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OPTIMIZATION OF ROASTING ROBUSTA SUKAMAKMUR COFFEE WITH OF RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Experimental design was used to investigate the effect of operating temperature (160–200^0 C) and roasting time (22-30 min) on caffein content. The coffee beans produced using the optimized conditions have the following characteristics: colour; L* 55.3, a* 0.5-4.and b* 18.6; The ranges of the factors investigated were 160–200^0 C for the operating temperature (X1), 22-30 minute for the roasting time (X2). The statistical analysis of the experiment indicated that roasting time, and the temperature had significant effect on caffein content. The central composite design showed that polynomial regression models were in good agreement with the experimental results with the coefficients of determination of 0.94 and 0.89 for caffein content respectively. The optimal condition for caffein content within the experimental range of the variables studied was at 178^{0}C and 29 min. At this condition, the predicted amount of cafeein content was 0.43 mg/100g.

KEYWORDS: Roasting, Coffe Robuska, Response Surface Methodology

1. INTRODUCTION

Coffee is a small red fruit that must go through many stages to become the tasty brown bean we all know as coffee. Most good coffee is first wet processed to remove the outer skin, pulp (which is actually fermented away), and inner parchment skin. Then the inner seed, or bean, is dried and becomes the green coffee that is shipped and stored around the world. Green coffee is a lot like a dry pinto bean- it can be stored for a long time yet still become a fresh and aromatic food item after it is roasted or cooked. The final step to make the coffee bean ready for brewing coffee is to roast the green beans. Without roasting, a beverage made from the green coffee bean would be bitter and extremely acidic- in short, undrinkable Fresh, roasted coffee is one of the most recognisable taste-oriented beverages in daily life for people all over the world, because of its attractive roasty aroma and pleasing bitter taste. Especially in Japan, coffee beverages are in high demand as the second most popular product following tea beverages. Canned coffee drinks are among the major coffee beverage products in Japan. Since these products are subjected to sterilisation treatment during manufacturing, original aromas are unintentionally changed and lost[1]. Generally, coffee flavour is added into the canned products to solve this problem.

For many people who drink coffee from ground beans, drip brewing using a paper filter is popularly used as a quick preparation method. The fresh aroma is better than that of the beverage products. In the flavour industry, development of the coffee flavour products responsible for the pleasant aroma of freshly brewed coffee is desired.

The chemistry of flavor development during roasting of coffee is not well understood. The flavor and aroma of coffee are highly complex, and difficult to describe, resulting from the combined action of over 800 volatile substances. Thus, in view of the large variety of coffees available, of variations in processing and storage conditions, and also of the fact that the content of amines is known to be related to quality of food products in general, an investigation of the profiles of amines in coffee samples of different qualities, as well as the effects of processing on those compounds is relevant.

In Bogor district, especially at Sukamakmur, there are farmer cooperative whose members as Robusta coffe farmers and also handling the post harvest wet process. The coffe plant produces a raw fruit or cherry that is harvested ripe. Once the pulp is removed from the cherry a seed or bean is left which is then dried. This bean is called a green bean and must be roasted before consumers use it to brew coffee. During the roasting process the natural sugars, fats and starches that are within the coffee beans are emulsified, caramelized and released when exposed to high temperatures. Roasting methods vary and help determine the flavor of the final brewed cup of coffee. But, it is important to know that the roast alone does not determien the overall coffee taste or quality. The original and quality of the beans are the true factors that determine the characteristics of particular coffee.

Roasting is an important step in the production of coffee because it enables the development of flavour, aroma and colour. The temperature and time of roasting will influence the development of flavour compounds such as pyrazines. compounds are formed by the reactions that occur during roasting such as Maillard reaction, Strecker degradation, degradation of sugar and breakdown of amino acids.

Recently, many statistical experimental design methods havebeen developed for process optimization [2]. Among them, response surface methodology stands out as a popular method utilized in many fields [3-4]. Many researches have been published in the literature on the on the RSM effect of optimization processing [5-6]. Therefore, the use of response surface methodology was introduced in this experimental research.

