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ORIGINAL ARTICLES

Moisture, Color and Texture Changes in Cocoa Seeds duringSuperheated Steam Roasting

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ABSTRACT

Roasting is one of the basic unit operations in the cocoa base industries.Cocoa beans were roasted using superheated steam oven in superheated steam mode at 150, 200 and 250^{0}C for 50 min. The effect of heating time and temperatures with roasting methods on the moisture content, color and texture of the cocoa beans were studied. The changes occurred in the moisture content, colorvalues (L-, a-, b- and BI) and textural properties (hardness and fracturability) of the cocoa seeds were investigated using the two different roasting methods. The moisture content was decreased with increased time and temperatures. Superheated steam roasting significantly affected the colors and texture values with extended roasting.The color values and textural properties were affected sharply at 200 and 250 ^{0}C thanat 150 ^{0}C during superheated steam roasting. Roasting with superheated steam achieves good results due to the short drying phase although high temperature required.

Key words: Superheated steam, Cocoa bean, Roasting, Moisture, Color andTexture.

Introduction

Cocoa beans are the seed of fruit tree (*Theobroma cacao*), that are essential ingredient of chocolate and chocolate base industries. (Krysiak, 2011). The cocoa butter,cocoa liquor, cocoa powder and cocoa cake obtained from cocoa beans which are widely used in food industries. The beans have a rich history because it contains characteristics flavor and aroma. Roasting is the basic unit operation that causes important physical, chemical, structural and sensorial changes and develops the flavor, brown color and texture of roasted beans (Ozdemir & Devres, 2000; Pittia *et al*., 2001; Saklar *et al*., 2001). The heat treatment also serves to loosen the shell when the beans are roasted (Krysiak and Motyl-Patelska, 2006).

Moisture, color and texture measurement are valuable indicators of the quality of roasted cocoa bean. Changes in moisture content or seed color are currently used as quality standards to determine flavor of cocoa after roasting. Maillard reaction plays an important role in the formation of this color and flavor during roasting (Ziegleder, 1991). The free amino acids and reducing sugarstwo major precursors involved in the reaction which develop during fermentation. The condensation of the of the carbonyl group of a reducing sugar with an amino compound involves in the first stages of the Maillard reaction, followed by the degradation of the condensation products to provide a number of different compounds. The convectional method is commonly used for roasting of cocoa beans taking into account the general impactof process parameters such as temperature and time (Jinap *et al*., 1998, Nebesny and Rutkowski, 1998). The high temperatures and low moisture contents are the ideal conditions for the Maillard reaction and these conditions can be found in suitable roasting method (Heinzler and Eichner, 1992).Roasting parameters varies from 120 to 250^{0}C for 10 to 120 minutes depending on the color, flavor, texture and application desired (Ramli *et al*., 2006). A number of drawbacks have been reported on due to traditional ways of heat and energy transfer and this heat treatment process takes too long that may contribute loss of aroma and increased bitterness of bean.The undesirable burned flavor and odors coming from bean is considered as quality damage (S`wiechowski, 1996). The temperature difference between the kernel and the husk of cocoa beans is also disadvantages of this method. Another important demerit is to transfer of cocoa butter from kernel to husk of the bean by this traditional convection roasting of cocoa bean beacuse it is economically important because industries only use the kernel (Nebesny and Rutkowski, 1998).The properties of the fat of cocoa beans are also damaged that is the main component of cocoa beans using convection roasting (Chaiseri and Dimick, 1989, Shukla *et al*., 2003).

