

Impact of Initial Moisture on Roasting and Sensory Profile of (*Coffea arabica* L.) from the State of Mexico

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ABSTRACT

The coffee-producing municipalities of the State of Mexico cultivate this fruit at an altitude ranging from 1700 to 2100 meters above sea level, giving it the distinction of high-altitude coffee. Indeed, coffee from the State of Mexico has received the designation of “quality coffee,” receiving awards received at the national “Taza de Excelencia México” competition in recent years. However, no studies have been conducted in the region on the standardization of the bean drying process before roasting, nor on its impact on the sensory profile. Therefore, the objective of this study was to evaluate the effect of the coffee bean initial moisture from the State of Mexico on the roasting process and the cup profile. In 2023, coffee (*Coffea arabica* L., Caturra rojo variety) was harvested and processed through a natural method. After drying, it was divided into 800-gram treatments of green coffee with different moisture percentages (10, 11, 12, 13, and 14%), and then roasted according to the 2023 Specialty Coffee Association protocol. The roasted coffee was evaluated using a sensory analysis based on the protocol of the same association, where 10 sensory attributes were assessed. The cupping indicated that the 13% moisture treatment yielded the highest scores, presenting medium-high fragrance notes, sweetness, and fruity characteristics, along with sweet notes of brown sugar. However, this moisture content poses a risk, as it allows the development of microorganisms that can damage the bean. All samples received sensory quality scores ≥ 80 , classifying them as “specialty coffees.”

Key words: Altitude; specialty coffee; sensory evaluation; moisture initial.

1 INTRODUCTION

Coffee is an important agricultural product and one of the most popular beverages in the world (Gutiérrez-Calle et al., 2021). After water, coffee is the most consumed beverage in the world and is, as, although there are other foods with higher amounts, coffee is consumed more frequently and in larger quantities (Rodríguez, 2021).

Globally, two species account for the vast majority of coffee production: Arabica coffee (*Coffea arabica* L.), which accounts for nearly two-thirds of global production, and Robusta coffee (*Coffea canephora*), which makes up one-third (Vega; Reyes, 2017). Brazil holds the first place in global coffee production, followed by Vietnam, while Mexico ranks tenth with a planted area of 710,417 hectares (Servicio de Información Agroalimentaria y Pesquera - SIAP, 2023). All of the coffee produced in Mexico comes from 14 states: Chiapas, Veracruz, Puebla, Oaxaca, Guerrero, Hidalgo, San Luis Potosí, Nayarit, Jalisco, Colima, State of Mexico, Morelos, Querétaro, and Tabasco (SIACON-SADER, 2022).

The State of Mexico ranks eleventh nationally in coffee production, with a cultivated area of 539 hectares and a production of 623 tons (Leguizamo et al., 2023). Climatic factors play a crucial role in coffee quality, with altitude above sea level and temperature being key determinants (Secretaría de Agricultura y Desarrollo Rural - SADER, 2015). Compared

to coffee farms in Chiapas, which are located at altitudes ranging from 900 to 1800 meters above sea level and have an average annual temperature of 24°C, coffee farms in the State of Mexico reach altitudes of up to 2100 meters above sea level and have an average annual temperature of 14.7°C. These conditions allow for slow but proper fruit ripening, promoting the production of high-density seeds of excellent quality (SIACON-SADER, 2022).

The density of coffee is defined as the mass of a coffee bean in relation to its volume. Dense beans contain higher levels of sugar, resulting in more complex and sweeter cup profiles, which is why these beans are highly valued today (Castellano, 2021). The characteristics of coffee from the State of Mexico have made it stand out as a high-quality coffee (Secretaría Del Campo Del Estado de México - SECAMPO, 2021).

A ripe, unprocessed coffee bean contains approximately 45 to 65% moisture after harvesting. Subsequently, during processing, the moisture content decreases to a range of 10 to 12% (Pashley, 2017). According to Puerta (1999), the drying process can be done in the sun, on patios, on rooftops, in slats, or in electric dryers. After drying, the coffee is known as “parchment coffee”, as it still has its protective husk, called the endocarp or parchment. The husk is then removed using hullers, resulting in green coffee (Pérez, 2020).

