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MULTIPLE LINEAR REGRESSION MODELLING OF HOT WATER EXTRACTION OF SOURSOP JUICE

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ABSTRACT

The effect of hot water extraction on juice yield, ascorbic acid, lightness and total soluble solids of soursop juice was modelled using the response surface methodology. The soursop samples were treated at extraction temperatures of 30, 60 or 90 ^{o}C for extraction times of 30, 90 or 150 minutes. The regression model adequately represented the experimental data with goodness of fit of R^2 greater than 0.60. The juice yield (p<0.05), ascorbic acid (p<0.05), lightness (p<0.05) and total soluble solids (p<0.001) were significantly affected by extraction temperature. The juice yield, ascorbic acid and total soluble solids of soursop juice increased while lightness decreased with increasing extraction temperature.

Keywords: *Hot water extraction, response surface methodology, soursop juice.*

INTRODUCTION

Soursop fruit is a sophisticated and exotic tropical fruit which is known as *durian belanda* in Malaysia. It possesses high values in antioxidant that helps in enhancing human immune system. Soursop is usually eaten in fresh or in other fruit derivatives such as juice, concentrated juice, nectar, purees, jellies and ice-cream [1]. However, juice appears to be the most demanding derivative due to its convenience for consumption. In the beverages industry, juice yield is an important target while colour, ascorbic acid and total soluble solids are responses determining juice quality and consumer acceptability.

Several studies that have been conducted on the extraction of other juices including roselle [2], banana [3] and sapodilla [4] also measured its juice yield and quality attributes. The process variables of temperature and time were used to model and predict the juice yield, ascorbic acid content, total soluble solids, odour, taste, astringency, anthocyanins content, colour density and polymeric colour of fruit juices in previous studies. Models are developed from these variables and responses as a tool to ease the control the processing and optimisation while giving a quantitative understanding of the product variable and response behaviours [5].

The objective of this research was to investigate the effect of extraction temperature and extraction time on the quantity and quality attributes of soursop juice by using response surface methodology.

MATERIALS AND METHODS

Materials

Fresh harvest soursop fruits (*Annona muricata* L.) were purchased from Sungai Ruan, Pahang, Malaysia. The total soluble solids of fresh soursop fruit is 12.95±1.57 ^{o}Brix at 25 ^{o}C

Sample preparation

Soursop fruit was washed, peeled and deseeded. The pulp was then homogenised for 1 minute using a high speed blender (MFM-202, Ta Feng Electrical Appliances Co. Ltd., Taiwan). In each treatment, sample with a mixture of 100 g of the homogenised pulp and 100 ml of distilled water was prepared.

Hot water extraction

The sample was placed into a 250 ml glass bottle and extracted for 30, 90 or 150 minutes with a water bath (BS-21, Jeio Tech Co. Ltd., Korea) at 30, 60 or 90 ^{o}C temperature. The treated sample was then centrifuged using a centrifuge (Biofuge primo, Heraus, United Kingdom) at 6000 rpm for 10 minutes. The supernatant was collected and analysed for juice yield, ascorbic acid, colour and total soluble solids measurements. All the measurements were the average of three samples from the same batch fruits.

Juice yield

The amount of juice extracted is the juice yield and it was determined based on the weight of juice collected, the weight of distilled water added and the weight of pulp used. Juice yield was calculated using Eq. 1:

$$\text{Juice yield}[\%] = \frac{\text{Weight}_{\text{juice}} - \text{Weight}_{\text{distilled water}}}{\text{Weight}_{\text{pulp}}} \text{X}\, 100\% \quad (1)$$

Ascorbic acid

Ascorbic acid was determined using the titrimetric method [6] based on the volume of titration for sample and volume of titration for standard dye. It is indicated by the amount of ascorbic acid obtained in 100 ml of juice. 10 ml of sample and standard ascorbic acid solution were titrated respectively with 2, 6-dichlorophenolindophenol until a faint pink colour persist for 15 s and the titrated volume of 2, 6-dichlorophenolindophenol was recorded as volume of titration for sample and volume of titration for standard respectively. Ascorbic acid was calculated using Eq. 2 [7]:

$$\text{Ascorbic acid}\left[\frac{\text{mg}}{100\text{ ml}}\right] = 20\ \text{X}\ \text{Volume}_{\text{titration of sample}}\ \text{X}\left(\frac{1}{\text{Volume}_{\text{titration of standard}}}\right) \quad (2)$$

Colour

Colour was measured using a Spectrophotometer (UltraScan PRO, Hunter Associates Laboratory Inc., VA, U.S.A.). Soursop juice was filled into a 50 mm glass cell to the top and placed against the reflectance port with an opaque cover. The juice colour parameters, L* (whiteness/brightness), a* (redness/ greenness) and b* (yellowness/blueness) read through the clear glass window were obtained.

