RESEARCH ARTICLE – AGRICULTURAL AND FOOD SCIENCE

Physical and chemical assessment quality of cocoa beans in south and center regions of Cameroon

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Received: 13 Mai 2014 / Revised: 31 July 2014 / Accepted 05 August 2014
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Organoleptic proprieties of chocolate are linked to profound modifications of physical, chemical and biochemical composition of the cocoa beans during fermentation and drying. A study of physical and chemical characteristics of market cocoa beans was carried out in Center and South region of Cameroon during 2008-2009, 2009-2010 cocoa season in order to assess their quality. Means of duration of fermentation process and turning were lowest and insufficient. The cut test revealed five types of colours: slaty (S), slaty-violet (SV), violet (V), violet-brown (VB) and brown (B). Their percentages varied according to localities. Brown coloration which predicts good fermentation and quality was very low as a whole. Only Mbangassina sample display 25% of brown beans. The high correlation observed between pH and cocoa beans color confirmed the view that pH value decreases with fermentation. Generally cocoa beans for these localities were not fermented enough to obtain good cocoa quality.

Keys words: Cocoa beans, cut test, fermentation, pH, Theobroma cacao.

Abstract

Les caractéristiques organoleptiques du chocolat sont liées aux profondes modifications physico-chimique et biochimique des fèves de cacao qui surviennent pendant la fermentation et le séchage. L’étude des caractéristiques physiques et chimiques du cacao marchand de quelques villages des régions du Centre et Sud Cameroun a été réalisée pendant les saisons cacaoyères 2008-2009, 2009-2010 afin d’évaluer la qualité du cacao marchand livré sur le marché. De ces travaux, il ressort que le temps de fermentation ainsi que le nombre de remuage du tas des fèves pendant la fermentation sont insuffisants et très bas pour garantir une bonne fermentation. Les paramètres physiques révèlent cinq types de couleur de fèves : ardoisé (S), ardoisé-violet (SV), violet (V), violet-brun (VB) et brun (B). Globalement, on note un faible pourcentage des fèves brunes qui atteint à peine 25% et une nette prédominance des fèves violettes, indicateur d’une fermentation insuffisante. Le pH des fèves diminue des fèves non fermentées (S) vers les fèves bien fermentées (B). La couleur des fèves est fortement corrélée au pH. Globalement la pratique de la fermentation n’est pas assez bien menée afin de garantir une bonne qualité du cacao marchand produit dans ces régions.

Mots clés : Couleur des fèves, épreuve à la coupe (cut test), fèves de cacao, pH, Theobroma cacao.

Introduction

Commercial cocoa is derived from the seeds (beans) of the ripe fruits (pods) of the plant Theobroma cacao (Malvaceae), which is native to the Amazon region and cultivated in tropical regions throughout the world (Beckett, 1994; Ardhana and Fleet, 2003). Each pod contains 30-60 beans, embedded in a mucilaginous pulp. Cocoa is an important ingredient in different kinds of foods such as cakes, biscuits, child-foods, ice-creams and sweets. It constitutes an inexpensive fat source and it is the principal raw material of chocolate (Tafuri et al., 2004). Export of raw cocoa beans is of great economic importance in producing countries. West Africa produces two-thirds of the World’s cocoa, with Côte d’Ivoire and Ghana as the major producers (Anon, 2004). In Cameroon during the last decades, production has been growing up and the government expected to reach 500,000 t by encouraging the setting-up of new cocoa plantations. This initiative should be link to quality improvement. The economy of most developing countries, based primarily on their agricultural resources, is strongly dependent on the often rigorous and rigid quality standards set by developed countries.

The flavour precursors of cocoa are developed during fermentation and drying. Development of flavour precursors involves the action of various micro-organisms on the cocoa pulp and the action of
enzymes on carbohydrates, proteins and polyphenols in the cocoa beans. Fermentation affects pH and temperature, thus influencing enzyme activities (Hansen et al., 1998; Biehl et al., 1990). It is well known that the time period of enzyme action is short during fermentation, as enzymes are strongly inactivated (aminopeptidase, invertase and polyphenol oxidase) or partly inactivated (carboxypeptidase), except for endoproteases and glycosidases that remain active during the whole fermentation process (Hansen et al., 1998).

