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Roasting affects the final quality of *Coffea arabica* from the Central Mexican Plateau

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Abstract

We conducted two experiments in order to characterize the physical and chemical qualities of coffee (*Coffea arabica*) of the red Caturra variety using a completely randomized design. In the first experiment, we used a roaster inlet temperature of 210°C for five roasting time intervals of 8, 9, 10, 11, and 12 min. In the second experiment, the inlet temperature was changed to 215°C. We determined category 1 and 2 defects from green coffee, characterized the temperature and time profiles during roasting, and determined antioxidants and phenols in aqueous and hydroalcoholic extracts of the roasted coffee. Data were analyzed using ANOVA ($p \leq 0.05$) and Tukey's HSD test ($p \leq 0.05$). The results indicated that in terms of physical quality, the analyzed product could be compared to a European preparation, as it had fewer than eight defects and a density of 684 kg/m^3. The highest amounts of antioxidants and phenols (584.46 ± 6.57 mg Trolox/mL and 6.01 ± 0.16 mg EAG/mL, respectively), both in aqueous extract, corresponded to the 215°C/12min treatment. Roasting has a distinctive effect on the quality of the coffee.

Keywords: roasting; antioxidants in coffee; quality.

Practical Application: The generated coffee roasting protocol will enable producers to enhance product quality.

1 INTRODUCTION

Coffee is a commodity that is second only to petroleum in terms of commercial value. It is cultivated in tropical regions and harvested in over 70 countries, with the leading producers being Brazil, Vietnam, Colombia, Indonesia, and Ethiopia (Slavova & Georgieva, 2019).

Approximately 7 million tons of coffee is produced annually, and over 3 billion cups of coffee are consumed daily (Slavova & Georgieva, 2019).

Mexico ranks 11th in global coffee production (CEDRSSA, 2019). Together, Chiapas (41.3%), Veracruz (24.4%), Puebla (15.8%), Oaxaca (8.2%), and Guerrero (4.5%) account for 94.1% of the total national production; Guerrero, Hidalgo, San Luis Potosí, and Nayarit contribute 14.19%; while Jalisco, Colima, Estado de México, Tabasco, Querétaro, Morelos, and Michoacán collectively generate only 1.02% (CEDRSSA, 2019).

Despite occupying only 0.07% of the national cultivated area, Mexico State ranks 11th in the country in the area of cultivated land with approximately 539 hectares, and coffee production is mainly concentrated in the southern part of the state (SIAP, 2021). Although the total coffee production is low, the coffee from this region is significant in its quality, consistently ranking among the top three in the most prestigious award for high-quality coffees in Mexico, the "Taza de Excelencia" competition (Vargas Flores et al., 2023). The coffee species found in the region is Arabica, with varieties including Bourbon, Yellow Caturra, Red Caturra, Garnica, Pacamara, and Typica, all of which are vulnerable to pests and diseases that can reduce yields.

Green coffee beans possess an herbal flavor and aroma and require roasting for consumption to release their characteristic flavor and aroma through chemical compounds such as caffeine, trigonelline, chlorogenic acids, citric acid, acetic acid, and formic acid (De Luca et al., 2016; Nguyen & Byun, 2013). Although the roasting process determines the quality of the final product, there is limited information on the process. Roasting involves applying heat to raw coffee beans, but the temperature must be carefully controlled to achieve the desired aroma and uniform color development of the beans (Illy & Viani, 2005).

Although the quality of coffee from Mexico State has been repeatedly recognized as mentioned above, roasting practices are heterogeneous, which compromises the inherent quality of the beans (Leguizamo et al., 2023). This highlights the need for generating information to establish proper roasting practices. The Specialty Coffee Association (SCA) defines "specialty coffee" as a product free from defective beans that possesses a distinctive flavor and has been treated with special care throughout the full process from cultivation to the barista's hands (known as the "value chain"), among other criteria. Thus, this study was conducted with the objective of characterizing the physical and chemical qualities of coffee (*Coffea arabica*).

