Roasting optimization of peaberry coffee beans from dry cherry fruits

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ABSTRACT. The roasting process involves the conduction and convection of heat from the roaster to the coffee beans, resulting in changes in the physical characteristics of the beans and in the sensory profile of the beverage. This study aimed to evaluate the conduction of the process by contrasting the changes in physical characteristics with the optimization of sensory parameters. The temperature profiles shown by the beans illustrate the appropriate conduction of the process under study. According to the different curves, differences in moisture, mass loss, bulk density and swelling were observed. The optimal condition for conducting the process, with achieved greater sensory merits, was the more severe roasting condition indicated by the high temperature.

Key words: roaster; peaberry beans; sensorial analysis; physical properties.

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INTRODUCTION

In Brazil and in many other countries, the coffee plants fruits are processed from two different forms according to the maturation stages of the fruits. The fruits are separated by densities: one being the cherry coffee processed a wet via and the other is a dry cherry fruit that floats during the process of separation and is processed by a dry via. The coffee beans from different type of processing have different cup qualities, chemical composition and flavor. In the dry via, the fruits are dried whole, with the peel, pulp and mucilage. This coffee is called natural coffee (Clemente et al., 2015; Kipkorir et al., 2015; Taveira et al., 2015; Fassio et al., 2017; Ribeiro et al., 2017).

Peaberries and flat beans are a classification of crude coffee beans according to the shape and size of the grains (Brasil, 2003). Peaberry is the term used when only one of the two ovaries in the flower ate pollinated or accept pollination. Thus, it produces a single oval bean rather than a usual pair of flat-sided beans (triaxial ellipsoid). Around 5% of all coffee beans harvested are of this form and demanding markets tolerate up to 10% peaberry beans in coffees classified as flat beans (Laviola et al. 2006; Garuma et al. 2015). Peaberry beans are often separated from the rest of the harvest and sold separately, in most cases it demands a higher price when compared with flat beans, it´s supposed to be a more concentrated flavor compared to normal beans (Suhandy & Yulia, 2017). In the literature, a few studies are found about the roasting of peaberry beans and the characterization of these roasted beans. Pimenta et al. (2009) assessed the physical, chemical and sensorial parameters and roasted curves of flat and peaberry from natural processing. Suhandy e Yulia (2017) used UV-Visible Spectroscopy combined with SIMCA and PLS-DA for discriminating peaberry coffee beans from flat coffee beans.

According to SCAA (2007), the first stage of the sensorial analysis consists of evaluating the fragrance/aroma attribute, with the first being assessed with the coffee powder still dry and the second after three minutes of adding water at the moment of breaking the crust formed on the surface of the infusion. The tasters assign scores from 0 to 10 based on their evaluation criteria, using mineral water at a temperature of 90°C. In the second stage, the evaluation of the attributes flavor, acidity, aftertaste, body, and balance is carried out. Each attribute receives scores from 0 to 10. The beginning of this stage occurs with the solution temperature between 45ºC and 50ºC. In the third stage, the attributes of sweetness, clean cup, uniformity, and overall impression are evaluated. For the first three criteria, the evaluation is done individually for each cup, which receives two points if the assessment is positive and zero points if the assessment is negative. The final result of these attributes is computed by summing the scores assigned to the 5 cups; for the overall impression attribute, scores from 0 to 10 were assigned. In the fourth and final stage, the final score was given by summing all the attributes.

Roasting is responsible for changes in physical and sensorial characteristics of crude beans. The major changes in physical characteristics are the change in colour, weight loss, bulk density, swelling and reduction on water content. These parameters are influenced by the degree of roast in the process (Shan et al., 2015; Vargas-Elias et al., 2016; Santos et al., 2016; Silva, 2008). Roasting can be divided in three main steps: drying, pyrolysis and cooling. Drying is characterized by large water removal, volatile compound losses and small changes in physical and sensorial properties. In pyrolysis, chemical reactions take place and considerable modification on grain properties occur with liberation of CO_2 . After the degree of roasting becomes desirable, cooling is necessary to avoid coffee burn (Eggers & Pietch, 2001; França et al., 2009; Wang & Lim 2016; Schenker & Rothgeb 2017).