There is a relatively narrow range of optimal bean moisture. At moisture contents below 10%, coffee beans have

decreased weight loss and become brittle, which compromises both their quality and flavor. On the other hand, with moisture content above 12%, they can provide an environment conducive to the growth of bacteria, fungi, and mold, causing the coffee to become rancid and affecting its taste and aroma (Juárez, 2019).

Cupping is the predominant sensory technique in the coffee production chain, used to identify attributes and defects in the beverage, quantify the intensity of sensory characteristics, and describe its aromatic profile. The sensory characteristics of coffee include aroma, acidity, bitterness, body, flavor, and the overall impression of the beverage. The aromatic profile refers to the olfactory notes and fragrances emitted by the coffee, which can range from subtle floral nuances to intense fruity and spicy aromas. The quality of coffee is determined based on the intensity and balance of these characteristics and the aromatic profile (Puerta, 2013). Therefore, the objective of this study was to evaluate the effect of coffee bean moisture from the State of Mexico on the roasting process and the cup profile.

2 MATERIAL AND METHODS

2.1 Natural processing

In 2023, coffee cherries (*Coffea arabica* L., Caturra rojo variety) were harvested on a farm in Temascaltepec, Mexico State, located 2100 meters above sea level. After collection, the coffee cherries were manually sorted to remove impurities such as branches, leaves, and soil. Subsequently, the fruits were immersed in a tub of water to separate defective beans, such as “bofos” or “hollow” beans, which float to the surface (“flotation” process).

Once the flotation process was completed, the fruits were sun-dried for 12 days, with a relative humidity of 56% during the day, using African beds—structures made of wood and galvanized mesh, elevated one meter above the ground to optimize aeration. The drying process continued until five different moisture levels were reached (10, 11, 12, 13, and 14%), which were determined using a hygrometer (Agratronix MT-PRO), with three replicates for each treatment. The hygrometer has an accuracy of $\pm 0.5\%$ in the normal humidity range for stored grain. Once the material was dried, the roasting process was carried out.

2.2 Roasting

According to the (Specialty Coffee Association - SCA, 2023), beans should be roasted for between 8 and 12 minutes, and the roasting profile should be light to light-medium, measured using the AGTRON M-Basic scale (Gourmet), which is approximately 58 Agtron for whole beans and 63 Agtron for ground coffee, with a ± 1 point tolerance.

The green coffee beans were roasted for 9 to 10 minutes at $190^{\circ}\text{C} \pm 10^{\circ}\text{C}$ with a medium roast level, using a traditional drum roaster (AZTK 2.5 kg/cycle) at the “Pare de dormir” roastery in Mexico City, Mexico. Once the roasting process was completed, the samples were cooled to room temperature ($22\text{--}24^{\circ}\text{C}$) and stored in airtight bags in a dark, cool place to minimize exposure to air and prevent contamination. Subsequently, sensory analysis was performed by coffee cupping.

2.3 Sensory Analysis

For the sensory analysis or coffee cupping, the methodology and format proposed by the SCA (2023) (Figure 1) was used, with 3 Q Grader cuppers—highly qualified individuals licensed by the Coffee Quality Institute (CQI) to determine whether a coffee is specialty grade. The variables evaluated, according to the association’s format, include: fragrance/aroma, flavor, residual flavor, acidity, body, balance, sweetness, uniformity, and cleanliness.

2.4 Experimental Design

Using a completely randomized design, we tested the effect of the 5 moisture treatments (10, 11, 12, 13, and 14%) each with three replicates, with 800 grams of green coffee, on the response variables of fragrance/aroma, flavor, aftertaste, acidity, body, and balance; sweetness, uniformity, and cleanliness, derived from the sensory analysis. ANOVA ($p \leq 0.05$) was used for each response variable, in the Statgraphics Centurion program, and when the effect of treatment was significant ($p \leq 0.05$) a non-parametric Kruskal-Wallis mean comparison test was applied.