2 MATERIALS AND METHODS

In April 2022, the red Caturra coffee variety was harvested at "La Ilusión" farm, located in the community of San Andrés de los Gamma, Temascaltepec municipality, Mexico State. The geographical coordinates for this location are 100°02′ west

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longitude and 19°03′ north latitude. A total of 100 kg of cherry coffee was harvested and then processed naturally. Afterward, it was dried on African beds, with a resulting weight of 33 kg after drying. Following the removal of the husk (threshing), it was passed through a number 16 sieve (SCA, 2015), and category 1 and 2 defects were eliminated, resulting in 13 kg of high-quality coffee. Using the quartering sampling method, 120 g of samples (the capacity of the roaster) was obtained. Then, two roasting experiments were performed to test the effects of roasting time (8, 9, 10, 11, and 12 min) at two different entry temperatures of 210°C (experiment 1) and 215°C (experiment 2). Physical analyses of green coffee were conducted (category 1 and 2 defects, density (kg/m^3), and moisture (%)) following the SCA methodology (2023).

To quantify the total phenols, chemical analyses of green coffee (mg GAE/mL) were carried out at the Quality Laboratory of the Faculty of Agricultural Sciences at the Autonomous University of the State of Mexico. Antioxidants (mg Trolox/mL) were determined at the Biochemistry Laboratory of the Faculty of Veterinary Medicine and Zootechnics at the Veracruzana University.

2.1 Physical analysis

The green coffee was analyzed for category 1 defects (black beans, sour beans, dried cherries, fungal damage, foreign matter, and severe insect damage) and category 2 defects (partially black beans, partially sour beans, parchment, floaters, immature beans, mottled beans, shells, split/bitten/cut beans, husks, and slight insect damage) according to the SCA methodology in 2023. The apparent density was determined following the NMX-F-593-SCFI-2013 methodology (Estados Unidos Mexicanos, 2013), and the moisture content was measured using the NMX-F-083-1986 methodology (Estados Unidos Mexicanos, 1986).

2.1.1 Coffee roasting

Medium roasting of the samples was performed at the “Pólvora” facilities, a specialty coffee factory in Mexico City, achieving a 65–55 Agtron scale (SCA, 2017) in accordance with the SCA methodology (2015), in a drum sample roaster, Suji model WE X SUJI, at the temperatures indicated above.

2.2 Chemical analysis

The extract of the samples was prepared according to the methodology described by Boyadzhieva et al. (2017). After grinding the coffee, 1 g of ground coffee was weighed out for every 10 mL of solvent. For hydroalcoholic samples, the coffee sample was added to a mixture of 25 mL of distilled water and 25 mL of alcohol, heated at a temperature of 70°C for 1 h, then filtered, and stored in amber bottles. For aqueous samples, the coffee sample was added to 50 mL of distilled water and heated to 90°C for 5 min, followed by filtration and storage in amber bottles.

2.2.1 Determination of total phenol

Total phenol was determined by the Folin–Ciocalteu method (Archundia et al., 2019; Arizmendi et al., 2016).

2.2.2 Determination of antioxidants

Antioxidants were determined according to the method developed by Borrelli et al. (2002).

2.2.2.1 Experimental design

A completely randomized design was used to establish 10 treatments with three replicates at two temperatures of 210°C with five time intervals of 8, 9, 10, 11, and 12 min and 215°C for the same time intervals. Each sample weighed 120 g. The results were evaluated by ANOVA ($p \leq 0.05$), and a Tukey’s mean comparison test was performed to determine the significant differences ($p \leq 0.05$) among treatments.

3 RESULTS AND DISCUSSION

3.1 Physical analysis

3.1.1 Green coffee defects

Category 1 Defects: Two defects, namely one black bean and one piece of foreign matter (coffee husk), were found in the analyzed sample. According to the SCA classification in 2023, a black bean is considered a complete defect. This defect is caused by improper harvesting and can be avoided by harvesting only ripe coffee cherries. The blackening indicates overfermentation associated with microorganisms, leading to a characteristic fermented, rancid/earthy acetic acid, musty/damp, sour, or phenolic taste in the cup, and it poses a potential risk of ochratoxin contamination. This earthy note, belonging to the earthy aromatic family, is included among the 36 coffee aromas around the world of Le Nez du Café (Leinor, 1997). The distinctive smell is due to a compound called geosmin, a secondary metabolite produced by fungi, cyanobacteria, and actinomycetes, when they experience nutritional deficiencies that hinder their proper growth and proliferation (Li et al., 2004). This note is also related to the dry processing method used in this research and occurs when coffee cherries absorb geosmin from the soil on which they are spread to dry, although it can also be detected when storing green coffee. A peculiarity of dry processing is that after pulping and drying the cherries, the resulting cup characteristics are sweetness, low acidity, and a light body (Vargas Flores et al., 2023).