Fermentation reactions have been reviewed by Fowler (1999) and Beckett (2000). Methods of fermentation strongly determine the commercial quality of cocoa beans. Indicators of well fermented and dried quality beans are brown color, low astringency and bitterness, and absence of off-flavors such as smoky notes and excessive acidity. Likewise, during the quality control, a cut test to observe changes in cotyledon colour during fermentation has been considered as a good indicator (Shamsuddin and Dimmick, 1986) when determining the degree of fermentation of cocoa beans (Pettipher, 1986; Misnawi et al., 2003). So, based on cut test score, many authors stated that in order to assess the degree of fermentation, cocoa beans can be divided into four categories: 1) fully fermented beans with brown color; 2) partly brown, partly purple beans; 3) fully purple beans and 4) slaty beans. The brown color is the characteristic of well fermented cocoa.

During fermentation, the diffusion rate of organic acids into the cotyledons is crucial for optimum flavour formation (Biehl et al., 1985). A large number of reports have referred that beans of higher pH (5.5-5.8) are considered unfermented - with low fermentation index and cut test score - and those of lower pH (4.75-5.19), well fermented. Many fermentation methods exist (heap, wooden, hole) and are used through different countries (Wood and Lass, 1985). In Cameroon practice of fermentation is not standard and differs between smallholders, this deficiency influence Cameroonian cocoa market quality and cause dequotation and loss of profit.

The objective of this study was to assess the quality of marketed cocoa beans of small farmers in Center and South Cameroon regions through the evaluation of physical and chemical characteristics. This evaluation intend having an overview of the overall cocoa quality in order to propose good practices to smallholders.

Materials and methods

Materials

The experiments were conducted during 2008-2009 and 2009-2010 cocoa seasons. Cocoa beans were originated from 08 localities: Meyomessala (Meyo.); Sangmelima (Sang.); Ebolowa (Ebol.); Mbalmayo (Mbal.); Ekali; Ndikinimeki (Ndiki); Mbangassina (Mbang.) (Table 1). For each locality, 30 samples were collected from different farmers. Sample of about 2-3 kg per farmer was collected from the site, brought to the laboratory and conserved in bottle hermetically. A questionnaire was addressed to farmer about post-harvest methods used (e g: fermentation time, turning number, drying method). A total of 240 samples were obtained.

Table 1. Geographic distribution of cocoa beans studied.

<table>
<thead>
<tr>
<th>Localities</th>
<th>Abbreviation</th>
<th>Latitude (N)</th>
<th>Longitude (E)</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bikok</td>
<td>Bikok</td>
<td>4°37'</td>
<td>11°25'</td>
<td>Center</td>
</tr>
<tr>
<td>Ebolowa</td>
<td>Ebol.</td>
<td>2°54'</td>
<td>11°08'</td>
<td>South</td>
</tr>
<tr>
<td>Ekali</td>
<td>Ekali</td>
<td>3°26'</td>
<td>11°46'</td>
<td>Center</td>
</tr>
<tr>
<td>Mbalmayo</td>
<td>Mbal.</td>
<td>3°30'</td>
<td>11°29'</td>
<td>Center</td>
</tr>
<tr>
<td>Mbangassina</td>
<td>Mbang.</td>
<td>4°33'</td>
<td>11°23'</td>
<td>Center</td>
</tr>
<tr>
<td>Meyomessala</td>
<td>Meyo.</td>
<td>3°06'</td>
<td>12°14'</td>
<td>South</td>
</tr>
<tr>
<td>Ndikinimeki</td>
<td>Ndiki.</td>
<td>4°45'</td>
<td>10°49'</td>
<td>Center</td>
</tr>
<tr>
<td>Sangmelima</td>
<td>Sang.</td>
<td>2°55'</td>
<td>11°58'</td>
<td>South</td>
</tr>
</tbody>
</table>

Methods

Physical quality assessment

Weight assessment

Weight value was measured using the procedure described by Handlaer (1980). For each sample, 300 random seeds were weighed on electronic balance and their means were calculated.

