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ISSN: 2224-0616
Int. J. Agril. Res. Innov. Tech. 14(2): 53-61, December 2024 Available online at https://ijarit.online
DOI: https://doi.org/10.3329/ijarit.v14i2.79399 https://www.banglajol.info/index.php/IJARIT

Evaluation of the organoleptic characteristics of chocolate made with cocoa beans from three main production areas in Côte d'Ivoire

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Received 26 September 2024, Revised 7 December 2024, Accepted 25 December 2024, Published 31 December 2024

A B S T R A C T

To evaluate the quality of chocolate produced with Ivorian cocoa beans, the study was carried out in the country's three main production areas (East, Centre-West, and South-West). The project involved collecting data on fermentation times and sourcing samples of cocoa beans from which chocolate had been produced and tasted. The findings of this study indicate that the average fermentation time for cocoa beans is identical across all regions. The observed values (5.30 days in the East, 5.0 days in the Center-West, and 5.04 days in the South-West) are below the recommended 6-day threshold for optimal fermentation. The chocolate produced from the collected beans has been found to have favourable organoleptic characteristics, as evidenced by the low bitterness ratings revealed in the tasting tests. Acidity and astringency are very low and aroma is average. The correlation study between fermentation time and organoleptic characteristics demonstrated that only bitterness ($y = -0.2926x + 4.0115$; $r = 0.62$; $p < 0.01$) and aroma ($y = 0.1619x + 2.1324$; $r = 0.5139$; $p < 0.01$) of chocolate were significantly influenced by fermentation time. Therefore, cocoa from Côte d'Ivoire is suitable for use in the production of high-quality chocolate. However, fermenting the beans for 6 days would be beneficial to achieve a superior quality chocolate product.

Keywords: Côte d'Ivoire, Cocoa, Beans, Chocolate, Quality, Organoleptic

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Cite this article as: Kouakou, B.J, Kobenan, K.C, Ouattara, T.V. and N'Goran, K.E. 2024. Evaluation of the organoleptic characteristics of chocolate made with cocoa beans from three main production areas in Côte d'Ivoire. *Int. J. Agril. Res. Innov. Tech*. 14(2): 53-61. https://doi.org/10.3329/ijarit.v14i2.79399

Introduction

Cocoa farming was introduced to Ivorian farmers at the end of the 19th century through colonization (Françoise and François, 1990). The economic importance of cocoa for Côte d'Ivoire is well established, with an area of 2,176,000 hectares (almost 7% of the country's territory) dedicated to cocoa farming. This has become the main source of income for more than 1 million farmers and provides a livelihood for some 4 million people (ICCO, 2001; RNA, 2001). Côte d'Ivoire's cocoa industry accounts for 30% of total export earnings and 15% of gross domestic product. Consequently, Côte d'Ivoire must not only enhance production by increasing yields but also by producing high-quality beans. Côte d'Ivoire's annual cocoa production exceeds 2 million tons (ICCO, 2005). While this performance is satisfactory overall, there is room for improvement, particularly in terms of bean quality (Tafuri *et al*., 2004). Some countries, such as Ghana and Cameroon, have their cocoa labelled on the international market, which is not the case for Côte d'Ivoire, whose cocoa is considered to be of lower quality (Sukha *et al*., 2014). It should be noted that the majority of this production is destined for export to European and American countries, which are major chocolate producers. Given the crucial role of cocoa beans in determining chocolate quality, it is essential to assess the suitability of beans from Côte d'Ivoire for producing high-quality chocolate. This study was designed to address this concern by evaluating the organoleptic quality of chocolate made from beans sourced from the country's major production regions.

