

Sensory profiling and genetic variability of *Coffea canephora* genotypes cultivated in the Western Amazon

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ABSTRACT

The characterization of variability in the sensory profile of *Coffea canephora* is essential for the coffee industry, as it supports the selection of plants with favorable quality attributes. This study aimed to evaluate beverage quality and quantify variability among the most widely cultivated clones in Western Amazonia through sensory analysis, based on total cup scores and specific quality descriptors. The samples were collected in Porto Velho, Rondônia over three agricultural seasons. Sensory evaluation was performed using the Fine Robusta Tasting Protocol. Fifty genotypes were evaluated, including registered cultivars, genotypes from the Embrapa Active Germplasm Bank, and public domain clones. Performance in different harvests was analyzed using simple and combined analysis of variance (ANOVA), genetic parameter estimates and principal component analysis (PCA). The effect of genotype × year interaction was significant, with a predominance of simple interaction. Total cup scores ranged from 74.77 to 84.21 points, with twenty-five genotypes scoring above 80 points and therefore classified as Fine Robustas. The weighted average of the descriptor frequencies, considering their position on the flavor wheel, ranged from 99.48 to 259.99. PCA indicated that clones with higher beverage quality are associated with the descriptors Nutty/Cocoa, Sweet, Floral, and Fruity. This study shows that the selection of coffee genotypes influences the sensory profile of the beverage. Moreover, it supports the production of high-quality coffee that not only achieves elevated overall cup scores but also presents balanced and pleasant sensory descriptors, adding value to the final product.

Key words: Beverage quality; genetic variability; cupping; clone evaluation; flavor descriptors.

1 INTRODUCTION

The beverage produced from genotypes of the species *Coffea canephora* has traditionally been considered a low-quality product, with its beans primarily used in blends mixed with those of the species *Coffea arabica*. However, recent studies have shown that *C. canephora* genotypes exhibit promising quality scores and flavor profiles, indicating their potential to meet the growing demand for high-quality or “specialty” coffees (Bollen et al., 2024; Viencz et al., 2024).

High sensory quality scores, combined with the growing demand from consumers seeking better-tasting, premium coffees, have drawn greater attention to beverages produced from *C. canephora*. This trend has expanded consumer markets and established the species as a rising focus of interest for both coffee research and the industry (Baqueta et al., 2024; Traore et al., 2018). These plants are primarily cultivated in Vietnam and Brazil and are better adapted to tropical climates compared to the *C. arabica* species (Nascimento et al., 2007). Alloamy and high genetic diversity are key characteristics of *C. canephora*, providing a strong foundation for the development of coffees with agronomic and industrial interest.

Studies report that the sensory profile of *C. arabica* coffee tends to feature flavor descriptors that emphasize its

sweetness, higher acidity, and fruity notes (Barbosa et al., 2019). In contrast, coffees from the species *C. canephora* contain higher levels of caffeine and chlorogenic acids (Agnoletti et al., 2019), contributing to a more bitter, nutty, and astringent flavor profile (Hall, Trevisan & Vos, 2022).

The most widely cultivated botanical varieties are Conilon and Robusta, which stand out in the commercial market (Rocha et al., 2025). A large portion of *C. canephora* plants grown in Brazil, especially in the Western Amazon region, exhibit hybrid characteristics, combining quality traits from both the Conilon and Robusta varieties. While the Conilon variety is characterized by predominantly neutral beverages with a lighter body, the Robusta variety is distinguished by its exotic and fruity flavor descriptors (Silva et al., 2025; Souza et al., 2018), with hybrids displaying characteristics of both varieties.

Improvements in the beverage quality of this species have been observed not only in Brazil, but also in other producing countries. In the Democratic Republic of Congo, in the Yangambi region, naturally processed coffees achieved scores of up to 84.75 points (Bollen et al., 2024), while washed and wet-fermented coffees reached 83.88 points. These beverages were described as smooth, fruity, and cocoa-flavored, with negative correlations to rough mouthfeel, tobacco aroma, and

leather taste (Bollen et al., 2025). In Indonesia, Robusta coffees from the Gunung Malang, Tanggul, and Pakis regions were characterized by sweet and acidic aromas (Belgis et al., 2023).

These aspects of coffee quality are closely associated with the flavor and aroma of the beverage (Vezzulli et al., 2022). They arise from the interplay between the physical characteristics of the cherries, the chemical composition of the green beans, and compounds formed during roasting (Debona et al., 2020; Malta et al., 2020), including methylpyrazine, furfural, 1-(acetyloxy)-2-propanone, and 5-methyl-2-furanmethanethiol (Debona et al., 2025). In addition, genetics, cultivation environment, and post-harvest processing also influence these quality attributes (Bollen et al., 2025; Bernardes et al., 2024; Santos et al., 2023; Pereira et al., 2021).

The recognition of beverage quality is a fundamental activity conducted for both scientific and commercial purposes through sensory analysis. Evaluation parameters include fragrance/aroma, flavor, aftertaste, saltiness/acidity, bitterness/sweetness, mouthfeel, balance, overall impression, uniformity, and cleanliness. The scales consist of 16 gradations representing quality levels, increasing in quarter-point increments between numerical values of 6 and 10 (Uganda Coffee Development Authority - UCDA, 2010).

Sensory analysis is performed by trained tasters who detect differences between samples. This tasting process, known as “cupping,” is conducted by professional tasters called Q-Graders (Pereira et al., 2018). The perception of these scores alone provides limited information as samples with the same rating can differ in their aroma and flavor descriptors. Without sensory descriptors, differences between coffees reduce to mere point variations on a scale. For this reason, the so-called “Coffee Flavor Wheel” is essential to complement sensory quality assessments (Chambers et al., 2016; Spencer et al., 2016).

Considering the coffee production potential of the Amazon region (CONAB, 2025), studies focused on the beverage quality are expected to contribute to the region’s economic growth. The literature includes studies reporting total cupping scores of coffees cultivated in this region (Lopes Junior et al., 2025; Reinicke et al., 2023), but these do not represent the diversity of the cultivated clones, nor are there studies evaluating this variable across multiple harvests.

Therefore, the objective of this study was to characterize the sensory profiles of *C. canephora* genotypes cultivated in the Western Amazon, while accounting for harvest year, using sensory analysis based on the Fine Robusta cupping protocol established by the Coffee Quality Institute (CQI) (UCDA, 2010), through phenotypic clustering patterns associated with beverage quality.

2 MATERIAL AND METHODS

In January 2019, a clonal competition trial was established at the experimental field of the Brazilian

Agricultural Research Corporation (Embrapa) at 8°48’05.5” S and 63°51’02.7” W, at an elevation of 88 meters above sea level. The predominant climate in the region is tropical rainy with a dry winter, classified as “Am” (Köppen), with an average temperature of 26.0 °C and an annual average precipitation of 2,095 mm. September is the hottest month of the year (27.1 °C), while May is the coldest (24.9 °C) (Alvares et al., 2013). During the flowering, fruit development, and maturation periods, climate data were recorded using Ambient Weather WS-2902 smart weather stations. Climate data and soil chemical properties are presented elsewhere (Lopes Junior et al., 2024).

The experiment lasted for 48 months to account for the effects of genotype and year, also referred to as also called harvests. To evaluate the effects of genotypes and harvest years, as well as their interaction, a completely randomized experimental design was employed. In this study, fifty genotypes were evaluated, including registered cultivars (6), genotypes from Embrapa’s Active Germplasm Bank (4), and publicly available clones widely cultivated in the Amazon region (39) (Table 1). The selection of these genetic materials is based on their prevalence in coffee plantations in the state of Rondônia, which resulted in their inclusion in the “Rondônia State Clone Evaluation Network” (ESPÍNDULA et al., 2022). The genotypes studied were also genetically characterized using SNP markers (Silva et al., 2025), grain mass (Junior et al., 2024).

Considering the maturation cycle of each genotype, harvesting was performed when approximately 80% of the fruits had reached the red-cherry stage. Single samples of cherry coffee were collected for each genotype, naturally sun-dried on raised drying beds until reaching approximately 12% moisture content, as measured using a Gehaka grain moisture meter (G600). The dried coffee cherries were then processed using a coffee depulper to obtain green beans, defective grains were removed, and 500 g samples were placed in paper bags and immediately sent for sensory analysis. For each genotype and harvest year, one composite field sample was evaluated; thus, the experimental unit corresponded to the genotype assessed in each harvest year.

Sensory analysis of the samples was conducted at the Coffee Analysis and Research Laboratory (LAPC) of the Federal Institute of Espírito Santo, Venda Nova do Imigrante campus. The samples were prepared according to the Uganda Coffee Development Authority methodology. Roasting was conducted using a test roaster with the Agtron-SCA disc set. The roasting point of these samples was defined based on the color of the beans, between the colors determined by the Agtron #65 and #55 manual discs, recommended for specialty coffees, with a medium to medium-dark roast variation, and prepared according to the international beverage classification method for *C. canephora* (UCDA, 2010).