This non-parametric test was chosen because it allows comparing differences between several groups without requiring a normal distribution, making it suitable for data obtained from people, such as *Q graders*.

3 RESULTS

Table 1 presents the results of the average attributes: fragrance/aroma, flavor, aftertaste, acidity, body, and balance from the sensory evaluation of the 5 treatments assessed by three Q Grader cuppers.

Table 2 presents the results of the average attributes: uniformity, sweetness, clean cup, and final score of the 5 treatments evaluated by three Q Grader cuppers.

4 DISCUSSION

4.1 Sensory Evaluation

The score for each variable is classified (very good, excellent, and outstanding) according to the SCA (2023).



Asociación de Cafés Especiales Formulario de catación de Arabica

Nombre: _____

Fecha: _____

Mesa #: _____

Clasificación

6.00 - BUENO	7.00 - MUY BUENO	8.00 - EXCELENTE	9.00 - EXTRAORDINARIO
6.25	7.25	8.25	9.25
6.50	7.50	8.50	9.50
6.75	7.75	8.75	9.75

Muestra #	El Nivel de tueste	Fragancia/Aroma	Total	Sabor	Total	Acidez	Total	Cuerpo	Total	Uniformidad	Total	Taza Limpia	Total	Puntaje Catador	Total	Total Score
		Seco Cualidades Espuma		Sabor Residual		Intensidad Alta Baja		Intensidad Alta Baja		Balance		Dulzura		Defectos (subtract)		
Notas:															Puntaje Final	

Muestra #	El Nivel de tueste	Fragancia/Aroma	Total	Sabor	Total	Acidez	Total	Cuerpo	Total	Uniformidad	Total	Taza Limpia	Total	Puntaje Catador	Total	Total Score
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Notas:															Puntaje Final	

Muestra #	El Nivel de tueste	Fragancia/Aroma	Total	Sabor	Total	Acidez	Total	Cuerpo	Total	Uniformidad	Total	Taza Limpia	Total	Puntaje Catador	Total	Total Score
		Seco Cualidades Espuma		Sabor Residual		Intensidad Alta Baja		Intensidad Alta Baja		Balance		Dulzura		Defectos (subtract)		
Notas:															Puntaje Final	

Este formato está diseñado para usarse en conjunto con el protocolo de catación de cafés especiales.

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Figure 1: SCA Sensory Evaluation Format, 2023.

Table 1: Results of fragrance/aroma, flavor, aftertaste, acidity, body, and balance of the evaluated samples.

Moisture treatment (%)	Fragrance/ aroma $\bar{x} \pm DE$	Flavor $\bar{x} \pm DE$	Aftertaste $\bar{x} \pm DE$	Acidity $\bar{x} \pm DE$	Body $\bar{x} \pm DE$	Balance $\bar{x} \pm DE$
10	7.66 $\pm$ 0.14a	7.41 $\pm$ 0.14a	7.41 $\pm$ 0.14b	7.5 $\pm$ 0.0b	7.58 $\pm$ 0.14b	7.33 $\pm$ 0.14b
11	7.75 $\pm$ 0.0a	7.75 $\pm$ 0.0a	7.41 $\pm$ 0.14b	7.58 $\pm$ 0.14b	7.41 $\pm$ 0.14b	7.58 $\pm$ 0.14a
12	7.58 $\pm$ 0.14a	7.66 $\pm$ 0.14a	7.85 $\pm$ 0.13a	7.75 $\pm$ 0.0a	7.66 $\pm$ 0.14b	7.58 $\pm$ 0.14a
13	7.08 $\pm$ 0.14b	7.66 $\pm$ 0.14a	8.00 $\pm$ 0.0a	7.75 $\pm$ 0.0a	8.00 $\pm$ 0.0a	7.75 $\pm$ 0.0a
14	7.16 $\pm$ 0.14b	7.58 $\pm$ 0.14a	7.18 $\pm$ 0.16b	7.5 $\pm$ 0.0b	7.58 $\pm$ 0.14b	7.33 $\pm$ 0.14b

Note 1: The values represent the mean $\pm$ standard deviation ($\bar{X} \pm SD$). Values with different letters (a and b) within the same column indicate a significant difference ($p \leq 0.05$) between treatments.