Cut test

Cut test, the first quality control of cacao beans, was done for sanitary and fermentation quality of all cocoa samples. Seventy two thousand dried cocoa beans were cut lengthwise through the middle using a knife. Both halves of each bean were examined in full daylight according to the cross sectional color of the beans. Observations were made for the color of the beans (slaty, slaty-violet, violet, violet-brown, brown and impurity). Slaty bean characteristics include rubbery cotyledon, blackish color, and resistance to cutting. Violet beans occurred if the fermentation had been achieved prematurely. Impurity beans were the sum of mould, dark and white beans. Fully brown beans were well-fermented beans. Results were expressed as a percentage of each type of beans and all analyses were done in triplicate. The percentage count of each color attribute was used to calculate the cut test score as follow:

\[ \text{Cut test score} = (10 \times \% \text{brown}) + (5 \times \% \text{partly purple/brown}) + (0 \times \% \text{purple and slaty}) \]
Chemical assessments

Chemical assessments were based on the determination of pH. The pH value was measured according to AOAC official method 9720.21 described by Roche (1987) and modified by Rohsius et al. (2006) as follow. Three grams of cocoa powder (deshelled beans) were homogenized in 10 ml boiled distilled water. The mixture was filtered with Whatman paper n˚4 and cooled to 20-25°C. The pH of the resulting filtrate was measured using a Hanna instruments, Microprocessor pH 211, which had been calibrated with buffers at pH 4 and 7. These measurements were performed in triplicate.

Statistical analysis

Multiway analysis of variance (ANOVA) was conducted using the Statistical Package for the Social Sciences (SPSS) 17.0 software. Least Significant Difference (LSD) was used to separate and compare the means and significance was accepted at 5% level (p<0.05). All treatments and measurements were conducted in triplicates and the mean values reported. Cluster analyses based on physical and chemical characteristics of cocoa beans, using the Unweighted Pairwise Group Methods with arithmetic Average (UPGMA) on the basis of Nei (1978) genetic distance, were performed with the assistance of SPSS 17.0.

RESULTS AND DISCUSSION

Fermentation time

Table 2 shows means of fermentation time process from different localities. Ndiki. displayed the highest fermentation time with about 5.13 days while Sang showed the lowest (one day). Mean of fermentation time of all localities studied was 3.04 days. On the other hand, these farmers turned about one time the heap of cocoa beans during fermentation. However, it was assumed that cocoa beans were well fermented between 4th and 6th with consecutive openings and turnings after every two days till the end (Sadoux, 1961; Rohsius et al., 2006; Afoakwa et al., 2011). As a whole, duration of fermentation was insufficient and had high impact on cocoa beans quality.

Cut test and types of color

The cut test is used as an index of fermentation and relies on changes in color of cocoa beans. It is the standard test used to assess the suitability of cocoa beans for chocolate processing. It is also the standard method of assessing quality as defined in grade standards and can be used to estimate two major off-flavors (mouldy and unfermented beans). It identifies other defects which can affect the storage quality (Wood and Lass, 1985). The cut test was carried out on beans and globally illustrated five types of color: Slaty, Slaty-violet, Violet, Violet-brown, Brown (Fig. 1). Their repartition varied according to the locality.