Table 1: Coffee genotypes evaluated for beverage quality from publicly available materials, the Active Germplasm Bank (BAG), and cultivars developed by Embrapa (BRS), cultivated in the Western Amazon, Brazil.

ID	Genotype	Cultivation status	Origin	ID	Genotype	Cultivation status	Origin
1	AR106	Public Domain	Aldnei Raasch ¹	26	GJ3	Public Domain	Geraldo Jacomin ¹
2	R152	Public Domain	Ronaldo Guedes ¹	27	GJ5	Public Domain	Geraldo Jacomin ¹
3	BG180	Public Domain	Ronildo Berger ¹	28	GJ8	Public Domain	Geraldo Jacomin ¹
4	P42	Public Domain	Wanderly Bernabé ¹	29	GJ25	Public Domain	Geraldo Jacomin ¹
5	CA1	Public Domain	Carlos Silva ¹	30	GJ20	Public Domain	Geraldo Jacomin ¹
6	GB7	Public Domain	Gilberto Boone ¹	31	GJ30	Public Domain	Geraldo Jacomin ¹
7	R22	Public Domain	Ronaldo Vitoriano ¹	32	LB10	Public Domain	Laerte Braun ¹
8	WP6	Public Domain	Vanderley Peter ¹	33	LB15	Public Domain	Laerte Braun ¹
9	L1	Public Domain	Alcides Rosa ¹	34	LB30	Public Domain	Laerte Braun ¹
10	GB1	Public Domain	Gilberto Boone ¹	35	LB33	Public Domain	Laerte Braun ¹
11	GB4	Public Domain	Gilberto Boone ¹	36	LB68	Public Domain	Laerte Braun ¹
12	SK41	Public Domain	Sergio Kalk ¹	37	LB80	Public Domain	Laerte Braun ¹
13	SK80	Public Domain	Sergio Kalk ¹	38	LB88	Public Domain	Laerte Braun ¹
14	SK244	Public Domain	Sergio Kalk ¹	39	LB110	Public Domain	Laerte Braun ¹
15	VP156	Public Domain	Valdecir Piske ¹	40	BAG21	Germoplasm	Embrapa ²
16	P50	Public Domain	Valdecir Piske ¹	41	BAG22	Germoplasm	Embrapa ²
17	AS1	Public Domain	Ademar Schmidt ¹	42	BAG24	Germoplasm	Embrapa ²
18	AS2	Public Domain	Ademar Schmidt ¹	43	BAG27	Germoplasm	Embrapa ²
19	AS5	Public Domain	Ademar Schmidt ¹	44	BAG38	Germoplasm	Embrapa ²
20	AS7	Public Domain	Ademar Schmidt ¹	45	BRS1216	Cultivar	Embrapa ³
21	AS10	Public Domain	Ademar Schmidt ¹	46	BRS2299	Cultivar	Embrapa ³
22	AS12	Public Domain	Ademar Schmidt ¹	47	BRS2336	Cultivar	Embrapa ³
23	N13	Public Domain	Nivaldo Ferreira ¹	48	BRS2357	Cultivar	Embrapa ³
24	N16	Public Domain	Nivaldo Ferreira ¹	49	BRS2314	Cultivar	Embrapa ³
25	N8(G8)	Public Domain	Nivaldo Ferreira ¹	50	BRS3213	Cultivar	Embrapa ³

ID: Genotype number. ¹Coffee growers who selected clones commercially available in the public domain. ²Clones from Embrapa's Active Germplasm Bank, RO. ³Cultivars developed by Embrapa, RO.

Roasting was executed within 24 hours of cupping and it was allowed to rest for 8 hours before grinding. All samples were roasted from 9 to 10 minutes. After roasting and cooling, the samples remained stored in sealed containers (UCDA, 2010).

Sensory evaluations were conducted by certified Q-Graders following standardized cupping procedures, aiming to ensure the reproducibility and reliability of the assessments. After 8 to 24 hours after the roasting process, the coffee was ground in a disc mill, samples were ground so that 70 to 75% of the particles passed through a 20-mesh sieve prior to cupping. A ratio of 8.75 ± 0.25 g of coffee to 150 mL of water at 92-95 °C was used for coffee infusion. The tasters conducted the evaluations when the temperature of the cups reached 55 °C, respecting the 4-minute tasting time after infusion. The water used for preparation was clean and odorless, neither distilled nor deionized. Five cups were evaluated by each taster, following the Fine Robusta cupping

protocol. Sensory evaluation was conducted using a cupping form to assess 10 key coffee attributes: fragrance/aroma, flavor, aftertaste, saltiness/acidity, bitterness/sweetness, mouthfeel, balance, overall impression, uniformity, and cleanliness. The total score was reduced by the number of defects. Descriptive sensory data were collected concurrently during the coffee cupping (UCDA, 2010).

The total cupping score was calculated by summing the scores of each primary attribute and subtracting the corresponding defect values. For the sensory descriptors listed by the Q-Graders, these were categorized according to the descriptive axes of the "Coffee Flavor Wheel." To determine the positioning of descriptors within the primary axes and subgroups, similarity was used: similar descriptors were grouped within the same category or subcategory, while less similar ones were placed further apart, following literature recommendations (Spencer et al., 2016).

In this study, categories and subcategories of the “Coffee Flavor Wheel” were grouped by similarity and converted into angles derived from its main axes. Angles were calculated as regions between two rays with a common vertex, expressed in degrees, with the starting point (zero) set at the descriptor “Fruity.” Each descriptor’s position was determined using the angle bisector, which divides the angle into two congruent parts.

The primary axes—Fruity, Floral, Sweet, Nutty/Cocoa, Spices, Roasted, Other, Green/Vegetal, and Sour/Fermented—were assigned numerical values according to their geometric positions on the wheel. To quantify sensory descriptors, a weighted average was calculated based on their frequency of citation, with axis weights determined by relative frequencies within a sample (Table 2).

Table 2: Geometric angles of the “Coffee Flavor Wheel” measured from a bisector.

Main axis	Geometric angle
Fruity	40°
Floral	85°
Sweet	112.5°
Nut/Cocoa	142.5°
Spices	165°
Roasted	200°
Other	255°
Green/Vegetable	315°
Sour/Fermented	350°

By combining citation frequencies with their respective angles, the flavor perceptions of Q-Graders were transformed into continuous numerical variables, enabling statistical analyses and direct comparisons between samples. This approach addresses limitations of traditional sensory analyses, which often reduce evaluations to a single “Score” and are prone to assessor subjectivity (Pinto et al., 2024).

The significance of the genotype effect was tested individually (Cruz, 2013), as follows:

$$Y_{ijk} = m + G_i + e_{ijk}$$

where Y_{ijk} refers to the observation of the i^{th} genotype in the j^{th} measurement, m is the experimental mean, G_i is the effect of the i^{th} genotype and e_{ijk} is the experimental error.

The homogeneity of residual variances and quantification of genetic variability in relation to environmental noise was performed using pooled analysis of variance, in which the effects of genotypes, years and their interaction ($G \times Y$) were explicitly modeled (Cruz, 2013):

$$Y_{ijk} = m + G_i + Y_j + GY_{ij} + e_{ijk}$$

where Y_{ijk} refers to the observation of the i^{th} genotype in the j^{th} measurement, m is the experimental mean, G_i is the effect of the i^{th} genotype, Y_j is the effect of the j^{th} measurement, GY_{ij} is the interaction effect between the i^{th} genotype and the j^{th} measurement, and e_{ijk} is the experimental error. The genotypic effect was considered fixed and the year effect was random. In this model, sensory scores correspond to evaluations performed by certified Q-Graders within each harvest year, and the associated variation is reflected in the degrees of freedom of the analysis.

From the estimates of the expected mean squares, repeatability was calculated by decomposing the phenotypic variance into genotypic, permanent environmental, and temporary environmental components. This approach allows quantifying the proportion of the total variance attributable to permanent individual effects, as follows equation 1:

$$r = \frac{COV(Y_{ij}Y_{ij'})}{\sqrt{\hat{V}(Y_{ij})\hat{V}(Y_{ij'})}} = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_{et}^2}$$

where: r is the repeatability coefficient; σ_p^2 is the variance associated with permanent individual effects (genotypic plus permanent environmental variance); σ_{et}^2 is the temporary variance associated with the experimental error.

The correlations between harvests were obtained based on Pearson estimates (Cruz, Carneiro, & Bhering, 2021). To interpret the diversity of descriptors, a matrix was constructed using a weighted average based on citation frequency. This average was calculated based on the number of times each evaluator mentioned a particular descriptor, assigning greater weight to those with higher recurrence in the evaluations. This procedure was performed individually for each genotype and no descriptor was excluded. This weighted average was also used to generate a word cloud, visually representing the most cited descriptors with proportional emphasis according to their weighted frequency.