The use of RSM in the process optimization leads to the need for an experimental design, which can generate a lot of samples for consumer evaluation in short period of time, and thus laboratory level tests are more efficient [7]. Central composite design (CCD) is the most useful design for estimating multifactor response surface which keeps the numbers of experiments to a minimum while allowing simultaneous assessments of variations of all the experimented factors studied and distinguishing the interaction among them [8]. The objective of this study is to optimise Robusta coffee beans roasting conditions that were able to produce superior quality coffee beans with low acrylamide formation.

2. MATERIALS AND METHODS

2.1. Sample Preparation

Dried wet process (WP) Robusta coffee beans samples were obtained from Sukamakmur Plantation, Bogor, West Java, Indonesia.

2.2. Roasting of Coffee Beans

Coffee beans were roasted using a roaster (PROBAT, Germany) with roasting conditions as suggested by Central Composite Design as shown in Table 1.

2.3. Grinding

Roasted coffee beans were finely ground in a coffee grinder.

2.4. Analysis of Cafeein

The caffeine concentration in coffee samples was determined method based on UV detection and extraction of caffeine with chloroform from aqueous extracts. The method was adapted from the reference methodologies aimed for caffeine determination in coffee [8]. 8 mL of final aqueous extract treated with Carrez reagents (Solution A) were extracted with 3 portions of chloroform (10, 5 and 5 mL). Each portion was shaken for one minute and chloroform phases were recollected and centrifuged for 4 min at 4000 rpm. Chloroform phases were perfectly separated and collected and the volume was filled up to 25 mL with chloroform. An aliquot of 1 mL was taken and diluted at 10 mL with chloroform in a volumetric flask. This solution was measured at 276 nm. The analysis was carried out in triplicate. A calibration curve of caffeine in chloroform with a range between 1 and 25 lg/mL was constructed.

2.5. Color Measurement

The CIELAB color parameters (L*, a*, b*) of the roasted ground coffee and of the soluble coffee were measured in a spectro-colorimeter (Hunter, model Color Quest XE, Reston, VA, USA) by reflectance with excluded specular, light source D65 and 108 observation angle. The hue angle (h8) value was calculated as h8 = arctan (b*/a*).

2.6 Effect of Roasting on the Presence of Bioactive

The roaster, working at a rotation speed of 80 rpm, was pre-heated during 10 min and then loaded with 1.0 kg coffee. The roasting time was selected so it would be enough to char the beans, assuring that the optimal degree of roast was achieved. Bean samples were collected every 5 min during roasting. HPLC analysis was carried out for detection and quantification of the following amines: Putrescine, spermidine, and spermine.

2.7 The Factorial Design

The high, middle and low levels defined for the 2^3 factorial design were listed in Table 1. The low, middle and high levels for the factors were selected according to some preliminary experiments. The factorial design matrix and q_e measured in each factorial experiment are shown in Table 2, with the low (−1), middle (0) and high (+1) levels as specified in Table 1. Q_e was determined as average of three parallel experiments. The order in which the experiments were made was randomized to avoid systematic errors. The results were analyzed with Design Expert 7.0 software, and the main effects and interactions between factors were determined.

Table 1: Factors and Levels Used in the Factorial Design

Factors	Symbol	Low	Middle	High
Temperature(^{0}C)	X1	160	180	210
Time (minute)	X2	22	26	30

Each response Y can be represented by a mathematical equation that correlates the response surface. The three independent variables can be represented as second-order polynomial equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_1b_2X_1X_2 + b_1X_1^2 + b_2X_2^2 \quad (1)$$

where Y is the predicted response, b_0 the offset term, X_1 is the temperature, X_2 is the roasting time and b_1 and b_2 are the coefficients of the adjusted equation. This quadratic model can be used for obtaining the response surface to be analysed.

3. RESULTS AND DISCUSSIONS

3.1 Optimal Conditions for Roasting of Coffee

Response surface methodology was used in order to obtain the relationship between the variables and responses. The range and levels of the variables investigated in the present study are given in Table 1. Generally, these parameters range have been arrived based on the preliminary experiments. It was found from the preliminary studies that t coffee content decreased when operating the process at temperature more than 180^{0}C and therefore the temperature range studied was between 160 and 200^{0}C..