Modern superheated steam is a clear, colorless gas obtained under normal pressure at 100°C to a higher temperature by the application of heating ordinary steam. The principle of superheated steam for roasting is that it has temperature above the saturation or boiling point. When water is heated and reaches its boiling point it is known as saturation steam at any specific pressure. The steam becomes unsaturated or superheated, once heated

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beyond the boiling point. Then steam can transfer heat to the products that is being dried increasing the products temperature. In compare to saturated steam, a drop in temperature does not cause condensation of the steam as long as the temperature is higher than the saturation temperature. The moisture loss becomes part of the drying medium that is evaporated there is no need to be exhausted (Tang and Cenkowski, 2000). Superheated steam can then be used in both the heating and drying of food (Iyota *et al*., 2001). It has been demonstrated that drying food using superheated steam yielded better colour, and lower percentage of oxidisation and nutrient loss(Yoshida and Hyodo, 1970). Superheated steam is an energy efficient process compared to conventional hot air due to possibly reuse of the latent heat of evaporation as drying medium (Fitzpatrick, 1998; Berghel and Renstrom, 2002). During the reheating process of food stuffs with high initial water content superheated steam has advantages than conventional method (Fraile and Burg, 1997). It has been also claimed that this technology heated foods while retaining vitamins and other essential nutrients known as healthy cooked (Chen *et al*., 1992; Mujumdar, 1995; Huang *et al*., 2004; Pronyk *et al*., 2004; Head *et al*., 2011).

The aim of this work to characterize the moisture, color and texture changes of cocoa beans by superheated steam roasting. The final goal is to ascertain which parameter could be used to be able to establish roasting time and temperature to produce optimally roasted cocoa beans.

Materials and Methods

Roasting of cocoa beans:

Approximately 200g portions of cleaned medium size raw beans with a diameter of 18-24mm (moisture content: 6.45±0.12) distributed in a single layer on a plate regardless of the roasting method were used in this study. The cocoa beans were collected from Cocoa Research and Development Center, Hilir Perak, Malaysia and stored in a chiller (7 ^{o}C) allowed to equilibrate before roasting at room temperature overnight. A superheated steam oven (Healsio, AV-1500V, SHARP) in superheated steam mode were used that was preheated to the roasting temperature. The roasting was carried out at 150, 200 and 250^{o}C and the oven door was only opened once to remove the beans.Samples were taken at different time intervals (10-50 min) during roasting processand immediately equilibrated to room temperature. The roasted sample beans were packed in polyethylene plastic bags and stored for further experiment. All experiments were repeated two more times for a total of three replications with every roasting time and temperatures.

Moisture measurement:

The raw and roasted sample beans were deshelled and then grinded after roasting. The moisture determinations were performed. Approximately 5g were used to determine the moisture content using the Automatic MX-50 moisture analyzer at 140 ^{0}C.

Color measurement:

The surface color of the roasted cocoa bean samples were measured using a Minolta CM-3500D colorimeter (Light source, Pulsed xenon arc lamp; Reflectance, d/8; Measuring head hole, 8mm; Measurement time, 2.5 sec) after calibration against white and black glass standards. The colors were expressed in CIELAB color values (L-, a-, b-) where the L- value represents the lightness to darkness gradation, a- value represents the greenness to redness spectrum and the b- value represents the blueness to yellowness spectrum. The color values (L-, a-, and b-) are the three dimensions which gives specific color values of the products. From the colorimeter readings of L-, a-, and b- values,the browning index (BI) (Eq.1) also used to estimate total color changes during roasting materials (Maskan, 2001).

$$BI= [100(x-0.31)] /0.17 \qquad (1)$$

Where, $x= (a+1.75L) / (5.64L+a-3.012b)$

Texture profile analysis:

Texture profile of the roasted beans were measured using Universal Texture Analyser (CNS, Farnell, UK) equipped with the Texture Pro^{TM} texture analysis software. A 36mm cylindrical probe P/36 R was used for the measurement of texture in terms of compression force (g) and the instrument was calibrated with a 30 kg load cell. The samples were placed onto the platform. The probe was allowed to compress 5 mm into the sample and the target value was set at 15 mm at 1mm/s. The texture profile analyzer enabled to calculate the hardness and fracturability of the sample beans. The textural properties were obtained from the force time curves (Bourne,

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1982). Hardness (N) (maximum peak of first compression) and Fracturability (N) (first peak of first compression) were considered to evaluate the textural properties of the cocoa beans.