The diversity of the sensory profiles of the genotypes was assessed through dispersion analysis of the first two principal components. The data were standardized before PCA, ensuring comparability and adequacy of assumptions. All statistical analyses were performed using GENES software, version 1990.2023.93 (Cruz et al., 2013), and R, version 4.4.0 (R Core Team, 2013).

3 RESULTS

The individual analyses of variance revealed significant genotype effects ($p < 0.01$), confirming consistent genetic differences in beverage quality among genotypes and across harvests (Table 3). The low coefficients of variation (1.29–2.18%) and similar mean values among evaluations indicate high experimental precision and stability in the sensory

assessments. The Q-grader effect was not significant in the first and third evaluations and only marginally significant ($p < 0.05$) in the second, suggesting good consistency among evaluators and the reliability of the cupping procedure. The overall means ranged from 79.70 to 80.19 points, all within the “very good cup” category, reinforcing the uniformity and reproducibility of the sensory scores across independent panels. These results support the robustness of the experimental design and validate the use of the combined analysis presented in Table 3.

The overall average cupping score across the three harvests was 79.93 points (Table 4), with consistent mean values observed for the genotypes in the 2021 and 2023 harvests, 79.70 and 79.91 points, respectively. In contrast, the 2022 harvest showed a slightly higher mean score of 80.19 points. Regarding the sensory descriptors, the overall average was 164.89, with no statistically significant differences among the harvests: 165.72 in 2021, 165.69 in 2022, and 163.26 in 2023.

The experimental coefficient of variation (CV) for overall beverage quality was 1.84%, classified as low ($CV < 10\%$). For the sensory descriptor trait, the estimated CV was higher (27.48%), reflecting lower precision due to variations in the descriptors provided by individual evaluators.

The standard deviations for the final cupping score and sensory descriptors were 1.36 and 38.30 in the 2021 harvest, 0.81 and 29.89 in 2022, and 1.53 and 43.60 in 2023, indicating consistency in the cupping evaluations. In contrast, the weighted descriptor citations converted into angles showed higher variability. Across crop years, standard deviations ranged from 0 to 3.76 for the total cupping score and from 7.57 to 89.14 for the weighted averages of descriptors (Table 4).

The combined analysis of variance allowed the comparison of mean values and the identification of significant differences between them. The F-test estimates for genotype

effects and genotype $\times$ year interaction were significant at the 1% probability level for both the overall cupping score and beverage quality descriptors (Table 4). When the G $\times$ Y effect is significant, it indicates the presence of genotypes with differential performance across harvests. In such cases, the behavior of the genotypes must be interpreted individually for each year, given their distinct performance across harvests.

The repeated measures analysis over time allowed consideration of both temporary and permanent effects of experimental error, showing that the G $\times$ Y interaction was classified as simple for the overall cupping score (Figure 1: A, B, C) and complex for the descriptors (Figure 1: D, E, F).

Regarding the total cupping score, the genotypes means ranged from 74.77 to 84.21 points forming five groups (Table 5). The highest mean score was observed for clone AS2 (84.21), while the lowest was recorded for cultivar BRS2357 (74.77). For quality descriptors, based on the weighted frequency of citations and their respective positions on the “Coffee Flavor Wheel,” the genotypes were divided into four groups, with the highest value reported for VP156 (259.99) and the lowest for LB88 (99.48).

The repeatability estimates, also referred to as the upper limit of heritability, for the total cupping score and descriptors in our study were 88.91 and 79.91, respectively (Table 4). This estimate accounts not only for genetic variance but also for environmental factors that influence the expression of quality over time.

The genetic coefficient of variation was 2.94% for overall beverage quality and 24.98% for sensory quality descriptors. The ratio between the genetic and experimental coefficients of variation (CV_g/CV_e) was 1.60 for the total cupping score and 0.91 for descriptors (Table 4). A CV_g/CV_e ratio greater than 1 indicates favorable conditions for achieving selection gains and demonstrates that the cultivation of selected genotypes directly influences beverage quality.

Table 3: Summary of the individual analyses of variance for the sensory characteristics of 50 genotypes of *Coffea canephora*, evaluated in three independent sensory panels (1st, 2nd, and 3rd evaluations) conducted by certified Q-graders during the 2021, 2022, and 2023 harvests at the Embrapa experimental field located in the municipality of Porto Velho, Rondônia, Brazil.

FV	1° evaluation			2° evaluation			3° evaluation		
	GL	MS	F	GL	MS	F	GL	MS	F
Genotype	49	18.75	7.83**	49	28.17	26.12**	49	21.60	7.12**
Q-grader	2	0.81	0.34 ^{ns}	2	2.62	2.43*	2	3.59	1.19 ^{ns}
Residual	98	2.39		98	1.08		98	3.03	
Total	149			149			149		
Overall Mean	79.70			80.19			79.91		
1st Q-grader Mean	79.60			79.94			79.76		
2nd Q-grader Mean	79.85			80.36			79.75		
3rd Q-grader Mean	79.67			80.29			80.22		
CV%	1.94			1.29			2.18		

FV = source of variation; GL = degrees of freedom; MS = mean square; F = F-statistic; ns, *, ** = not significant, and significant at 5% and 1% probability levels, respectively; CV (%) = coefficient of variation.

Table 4: Summary of the analysis of variance for the sensory characteristics of 50 genotypes of *C. canephora*, most commonly cultivated in Western Amazon, Brazil, evaluated in three agricultural years, 2021, 2022, and 2023, at the Embrapa experimental field located in the municipality of Porto Velho - RO.

S.V.	D.F.	FCS	Descriptors
Genotypes (G)	49	9.01**	4.97**
Years (Y)	2	1.46 ^{NS}	0.07 ^{NS}
GxY	98	2.86**	1.87**
Residual	300		
Total	449		
Overall Mean		79.93	164.89
1st Year Mean		79.70b	165.72a
2nd Year Mean		80.19a	165.69a
3rd Year Mean		79.91b	163.26a
CVe		1.84	27.48
r		88.91	79.91
CVg		2.94	24.98
CVg/Cve		1.60	0.91

**Significant at 1% probability. *Significant at 5% probability. NS: not significant. S.V.: Source of Variation. D.F.: Degrees of Freedom. FCS: Final Cup Score. Descriptors: Weighted average based on the frequency of descriptors mentioned in each evaluation. CVe: Coefficient of Experimental Variation. CVg: Coefficient of Genetic Variation. r: Repeatability.

In identifying phenotypic clustering patterns, the projection of variables shows that, with the exception of genotypes GJ5, BAG38, and LB10, those located in the right quadrant had mean values above 80 points (Figure 2).

This indicates that the best sensory performances were associated with coffees whose descriptors were related to flavors and aromas such as Fruity, Floral, Sweet, and Chocolate. In contrast, descriptors such as Spices, Vegetal, Cereal, and Woody tended to be associated with lower cupping scores. The genotypes evaluated in this study yielded a total of 1,230 descriptors assessed by Q-graders, of which 250 distinct flavors were grouped according to their similarity (Figure 3).

These descriptors were mainly associated with naturally occurring flavors, consistent with previous reports (Mori et al., 2018; Pereira et al., 2017). The descriptor “Sweet” had the greatest weight in the word cloud (A), followed by “Chocolate” and “Fruity.” Considering the main axes of the “Coffee Flavor Wheel,” 25% of the descriptors cited for the beverage were grouped as “Sweet,” followed by “Nut/Cocoa” and “Fruity” (B), with a predominance of attributes that tend to enhance the commercial value of coffee. Among the genotypes, AS2 exhibited 30 descriptors, followed by P50 (26) and LB68 (21), with mean overall quality scores of 84.21, 77.11, and 76.00, respectively.

Clone AS2 received the highest overall cupping score and, based on PCA, was classified as a sweet beverage (Figure

3). Sweetness is one of the most desirable flavor attributes in specialty coffees (Borém et al., 2006). By contrast, P50 and LB68 displayed flavors considered unpleasant by evaluators, most notably dry, harsh, cereal, vegetal, and herbal.

Among the cultivars developed by Embrapa, BRS2314 achieved a total score of 83.50, BRS1216 scored 82.50, and BRS2357 74.77. The descriptors Chocolate and Fruity contributed to the higher scores of these cultivars. The quality descriptors of the most contrasting genotypes were displayed as word clouds. BRS2314 was mainly associated with Nut/Cocoa descriptors, whereas BRS1216 was characterized by Good Finish, Woody, and Dry notes.

4 DISCUSSION

Coffee sensory evaluation is a process that quantitatively and qualitatively assesses flavor perceptions. These evaluations are performed by Q-Graders, certified professional cuppers trained to identify the organoleptic characteristics of the beverage, assign scores, and record both positive attributes and defects. Nevertheless, even trained and calibrated evaluators may be influenced by personal preferences, subjective perceptions, temporary sensory fatigue, prior knowledge of the sample, insufficient interaction with other panel members, and other factors (Artencio et al., 2023; Pereira et al., 2017), all of which can directly affect the overall cupping score and its associated descriptors.

