Physicochemical and sensory quality of coffee from the state of Mérida (Venezuela)

Calidad fisicoquímica y sensorial de café del estado Mérida (Venezuela)

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Abstract

The state of Mérida is one of the main producers of coffee in Venezuela. However, the quality characteristics of cup coffee are not known. The quality of the coffee drink depends on factors ranging from the seed to the time of its preparation. That is why the quality of the coffee is evaluated through physicochemical parameters, under the criteria of the COVENIN standards in force in Venezuela. In addition to studying sensory parameters in accordance with the tasting protocol of the Specialty Coffee Association (SCA). For the tests, three coffees with different levels of roasting from the state of Mérida were selected. In the physicochemical parameters evaluated such as ash, crude fiber, caffeine, pH there are no statistically significant differences ($p \geq 0.05$), while parameters such as fat and sugar content show significant differences between the samples ($p \leq 0.05$), which may be associated with genetics and the height at which the coffee was planted. The organoleptic properties varied with the degree of roasting of the coffee.

Keywords: *coffee, quality, sensory analysis.*

Resumen

El estado Mérida, es uno de los principales productores de café en Venezuela. Sin embargo, no se conoce cuáles son las características de calidad del café en taza. La calidad de la bebida de café depende de factores que van desde la semilla hasta el momento de su preparación. Es por esto por lo que se evalúa la calidad del café mediante parámetros fisicoquímicos, bajo los criterios de las normas COVENIN vigentes en Venezuela. Además de estudiar parámetros sensoriales de acuerdo con el protocolo de cata de la Asociación de Cafés Especiales (SCA). Para las pruebas se seleccionaron tres cafés con diferentes niveles de tostado del estado Mérida. En los parámetros fisicoquímicos evaluados como cenizas, fibra cruda, cafeína, pH no existen estadísticamente diferencias significativas ($p \geq 0,05$), mientras que parámetros como contenido de grasa y azúcares presentan diferencias significativas entre las muestras ($p \leq 0,05$), lo cual puede estar asociado a la genética y la altura a la cual se sembró el café. Las propiedades organolépticas variaron con el grado de tostión del café.

Palabras claves: *café, calidad, análisis sensorial.*

1 Introduction

Coffee is a drink obtained from the roasted seeds of plants called coffee trees. (Forero, 2009) explains that coffee trees are shrubs with evergreen leaves and a bright green color and assures that a white flower three days after flowering gives way to the fruit, which looks like a cherry, but smaller in size. Regarding the etymology of the word coffee, some researchers claim that it comes from the Turkish term: *anger*, in turn comes from Arabic *Coffee* which is an abbreviation of the expression *Kahwat Albun* which referred to the liquor extracted from the fruits of the plant *coffea*. (Henao,1982) indicates that the word coffee was originally from the Arabic *Kwwa* whose meaning was restlessness, energy, action, which was related to the sensations experienced by those who consumed the drink. Another possible origin of the word is attributed to the name of *Kaffa* which is a region in the south-

west of Ethiopia where the largest number of varieties of the Arabica species were found.
All known coffee species are in the Rubiaceae family (*Rubiaceae*), belongs to the tribe *Coffeae* and to the genre: *Coffea.*
The Venezuelan Andes are recognized for being the coffee-growing area of the country since 1870, says (Ardao, 1984), at the end of the 18th century there were already coffee crops in Táchira, Mérida and Trujillo, but its diffusion was limited until the mid-19th century. The same author affirms that it is possible that coffee in the state of Mérida came from the Jesuits, who cultivated it on a very small scale in the haciendas and farms that belonged to the Company of Jesus in the surroundings of the city. On the other hand, (Graterol and, col.,1983), argues that among the first landowners who grew coffee in Mérida, was Juan Nepomuceno Uzcátegui, who had several farms in the La Punta sector. In 1800 a slow diffusion of cultivation began in the city of Mérida, Ejido, La Punta, Lagunillas and Tovar. The first commercial diffusion of coffee began between 1830 and 1875.