In the coffee folklore, peaberries are considered superior to the rest of same crop harvested because all the flavors and nutrients that would be divided into a double bean are instead condensed into just the one bean and its flavor tends to have a finer quality than the rest of the crop. The appeal of the peaberry lies in the fact that peaberries are thought to roast better than regular coffee beans. It is said that by their rounded shape, peaberries are heated more evenly during the roasting process. This produces a flavor that is more complex when compared to a flat coffee bean. All the information is available in websites that sell roast peaberry coffee with high prices in the markets of word, without scientific knowledge. This information is not in accordance with the study of Pimenta et al. (2009) that found the same behavior in the roasting process when comparing peaberries with flats beans and minor notes for all sensorial attributes for peaberries beans based on methodologies of the Specialty Coffee American Association (SCAA, 2008) when compared with flat beans of the same crop harvested.

The aim of this work was to determine the best interaction between time and temperature of roasting conditions of peaberry beans from dry cherry fruits combined with three different degrees of roasts (light, medium and dark) in order to obtain the best results for sensorial parameters and also to verify the changes in physical attributes of these roasted coffees.

MATERIALS AND METHODS

The experiments were performed in the Polo of Technology in Coffee Quality of the Research and Education of Agro Business Coffee (CEPECAFÉ) from the Federal University of Lavras (UFLA), Lavras, Minas Gerais, Brazil. The beans were all from the same planting field and the same variety. The fruits were processed in the same day and presented initial moisture content around 11 to 12% (w.b). The peaberry crude beans from dry cherry fruits were manually separated according to the size of screens of sieves used for coffee classification, according to the Normative Instruction of June 11 th , 2003, the Ministry of Agriculture, Livestock, and Supply (MAPA) (Brasil, 2003). Such sieves were numbered from 12 to 19 for flat beans and from 8 to 13 for peaberry beans. The samples used in the present work were sets of mixed peaberry beans retained in sieves 13, 12 and 11. The defective (immature, black, sour, etc.) beans were manually removed.

Crude beans were ground in a ball grinder (model Prolabo, France), with liquid nitrogen. After this, the coffee was packed and stored at -18 o C for further analysis. Samples of 140g of coffee were submitted to convective roasting in a roaster Probat, model BRZ-6 (Germany). During the roasting process, time and temperature were measured with a digital chronometer (±0,001s, Quartz, model BVQI, Brazil) and a digital pen thermometer (±1 o C, Incoterm, model 9790, Brazil) in contact with the grains in the frontal part of the roasting chamber. The peaberry beans were submitted to light, medium and dark roasts. In the roasting, three types of process were evaluated (Table 1).

Table 1: Ways of conduction of roasting process.

Nomenclature	Temperature variation	Thermostat
T1	High temperature the entire time	100%
T2	Temperature increasing with time	70 to 100% each 3 minutes
T3	Low temperature all the time	70%

The heating rate was calculated by the ratio of temperature and time variation. These different roasting curves were applied in order to identify the degree of roast and the curve that achieved the best peaberry coffee maximum quality potential in relation to physical and sensorial characteristics. After roasting, the coffee was ground with a grinder model Pinhalense.

The physical analyses conducted in crude and roasted grains were: bulk density, with a 1000mL ± 10mL graduated cylinder (Merck, Germany); grain dimensions measurement, with a digital paquimeter (Digimess, China) in three dimensions using 50 grains, as proposed by Fishcher eCammenga (2001); swelling was obtained by the difference between roasted and crude bean dimensions; weight loss was evaluate as a percentage in sample weight, prior to and after roasting and moisture content according to the Association of Official Analytical Chemists procedures (AOAC, 2005).

Color analyses of the ground coffee were performed with the colorimeter (Minolta, model CR 300, Japan), D 65 (day light), angle of observation 10 o . The values Hunter L*, a* and b* were processed by the software COLORPRO (USA) (Rodrigues et al., 2003). The measurements were done in five points of a grind sample in a Petri plate and the average value was processed by the software. Polar coordinates were used and so was the hue angle – h, which corresponds to the shade related to the final point of roasting.

Sensorial analyses were performed by two trained tasters, based on Specialty Coffee American Associations recommendations (SCAA, 2008). All roasted samples had stayed in rest for 12h before the sensorial analysis. In order to apply the treatments, 5 cups were prepared using 8.5 x 10 -3 kg of ground coffee of the size 20 mesh sieve in each cup, for each kind of roasted coffee. The attributes were evaluated with merits from 0 to 10 (maximum).

