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INFLUENCE OF FERMENTATION TIME ON THE SENSORY QUALITY OF ARABICA COFFEE GENOTYPES IN GUATEMALA

INFLUENCIA DEL TIEMPO DE FERMENTACIÓN EN LA CALIDAD SENSORIAL DE GENOTIPOS DE CAFÉ ARABICA EN GUATEMALA

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SUMMARY

In recent years, the Guatemalan coffee plantations have suffered a decline in its yield as a result of coffee rust. The use of cultivars resistant to this disease and with the potential to produce coffee with good drinking quality is essential for the sustainability of coffee cultivation in the country. The aim of this study was to analyze bean quality potential and the sensory profile of rust-resistant Arabica coffee genotypes as a function of different times of biological fermentation. The experiment was carried out in July 2014, at El Panorama farm, located in the municipality of San Rafael Pie de La Cuesta, Department of San Marcos, Guatemala. Eight rust resistant F_5 progenies were tested and cultivars Marsellesa and Bourbon Amarelo were used as controls. Each genotype was subjected to two times of biological fermentation in water, after peeling (24 and 72 h). The experimental design was randomized complete blocks with three replications, in a 10 (genotypes) × 2 (times) factorial scheme, totaling 60 experimental units. The quality, sensory profile and granulometry of the treatments were evaluated. All the rust-resistant genotypes studied showed potential to produce specialty coffees in Guatemala and a superior granulometry in relation to Bourbon Amarelo. Marsellesa and Bourbon Amarelo obtained higher final scores and the attributes flavor, aftertaste, acidity, body, balance and overall were more accentuated. The time of biological fermentation did not influence the final score of the coffee (total score in the SCA protocol); however, there was a change in the sensory profile, with emphasis on cultivar Marsellesa, which increased the frequency of fruity notes and reduced caramel notes with longer fermentation time.

Index words: *Coffea arabica* L., fermentation, sensory profile, specialty coffees.

RESUMEN

En los últimos años el cultivo de café guatemalteco ha sufrido declinación en su rendimiento como resultado de la roya del café. El uso de cultivares resistentes a esta enfermedad y con potencial para producir cafés con buena calidad de bebida es fundamental para la sustentabilidad del cultivo en el país. El objetivo de este estudio fue analizar el potencial de calidad del grano y el perfil sensorial de genotipos de café Arábica resistentes a la roya, en función de diferentes tiempos de fermentación biológica. El experimento se implementó en julio de 2014, en la finca El Panorama, ubicada en el municipio de San Rafael Pie de La Cuesta, Departamento de San Marcos, Guatemala. Se probaron ocho progenies F_5 resistentes a la roya y se utilizaron como controles los cultivares Marsellesa y Bourbon Amarelo. Cada genotipo fue sometido a dos tiempos de fermentación biológica en agua, después del pelado (24 y 72 h). El diseño experimental fue bloques completos al azar con tres repeticiones en un esquema factorial 10 (genotipos) × 2 (tiempos), totalizando 60 unidades experimentales. Se evaluó la calidad, perfil sensorial y granulometría de los tratamientos. Todos los genotipos estudiados resistentes a la roya mostraron potencial para la producción de cafés especiales en Guatemala y una granulometría superior en relación al Bourbon Amarelo. Marsellesa y Bourbon Amarelo obtuvieron puntajes finales más altos y los atributos de sabor, regusto, acidez, cuerpo, equilibrio y en general, fueron más acentuados. El tiempo de fermentación biológica no influyó en la puntuación final del café (pontuación total en el protocolo SCA); sin embargo, hubo un cambio en el perfil sensorial, con énfasis en el cultivar Marsellesa, que aumentó la frecuencia de notas frutales y redujo las notas de caramelo con mayor tiempo de fermentación.

Palabras clave: *Coffea arabica* L., cafés especiales, fermentación, perfil sensorial.

