MATHEMATICAL MODELING AND OPTIMISATION OF SUGARCANE JUICE LEVEL IN GRAPE BEVERAGE USING RESPONSE SURFACE METHODOLOGY (RSM)

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ABSTRACT
The vegetative clarified sugarcane juice (SCJ) was used as sugar replacer in the preparation of beverage. The specific proportions of sugarcane juice were utilized for beverage preparation using central composite rotatable design (CCRD). Response surface analysis for grape beverages indicated that sensory flavor and overall acceptability (OAA) scores varied from 6.04 to 8.10 and 6.72 to 7.95, respectively on nine point hedonic scale. The differences in the sensory scores for respective attributes were highly significant (P≤0.01). The beverage containing 4% sugar and 40% SCJ resulted in 16° Brix and 47 TSS-acid ratios, which were the best in terms of their flavor and overall acceptability. Sensory data were regressed against sugarcane juice (x₁) and sugar (x₂) for second order polynomial models, which were found to be adequate as coefficient of multiple determinants (R²) was more than 80%, calculated F-ratio more than that of the F-table value and insignificant lack of fit test. Multiple response optimizations resulted in the best combinations of sugarcane juice and sugar as 43.6% and 4.38%, respectively. Subsequent evaluations on storage for 90 days at 37°C reduced sensory scores from 7.55 to 7.15. Ready-to-serve beverages prepared from optimized recipe gave products of microbiologically safe and sterile nature. Their storage for 90 days at 37°C reduced sensory scores Sugarcane juice could be used as replacer of sugar in the preparation of sugarcane juice based beverage.

Key words: Sugarcane juice, Optimization, Response Surface Methodology, Grape beverage, Ready-to-serve.

INTRODUCTION
Sugarcane is an important commercial cash crop that provides raw material for the second largest agro-industry in India. India stood second in 2005 in terms of acreage (3.66 million hectare) and production (237.09 million tonnes) of sugarcane, next to Brazil, 5.80 million hectare and 422.96 million tones (FAO, 2008). Major share of sugarcane is utilized for the production of white sugar, jaggery and khandsari. A small quantity is used to produce juice, which is consumed as soft drink for its flavour, nutritive and therapeutic values.

Sugarcane juice (SCJ) is extracted by small street vendors, often under unhygienic conditions. It is a popular summer beverage in India with 9.0 to 24.56% total soluble solids (TSS). Despite of vast potential of sugarcane juice as beverage it is not being processed commercially due to its short shelf life and problems during processing such as browning, sedimentation and loss of its typical

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aroma and taste. Inadequate clarification reduces shelf life of the SCJ. Industrially low recovery of sugarcane juice, cost involved in sugar manufacture and low sugar recovery from SCJ, and its further use as a source of sweetener increases cost of beverage considerably. Utilization of sugarcane juice directly as a sweetener will reduce the cost of beverage (Prasad 2000). Since, sugarcane juice is rich in minerals; its addition to beverage will improve the nutritional value. It can be used as a sweetener in ready-to-serve (RTS) beverages where TSS varies from 10 to 20% (Prasad and Nath 2002a). Further it may provide diversifications to the soft drink industry. Moreover, augmented demand of soft drinks could stimulate processing leading to cane juice-based beverages to partially meet the need for an inexpensive eco-friendly drink.

Response surface methodology (RSM) is collection of techniques for exploring empirical relationships. This includes experimental designs, model fitting, and diagnosing techniques. RSM originally described by Box and Wilson (1951) is effective for responses that are affected by many factors and their interactions. The author has successfully applied technique in the optimization of various products (Prasad and Sharma 2002; Sharma et al, 2002).

Objective of present work was to provide better insight about the relationship between the independent variables as sugarcane juice and sugar with the dependent responses as sensory and physico-chemical aspects in a better way to optimize the process and ingredients level.

**MATERIALS AND METHODS**

Coloured grapes (Bangalore blue) were procured from the local market and sugarcane (CoPant-84212) from the Crop Research Center, Pantnagar.

**Preparation of grape and sugarcane juice**

Grapes were washed, crushed, heated to 80°C and pressed to extract the juice. The extracted juice was analyzed and used for the preparation of sugarcane juice based grape beverage. The freshly harvested sugarcane (var. CoPant 84212) was topped 5cm to remove growing portions, which contributes maximum darkening of SCJ (Prasad and Nath 2002b). Sugarcane was peeled and juice extracted using double roller hand-operated cane crusher. The filtered extract of slurry made from ground okra stem and water (1:20 wt:wt) was used at the rate of 500ppm to clarify sugarcane juice following the procedure of Prasad and Nath, (2002b).

**Preparation of grape RTS beverage**

Grape juice and clarified sugarcane juice along with sugar and water were mixed in different proportions as per central composite rotatable design (CCRD) (Table 1.) The obtained beverage was hot filled at 85±5°C in 250ml glass bottles and then crown corked followed by sterilization at 95±2°C for 30 min. The sterilized RTS beverage was air cooled and then stored at an elevated (37±2°C) temperature for the storage studies.