For the physical analyses of the experimental design were completely random, using three replicas of factorial scheme 3x3. The factors consist in degrees of roasting (light, medium and dark) and roasting conditions (T1, T2 and T3). For the sensorial analyses, the experimental design was in complete blocks, consisting of two blocks where each block represented a trained taster (Mason et al., 2003). In order to compare the means the Tukey test was used with a level of 5% significance. All the obtained data was evaluated by the software Sisvar 5.6 (Ferreira, 2011).

RESULTS AND DISCUSSION

The physical attributes of crude peaberry beans are shown in Table 2. The bulk density value found in this work is higher than those found by Belay et al. (2014), Olunkule e Akinnuli (2012), Mendonça et al. (2009), França et al. (2005a) and França et al. (2005b) that ranged between 407-660 kg m -3 for flat beans. These results showed that peaberry beans present lower volume when compared with flat beans.

Table 2: Physical attributes of dimension, bulk density and moisture content of crude peaberry beans.

Attributes	Crude Peaberry Beans
Bulk density (kg m^{-3})	679.0±1.0
Dimension X-axis x 10^{-3}	8.4±0.2
Dimension Y-axis x 10^{-3}	5.1±0.2
Dimension Z-axis x 10^{-3}	4.5±0.1
Moisture content (w.b)	11.1±0.1

The length (X-axis) of peaberry beans is similar to those found by flat beans for Belay et al. (2014) and Olunkule e Akinnuli (2012). Width (Y-axis) and thickness (Z-axis) lower and higher values, respectively. The knowledge of these attributes is important for the monitoring of the physical changes that occur during roasting.Figures 1 and 2 show the roasting curves obtained in this work and present the development of temperature that present the best sensorial merits (Table 5).

The average heating rate of T1, T2 and T3 were respectively 12 o C/min, 10 o C/min and 8 o C/min. The roasting times and temperatures for T1 was 12 minutes and 233 o C; T2, 15 minutes and 236 o C and T3, 17 minutes and 230 o C for dark roast (Figure 2).

The similarity of the temperature profile showed in Figure 1 is an indicative of the suitable roasting process conduction with the roasted used in this work; the same can be noted for the other roasting curves (data not showed). With the different forms of heat conduction, the roasting curves (Figure 2) presented different behavior, this is in agreement with the study conducted by Pimenta et al. (2009), which concluded that temperature profiles of roasted beans depend on the way of heat increases rather than the grain shape.

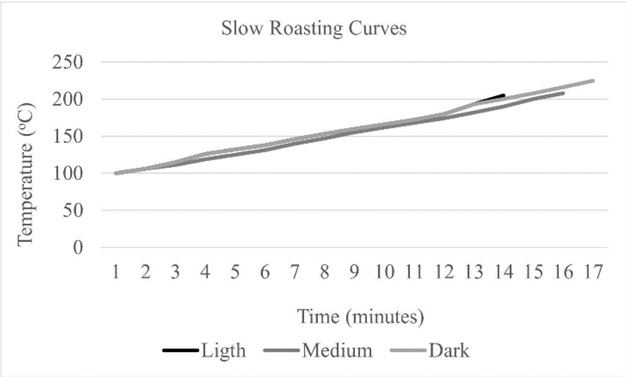

Figure 1: Roasting curves of beans roasted in light, medium and dark degrees of roast.

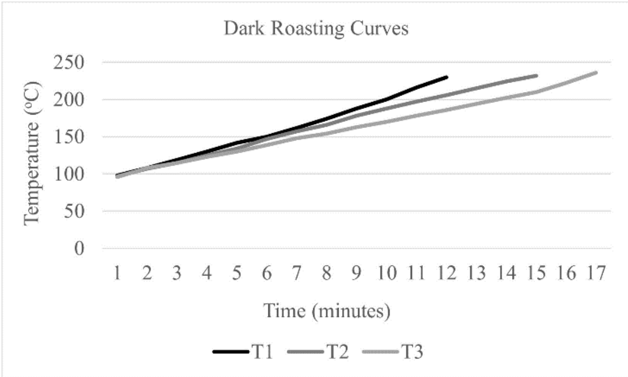

Figure 2: Roasting curves of beans roasted in T1, T2 and T3 conditions.