Studies on the optimal number of Q-Graders indicate that panels of three to six evaluators provide good experimental precision. In our study, precision—represented by the mean standard deviation per measurement—ranged from 0.81 to 1.53 for the overall cupping score and from 29.89 to 38.30 for the descriptors. The 2022 crop year showed the lowest mean standard deviation, reflecting greater consistency among Q-Graders in assigning the overall cupping score.

In a study conducted in Yangambi, Democratic Republic of Congo, the standard deviation of final cupping scores ranged from 0.20 to 2.07 points, with an average of 0.92 (Bollen et al., 2025). These results suggest that the number of evaluators in our study was adequate. In contrast, the sensory descriptors exhibited greater variability, reflecting the subjectivity involved in how each evaluator assigns flavor nuances.

The study identified variability in the sensory profile of *C. canephora* clones cultivated in the Western Amazon. Such variability is a characteristic feature of coffees from Rondônia, where similar results have been reported by other authors (Viencz et al., 2024; Rocha et al., 2021). As shown in Figure 1, correlation analysis of total cupping scores across crop years, with values above $r=0.50$, indicated a simple $G \times Y$ interaction. This demonstrates the importance of genotype in assessing performance across harvests and stability over time, with some clones maintaining consistent scores. In contrast,

the G×Y interaction for sensory descriptors exhibited greater variability and lower repeatability indices, reflecting differences in individual evaluator perceptions (Fioresi et al., 2023).

This indicates that genotypes tend to maintain their performance over time. In a study with 22 *C. canephora* genotypes of the Robusta variety in the Democratic Republic of Congo during the 2020–2021 and 2021–2022 harvests, a correlation value of 0.60 was observed for the total cupping score in repeated measures analysis (Bollen et al., 2024),

consistent with the present results. These observations suggest that genotypes classified as “fine” beverages consistently stand out across harvests, while also reflecting the greater complexity of the G×Y interaction when quality attributes are considered.

Regarding the estimates of genetic and environmental parameters (Table 4), the values were comparable to those reported in the literature, with C_{Ve} ranging from 1.45% to 4.14%, CV_g from 1.03% to 2.15%, and CV_g/C_{Ve} ratios

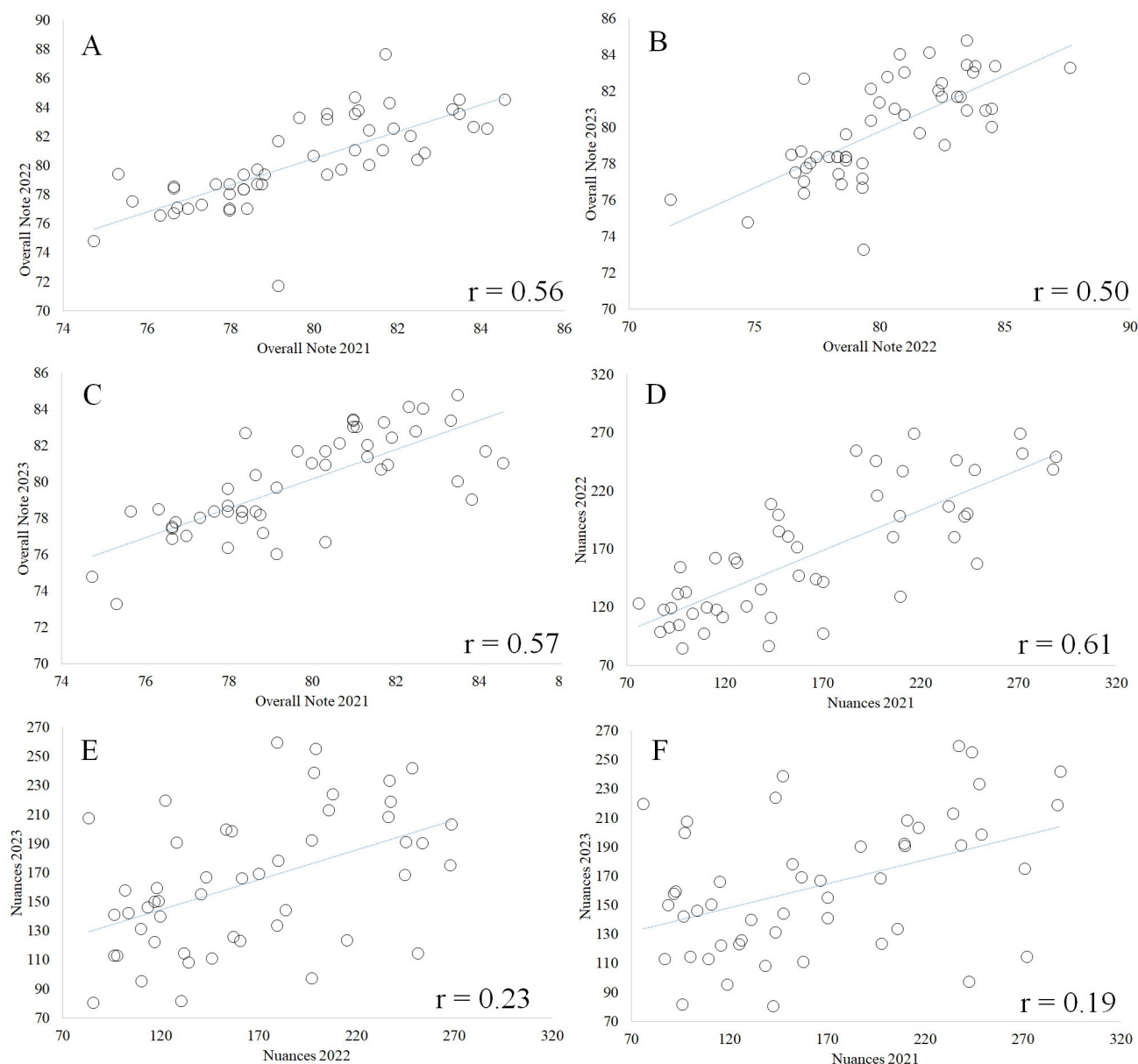


Figure 1: Correlation analyses of the sensory characteristics of 50 genotypes of *C. canephora* cultivated in the Western Amazon, Brazil. Genotypes were evaluated over three consecutive harvests (2021, 2022, and 2023) at the Embrapa experimental station in Porto Velho, RO. A–C: Pairwise correlations for overall beverage quality scores between agricultural years: A) 2021 vs. 2022 ($r = 0.56$), B) 2022 vs. 2023 ($r = 0.50$), and C) 2021 vs. 2023 ($r = 0.57$). D–F: Pairwise correlations for the frequency of quality descriptors (nuances) between agricultural years: D) 2021 vs. 2022 ($r = 0.61$), E) 2022 vs. 2023 ($r = 0.23$), and F) 2021 vs. 2023 ($r = 0.19$). Axes represent the scores obtained in each year, as indicated.

Table 5: Mean value $\pm$ standard deviation of the sensory attributes of total tasting score and descriptors referring to the sensory characteristics of 50 *C. canephora* genotypes most cultivated in the Western Amazon, Brazil, evaluated in three harvests, agricultural years 2021, 2022, and 2023, at the Embrapa experimental field located in the municipality of Porto Velho - RO.

