Optimization of sodium metabisulphite addition and vacuum evaporation temperature on production of sweet sorghum juice (*Sorghum bicolor* L. Moench) concentrate using response surface methodology

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**Abstract.** Sweet sorghum (*Sorghum bicolor* L. Moench) is one of the sugar source plants. The purpose of sorghum juice evaporation is to raise total soluble solid content (°Brix). The process produces a dark-brown color concentrate. The aim of this study was to optimise the addition of sodium metabisulphite and the temperature of evaporation to enlighten the color of sweet sorghum concentrate. This current study employed Respond Surface Methodology (RSM) using Central Composite Design (CCD) with 2 factors include the addition of sodium metabisulphite and evaporation temperature. The major responses in this research were the value of Total Soluble Solid (TSS) (°Brix) and the lightness value (*L*). The result showed that the optimum treatment was a combination of 0.50 g/L sodium metabisulphite and 83.71°C vacuum evaporation temperature. The optimum condition resulted sweet sorghum concentrate with pH value of 6.01, TSS of 42.40°Brix, lightness of 36.13, redness of +0.08, yellowness of +17.08, turbidity of 1227 NTU, viscosity of 10.33 cP, density of 1.182 gr/mL and yield of 28.64%, respectively.

1. Introduction

The role of sugar as a sweetener is still dominated by sugar cane as raw materials. Based on the data from the Ministry of Industry, sugar consumption in Indonesia reaches approximately 5.7 million tons per year while sugar production was only 2.2 million tons per year [1]. Therefore, it is need an alternative sweetener, preferably in liquid form and not from sugar cane as raw materials. Liquid sugar is more effective and practical because it is easily applied with other food ingredients. Another advantage include less energy consumption in the making process of liquid sugar compared to that of crystalised sugar.

Sweet sorghum (*Sorghum bicolor* L. Moench) is one of the plants potential as an alternative raw material for making liquid sugar. Sweet sorghum belongs to Kingdom Plantae, Family Poaceae and Genus *Sorghum*, which is categorised as a multipurpose crop. For example, the sugary juice from the stalk can be used for making syrup and liquid sugar. Moreover, sweet sorghum has a great tolerance to a wide range of climatic and soil condition [2]. It has a short duration crop of 90-130 days as compared to 12-18 months for sugarcane, thus amenable for crop rotation. In addition, the water and
fertilizer requirement are also lower than sugar cane, thus reducing the cultivation cost [3]. The sugar content in juice extract from stalk of sweet sorghum varies from 16.8-18°Brix, and these values are within the range of sugar content of sugar cane (15-20°Brix) [4]. In general, evaporation process aims to raise °Brix. But conventional evaporation can produce semi-finished product with dark color due to the occurrence of an enzymatic reaction or browning reaction when using high temperatures [5]. In this research, addition of sodium metabisulphite and vacuum evaporation can inhibit enzymatic reaction. Sodium metabisulphite reduced disulfide group in the enzyme so that it cannot catalyse the oxidation of phenolic compounds, which causes the color turn dark. Vacuum evaporation using Falling Film Evaporator (FFE) has also been widely applied to the production process of sweetened condensed milk to prevent browning reaction.

2. Materials and Methods
2.1. Materials and chemicals
Sweet sorghum plants from Center for Agricultural Biotechnology and Genetic Resources (BB BIOGEN), Bogor, Indonesia were harvested at physiological maturity stage (90 days). Juice was extracted from sweet sorghum stalks using a horizontal three roller crusher with distance between rolls are 3/8 inches. Zeolites used for purification of sweet sorghum juice and sodium metabisulphite used for lighten evaporated sweet sorghum juice. Evaporation was carried out using FFE. Centrifuge type WINA Instrument/5020A was also used for purification of sweet sorghum juice.

2.2. Research design
The research design was carried out using Design Expert 7.1.5 software with Response Surface Methodology method. The design chosen was Central Composite Design with two factors, first, addition of sodium metabisulphite with the lower limit of 0.1 g/L and the upper limit of 0.5 g/L. Second, vacuum evaporation temperature with the lower limit of 70°C and the upper limit of 90°C. Main responses are the value of total soluble solid (°Brix) and lightness. Table 1 shows design of coded level vs value level of experiment factors and Table 3 shows experimental designs of the two levels.

| Coded Level | 1       | 0 | 1   |
|-------------|---------|---|-----|
| X1          | 65.86   | 70| 80  |
| X2          | 0.02    | 0.1| 0.3 |

2.3. Physical characteristic
Total soluble solid (°Brix) and pH of juice were measured with digital hand refractometer (ATC) and pH meter (Ezido/P-600). Lightness and color were identified using Color Reader (Konica Minolta CR-10). Turbidity, density and viscosity were measured using turbidity meter (Lutron TU-2016), picnometer and viscometer (Elcometer 2300).

