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Cocoa analysis test and its importance in the postharvest procedure

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Abstract

To ensure the quality and safety of Venezuelan fine-flavored cocoa for entry into national and international markets, it must be evaluated strictly according to national and international standards. The purpose of this work is to associate each parameter evaluated in the analysis test with the good agricultural, harvesting, and storage practices applied to cocoa beans intended for domestic use or export, and to alert farmers so that they can correct the problems causing defects in the analysis. The methodology involved sampling from the warehouse, applying the quartering procedure to obtain representative samples, and conducting the analysis test. The analysis test comprises steps such as determining moisture content, waste, and bean count, as well as conducting a cut test to assess the quality and safety of the cocoa batch. This test revealed deficiencies in the post-harvest flow chart that could help farmers optimize their final product. Important findings showed that the samples met the required moisture content of 7.5%, as specified by the standards; however, some exhibited external and internal defects that could compromise their commercialization. The study is a useful tool for farmers to improve their post-harvest procedures.

Keywords: Analysis test, Cocoa, Criollo cocoa, Fine flavored cocoa, Cut test, Good agricultural practices, Cocoa quality.

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Contribution of this paper to the literature
It is an unpublished study because, despite there being numerous scientific contributions regarding cocoa quality control and its post-harvest handling in the literature, this work compiles information revealing that, besides being used for quality control and assurance, analytical tests are a tool for providing farmers with information to improve their procedures.

1. Introduction

Venezuelan cacao is globally recognized as the best in the world, thanks to its classification as "fine aroma" cacao by several international *chocolatiers* and also certified by International Cocoa Organization [1]. This distinction grants it a truly incomparable complexity of flavors and aromas, ranging from floral and fruity notes to those of nuts. Its immense importance lies in the fact that it preserves the greatest genetic diversity and purity on the planet, while also serving as a pillar of the country's history, culture, and sustainable economic development. In addition to its functional and aromatic properties, Venezuelan cocoa is a work of art that harmonizes with nature (Figure 1).

Figure 1. Cocoa pods from the Venezuelan regions: A harmonic glance.

Morris in 1882 and Chessman in 1944 (cited by Bhattacharjee and Akoroda [2]) classified the *Theobroma cacao* species into two varietal groups: Criollo and Forastero. Subsequently, and with limited information regarding its origin, the Deltano or Trinitario type emerged. Deltano or Trinitario cacaos are generally considered to be the product of hybridization between Criollo and Forastero, although this lacks exhaustive bibliographic support. It is worth noting that, due to the influence of microclimate and time, these hybrid cacaos exhibit varying proportions of seeds with cotyledons of different colors, ranging from purple to white, including pinkish and light purple shades (Figure 2) and with excellent and varied flavor descriptors.

Figure 2. Cross-section and longitudinal section of two Venezuelan hybrid cacao pods.
Note: The photos show the color variation of the seed cotyledons within the pods.

Of these three types of cocoa found in the world, the Criollo and Deltano cocoas are the ones growing the most in Venezuela and are distributed throughout the country and they are considered fine-flavored cocoas. Figure 3 shows the characteristic color of the cotyledons of the Deltano cocoa (hybrid) and the Criollo cocoa from three regions of Venezuela.

Criollo cacao is a native variety, highly prized, aromatic, and delicate, characterized by white beans and low bitterness. Hybrid cacao (such as local Deltano o Trinitarios) is a cross with Forastero that yields more fruit, offers better disease resistance, and delivers bold, complex flavors. Deltano o Trinitarios are named in Venezuela "Criollos Modernos".

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Figure 3. Venezuelan: Hybrid cacao and Criollo cacao pods.

Note: A: Hybrid from the north-central region; B: Hybrid from north-oriental region, and C: Criollo comes from the Venezuelan north-western region. The photos show the color variation of the pods and seed cotyledons outside the pods.