INTRODUCTION

Coffee is one of the main agricultural commodities in the world, whose estimated production in the 2019/2020 harvest was 169.34 million bags. Among the various producing countries, Guatemala stands out as the second largest producer of coffee in Central America (ICO, 2020), with an estimated production of 3.67 million bags in the 2019/2020 harvest (USDA, 2020). Coffee is the second most important agricultural export product in Guatemala and is responsible for employing around 500 thousand people, corresponding to 10 % of the jobs in the country (Bunn *et al*., 2019).

In recent years, the demand for specialty coffees and peculiar sensory profiles has increased considerably, compared to the commercial coffee consumption (Barbosa *et al*., 2019); however, sensory quality is influenced by several factors, emphasizing three most relevant aspects: environment of cultivation (Ribeiro *et al*., 2016), promising

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genetic material (Barbosa *et al*., 2020; Malta *et al*., 2020) and post-harvest processes (Fassio *et al*., 2019; Mota *et al*., 2020).

In Guatemala, cultivated species are made up of several cultivars, both traditional and modern, derived from genetic improvement. According to ANACAFE (2019), Bourbon is among the most widely planted cultivars in the country, due to the high potential for beverage quality; however, this cultivar is susceptible to coffee rust, which is one of the main diseases of the crop.

In 2012, the country faced a major coffee rust epidemic, caused by the fungus *Hemileia vastatrix* Berk et Br., which caused significant yield losses (Cressey, 2013). Since then, there has been a continuous effort on the part of producers and the government to renew crops with the use of cultivars resistant to this disease (Avelino *et al*., 2015).

Among the rust-resistant cultivars adopted, Marsellesa stands out, originating from the cross between Híbrido de Timor CIFC 832/2 and Villa Sarchi, for having good productive potential and beverage quality (World Coffee Research, 2020). Thus, the search for new rust-resistant genotypes with good beverage quality becomes essential to guarantee the sustainability of coffee cultivation in the country, since the variability of resistant genotypes reduces the risks of a new epidemic (Avelino *et al*., 2015). Among these alternatives, there are genotypes with diverse resistance origins, such as the groups Catimor (Caturra × Híbrido Timor) (Rivillas *et al*., 2011), Icatu (interspecific hybrid: *Coffea arabica* L. × *Coffea canephora* Pierre and Frohner) and Catucaí (Catuaí × Icatu) (Sakiyama *et al*., 2015).

In addition to identifying promising genotypes for the obtention of high-quality coffees, knowledge of their performance in different post-harvest processes is crucial. Post-harvest coffee processing involves dry and wet processes; the latter is the most used in Guatemala (Farah, 2019). Wet processing makes it possible to originate peeled, demucilated and pulped (whih is the object of this study) coffees, consisting of the mechanical removal of the husk and subsequent removal of the mucilage by biological fermentation in water (Pereira *et al*., 2019).

This fermentation process for removing mucilage has a direct influence on quality, and the microbial activity in this process produces enzymes that degrade acids, sugars, lipids and proteins and convert them into substances that can directly alter odor, color and acidity, influencing the sensory profile of coffee (Rodrigues *et al*., 2020). The success of fermentation is linked to time, temperature, microorganisms present in coffee, water quality, among other factors (Puerta, 2012). Fermentation time is one of the main variables to be considered, since there is a threshold between the type of fermentation, which can be beneficial or harmful in the construction of the beverage sensory profile (Rodrigues *et al*., 2020). Therefore, the study of these factors becomes essential for understanding the process and increasing the assertiveness of the practice.

Thus, the objective of this study was to analyze the bean quality potential and sensory profile of rust-resistant arabica coffee genotypes as a function of different biological fermentation times.

MATERIAL AND METHODS

The experiment was implemented in the field in July 2014, on El Panorama farm, located at the municipality of San Rafael Pie de La Cuesta, Department of San Marcos in Guatemala. The municipality is at 1060 m altitude, with average annual rainfall of 4000 mm. The spacing used was 2.00 m (between rows) x 1.50 m (between plants), giving a stand of 3,333 plants ha^{-1}. The crop treatments in the experiment were conducted in accordance with plant requirements, similar to the management adopted by the farm.

The implantation consisted of 29 arabica coffee genotypes, with 150 plants each, arranged in three randomized blocks, evaluated in 2016 and 2017, through growth, rust incidence and yield assessments. After these evaluations, eight genotypes (progenies in generation F_5) were selected, which reached an average yield above 54 bags ha^{-1}, good plant development and rust incidence < 7 %.