Coffee is a complex product from a chemical point of view due to the large amount of chemical compounds contained in green coffee that are later transformed during the coffee processing process. (Gotellan, *and col.,* 2007) claim that coffee beans have around 2,000 different chemical compounds, including water, nitrogenous compounds (alkaloids, amino acids, proteins), carbohydrates (cellulose), polysaccharides, volatile acids (formic and acetic) and not volatiles (lactic, tartaric, pyruvic, citric), aliphatic acids, lipids (triglycerides, fatty acids), diterpenes (cafestol and kahweol), phenolic compounds (chlorogenic acid), volatile substances, vitamins and minerals.

The quality of the coffee must adapt to norms, consumer demands and quality standards, since its commercial value depends on this. (Barrier, *and col*., 2019) ensure that the coffee is valued based on descriptors, such as sensory analyzes (cup test), carried out by expert coffee tasters who use a characteristic vocabulary for the category (SCA Coffee Wheel), who are trained to appreciate sensory differences between coffee drinks, the result of these tests directly influences the price.

(Mastronardi, 2012) studies the quality from different points of view, since for the producer the quality of the coffee is related between the price of production and ease of cultivation. At the export/import level, coffee quality is related to the size of the bean, the presence or absence of defects, physical characteristics and price. From the roasting point of view, the quality of the coffee depends on the botanical variety of coffee, processing of the beans, and roasting process. While at the consumer level, quality is related to taste, flavor, price, health effects, geographical origin, and environmental and sociological aspects.

On the other hand, (Zuluaga, 1990) highlights the concept of coffee quality, which is focused from a technological point of view and is defined as the result of a set of processes that allow the expression, development and conservation of physicochemical characteristics. intrinsic characteristics of the product, until the moment of its transformation and/or consumption. That is, the quality of the coffee is related to the chemical components of the roasted coffee beans, but this composition depends on the degree of maturity of the coffee beans. Due to this, the International Organization for Standardization (ISO) defines standards for the quality of green coffee (ISO 9116:2004) in which information is required such as botanical and geographical origin, harvest year, moisture content, total defects, quantity of grains with defects and grain size.
The sensory attributes of coffee are associated with characteristic chemical compounds, among which are: sweetness that is produced by proteins and carbohydrates; the salty taste due to the presence of potassium, phosphorus and calcium; acidity, which is attributed to acetic, chlorogenic, citric, tartaric and malic acids; bitterness, which is produced by alkaloids and phenolic compounds that also contribute to the coffee astringency. In this sense, (Marcano, 2011) states that phenolic compounds cause a combination of sweet-bitter flavor, but the sweetness is overshadowed by alkaloids such as caffeine and trigonelline that contribute to the bitter flavor. The coffee drink is acidic and the acids responsible are aliphatic acids with up to ten carbon atoms (citric, malic, lactic acid, etc.) and benzene derivatives, such as chlorogenic acids, which degrade during the brewing process. toasted.

The quantity and types of amino acids affect the intensity and quality of the aroma. Because the free amino acids in coffee beans are transformed during coffee roasting through the Maillard reaction., (Puerta, 2001). (Arnold and Ludwig, 1996) state that free amino acids such as glutamic acid, asparagine, arginine, leucine, phenylalanine, tryptophan and lysine decrease markedly during the roasting process and conclude that amino acids bound to proteins amounted to 95% of the original value. after an hour of roasting. Thus, in this research it has been proposed as main objective to determine physical, chemical and sensory parameters linked to the quality of coffee, based on the official regulations in force in Venezuela, to determine its commercial quality.

