Optimization of cocoa nib roasting based on sensory properties and colour using response surface methodology

Penentuan kondisi optimum penyangraian keping biji kakao berdasarkan sifat organoleptik dan warna menggunakan response surface methodology

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Summary

Roasting of cocoa beans is a critical stage for development of its desirable flavour, aroma and colour. Prior to roasting, cocoa bean may taste astringent, bitter, acidy, musty, unclean, nutty or even chocolate-like, depends on the bean sources and their preparations. After roasting, the bean possesses a typical intense cocoa flavour. The Maillard or non-enzymatic browning reactions is a very important process for the development of cocoa flavor, which occurs primarily during the roasting process and it has generally been agreed that the main flavor components, pyrazines formation is associated within this reaction involving amino acids and reducing sugars. The effect of cocoa nib roasting conditions on sensory properties and colour of cocoa beans were investigated in this study. Roasting conditions in terms of temperature ranged from 110 to 160^{O}C and time ranged from 15 to 40 min were optimized by using Response Surface Methodology based on the cocoa sensory characteristics including chocolate aroma, acidity, astringency, burnt taste and overall acceptability. The analyses used 9- point hedonic scale with twelve trained panelist. The changes in colour due to the roasting condition were also monitored using chromameter. Result of this study showed that sensory quality of cocoa liquor increased with the increase in roasting time and temperature up to 160^{O}C and up to 40 min, respectively. Based on the Response Surface Methodology, the optimised operating condition for the roaster was at temperature of 127^{O}C and time of 25 min. The proposed roasting conditions were able to produce superior quality cocoa beans that will be very useful for cocoa manufactures.

Key words : Cocoa, cocoa liquor, flavour, aroma, colour, sensory characteristic, response surface methodology.

Ringkasan

Penyangraian merupakan tahapan yang sangat penting di dalam pengolahan kakao. Cita rasa, aroma dan warna khas cokelat yang baik berkembang selama proses penyangraian. Sebelum disangrai, biji kakao memiliki rasa sepat, pahit, asam, apek, kotor, terasa seperti kacang atau bahkan menyerupai cokelat, tergantung

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kepada sumber biji dan cara pengolahannya. Setelah mengalami penyangraian, biji kakao memiliki cita rasa khas cokelat yang kuat. Reaksi Maillard yang berlangsung selama penyangraian memiliki peran yang penting dalam penbentukan senyawa cita rasa khas cokelat, diantaranya pirazin sebagai senyawa utama cita rasa khas cokelat dari sejumlah asam amino dan gula pereduksi. Penelitian ini mengkaji pengaruh kondisi penyangraian keping biji kakao terhadap sifat sensori dan warna pasta cokelat yang dihasilkan. Kondisi penyangraian yang dikaji meliputi suhu dari 110 sampai 160°C dan lama sangrai dari 15 sampai 40 menit. Pengamatan terhadap pasta cokelat yang dihasilkan meliputi aroma cokelat, keasaman, rasa sepat, rasa terbakar dan kesukaan keseluruhan yang dikaji menggunakan 9-titik skala hedonik oleh dua belas panel yang terlatih. Perubahan warna pasta diamati mengunakan chromameter. Hasil penelitian menunjukkan bahwa mutu sensori pasta cokelat meningkat dengan meningkatnya suhu penyangraian sampai 127°C dan lama sangrai sampai 25 menit. Berdasarkan Response Surface Methodology *diperoleh kondisi optimum penyangraian pada suhu 127°C selama 25 menit. Kondisi penyangraian tersebut memungkinkan untuk menghasikan mutu pasta cokelat yang baik dan berguna untuk diterapkan oleh pabrikan cokelat.*

Kata kunci: *Kakao, pasta kakao, cita rasa, aroma, warna, sifat sensori,* response surface methodology.

INTRODUCTION

The characteristics of aroma, flavour and colour that develop during roasting as a result of Maillard reaction are the most important characteristics in cocoa products. Therefore, these characteristics can be used to determine cocoa beans quality (Misnawi *et al.*, 2004). Upon roasting, cocoa moisture is removed, desired flavors are developed and astringency is reduced; the nib becomes more brittle and generally darkens in color (Minifie, 1990). After roasting the bean posseses the typical intense aroma of cocoa, although remaining tasteless (Jackson, 1990).