In 2018, bean quality and the sensory profile of the eight genotypes (Genotypes 1 to 8) were evaluated, which are described in Table 1, in addition to two commercial cultivars used as controls (Genotypes 9 and 10), for presenting high beverage quality potential in this region. Each genotype was subjected to two periods of biological fermentation in water, after peeling. The experimental design used was in randomized blocks (RBD), in a factorial scheme 10 (genotypes) × 2 (fermentation periods) with 3 replications, totaling 60 experimental units.

Harvest was carried out in November 2018, selecting 16 L of ripe fruit per replication of each genotype. Soon after harvest, the samples were sent to the post-harvest sector, being washed for separation and removal of low-density fruits and impurities.

These samples were divided into two subsamples, containing 8 L each, to be subjected to pulping in two different biological fermentation periods in water, after

Table 1. Relationship and characterization of ten coffee genotypes.

Genotype	Name	Origin
1	CIA-1-41-19cv.3	Icatu × Catimor
2	CIA-31-5-16cv.8	Icatu × Catimor
3	CIA-16-55-9cv.6	Icatu × Catimor
4	CIA-15-0cv.11	Icatu × Catimor
5	CIA-19-66-31cv.9	Icatu × Catimor
6	CIA-1-41-23cv.45	Icatu × Catuaí
7	CIA-1-41-23cv.5	Icatu × Catuaí
8	CIA-mezcla linea cv. 178	Icatu × Catuaí
9	Marsellesa	Híbrido de Timor × Villa Sarchi
10	Bourbon Amarelo	Bourbon Vermelho × Amarelo de Botucatu

peeling. Thus, a 10 L bucket was used for each sample, fully immersed, allowing aerobic fermentation.

Half of the samples were kept in these containers with water for a period of 72 hours, where the samples were washed, rubbing the beans, and the water was changed four times (after 24, 24, 12 and 12 hours, respectively). The other half of the samples were kept for only 24 hours in water, uninterruptedly.

After the fermentation periods concluded, the samples were washed and directed to drying in screens suspended from the floor, with 7 L m^{-2} and, revolving every 30 minutes until reaching 11 % of water content. After drying, the samples were stored for 30 days to standardize the water content in the beans, followed by processing.

First, bean size was evaluated using a sample of 300 g of processed raw beans, absent of impurities and pieces, and passed through a set of sieves (19/64 to 12/64 for flat beans and 13/64 to 08/64 for mocha beans). Weights of beans retained in sieves 17 up (19, 18 and 17/64) were added, followed by conversion to percentage.

The sensory analysis was carried out in the classification and tasting laboratory of the company Agrícola Exclusiva S.A., in Guatemala City, by three Q-Grader panelists (one Brazilian and two Guatemalans), using the protocol described by the Specialty Coffee Association – SCA (Lingle, 2011). The samples were standardized on a sieve 16 up, free of extrinsic and intrinsic defects, being roasted, until reaching the color pattern #55 to #65 for whole beans on the Agtron scale, in a roasting period between 8 and 12 minutes.

Five cups per sample were analyzed, evaluating the ten sensory attributes in the protocol, which are: fragrance/aroma, flavor, aftertaste, acidity, body, balance and overall, evaluated with scores in the range of 6 to 10 points each, besides the attributes uniformity, sweetness and clean cup, to which 2 points are assigned per cup absent of defects, uniform and with a minimum sweetness equivalent to the concentration of 0.5 % w/v of sucrose. The final score was obtained by adding the scores of the ten attributes mentioned. In addition, the judges noted the nuances that characterized the samples.

The data on the sensory attributes aroma, flavor, aftertaste, acidity, body, balance and overall, final score and sieve 17 up, were subjected to analysis of variance and the Scott-Knott test was applied for grouping the means when a significance was observed by the F test ($P \leq 0.05$). The data on the sensory attributes aroma, flavor, aftertaste, acidity, body, balance and overall were also submitted to multivariate principal component analysis. The GENES software was used for these analyses (Cruz, 2013). The sensory attributes uniformity, sweetness and clean cup were not evaluated statistically, since score 10 was attributed to these attributes in all samples.