2 Materials and methods.

2.1 Sampling

In the study, three samples of small organizations linked to the production of coffee beans or ground were selected in conjunction with the advice of the Civil Coffee Association of the state of Mérida, Venezuela. In this sense, a random sampling of duly identified lots was carried out in order to know their traceability (Table 1).
All analyzes were performed in triplicate. The results were evaluated under an analysis of variance and a Tukey mean

comparison test with a significance level of 95%, using the Minitab 15 program (Minitab, 2007), in order to describe the behavior of the physicochemical parameters associated with the Sensory analysis of coffee.

Table 1. Coffee samples.

Sample Code	Sample identification
M1	L.T. International C.A. (45 scale AGTRON/SCA)
M2	Café Affogato C.A. (55 scale AGTRON/SCA)
M3	Finca La Mesa (55 AGTRON/SCA scale)
M4	Café Affogato C.A. (35 scale AGTRON/SCA)

The analyzes of the drink quality of the coffee and water were carried out under the COVENIN standards for brewed coffee:

2.2 Parameters evaluated

Determination of ash content and its characteristics. Brewed Coffee. (COVENIN 46:1994).
The method for determining ash in brewed coffee consists of completely calcining a certain amount of sample, at a maximum of 550 °C and expressing the result as a percentage.

Determination of reducing and non-reducing sugars. Brewed coffee. (COVENIN 2134:1984).
The test method for the determination of reducing and non-reducing sugars is based on the Munsol Walker method for brewed coffee. The principle of the method is based on the fact that the reducing and non-reducing sugars, after being hydrolyzed, reduce the cupric ions of Fehling's reagent to cuprous ions in an alkaline medium, forming cuprous oxide, which is determined by gravimetry.

Determination of fat content in foods. (COVENIN 3218:1996).
The determination of fat in coffee was carried out by the Soxhlet extraction method, using petroleum ether as a solvent.

Determination of crude fiber content. Brewed coffee. (COVENIN 430:1982).
The method consists of subjecting the previously degreased sample to a successive acid and basic hydrolysis treatment to remove fats and proteins. The residue obtained is calcined at a maximum temperature of 650 °C, where the weight loss during incineration represents the amount of crude fiber present in the sample.

Determination of caffeine.
The method to quantify caffeine consists of separating the active ingredient by solid-liquid and liquid-liquid extraction and then detecting it by spectrophotometric techniques, (García *and col.,* 2018).

Determination of chlorides. Gravimetric method brewed coffee (COVENIN 431:1981).
The standard for the determination of chlorides in processed coffee consists of the gravimetric method in the form of AgCl.

Determination of metals (calcium, sodium, potassium and magnesium) in the coffee drink.
The extraction was carried out with 1 g of coffee in 100 mL of water at 80 °C for 10 minutes. Measurements were then carried out by flame atomic absorption spectroscopy with flow injection. According to the following wavelengths: Na: 580 nm; K: 550 nm; Ca: 422.7 nm and Mg: 285.2 nm.

Sensory analysis of coffee

Cupping protocols of the Specialty Coffee Association (SCA).
A cupping panel evaluated four coffees and four different types of water.
The water samples were taken: a sample of commercial water from an identified batch (water 1), from the city aqueduct (water 2), distilled water from the same origin (water 3), and water with conditioning capsule treatment. of water for coffee preparation (Third Wave Water) (water 4)
The coffees were prepared in blind cupping sessions according to the SCA cupping protocol (2015). It was evaluated on a scale of 1-10. Each of the cups evaluated the coffee extracted with the four different waters and was repeated three times.

3 Results and Discussion

Determination of ash content
Table 2 shows the results in ash percentage of the coffee samples evaluated. The statistical analysis showed $p \geq 0.05$, which indicates that there are no significant differences between the means of the samples.

Table 2. Results of ash content in coffee samples.

Sample	Ash (%) ±0.1
M1	3,97
M2	4,04
M3	3,94
M4	3,75

When comparing the results obtained with the COVENIN 46:1994 standard, which establishes a maximum ash requirement of 5% (w/w) for ground coffee, they indicate that the evaluated samples comply with said standard.