According to the United Nations Conference on Trade and Development [3] and Pérez Sir [4] fine-flavor cocoa is characterized by a complex sensory profile comprising basic attributes that are well-balanced with specific aromatic and flavor notes; complementary attributes can be clearly perceived and identified in the expression of its aromas and flavors. It results from the interaction between (a) a specific genetic composition, (b) favorable growing conditions in a specific environment or *terroir*, (c) specific plantation management techniques, (d) specific harvesting and post-harvesting practices, and (e) stable chemical and physical composition and bean integrity. International Cocoa Organization [1] also pointed out that fine-flavored cocoa beans come from the Criollo or Trinitario (Deltano) cocoa types.

Figure 4 shows the longitudinal section of seeds from Criollo cocoa; it is evident that there is a complete absence of anthocyanins, and that immediate oxidation due to the action of the polyphenol oxidase enzyme on the tannins present during fermentation occurs.

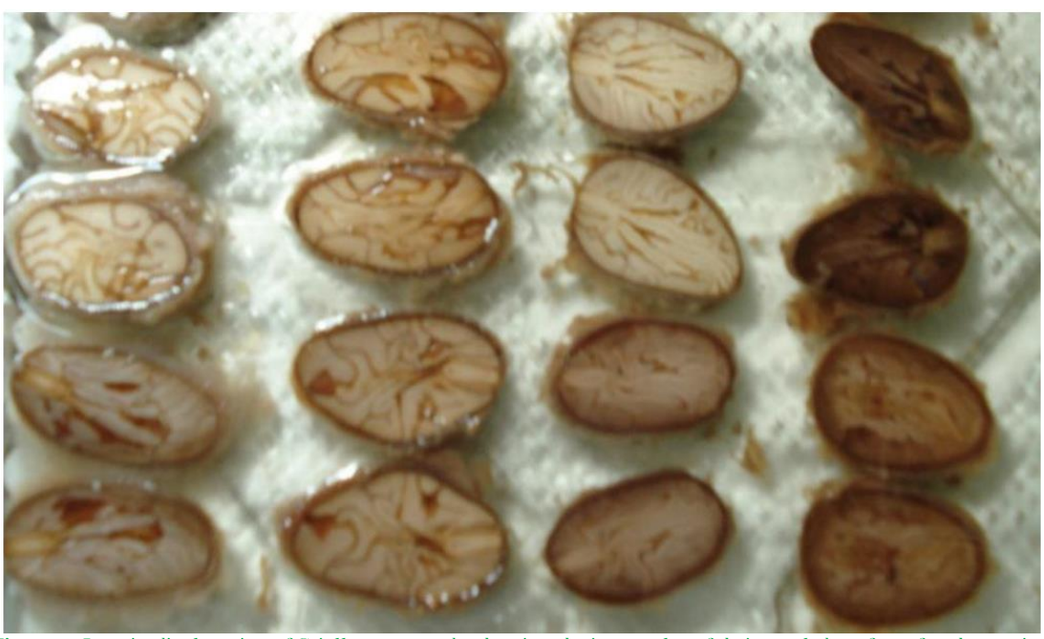

Figure 4. Longitudinal section of Criollo cocoa seeds, showing the ivory color of their cotyledons free of anthocyanins.

Even though the Venezuelan cacaos are promising due to their genetic characteristics, to overcome barriers to entering international cocoa markets in different countries, Venezuela must establish optimal quality control parameters for its fine-flavored cocoa to ensure that they are in line with international and national regulations. Moreover, it has been detected that the quality of fermented and dried cocoa beans is also a function of the harvest and postharvest handling.

For this reason, there are national and international standards for the quality control of cocoa once they are fermented, dried, and stored, which define quality characteristics associated with harvest and post-harvest handling.

Cocoa quality control includes physical, physicochemical, chemical, and sensory parameters, among others. As national and international consensus among the physical and physicochemical analysis or guarantee the optimal quality of the cocoa is the Analysis Test. This test is performed after the application of sampling in several steps, such as moisture and waste determination, bean count determination, and conducting a cut test.

The physical quality characteristics of cocoa beans allow them to be classified for specific markets based on bean size uniformity, shell percentage, fermentation index, and the number of visible defects [5]. Regarding chemical composition, fat, or cocoa butter, is the primary non-volatile constituent and the parameter most commonly used to define chocolate quality and price. It is responsible for the product's hardness, rapid and complete melting in the mouth, gloss, texture, and shelf life. Cocoa contains other major components, the concentrations of which vary during post-harvest processing.