Table 3 showed the cut test result from different localities. The percentage of brown and violet-brown were found to range approximately from 0% to 25%, and from 0% to 42.5% respectively. The highest percentage of brown beans was recorded for Mbang., which indicated a higher level of browning as compared to others. Violet beans were predominant in Ndiki., Bikok and Meyo. with 86.75, 42, and 86.42% respectively. Indicator of well fermented and dried beans is brown color (Sadoux, 1961; Rohsius et al., 2006; Afoakwa et al., 2011). In a typical fermentation process, seed color change from slatly (unfermented) to violet (under fermented) finally to brown with transition stage slatly-violet and violet-brown respectively (Handlaer., 1980; Niemenak, 2006). Taking into account the eight localities studied, it is noticed that brown color represented only 9.27% and violet 41% (Fig. 2). These results showed that in our localities cocoa beans are underfermented because, according to the official standard, a batch of cocoa beans with more than 60% fully brown color beans is considered as good quality product. The cut test score (Fig. 3) confirmed this view, which ranged from approximately 0 to 47.5 %. A high cut test score usually indicates betterrowning of the cocoa nibs during fermentation. The cut test score of samples from Mbang. and Ebol. was significantly higher (p<0.05) than others. The degree of browning in Mbang. and Ebol. could be due to their fermentation time. In contrast, beans of Ndiki. displayed high fermentation time and didn’t present a high test score. Likewise, beans of Ebol. gathered low fermentation time and presented a high test score. This could be due to the conduction of fermentation process in these two localities. In fact, during the 5.13 days of fermentation, the heap beans of Ndiki. was turned only one time. Now, it is believed that the heap size, pod storage after harvest, fermentation time, number and time of turning during fermentation affect the quality of the fermented cocoa beans (Jinap and Zeslinda, 1995; Camu et al., 2008). An adequate aeration of the fermenting cacao seed mass is a fundamental prerequisite for a satisfactory fermentation (Leal et al., 2008). The technique of periodically turning the fermenting seeds increase aeration, reduce level of acetate and lactate in beans (Thompson et al., 2001; Leal et al., 2008). For instance, pod storage and duration of fermentation will affect pH and temperature during fermentation, thus influencing enzyme activities and flavour development and hence acidity, bitterness and astringency of the processed cocoa beans (Hansen et al., 1998).
Table 2. Duration of fermentation, heap turning time and type of fermentation from different localities.

<table>
<thead>
<tr>
<th>Localities</th>
<th>Meyo</th>
<th>Sang</th>
<th>Ebolo</th>
<th>Mbal</th>
<th>Ekal</th>
<th>Bik</th>
<th>Ndiki</th>
<th>Mbang</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermentation times (days)</td>
<td>2.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.66&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.26&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.04&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Turning time</td>
<td>1.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.76&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.73&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.07&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Type of fermentation</td>
<td>box</td>
<td>bag</td>
<td>bag</td>
<td>bag</td>
<td>box</td>
<td>bag</td>
<td>box</td>
<td>box</td>
<td>box</td>
</tr>
</tbody>
</table>

Means followed by the same letter in the same row are not significantly different according to Duncan’s multiples range test (p < 0.05).

Fig. 1. Different colours obtained after cut test. (A) slaty; (B) slaty violet; (C) violet; (D) violet-brown; (E) Brown; (F) mouldy

Table 3. Cut test evaluation of cocoa beans from various localities.

<table>
<thead>
<tr>
<th>Localities</th>
<th>Slaty (%)</th>
<th>Slaty-violet (%)</th>
<th>Violet (%)</th>
<th>Violet-brown (%)</th>
<th>Brown (%)</th>
<th>Impurity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meyo.</td>
<td>17</td>
<td>17</td>
<td>42</td>
<td>02</td>
<td>17</td>
<td>05</td>
</tr>
<tr>
<td>Sang.</td>
<td>92.3</td>
<td>3.6</td>
<td>4.1</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
<tr>
<td>Ebol.</td>
<td>27</td>
<td>16</td>
<td>11</td>
<td>21</td>
<td>21</td>
<td>04</td>
</tr>
<tr>
<td>Mbal.</td>
<td>06</td>
<td>58</td>
<td>23</td>
<td>09</td>
<td>02</td>
<td>02</td>
</tr>
<tr>
<td>Ekal.</td>
<td>4.2</td>
<td>16.7</td>
<td>71</td>
<td>2.2</td>
<td>05</td>
<td>0.9</td>
</tr>
<tr>
<td>Bikok</td>
<td>0.7</td>
<td>10.45</td>
<td>86.17</td>
<td>0.16</td>
<td>1.78</td>
<td>0.74</td>
</tr>
<tr>
<td>Ndiki.</td>
<td>0.1</td>
<td>4.1</td>
<td>86.75</td>
<td>4.8</td>
<td>2.4</td>
<td>2.05</td>
</tr>
<tr>
<td>Mbang</td>
<td>10.5</td>
<td>14</td>
<td>04</td>
<td>42.5</td>
<td>25</td>
<td>01</td>
</tr>
</tbody>
</table>