**Physico-Chemical Parameters**

Total soluble solids (TSS) were measured using hand refractometer (Range 0-50°Brix, Gardener Corporation, New Delhi) at 20°C. Titratable acidity of the samples was estimated by potentiometric titration (A. O. A. C., 1980). The pH of the juice and beverage sample was determined using a digital pH meter (Hanna Instruments, Portugal). Viscosity of the juice and RTS beverages was measured using Brookfield viscometer (Model LVT). For this spindle number 1 was used at constant speed (60 rpm) with a temperature maintained at 25±2°C throughout the experiment. Non-enzymatic browning was measured as described by Ranganna (1986).

**Microbial Quality**

Total plate count, coliform count and yeast and mould counts of fresh and stored RTS beverage samples were determined as per the standard method given in Refai (1979).
Sensory Quality

The sensory evaluation for colour, and flavour of grape beverages was conducted by a panel of eleven judges from faculty and students of Food Technology Department. The panelist was asked to evaluate the chilled (10±2°C) RTS beverages for various sensory attributes, namely, colour, flavour and over all acceptability using a nine points hedonic scale (Amerine, 1965). A score of 7.0 was considered as minimum acceptability score.

Statistical

\[ Y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} a_{ij} x_i x_j + \sum_{i=1}^{n} a_{ii} x_i^2 \]  

(1)

The observed responses for sensory and physico-chemical parameters were regressed against sugar and sugarcane juice levels for second order polynomial model using Minitab (v-13.20).

Where, Y is response, \( a_0, a_i, a_{ii}, a_{ij} \) are intercept, linear, quadratic and interaction regression coefficient terms, respectively and \( x_i \) and \( x_j \) are independent variables. These models were analyzed for its adequacy on the basis of co-efficient of multiple determinants (R^2), F-ratio and Lack of fit. Contour plots were developed using the fitted quadratic polynomial models using Matlab (v-5.2).

RESULTS AND DISCUSSION

Sensory flavour and colour scores of grape RTS beverage varied from 6.04 to 8.10 and 7.40 to 7.79, respectively. The minimum flavour score was found at Expt. No. 1, which was having 10.9°Brix lowest TSS, 31.3 TSS-acid ratio and 4.00 cP viscosity (Table 2). The sensory flavour scores were significantly different among the experimental samples whereas, insignificant difference in colour scores was found due to dark purple colour of prepared beverage samples. A minimum score of 7.0 for colour and flavour score was considered essential during determining the range of levels of various ingredients for RTS beverages.

Sensory data of grape beverages were fitted into second order polynomial model and following equations were obtained (Eq. 2 to 3).

Flavour score = 7.940 + 0.374X_1 + 0.146X_2 - 0.135X_1X_2 - 0.477X_1^2 - 0.389X_2^2  

(2)

Colour score = 7.690 + 0.049X_1 + 0.035X_2 - 0.109X_1X_2 - 0.048X_1^2 - 0.058X_2^2  

(3)

The analysis of variance (ANOVA) for full second order polynomial model for sensory flavour and colour scores showed that F-ratio for flavour (11.04) and clolour (6.38) scores were more than table F value of 3.97. Standard error of estimate for sensory flavour and colour scores, were 0.259 and 0.059, whereas coefficient of determination (R^2) were 0.887 and 0.820, respectively. These values showed that the models explained >80% variability. According to Filmore et al. (1976) and Joglekar and May (1991) a value of R^2 of more than 80% is good for explaining the variability in the model. Thus the model developed for predicting sensory scores for sugarcane juice based grape beverages with different ingredient levels could be used.

To establish range of ingredients for grape beverage preparation, a minimum acceptable score of 7.0 for flavour and colour was considered essential. Contour plot give effect of different levels of CSJ and sugar on

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Coded variable levels*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-1.414 (-a)</td>
</tr>
<tr>
<td>Sugarcane juice (gm)</td>
<td>x_i</td>
<td>25.86</td>
</tr>
<tr>
<td>Sugar (gm)</td>
<td>x_j</td>
<td>0.00</td>
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</table>

*Transformation of coded variable (x) levels to uncoded variable (X) levels could be obtained from \( X_i = 10x_i + 40 \) and \( X_j = 2.83x_j + 4.00 \).
sensory score. Superimposition of sensory contours (Fig. 1) resulted in an acceptable beverage of minimum seven sensory score on using CSJ from 28.95 to 55.00% and sugar from 0.00 to 8.25%. Therefore, we can say that 100% sugar could be replaced using SCJ. This results that there is flexibility in selection of the ingredient combinations, depending upon its availability and prevailing cost, so as to make a better product at lower cost.