Statistical Analysis:

Every sample with each time and temperature parameter was measured in triplicate and the obtained data was expressed as the means of measurements ± S.D. The two-ways analysis of variance method (ANOVA) was used to determine the effect of time and temperature on these responses. The analysis of variance tests were performed using SPSS 17.0 (SPSS Inc., Chicago, IL, USA). All the tests of statistical significance were based on the total error criteria with a confidence level of 99%.

Results and Discussion

Heat loss analysis:

During roasting by superheated steam method the changes in the moisture content of cocoa beans at 150, 200 and 250 ^{0}C as a function of roasting time were shown in Fig 1. There were similar trend observed at three roasting temperature.The study observed that roasting temperatures significantly ($p>0.01$) affected the moisture loss during roasting process. Faster moisture loss occurred with extending time and temperatures.

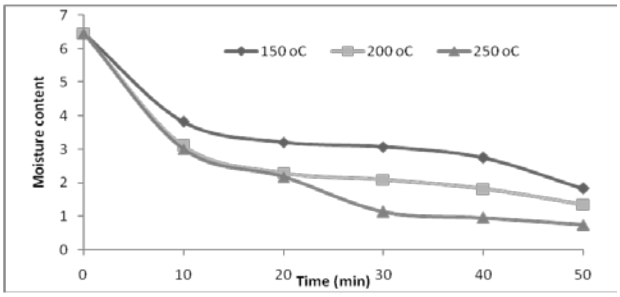

Fig. 1: Changes in the moisture content of cocoa beans during superheated steam roasting at different temperatures (150, 200 and 250 ^{o}C) for 50 min.

Analysis of color formation:

Color is important parameter of food material that is used for controlling of a process. Roasting operations are controlled on the basis of color formation because brown pigment develops as browning and caramelization reaction progress during roasting periods (Saklar *et al*., 2003). The changes in L-, a-, b- and BI values of cocoa beans roasted at different temperatures were presented in Fig. 2. The implemented two-ways ANOVA indicated that time and temperature significantly ($p < 0.05$) affected the color values of cocoa beans during superheated steam roasting.

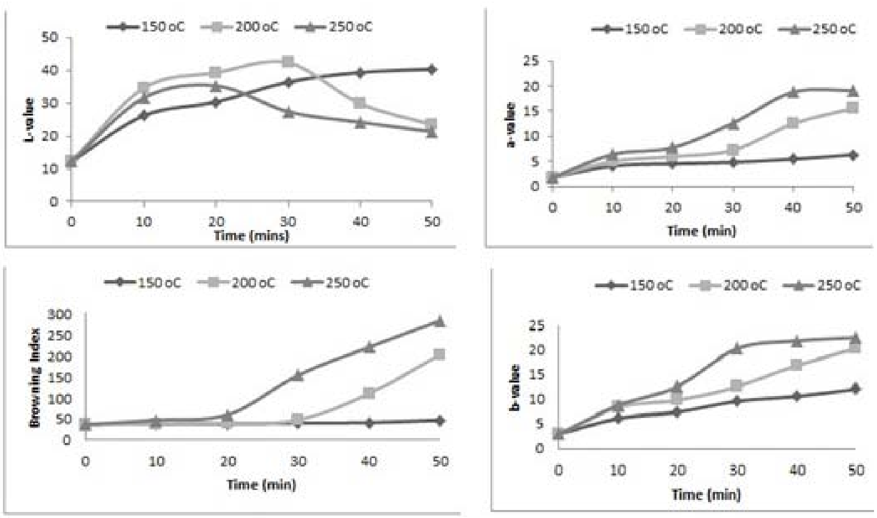

Fig. 2: Changes in the color parameters of cocoa beans during superheated steam roasting at different temperatures (150, 200 and 250 ^{o}C) for 50 min.