Materials and Methods

Geographical location of the study site

The location of the study site was conducted in Côte d'Ivoire's primary cocoa-producing regions. The decision to select the East, Centre-West, and

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South-West as the primary study zones was driven by their status as the primary cocoa production regions in Côte d'Ivoire. Cocoa farming originated in eastern Côte d'Ivoire (the first cocoa loop), where it was introduced during the colonial period. Subsequently, it spread to the post-pioneer region of central-western Côte d'Ivoire and is currently expanding in the southwestern part of the country, known as the recent pioneer front. It is worth noting that approximately 64% of cocoa-growing areas are concentrated in these three zones (Figure 1). Even more impressively, these regions frequently account for over 75% of the country's annual output. Each zone is represented by an administrative locality. Abengourou represents the eastern zone, Oumé the central west zone, and Soubré the southwest zone.

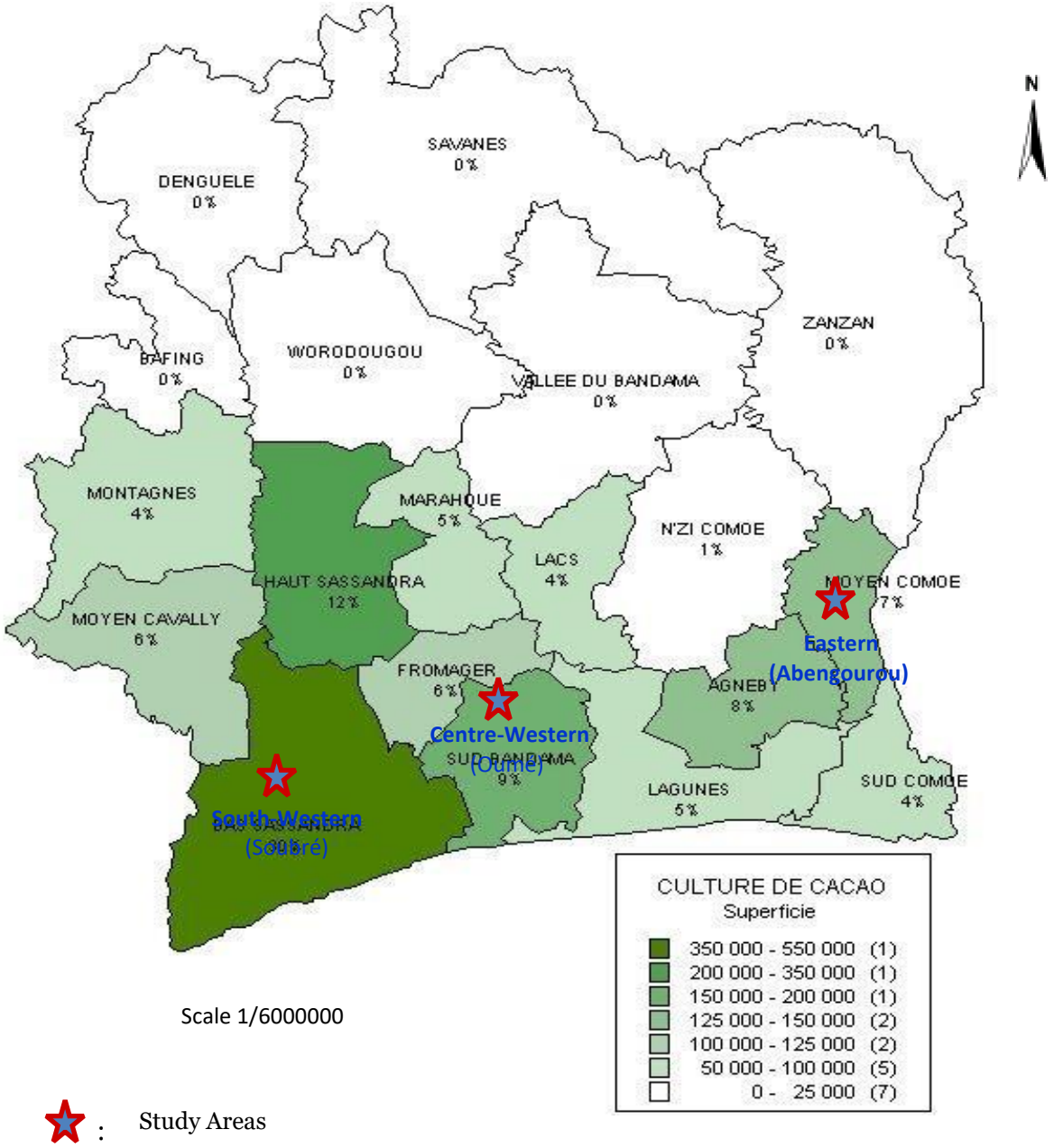

Figure 1. Extent of orchards (% national) in the different cocoa-growing regions in Côte d'Ivoire (RNA, 2001).

Materials

Plant material

The plant material used in this study is merchantable cocoa. The beans underwent all stages of harvesting and post-harvest technology. They were collected from the three main production zones selected for this study.

Sample collection equipment

Samples weighing 3 kg each were weighed on a CAMRY hand-held balance with a maximum capacity of 5 kg. The samples were packaged in plastic bags prior to transportation to the laboratory.

Methods

Cocoa bean sampling

To analyze the organoleptic characteristics of chocolate, samples of merchantable cocoa beans were collected in each production locality. These samples were taken from producers' stocks. A mass of 3 kg of cocoa beans was collected from each farmer immediately after drying, or during storage at the producers' premises.

Gathering information on cocoa bean fermentation times

The fermentation times for all samples collected in the production areas were recorded and used to establish a correlation between the level of fermentation of the beans and the organoleptic characteristics of the resulting chocolate.

Chocolate preparation