A 2^2 factorial design with five star points and five replicates at the central points were employed to fit the second-order polynomial model, which indicated that 14 experiments are required and presented in Table 2. The central values (zero level) chosen for experimental design were: temperature 180^0C and roasting time 26 minute and experimental runs 2, 6, 8, 10 and 13 were repeated in the random order at these conditions for obtaining the experimental error. By using multiple regression analysis, the responses were correlated with the three variables studied using the polynomial Eq. (1). Table 2 shows the coded experiments conducted as per experimental design along with the response values.

Table 2: Design Matrix and the Results of the 2^3 Full Factorial Design

No	Temperature (0^0C)	Roasting Time(Minutet)	Caffein (Mg/100g)
1	180	26	0.43
2	180	26	0,43
3	200	22	0,34
4	160	22	0.28
5	180	32	0,33
6	180	26	0,43
7	200	30	0,32
8	180	26	0,43
9	160	30	0,35
10	180	26	0,43
11	208	26	0,35
12	150	26	0,43
13	180	26	0,21
14	160	26	0,36

As shown in Table 2, the total numbers of 14 experimental runs based on central composite designs (CCD) with six center points were performed

By applying least squares method and multiple regressionand the interaction term X_1, X_2, were significant model terms. It can be revealed that independent variables individually affected dependent variable.By applying least squares method and multiple regression analysis on the experimental results, the following second order polynomial equation was found to explain the dependent variable by considering the significant terms and was shown in Eq. (2).

$$R = 0,84 + 0,06X1 + 0,26\ X2 - 2,8 \times 10^{-4}X1X2 - 1,62\ X1^2 - 4,07X2^2 \quad (2)$$

with $R^2 = 0,89$

Model Fitting

The F-value is calculated for each type of model, and the highest order model with significant terms normally would be chosen. The first step sequential F-value tests were performed using analysis of variance (ANOVA). As shown in Table 3, the quadratic model is the highest order model with significant terms, due to the P-value of quadratic model is less than that of other model; therefore, it would be the recommended model for this experiment design. The cubic model was found to be aliased. Typically, regression analyses for different models indicated that the fitted quadratic models accounted for more than 95% of the variations in the experimental data, which were found to be highly significant.

The independent variables were fitted to the recommended quadratic equation and examined for the goodness of fit. Several indicators were used to evaluate the adequacy of the fitted model and the results are shown in Table 4.

Table 3: Statistical Parameters for Sequential Models

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Value	P-Value
Linear	6	0.035	$5.84x10^{-3}$	194.62	<0.0001
2FI	5	0.033	$6.60x10^{-3}$	220.04	< 0.0001
Quadratic	3	$8.41x10^{-3}$	$2.80x10^{-3}$	<u>93.49</u>	<u>0.0004</u>
Cubic	1	$4.51 x 10^{-3}$	$4.51x10^{-3}$	150.42	0.0003
Pure error	4	$1.20 x 10^{-4}$	$3.00x10^{-5}$		

Table 4: Statistical Parameters for Sequential Models

Source	Standard Error of Coefficient	Degrees of Freedom	Sum of Squares	Mean Squares	F-Value	P-Value
Model	3.25	5	0.027	$5.45x10^{-3}$	4.47	0.038
X_1	2.16	1	$5.95x10^{-4}$	$5.95x10^{-4}$	*0.49*	*0.051*
X_2	2.16	1	$5.36x10^{-5}$	$5.36x10^{-5}$	*0.044*	*0.84*
$X_1 X_2$	2.16	1	$2.02x10^{-3}$	$2.02x10^{-3}$	*1.66*	*0.24*
X_1^2	2.82	1	$9.20x10^{-3}$	$9.20x10^{-3}$	*0.020*	*0.8*
X_2^2	2.82	1	0.018	0.018	*7.55*	*0.03*
Residual	2.82	12	$8.5x10^{-3}$	$1.21x10^{-3}$	*15.06*	*0.6802*
Lack of Fit	2.10	3	$8.4x10^{-3}$	$2.80x10^{-3}$	*93.46*	*0.006*
Pure Error	2.10	4	$1.2x10^{-4}$	$3.00x10^{-5}$		
Cor Total	2.10	12	*0.036*			