Black beans are visible when removing the parchment; they are smaller and less dense and can be removed by screening, density sorting, or manually (SCA, 2023).

Foreign matter—here, a coffee husk—is classified as a full defect because it has the potential to generate undesirable flavors, affect the appearance of the green coffee, cause damage to the roaster, or even lead to health issues (SCA, 2023). Foreign matter can accumulate at any stage of the process.

Category 2 Defects: Defects found included three partially black beans, five overfermented beans, five shells, and five split/bitten/cut beans. According to the SCA classification in 2023, the three partially black beans result in flavors such as fermented, acetic acid, rancid/earthy, musty/damp, sour, or phenolic tastes.

Another potential issue is the production of ochratoxins, which is caused by overfermentation associated with microorganisms. This defect can be avoided by exclusively harvesting ripe coffee cherries, and during threshing, these defects can be removed through screening or manual selection because they are smaller and less dense. The five overfermented beans represent a complete defect. This defect impairs cup quality with herbal, green, or hay flavors, depending on the quantity, and it also affects the appearance of the green bean. Overfermented beans are caused by a lack of water during the bean's development inside the cherry, and the extent of damage is related to the duration of the drought. It is also magnified when the proportion of damaged beans is high, often stemming from weak plants (SCA, 2023). An overfermented bean is smaller and misshapen and has wrinkles resembling those of a raisin. Five shells also correspond to a complete defect. This can lead to charring during roasting, as the bean's unevenness causes heat to reach different parts of the bean at different times, resulting in some parts burning and developing a smoky aroma, while others remain under-roasted. The cause is related to the coffee's genetics and occurs naturally. To reduce this defect, it is advised to plant suitable varieties and implement good agricultural practices in coffee plants (SCA, 2023). During the selection process, shells are removed using density sorters, as they are less physically dense. The outer part of the bean resembles a seashell, while the inner part can be conical or cylindrical. Finally, five split/bitten/cut beans also represent a complete defect and result in rancid/earthy, dusty, sour, or fermented flavors. This defect affects the appearance of both green and roasted beans. It occurs naturally in the coffee processing and should be addressed through machine calibration to prevent friction between beans, which can cause them to split, bite, or cut. It is suggested that this may be attributed to the extended drying time in natural coffee processing, which makes the beans brittle and more prone to breakage during mechanical husking. Similar to the previous defect, this can generate smoky flavors (Oliveri et al., 2019).

Another point to consider is the threshing step which, when done correctly, should not result in the presence of husks (fragments of dried pulp with a dark red coloration). These husks could produce rancid, dirty, earthy, musty, or phenolic flavors and are related to poor calibration of the husking machine.

In Mexico, all of the defects mentioned above are described in the NMX-F-597-SCFI-2016 standard (Estados Unidos Mexicanos, 2016), which also includes the commercial schemes agreed upon between buyers and sellers to classify the final product obtained from dry processing based on grain size, density, color, and specific physical and sensory criteria. Additionally, it is mentioned that for a preparation referred to as "Americana" in the standard, a maximum of 22 defects is accepted, while for a "European" preparation, a maximum of eight defects is allowed, without specifying the type of defect. As previously indicated, all these defects have a negative impact, resulting in an ashy characteristic aroma that diminishes beverage quality. The results indicated the presence of eight defects, which enters as a European preparation, which has fewer defects and higher quality as reflected in better cup evaluations, higher prices, and increased sales, among other benefits.

3.1.2 Coffee bean density

The coffee beans in this study had an average density of 684 kg/m^3, which, according to the Specialty Coffee Association (2004), is classified as medium density. Muñoz and Noguera (2016) analyzed coffee under the same processing conditions and obtained a value of 813.40 kg/m^3 for the Castillo variety at an average altitude of 2,100 m, which is the same altitude where the beans in this study were harvested. However, the density of Castillo coffee beans is notably higher, suggesting that density is more related to the coffee variety than the altitude above sea level.