In this sense, (Pigozzi *and col*., 2018) states that the average ash content in Arabica varied from 2.5 to 4.5%, while that of Robusta coffee was 4.64%, associating this variation in the mineral composition of coffee with the state nutritional status of the coffee plantation and its location. On the other hand, (Puerta, 2011) states in his work chemical composition of a cup of coffee that the ash content in roasted coffee varies between 3.05 and 5.25%, with an average of 4.36%, one of the reasons associated with these differences are the type of processing carried out in the coffee. Both authors agree that the differences are due to the variety of coffee, with robusta coffee having a higher content than arabica coffee. While (Bonnlander *and col*, 2005) state that the changes in the amount of ash during the roasting process are not significant, which is demonstrated with the results of samples M2 and M4.

Fat determination

In Table 3, the means of fat content in percentage for each of the coffee samples are presented. The statistical analysis indicates that there are significant differences between the samples ($p \leq 0.05$). A post hoc Tukey test was performed indicating that samples M2 and M3 have significant differences between them, as do samples M1 and M2. Samples M2 and M4 do not present statistically significant differences.

Table 3. Results of fat content in coffee.

Sample	Fat (%)
M1	19,09 ± 1
M2	23,61 ± 2
M3	16,41 ± 1
M4	22,89 ± 1

The differences found in the percentage of fat in samples M1, M2 and M3 may be associated with different geographical origins. Villarreal *et al.* (2012) indicate that factors such as the species, culture conditions, extraction method and even the method used for quantification can affect the values of total lipid content. Between sample M2 and M4 the difference is not significant because it is the same coffee with a different level of roasting, however, sample M4 has a lower amount of lipids than M2. Regarding this, Lago (2001) comments that the content lipid increases after the roasting process due to the transformation of carbohydrates during thermal processing, while Valencia (2015) comments that most of the lipids contained in the coffee bean are not degraded during roasting, although some fatty acids increase, unsaponifiable lipids decrease and some lipids are oxidized and form aldehydes and other volatile compounds.

Regarding the values achieved in the literature, they vary from 9.9 to 20% depending on each author, obtaining relative percentages similar to those found in the literature consulted.

The importance of lipids lies in the fact that they contribute to the transport of flavors and aromas, in addition to providing sensory body to the coffee drink, recent research such as that of (Pazmiño *and col*.,2019) confirm that during storage, the content of free fatty acids increases and the content of caffeic acid decreases, likewise, they indicate that physiological changes, such as membrane modifications and lipid body breakdown, They additionally contribute to the development of coffee flavor at rest, where many of these processes can be attributed to oxidation.

Determination of crude fiber

Table 4 shows the results of crude fiber in the analyzed coffee samples, which do not statistically present significant differences ($p \geq 0.05$).

Table 4. Crude fiber results in percentage

Samples	**Raw fiber (%)** ± 1
M1	26,32
M2	25,71
M3	24,89
M4	24,84

In this case, the values do not coincide with those reported in the literature. Puerta (2011) states that the crude fiber content depends on the variety of coffee; the author indicates in her research values between 15.53 to 21.75%. Although the COVENIN standard 430:1982 requires its determination, it does not establish an interval associated with the quality of the coffee.

Determination of caffeine

The linear regression of the calibration curve (0 - 10 ppm), shown in Figure 1, presents a coefficient of determination of 0.993 indicating a direct relationship between the concentration of caffeine in mg/L with the absorbance.

The values of the means in percentages of caffeine are shown in Table 5. The analysis of caffeine did not show a statistical difference between the means with a p value ≥ 0.05.

The values obtained for caffeine are higher than those reported in the literature, this may be due to the fact that the different researchers consulted carried out the extraction of caffeine with different solvents than dichloromethane (CH_2Cl_2). (Aznar, 2011) states that caffeine is more soluble in an organic solvent than in water. Another factor that can affect the amount of caffeine extracted is the size of the ground bean, which is not referred to in the literature, but since the coffee particles are smaller, their extraction will be greater. The particle size used was 800 µm.