The coefficient of determination (R^2), the adjusted determination coefficient (adj. R^2), coefficients of variation (CV) and model significance (F-value) were used to judge the adequacy of the model [9]. As shown in Table 4, the Model F-value of 4.47 implies that model is significant. There is only a 0.01% chance that Model Fvalue this large could occur because of noise [10]. There is a very low probability value (P-value < 0.0001). P-value less than 0.0500 shows that model terms are significant. The F-value of the lack-offit of 93.46 implies the lack-of-fit is significant relative to the pure error. There is a 0.01% chance that the F-value of the lack-of-lit this large could occur due to noise. The accuracy and variabilityof the above model could be evaluated by the coefficient of determination R^2. The coefficient of determination (R^2) of the model is obtained 0.89, which indicates that 89% of the variability in the dependent variable could be explained, and only 11% of the total variations cannot be explained by the model [11]. When R^2 approaches 1, the better empirical model fits the actual data. The value of the adjusted determination coefficient (adj. R^2) is 0.89, which suggested that there are excellent correlations between the independent variables [9]. The CV as the ratio of the standard error of estimate to the mean value of the observed response, expressed as a percentage, is a measure of reproducibility and repeatability of the models [12]. A model can be considered reasonably reproducible if its CV is not greater than 10%. In the present case, a very lower value of CV (0.38%) clearly showed a high degree of precision and a good deal of reliability of the experimental values [10]. The P-values are also used as a tool to estimate the significance level of each independent variable, which also indicate the interaction strength between each independent variable. The smaller P-values show the bigger the significance level of the corresponding variable.

3.3 Interactions among the Factors

3.3.1 Effect of Temperature and Roasting Time

The temperature plays an important role in the whole roasting process and particularly on the cafeein content. Therefore, the range of temperature for roasting experiment selected in this study was kept in the range of 160-180^{0}C. The result is shown in Figure. 1.

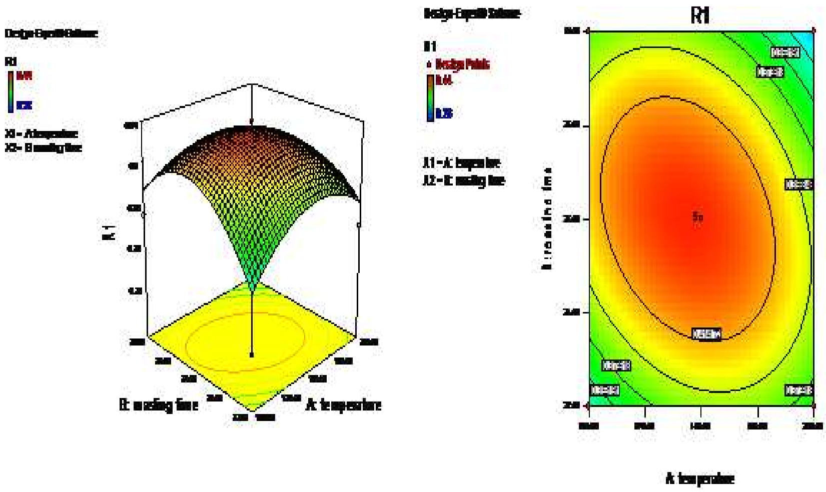

Figure 1: Effects Temperature and Roasting Time on Caffein Content

The effect of roasting time and temperature on the caffeein content is shown in Figure. 1. It indicated that the caffein content increased with increasing temperature over the temperature range 160-200^{0}C, The highest cofee content was observed to be in the temperature range of 160-180^{0}C.