On the other hand, it is noted that the Analysis Test could reveal mistakes in the postharvest chart flow, which could help the farmer optimize their end product.

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Therefore, this work aims to associate each one of the evaluated parameters in the Analysis test with good agricultural, harvesting, and storage practices performed on the cocoa bean for national use or exportation.

2. Materials and Methods

2.1. Sample

4 kg of Cocoa population samples, random sampling of the warehouse batch.

2.2. Working Kit

- Cocoa moisture tester
- Precision balance (4 kg capacity)
- Guillotine cutter
- Moisture meter
- Stereomicroscope or magnifying glass
- Vernier caliper
- Bucket
- 250 ml plastic beakers
- 4 kg plastic container
- Sampling probes
- Sample collection shovel
- Knives
- Plastic ruler

Format of certificate of analysis (COA) according to Flores, et al. [6].

2.3. Working Conditions

Well-lit area (white or natural light)
Ventilated
Clean
Work table
Labeled plastic bags for packaging control samples
Waste bins

2.4. Sampling Procedure for Composite Sample

The composite sample collection is performed using a sampling probe and plastic containers. If it is an industrial sampling, the sample is collected from the warehouse from the batch of jute sacks (Figure 1), randomly sampling with the probe and taking a sample of the entire cocoa population and using the sack number determined by COVENIN [7] for the batch sack of cocoa quantity until collecting approximately 4 kg. From this, 3 kg will be used for analysis, while 1 kg is set aside and coded as a reference sample Figure 5.

If it is a small-business farmer, the sampling must be performed on several sacks as a function of the quantity.

Figure 5. Sample composite collection with a probe on the stack of jute sacks in the warehouse.

2.5. Test Analysis Procedure

Cocoa testing begins with the determination of moisture content in the composite sample of approximately 4 kg, randomly drawn from the warehouse.

The cocoa moisture content and an external examination are performed on the quantitative, representative composite sample.

2.6. Moisture Content

In the lab, the official methods are used as follows. It can be done using one of these methodologies: 1. By AOAC International [8]: Weigh a 2 g prepared test sample into a flat metal or platinum dish. Dry in an air oven at 100°C to constant weight. Report the weight loss as water percentage. Or 2, by International Organization for Standardization [9]: Crush representative cocoa bean samples. Dry a crushed test portion in a ventilated oven at 103°C (±2°C) for 16 hours. Cool in a desiccator and weigh to find mass loss. Even more, it can be determined with less precision in the warehouse using a moisture meter.

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2.7. External Examination

The external examination determines the waste material (shell fragments, placental tissue, broken beans, wood splinters, and plant debris) and foreign matter (foreign grains, plastic, metal, or wood pieces), as well as the presence of macro- and microorganisms. It also includes the grain grading or characterization of the cocoa beans (size, shape, bean index, and bean count per 100 grams) and the identification of double or multiple beans, shrunken beans, and germinated beans; all data are expressed as percentages in the COA format [6]. Also, the cocoa beans are evaluated sensorially to be free of smoky smell or objectionable or foreign odors.

Before the internal examination, the 3 kg sample undergoes the quartering rule by machine [10] or manually (Figure 6) to obtain a working sample weighing between 600 and 700 grams (Quantitatively).

Figure 6. Procedure for application of quartering rule manually.

The composition of cocoa foreign material is determined through physical cleaning, winnowing, and sieving methods. In the laboratory, foreign material other than cocoa material, such as foreign grains, plastic, metal, or wood pieces, is manually separated from the composite sample, and the results are expressed as a percentage. If necessary, a sieve could be used.

On the other hand, the waste from cocoa material (Shell fragments, placental tissue, broken beans, wood splinters, and plant debris) is also manually separated from the composite sample and expressed separately as percentages.

The grading or characterization of the cocoa beans (size, shape, bean index, and bean count per 100 grams) and the identification of double or multiple beans, shrunken beans, and germinated beans are also performed on the composite sample and expressed separately as percentages.

Grading and size: Bean index (weight in grams of one bean), dimensions (length, width, thickness and large/wide relationship), and bean count per 100 grams.