In addition, the Official Mexican Standard NOM-169-SCFI-2007 (Mexico, 2007) indicates that high-altitude coffee starts at 1,000 m above sea level (masl), which is the case for both experiments. This altitude has a fundamental impact on bean size, flavor, and density (hardness), which, in turn, affects roasting characteristics. Similarly, Porras-Zúñiga et al. (2019) noted that factors affecting roasting include bean size, as larger beans require more energy (temperature) for roasting, and bean density, as higher density beans adapt better to high roasting temperatures. Finally, Duicela-Guambi and Corral-Castillo (2004) stated that beans with a density exceeding 650 kg/m^3 are considered high density, associated with a slower and more uniform maturation process that allows for the accumulation of important coffee aroma and flavor precursors, while lower density results in more fragile beans which increase the occurrence of different coffee defects, such as broken, malformed, hollow, fermented, and pest-damaged beans. All of these can result in rancid/earthy, sour, or musty flavors, especially when present in large quantities. This effect did not occur in the coffee in this study because of its density of 684 kg/m^3.

3.1.3 Coffee bean moisture content

The moisture content of the coffee beans was 10%. The Arabica Washed Coffee Green Coffee Defects Guide mentions that specialty-grade green Arabica coffee, *Coffea arabica*, should have moisture levels ≥ 10 and $\leq 12\%$ upon receipt. The NOM-169-SCFI-2007 standard indicates in its table of physical specifications for "Café Chiapas" that the moisture content should be between 10 and 12.5% (Mexico, 2007). Similarly, the NOM-149-SCFI-2001 mentions that the moisture content for generic, special Caracol, and SCA-type coffee should be in the range of 11.5–12.5% (Mexico, 2001). Thus, the analyzed coffee falls within the established ranges.

Moisture content exceeding 12.5% facilitates fungal growth and the presence of mycotoxins in coffee beans, which not only influences the quality of the final beverage but also poses a risk to consumers. Furthermore, a high moisture content requires more time and higher temperature during the roasting process to achieve the complete dehydration that is necessary in order to initiate the Maillard reaction and its corresponding aromas. Additionally, overly moist coffee cannot be marketed. Conversely, low moisture content (below 8%) harms coffee quality by producing shrunken beans with an undesirable appearance (Bicho et al., 2014).

3.1.3.1 Roasting

According to the SCA (2015), the roasting duration should be between 8 and 12 min and should occur between 8 and 24 h before cupping. The roast level or color is measured between 30 min and 4 h after roasting. For the current study, the roast color was classified as medium roast, ranging from 65 to 55 on the Agtron scale. From this point, the chemical analyses are reported separately for experiment 1 (210°C) and experiment 2 (215°C).

Roasting is an essential step in the coffee processing chain; it is typically carried out between 200 and 240°C, with varying time intervals depending on the characteristics of the beans (Cho et al., 2014; Schenker & Rothgeb, 2017). The increase in heat triggers the Maillard reaction, caramelization, and the oxidation of polyphenolic compounds, which develop the characteristic properties of coffee, including flavor, color, and aroma (Bruhns et al., 2019; Hemmler et al., 2017).

3.1.3.2 Roasting results for the experiments

For the first experiment, the roasting process started for all treatments (8–12 min) at 210°C. The dehydration phase and equilibrium point occurred at 103°C, after which there was a temperature drop for each treatment, as given in Table 1, referred to as the point of return. From this point, the temperature started to rise again in a particular manner, and the change in bean color occurred at 140°C, where the caramelization and Maillard reactions apparently took place. Subsequently, cracking occurred at different temperatures (Table 1). The exit temperature of the samples from the roaster was around 205°C ± 3°C (Table 1), and the coffee samples were allowed to degas (CO_2 elimination) for 2 days.

For experiment 2, the roasting conditions were the same as described in experiment 1, except that the entry temperature was 215 ± 3°C.

Graphs 1 and 2 provide a comparison among the five treatments of experiment 1 a comparison of the results from the current study with those of Abarca Mora (2017), Castillo Luzon et al. (2016) and Herrera and Lambot (2017); regarding roasting conditions.

In Graphs 1 and 2, it can be observed that seven of the roasting curves start at around 200°C, while Abarca Mora (2017) starts at 280°C. This is because Abarca Mora (2017) used coffee beans from Costa Rica, which are less dense. Subsequently, all treatments experience a temperature drop of approximately 100°C in both graphs. Pittia et al. (2007) mentioned that during the initial phase of roasting, moisture is eliminated from the coffee beans, which aligns with the proposal by Vargas Flores et al. (2023) of dehydration during this phase. This also coincides with the report by Castillo Luzon et al. (2016), suggesting a phase of dehydration or drying, where water turns into vapor at its boiling point, releasing (presumably free) water.