3.2. Color Analysis

The colour description in this study was performed by the components L⁄, a⁄, and b⁄ (Table 2). At the end of three months of storage (‘‘resting period’’) the samples were hulled, and after that there were changes in the colour components in both CN and CD. An increase in L⁄, a⁄ and b⁄ values was observed until the end of the storage, which means an increase in the lightness and in the yellow colour of the beans.

Table 5: Colour Parameters of Coffee During Storage of Unhulled Coffee Beans at Room Temperature and Relative Humidity (Rh) between 60 and 80%

No	Parameter	Start	2 Month	4 Month
1	L	55.3	56.2	58.2
2	a	0.5	0.5	0.6
3	b	18.6	18.5	18.6

3. The Effect of Roasting on Total Amine Content

The effect of roasting on total amine content can be viewed in Figure. 2. There was a significant decrease in total amine content during roasting. After 5min, total amine levels decreased by approximately 44%, for both samples. After 10 min, amine levels were approximately 20% and 3% of the original values, for the samples, respectively.

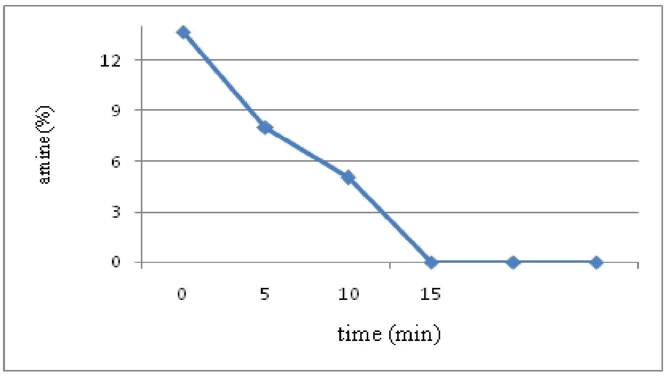

Figure 2: Effect of Roasting on Total Amine Contents

The weight loss during the first 10–12 min is due to the slow release of water and volatile components (drying stage). The increase in weight loss rate after that time can be attributed to an intensive release of organic compounds and CO_2 during pyrolysis. The onset of pyrolysis can be associated with the transition between the two slopes. A comparison of the results presented in Figures. 2 and 3 indicates that amine degradation takes place mainly during the drying stage. Thus, even after a mild roast, total amine levels should be quite small. This is in agreement with the few results presented in the literature[13] reported a reduction of approximately 90% in total amine levels after a light roast (6 min, 300^0C). However, an increase in total amine content was observed for a darker roast (12min, 300^0C)

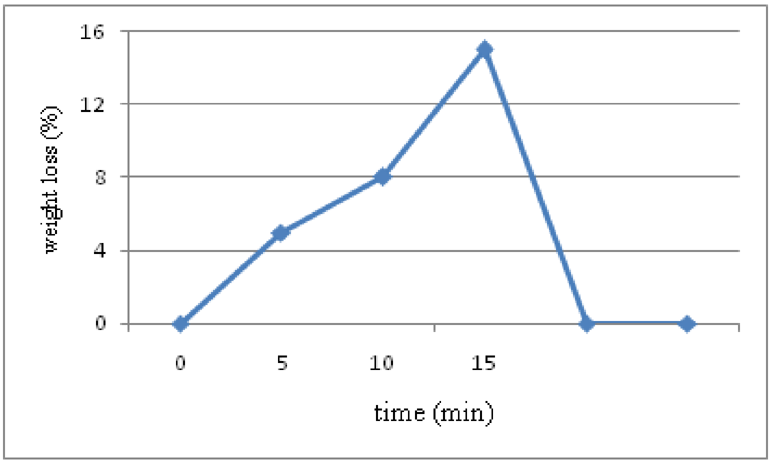

Figure 3: Weight Loss during Roasting of Coffee Samples

CONCLUSIONS

Results obtained from this study indicate that cafeein content significantly influenced by roasting temperature and time with optimum conditions of 178^0C for 29 minute. Under the stuided roating conditions, high amount cafeein was detected 0.43 mg/100 g High quality coffee were characterized by the presence of total amines, weight loss and color analysis. There was a significant decrease in total amine content during roasting, with degradation of total amine during the drying stage.

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