The production of chocolate to assess the organoleptic quality of cocoa beans has already been the subject of research (Moreau and Pontillon, 1998). Chocolate samples for sensory testing were obtained using the dark chocolate preparation method (Dodemont, 2007). The chocolate wafers thus obtained are composed of 49.0% shelled cocoa beans, 39.2% sugar and 11.8% cocoa butter. The manufacturing process follows the essential stages of roasting, hulling, grinding, refining, conching, tempering, molding and chilling (Figure 2).

- *Roasting and hulling*

The cocoa beans were roasted in a GALLENKAMP ventilated oven at 140 ± 2°C for 35 minutes. Subsequently, the beans were crushed and winnowed before being transferred to a mortar for grinding (Figure 2).

- *Grinding*

The crushed beans were placed in an electric mortar fitted with a pestle and ground under electric heat to maintain the fluid of the paste during the operation. Once the particle size had been significantly reduced, sugar was added at a rate of 80% of the shelled bean mass.

- *Refining*

The reduction of particle size is achieved through the use of a refiner, comprising three cylinders rotating in opposite directions, which is employed to process the ground pulp.

- *Conching and tempering*

The refined paste was returned to the mortar and 13.4% cocoa butter was added. A second grinding produced a paste with no perceptible particles on the tongue. At this stage, the paste was left to cool to room temperature.

- *Moulding and cooling*

Once cooled, the dough was transferred to molds and stored in a refrigerator at a constant temperature of 12°C. After one hour, the chocolate bars were ready for consumption.

Chocolate tasting

Following the taste acuity test, the tasters were selected to form the chocolate-tasting panel. Each taster was tasked with noting the degrees of bitterness, acidity, astringency, and aroma of the chocolate. A score was assigned for each parameter on a scale of 0 to 5, in accordance with the rating scale shown in Table 1.

Data analysis

The data from the quality analyses conducted in the laboratory on the beans were processed using Statistica 6.0 software. The Student's T-test was employed to compare the parameter averages with the standard values outlined in the quality standards. Additionally, an analysis of variance was carried out to compare these averages with each other for a given quality parameter. The Newman-Keuls test at the 5% threshold was used to separate the means. A linear regression test was conducted using Statistica 7.0 software to evaluate the impact of bean fermentation duration on chocolate quality parameters.