The physical parameters of roasted beans in different roast condition and degree of roast are shown in Table 3. The shade (h) of beans did not present differences for each way of roast in the three final colours of the beans studied. This fact is important due to the physical and sensorial characteristics which are variable according to the final colour of roasted beans. These results confirm proper conduction of the roasting, since the end of the process was evaluated by visual inspection of the colour. In the other hand, in the degree of roasts studied, the shade present difference, where light and dark roasts obtained major and less values, respectively. This fact is in accordance with the one obtained by Rodrigues et al. (2003), Borges et al. (2004) and Bicho et al. (2012).

Moisture content presents differences with different roast conditions in all degree of roasts studied. The values for fast roasting (T3) tend to be smaller than T1 due to the minor time of roasting where less vaporization of water, degradation and volatilization of organic compounds occur. Light roast, with minor time and final temperature of the beans, present greater moisture content than medium and dark roasts. There was a tendency of major values for T1 when compared with T3, probably due to the different times of the process. Vasconcelos et al. (2007) obtained minor values for water (%db) of non-defective beans when compared with this work of 0.9,0.9 and 1.0 for the light, medium and dark roasts due to the major time of roasting (30, 60 and 120 minutes). The values obtained by Bicho et al. (2012) varied from 1.32 to 3.12 for the different roasting conditions.

Only in dark roast, there was difference according to the different roast conditions for weight loss (W L). Light roast presents minor values when compared to the medium and dark ones, due to the minor roasting time and consequently minor release of CO_2 , vapour and organic compounds during pyrolysis. França et al. (2009) obtained weight loss values of 19, 15 and 14% corresponding to dark, medium and light roasts, and the weight loss obtained by Silva (2008) was smaller, varying from 17 to 13% for light and dark roasts, respectively. Vargas-Elias et al. (2016) obtained for weight loss average, values of 20, 18 and 17 for dark, moderately dark and light roasts, respectively.

The bulk density (ρ_B) of roasted coffee beans has the greatest importance to influence the quality of the packaging process of the whole roasted beans, roasted and ground coffee, since roasted beans presenting minor density in grind generate a greater number of particles (beans with greater swelling). This fact may hamper the packing step if the packages are not correctly sized or if the company does not have densification systems (Silva, 2008). In this work, there was a significant decrease in bulk density (678,67 kg m-3 – Table 1) after roasting due to simultaneous increase in volume (due to an increase in internal pressure) and decrease in mass (due to loss of volatiles). Coffee roasting in T3 conditions presented greater bulk density than those roasting in T1 conditions for light and medium roasts, indicative of smaller final volume of beans in roasting with slow temperature and greater roasting time. This fact is related to slow liberation of steam, CO_2 and volatile compounds, resulting in lower pressure on cellular structure during roast T3. Similar results were obtained by Pimenta et al. (2009). In relation to the degree of roasts, light roast presented greater bulk density when compared with medium and dark roasted coffee, just by short period of time process with consequent interruption of the pyrolytic product reaction. Dutra et al. (2001) and Rodrigues et al. (2003) cite that for an adequate roasting process the bulk density varies between 315 and 370 kg m -3 for light-medium degree of roast and 250-290 kg m -3 for dark roast. In this work, similar values were obtained for light and medium roast, and the dark roast has obtained greater values.

Table 3: Physical attributes of coffee beans submitted to different degrees and ways of roasting.

Degree of roast	Roasting	h	MC	WL	ρB	X axis	Y axis	Z axis
	T1	66.4±1a	2.7±0a	14.7±1a	374±8b	9.4±1b	34±0a	28.9±1a
Light	T2	66.4±0a	2.4±0b	15.6±0a	369±9b	12.8±2a	34.7±1a	27.3±2a
	T3	66.6±0a	2.2±0b	14.9±0a	390±9a	10.5±1b	34.7±1a	25.8±1a
Average		66.5A	2.4A	15.1B	377A	10.9C	34.5A	27.3A
	T1	63.5±0a	1.5±0b	18.4±1a	335±8b	13±1a	35.5±1a	28.2±1a
Medium	T2	63.5±1a	1.9±0a	18.1±0a	337±2b	12.4±1a	34.4±1ab	29.1±1a
	T3	64±0a	1.4±0b	17.5±1a	363±1a	11.3±1a	30.8±1b	26±1a
Average		63.4B	1.6B	18A	344B	12.2B	33.5A	27.8A
	T1	61±0a	1.8±0a	19.3±1b	328±2b	13.2±1a	34.7±1a	27.5±1a
Dark	T2	60.4±0a	1.5±0b	20.7±0a	317±4b	14.8±1a	34.5±2a	29.5±1a
	T3	61.8±0a	1.2±0b	20.1±0a	330±1a	14.2±1a	35.3±1a	28.9±2a
Average		61.1C	1.5B	20A	325C	14.1A	34.8A	28.6A

Average ± standard deviation. Values followed by the lowercase and uppercase column do not differ significantly using the Tukey test at 5% probability.

