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Color Characteristics of Dried Cocoa Using Shallow Box Fermentation Technique

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***Abstract*—**Fermentation is well known as an essential process to develop chocolate flavor in dried cocoa beans. Besides developing the precursor of cocoa flavor, it also induces the color changes in the beans. The fermentation process is influenced by various factors such as planting material, preconditioning of cocoa pod and fermentation technique. Therefore, this study was conducted to evaluate color of Malaysian cocoa beans and how the duration of pods storage and fermentation technique using shallow box will effect on its color characteristics. There are two factors being studied i.e. duration of cocoa pod storage (0, 2, 4 and 6 days) and duration of cocoa fermentation (0, 1, 2, 3, 4 and 5 days). The experiment is arranged in 4 x 6 factorial designs with 24 treatments and arrangement is in a Completely Randomised Design (CRD). The produced beans are inspected for color changes under artificial light during cut test and divided into four groups of color namely fully brown, purple brown, fully purple and slaty. Cut tests indicated that cocoa beans which are directly dried without undergone fermentation has the highest slaty percentage. However, application of pods storage before fermentation process is found to decrease the slaty percentage. In contrast, the percentages of fully brown beans start to dominate after two days of fermentation, especially from four and six days of pods storage batch. Whereas, almost all batches of cocoa beans have a percentage of fully purple less than 20%. Interestingly, the percentage of purple brown beans are scattered in the entire beans batch regardless any specific trend. Meanwhile, statistical analysis using General Linear Model showed that the pods storage has a significant effect on the color characteristic of the Malaysian dried beans compared to fermentation duration.

***Keywords*—**Cocoa beans, color, fermentation, shallow box.

I. Introduction

FERMENTATION is an essential process during curing of the cocoa beans, which enable the development of flavor precursor [1] and determine the final color of dried cocoa beans [2]. The process begins once the cocoa beans are exposed to the environment, promoted the growth of various microbial at the white surrounding layer. These microbial activities lead to the increasing temperature of cocoa mass, producing alcohols and organic acids such as lactic and acetic acid as metabolites [3]. At the same time, these metabolites are diffused into the cocoa cotyledon thus resulted in the acidification of cotyledon (nib) and triggers biochemical changes on proteins [4], polyphenols [5], sugars [6] and cocoa butter [7] producing precursors such as polypeptides, amino acids, reducing sugars and free fatty acids. These changes will ensure the existence of cocoa flavor, reduced the levels of acidity as well as bitterness, astringency and color development in finished chocolates. The production of the best quality dried cocoa beans is proven as a resulted from the complete fermentation process and is indicated by fermentation degree. Upon completion, the cocoa fermentation process should be terminated as soon as possible to prevent over-fermented by drying the beans either using sun dryer or artificial dryer. On the other hand, terminating incomplete cocoa fermentation will produced under-fermented beans with weak chocolate flavor. The degree of fermentation can be determined either by cut test or by fermentation index analysis [8].

Cut test is based on visual observation for color changes on the surface of cocoa cotyledon. The test is most widely used to assess the quality of a random sample of beans from a batch as the method is simple and does not required a costly instrument. The test is carried out by cutting lengthwise through the middle to expose the maximum cut surface of cotyledons on a selected number of dried cocoa beans. The beans then will be grouped according to color i.e. slaty, fully purple, partly purple, partly brown, and fully brown [9]. The total of beans in each group will be counted and expressed in percentage. The dried cocoa batch will be considered good if their fully brown beans are more than 60%, moderately good (45%-60%) and fairly good for below 45% with slaty beans should not exceeding 3% [10], [11]. On the contrary, the fermentation index is more complicated and accurate as the determination is using spectrophotometer. The method is based on hyphothesis that the polyphenol compound which responsible for purple color is break down to their products during fermentation process. Oxidation of these products is suspected to contribute in the development of brown pigments [12]. Therefore, the value of fermentation index obtained from the ratio of absorbance of 460 nm to absorbance at 530 nm [13]. The cocoa beans are considered as under-fermented if the value of fermentation index is below 1.000, 1.000 - 1.599 is completely fermented and more than 1.600 as over-fermented, respectively [11].

The fermentation process is reported to be influenced by duration of pod storage and fermentation. While, it is reported that color has given an impact on flavor perception of other foods and beverages. Report on the impact of combination pods storage with either heap or woven basket fermentation technique on the percentage of color in dried cocoa beans has been reported [14], [15], but the extent to which this combination of pods storage and shallow box technique would influence the color characteristics of Malaysian beans still

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remains unknown. Therefore, this study was conducted to evaluate the effect of the duration during pods storage and fermentation process using a shallow box technique on to color characteristics of Malaysian dried cocoa beans.

