ROASTING PROCESSING OF DRY COFFEE CHERRY: INFLUENCE OF GRAIN SHAPE AND TEMPERATURE ON PHYSICAL, CHEMICAL AND SENSORIAL GRAIN PROPERTIES

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Roasting is responsible for physical, chemical and sensorial changes in coffee, like color change, weight loss, swelling and compounds generation that are responsible for the flavor and the taste of the beverage. Roasting of dry coffee cherry in two shapes process was studied in this work with flat and peaberry beans. The influences of temperature development and grain shape were evaluated with respect to bulk density, moisture reduction, swelling rate, changes in grain dimensions, pH, soluble solids, acidity, weight loss, reducing and non-reducing sugars, color and sensorial attributes. Three types of temperature development were compared: high temperature all the time (T_1); temperature increasing with time (T_2) and low temperature all the time (T_3) for flat and peaberry. Roasting T_1 and T_3 were developed on shorter periods for peaberry beans. The same was observed with T_2 for flat beans. Differences on bulk density, final moisture content, pH, swelling and soluble solids were also observed. The best results of sensorial analysis were obtained with T_2 conditions for both types of coffees.

KEY-WORDS: ARABICA COFFEE; ROASTING; FLAT BEANS; PEABERRY BEANS; COFFEE - GRAIN SHAPE.

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1 INTRODUCTION

In Brazil, coffee is used to be processed by dry or wet method. Most of the cases, dry processing is used. It is called natural processing. In such process, the fruit is whole dried, with peel, pulp and mucilage due to its maturation stage (MALTA, CHAGAS & OLIVEIRA, 2003).

The roasting process is complex and several parameters and processes influence each other. Roasting is induced by heat energy from the roaster. Heat from hot gases or hot metallic surfaces is transported into the green bean. The bean heats up and water begins to evaporate in an endothermic process. Gaseous reaction products like carbon dioxide and water vapor leave the bean. Gases entrapped in cells lead to an increase in the internal bean pressure. Mass and heat transfer are unsteady so that time-dependent temperature and concentration profiles form inside the bean, which have not yet been elucidated (EGGERS and PIETSCH, 2001).

Roasting is a decisive operation on coffee final quality. It is dependent on variables as coffee type, temperature and time. Roasting causes physical, physical-chemical and chemical changes. Those changes are responsible by characteristics compounds, color, taste and flavor. The kind of physical-chemical and chemical changes involved on roasting are function of preliminary physical and chemical characteristics, stability of substances on raw grains, type of equipment and variables control, like temperature and time (MARIA et al., 1996).

The roasting process can be divided into three consecutive stages: drying, roasting or pyrolysis and cooling. Drying is characterized by slow water and volatile compounds losses. In the beginning of drying, a slight change in the aroma and color occurs. The beans color changes from green to yellow. During the second stage of drying, pyrolysis reactions take place, resulting in considerable changes in physical and chemical properties of the beans. A great production of CO_2 is noted, water and volatile substances and the beans turn brown, due to sugar caramelization that came together with Maillard reactions. At this point, cooling is required in order to avoid coffee burning (ILLY and VIANI, 1998; RODRIGUES et al., 2003).

BORGES et al. (2004) classified roasting as a pirolysis process with several chemical and physical reactions like CO_2 removal, beans swelling and characteristic flavor development. For a classification of coffee with respect to cup quality, clean, or American roasting is used because it takes into account the main sensorial attributes taste, aroma, sweetness, body and acidity. The American roasting shows the characteristics of raw grains in a more evident way (VILELLA et al., 2002).

The aim of this work was the study of roasting of flat and peaberry beans, originated from natural processing. It was intended to relate such variables to the quality of the final product with respect to bulk density, moisture reduction, swelling, grain dimensions, soluble solids, acidity, weight loss, total, reducing and non-reducing sugars, and color. Sensorial analysis were also used.

2 MATERIAL AND METHODS

The experiments were accomplished in the Technology Pole of Coffee Quality in the Research and Education of Agro Business Coffee (CEPECAFÉ) from the Federal University of Lavras (UFLA), Lavras (MG – Brazil). The beans were all from the same planting field and the same variety. The fruits were processed in the same day. They came from grain drying with moisture content about 11 to 12% (w.b.).