In order to systematically analyze the terms mentioned by the panelists in relation to the evaluated sensory attributes, the content analysis method was used to elucidate the sensory profile of the genotype groups. Therefore, the genotypes were grouped according to their genetic origin: group 1 (Genotypes 1 to 5 - Icatu × Catimor), group 2 (Genotypes 6 to 8 - Icatu × Catuaí), group 3 (Genotype 9 - Híbrido de Timor x Villa Sarchi) and group 4 (Genotype 10 - Bourbon Vermelho × Amarelo de Botucatu). The aroma/flavor nuances identified by the Q-grader panelists were tabulated and associated with the following categories: chocolate, caramel, fruity, nutty and floral. Through these categories, the graphs of distribution of relative frequencies were plotted.

RESULTS AND DISCUSSION

The analysis of variance for the sensory attributes final score and sieve percentage 17 up is shown in Table 2. It is observed that there was no significant difference for fermentation times (T) or for interaction between genotypes and fermentation times (G × T); however, significance ($P \leq 0.05$) was observed between the means of the genotypes (G) for the attributes aroma, flavor, aftertaste, acidity, body, balance, overall, final score and sieve 17 up.

All genotypes had final scores above 80 points, indicating the potential for producing specialty coffees; this is the minimum threshold required by the SCA (Lingle, 2011). Several studies have also shown satisfactory results in the final scores of sensory analysis for rust-resistant genotypes (Barbosa *et al.,* 2020; Carvalho *et al*., 2016; Fassio *et al*., 2019; Malta *et al*., 2020; Sobreira et al., 2016). Beverage quality is associated with a combination of sensory attributes, which is why it is important to study them (Fassio *et al*., 2019).

For the attributes aroma, balance and final score, the genotypes that showed the worst performance were 1 and 3, the latter with the worst performance also for the attribute acidity (Table 3).

Aroma is identified as one of the main characteristics for the construction of the sensory profile of specialty coffees (Sunarharum *et al.,* 2014). This is because the olfactory association integrates a large part of the sensory perception of human taste (Spence, 2015). Acidity can influence coffee aroma, sweetness and bitterness; therefore, a good acidity is closely related to a good quality beverage (Sunarharum *et al*., 2014).

Cultivars Marsellesa and Bourbon Amarelo had the best scores for the attributes flavor, aftertaste, acidity, body, balance and overal, besides final score (Table 3). Ribeiro *et al*. (2019) observed similar results in a sensory study with different cultivars, where the sensory attributes and final scores were higher for Bourbon Amarelo and Obatã (Sarchimor), which has the same genetic origin as Marsellesa, showing a predisposition of these groups of genotypes for quality potential.

It is also observed that genotypes 1 and 3 obtained a higher percentage of sieves 17 up. Bourbon Amarelo had the lowest percentage (Table 3). The large bean size is essential for the yield of processed raw beans, as well as favoring a more uniform batch roasting, being highly desirable in the specialty coffee market. According to Ferreira *et al*. (2013), as the size of the beans increases, the batch becomes more uniform and gives a better physical appearance, arousing greater interest for use in espresso coffee machines in cafeterias, where the roasted beans are exposed to the consumer.

Although the analysis of variance did not indicate significant difference between the fermentation times, it can be observed in Figure 1 that, at 72 h of fermentation time, genotypes 9 and 10 showed a greater distance between the notes of their sensory attributes in relation to the others while, at 24 h, there is a greater approximation of the means. This can be explained by the influence of the time of occurrence of the biochemical processes of microorganisms that act in the degradation of coffee mucilage, which can modify the sensory profile of the coffee beverage (Rodrigues *et al*., 2020). In addition, it is evident that, at both fermentation times, in general, the attributes aroma and acidity were more accentuated, being in line with Tarzia *et al*. (2010), who associated these attributes to the wet coffee processing.