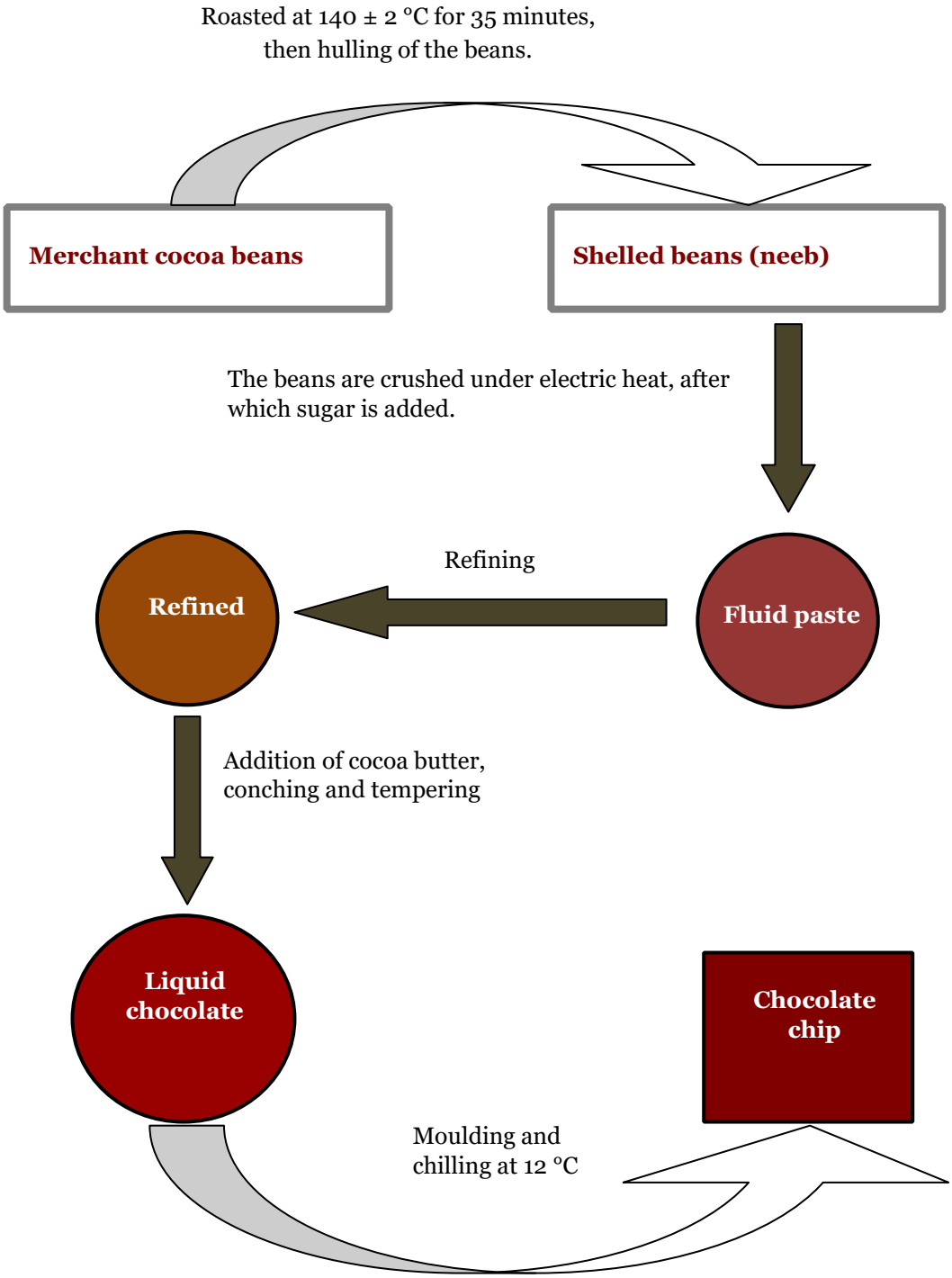

Figure 2. Chocolate preparation steps.

Table 1. Chocolate flavour and preference rating scale.