The bulk density (ρ B) of roasted coffee beans has the greatest importance to influence the quality of the packaging process of the whole roasted beans, roasted and ground coffee, since roasted beans presenting minor density in grind generate a greater number of particles (beans with greater swelling). This fact may hamper the packing step if the packages are not correctly sized or if the company does not have densification systems (Silva, 2008). In this work, there was a significant decrease in bulk density (678,67 kg m-3 – Table 1) after roasting due to simultaneous increase in volume (due to an increase in internal pressure) and decrease in mass (due to loss of volatiles). Coffee roasting in T3 conditions presented greater bulk density than those roasting in T1 conditions for light and medium roasts, indicative of smaller final volume of beans in roasting with slow temperature and greater roasting time. This fact is related to slow liberation of steam, CO_2 and volatile compounds, resulting in lower pressure on cellular structure during roast T3. Similar results were obtained by Pimenta et al. (2009). In relation to the degree of roasts, light roast presented greater bulk density when compared with medium and dark roasted coffee, just by short period of time process with consequent interruption of the pyrolytic product reaction. Dutra et al. (2001) and Rodrigues et al. (2003) cite that for an adequate roasting process the bulk density varies between 315 and 370 kg m -3 for light-medium degree of roast and 250-290 kg m -3 for dark roast. In this work, similar values were obtained for light and medium roast, and the dark roast has obtained greater values.

In relation to swelling there is a trend of non-variation within the different roast condition for X, Y and Z-axis. Only the X-axis presents variation according to different colored beans being that in light roast where minor value was obtained due to a shorter processing period. For flat beans, due to convex shape plan, there is minor resistance in the Z- axis, thus providing bigger swelling during roasting (Silva,2008). For the peaberry beans, greater swelling in Y-axis was noticed due to the oval shape.

Table 4 and 5 shows the merits obtained by the roasting coffees, according to an evaluation by trained taster based on SCAA recommendations (SCAA, 2008).

In respect to aroma/fragrance, the values of light and dark roast were the same and not a function of the way of roasting. In medium roast, a major value was obtained for slow roasting (T3) when compared with fast roasting (T1). The degree of roast did not present influence for this attribute. The values obtained by Silva (2008) for flat beans varied between 6.75-7.5 being the closest for this research work.

In relation to the comments made by the tasters, they had the following characteristics for aroma/fragrance: slow roasts with slight fragrance of chocolate and vanilla, slight chocolate and bitter chocolate for light and dark degrees of roasting, respectively. T2 had a slight fragrance of chocolate, a light fragrance of cinnamon and fragrance of bitter chocolate with a hint of cinnamon flavor for light, medium and dark roasting, respectively.

Table 4: Sensorial attributes of coffee beans submitted to different degrees and ways of roasting.

Degree Roast	Roasting	Aroma	Uniformity	Clean Cup	Sweetness	Flavor
	T1	7.2±0.2a	10±0a	8±0.2a	8±0.2a	7±0.1a
Light	T2	7.2±0.2a	10±0a	8±0.2a	8±0.0a	6.5±0.2b
	T3	7.2±0.1a	10±0a	8±0.2a	8±0.2a	7±0.1a
Average		7.2A	10A	8B	8B	6.8A
	T1	6.7±0.2b	10±0a	10±0a	10±0a	6.5±0.3a
Medium	T2	7±0.2ab	10±0a	10±0a	10±0a	6.7±0.1a
	T3	7.2±0.1a	10±0a	10±0a	10±0a	6.7±0.3a
Average		7A	10A	10A	10A	6.7A
	T1	7±0.1a	10±0a	10±0a	10±0a	6.2±0.1b
Dark	T2	7.2±0.3a	10±0a	10±0a	10±0a	6.5±0.2a
	T3	7.2±0.2a	10±0a	10±0a	10±0a	6.5±0.3a
Average		7.2A	10A	10A	10A	6.4B

Average ± standard deviation. Values followed by the lowercase and uppercase column do not differ significantly using the Tukey test at 5% probability.