To calculate the bean index, thirty cocoa beans are weighed individually; the results are averaged, the standard deviation is determined, and the value is reported in the COA format.

The dimensions are calculated from the length, width, and thickness of thirty beans using a caliper. The results are averaged, the standard deviation is determined, and the value is reported in the COA format.

The determination of the number of beans per 100 grams. This is known as the "bean count" and indicates the average size and weight of the individual beans. Typically, a sample ranges from 90 to 110 beans per 100 grams.

An account of 50 to 80 beans for 100 g is indicative of large and heavy beans, with a high ratio of valuable nibs to outer shell. This value, in conjunction with another parameter, can be graded as Premium. This grade is specifically for retailers who demand uniform sizes of beans with no wastage. Conversely, an account of 120 -160 beans in 100 grams means that individual beans are small and light and come from younger trees, dry soil or immature pods.

To calculate the number of cocoa beans in 100 grams (known in the industry as the bean count), weigh exactly 100 grams of whole, clean, dry beans on a precision balance. Count the individual whole beans in that sample, removing any broken pieces, debris, or flat beans, and record the total number. It must be done by triplicate and the results are averaged, the standard deviation is determined, and the value is reported in the COA format.

2.8. Internal Examination

The internal examination using the cutting test will also reveal the effectiveness of good cultural and postharvest procedures, with an emphasis on the fermentation grade.

A cocoa cut test is a visual quality control method where a representative sample of beans (usually 50 to 300 beans) is sliced lengthwise or crosswise in half using a kind of guillotine or manually with a knife. It is performed on this representative sample, where the valuators inspect the exposed inner cotyledons to check the degree of fermentation by analyzing the different fermentation statuses: fully fermented, non-fermented (slaty) and semi-fermented (violet) cocoa beans; non-fermented slaty, over-fermented (black), and internal macro- and micro contamination or germination [11-15]. Among the fully fermented beans, as can be seen in Figure 7, a distinction is made between white ("light break") and dark interior ("dark break") beans; all data are expressed as percentages.

The last evaluation is performed on the cocoa paste (liquor). The protocol, roasting time, and temperature of the paste liquor elaboration are decided by the customers. A trained sensory panel evaluates the odor and taste descriptors of the cocoa paste using a descriptive test [16], and they are reported as radial graphics

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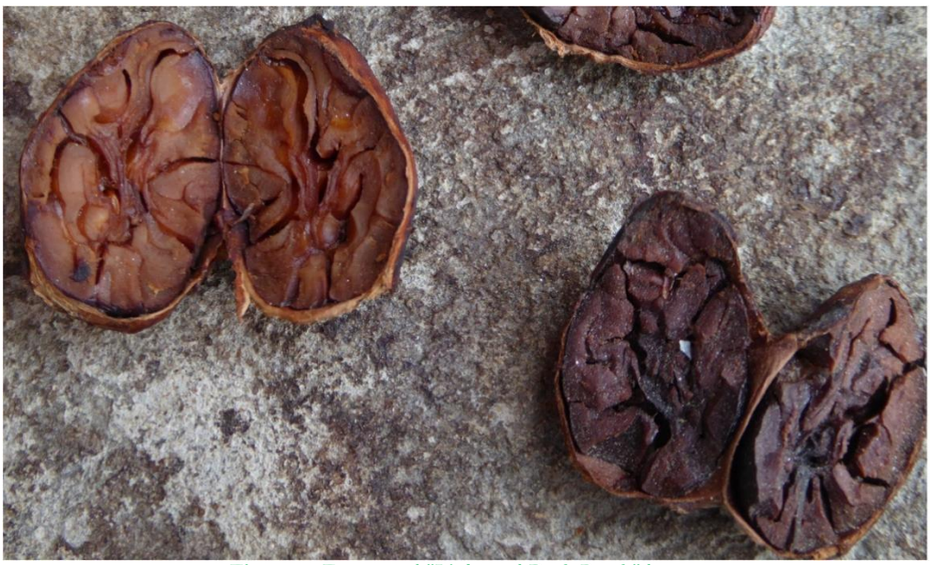

Figure 7. Fermented "Light and Dark Break" beans.