Flavor Characteristics	Note
Nil	0
Very low	1
Low	2
Medium	3
High	4
Very high	5

Results

Bean fermentation time

The fermentation time varies according to the cocoa-growing locality (Table 2). The fermentation period lasts between 2 and 7 days in Abengourou, 3 to 7 days in Oumé, and 3 to 8 days in Soubré. The most common fermentation times are 4, 5, or 6 days. In Abengourou, 22% of growers ferment their beans for 4 days, 18% for 5 days, and 42% for 6 days. The data from Oumé indicates that the proportions of producers who recorded the same fermentation times were 30%, 36%, and 22%, respectively. In Soubré, 26% of growers carried out fermentations lasting four to five days, while 20% carried out fermentations lasting six days. When examining fermentation duration in terms of two classes of duration (< 6 days and ≥ 6 days), it was found that in Abengourou, 54% of growers ferment their beans for at least six days. In both Oumé and Soubré, less than half of the growers (30% and 36%, respectively) ferment their cocoa beans during this time (Table 2). The average fermentation time for cocoa beans is 5.30 ± 1.18 days in Abengourou, 5.00 ± 1.01 days in Oumé, and 5.04 ± 1.31 days in Soubré. These average durations are statistically identical according to the Newman-Keuls test and significantly lower ($p < 0.01$) than the minimum duration (6 days) recommended for optimal fermentation.

Table 2. The average fermentation time for cocoa beans in the locations under review.

	Fermentation times (days)			Standards
Locations	Abengourou	Oumé	Soubré	
Average	5,30 ± 1,18a	5,00 ± 1,01a	5,04 ± 1,31a	D = 6 days
Duration Comparaison	P* < 0,01	P* < 0,01	P* < 0,01	Average to standard

NB: On the same line, means followed by the same letter are not significantly different at the 5% threshold (Newman-Keuls test).
D = Recommended fermentation time

**: Mean significantly lower than the norm at the 5% level (Student's t-test) ±: Standard deviation*

Organoleptic characteristics of chocolate: bitterness, acidity, astringency and aroma

The bitterness, acidity, astringency, and aroma of chocolates made from beans sourced from selected localities were evaluated on an intensity scale, with the following categories: none, very low, low, medium, high, and very high. The sensory profile obtained indicates that the bitterness of chocolates made from beans supplied by producers (Figure 3) was perceived to be either low (according to 32.00%, 41.33%, and 42.67% of tasters) or medium (according to 26.67% of tasters). The results indicated that the bitterness of chocolates made from beans supplied by producers in Abengourou, Oumé, and Soubré was either low (according to 32.00, 41.33, and 42.67% of tasters, respectively) or medium (according to 26.67% of tasters for Abengourou and Soubré, versus 33.33% for Oumé). The chocolates, made from cocoa beans sourced from growers in the three localities, were evaluated by tasters and found to have zero acidity (19.00 to 24.00%), very low acidity (40.00 to 44.00%), or low acidity (27.00 to 37.33%) (Figure 4).

The astringency of chocolates made from cocoa beans collected from producers in Abengourou, Oumé, and Soubré was also found to be low (Figure 5). Indeed, the astringency of chocolates from these localities was rated as nil by 26.67% to 36.00% of tasters, very low by 40.00% to 46.67%, and low by 10.67% to 32.00%. The aroma of chocolates made with beans sourced from producers in Oumé and Soubré was rated as average by 50.67% and 54.67% of tasters, respectively. By contrast, the aroma of the Abengourou beans exhibited considerable variation, with 26.67%, 29.33%, and 28.00% of tasters rating it as high, medium, and low, respectively (Figure 6).