The flat and peaberry raw beans were used. These beans were separated according to the size of screens of sieves used for the classification of coffee, according to the Normative Instruction of June 11th, 2003, the Ministry of Agriculture, Livestock, and Supply (MAPA) (BRASIL, 2003). Such sieves were numbered 12 to 19 for flat beans and from 8 to 13 for peaberry beans. Flat beans were selected in sieves 15; 14; 13 and 12, and peaberry beans obtained in sieves 13; 12 and 11 of the species *Coffea* *arabica* L. originated from a natural processing. The flat beans retained in sieves 15; 14; 13 and 12 were mixed and treated as a unique sample in the experiments. Peaberry beans retained in sieves 13; 12 and 11 were mixed and treated as a unique sample in the experiments also. The defective beans were removed manually. The experimental design was completely randomized with four repetitions, and the treatments made by dry coffee cherry, subcategory flat and peaberry.

Raw grains were ground in a ball grinder (model Prolabo, France), with liquid nitrogen. After this, the coffee was packed and stored at -18ºC until submitted to chemical analysis.

Samples of 140 g of coffee were submitted to roasting in a roaster Probat, model BRZ-6 (Germany). The experimental design was completely randomized with three repetitions, with factorial (2 x 3) submitted to three ways of roasting (MASON, GUNST & HESS, 2003).

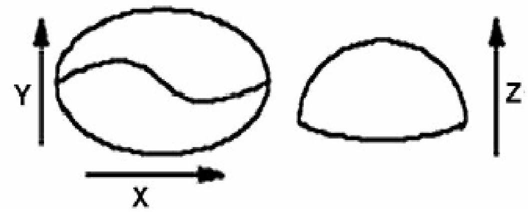
During roasting process, time and temperature were measured with a digital chronometer (±0,001s, Quartz, model BVQI, Brazil) and a digital pen thermometer (± 1ºC, Incoterm, model 9790, Brazil) in contact with the grains in the frontal part of the roasting chamber.

Each subcategory of coffee was submitted to light or American roasting (MENDONÇA, PEREIRA & MENDES, 2005). After roasting, coffee was ground with a grinder model Pinhalense (Brazil). The color of roasted beans was evaluated with a Minolta colorimeter; model CR 300 (Japan). Then, physical and chemical analyses were done.

In the roasting, three types of process were evaluated: high temperature all the time (T_1); temperature increasing with time (T_2) and low temperature all the time (T_3) (SILVA, 2008). T_1 was done with the thermostat at 100% in a period of about 10 minutes and T_2 was done with increasing temperature. The thermostat was from 70% to 100%, increasing 10% each 3 minutes. In the T_3 process, the thermostat was at 70% during all the roasting time for about 15 minutes. The initial temperature for all roasting was 150ºC, temperature recommended by the roaster manufacturer.

The physical and chemical analyses done in the raw grains and roasted grains were: bulk density, with a 1000 mL ± 10 mL graduated cylinder (Merck, Germany). The goal of this analysis was the determination of density in a coffee package; Grain dimensions measurement, with a digital paquimeter (Digimess, China) in three dimensions (Figure 1) using 90 grains, like proposed by FISCHER and CAMMENGA (2001), weight loss and moisture content, total, reducing and non-reducing sugars, acidity (expressed in mL NaOH g coffee^{-1}) and pH (AOAC, 2005). Color analyses were done with ground coffee using a Minolta colorimeter, model CR 300 (Japan), D_{65} (day light), angle of observation 10º. The values Hunter L*, a* and b* were processed with the software COLORPRO (USA) (COLORPRO, 2007). The measurements were done in five points of a sample in a Petri plate and the average value was processed by the software. Polar coordinates were used and the variable h, which corresponds to the shade related to the final point of roasting.

FIGURE 1 - DIMENSION OF THE COFFEE BEAN



Sensorial analyses were performed with two trained tasters, based on Specialty Coffee American Association (SCAA, 2007) recommendations. The attributes were evaluated with ranges from 0 to 10 (maximum).

All the obtained data was statistically evaluated with the software Sisvar (FERREIRA, 2000), and Tukey test level at 5% of significance.

3 RESULTS AND DISCUSSION

The average data of physical and chemical attributes of raw coffee beans are listed in Table 1.

According to Table 1, length of the grains (X axis) flat and peaberry were not significantly different. In order to establish a difference between flat and peaberry beans, LAVIOLA et al. (2006) reported that the difference between peaberry and flat coffees are that peaberry presents larger values of X and Z dimensions. This was true for the present work only for Z dimensions. With respect to Y axis, that represent the intermediate diameter, flat beans presented greater values than the presented by peaberry beans. These initial analyses are important to measure grains swelling after roasting.