Heat must be applied over a sufficient period to allow steady penetration in order to prevent the burning of the cell. Usually a long time-low temperature or short time-high temperature process with temperature up to 150°C and roasting time up to 40 min are used (Holm, 1991). Variety of bean influences roasting conditions; as an illustration, Ghanaian bean may require the heat of 148–184°C while Caracas and Maracaibos beans need temperature of 131–146°C (Meursing, 1983).

During roasting, pleasant sensory characteristics such as flowery, green, roasty, malty, caramel and nutty will be developed. According to Jinap *et al.* (1998), temperature is a main factor that affect the colour of roasted cocoa beans. Oxidation and polymerisaton of polyphenols, degradation of protein, and Maillard reaction contribute to brown colour of roasted cocoa beans. Thus, it is necessary to control the roasting time and temperature to develop these desired flavour, aroma and colour without burning the beans. Generally, conventional cocoa roasting methods use temperature in the range of 110-140°C and time in the range of 20-50 min (Krysiak, 2006).

Response Surface Methodology (RSM) is an effective tool for optimixing the process when a few factors affect the design responses in certain process. It will give statistical model which help in understanding the interaction among the parameters that have been optimized (Nurdiyana & Mazlina, 2009). Several researchers had investigated the effect of cocoa beans roasting on sensory properties and colour (Counet *et al.*, 2005; Swiechowski, 1996; Ramli, 2008) but there are no studies have been done to optimise roasting process based on sensory quality and colour. Therefore, this study was conducted to determine the optimum roasting conditions using Response Surface Methodology based on these characteristics. The optimised conditions will be very useful for cocoa beans manufactures.

MATERIALS AND METHODS

Sample Preparation

Indonesian cocoa beans were obtained from a plantation in Banyuwangi, East Java, Indonesia. Cocoa beans were de-shelled and cut to particle size of 10-5 mm. The desired cocoa beans nib were collected using a sieve. The samples were kept sealed in plastic and store at room temperature for further works.

Roasting Conditions

Cocoa nib roasting condition had been carried out as suggested by Central Composite Design (CCD) using Design-Expert Software Version 6.0 (Stat Ease Software). Two independent variable were used, temperature (110-160^{o}C) and time (15-40 min). Eight dependent variable (responses) were determined; sensory characteristics (chocolate aroma, acidity, astringency, burnt taste, overall acceptability) and color (L, a*, and b*). The models with statistically significant parameters ($P \leq 0.05$) have been considered and the non-significant parameters ($P \geq 0.05$) were withdrawn from the model (Jinap *et al.*, 1995). Cocoa beans were roasted using roaster (Mitsubishi Probat – Magnetic Contractor model S-N20, the Pascall Engineering Co. Ltd., England).

Sensory Evaluation

Sensory evaluation was carried out by using 12 trained panelists. Cocoa liquor was prepared using Mortar and Pestle Mill (Model 2, The Pascall Engineering Co. Ltd., England). Cocoa liquor flavour is classified as strong, moderate and weak. The panelist were required to taste the samples in term of flavour using the scale of 1-9; 0 for not detected, 1-2 for weak, 3-4 for moderately weak, 5-6 for moderately strong, 7-8 for strong, 9-10 for very strong.

Colour Analysis

Colour of roasted cocoa beans was determined by using Konica Minolta's Chromameter CR-400.The results were expressed in L for luminosity (lightness), a*(green to red) and b* (yellow to blue). The determination was replicated three times.

RESULTS AND DISCUSSION

Preliminary studies had been conducted at different temperature and time in order to get suitable roasting conditions. Based on the CCD, 14 treatments were assigned. Table 1 shows the CCD for the roasted cocoa beans.

The summary of the results obtain from the effect of independent variable; temperature and time on each independent from CCD are shown in Table 2. The effect of independent variable; temperature (T) and time (min) on each variable was divided into first-order (linear), second-order (quadratic) and interactive effects (interaction between pairs of variables). By using lack-of-fit and coefficient of determination (R^2), adequacy of the model can be determined. The significance of equation parameter for all response variables were also assessed by F-ratio at a probability (p) of 0.05. Zaibunnisa *et al.* (2009) suggested R^2 should be at least 0.80 to have good fit of the model. The close the value of R^2 to unity, the better empirical model fits the actual data. The low R^2 value observed for colour, a* (0.459) and b* (0.463) as shown in Table 2 indicates that a* and b* in cocoa beans was not influenced by the roasting temperature and time as suggested by RSM. All sensory characteristics have significant quadratic model and not significant lack of fit except for astringency. However, for colour only L value has significant quadratic model and not significant lack of fit.