Table 2: Results of uniformity, sweetness, clean cup and total score of the evaluated samples.

Moisture treatment (%)	Uniformity $\bar{x} \pm DE$	Sweetness $\bar{x} \pm DE$	Clean cup $\bar{x} \pm DE$	Total score $\bar{x} \pm DE$
10	10 $\pm$ 0.0a	10 $\pm$ 0.0a	10 $\pm$ 0.0a	82.02 $\pm$ 0.14b
11	10 $\pm$ 0.0a	10 $\pm$ 0.0a	10 $\pm$ 0.0a	82.93 $\pm$ 0.14b
12	10 $\pm$ 0.0a	10 $\pm$ 0.0a	10 $\pm$ 0.0a	83.46 $\pm$ 0.14b
13	10 $\pm$ 0.0a	10 $\pm$ 0.0a	10 $\pm$ 0.0a	84.03 $\pm$ 0.0a
14	10 $\pm$ 0.0a	10 $\pm$ 0.0a	10 $\pm$ 0.0a	81.66 $\pm$ 0.14b

Note 2: The values represent the mean $\pm$ standard deviation ($\bar{X} \pm SD$). Values with different superscript letters (a and b) within the same column indicate a significant difference ($p \leq 0.05$) between treatments.

4.2 Fragrance/aroma

The scores obtained for the fragrance/aroma variable ranged from 7.08 to 7.75, considered very good. These attributes represent the olfactory perception of coffee. Volatile components are grouped under fragrance, which is defined as the characteristic smell of the ground dry coffee sample, while aromatic components are considered part of the aroma, referring to the smell of coffee when mixed with hot water (Osorio, 2021; SCA, 2023). In Guerrero, Mexico, Juárez et al. (2021) evaluated a Caturra variety coffee at an altitude of 1420 meters above sea level, with a moisture content of 12%. The score obtained for the natural processing method was 7.25, for honey processing it was 7.17, and for washed coffee, it was 7.50. On the other hand, in Chiapas, Mexico, González and Alcántara (2022) evaluated Typica-Bourbon and Bourbon coffee at an altitude of 919 meters above sea level, with a moisture content of 12%, and obtained scores of 7.33 and 7.58, respectively, for washed coffee.

The score obtained for the treatments evaluated in this study, ranging from 7.08 to 7.75 for natural processing at an altitude of 2100 meters above sea level, is higher than the values reported by Juárez et al. (2021), who documented scores of 7.25 for natural processing, 7.17 for honey, and 7.50 for washed, as well as the values obtained by González and Alcántara (2022), with scores of 7.33 and 7.58 for washed coffee. This result suggests that the coffee evaluated in this study exhibits superior quality in these two attributes.

4.3 Flavor

For this variable, the range of values was from 7.41 to 7.75, considered very good. The flavor attribute represents an integrated impression of all the sensations (provided by the taste buds) and retro-nasal aromas that travel from the oral cavity to the nose. The score assigned to flavor should reflect the intensity, quality, and complexity of the combined flavor and aroma experienced when the coffee is vigorously sipped, allowing the entire palate to be activated during the evaluation (SCA, 2023).

Juárez et al. (2021) obtained flavor attribute values of 7.3 for natural, 7.1 for honey, and 7.5 for washed coffee, while González and Alcántara (2022) reported scores of 7.42 and 7.5 for washed coffee. The scores obtained in this study, which range from 7.41 to 7.75 for natural processing, exceed those reported by the previous authors.

At higher altitudes, coffee cherries mature more slowly, resulting in denser beans. This gives them higher sugar levels, contributing to more complex and sweeter cup profiles, increasing their value (Castellano, 2021). This phenomenon is confirmed in the present experiment, where the coffee, harvested at an altitude of 2100 meters above sea level, exhibited a superior cup profile compared to the results obtained in the studies by Juárez et al. (2021) and González and Alcántara (2022), where the coffee was harvested at altitudes of 1420 and 919 meters above sea level, respectively.