TABLE 1 - PHYSICAL AND CHEMICAL ATTRIBUTES OF RAW COFFEE BEANS

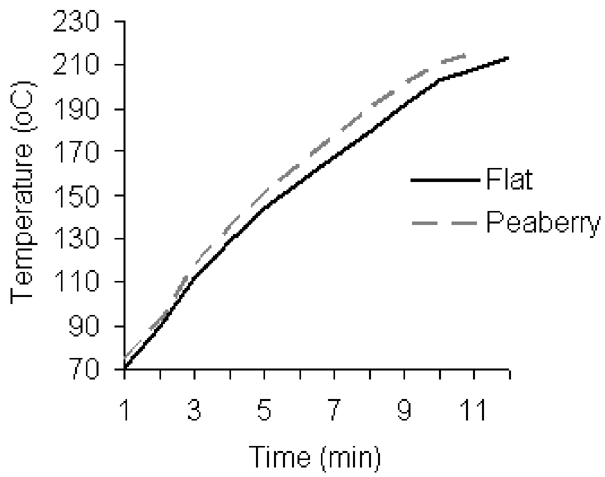
Grain shape	Flat beans	Peaberry beans
Bulk density (kg m^{-3})	674.8 ± 2.23^a	678.6 ± 1.07^a
Dimension X axis (mm)	8.4 ± 0.13^a	8.4 ± 0.2^a
Dimension Y axis (mm)	5.8 ± 0.06^b	5.0 ± 0.07^a
Dimension Z axis (mm)	3.4 ± 0.07^a	4.5 ± 0.19^b
Moisture (w. b.)	11.1 ± 0.05^a	11.1 ± 0.04^a
Soluble solid (°Brix)	27.3 ± 2.6^a	30.5 ± 1.3^a
Acidity (mL NaOH 0,1 N g coffee^{-1})	192.1 ± 13.25^b	165.6 ± 13.25^a
pH	6.06 ± 0.01^a	6.05 ± 0.01^a
Total sugars (%)	7.24 ± 0.14^a	7.30 ± 0.17^a
Reducing sugars (%)	2.46 ± 0.29^b	1.62 ± 0.28^a
Non-reducing sugars (%)	4.77 ± 0.25^a	5.68 ± 0.41^b

Same letter means without significant difference at 5% by Tukey test.

Table 1 also shows that flat beans presented higher acidity and reducing sugars and peaberry beans, higher non-reducing sugars. The other variables (bulk density, moisture content, soluble solids, pH and total sugars) do not present significant difference by Tukey test.

Figures 2 to 4 present the temperature profile of peaberry and flat coffee beans on roasting process at T_1, T_2 and T_3 conditions, respectively.

FIGURE 2 - TEMPERATURE PROFILE OF COFFEE BEANS WITHIN T_1 CONDITIONS (HIGH TEMPERATURE ALL THE TIME)



According to Figure 2, flat beans presented the greater roasting time at T_1 conditions (12 minutes) and final temperature about 215ºC. Peaberry beans presented greater temperatures since the beginning of the process.

Figure 3 shows that after five minutes of roasting, the behavior of the temperature profiles changed. In the beginning, flat grains presented lower temperatures than peaberry grains, but in the end of the process, the temperatures were 214ºC for flat beans and 212ºC for peaberry beans. The period of roasting was shorter for flat beans (about 2 minutes less).

FIGURE 3 - TEMPERATURE PROFILE OF COFFEE BEANS WITHIN T_2 CONDITIONS (INCREASING TEMPERATURE WITH TIME)

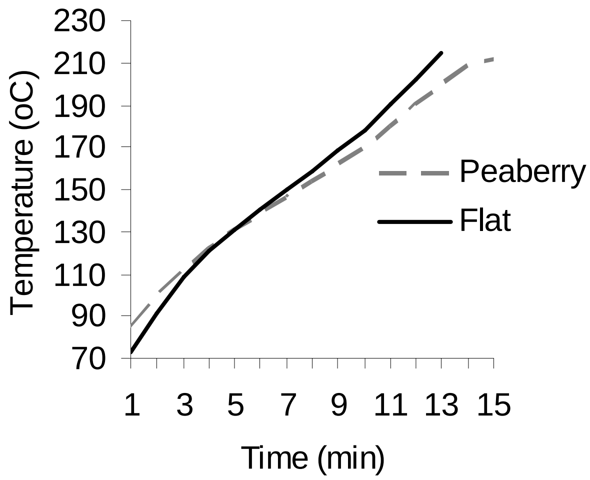


Figure 4 shows that process with low temperature all the time, T_3, carried out to a similar roasting curve in the first 7 minutes. After this point, peaberry beans presented higher temperature than flat beans. Roasting of peaberry beans finished in a shorter time, at 208ºC.