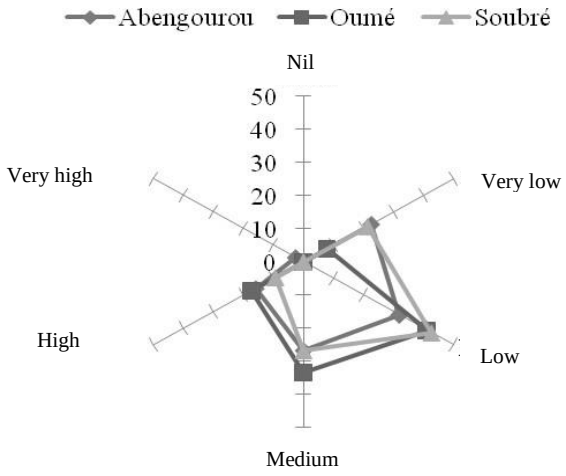

Figure 3. Characteristics of bitterness in chocolates made from beans supplied by local producers.

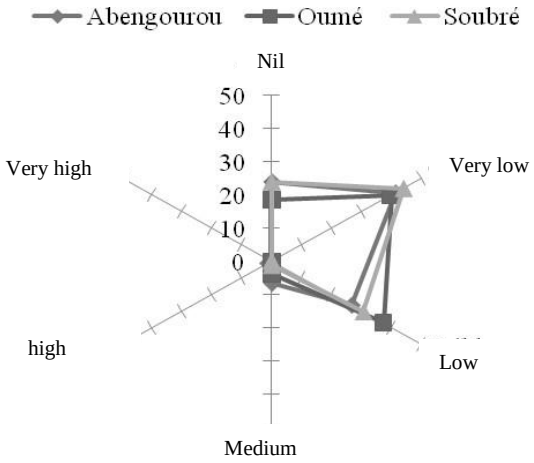

Figure 4. Acidity characteristics of chocolates made from beans supplied by different local producers.

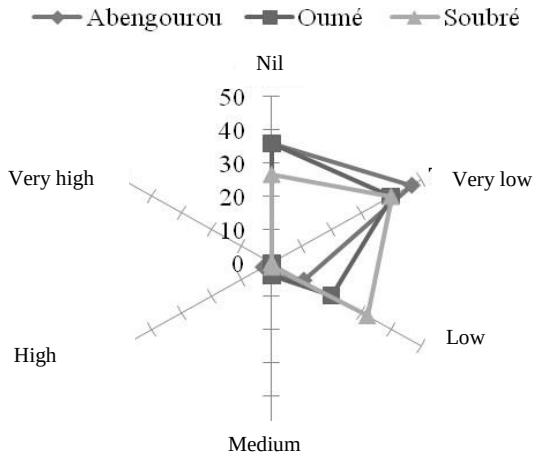

Figure 5. Astringency characteristics of chocolates made from beans prepared in different localities according to quality standards.

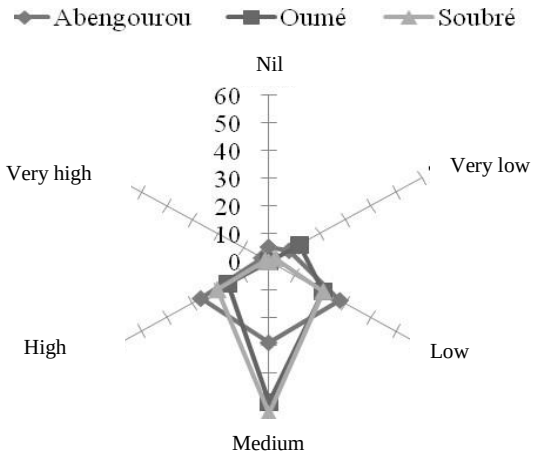

Figure 6. Aroma characteristics of chocolates made from beans supplied by different local producers.