II. Experimental Procedure

A. Sample Preparation

Ripe and healthy cocoa pods of mixed clone were harvested from Cocoa Research and Development Centre (CRDC) Perak, Malaysia and pulp preconditioning was done according to [16] with slight modification. The cocoa pods were stored in dry and well aerated conditions under a roof for 2, 4 and 6 days. Prior to fermentation, the pods were opened, fresh cocoa bean extracted and sorted manually. Only healthy fresh beans were used for fermentation.

B. Fermentation and Drying

Fermentation was carried out simultaneously in shallow box measuring 90 X 60 X 31 cm3 for five days (Fig. 1) as described in [16] for all treatment. A total of 150 kg wet beans were loaded into each box and the mass was covered with gunny sack. The beans mass was turned at 72 hours by transferring from one box to another. Approximately 15 kg of fermented beans were taken randomly at the top, middle and the bottom layer of mass for duration of 0, 24, 48, 72, 96 and 120 hours fermentation, respectively. The beans were sun dried at one bean thickness on drying platform until the moisture content reduced to less than 7.5 per cent. Upon dry, each of samples were "quartered" down using quartering tools to approximately two kilogram each, labeled and stored in sealed container.

Fig. 1 Shallow box used in the experiment

C. Cut Test

A total of 100 dried beans samples were taken randomly from 250 gram samples derived by quartering technique [10] with slight modification. The dried beans were cut lengthwise into halves for maximum surface exposed. Both halves of each surface were inspected under artificial light and divided into four groups (fully brown, purple-brown, fully purple and slaty) as showed in Fig. 2. The total of dried beans in each group were counted and expressed in percentage and replicated for six times.

Fig. 2 Color of cut surface of dried cocoa beans

D. Statistical Analysis

All of data obtained was analyzed for ANOVA using Minitab version 16.1.0 to investigate and recognize the effect of fermentation duration using shallow box technique and pods storage on the color changes of dried cocoa beans. Comparison of treatment means and significant differences between treatments means separated were assessed using Tukey Method.

III. Result and Discussion

In this research, cut test was done on 100 beans of dried cocoa from each fermentation batch, which was obtained by quartering technique. The color percentages of dried unfermented cocoa beans are presented in Fig. 3. A total of 93% of the dried unfermented cocoa beans were slaty and 7% were purple beans, respectively. There is no purple-brown and fully brown beans observed in the samples. The absence of purple-brown and fully brown cocoa beans was in accordance with expectations. However, the presence of purple beans is unexpected as the purple cocoa beans have been reported to be presence when the fermentation has been terminated prematurely [17].

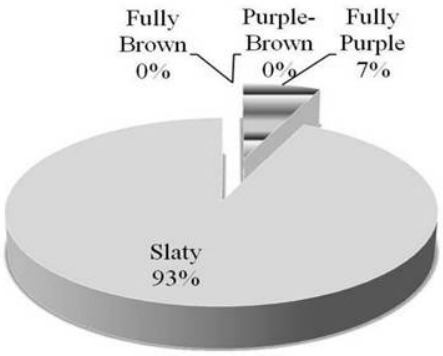

Fig. 3 The color percentages of dried unfermented cocoa beans

Slaty bean is a bean that has more than 50% of the grey cotyledon, have rubbery cotyledon and resistance for cutting. The bean was reported as a product of drying the beans which are not undergone fermentation. Whereas, fully brown bean is a bean which has gone through a complete fermentation process before being dried [17]. These two colors were used as the indicator for the quality of fermentation because farmers

claim that fermentation and drying process are troublesome and delay their income earning, so they tend to neglect fermentation by directly drying the fresh cocoa beans after pods are broken. Therefore, the usage of fermentation indicator will help buyers of cocoa beans to differentiate either the batch of dried beans has undergo a complete fermentation process or not and at same time ensuring the quality.

The color percentages of dried cocoa beans from different fermentation durations are shown in Fig. 4. The percentage of slaty beans decreased from 80.5% to 6% for fermentation duration of one and two days. The slaty beans were no longer presence when the fermentation is carried out for more than three days. Similar to slaty, the percentage of purple beans were also decreased until 0% with the extension of fermentation duration to four and five days. Meanwhile, there are no fully brown beans for duration of one or two day's fermentation. However, the fully brown beans were increased to 47.5%, 59.5% and 65% when the fermentation duration was extended for three, four and five days, respectively. Interestingly, the purple-brown beans were always presence throughout fermentation duration. The percentage of the purple-brown beans were increased from 6.5% to 76.2% for one and two days of fermentation duration and subsequently decreased to 51.3%, 40.5% and 35.0% for fermentation duration of three, four and five days, respectively.