Following this, there is an ascent, and at around 140°C, all curves converge again, except for Herrera and Lambot (2017), which maintains a more conservative temperature. Subsequently, there is an upward trend. The second phase of roasting is known as the Maillard and caramelization reactions (Castillo Luzon et al., 2016; Vargas Flores et al., 2023). Both agree that during this stage, carbohydrate fusion occurs (fructose at 128°C, glucose at 146–150°C, and sucrose at 186°C). Additionally, Wang and Lim (2014) add to this proposition, mentioning the degradation of sugars, amino acids, and chlorogenic acids, resulting in the formation of caramelization and condensation products.

In the third stage of roasting, referred to as development by Vargas Flores et al. (2023) and thermal transition by Castillo Luzon et al. (2016), the first crack occurs (expansion of the bean, complete moisture evaporation, generating high internal pressure, and the initiation of characteristic aroma formation). At this point, rupture and cracking of the bean also occur, typically in the range of 210–215°C. This is where the decision is made regarding whether the roast will be light, medium, or dark, and the beans expand and shine (Vargas Flores et al., 2023). The first crack, in both the five treatments of experiment 2 and Abarca Mora (2017), occurs at 200°C, contrary to Castillo Luzon et al. (2016) and Herrera and Lambot (2017), where it happens at 170°C.

The fourth stage of roasting, referred to as "finishing," involves rapidly cooling the coffee to room temperature within 3 min (according to Castillo Luzon et al., 2016) or 3–5 min (Vargas Flores et al. 2023). The final stage, degassing, requires at least 24 h for the coffee to release the CO_2 that developed during the process (Vargas Flores et al., 2023). The roasting was completed according to the protocol, within 8–12 min, with a finishing temperature of approximately 200°C, 200°C for Herrera and Lambot (2017), 225°C for Castillo Luzon et al. (2016), and 240°C for Abarca Mora (2017). De Luca et al. (2016) and Oliveros et al. (2017) indicated that carbon monoxide and carbon dioxide are released during roasting. Macromolecule

Table 1. Results of the roasting experiments*.

Roasting entry Temperature	**210°C**					**215°C**				
Activity \ **Time (min)**	**8**	**9**	**10**	**11**	**12**	**8**	**9**	**10**	**11**	**12**
Return point temperature (°C)	103	101.1	100.08	98.03	118	105	105	102.2	102.4	100.5
Return point time (min)	1:00	1:04	1:02	0:54	1:50	1:05	1:05	1:03	1:00	1:05
Crack temperature (°C)	198.4	199	200.6	198.5	198.3	201	200.6	198.2	199	198.1
Time at cracking (min)	7:15	7:53	9:20	9:08	10:30	6:30	7:20	9:15	9:55	11:30
Development time (min)	0:45	1:07	0:40	1:92	1:70	1:70	1:80	0:85	0:45	00:70
Percentage yield (%)	85	85	88	87.5	86	88	86	86	87.5	87.5

Development time = (final time - time at cracking); *the data in this table were obtained from the roasting process.

disintegration occurs immediately, including fats, proteins, and carbohydrates, leading to increased grain porosity (from 9.8 to 34.2%) and volume (50–80%).