Total soluble solids

The total soluble solid, expressed in brix, is an indication of the sweetness of the soursop juice. A total soluble solid was measured using a digital refractometer (PAL-α, Atago, Japan) with a scale of 0-85 ^{o}Brix by placing a few drops of juice on the glass.

Experimental design and statistical analysis

The Minitab Statistical Software (Version 15, Minitab Inc., USA) was used to design a face-centred central composite design for the experimental study and to analyse the responses using ANOVA and regression analysis. The three levels of extraction temperature and extraction time were 30, 60 and 90 ^{o}C, and 30, 90 and 150 minutes respectively. Table 1 shows the experimental design consisting of 13 combinations of test conditions, including 5 replicated centre points.

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Table 1: Face-centred composite design of hot water extraction of soursop juice

Run	Time, x_1 [min]	Temperature, x_2 [^oC]
1	90	60
2	90	60
3	150	60
4	150	90
5	30	30
6	90	60
7	30	60
8	30	90
9	90	60
10	90	60
11	90	90
12	150	30
13	90	30

A full quadratic polynomial model was selected and fitted to the experimental data to represent the effects of factors on responses following Eq. 3:

$$y = C_0 + C_1x_1 + C_2x_2 + C_{11}x_1^2 + C_{22}x_2^2 + C_{12}x_1x_2 \quad (3)$$

where y is the estimated responses, x_1 and x_2 are the uncoded independent variables, the coefficient terms are C_0 (constant), C_1 and C_2 (linear), C_{11} and C_{22} (quadratic) and C_{12} (interaction).

RESULTS AND DISCUSSIONS

Modelling the effects

The experimental data were fitted into regression model (Eq. 3). Eqs. (4)-(7) represented the juice yield (y_1), ascorbic acid (y_2), lightness (y_3) and total soluble solids (y_4) of the extraction process:

$$y_1 = 36.202 + 0.688x_1 + 5.239x_2 - 1.419x_1^2 - 8.132x_2^2 - 1.317x_1x_2 \quad (4)$$

$$y_2 = 4.693 - 0.036x_1 + 0.217x_2 + 0.108x_1^2 - 0.578x_2^2 + 0.054x_1x_2 \quad (5)$$

$$y_3 = 32.120 - 0.226x_1 - 0.385x_2 + 0.226x_1^2 - 0.364x_2^2 + 0.289x_1x_2 \quad (6)$$

$$y_4 = 3.524 + 0.033x_1 + 0.422x_2 - 0.068x_1^2 - 0.168x_2^2 + 0.033x_1x_2 \quad (7)$$

To evaluate the adequacy of the model fitting, the coefficient of determination, R^2, was calculated. The R^2 for the regression equations of juice yield, ascorbic acid, lightness and total soluble solids were 0.779, 0.879, 0.668, and 0.688, respectively. A model is considered valid if $R^2 \geq 0.60$ [8], therefore, all the regression models can describe the experimental data satisfactorily. Overall, the ANOVA shows that the extraction temperature ($p<0.05$) has a greater effect than the extraction time on the soursop juice extraction for all the responses except for the total soluble solids where $p<0.001$.

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Effect of temperature and time on the responses

Juice yield

'Fig. 1' shows that juice yield of soursop juice increased with temperature up to 60 ^{o}C and then decreased after 60 ^{o}C. At higher temperature, the decrease in juice yield may be due to the denaturation of natural enzymes or gelatinisation of pectin which leads to the increase in viscosity and thus a reduction in the juice yield [9]. A study reported that Fuji apple mash undergone heat treatment at 40-70 ^{o}C yielded maximum juice at 60 ^{o}C and then there was a slight decrease at 70 ^{o}C [10]. The yield of heat treated grape juice also reduced significantly with increasing temperature from 60 ^{o}C to 90 ^{o}C [9].