In addition to the study of the distribution of sensory attributes on the radar chart, principal component analysis (PCA) was used for both fermentation times. This analysis is pointed as a versatile alternative for this purpose, which allows extracting complex and relevant multivariate data (Chalfoun *et al*., 2013).

Regarding the 24 h fermentation time (Figure 2), the first two principal components added accounted for 97.48 % of the total data variation. In the graphical analysis of the spatial dispersion of the genotypes and the spatial

Table 2. Analysis of variance for sensory attributes (aroma, flavor, aftertaste, acidity, body, balance and overall), final score and percentage of sieve 17 up (% 17 up).

FV	DF	QM								
		Aroma	Flavor	Aftertaste	Acidity	Body	Balance	Overall	Final Score	%17up
Blocks	2	0.1053	0.0071	0.0078	0.0043	0.0022	0.0036	0.0108	0.0907	24.6167
G	9	0.1298**	0.1757**	0.1652**	0.1334**	0.0362**	0.1484**	0.1317**	5.7078**	487.4500**
T	1	0.0094	0.0116	0.0116	0.0418	0.0296	0.0000	0.0074	0.6000	4.8167
G × T	9	0.1555	0.0360	0.0237	0.0125	0.0155	0.0386	0.0141	0.7353	2.4463
Res	38	0.03807	0.0313	0.0237	0.0189	0.0194	0.0250	0.0212	0.8254	20.5465
Mean		7.6819	7.5278	7.2139	7.5514	7.5514	7.3194	7.3412	82.2222	68.4833
CV (%)		2.5398	2.3905	2.1742	1.8521	1.8106	2.1615	1.9852	1.1049	6.6189

*: P ≤ 0.05, **: P≤ 0.01, by the F test.

projection of the vectors, it was observed that genotypes 4 and 10 (Bourbon Amarelo) had a greater positive correlation with all the sensory attributes analyzed. Genotypes 1 and 3, on the other hand, showed a negative correlation with the sensory attributes analyzed, with emphasis on the negative correlation between genotype 1 and the attribute aroma. There were correlations between the genotypes: (4 and 10), (2 and 5), (6, 7 and 8). It can be observed in Figures 2 and 3 that the attribute aroma along the vertical axes tended to be more accentuated in the two pulping times, which can be explained by the fact that wet processing accentuates this attribute (Salem *et al*., 2020).

PCA for the 72 h fermentation time (Figure 3), showed that the first two components accounted for 91.78 % of the total data variation. The spatial dispersion and projection of the vectors showed that cultivars Marsellesa and Bourbon Amarelo showed a greater positive correlation with all the sensory attributes (genotypes 9 and 10, respectively). Genotypes 1, 3 and 8 showed a more accentuated negative correlation with the attribute aroma, and genotypes 2, 4, 5, 6 and 7 a more accentuated negative correlation with the attribute body. The graph shows the following groups of correlations between the genotypes: (2, 4, 5, 6 and 7), (1 and 8), (3) and (9 and 10). It can be observed in Figure 3 that the longer fermentation time provided an improvement in the sensory attributes for Bourbon Amarelo.

Regarding the relative frequency of nuances (Figure 4), the chocolate category was observed at both fermentation times and with variation between the groups of genotypes. Bourbon Amarelo had a low frequency of the term chocolate at 72 h, and this nuance was not observed at 24 h. Regarding the caramel category, it is observed that there was variability in the results according to the genetic material and as a function of fermentation time, with emphasis on groups 2 and 3 (Marsellesa), which considerably reduced the frequency of this nuance, the longer the fermentation time.

The longer fermentation time increased the frequency of the fruity category, with an increase of close to 10 % for group 3. Regardless of fermentation time, group 4 (Bourbon Amarelo) presented a higher relative frequency of fruity notes. The nutty category, was little influenced by pulping time, with minute differences in frequencies. For the floral category, except for Bourbon Amarelo, the other genotypes changed due to pulping time, with reduced frequencies (group 1 and Marsellesa) and increased frequencies in group 2 with longer fermentation time.

It is worth mentioning that the fermentation occurred only with the microorganisms naturally present in the samples, which are responsible for the modification of the sensory profile, which favors reaching specific market niches by peculiar sensory profiles of coffees.