Influence of cocoa bean fermentation time on the organoleptic characteristics of chocolate

Figure 7 illustrates the average rating for chocolate astringency as a function of the fermentation time of the beans used to manufacture the chocolate. The regression line (y = -0.0561x + 1.0488) indicates a negative linear correlation between this organoleptic quality indicator and the fermentation time of the beans. However, the correlation coefficient (r = 0.2080) and probability (p = 0.17) are relatively low. The same linear and negative correlation was found for chocolate acidity (Figure 8) and bitterness (Figure 9), as evidenced by the regression equations (y = - 0.1033x + 1.9893 and y = - 0.2926x + 4.0115) and the associated probabilities (p = 0.02; p < 0.01). However, the correlation coefficients indicate that acidity is only slightly correlated with fermentation time (r = 0.3601), while bitterness is moderately correlated (r = 0.6210 In contrast to the above indicators, there was a positive linear correlation between chocolate aroma and fermentation time (r = 0.5139; p < 0.01), with a correlation coefficient of 0.5139 and a p-value of less than 0.01. As the fermentation time increased, the aroma became more pronounced (Figure 10).

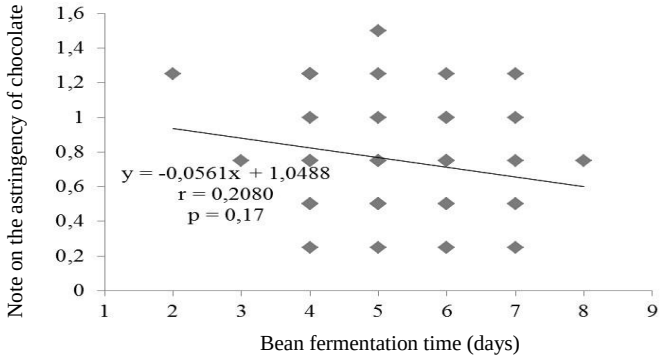

Figure 7. Rating of chocolate astringency as a function of bean fermentation time.

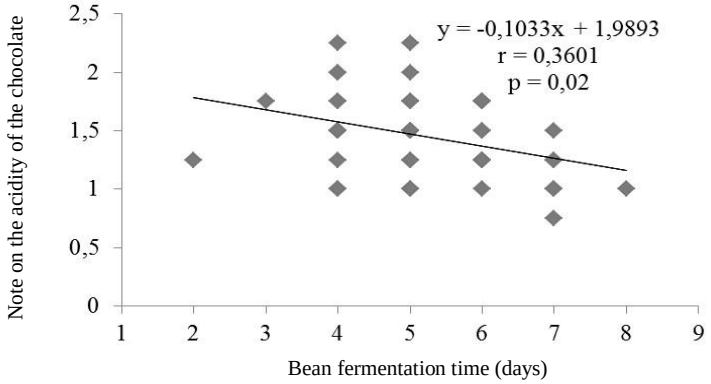

Figure 8. Rating of chocolate acidity as a function of bean fermentation time.

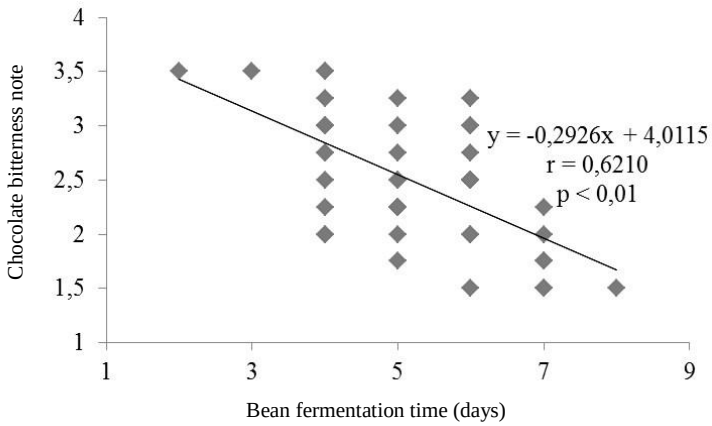

Figure 9. Rating of chocolate bitterness as a function of bean fermentation time.