3. Results and Discussion

3.1. Grain Grading: Moisture Content, Foreign Matter, and Damaged Beans

Moisture: The moisture content of the beans, according to international and national norms, is usually 7.5%; however, International Organization for Standardization [9] recommend by the cocoa bean should not exceed 8%.

If the moisture content of the beans is under 8%, it is indicative of low drying or storage with high relative humidity. Therefore, excess moisture not only adds weight to the grain batch, which could affect the payment of the lot by customers, but can also lead to consequences such as the growth of macro- and microorganisms. Farmers must check cocoa bean moisture content after the drying process and control the temperature and relative humidity of the warehouse.

Conversely, a moisture content below 8% could lead to grain breakage during handling and storage, thereby increasing the level of impurities in the batch and diminishing the quality of the cacao.

Other factors in cocoa grading are foreign matter and impurities, which include waste (stones, dirt, twigs, string, and metal pieces), non-cocoa beans (seeds or grains from other plants), and cocoa-byproduct matter (Figure 8): broken beans, loose shells, flat beans, and placenta pieces.

Figure 8. Cocoa-by products matter: loose shells, broken beans and flat beans.

3.2. External Examination

The excessive presence of foreign matter and impurities in dry cocoa beans, which must not exceed 1% according to international commercial grading and food safety standards, is directly indicative of poor post-harvest handling, sub-standard agricultural processing, and inadequate quality control [17-19].

The presence of this foreign matter and impurities is an index of:

1. Flawed drying and handling practices; how and where the beans were processed. High amounts of stones, dust, and soil indicate that cocoa beans were dried directly on uncleaned patio floors or open roadsides rather than on a raised drying table.
2. Lack of sorting and pre-cleaning: It signifies that the farm or supplier skipped the essential sorting phase before bagging. Properly sorted cocoa requires ridding the lot of debris.
3. Potential adulteration: An excessive volume of cocoa-related debris—such as placenta, pod veins, or loose shells—is often a sign of deliberate or negligent bulk padding (Adulteration) to artificially increase shipment weight.
4. Poor Storage and warehouse sanitation: The presence of non-cocoa impurities like feathers, strings, plastics, or rodent and bird droppings indicates heavily contaminated storage conditions.

Therefore, more than the farmer, the buyers have to be aware of foreign matter and impurity analysis.

Bean size and count are measured as the number of beans per 100 grams. If there are fewer beans, it means there is a large average size: 50 to 80 beans per 100g. means. Larger beans often fetch a premium because they are easier to process uniformly. Conversely, more beans mean a smaller average size. A count of 120 to 160 beans per 100g means the beans are smaller, lighter, and often contain a higher ratio of shell to usable inner nib.

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In Venezuela, the cocoa bean count per 100 g ranges from 63 to 91 beans. Criollo cocoa is the most rounded (low large/wide value; Figure 9) in form and bigger in size than Deltans (hybridized) or Forasteros. The Deltans (hybridized) or Forasteros gradings are shown in Figure 3. The Criollo cocoa is from the Sur del Lago region, while the hybridized are spread in the central and oriental regions.

Bean weight is a key quality sign for chocolate. Heavier beans mean more inner meat (nibs) and rich cocoa butter. Light beans mean low food value and poor taste. A single dry bean usually weighs about 1 gram. As can be shown by the data of the weight data in Figure 9, all of them have a weight over 1g.

1 gram or higher (Corresponding to a bean count of 100 beans or fewer per 100 grams) is the global industry benchmark for high commercial quality and Grade-1 merchantable standards. Beans below this weight indicate lower yields, reduced fat content, and higher processing costs [20].

Larger beans have a more favorable ratio of inner cotyledon (nib) to outer shell. Because fat accounts for roughly half of the bean's dry weight and forms valuable cocoa butter, heavier beans directly maximize chocolate and butter manufacturing yields. Contrarily, the smaller beans (under 1 g) contain a higher percentage of outer husk/shell. High shell content means less usable material for chocolate makers and a lower overall lipid concentration.

Moreover, Uniform batches of large, heavy beans roast, crack, and winnow evenly. Undersized or mixed-weight batches require factory adjustments that increase processing energy and operational costs. On the other hand, international trade guidelines categorize standard Grade-1 batches at a bean count ≤ 100 per 100 g (an average dry weight ≥ 1g per bean). Parcels with a high count of tiny beans (more than 100–120 beans per 100 g) often face severe financial penalties or rejection.