CONCLUSIONS

All rust resistant genotypes studied showed potential to produce, specialty coffees in Guatemala and a bean size greater than that of Bourbon Amarelo. Marsellesa and Bourbon Amarelo had higher final scores and the attributes flavor, aftertaste, acidity, body, balance and overall were more accentuated. The biological fermentation time did not influence the final coffee score (total score in the SCA protocol); however, there was a change in the sensory profile, with emphasis on cultivar Marsellesa (Híbrido de Timor x Villa Sarchi) which increased the frequency of fruity notes and reduced caramel notes with greater fermentation time.

Table 3. Means of sensory attributes (aroma, flavor, aftertaste, acidity, body, balance, overall), final score and percentage of sieve 17 up (%17up).

Genotypes	Aroma	Flavor	Aftertaste	Acidity	Body	Balance	Overall	Total score	% 17 up
1	7.40 b	7.36 b	7.06 b	7.47 b	7.51 b	7.15 c	7.26 b	81.22 c	83.67 a
2	7.75 a	7.50 b	7.15 b	7.50 b	7.54 b	7.29 b	7.35 b	82.08 b	74.50 b
3	7.49 b	7.26 b	6.99 b	7.29 c	7.50 b	7.07 c	7.11 b	80.71 c	78.33 a
4	7.72 a	7.57 b	7.24 b	7.57 b	7.60 b	7.29 b	7.32 b	82.31 b	63.17 c
5	7.85 a	7.53 b	7.24 b	7.58 b	7.57 b	7.38 b	7.32 b	82.46 b	68.50 b
6	7.64 a	7.49 b	7.19 b	7.53 b	7.56 b	7.31 b	7.29 b	82.00 b	71.33 b
7	7.65 a	7.44 b	7.14 b	7.46 b	7.56 b	7.28 b	7.26 b	81.79 b	62.83 c
8	7.67 a	7.51 b	7.17 b	7.54 b	7.58 b	7.29 b	7.32 b	82.08 b	69.00 b
9	7.82 a	7.82 a	7.56 a	7.83 a	7.71 a	7.57 a	7.64 a	83.94 a	60.17 c
10	7.83 a	7.79 a	7.42 a	7.74 a	7.51 a	7.15 a	7.26 a	83.63 a	53.33 d

Means followed by the same letter in the column, do not differ statistically (Skott-Knott, P ≤ 0.05).

