	1.231	-0.064	-1.446	0.157	NS
TSS	-2.397	.320	-0.356	-7.489	0.000	**
Vitamin C	-10.291	1.928	-0.285	-5.338	0.000	**
Antioxidant activity	-1.063	.331	-0.169	-3.215	0.003	**
TPC	2.374	1.139	0.139	2.084	0.044	*
R^2	0.997					
Adjusted R^2	0.997					
F value	2658.046**					

*Dependent variable-Days, Predictor variables-pH, TSS, Vitamin C, Antioxidant activity, TPC ** Highly significant (P<0.01), * Significant (P<0.05), NS No significant (P>0.05)*

Conclusion

It can be concluded that the multiple linear regression analysis was able to provide information for all variables tested in the analysis with significant p-values ($p<0.01$) and higher values of R-square and adjusted R-square values are considered to have a significant response to the predicted variable. F value and corresponding p-value indicated that the prediction model is statistically significant ($p<0.01$). Hence, the regression equation obtained was selected to be the mathematical model for prediction of age of the juice based on independent variables.

Application of research: 1. Preservation of Sugarcane juice using novel technologies. 2. Developed the predictive model to assess the shelf life of juice

Research Category: Food Process Engineering, Food Technology

Abbreviations: mL-millilitre, µs-microsecond, kV-kilovolt, s-second, L-Litre, h-hour, V-voltage, cm-centimetre, ˚C-Degree Celsius, min-minute

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Cultivar / Variety / Breed name: Sugarcane - "Mandya" variety Co 62175.

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