Polynomial regression equations relating the responses to the independent variable were generated to obtain the optimal level of two factors (A and B). Numerical optimisation was also been carried out to determine the exact optimum level of independent variable leading to desirable roasting condition. Targets were set at maximum for sensory properties and in range for L. By using predicted equations determined by RSM, the optimal condition that depended on independent variable was obtained. Since the astringency, a* and b* were not good indica-

Table 1. Results of Central Composite Design (CCD) for sensory characteristics and colour of roasted cocoa beans
Tabel 1. Hasil Rancangan Komposit Sentral untuk karakter sensori dan warna biji kakao sangrai

Exp. No. *No. Perc.*	Temp. *Suhu* (°C)	Time *Lama* (min.)	Sensory Properties *Sifat sensori*					Colour *Warna*		
			Chocolate aroma *Aroma cokelat*	Acidity *Keasaman*	Astringency *Rasa sepat*	Burnt taste *Rasa terbakar*	Overall acceptability *Penerimaan keseluruhan*	L	a*	b*
1	135	28	5.0	1.7	2.7	2.0	3.7	39.9	3.6	3.7
2	135	28	4.9	3.0	2.6	2.7	5.1	40.3	2.4	2.4
3	135	28	5.6	4.3	2.6	1.3	6.1	39.5	2.6	3.4
4	135	28	5.6	3.4	2.5	2.0	5.0	39.0	4.0	2.7
5	135	28	5.2	3.7	2.8	1.6	5.4	40.9	2.8	2.7
6	135	28	5.4	4.0	2.9	2.1	4.4	40.3	1.0	1.5
7	110	28	7.2	5.3	3.9	0.0	6.5	42.3	2.6	2.7
8	160	28	3.0	2.4	5.6	7.0	2.6	35.3	0.7	1.0
9	135	40	2.1	2.6	4.9	6.1	2.3	36.9	2.8	3.3
10	135	15	8.0	4.9	1.9	0.0	6.6	41.9	4.2	3.5
11	118	36	4.6	5.3	5.3	2.1	6.4	42.8	2.5	2.3
12	153	19	4.3	3.9	6.3	2.6	5.4	36.0	3.1	3.3
13	153	36	1.3	0.7	7.0	8.6	0.3	34.2	1.7	1.9
14	118	18	7.0	5.3	4.4	0.7	6.0	43.9	1.4	1.7

Note *(catatan)*: sensory properties; 0= not detected, 1-2= weak, 3-4= moderately weak, 5-6= moderately strong, 7-8= strong, 9-10= very strong (*Skala sensori; 0= tidak terdeteksi, 1-2= lemah, 3-4= agak lemah, 5-6= agak kuat, 7-8= kuat, 9-10= sangat kuat*).

tors, the major sensory attributes (chocolate Aroma, acidity, burnt taste, overall acceptability) and colour, L (luminosity) were used for optimization.

Cocoa flavour consists of aroma comprises of volatile compounds produced through Maillard reaction and taste, a balance of bitterness, sourness (acidity) and

Table 2. Analyses of variance for response surface for sensory characteristics and colour of roasted cocoa beans

Tabel 2. Analisis varian dari respon permukaan karakteristik sensori dan warna biji kakao sangrai

Parameters *Tolok ukur*	Model *Model*	Lack of fit *Ketidak-sesuaian*	R^2 R^2	Equation *Persamaan*	Significant model term *Bagian model yang nyata*
Chocolate aroma *Aroma cokelat*	Quadratic Significant *Nyata kudratik*	Not Significant *Tidak nyata*	0.962	$Y = 5.28-1.15A-1.71B-0.29A^2-0.31B^2-0.16AB$	A, B
Acidity *Keasaman*	Quadratic significant *Nyata kudratik*	Not significant *Tidak nyata*	0.826	$Y = 3.35-1.26A-0.08B+0.26A^2+0.18B^2-0.79AB$	A, B, AB
Astringency *Rasa sepat*	Quadratic significant *Nyata kudratik*	Significant *Nyata*	0.877	$Y = 2.66+0.74A+0.73B+1.45A^2+0.77B^2-0.027AB$	A, B, A2,B2
Burnt Taste *Rasa terbakar*	Quadratic significant *Nyata kudratik*	Not significant *Tidak nyata*	0.822	$Y = 2.45+2.27A+2.01B+0.58A^2+0.36B^2+1.14AB$	A, B
Overall Acceptability *Penerimaan keseluruhan*	Quadratic significant *Nyata kudratik*	Not significant *Tidak nyata*	0.915	$Y = 4.96-1.52A-1.35B-0.21A^2-0.26B^2-1.37AB$	A, B, AB
L	Quadratic significant *Nyata kudratik*	Not significant *Tidak nyata*	0.912	$Y = 39.97-3.32A-1.24B-0.55A^2-0.24B^2-0.16AB$	A, B
a*	Quadratic not significant *Tidak nyata kudratik*	Not significant *Tidak nyata*	0.459	$Y = 2.71-0.22A-0.27B-0.63A^2+0.29B^2-0.63AB$	-
b*	Quadratic not significant *Tidak nyata kudratik*	Not Significant *Tidak nyata nyata*	0.463	$Y = 2.74-0.15A-0.14B-0.54A^2+0.25B^2-0.51AB$	-