Genotypes	Final cupping score	Descriptors	Genotypes	Final cupping score	Descriptors
AS2	84.21 $\pm$ 3.05a	108.39 $\pm$ 17.38d	GB7	79.56 $\pm$ 0.83c	248.16 $\pm$ 34.15a
LB30	83.92 $\pm$ 0.72a	129.90 $\pm$ 89.14d	AR106	79.37 $\pm$ 2.94c	212.70 $\pm$ 85.37a
BRS2314	83.50 $\pm$ 0.28a	130.44 $\pm$ 24.53d	GJ5	78.78 $\pm$ 1.89c	150.22 $\pm$ 46.22c
SK80	83.37 $\pm$ 2.04a	102.91 $\pm$ 25.67d	BAG38	78.76 $\pm$ 0.79c	147.82 $\pm$ 42.70c
LB33	82.99 $\pm$ 1.83a	117.34 $\pm$ 10.81d	AS10	78.56 $\pm$ 0.69c	173.16 $\pm$ 59.17b
LB101	82.81 $\pm$ 1.11a	118.78 $\pm$ 46.66d	LB10	78.56 $\pm$ 0.19c	158.98 $\pm$ 29.79c
AS7	82.78 $\pm$ 1.27a	115.73 $\pm$ 20.48d	GJ8	78.53 $\pm$ 0.32c	170.27 $\pm$ 26.28c
BAG24	82.67 $\pm$ 2.36a	114.33 $\pm$ 26.71d	R22	78.46 $\pm$ 1.13c	225.59 $\pm$ 63.12a
LB88	82.64 $\pm$ 1.41a	99.48 $\pm$ 12.85d	BRS2336	78.33 $\pm$ 0c	192.00 $\pm$ 65.38b
LB15	82.62 $\pm$ 1.37a	127.13 $\pm$ 19.72d	BRS3213	78.33 $\pm$ 0c	229.56 $\pm$ 30.69a
BRS1216	82.50 $\pm$ 1.58a	136.62 $\pm$ 15.72c	GB4	78.22 $\pm$ 0.50c	218.62 $\pm$ 22.62a
R152	82.36 $\pm$ 1.72a	123.58 $\pm$ 17.64d	VP156	78.11 $\pm$ 0.19c	259.99 $\pm$ 21.10a
WP6	82.29 $\pm$ 0.31a	136.14 $\pm$ 46.60c	P42	77.86 $\pm$ 0.90c	225.19 $\pm$ 35.02a
AS12	81.91 $\pm$ 0.52b	158.70 $\pm$ 14.19c	N16	77.53 $\pm$ 0.41d	179.08 $\pm$ 76.40b
BG180	81.87 $\pm$ 1.32b	128.50 $\pm$ 9.86d	CA1	77.50 $\pm$ 0.85d	201.33 $\pm$ 59.69b
L1	81.82 $\pm$ 2.51b	139.50 $\pm$ 72.44c	GJ20	77.34 $\pm$ 1.01d	199.74 $\pm$ 24.91b
GJ30	81.71 $\pm$ 1.39b	136.40 $\pm$ 15.00c	BAG27	77.21 $\pm$ 0.50d	176.26 $\pm$ 46.33b
BAG21	81.67 $\pm$ 1.15b	106.39 $\pm$ 12.48d	N8(G8)	77.16 $\pm$ 1.36d	217.90 $\pm$ 16.75a
SK41	81.59 $\pm$ 1.68b	155.40 $\pm$ 21.65c	P50	77.11 $\pm$ 0.83d	238.07 $\pm$ 58.72a
GJ3	81.53 $\pm$ 1.79b	121.33 $\pm$ 19.62d	N13	77.10 $\pm$ 1.18d	239.31 $\pm$ 15.62a
GB1	81.11 $\pm$ 0.50b	118.49 $\pm$ 7.57d	BAG22	77.00 $\pm$ 0d	210.47 $\pm$ 29.18a
GJ25	80.89 $\pm$ 0.76b	126.95 $\pm$ 26.67d	BRS2299	76.94 $\pm$ 0.48d	203.63 $\pm$ 9.30b
SK244	80.81 $\pm$ 1.21b	103.11 $\pm$ 10.01d	LB68	76.00 $\pm$ 3.11e	232.83 $\pm$ 31.75a
LB80	80.54 $\pm$ 0.50b	138.58 $\pm$ 20.85c	AS1	75.61 $\pm$ 3.76e	194.94 $\pm$ 51.80b
AS5	80.16 $\pm$ 1.29b	178.95 $\pm$ 47.48b	BRS2357	74.77 $\pm$ 0e	165.63 $\pm$ 8.66c

Descriptors: weighted average based on the frequency of citation in each test. Means followed by the same letters in the vertical do not differ according to the Scott-Knott test at a 5% probability level.

between 0.37 and 1.08 (Reinicke et al., 2023; Morais et al., 2021; Dalazen et al., 2020). The repeatability of 88.91% for the final cupping score is considered high, emphasizing the importance of the genotype effect on quality expression (Resende, 2002). In practice, coffee growers often select genotypes they consider most suitable for producing differentiated beverages. The results of this study reinforce that, just as processing methods influence the sensory attributes of coffee, genotype selection also plays a decisive role in shaping these characteristics.

In terms of the total cupping score, across the three harvests, our study observed values ranging from 74.77 to 84.21 (Table 5). Other authors, studying five hybrid *C. canephora* genotypes in a single harvest, reported an overall mean of 78.2 points, with a range from 76.7 (clone GJ8) to 79.7 (clone GJ3) (Dalazen et al., 2020). Working with fourteen genotypes in the

Western Amazon, they observed a mean of 80.28 points, with a maximum score of 84.67 (AS7) and a minimum of 75 (N13) in a single harvest (Reinicke et al., 2023). In our study, the maximum score was 84.21 (AS2) and the minimum was 74.76 (BRS2357).

The Scott-Knott clustering test indicated, at a 5% probability level, that the genotypes were grouped into five clusters, with groups 1 and 2 having scores above 80 points, representing 50% of the materials classified as fine beverage. According to recent studies, for the Conilon botanical variety, overall beverage quality scores ranged from 73 to 82 points (Machado et al., 2021; Lemos et al., 2020; Pereira et al., 2018). Regarding the Robusta variety, the literature reports scores above 75, with genotypes reaching a maximum score of 84.75 points (Bollen et al., 2024).

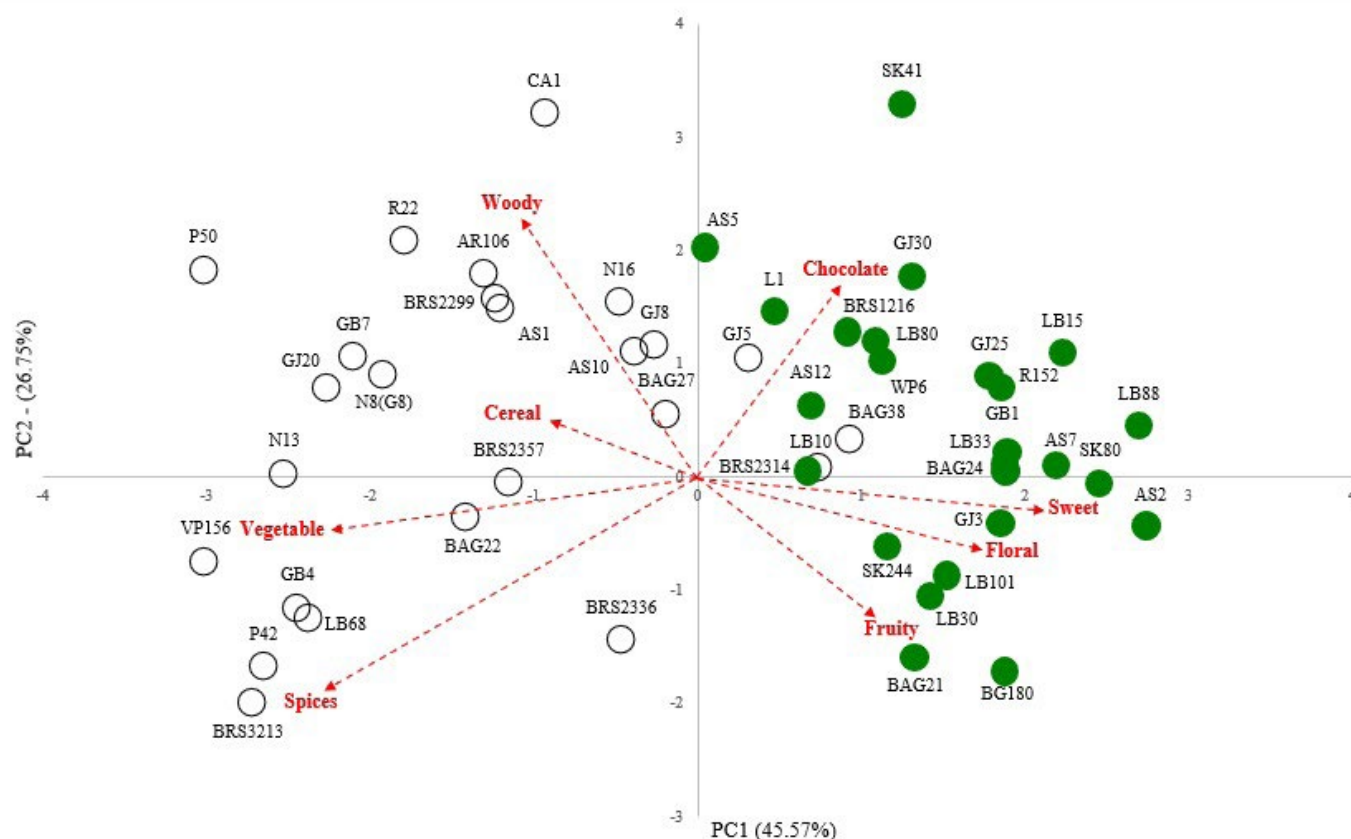


Figure 2: Graphical dispersion biplot of the sensory characteristics of 50 *C. canephora* genotypes most cultivated in the Western Amazon, Brazil, evaluated in three harvests: agricultural years 2021, 2022, and 2023, at the experimental field of Embrapa located in the municipality of Porto Velho - RO, with reference axes for PC1 and PC2 (Principal Component Analysis). The red vectors represent the projection of the sensory descriptors. Genotypes marked in green indicate an average overall score between 80.16 and 84.21 points. Genotypes without color indicate an average overall score between 74.77 and 79.56 points.