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The L-value shows lightness of the roasted products and the gradual increase in the L-value was observed at the initial period of superheated steam roasting. Similar trends were observed for hazelnuts by Ozdemir and Devres (2000) and peanuts by Moss and Otten (1989). During roasting, the denaturation of protein, the concentrated amount of oil particles surrounded in protein matrix and low moisture content could be reasons of lightening of cocoa beans. There was a declining in the L- value (darkening) of the cocoa beans at higher roasting temperatures (200 and 250 ^oC) with time after initial lightening. Nonetheless, there was no reduction observed in the L-value during roasting at 150 ^oC in both methods and the lightening period become shorter as the roasting temperature.

The a-value shows redness of the products. The changes in the a-value during roasting in both methods were shown in Fig. 2. An initiation period was also found and then increased sharply in the a-value during roasting of cocoa beans at 200 and 250 ^oC but the a-values of roasted beans at 150 ^oC did not increase sharply. The formation of brown pigments through the non-enzymatic browning and phospholipids degradation could be reasons of increasing of a-value. The study observed that the increase in the a-value was correlated with decrease in the L-value during roasting process.

The b-value shows the yellowness and the variation in the b- value during cocoa roasting were shown in Fig. 2. The b-value increased with extending of roasting time and temperature in superheated steam. Similar trend was observed as in the a-value for the changes of b-value during roasting in both methods. Similar results were also reported for the b-value of roasted hazelnuts at initial stages of roasting (Ozdemir and Devres, 2000).

The purity of brown color is known as browning index (BI) of products (Maskan, 2001). The changes in the BI value of cocoa beans during superheated steam roasting were presented in Fig. 2. The browning index plots give better possibility to estimate roasting time at which darkening initiated. The browning index value of cocoa beans continued nearly constant during roasting period at 150 ^0C whereas it was constant up to 20 min at 200 ^0C and up to 30 min at 250 ^0C, then BI value sharply increased.

The formation of more dark color is the common problem with the processing of cocoa beans. The roasting process of cocoa beans should be controlled properly because if cocoa beans were over-roasted, consumers might not accept the products and if under-roasted then desirable color and flavors will not come out.

The relationship between the color values as L-, a-, b- and BI with the duration roasting time at different temperature were presented in Table 1. The correlation (r) and p-value of each temperature were analyzed using the regression fitted line plot at each method. The r- value represents the strength of association between color analyses with duration of roasting time in this study. The value vary between +1 and -1, where +1 indicating a strong positive correlation with both variables increasing together while one variable decreasing as the other increase indicating -1 (negative correlation) and 0 means (zero correlation) no correlation with each other's. A correlation coefficient between -0.20 and 0.20 is not strong enough to be considered significant with each other's (Epstein *et al*., 2002).

The lightness value increased initially and then decreased over time and the r-value was statistically significant ($p<0.01$) at 150 whereas not significant at 200 ^0C and 250 ^0C. The roasting at 150 ^0C showed a better positive relationship of lightness (L*) value with time (r=-0.94) as compared with the other roasting temperature (Table 1). There were also significant relationship found in browning index value (BI) with time obtained from L-, a- and b- at three temperature and very strong relationship observed at 250 ^0C.

Redness (a-) and yellowness (b-) values showed significant ($p<0.01$) relation over roasting time at each temperature during roasting. Study observed that superheated steam roasting at 250 ^0C showed better relationship in the a- and b- values as compared to roasting at 150 ^0C and 200 ^0C temperatures. During superheated steam roasting method, the color values (L-, a-, b- and BI) were more affected by higher temperatures of roasting than lower temperature applied.

Table 1: The relationship between the color values with the duration of superheated steam roasting of coco beans.

Analysis	Roasting method	Temperature (^0C)	Time (min)	p-value	r-value
Lightness(L-)	Superheated steam	250	10-50	0.857	0.096
		200	10-50	0.686	0.212
		150	10-50	0.005	0.939
Redness(a-)	Superheated steam	250	10-50	0.001	0.981
		200	10-50	0.001	0.971
		150	10-50	0.005	0.941
Yellowness(b-)	Superheated steam	250	10-50	0.002	0.966
		200	10-50	0.000	0.990
		150	10-50	0.000	0.984
Browning Index (BI)	Superheated steam	250	10-50	0.002	0.961
		200	10-50	0.035	0.844
		150	10-50	0.011	0.911