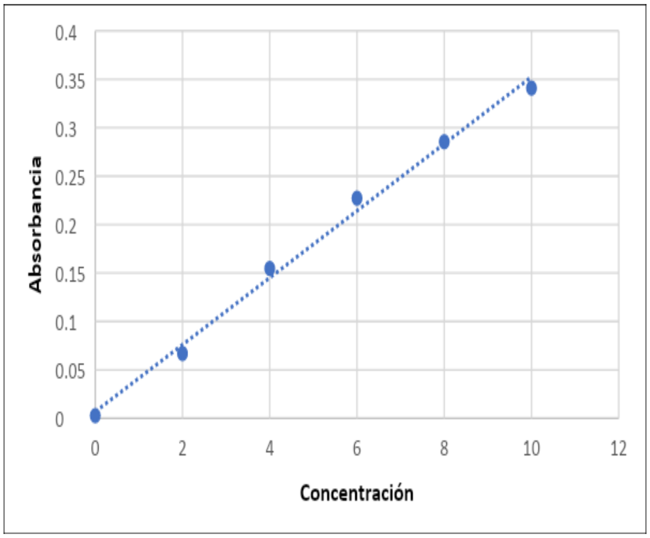

Fig. 1 Calibration curve for caffeine determination.

Table 5. Caffeine content in the coffee samples studied.

Samples	Caffeine (%)
M1	2,94 ± 0,1
M2	2,66 ± 0,2
M3	2,47 ± 0,1
M4	2,10 ± 0,1

The concentration of caffeine is of great importance because it can be used to differentiate coffee varieties, as explained by (Valero, 1997). These researchers use hot water (80 °C) as a caffeine extractant. On the other hand, (Serna *and col.* 2016), obtained a caffeine percentage of 3.7% using ethanol as a solvent (values slightly higher than those obtained in this work). Meanwhile, (Lara, 2016) obtained caffeine values between 1.21 and 1.31% in his research, stating that there is variation depending on the drying treatment, finding a trend towards an increase in concentration when temperatures are used for drying. (in the post-harvest processing) of 50 ºC and when dried in the sun.

On the other hand, in this research it has been achieved that roasting does not significantly affect the concentration of caffeine, this is evidenced by the values obtained for samples M2 and M4 that vary in their level of roasting.

Determination of chlorides. Brewed coffee gravimetric method.

The values of the means in percentages of chlorides in coffee are shown in Table 6. In this case, the chloride analysis showed a statistical difference between the means ($p \leq 0.05$).

Table 6. Chloride content in the coffee samples studied.

Samples	Chlorides (%)
M1	1,34 ± 0,1
M2	0,73 ± 0,1
M3	0,94 ± 0,1
M4	0,85 ± 0,2

The chloride percentages of samples M2 and M4 do not present statistically significant differences. The sample that has the greatest amount of chlorides is sample M1. In the available literature, there are few data found on the chloride content in coffee and they do not coincide with what is available in the literature consulted. (Alcanzar, *and col.*, 2003), state that the average chloride level for Arabica coffee is 0.49 mg/g (0.049%) and 0.65 mg/g (0.065%) for Robusta coffee, while (Silva *and col.*, 1998) obtains 0.00332 mg Cl^-/g in the fruit.

According to the methodology used (gravimetric method for elaborated coffee, COVENIN 431:1981), the incineration of the ground grains makes the extraction of chlorides in the samples more effective, due to the breakdown of organic compounds and the reduction of particle size, which is why higher concentrations of this anion are presented in this research.

Determination of metals in coffee.

Below are the mean values in percentages of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), in the samples of coffees evaluated (Table 7).