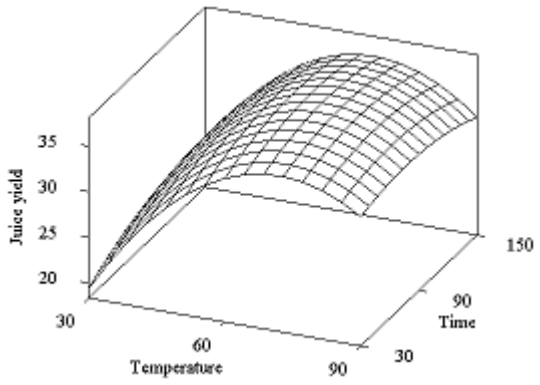

Fig. 1: Effect of extraction temperature and extraction time on juice yield.

Ascorbic acid

'Fig. 2' shows that the ascorbic acid increased up to 60 ^{o}C and then it decreased. This explained the ascorbic acid can sustain up to 60 ^{o}C while thermal destruction of ascorbic acid occurs at high temperature of 60 ^{o}C and above [11].

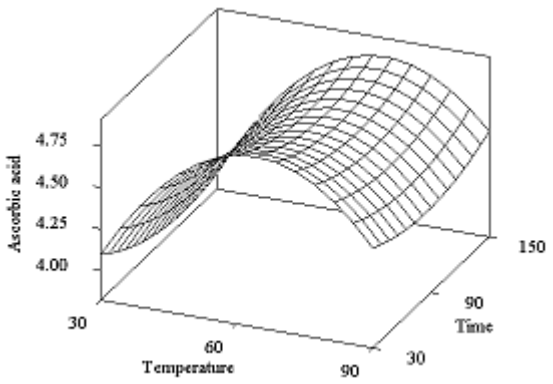

Fig. 2: Effect of extraction temperature and extraction time on ascorbic acid.

Lightness

The lightness of soursop juice decreased with extraction temperature ('Fig. 3'). This indicates that the colour degradation occurs and juice becomes darker in a hot water extraction process. Similarly, Ávila and Silva [12] reported that the lightness of peach puree decreased after the being heat treated at 110-135 °C temperature in an oil bath.

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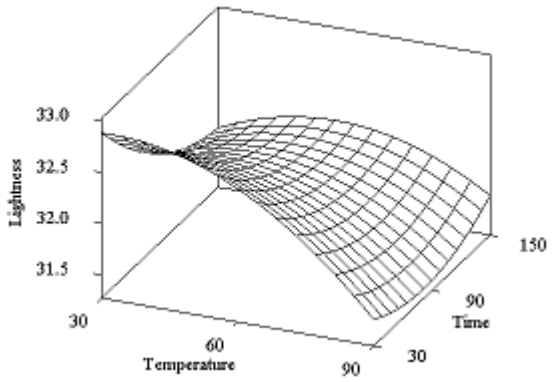

Fig. 3: Effect of extraction temperature and extraction time on lightness.

Total soluble solids

'Fig. 4' shows that the total soluble solids increased linearly with extraction temperature. This explains that the soursop juice becomes sweeter after the soursop samples were extracted. This results is in agreement with Lee et al. [3] findings where the total soluble solids of banana juice increased after being treated at 35-95 ^{o}C for 30-120 minutes.

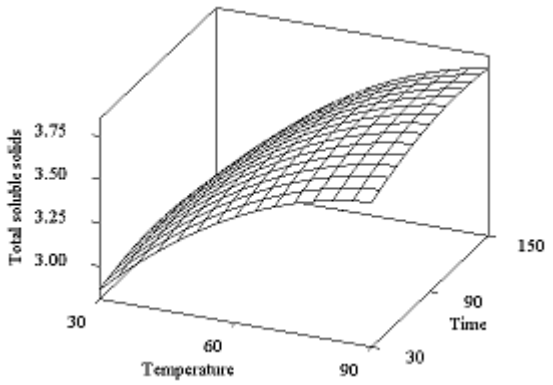

Fig. 4: Effect of extraction temperature and extraction time on total soluble solids.

CONCLUSIONS

The hot water extraction has significant effect on the juice yield (p<0.05), ascorbic acid (p<0.05), lightness (p<0.05) and total soluble solids (p<0.001) of soursop juice. Extraction temperature showed greater effect over extraction time. There is no significant effect in the combined effect of extraction temperature and time. Hot water extraction at temperature of 60 ^{o}C for 30 minutes of extraction time is suggested as it gave maximum values of juice yield at 34.09%, ascorbic acid at 4.84 mg/100ml, lightness at 32.57 and total soluble solids at 3.42 ^{o}Brix.

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