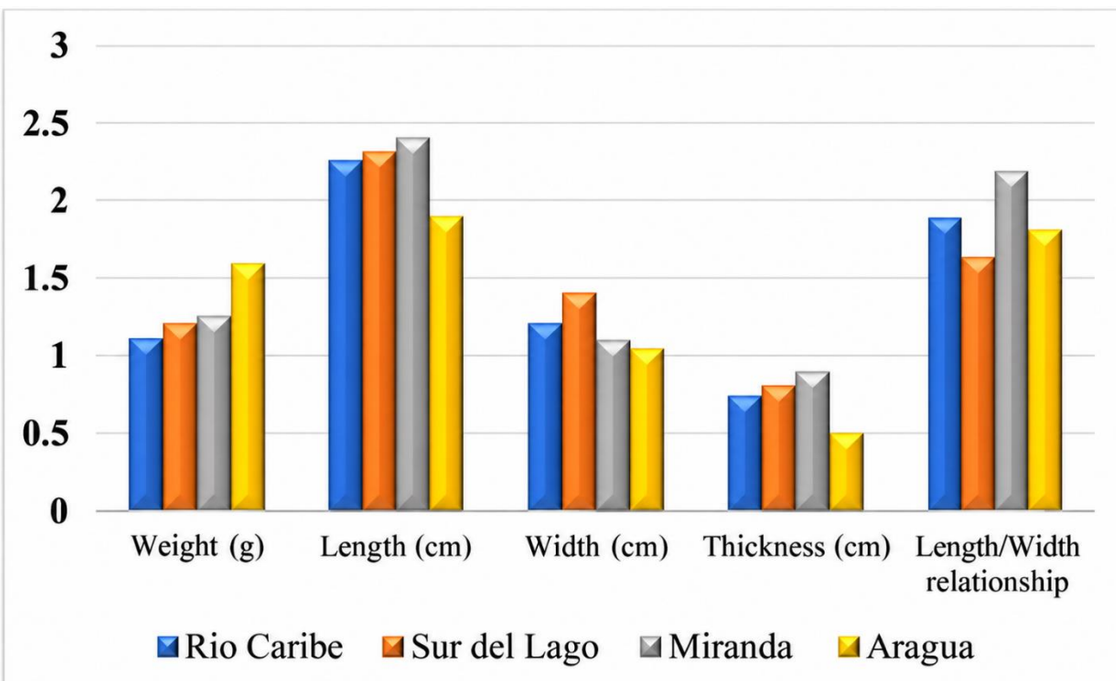

Figure 9. Grading of cocoa beans from four Venezuelan regions.

A minor important characteristic is the beans' color, as it varies due to various factors, especially climatic ones. Within the reddish coloration dominant in current varieties, the following shades stand out: brown, reddish, grayish, black, or whitish, which do not give a good appearance to the beans. However, it could appear better if the farmer introduces in the flowchart after the fermentation process, once the cocoa is cooled, a cleaning technique. The process could be drying (gentle friction) or potable water rinses (Figure 10). This preserves the characteristic reddish color of the cocoa beans and yields beans free of mucilage residue, making them less hygroscopic and safer, while also improving their color in appearance.

In the global industry, cocoa beans are generally not washed. Washing cocoa is an optional and very uncommon practice carried out by small-scale artisanal and traditional producers, primarily in Mexico and regions of Central and South America, to remove the mucilage or pulp and create micro-lots with more astringent or direct flavor profiles. However, research performed with Venezuelan farmers has indicated that washing does not affect the quality characteristics of the chocolate, as has been sought to be demonstrated.

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Figure 10. Uncleaned and cleaned cacao by rinsing with potable water, and the chocolate elaborated with these cocoas.

Figure 10 also shows chocolate elaborated with cocoa, rinsed and not rinsed. To evaluate the effect of washing on the sensory properties of chocolate, preference tests using a 9-point hedonic scale with semi-trained panelists were conducted on them. This preliminary sensory test determined that there are no significant differences in the flavor of the produced chocolate compared with the chocolate elaborated with unwashed cacao. Also, it can be observed in the photograph in Figure 10 that the chocolate elaborated with washed cocoa has good shine and texture.