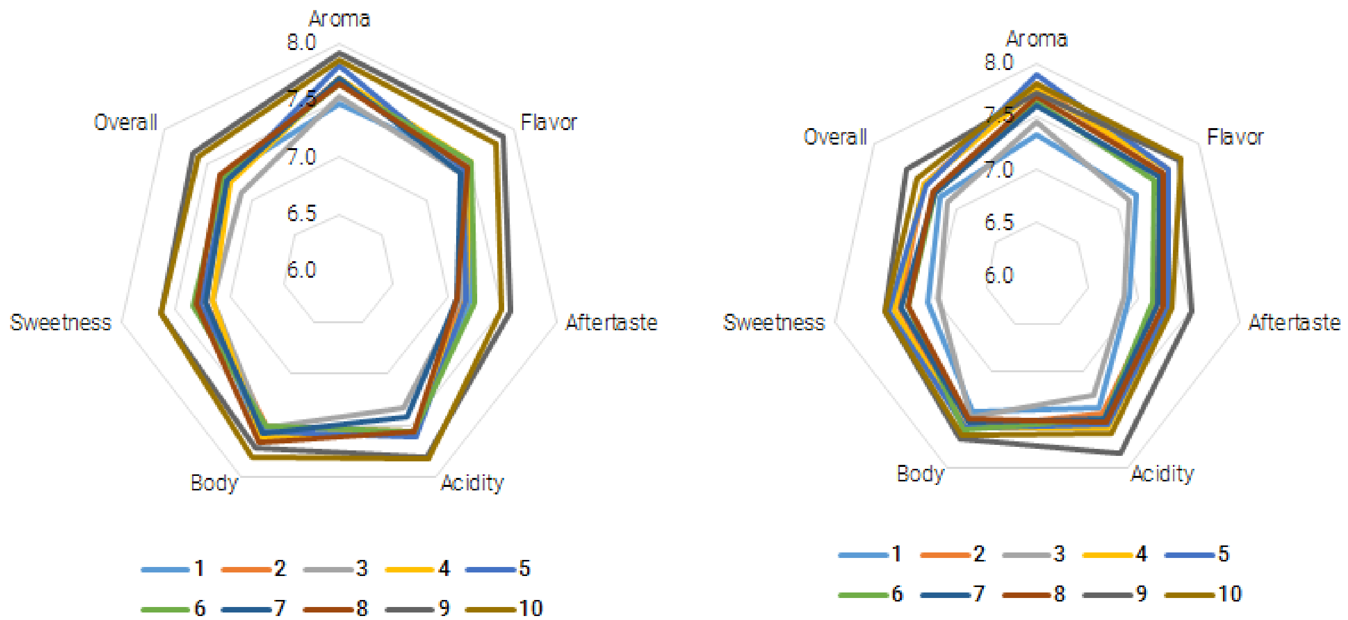

Figure 1. Radar chart for sensory attributes, at fermentation times 24 h (left) and 72 h (right).

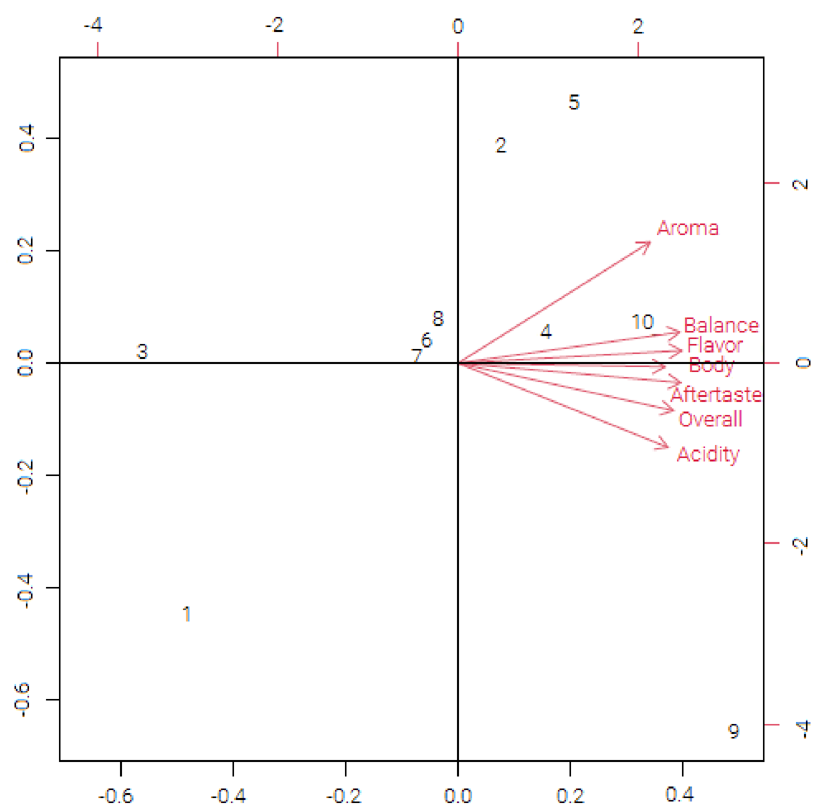

Figure 2. Dispersion of *Coffea arabica* L. genotypes and spatial projection of vectors of sensory attributes in relation to the first two principal components (PC1-horizontal; PC2-vertical) for 24-hour processing.