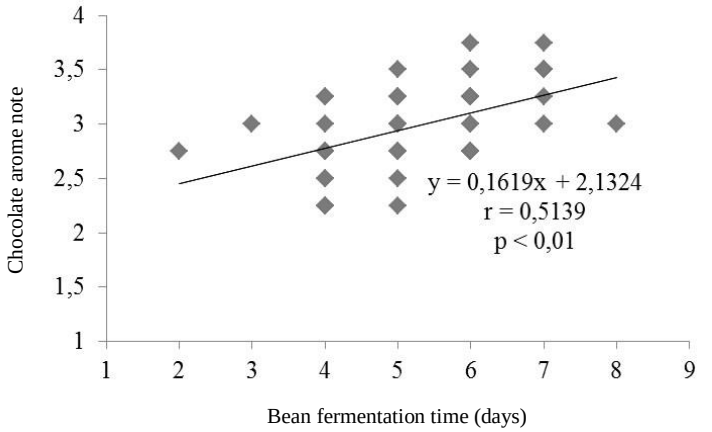

Figure 10. Rating of chocolate aroma as a function of bean fermentation time.

Discussion

The variation in fermentation time between a minimum of 2 days and a maximum of 8 days in all localities reflects heterogeneity in the duration of this operation. This, in turn, results in a variation in the control of the fermentation process by growers in all production zones. Each producer has the autonomy to choose the fermentation process that best suits their needs. The work of (Davrieux *et al.*, 2006) corroborates this heterogeneity in terms of fermentation times. The study demonstrates that fermentation periods range from 0 to 8 days in producer countries, including Côte d'Ivoire, Venezuela, Trinidad, and Haiti. It should be noted that the average fermentation times are identical in all localities. The average values, all below the required fermentation time of 6 to 7 days (Braudeau, 1969; Barel, 1998; Barel, 2001; Camu *et al.*, 2008), indicate a general lack of fermentation in all cocoa-producing areas of Côte d'Ivoire. Furthermore, the data indicates that a higher percentage of growers in Abengourou carry out this operation for at least six (6) days than in Oumé and Soubré. This suggests that cocoa beans ferment more effectively in Abengourou.

Chocolates made from cocoa beans collected in production zones are distinguished by their low acidity and astringency, as well as their average aroma. Furthermore, the majority of tasters rated those obtained from beans grown in Abengourou (49.33%), Oumé (54.67%), and Soubré (50.67%) as good or even very good (30.67%, 24.00%, and 29.33%, respectively, for chocolates from the aforementioned localities). This positive assessment demonstrates that the technological conditions for preparing the beans in the various production zones, particularly the level of fermentation, can ensure good organoleptic quality in the resulting chocolates.

It is important to note that fermentation times that are either too short (less than 5 days) or too long (more than 8 days) can affect the sensory characteristics of chocolate, particularly in terms of acidity, astringency, bitterness, and aroma.

The desired outcome of fermentation is the production of brown cocoa beans, which is achieved through the action of enzymes such as polyphenoloxidases (Clapperton *et al.*, 1992).

Correlation tests have demonstrated the impact of cocoa bean fermentation level on chocolate flavour, particularly in terms of bitterness and aroma. Indeed, a longer fermentation time is accompanied by a reduction in bitterness and an improvement in cocoa aroma, which is an important quality criterion for chocolate products, as highlighted by (Aigbekaen *et al.*, 2006).

Conclusion

The study demonstrated that the fermentation time for cocoa beans was not significantly different between locations. The average fermentation time was below the recommended 6 days, which is necessary for optimal fermentation. Chocolates produced from beans sourced from the production zones included in the study exhibit favourable organoleptic characteristics. The results of the tasting tests indicated that the chocolates exhibited a low level of bitterness. The chocolates display low acidity and astringency, with an average aroma. The correlative study between the number of days of fermentation and organoleptic characteristics demonstrated that only bitterness and chocolate aroma are significantly influenced by the level of fermentation of the beans. Cocoa beans from Côte d'Ivoire are suitable for use in the production of high-quality chocolate. It is recommended that the 6-day limit for bean fermentation be respected in order to achieve the highest possible quality of chocolate.

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