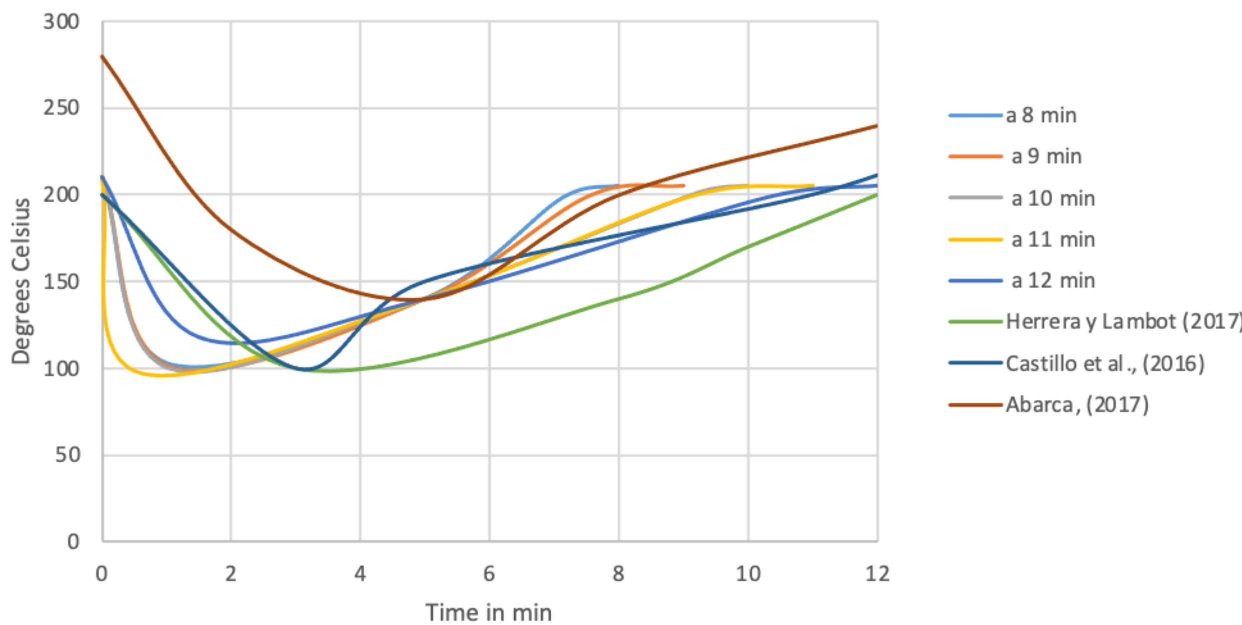
To conclude the process, Porras-Zúñiga et al. (2019) mentioned that factors affecting roasting include bean size (larger beans require more energy for roasting), bean density (higher density adapts better to high temperatures), roasting machine type (air roasters are recommended for temperature stability), temperature (too high or too low can produce undesirable flavors in the bean), and bean moisture (moisture content between 10 and 12% is recommended; less than 10% can lead to faster burning of carbohydrates with unpleasant flavors, while over 12% can promote fungal growth with similar effects). Additionally, the rate of temperature increase over time is significant.

3.2 Chemical analysis

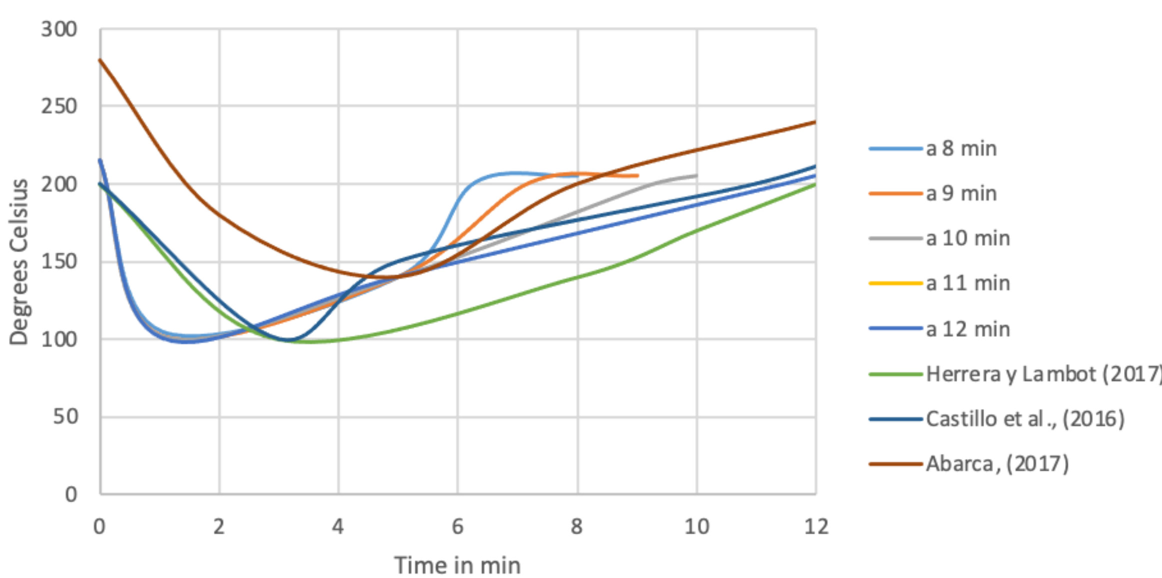
Table 2 presents the results of the chemical analysis of antioxidants (mg Trolox/mL) and phenols (mg GAE/mL) for the hydroalcoholic and aqueous extracts from both experiments (210 and 215°C, respectively) roasted for 8–12 min.