The presence of multiple or "double cocoa beans" (two fused beans; Figure 11, or multiple embryos sharing a single shell) is highly important because it directly penalizes cocoa bean grading, disrupts roasting uniformity, and reduces the financial yield of chocolate production. In global commercial markets, double or multiple beans are classified as physical defects.

Figure 11. Image of double cocoa beans.

This defect is a signal of bad fermentation or drying practices due to defective turnover. Therefore, the farmer must have a standardized protocol for fermentation and drying turnover.

Besides the factors mentioned, such as roasting uniformity and reduction in chocolate production, failures in fermentation turnover have an impact on the optimal development of the flavor precursors, due to inadequate ventilation of the bean mass and oxygen distribution to microbial succession. Similarly, in the case of drying, it fails in turnover have an impact on the uniformity of moisture outflow from the grain, with consequently high final moisture content.

Figure 12. Cocoa germinated and pod with high germinated beans.

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Germinated cocoa beans are fresh seeds that have begun their development process. Depending on the context, this can mean two very different things: a serious defect in industrial chocolate production caused by over-ripe pods, or the initial step in planting and cultivating new cocoa trees.

This occurs when the pod spends an extended period ripening on the tree before harvest, or when the beans remain in the pod during the post-maturity holding period, leading to quality issues. As shown in Figure 12, the embryo ruptures the seed coat, creating an opening through which the radicle emerges; this opening facilitates contamination by allowing the entry of fungi and insects. Furthermore, the biological process of germination consumes the mucilage, which serves as a nutrient reserve for plant development, rendering these beans defective during processing; they disrupt uniform fermentation, ultimately resulting in chocolate with poor sensory quality. Producers must remain vigilant, understand the pod maturation cycle, and develop an optimal maturity index that ensures good fermentation and prevents germination, either within the pod or during the holding period.

3.3. Internal Examination

The percentage of these defects in the beans in internal examination is revealed by the cutting test (Figure 13).

The presence of slaty, violet, and partial violet beans is an index of poor fermentation. International and national norms set minimal percentages of this defect for grading cocoa (Figure 14). In slaty beans, no fermentation took place, typically because the beans were dried immediately after harvest and skipped the fermenting boxes. Slaty beans are a major trade defect because they impart a highly bitter, astringent, and metallic flavor with zero chocolate aroma.

In the cocoa cut test, the presence of completely violet beans indicates a total absence or severe lack of fermentation. The bean did not undergo the necessary chemical changes during the post-harvest stage. This affects the sensory quality of the chocolate made from this cacao, resulting in high astringency and bitterness; because the polyphenols do not break down, the bean retains an intensely bitter, mouth-drying taste, while the chocolate flavor precursors fail to develop properly, leaving a profile that is flat, raw, or excessively acidic.

Figure 13. Guillotine for cutting test and guillotined beans showing different defects, and "Light Break" and "Dark Break" beans.

Partial violet beans show patchy, mixed tones of brown and purple. They are the result of uneven fermentation or poor aeration (e.g., failing to mix the cacao mass thoroughly). Partial violet beans are indicative that chemical reactions that break down natural anthocyanin pigments did not finish, revealing a short fermentation window or inadequate heat buildup. These beans produce chocolate that requires heavy sweetening to mask extreme bitterness. While they retain some bitterness, a small percentage (around 10–20%) is often tolerated in standard commercial batches and can still yield decent flavor profiles upon roasting.

Figure 14. Slaty, violet, and partial violet beans.

Therefore, farmers need to standardize the fermentation process and be aware of its importance.

The contamination of beans with molds and insects is an indicator of poor drying and storage practices. Contamination of cocoa beans with mold and insects ruins the taste and safety of chocolate. Using as little as 3% moldy beans creates an unpleasant, musty flavor, while insect damage introduces hollowed-out, powdery beans that lower fat content and spoil the rich, smooth profile of finished chocolate.