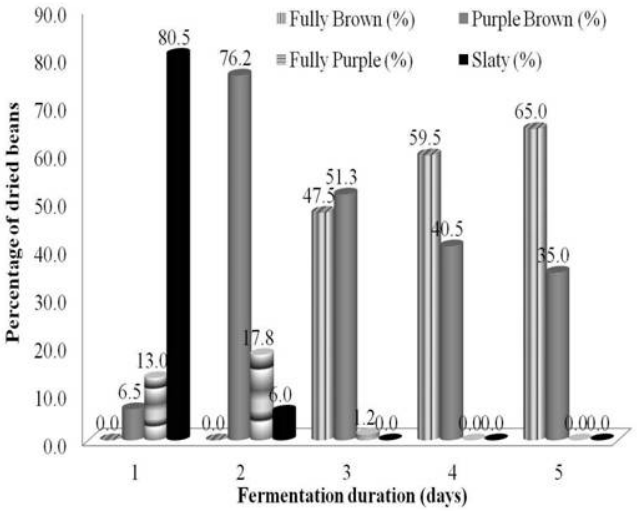

Fig. 4 The color percentages of dried cocoa beans from different fermentation durations

Effect of pods storage on color changes of unfermented dried cocoa beans is presented in Table I. The slaty beans were highest in all batches of dried cocoa and in agreement with early prediction, whereby drying the unfermented cocoa directly will produced slaty beans [18]. Meanwhile, the purple-brown and fully purple beans were in the range of 0.0 to 10.7% and 6.0 to 9.33% except for fully purple beans from four days storage (34.8%), respectively. About 1.2% fully brown observed from the dried unfermented cocoa beans which pretreated with six days of pods storage. Other researcher [15] has also observed up to 22.67% of brown beans for seven days pods storage. This is surprising because previously, fully brown beans are reported to be produced by fermentation.

Application of pods storage before fermentation process is found to decrease the slaty percentage. Interestingly, the percentage of slaty beans from pods storage for four days was significantly lower than the beans from six days of pods storage. The differences can also be seen in the percentage of fully purple beans of pods storage for four days whereby the percentage is significantly higher than most others. This might be due to differences in polyphenol content and also the type of pigment available in fresh cocoa beans as reported by [19].

TABLE I
THE EFFECT OF PODS STORAGE ON COLOR CHANGES OF UNFERMENTED DRIED COCOA BEANS

Pods Storage (days)	Fully Brown (%)	Purple Brown (%)	Fully Purple (%)	Slaty (%)
0	0.0[b]	0.0[b]	6.8[b]	93.2[a]
2	0.0[b]	0.0[b]	6.0[b]	94.0[a]
4	0.0[b]	10.7a	34.8[a]	54.5[b]
6	1.2a	10.2a	9.3[b]	79.3[ab]

Means that do not share a letter are significantly different. Tukey 95% Simultaneous Confidence Intervals. All Pairwise Comparisons among Levels of Pods Storage. Individual confidence level = 98.89%.

Pods storage is found to have significantly influenced towards the color formation of dried unfermented cocoa beans. Observation on the combination effect of the pods storage and fermentation duration using shallow box technique towards the color characteristics of Malaysian dried cocoa beans were carried out. Cut test result for dried cocoa beans from different duration of pods storage as well as fermentation are shown in Table II. Overall, the slaty beans were found on the first day with percentages of 80.5%, 78.2%, 1.3% and 16.0% and subsequently decreased to 6.0%, 3.2%, 1.3% and 0.3% on the second day of fermentation, respectively, for all duration of pods storage. In contrast, the fully brown beans exhibit increasing trend in line with the increment of pods storage and also fermentation duration. The percentages of fully brown beans are found to start dominating as early as one day fermentation with six day pods storage and reached more than 60% after two days of fermentation, especially from four and six days of pods storage batch. Regardless any pods storage treatments, the purple beans were found until third days of fermentation with the percentages less than 20% except for beans from six days pods storage which fermented for one day. Whereas, the purple brown appeared in all days of fermentation duration and interestingly, the percentage of purple brown beans are scattered in the entire beans batch regardless any specific trend. Statistical analysis using General Linear Model showed that the pods storage has a significant effect on the color characteristic of the Malaysian dried beans compared to fermentation duration.