In the determination of calcium, the samples present statistically significant differences, although samples M1 and M3 do not present significant differences between them. The values of the percentage of magnesium content in samples M1, M2 and M3 do not present significant differences ($p \geq 0.05$), but sample M4 is statistically different. On the other hand, in the determination of sodium, samples M2, M3 and M4 do not present statistical differences ($p \geq 0.05$), while sample M1 is statistically different. The mean potassium values do not present statistically significant differences ($p \geq 0.05$).

Table 7. Calcium, magnesium, sodium and potassium content in the coffee samples studied.

Samples	Calcium (mg/kg)	Magnesium (mg/kg)	Sodio (mg/kg)	Potassium (mg/kg)
M1	5,2± 0,1	0,093± 0,005	69,3± 3,3	128± 7
M2	4,4± 0,1	0,070± 0,004	45,3± 2	148,3± 7,6
M3	5,5± 0,2	0,077± 0,012	28± 1	140± 7
M4	3,6± 0,1	0,066± 0,003	41± 2	141± 7

The results for metals are higher compared to the values in the literature; this difference is possibly due to agronomic management conditions, such as mineral nutrition, microclimate, soil organic matter, irrigation, periods of rain and water deficit, among others., as stated Sadeghian *et al.* (2013).

On the other hand, researchers like (Muñiz *and col.*, 2013) y (Stelmach *and col.*,2015), states that the contents of the metals Ca, Cu, Fe, K, Mg, Mn, Na and Zn could be considered as possible chemical descriptors to differentiate green coffees according to their geographical origin. This indicates that the difference in concentration obtained is also associated with the geographical origin of the different coffee samples analyzed in the state of Mérida.

Determination of reducing sugars, total sugars and sucrose content

Table 8 presents the results of reducing sugars, sucrose and total sugars evaluated in the different samples of roasted and ground coffee beans. It is observed that sample M4 has the lowest sugar content because of its high roasting, while in the rest of the coffees there is no significant difference between them ($p > 0.05$).

Table 8. Results of the analyzes of reducing sugars, total sugars and sucrose content in the different coffee samples evaluated.

Samples	Reducing sugars (%)	Sucrose (%)	Total sugars (%)
M1	1,62 ± 0,1	1,98 ± 0,3	3,70 ± 0,2
M2	1,92 ± 0,1	1,80 ± 0,3	3,81 ± 0,2
M3	1,53 ± 0,2	1,66 ± 0,2	3,27 ± 0,2
M4	0,25 ± 0,004	0,25 ± 0,1	0,51 ± 0,1

Reducing sugars: The high concentrations of reducing sugars in coffee beans are not only associated with the genetics of the coffee but also with environmental conditions, harvest time and processing. Which in turn contributes to the formation of aroma compounds such as pyrazines and melanoidins, (Mastronardi, 2012). (Puerta, 2011) points out that depending on the roasting and initial levels of reducing sugars, concentrations of said compounds of less than 0.01% can be obtained in roasted coffee beans, since these sugars react with amino acids in the well-known Maillard reaction. or glycation.

Total sugars: Regarding the content of total sugars, the literature commonly expresses the results as polysaccharide content, only as indicators of the total level of sugars, while the COVENIN 2134:1984 standard incorporates it as a tool in the determination of reducing and non-reducing sugars. as has been the case in this case. In this sense, the total sugar content varied between 3.27 and 3.81% for low-roasted coffees (M1 – M3), while high-roasted coffee has a concentration of 0.51%. In addition, the concentration of total sugars also depends on the variety of coffee, the microclimate of the plantation, time of year, state of ripening of the fruit, post-harvest processing process, degree of roasting, among others (Belitz *and col.*, 2009). Thus, total sugars can vary widely, which is why they are not commonly considered a quality criterion.

Saccharose: In this investigation for samples M1 – M3, there are values that range between 1.66 and 1.98% sucrose. On the other hand, as in the previous cases, the low levels of sucrose in sample M4 are due to the high roasting process, where the sucrose has decomposed and caramelized, producing melanoidins and acids in the drink. Which will be discussed later. (Belitz *and col.*, 2009) published that sucrose levels range between 0.4 and 2.8%, according to the type of coffee, variety, agronomic management, harvest time and location. In this way, the results obtained in this research coincide with their assessments, in the case of commercial coffees in the state of Mérida.