Therefore, to ensure optimal sensory quality and safety, producers must prevent contamination of their cocoa, and buyers must be on the alert to avoid purchasing contaminated cocoa.

Even when the cocoa bean shows no visible signs of external or internal fungal or insect contamination, the use of a stereomicroscope has revealed the presence of hyphae and insect eggs or larvae within the bean's cotyledons. As

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is shown in Figure 15, fungal hyphae are not visible to the naked eye, but with the aid of a stereomicroscope, they become quite visible. In Figure 16, a worm growing in the cocoa is visible to the naked eye.

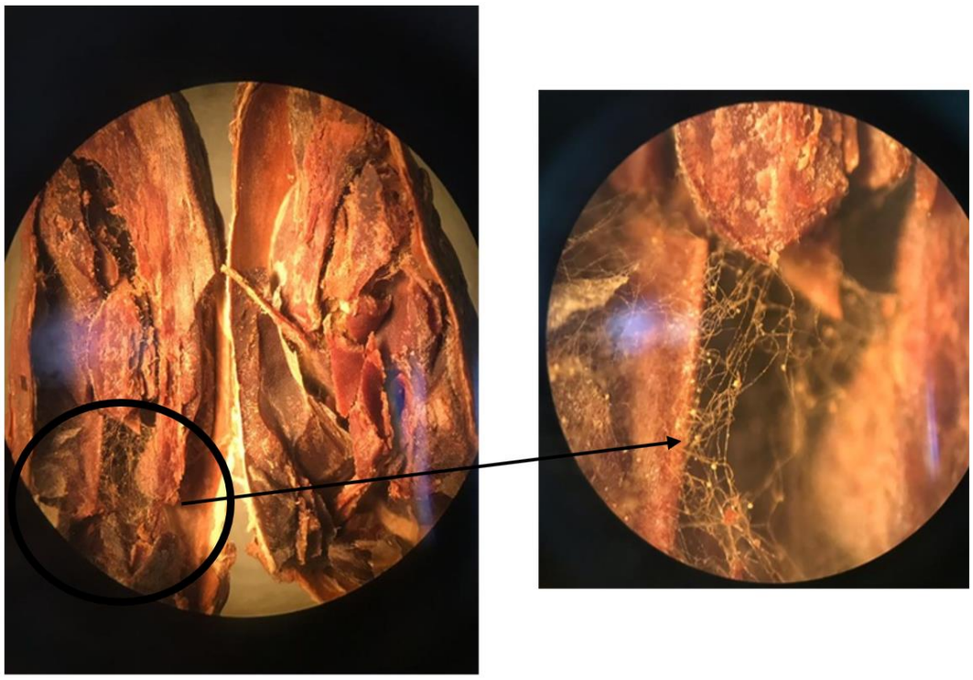

Figure 15. Microphotography of mold contamination in cocoa bean by optical stereomicroscope.

Figure 16. Microphotography of worm contamination in cocoa bean by optical stereomicroscope.

Finally, the well-fermented beans have a rich brown interior ("Light Break" for Criollo or "Dark Break" for Deltano or Forastero beans; see Figures 3 and 17), a pleasant fruity or alcoholic aroma, and lack a raw purple color (Figures 17 and 18), which produces a chocolate with rich flavor, with less bitterness and a smooth finish.

Also, the percentage of well-fermented beans varies across different grades, as determined by international and national standards. In this context, the COVENIN norm from Venezuela describes three types of cocoa such as: Extra fine (≥80 % of fermented beans), Fine of first (≥74 % of fermented beans), and Fine of second (≥20 % of fermented beans).

Figure 17. Well-fermented grain.

Source: Criollo Nuñez, et al. [21].

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A higher percentage of fermented beans and a lower proportion of violet, slaty, and over-fermented beans will enhance the cocoa's flavor and quality, resulting in lower acidity, astringency, and bitterness, or the absence of undesirable flavors in the chocolate. Resulting in optimal chocolate.

Figure 18. Well-fermented cocoa beans.

4. Conclusion

Besides the functional use of the Analysis test, in particular the cutting test for demonstrating the quality and safety of the cocoa for national consumption and for exportation, the analysis is quite adequate to inform the farmers where are the fails in their products and how they can correct.

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