Table 5: Sensorial attributes of coffee beans submitted to different degrees and ways of roasting.

Degree Roast	Roasting	Acidity	Body	After taste	Balance	Overall	Final score
	T1	7.2±0.3a	6.7±0.2a	6.2±0.2b	6.5±0.2a	6.2±0.1b	73±0.7a
Light	T2	7.2±0.2a	6.7±0.7a	6.5±0.2a	6.7±0.3a	6.7±0.2a	73.5±1.3a
	T3	7.2±0.2a	6.7±0.3a	6.2±0.3b	6.5±0.3a	6.2±0.1b	73±0.8a
Average		7.2A	6.7A	6.3A	6.6A	6.4A	73.4C
	T1	6±0.3a	6.2±0.2a	6.5±0.3a	6.2±0.1b	6.2±0.2b	74.3±1.5b
Medium	T2	6±0.2a	6±0.2a	6.5±0.1a	6.5±0.1a	6.5±0.1a	75.4±0.8a
	T3	6.2±0.3a	6.2±0.1a	6.5±0.3a	6.5±0.1a	6.5±0.1a	75.8±1.1a
Average		6B	6.2B	6.5A	6.4A	6.4A	75,2B
	T1	6.2±0.3b	6.5±0.2b	6.2±0.3b	6.2±0.1b	6.2±0.1b	74.5±0.9b
Dark	T2	6.5±0.2a	7±0.1a	6.5±0.2a	6.5±0.2a	6.5±0.2a	76.7±1.2a
	T3	6.5±0.3a	7±0.2a	6.5±0.3a	6.5±0.1a	6.5±0.1a	76.7±1a
Average		6.4B	6.8±A	6.4A	6.4A	6.4A	76.1A

Average ± standard deviation. Values followed by the lowercase and uppercase column do not differ significantly using the Tukey test at 5% probability.

The attributes uniformity is the same in all treatments studied and present greater merits. The uniformity refers to consistence of different cups and tasting samples. The same results were found by Silva (2008). In relation to a clean cup, light roasts present minor values when compared to medium and dark roasts, even with no defects. The same occurs in sweetness that refers to the pleasurable sweet flavor being perceived as the result of certain carbohydrates present. The opposite of sweetness, in this context, is astringency or bitterness (SCAA, 2008).

In relation of flavor, major notes were obtained for light and medium roasts when compared to dark ones. According to SCAA (2008), the acidity may be pleasant or not varying in nature of acids predominant in the brew being that pleasant acidity contributes to the vivacity of the coffee, increases the perception of sweetness and confers the characteristic of dry fruits. Light roast presented major values when compared with medium and dark roasts. According to Silva (2008), light roast accents the perception of this attribute, while in slow roasting the opposite is noticed. These were verified in this study.

Balance or equilibrium refers to the synergy of flavor, acidity and body. This attribute was the same in the degree roasting studied. In medium and dark roasts, T1 presents minor value. In relation to overall, the values did not present any difference according to the degree of roasting. T2 in light roast and T2 and T3 in medium and dark roasts obtained higher values.

For the body, light and darks roasts obtained the same value, with differences of medium roast that present a minor value. In dark roast, there was variation according with the different ways of conduction with process being a slow roast, thus obtaining minor value. For the aftertaste, the values obtained for light, medium and dark roasts where the same. In medium roast, the same values were obtained for different roast conduction, while in the other degrees of roast, T2 presents major values. T2 and T3 in light roast present an astringent aftertaste that is worse with sample cooling.

With respect to the final score, that is a sum of the other attributes, the light roast obtained minor values. T2 e T3 in dark roast obtained the same results, since in all of its attributes evaluated the notes are equal, with final score of 76.7. These conditions of roasting and degree of roast are optimum for peaberry beans from dry cherry fruits, obtaining the maximum quality potential in relation to sensorial attributes.

CONCLUSION

In this study, the roasting steps were not distinguished in the temperature profile. Evaluation of the roasting curves concludes that the roasting was conducted properly. Physical parameters of peaberry roasted beans are in accordance with the literature values for flat beans, with variation only in the Y-axis swelling that correspond to width. Peaberry roasted beans were optimum in dark roast and two different ways of roasting: a fast way and an increase in temperature being classified as below Premium, according to the final score of the SCAA.

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DECLARATION OF CONFLICT OF INTEREST

We have no conflict of interest to declare

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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