Fig. 3. Cut test score of cocoa beans from various localities. Means followed by the same letter are not significantly different according to Duncan’s multiples range test (p < 0.05).
Weight of cocoa beans

Table 4 shows the means values of beans weight which ranged from 1.17 to 1.39 g. Beans from Mbal. and Ndiki were significantly higher (p < 0.05) than other with 1.35 and 1.39 g respectively. It is interesting to note that all localities showed weight higher than 1.05 g which represent minimum value acceptable by chocolate makers (Adomako et al., 2003). According to these authors, beans less than 1.05 g have high ratio testa on cotyledon and cannot be shelled easily.

Chemical evaluation

The pH values of cocoa beans from the different localities are shown in Table 5. As a whole for all localities, we observed that level of acidity decreased from unfermented beans (slaty) towards fermented beans (brown). Thus, acidity of beans is linked to fermentation. The correlation between color and value of pH confirms this view.

It was interesting to note the exceptional correlation between Slaty-violet and Violet, and we observed a significant positive correlation between successive colors which occurred during fermentation process (Table 6). In fact, pH is the most important chemical characteristics used to assess quality of cocoa beans.
(Ilangantileke et al., 1991; Thery, 1995). Means of mixed pH value ranged from 5.79 to 6.38. Ekali showed lower acidity (p < 0.05) than others while Sang, displayed the highest. In general, the pH value obtained decreased gradually from the slaty beans (unfermented) to the brown (well fermented) ones. This result is in accordance to the findings of Lopez (1986) who stated that the pH of the unfermented cotyledon is about 6.5 and may decrease to as low as 4.5 by the end of the fermentation. This lowering of pH occurs after seed death and is primarily due to the diffusion into the beans of organic acids produced by lactic and acetic acid bacteria. In the same way, Biehl et al. (1985) stated that beans of higher pH (5.5-5.8) are considered unfermented and those of lower pH (4.75-5.19) well fermented. During fermentation, the rate and duration of diffusion of organic acids into the cotyledons and optimum pH are crucial for flavor precursor development (Biehl et al., 1985). Although lactic and acetic acids are produced from the external mucilage of beans by microbial activity, chocolate flavor development is largely depend on the enzymatic formation of flavor precursors within the cotyledon that are unique to cocoa. Such classes of compounds include free amino acids, peptides, reducing sugars, and polyphenols. When fermented and dried cocoa beans containing these flavor precursors are subjected to roasting during chocolate manufacture, a necessary step in flavor development, a series of complex non-enzymatic browning reactions occurs to produce flavor and colored compounds characteristic of chocolate (Rohan and Stewart, 1967). However, if unfermented cocoa beans lacking these precursor compounds are roasted, very little chocolate flavor is produced. It is therefore, important that these flavor precursors be formed inside the cocoa beans during fermentation. According to our study, value of pH showed that cocoa beans are fermented but the fermentation time and turning time are insufficient to guaranteed cocoa quality. However, the dendrogram based on physical and chemical characteristics (Fig. 4) displayed three groups where cocoa beans from Mbangassina have the better characteristics based on their cut test score, weight cocoa beans and fermentation practices. These results are not surprising since Mbangassina is considered as a new pioneer area of cocoa culture in Cameroon. The farmers of the other localities must then enforce the technique of post-harvest in force in Mbangassina in order to have a cocoa beans of good quality.

Conclusion
Cocoa beans from various localities in Center and South region in Cameroon was inspected for their quality. Fermentation time is different between localities and it is low in relation to the time recommended. The bean color shows variation between localities and low frequency of brown color cocoa beans globally. The range of means of pH of mixed random beans is excellent and could predict good quality if fermentation time was sufficient. Decrease of pH value observed from different types of color in the same sample confirms that fermentation process is conduct but not enough for guaranteed good cocoa beans quality. High correlation obtained between coloration of cocoa beans and pH value shows once more that these parameters are most important and are usually examined to predict cocoa beans quality.

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