The final cupping score was positively associated with Fruity, Floral, Sweet, and Nut/Cocoa notes, indicating that these descriptors contribute to higher overall beverage quality (Figure 2). Although this overall trend was observed, some clones deviated from this pattern. For example, clones GJ5, BAG38, and LB10, while exhibiting Fruity, Sweet, and Nut/Cocoa descriptors, also showed flavors deemed unpleasant by the Q-Graders, which kept their total cupping scores below 80 points. Similar observations have been reported for the BRS3193 cultivar, in which the presence of descriptors associated with beverage quality, such as Chocolate, Caramel, and Almond notes, did not result in higher scores (Morais et al., 2021).

Regarding the sensory descriptors, these are essential for a comprehensive sensory evaluation, representing the distinctive flavor characteristics of a given genotype as cited by Q-Graders during the beverage assessment. These descriptors are grouped according to the main axes of the “Coffee Flavor Wheel” and were quantitatively represented in this study. Thus, the “Coffee Flavor Wheel” moves beyond being merely a common tool for describing different flavors to become a complementary instrument for systematic quantitative cupping.

The higher variability of the descriptors may be associated with specific aspects of coffee quality, including the synthesis of volatile compounds and aromatic precursors, which are known to be influenced by annual climatic variations and post-harvest conditions (Perez et al., 2023; Bertrand et al., 2012).

Lower values of this descriptor index are associated with more highly appreciated sensory nuances (Figure 2). Among the evaluated genotypes, clone LB88 showed the lowest weighted mean based on Q-Graders’ citations, whereas VP156 presented the highest value (Table 5). For clone LB88, among the 32 quality descriptors cited by the evaluators, 10 were grouped at the 40° axis (Fruity), 12 at 112.5° (Sweet), 8 at 142.5° (Nut/Cocoa), 1 at 65° (Spices), and 1 at 200° (Roasted). In contrast, for clone VP156, of the 26 descriptors identified, approximately 77% were grouped at angles above 175° (Roasted, Other, Green/Vegetal, and Sour/Fermented). Previous studies have shown that coffees described as Nutty, Sweet, Fruity, Chocolate, and Floral tend to achieve higher beverage quality (Dalazen et al., 2020), whereas descriptors such as Cereal and Herbal are more often associated with beverages of acceptable commercial quality but with scores below 80 points.

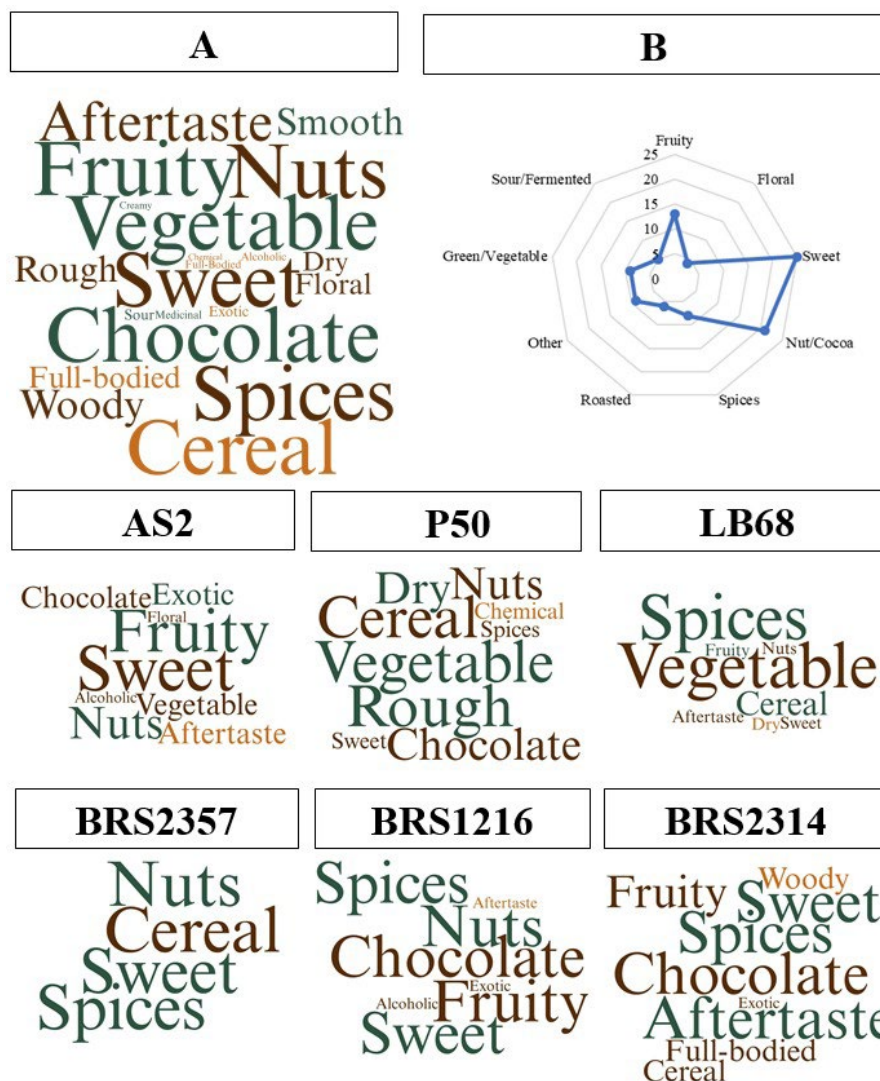


Figure 3: Word cloud containing sensory descriptors of *C. canephora* genotypes most cultivated in Western Amazon, Brazil, evaluated across three harvests, agricultural years 2021, 2022, and 2023, at the Embrapa experimental field located in Porto Velho, RO. A: Word cloud with descriptors of the 50 *C. canephora* genotypes. B: % of citations by Q-Graders for the main axes of the “Coffee Flavor Wheel.

In addition to genotype the post-harvest processing strongly influences beverage quality attributes. In a study with the GJ25 clone, widely cultivated in the Western Amazon, the type of fermentation (natural, semi-carbonic maceration, or induced) did not significantly affected the overall cupping score, indicating that both fermented and natural coffees can yield “fine” beverages (Alves et al., 2020). This finding is consistent with our results, where descriptors commonly associated with fermented coffees—such as Fruity, Sweet, Caramel, and Chocolate—were also reported in natural beans. By contrast, in the Democratic Republic of Congo, processing methods significantly influenced sensory scores (Bollen et al., 2025), with fermentation producing smooth, fruity coffees with cocoa notes.

The sensory differences observed among clones can be largely explained by their distinct genetic backgrounds and adaptation to local edaphoclimatic conditions. Clones derived from Conilon ancestry tend to produce more neutral beverages, which may display high sweetness and balanced acidity, whereas those with Robusta lineage generally exhibit greater body and more pronounced Fruity, Floral, and Cocoa notes. The superior performance of clone AS2, for instance, may be linked to its late-maturing cycle, which allows a longer and more uniform fruit development period, favoring the accumulation of organic acids, sugars, and volatile precursors that enhance sweetness and aromatic complexity. The warm and humid climate of the Western Amazon also promotes intense metabolic activity during bean development, favoring the synthesis of sugars and aromatic compounds.

In a sensory acceptance test of Robusta coffee beverages from the Amazon, conducted with untrained consumers using the Check-All-That-Apply (CATA) method, two Embrapa cultivars were evaluated under two different post-harvest processing methods (natural and fermented). The results showed high overall acceptance for both types of coffee, with a clear preference for naturally processed coffees, which received significantly higher acceptance scores compared to the fermented ones. Consumers associated the natural coffees with a more pleasant taste, whereas the fermented samples were associated with slightly bitter and distinctly fermented flavor notes (Vienetz et al., 2024).

In a study with 70 Robusta genotypes cultivated in the Congo, it was observed that an ideal *C. canephora* genotype tends to exhibit a sensory profile with descriptors such as Fruity, Sweet, and Alcohol/Fermented (Bollen et al., 2024). Promising Robusta genotypes from Sumatra were described as having Fonce and Floral flavors (Wicaksono et al., 2022). Regarding clonal Conilon varieties in Brazil, the most relevant terms were bitterness, strong flavor, full-bodied, astringent, and lingering taste (Mori et al., 2018). A combination of sensory and metabolomic analyses characterized Arabica and Robusta coffee samples by descriptors, revealing a predominance of Fruity notes and a more intense olfactory perception in Arabica coffee, whereas Robusta beverages exhibited more Caramelized notes and a fuller body (Vezzulli et al., 2022). Thus, it is observed that the intervarietal hybrids evaluated in this study tend to produce beverages with high potential, “fine” coffees with remarkable sweetness, smoothness, and distinctive notes.