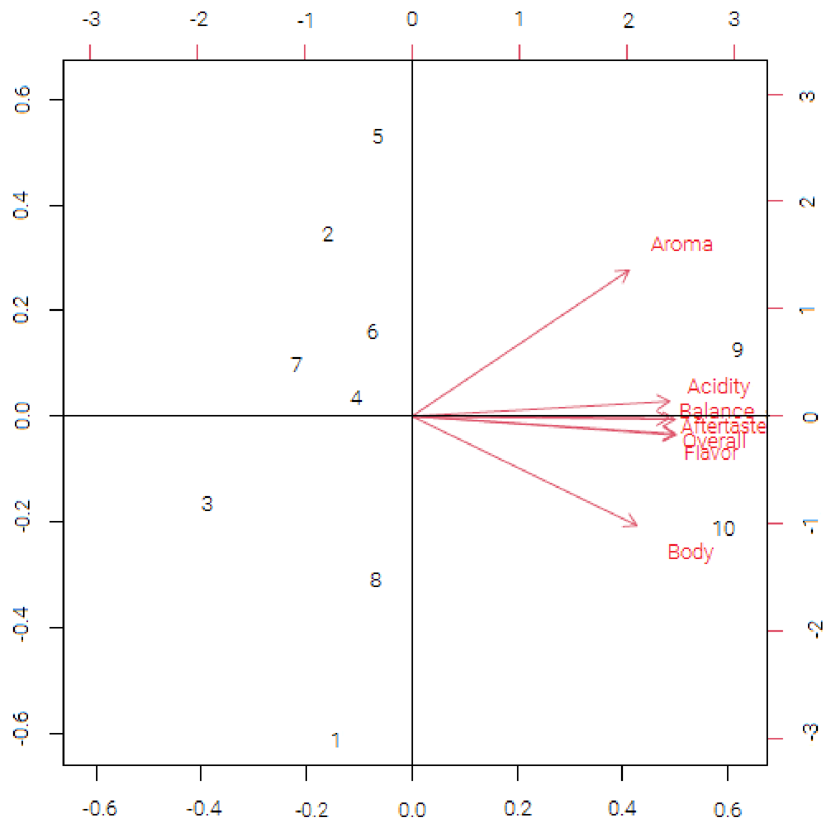

Figure 3. Dispersion of *Coffea arabica* L. genotypes and spatial projection of vectors of sensory attributes in relation to the first two principal components (PC1-horizontal; PC2-vertical) for 72-hour processing.

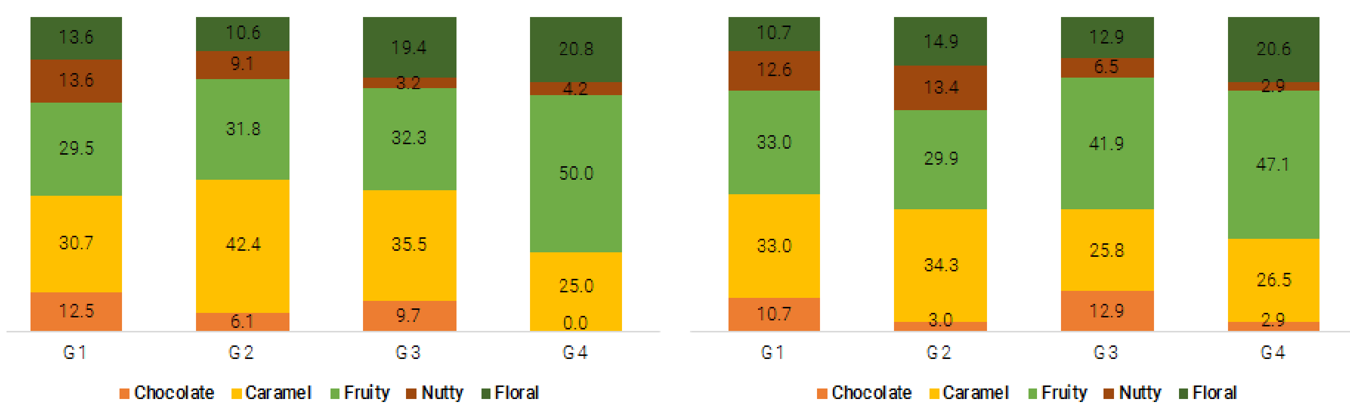

Figure 4. Relative frequency of aroma and flavor nuances for 24 h (left) and 72 h fermentation processes (right). G1: Icatu × Catimor, G2: Icatu × Catuaí, G3: Marsellesa, G4: Bourbon Amarelo.

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