2.4. Purification of sweet sorghum juice
Sweet sorghum juice is obtained from extraction of sweet sorghum stalks. Sweet sorghum stalks were removed from leaves and dirt, following the extraction with three rolls crusher. Then, the sweet sorghum juice was filtered using 90 mesh sieve to separate it from the impurities. After that, sweet sorghum juice was analysed for total soluble solid (TSS), density, color, turbidity and viscosity. Furthermore, 400 ml of sweet sorghum juice was then purified by adding 3% zeolites and leave it for 60 minutes. Then, the samples were centrifuged with rotational speed of 700 rpm for 60 minutes.
2.5. Processing of making sweet sorghum concentrate

After the purification process, sodium metabisulphite was added to sweet sorghum and the evaporation process was carried out using FFE. The amount of addition sodium metabisulphite and the FFE temperature used were based on the design suggestion that appears on Design Expert. Evaporation ended until the sorghum juice reaches at least 40° Brix of TSS.

3. Results and Discussion

3.1. Raw material

Before being processed into concentrate, raw sweet sorghum juice is analysed for TSS, turbidity, pH, density, color and viscosity. The results of raw sweet sorghum juice characterisation (Table 2) indicated that the values of TSS, pH and density were well within the values reported in other studies [4, 6]. However, the turbidity values was significantly different, which possibly due to the high fiber content of sorghum stalk and the consistency differences of the sorghum juice, as previously found by Andrzejewski et al. [4]. In addition, during the extraction process of sorghum stalks, parts of sorghum plants such as stalks, leaves, and part of the roots were included in the cruiser which may also contribute to increase the turbidity of the sweet sorghum juice obtained [7].

Table 2. Raw material characterisation

| Characteristics | Results         | Literatures |
|-----------------|-----------------|-------------|
| TSS (°Brix)     | 16.20 ± 0.07    | 16.8 [4]    |
| Turbidity (NTU) | 1446.67 ± 6.50  | 3943 ± 342 [4] |
| pH              | 6.13 ± 0.01     | 6.0 [6]     |
| Density (g/mL)  | 1.08 ± 0.01     | 1.04 [6]    |
| Color           |                 |             |
| - L             | 36.0 ± 0.83     |             |
| - a             | -2.12 ± 0.45    |             |
| - b             | +17.78 ± 1.04   |             |
| Viscosity (cP)  | 2.33 ± 0.58     | -           |

3.2. Optimization of sodium metabisulphite addition and vacuum evaporator temperature

Based on the central composite design in Design Expert software, there were coded level (Table 1) and 13 runs of experiments with main responses observed were TSS and lightness (Table 3). Analysis of TSS and lightness value (L*) was performed in triplicate. The collected data was analysed using Design Expert Software for analysis of the equation and determination of the optimum point model.

3.2.1. Effect of addition sodium metabisulphite and vacuum evaporator temperature on TSS response

Based on ANOVA TSS response, vacuum evaporator temperature factors have a significant effect. However, the addition of sodium metabisulphite did not significantly influence the TSS value. The amount of heat, introduced to the sweet sorghum juice, evaporated the existing water causing the TSS values to increase [8, 9]. The correlation between the addition of sodium metabisulphite and vacuum evaporator temperature can be seen in Figure 1.

From ANOVA was also obtained polynomial model equations that can be used to determine the value of TSS responses if the value of the factors used in the process of making different concentrates.

\[ Y = 17.765 + 0.573X_1 - 7.343X_2 + 0.875X_1X_2 - 3.337x10^{-0.003}X_1^2 + 0.406X_2^2 \]

(1)

Where:
- \( X_1 \) = Vacuum Evaporator Temperature (°C)
- \( X_2 \) = Sodium Metabisulphite (g/L)
- \( Y \) = TSS Value
3.2.2. Effect of addition sodium metabisulphite and vacuum evaporator temperature on lightness response

Based on ANOVA, the lightness response of sodium metabisulphite addition and vacuum evaporator temperature factor have a significant effect on the lightness value. The correlation between the addition of sodium metabisulphite and vacuum evaporator temperature factors can be seen in Figure 2.