4.4 Aftertaste

This attribute obtained scores ranging from 7.18 to 8.0, the latter being excellent. Aftertaste is defined as the duration of the positive flavor attributes (taste and aroma) that persist at the back of the palate after the coffee is expectorated or swallowed. A brief or unpleasant aftertaste will receive a lower score (SCA, 2023).

Juárez et al. (2021) evaluated the aftertaste for natural processing with a score of 7.3, for honey with 7.1, and 7.5 for washed coffee. On the other hand, González and Alcántara (2022) obtained scores of 7.17 and 7.5. The results obtained in this study are higher than those reported by the previous authors, with some even classified as excellent.

4.5 Acidity

This attribute scored between 7.5 and 7.75, considered very good. Acidity is often described as brightness when it is favorable or sour when it is unfavorable. In its optimal manifestation, acidity adds liveliness to the coffee, accentuates sweetness, and gives a fresh fruit character, being perceived almost immediately after the coffee is ingested. An excessively intense or dominant acidity can be unpleasant, and excess acidity may not align with the desired flavor profile for the sample (SCA, 2023).

Altitude and processing method have a significant influence on the acidity of coffee. Coffees grown at higher altitudes tend to have brighter acidity. This is due to cooler temperatures and greater sun exposure, which allow for slower bean maturation. On the other hand, the natural processing method, which involves drying the coffee beans with the pulp intact, tends to produce coffees with sweeter and less acidic profiles. In contrast, washed processing, which involves removing the pulp and fermenting the coffee before drying, generally results in coffees with higher acidity and cleaner characteristics (Hernández, 2023).

This phenomenon is confirmed in the present experiment, where the combination of coffee harvested at a higher altitude and the selected processing method (natural) resulted in superior acidity compared to what was reported by Juárez et al. (2021), who recorded values of 7.4 for natural, 7.4 for honey, and 7.6 for washed, and González and Alcántara (2022), who obtained scores of 7.33 and 7.42 for washed.

4.6 Body

For this variable, values ranged from 7.41 to 8.0, with the latter being excellent. The quality of the body is based on the tactile sensation of the liquid in the mouth, particularly the interaction between the tongue and the palate. Most samples with a denser body tend to receive high scores in terms of quality due to the presence of colloids in the infusion. However, some samples with a lighter body can still provide a pleasant mouthfeel (SCA, 2023).

Each coffee has a distinctive body profile, influenced by factors such as coffee variety, roast level, and the extraction

method used during preparation. Additionally, the body of the coffee is also determined by its origin and specific growing conditions. Higher altitudes are associated with a greater body presence in the coffee compared to varieties grown at lower altitudes (Barrantes, 2024).

This is corroborated in this study, as the values obtained in the present research are higher than those reported by Juárez et al. (2021), who recorded values of 7.1 for the natural process, 7.0 for honey, and 7.4 for washed, while González and Alcántara (2022) obtained scores of 7.33 and 7.42 for washed.

4.7 Balance

This attribute reports values ranging from 7.33 to 7.75, considered very good. The balance reflects the interaction between different attributes, such as flavor, aftertaste, acidity, and body, and how they complement or contrast with each other. If the sample shows deficiencies in certain aromatic or flavor qualities, or if some characteristics dominate excessively, the balance score will be negatively affected (SCA, 2023).

Juárez et al. (2021) reported values of 7.3 for natural, 7.0 for honey, and 7.5 for washed coffee. On the other hand, González and Alcántara (2022) assigned scores of 7.33 and 7.50 for washed coffee. The values obtained by Juárez et al. (2021) and González and Alcántara (2022) suggest that the balance of the coffee evaluated in these studies is comparable to that of the present study.

4.8 Uniformity, sweetness, and clean cup

For each of these variables, values of 10 were recorded, considered excellent. These values were the same as those reported by Juárez et al. (2021) for all three processes (natural, honey, and washed), and the same as González and Alcántara (2022) for washed coffee. This suggests that the coffee evaluated by these authors exhibits uniformity, sweetness, and clean cup similar to those observed in the present research.