The range of values found for antioxidants in the hydroalcoholic extract are between 794.97 and 269.07 and in aqueous extract between 472.02 and 584.46 mg Trolox/mL. For phenols in hydroalcoholic extract, it ranges from 8.76 to 5.05, and for aqueous extracts, it ranges from 5.23 to 6.01 mg GAE/mL (Table 2).

The amount of phenols was lower in this experiment than in previous works; we found 2,800 mg of gallic acid/100 g of



Graph 1. Roasting curve of coffee with an entry temperature of 210°C (experiment 1).



Graph 2. Roasting curve of coffee with an entry temperature of 215°C (experiment 2).

Table 2. Results of the chemical analysis of the roasted coffee*.

Treatments		Antioxidants (mg Trolox/mL)		Phenols (mg EAG/mL)	
		Hydroalcoholic	Aqueous	Hydroalcoholic	Aqueous
Temperature (°C)	Time (min)	X̄ ± DE	X̄ ± DE	X̄ ± DE	X̄ ± DE
	8	794.97 ± 33.76a	472.02 ± 40.73g	8.76 ± 1.34a	5.23 ± 1.28c
	9	769.97 ± 04.88b	510.87 ± 04.62f	7.46 ± 0.25b	5.46 ± 0.68b
210	10	757.54 ± 19.68b	521.51 ± 02.69e	6.17 ± 0.16d	5.35 ± 0.90b
	11	741.64 ± 57.69b	526.12 ± 00.92d	5.63 ± 1.23e	5.24 ± 0.86c
	12	722.28 ± 05.00c	531.76 ± 03.22d	6.38 ± 0.47c	4.75 ± 0.29d
	8	675.87 ± 04.22d	538.94 ± 00.62c	6.19 ± 0.35d	4.34 ± 0.44f
	9	576.25 ± 14.92e	543.05 ± 02.90c	6.47 ± 0.86c	4.52 ± 0.33e
215	10	406.13 ± 60.43f	550.61 ± 02.16b	5.13 ± 0.51f	5.44 ± 0.48b
	11	310.87 ± 21.93g	561.76 ± 06.54b	5.61 ± 0.15e	4.84 ± 0.60d
	12	269.07 ± 18.47g	584.46 ± 06.57a	5.05 ± 0.75f	6.01 ± 0.16a

*Values are expressed as mean ± standard deviation (X̄ ± DE). Values with different letters (a, b, c, d, e, f, and g) within the same column indicate significant differences ($p \leq 0.05$) between variables for both experiments and the five roasting times.

sample, while Díaz et al. (2018), which reported 3,300 and 3,400 mg of gallic acid/100 g of sample. The total phenol content was significantly lower with longer roasting times, showing that roasting time negatively affected the retention of total phenols. This is in line with the findings of Kwak et al. (2017), who found that high temperatures reduced the preservation of total phenols in coffee roasted at 180–200°C using hot air. Similarly, Somporn et al. (2011) found that the amount of polyphenols decreased with the increasing roast strength of coffee (light to dark).

The increase in phenol content during roasting times is directly related to the thermal process involved in the synthesis of secondary products of the Maillard reaction (Moreira et al., 2017). Some of these secondary additives are melanoidins or brown-colored compounds with antioxidant action, flavor formation, color, and reducing attributes (Lee et al., 2017). In conclusion, Ross et al. (2011) stipulated that phenolic compounds have a thermo-sensitive nature compared with their antioxidant activity formed in the roasting process due to the breakdown and transformation of chlorogenic acids. These compounds are decisive in the cup profile because they form a wide range of compounds affected by the degree of roasting and coffee processing. Lazcano-Sánchez et al. (2015) determined that the effect of roasting on antioxidant activity tends to decrease as the roasting level increases in coffee beans from Nayarit, Puebla, and Chiapas, as was the case with antioxidants in hydroalcoholic extracts in both experiments in the present research. In summary, the best numerically evaluated sample from the two experiments with the five roasting times was the 215°C/10 min treatment, though this difference was not significant ($P \leq 0.05$).

4 CONCLUSION

Based on the density obtained and the number of defects found, coffee from the State of Mexico can compete with coffee from areas in the country that are more widely recognized for their coffee production. The best treatment from a physical and chemical point of view was at a temperature of 215°C and between 10 and 12 min of roasting.

A roasting protocol has been developed that lays the foundation for improving coffee processing in the State of Mexico.

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