The marginal points at regular interval of 0.1 for coded values of CSJ used in the shaded portion of contour diagram (Fig. 1) for sensory scores of flavour and colour having minimum acceptable value of 7 were generated using program developed in Matlab (v-5.2) and

FIG. 1: Sensory flavour and colour scores for grape beverage as a function of sugarcane juice and sugar with shaded portion showing minimum sensory score of 7.0.

FIG. 2: Sensory flavour and TSS of grape beverage as a function of sugarcane juice and sugar.
used in determining the range of other physicochemical parameters for the possible combination of CSJ and sugar. The generated points were fitted to obtain the extremes for the TSS (Fig. 2) generated by the respective models using coefficients of linear, quadratic and interactions represented in Table 3, while the values of other physico-chemical parameter are shown in the Table 4.

Multiple response optimizations were done to maximize the sensory colour and flavour scores individually and in the combination of colour and flavour to get a compromised optimum point. Experimentation on adopting these combinations showed that the level of CSJ and sugar varied for individually optimized and compromised optimum point in grape-beverage preparation. The acceptability of beverage was found best when the sensory flavour scores were maximized. The above results were confirmed by preparing grape beverages of calculated composition. Their sensory evaluation showed that the grape beverage containing 43.6% CSJ had highest sensory overall acceptability (OAA) score of 8.17 when sensory flavour score was maximized whereas OAA scores of 7.29 and 7.33 were found when colour and colour & flavour scores were maximized, respectively.

Hence highest OAA score for sensory flavour optimum point and respective ingredient combination (43.6% CSJ and 4.38% sugar) was

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**TABLE 2: Central composite rotatable design arrangement and responses**

<table>
<thead>
<tr>
<th>Expt No.</th>
<th>SCJ</th>
<th>Sugar</th>
<th>Sensory flavour</th>
<th>Sensory colour</th>
<th>TSS (°Brix)</th>
<th>Acidity (%)</th>
<th>TSS-acid ratio</th>
<th>pH</th>
<th>Viscosity (cP)</th>
<th>Non-enzymatic browning</th>
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<tbody>
<tr>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>6.04</td>
<td>7.40</td>
<td>10.9</td>
<td>0.35</td>
<td>31.3</td>
<td>3.7</td>
<td>4.00</td>
<td>0.227</td>
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<tr>
<td>2</td>
<td>1</td>
<td>-1</td>
<td>7.40</td>
<td>7.75</td>
<td>15.0</td>
<td>0.34</td>
<td>44.0</td>
<td>3.8</td>
<td>4.37</td>
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<td>3</td>
<td>-1</td>
<td>1</td>
<td>6.79</td>
<td>7.67</td>
<td>16.5</td>
<td>0.34</td>
<td>48.1</td>
<td>3.7</td>
<td>4.33</td>
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<td>4</td>
<td>1</td>
<td>1</td>
<td>7.60</td>
<td>7.58</td>
<td>20.2</td>
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<td>58.9</td>
<td>3.9</td>
<td>5.00</td>
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<td>5</td>
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<td>7.54</td>
<td>12.5</td>
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<td>36.0</td>
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<td>7.63</td>
<td>18.3</td>
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<td>4.30</td>
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<td>8</td>
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<td>7.35</td>
<td>7.63</td>
<td>19.6</td>
<td>0.34</td>
<td>58.0</td>
<td>3.9</td>
<td>4.77</td>
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</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>8.10</td>
<td>7.79</td>
<td>16.1</td>
<td>0.34</td>
<td>47.1</td>
<td>3.8</td>
<td>4.40</td>
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<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>8.00</td>
<td>7.71</td>
<td>15.6</td>
<td>0.34</td>
<td>46.2</td>
<td>3.8</td>
<td>4.33</td>
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<tr>
<td>11</td>
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<td>0</td>
<td>7.98</td>
<td>7.63</td>
<td>15.4</td>
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<td>4.43</td>
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<tr>
<td>13</td>
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<td>0</td>
<td>7.81</td>
<td>7.71</td>
<td>15.7</td>
<td>0.34</td>
<td>46.4</td>
<td>3.9</td>
<td>4.43</td>
<td>0.300</td>
</tr>
</tbody>
</table>

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**Nonrandomized.**

**Coded symbols and levels of independent variables refer to Table 1.**

**Average value of duplicate determination except design points 9 to 13.**
selected as an optimum combination for the storage studies.

Storage studies indicated that the Non–enzymatic browning showed a gradual increase from 0.398 to 0.574 with a decrease in the sensory flavour score from 7.55 to 7.15 with insignificant change in sensory colour score after 90 days of storage at 37°C. No microbial counts were observed during entire storage period. Therefore, the products were microbiologically safe and sterile. Sensory analysis of beverages on storage at 37°C revealed that grape beverage was remained acceptable after 90 days of storage. Thus the above results clearly indicate that shelf stable acceptable quality of sugarcane juice based grape beverage could be prepared.

REFERENCES