Table 3. TSS and lightness obtained for each experimental running of central composite design.

| Std | Run | Evaporation Temperature (°C) (X1) | Sodium Metabisulphite Concentration (g/L) (X2) | TSS (°Brix) (Response 1) | Lightness (Response 2) |
|-----|-----|---------------------------------|---------------------------------------------|-----------------|------------------------|
| 4   | 1   | 90                              | 0.5                                         | 42.8            | 34.86                  |
| 10  | 2   | 80                              | 0.3                                         | 42.0            | 35.97                  |
| 8   | 3   | 80                              | 0.58                                        | 42.4            | 37.17                  |
| 12  | 4   | 80                              | 0.3                                         | 42.4            | 35.85                  |
| 13  | 5   | 80                              | 0.3                                         | 42.07           | 36.27                  |
| 7   | 6   | 80                              | 0.02                                        | 42.13           | 36.30                  |
| 2   | 7   | 90                              | 0.1                                         | 42.67           | 33.17                  |
| 5   | 8   | 65.86                           | 0.3                                         | 40.8            | 32.47                  |
| 9   | 9   | 80                              | 0.3                                         | 42.4            | 36.34                  |
| 6   | 10  | 94.14                           | 0.3                                         | 42.4            | 32.77                  |
| 11  | 11  | 80                              | 0.3                                         | 42.6            | 36.53                  |
| 1   | 12  | 70                              | 0.1                                         | 41.4            | 34.45                  |
| 3   | 13  | 70                              | 0.5                                         | 40.8            | 33.97                  |
Figure 1. Contour plot and surface curve of addition sodium metabisulphite and vacuum evaporator temperature to TSS response.
The results indicated that increasing the vacuum evaporator temperature used contribute to lowering the lower lightness value. This is due to the damage of the chlorophyll structure in sorghum juice. Degradation occurred on chlorophyll due to heat treatment or acidic conditions. Damage to the chlorophyll structure was also caused by the loss of Mg\textsuperscript{2+} ion, and triggering the chlorophyll compounds to transform into pheophytin (brownish green) or pheophorbide (brown) compounds [10]. Sodium metabisulphite effectively inhibited browning reaction [11]. This was evident in this study, where adding Sodium metabisulphite to the extraction process was able to increase the lightness of sweet sorghum concentrate. Based on the results of ANOVA, polynomial model equations obtained was used to determine the value of lightness response from different concentration of sodium metabisulphite.

\[
Y = -93.293 + 3.247X_1 - 9.566X_2 + 0.187X_1X_2 - 0.020X_1^2 - 4.094X_2^2 \quad (2)
\]

Where:
Based on the optimization analysis results using Design Expert 7.1.5, the optimum point of addition sodium metabisulphite was 0.50 g/L and vacuum evaporation temperature was 83.71°C, resulting the optimum TSS response value of 42.44°Brix and the lightness value of 36.67. This combination generates a desirability value of 0.883 which means that this optimisation accuracy is 88.3%. Then verification was carried out to confirm the optimum conditions between factors. There were differences between the verification results and the prediction, 0.02% and 0.54% for TSS value and lightness value consecutively. The accuracy of the model was less than 5%.

Table 4. Results of the characteristic analysis of sweet sorghum concentrate.

| Analysis          | Raw Sweet Sorghum Juice* | Optimum Sweet Sorghum Concentrate* |
|-------------------|--------------------------|-----------------------------------|
| pH                | 6.13 ± 0.01              | 6.01 ± 0.02                       |
| TSS (brix)        | 16.20 ± 0.07             | 42.40 ± 0.04                      |
| Color             |                          |                                   |
| L                 | 36.0 ± 0.83              | 36.13 ± 0.68                      |
| a                 | -2.12 ± 0.45             | +0.08 ± 0.47                      |
| b                 | +17.78 ± 1.04            | +17.08 ± 2.04                     |
| Turbidity (NTU)   | 1446.67 ± 6.50           | 1227 ± 19.07                      |
| Viscosity (cP)    | 2.33 ± 0.58              | 10.33 ± 2.08                      |
| Density (g/mL)    | 1.08 ± 0.01              | 1.18 ± 0.02                       |
| Yield (%)         | -                        | 28.64 ± 1.48                      |

*The values reported were from the average values of 3 samples

3.2.3. Analysis of optimum formulation of sweet sorghum concentrate characteristic

The optimum sweet sorghum concentrate was analysed with chemical and physical parameters including pH, TSS, color, turbidity, viscosity, density and yield (Table 4). The increase in TSS was due to a decrease in water content of the material during evaporation process. The TSS values of the sorghum concentrate can be influenced by several factors include sweet sorghum juice composition and processing condition. For color analysis, lightness value (L*) on the optimum sweet sorghum concentrate was increased compared to that of the raw sweet sorghum juice. This was due to the addition of sodium metabisulphite and vacuum evaporation temperature, which can inhibit browning enzymatic reaction. An increase in the redness intensity (a*) indicated the formation of brown color from the damaged chlorophyll pigment during heating in the evaporation process [10].

4. Conclusion

Evaporation process is one of the factors that cause damage to chlorophyll pigment found in sweet sorghum juice. Optimization of sodium metabisulphite addition and vacuum evaporator temperature can inhibit the occurrence of the enzymatic browning process that occurs. Based on the results, the optimum condition was 0.50 g/L sodium metabisulphite addition and evaporation temperature 83.71°C. The prediction results for the optimum sample based on the response surface analysis were 42.44°Brix for TSS and 36.67 for the lightness value.
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