Sensory analysis

All the previous analyses, conditions and parameters are linked to the sensory test to reach an assessment that determines the quality of the coffee. Therefore, the sensory analysis was carried out under the standards of the SCA (2015), to standardize the results of the evaluation of the sensory properties of the beverage and thus correlate these with the physicochemical parameters of the coffee. Figure 2 shows the sensory behavior of the different coffees evaluated, through a trained panel.

In this case, for the fragrance/aroma relationship: the results of the sensory analysis carried out by the panel trained on the coffee drink (Figure 1), show that the aroma in all samples has a rating of average, superior or equal to 6, which indicates that in general they have a natural aroma to the coffee drink, being a positive quality present in coffees with a fresh or roasted aroma.

Acidity: The acidity in all samples has an average rating greater than 6.5; which is indicative of a natural acidity of the coffee samples, with a rounded sensation.

Body: The overall body has an average rating greater than or equal to 7, indicating a moderate body of the coffee drink, with a normal running character. (Diaz *and col.*,2015) attributes the body in the coffee drink to the type, origin, and altitude at which the coffee is harvested.

Flavor: The flavor in all sampless has a rating greater than 6.5. Something important to mention is what was confirmed by (Diaz *and col.*,2015) when he describes that the perceived flavor depends on the harvest, processing and storage of the coffee.

Balance: The balance in all samples has an average rating greater than 6.5.

Aftertaste: The aftertaste in all samples it has a classification between 6.5 and 7.5.

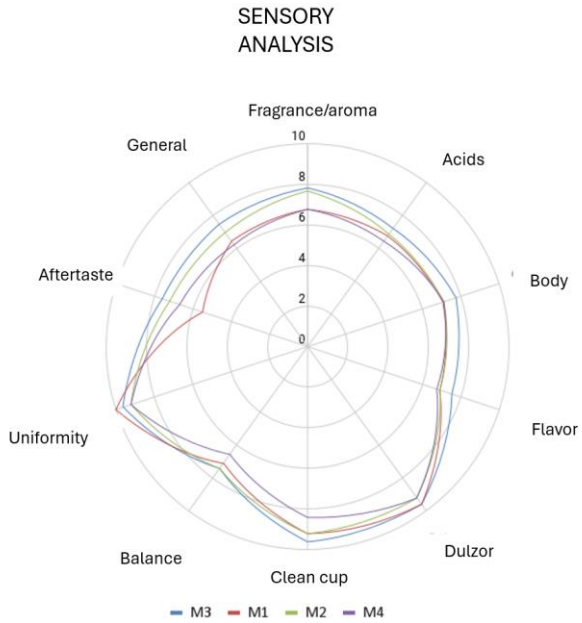

Fig. 2 Sensory profile of the coffees analyzed according to the SCA, 2015.

General (overall impression): The average of the average classification for this sensory variable is greater than 6.7, which expresses a Current, normal overall impression of good coffee cup. (Puerta, 2000) assures that this variable allows accepting or rejecting a coffee sample due to its quality and is related to all the properties perceived in the sensory analysis.

Table 9. Overall quality results in the different coffee samples evaluated.

Coffee sample	Global Quality
M1	7,3
M2	5,7
M3	5,4
M4	4,0

4 Conclusions

In accordance with the standard for determining the ash content and its characteristics (COVENIN 46:1994), the coffee samples analyzed comply with the maximum allowed ash content (5%).

The overall impression of the coffee samples evaluated is greater than 6.5, which indicates that the perceived feeling of the samples evaluated by the panelists is good.

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Recibido: *1 de julio de 2024*

Aceptado: *1 de noviembre de 2024*

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