Specialty coffee buyers seek beans that exhibit distinctive characteristics and unique flavors (Smith, 2018), rather than simply the absence of physical defects in the beans (Conley & Wilson, 2020). In this context, based on the ideal reference points for maximum performance of each descriptor within the PCA (Figure 2), it was observed that clone LB30 tends to be described as Fruity, GJ3 as Floral, AS2 as Sweet, and BRS1216 as Chocolate, all descriptors that can ensure a high market value.

Studying the sensory characteristics of *C. canephora* genotypes of the Conilon variety in Venda Nova do Imigrante, ES, a grouping was observed among genotypes exhibiting Citrus, Floral, and Fruity traits on PC1, while on PC2, descriptors related to Cereal, Chocolate, Body, and Roasted. The genotypes with the highest total cupping scores in that study mainly exhibited descriptors such as Citrus, Fruity, Alcoholic, Floral, Cereal, and Caramel. In contrast, coffees with lower scores were associated with descriptors such as Woody and Roasted (Filete et al., 2022). Unlike our study, where the PCA grouped genotypes with higher quality scores near descriptors that soften the beverage’s flavor.

Among the cultivars developed by Embrapa and used as reference cultivars, BRS2314 achieved a total score of 83.50, BRS1216 scored 82.50, and BRS2357 scored 74.77 (Table 5). The descriptors Chocolate and Fruity contributed to the higher scores of the superior cultivars, whereas Nut and Cereal were considered less appreciated by the evaluators (Figure 3). Quality descriptors for these cultivars have also been reported in the literature. In the word cloud, BRS2314 was mainly associated with Nut/Cocoa, while BRS1216 was characterized by Good Finish, Woody, and Dry notes. The Cereal flavors of BRS2357 are likewise documented in the literature (Lopes Junior et al., 2023).

Across all genetic materials evaluated in this study, clone LB88 received the highest number of descriptor citations from Q-Graders, whereas clone GJ30 had the lowest. Both, however, achieved total cupping scores above 80 points. It is important to emphasize that the number of citations does not necessarily influence the overall quality score. In another study, 38 different descriptors were identified in *C. canephora* genotypes from the Western Amazon. Clone GJ8 showed the highest number of descriptors (24), followed by GJ3 (21), GJ66 (20), GJ25 (18), and GJ5 (18). These descriptors varied among clones and were not necessarily associated with higher beverage quality (Dalazen et al., 2020).

In coffee commercialization, in addition to sensory beverage attributes, bean size is one of the main attributes considered in determining the final price. Among the genotypes in this study, clones SK41, BRS1216, SK80, L1, AS5, and R152 stand out, as they not only have larger bean size (Junior et al., 2024) but also exhibit total cupping scores classifying them as “fine” beverages, with respective scores of 81.59, 83.37, 81.82, 80.16, and 82.36 points.

Even considering the complexity of the chemical compounds present in the beans and their interactions with high temperatures during the roasting process, the total cupping scores of clones GJ25, LB30, AS7, AS2, LB88, LB15, LB101, BRS2314, SK80, AS5, and GJ30 may be related to the concentration of total soluble sugars in their green beans, with concentrations above 8% (Lopes Junior et al., 2024). Sucrose has been a good discriminative marker for beverage quality in green *C. arabica* beans (Borém et al., 2016) and in roasted *C. canephora* beans (Ribeiro, Ferreira, & Salva, 2011), where coffees with higher scores exhibited higher sucrose content.

This study confirmed that intervarietal hybrids of *C. canephora* cultivated in the Western Amazon exhibit sensory characteristics comparable to those of Robusta coffee, with descriptors such as Nut/Cocoa and Fruity, combined with the smoothness and neutrality typical of Conilon. These hybrids tend to express superior sensory traits, both in total cupping scores and in individual descriptors. Moreover, they present quality attributes valued by cuppers and buyers of high-quality *C. arabica*, including Fruity, Floral, and Sweet notes (Traore et al., 2018).

Specialty coffee consumers expect to perceive notes of Chocolate, Caramel, Fruit, Nut, and Almond. Among the five basic tastes represented on the “Coffee Flavor Wheel,” Sweetness is the most anticipated flavor (Bressani et al., 2021), along with a pleasant aroma (Arruda et al., 2009), both strongly associated with positive emotional responses (Pinsuwan et al., 2022). For the coffee industry, the marketing of coffees with descriptors below the 142.5° angle on the “Coffee Flavor Wheel” is not necessarily consistent across all countries, varying according to local cultural preferences.

Thus, we conclude that coffees produced in the Western Amazon tend to display quality descriptors that directly influence the total cupping score, which is intrinsically linked to the presence of specific sensory attributes in the samples. Increasingly, consumers are recognizing the high quality of beverages derived from Robusta, Conilon, and *C. canephora* hybrids (Condelli et al., 2022). Coffees scoring above 80 points often exhibit characteristics comparable to high-quality Arabica, including Fruity, Sweet, and Floral notes, complemented by Chocolate undertones, making them exotic, complex, and distinctive.

Finally, the cultivars BRS2314 and BRS1216, the germplasm collection plants BAG21 and BAG24, and the publicly available clones AS2, LB30, SK80, LB33, LB101, LB88, R152, and BG180 stood out for their superior beverage quality. In contrast, the clones P50, N13, BAG22, BRS2299, LB68, AS1, and BRS2357 were characterized by descriptors less appreciated by the cuppers in the evaluated harvests.

5 CONCLUSIONS

Among the *Coffea canephora* genotypes, several clones exhibited consistent potential for producing high-quality beverages. In particular, the genotypes AS2, LB30, BRS2314, SK80, LB33, BAG24, LB88, LB15, BRS1216, and AS12. Although the genotype × year interaction was significant for the final cup score, its simple nature indicated stable sensory performance across harvests. Multivariate projections further associated beverage quality with the descriptors Sweet, Fruity, Chocolate, and Floral. These findings provide a solid foundation for genetic improvement programs aimed at developing new materials.

6 AUTHOR CONTRIBUTIONS

Conceptual Idea: Lopes Junior, H.; Rocha, R.B., Methodology design: Lopes Junior, H.; Rocha, R.B., Data collection: Espíndula, M.C.; Anastácio, E.A., Data analysis and interpretation: Lopes Junior, H.; Rocha, R.B.; Baqueta, M.R.; Silva, R.N.P.; Filho, J.A.M., and Writing and editing: Lopes Junior, H.; Rocha, R.B.

7 DATA AVAILABILITY STATEMENT

Data available upon request to authors

8 REFERENCES

- Agnoletti, B. Z. et al. (2019). Discriminação de café arábica e conilon utilizando propriedades físico-químicas aliadas à quimiometria. *Revista Virtual de Química*, 11(3):785-805.
- Alvares, C. A. et al. (2013). Köppen’s Climate Classification Map for Brazil. *Meteorologische Zeitschrift*, 22:711-728.
- Alves, E. A. et al. (2020). Efeito da fermentação sobre qualidade da bebida do café robusta (*Coffea canephora*) cultivado na Amazônia Ocidental. *Revista Ifes Ciência*, 6(3):159-170.
- Arruda, A. C. et al. (2009). Justificativas e motivações do consumo e não consumo de café. *Food Science and Technology*, 29:754-763.
- Artêncio, M. M. et al. (2023). The impact of coffee origin information on sensory and hedonic judgment of fine Amazonian robusta coffee. *Journal of Sensory Studies*, 38(3):e12827.
- Baqueta, M. R. et al. (2024). An Overview on the Brazilian *Coffea Canephora* Scenario and the Current Chemometrics-Based Spectroscopic Research. *Food Research International*, 194:114866.
- Barbosa, M. D. S. G. et al. (2019). Correlation between the composition of green Arabica coffee beans and the sensory quality of coffee brews. *Food Chemistry*, 292:275-280.
- Belgis, M. et al. (2023). Sensory profile on robusta coffee by Rate-All-That-Apply (RATA). *Pelita Perkebunan*, 39(1):32-42.
- Bernardes, P. C. et al. (2024). Impact of self-induced anaerobiosis fermentation (SIAF) on chemical and sensorial characteristics of *Coffea canephora*. *Food Bioscience*, 62:105281.
- Bertrand, B. et al. (2012). Climatic factors directly impact the volatile organic compound fingerprint in green Arabica coffee bean as well as coffee beverage quality. *Food Chemistry*, 135(4):2575-2583.
- Bollen, R. et al. (2025). The impact of coffee genotype and processing method on the sensory and metabolite profiles of Robusta coffee (*Coffea canephora*). *European Food Research and Technology*, 251:1171-1190.