Note (*Catatan*): The central composite design was generated using Design Expert 6.0 Software *(Rancangan Sentral Komposit mengunakan perangkat lunak Design Expert 6.0)* A= Temperature, °C *(suhu, °C)*; B= Static time, min *(waktu tetap, menit)*.

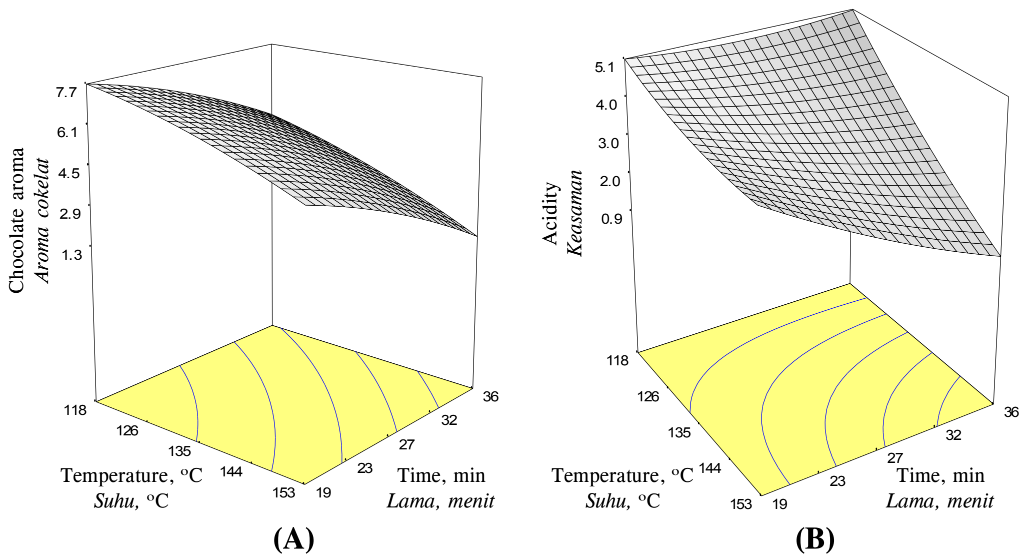

Figure 1. Design-Expert 3D plots for chocolate aroma (A) and acidity (B).

Gambar 1. Plot Design-Expert 3D untuk aroma cokelat (A) dan keasaman (B).