Texture analysis:

Texture is another important quality control parameter for roasting of cocoa beans. The cooking temperature and moisture content were significant factors that affect the texture of foods (Lin *et al.*, 2000). During roasting method the texture became more fracture (crispy) and crumbly because of the loss of moisture content (Vincent, 2004; Emily *et al.*, 2009). The texture of food can be affected due to changes in the distribution of fracture intensities even at low level of moisture. The textural characteristic of extruded and crunchy products is known as fracturability and deformation propertie (Barrett and Kaletunc, 1998).The hardness and fracturability (first fracture force) were decreased during roasting of cocoa beans at different temperatures presented in Fig. 3. The trend of textural parameters as a function of the corresponding time was almost similar showing a progressive and significant decrease ($p < 0.01$) as exposure time, indicating a progressive reduction in the strength of cocoa beans regardless of different roasting temperature. The decrease in hardness shows that at the same deformation, the required force to break the cocoa beans decreased with extending temperature and time. It also observed the decreasing in the first fracture point during hazelnuts roasting (Saklar *et al.* 2001).

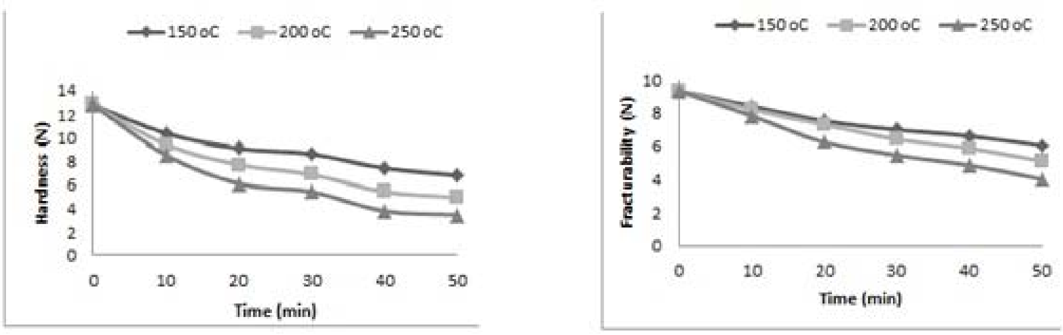

Fig. 3: Effect of temperature and time on the hardness and fracturability of cocoa beans during superheated steam roasting at different temperatures (150, 200 and 250 ^{o}C) for 50 min.

The relationship between the textures values with the duration of roasting at different method were shown in Table 2. There were strong negative relationships between the hardness values with roasting time regardless of different roasting temperature and the fracturability and hardness values were positively correlated with each other.

Table 2: The relationship between the texture values with the duration of roasting at different method.

Analysis	Roasting method	Temperature (^{0}C)	Time (min)	p-value	r-value
Hardness	Superheated steam	250	10-50	0.005	-0.940
		200	10-50	0.003	-0.958
		150	10-50	0.002	-0.967
Fracturability	Superheated steam	250	10-50	0.001	-0.981
		200	10-50	0.000	-0.995
		150	10-50	0.000	-0.986

Conclusion:

The physical changes of cocoa beans occurred during roasting process using superheated methods that favorably affected the physical properties of cocoa beans. The moisture content of cocoa beans decreased with extending of time and temperatures. The lightness of cocoa beans initially increased and then decreased during roasting process at different temperatures. It was observed that the increase in the redness and yellowness of cocoa beans with increasing time and temperatures. The browning index values of cocoa beans maintain nearly constant initially and sharply increased at higher temperature and time.There were observed more fracture and less hard with the effect of roasting that might be evidence of crisp texture of cocoa beans. Superheated steam roasting as a new method could be more appropriate and flexible than conventional methods because the desirable characteristics of food in terms of color and textural are preserved. This method takes short time to achieve the optimum roasting characteristicswhereas the traditional method takes too long that may contribute loss of aroma and increased bitterness of cocoa bean.

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