- Bollen, R. et al. (2024). Sensory profiles of robusta coffee (*Coffea Canephora*) genetic resources from the Democratic Republic of the Congo. *Frontiers in Sustainable Food Systems*, 8:1382976.
- Borém, F. M. et al. (2016). The relationship between organic acids, sucrose and the quality of specialty coffees. *African Journal of Agricultural Research*, 11:709-717.
- Borém, F. M. et al. (2006). Qualidade do café submetido a diferentes temperaturas, fluxos de ar e períodos de pré-secagem. *Coffee Science*, 1(1):55-63.
- Bressani, A. P. P. et al. (2021). Into the minds of coffee consumers: Perception, preference, and impact of information in the sensory analysis of specialty coffee. *Food Science and Technology*, 41:667-675.
- Chambers, E. et al. (2016). Development of a “living” lexicon for descriptive sensory analysis of brewed coffee. *Journal of Sensory Studies*, 31(6):465-480.
- Companhia Nacional de Abastecimento - CONAB. (2025). Observatório agrícola—Acompanhamento safra brasileira de café 2025. Available in: <<https://www.gov.br/conab/pt-br/atuacao/informacoes-agropecuarias/safras/safra-de-cafe/3o-levantamento-de-cafe-safra-2025/3o-levantamento-de-cafe-safra-2025>>.
- Condelli, N. et al. (2022). Drivers of coffee liking: Effect of physicochemical characteristics and aromatic profile on consumers’ acceptability of mono-origin and mono-variety coffees. *Journal of Food Science*, 87(10):4688-4702.
- Conley, J., & Wilson, B. (2020). Coffee terroir: cupping description profiles and their impact upon prices in Central American Coffees. *GeoJournal*, 85:67-79.
- Cruz, C. D. (2013). GENES - Software para análise de dados em estatística experimental e em genética quantitativa. *Acta Scientiarum. Agronomy*, 35(3):271-276.
- Cruz, C. D., Carneiro, P. C. S., & Bhering, L. L. (2021). Biometry in plant breeding ARTICLE. *Crop Breeding and Applied Biotechnology*, 21:380621-380626.
- Dalazen, J. R. et al. (2020). Beverage quality of most cultivated coffea canephora clones in the western Amazon. *Coffee Science*, 15: e151711.
- Debona, D. G. et al. (2025). Comprehensive evaluation of volatile compounds and sensory profiles of coffee throughout the roasting process. *Food Chemistry*, 478:143586.
- Debona, D. G. et al. (2020). Avaliação da composição química de café arabica submetido a diferentes perfis de torra. *Revista Ifes Ciência*, 6(3):124-133.
- Filete, C. A. et al. (2022). The new standpoints for the terroir of *Coffea Canephora* from Southwestern Brazil: Edaphic and sensorial perspective. *Agronomy*, 12(8):1931.
- Fioresi, D. B. et al. (2023). Adherence and concordance among Q-Graders in the sensory analysis of coffees. *Journal of Sensory Studies*, 38(2):e12805.
- Junior, H. L. et al. (2024). Fruit and bean traits of the *Coffea canephora* Genotypes most grown in western Amazon. *Pesquisa Agropecuária Brasileira*, 59:e03457
- Hall, R. D., Trevisan, F., & de Vos, R. C. (2022). Coffee berry and green bean chemistry—Opportunities for improving cup quality and crop circularity. *Food Research International*, 151:110825.
- Lemos, M. F. et al. (2020). Chemical and sensory profile of new genotypes of Brazilian *Coffea Canephora*. *Food Chemistry*, 310:125850.
- Lopes Junior, H. et al. (2023). Robustas Amazônicos: qualidade do café de Rondônia. *Revista Científica da Faculdade de Educação e Meio Ambiente*, 14(2):466-481.
- Lopes Junior, H. et al. (2024). Genetic variability in the physicochemical characteristics of cultivated *Coffea Canephora* Genotypes. *Plants*, 13:2780.
- Lopes Junior, H. et al. (2025). Genotype X environment interaction affecting the physicochemical quality of coffea canephora Clones Cultivated in Western Amazonia. *Ensaio e Ciência: Ciências Biológicas, Agrárias e da Saúde*, 29(4):1004-1022.
- Machado, J. L. et al. (2021). Compostos voláteis e nota global dos atributos sensoriais na discriminação de variedade clonais de *Coffea Canephora* com genótipos de diferentes ciclos de maturação. *Revista Ifes Ciência*, 7(3):1-14.
- Malta, M. R. et al. (2020). Discrimination of genotypes coffee by chemical composition of the beans: potential markers in natural coffees. *Food Research International*, 134:109219.
- Morais, J. A. et al. (2021). Beverage quality of *Coffea Canephora* Genotypes in the Western Amazon, Brazil. *Acta Scientiarum. Agronomy*, 43:e52095.
- Mori, A. L. B. et al. (2018). Sensory profile of Conilon Coffee brews from the State of Espírito Santo, Brazil. *Pesquisa Agropecuária Brasileira*, 53(9):1061-1069.
- Nascimento, E. A. do. et al. (2007). Composição química do café conillon em diferentes graus de torração. *Ciência & Engenharia*, 16(1):17-21.

- Pereira, L. L. et al. (2017). The Consistency in the sensory analysis of coffees using Q-Graders. *European Food Research and Technology*, 243:1545-1554.
- Pereira, L. L. et al. (2018). Propositions on the optimal number of Q-Graders and R-Graders. *Journal of Food Quality*, 3285452, 7 pages.
- Pereira, P. V. et al. (2021). Effect of altitude and terrain aspect on the chemical composition of *Coffea Canephora* cherries and sensory characteristics of the beverage. *Journal of the Science of Food and Agriculture*, 101:2570-2575.
- Perez, J. et al. (2023). Variability of volatile compound profiles during two coffee fermentation times in northern Peru using SPME-GC/MS. *Brazilian Journal of Food Technology*, 26:e2022077.
- Pinsuwan, A. et al. (2022). Sensory drivers of consumer acceptance, purchase intent and emotions toward brewed black coffee. *Foods*, 11:180.
- Pinto, L. et al. (2024). A design of experiment strategy for quality control of specialty coffee drink based on sensory analysis and statistical tools. *Brazilian Journal of Food Technology*, 27:e2024002.
- R Core Team. (2013). *R: A language and environment for statistical computing*. Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.
- Reinicke, L. C. T. S. et al. (2023). Divergência genética dos atributos sensoriais de clones de *Coffea canephora* cultivados na Amazônia Ocidental. *Ensaio e Ciência: Ciências Biológicas, Agrárias e da Saúde*, 29(4):1004-1022.
- Resende, M. D. V. (2002). *Genética biométrica e estatística no melhoramento de plantas perenes*. Brasília, DF: Embrapa Informação Tecnológica; Colombo: Embrapa Florestas.
- Ribeiro, J. S., Ferreira, M. M. C., & Salva, T. J. G. (2011). Chemometric models for the quantitative descriptive sensory analysis of arabica coffee beverages using near infrared spectroscopy. *Talanta*, 83:1352-1358.
- Rocha, R. B. et al. (2025). Genomic-assisted selection to guide mate allocation and leverage hybrid vigor in *Coffea canephora*. *Tree Genetics & Genomes*, 21:1-12.
- Rocha, R. B. et al. (2021). *Coffea canephora* breeding: estimated and achieved gains from selection in the Western Amazon, Brazil. *Ciência Rural*, 51:1-11.
- Santos G. W. et al. (2023). Preliminary study of variation in quality of fermented *Coffea Canephora* genotypes using sensory assessment and mid-infrared spectroscopy. *European Food Research and Technology*, 249:2935-2946.
- Silva, A. C. A. et al. (2025). Genetic diversity and disease resistance genes profiling in cultivated *Coffea canephora* Genotypes via Molecular Markers. *Plants*, 14(17):2781.
- Smith, J. (2018). Coffee landscapes: specialty coffee, terroir, and Traceability in Costa Rica. *Culture, Agriculture, Food and Environment*, 40(1):36-44.
- Souza, C. A. et al. (2018). Characterization of beverage quality in *Coffea Canephora* Pierre Ex A. Froehner. *Coffee Science*, 13(2):210-218.
- Spencer, M. et al. (2016). Using single free sorting and multivariate exploratory methods to design a new Coffee Taster's Flavor Wheel. *Journal of Food Science*, 81:S2997-S3005.
- Traore, T. M. et al. (2018). What explains specialty coffee quality scores and prices: a case study from the cup of excellence program. *Journal of Agricultural and Applied Economics*, 50(3):349-368.
- Uganda Coffee Development Authority - UCDA. (2010). *Robusta cupping protocols 2010*. Available in: <https://www.ico.org/documents/pscb-123-e-robusta.pdf>
- Vezzulli, F. et al. (2022). Metabolomics combined with sensory analysis reveals the impact of different extraction methods on coffee beverages from coffea arabica and Coffea Canephora var. Robusta. *Foods*, 11(6):807.
- Vienz, T. et al. (2024). Sensory characterization and acceptance of amazonian robustas coffee brews by consumers using a home-use test. *Beverages*, 10(3):57.
- Wicaksono, I. N. A. et al. (2022). superior morphological characteristics of kobura promising robusta coffee clones from south sumatera province. *Proceedings of the IOP Conference Series: Earth and Environmental Science*, 974:012088.