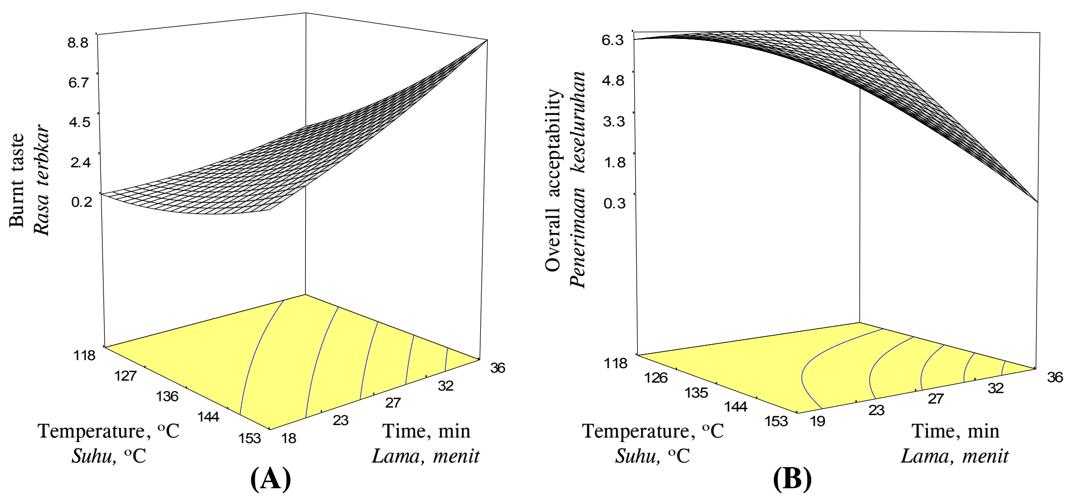

Figure 2. Design-Expert 3D plots for burnt taste (A) and overall acceptability (B).

Gambar 2. Plot Design-Expert 3D untuk rasa terbakar (A) dan penerimaan keseluruhan (B).

sweetness sensation in mouth (Misnawi & Wahyudi, 2010). Chocolate aroma is very specific and cannot be replaced by other sources. As shown in Figure 1A, the highest chocolate aroma was obtained at high roasting temperature (135°C) but at short roasting time (15 min). This is most likely due to cocoa flavour that will be develop better at high temperature, but it will burnt if roasting temperature is too high. This burnt flavour will mask the cocoa flavour. This result correlates well with burnt taste results, whereby it increased with roasting time and temperature, Figure 2A. During roasting, diketopiperazines or know as cyclic dipeptides will be generate and mix with theobromine. This will induce the bitter taste in cocoa (Beckwett & Ziegleder, 2009). As temperature increase, more formation of diketopiperazines will generate and this will result to burnt taste in cocoa.

Inverse relationship was noticed for acidity as shown in Figure 1B. Acidity was an important attribute to balance cocoa flavour. However, excessive acidity will give defect flavour for cocoa beans (Ramli *et al.*, 2008). In this study, pH obtained for cocoa beans was 5.0-5.1 and after roasting was 5.1-5.3. This acidity usually preferred by chocolate manufacture (Beckwett & Ziegleder, 2009). In term of overall acceptability, there were gradual acceptability of the panelists as time and temperature increased up to a certain level and started to reduce after that as shown in Figure 2B.

Besides sensory characteristics, colour of roasted beans and the loss of weight occurred after roasting also can be used as reference standard to characterize the best of roasting condition as suggested by Luciane (Luciane *et al.*, 2001). Thus, in this study colour value L (luminosity) was used to determine the quality of the beans. The L value was decreased linearly with increase in temperature and time as shown in Figure 3. This result correlates well with the findings obtained by Luciane (Luciane *et al.*, 2001). Similar results were obtained by Krysiak (2006) whereby superior colour pigment content in roasted cocoa beans can be obtained after roasting for 120-140°C for 20 min. The colour component L, found in optimal roasting condition (127°C at 25 min) was 39.97.

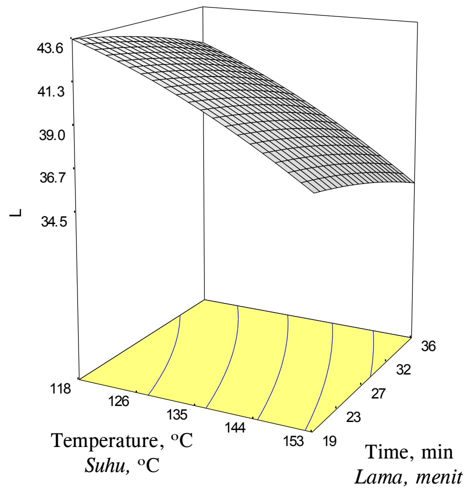

Figure 3. Design-Expert 3D plot for colour value, L (luminosity).

Gambar 3. Plot Design-Expert untuk nilai warna L (luminosity).

Statistical optimisation based on maximum sensory attributes (chocolate aroma, acidity, spoilage, overall acceptability) and colour, L (luminosity) was a temperature 128°C and a time of 25 min which gave desirability value of 0.715. This optimized condition can be produce superior quality cocoa beans that will be very useful for cocoa manufacturers.

CONCLUSION

From this study, sensory quality of cocoa beans increased with the increase in roasting time and temperature from 110 to 160°C and 15 to 40 min, respectively. The optimized condition in terms of time and temperature for cocoa beans roasting is at temperature of 127°C and a time of 25 min.

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