The evaluators concluded the exercise by describing the fragrance, aroma, and flavor notes perceived in the analyzed coffee (Table 3).

The composition of coffee includes a wide variety of compounds that significantly contribute to its aromatic profile. Caramel aromas primarily consist of acids and furans; roasted aromas are made up of aldehydes, ketones, furans, and pyrazines; fruity and sweet aromas include aldehydes, ketones, esters, alcohols, and acids; floral aromas are mainly alcohols; smoky odors are mostly phenols; roasted aromas are composed of pyrazines; rancid and greasy odors are made up of alcohols, aldehydes, ketones, and esters; earthy and moldy odors consist of phenols, pyrroles, alcohols, and hydrocarbons; solvent odors correspond mainly to hydrocarbons and ketones, and rotten aromas are primarily nitrogenous and sulfur compounds such as amines, pyridine, thiols, and thiophenes (Puerta, 2013).

For the fragrance and aroma notes, differences were observed compared to those reported by Juárez et al. (2021) for natural processing, who identified notes of walnut, caramel, almond, and macadamia. González and Alcántara (2022), with washed processing, reported notes of pepper, chocolate, spices, and caramel, indicating differences from the notes found in the coffee evaluated in this study.

Regarding the flavor notes, Juárez et al. (2021) for natural processing identified similar notes to those in the present research, particularly apple and chocolate. In contrast, González and Alcántara (2022) for washed processing reported herbal, nut, pineapple, chocolate, and maple flavor notes, which differ from the notes found in this study.

Although the intrinsic characteristics of coffee mainly originate from the chemical composition of the bean (Poltronieri; Rossi, 2016), they are also a result of the processing method used. In dry processing, the final product develops characteristic fruity aromas and flavors because no layer is removed from the coffee cherries. Meanwhile, in wet processing, the removal of the mucilage by various microorganisms responsible for fermentation leads to the release of volatile aromatic compounds and metabolites that diffuse into the beans, contributing to the development of flavor, aroma, and increasing the acidity and complexity of the coffee (Melo-Pereira et al., 2018).

Table 3: Fragrance, aroma, and flavor notes of coffee.

Moisture treatment (%)	Fragrance notes	Aroma notes	Flavor notes
10	Sweet notes of chocolate, plums, and brown sugar.	Sweet, floral, with light woody notes.	Citrusy, light dry wood, lemon.
11	Sweet, floral notes with light hints of wood and plums.	Sweet, woody notes.	Citrusy, plums, yellow apple.
12	Raw sugar, plum, and brown sugar.	Sweet and floral, with a note of brown sugar.	Citrusy, yellow fruits, apple, and brown sugar.
13	Sweet and fruity notes.	Sweet notes of brown sugar.	Brown sugar, plum, and yellow fruits.
14	Dried fruits and toasted seeds.	Slightly fruity.	Citrusy with strong notes of dark chocolate, slightly dry.

5 CONCLUSION

The Q graders rated the 13% moisture sample highest (84 points), highlighting its medium-high fragrance and sweet, fruity notes like brown sugar, plum, and yellow fruits. Moisture significantly influenced fragrance, aroma, and flavor. Although all samples scored ≥ 80 , qualifying as specialty coffees, moisture above 12% requires careful handling to avoid fungal growth, such as Ochratoxin A, which can spoil the product. These findings underscore the importance of controlling moisture content to maintain sensory quality and safety in specialty coffee.

6 AUTHOR CONTRIBUTION

Conceptual idea: Mariezcurrena, M. D.; Vargas, G. A.; and Aristeo, D. A. Methodology design: Mariezcurrena, M. D.; Vargas, G. A.; and Aristeo, D. A. Data collection: Aristeo, D. A. Data analysis and interpretation: Mariezcurrena, M. D.; Moreno, J. A.; and Aristeo, D. A. Editing and writing: Aristeo, D. A.; Mariezcurrena, M. D.; Vargas, O. R.; Vargas, G. A.; Castillo, J.; and Moreno, J. A.

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