TABLE II
THE EFFECT OF PODS STORAGE ON COLOR CHANGES OF DRIED COCOA BEANS FROM DIFFERENT FERMENTATION DURATIONS

Pod Storage (days)	Fermentation Duration (days)	Fully Brown (%)	Purple Brown (%)	Fully Purple (%)	Slaty (%)
0	1	0.0^{g}	6.5^{h}	13.0^{bc}	80.5^{a}
	2	0.0^{g}	76.2^{ab}	17.8^{ab}	6.0^{c}
	3	47.5^{de}	51.3^{cde}	1.2^{e}	0.0^{c}
	4	59.5^{cde}	40.5^{def}	0.0^{e}	0.0^{c}
	5	65.0^{cd}	35.0^{def}	0.0^{e}	0.0^{c}
2	1	0.0^{g}	4.2^{h}	17.7^{abc}	78.2^{a}
	2	4.7^{g}	79.5^{a}	12.7^{c}	3.2^{c}
	3	39.2^{ef}	59.0^{abcd}	1.8^{e}	0.0^{c}
	4	62.0^{cde}	38.0^{def}	0.0^{e}	0.0^{c}
	5	80.0^{abc}	20.0^{fgh}	0.0^{e}	0.0^{c}
4	1	19.3^{fg}	72.3^{abc}	7.0^{d}	1.3^{c}
	2	46.0^{de}	51.7^{bcde}	2.2^{de}	0.2^{c}
	3	67.7^{bcd}	32.2^{efg}	0.2^{e}	0.0^{c}
	4	82.7^{abc}	17.3^{fgh}	0.0^{e}	0.0^{c}
	5	90.8^{ab}	9.2^{gh}	0.0^{e}	0.0^{c}
6	1	16.0^{fg}	47.0^{de}	21.0^{a}	16.0^{b}
	2	53.2^{de}	45.7^{de}	0.8^{e}	0.3^{c}
	3	68.2^{bcd}	31.7^{efg}	0.2^{e}	0.0^{c}
	4	81.5^{abc}	18.5^{fgh}	0.0^{e}	0.0^{c}
	5	95.5^{a}	4.5^{h}	0.0^{e}	0.0^{c}

Means that do not share a letter are significantly different. Tukey 95% Simultaneous Confidence Intervals.

Fresh cocoa seeds are known as rich with polyphenols mainly catechin, procyanidin, anthocyanin and flavonol glycosidase [20]. Anthocyanins are the compound which responsible for the color characteristic of fresh cocoa seeds and presence in four types namely in order of decreasing abundance were 3-α-L-arabinosidyl cyanidin, 3-β-D-galactosidyl cyanidin, cyanidin rutinoside and cyanidin pentoside [21]. It is also reported that there is a total of six major types of anthocyanin namely pelargonidin, cyanidin, peonidin, delphinidin, petunidin and malvidin. The color of anthocyanins changes depending on the pH, co-pigments which typically flavones and flavonols, and metal ions. *In vitro*, anthocyanidins are redder and more stable as the flavilium cation form at lower pH (pH <3), colorless under mildly acidic conditions (pH 3–6), and bluer and unstable as the quinonoidal base form at pH 6 and above [22].

Although the proper compounds responsible for color in dried beans are not yet fully recognized; it is assumed that the formation of brown color of the dried cocoa beans is resulted from various transformations of athhocyanins and it co-pigment during fermentation and drying to form polycondensation products [23]. Furthermore, anthocyanins were reported disappearing rapidly during fermentation, which changing to be anthocyanidins and then polymerize along with simple catechins to form complex tannins. The transformations of anthocyanins were caused the color of the beans changes from slaty over purple to brown [24]. Thus, anthocyanin content has been considered as a good index for determination of the degree of cocoa bean fermentation.

IV. CONCLUSION

The results of this work allowed to draw some general conclusions that fresh cocoa beans which directly dried without fermentation is characterized by 93% of slaty and 7% of fully purple. Implementation of pods storage will changes the color combinations of dried cocoa beans, where the longer pods storage is will reduce slaty percentage and at the same time, increase the possibility of fully brown existence. Fresh cocoa beans either from without or up to two days pods storage, require four days fermentation using shallow box to allow the dried beans have as many as 60% fully brown and without slaty. When the pods storage is extended for four and six days, the duration of cocoa fermentation can be terminated as early as three days. In addition, attention should be given to purple brown because the beans are scattered with specific trend of increase and then decrease irrespective of any pods storage or fermentation duration. Furthermore, statistical analysis using General Linear Model showed that the pods storage has a significant impact on the color characteristic of the Malaysian dried beans compared to fermentation duration.

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