By comparing Figures 2; 3 and 4, it can seen that temperature profiles are not significantly dependent on grain shape, but dependent on the way heat is increased on the roasting process.

FIGURE 4 - TEMPERATURE PROFILE OF COFFEE BEANS WITHIN T_3 CONDITIONS (LOW TEMPERATURE ALL THE TIME)

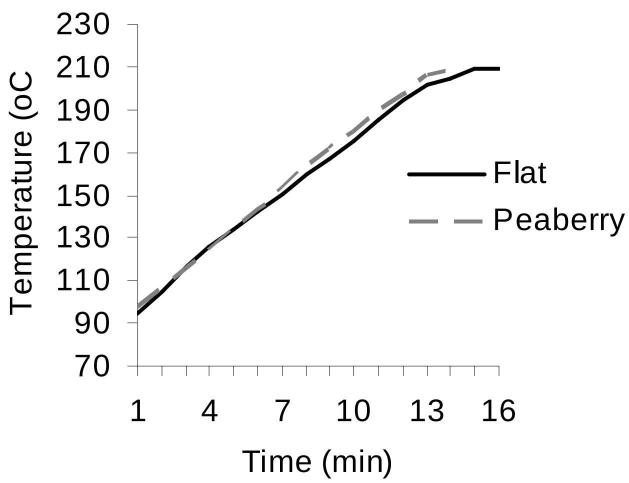


Table 2 presents physical characteristics of roasted coffee beans. This Table shows that by regarding to physical characteristics of roasted grains, both types of grains did not present significant differences with respect to shade, represented by coordinate h in T_1, T_2 and T_3. This fact suggests that the roasting processes were uniformly developed. The obtainment of a standard roasting point is important to further comparison of chemical and physical characteristics, because such characteristics are dependent of roasting point at all.

According to Table 2, the different conditions of T_1, T_2 e T_3 were not influent on the average values of weight loss for both coffee types. Weight loss is in the range 14.7 to 16.4%. SILVA (2008) studied the influence of the temperature in physical and sensorial characteristics and obtained weight loss of about 13.5% for light roasting. That author observed that weight loss was not influenced by roasting type.

TABLE 2 - PHYSICAL ATTRIBUTES OF ROASTED COFFEE BEANS

Grain shape	Flat beans			Peaberry beans		
Roasting	T_1	T_2	T_3	T_1	T_2	T_3
h	66.6 ± 0.34^a	66.3 ± 0.05^a	66.6 ± 0.06^a	66.3 ± 0.20^a	66.4 ± 0.16^a	66.6 ± 0.19^a
Weight loss (%)	15.6 ± 0.40^a	16.4 ± 0.14^a	15.6 ± 0.63^a	14.7 ± 1.03^a	15.6 ± 0.47^a	14.9 ± 0.47^a
Bulk density (kg m^{-3})	365.9 ± 6.56^a	352.1 ± 5.15^a	394.6 ± 9.85^b	373.9 ± 8.74^a	369.0 ± 8.86^a	389.9 ± 9.63^b
Swelling X axis (%)	15.9 ± 1.43^a	16.8 ± 0.18^b	15.3 ± 0.12^a	16.4 ± 0.29^b	14.5 ± 0.37^a	19.6 ± 0.39^c
Swelling Y axis (%)	21.6 ± 1.18^b	22.9 ± 0.11^c	20.3 ± 0.40^a	36.1 ± 0.20^e	34.6 ± 0.36^d	34.8 ± 0.49^d
Swelling Z axis (%)	24.8 ± 0.50^b	25.7 ± 0.30^c	22.3 ± 0.31^a	26.3 ± 0.14^d	26.9 ± 0.03^d	25.4 ± 0.51^c

Same letter means without significant difference at 5% by Tukey test.

Bulk density was greater for both coffee types at T_3. This means smaller grain volume at T_3 conditions (lower temperatures and greater roasting periods) is related to slow liberation of steam, CO_2 and volatile compounds, resulting lower pressure on cellular structure during the process. This corroborated to the work of SCHENKER et al. (2000), that observed volumetric expansion and opening micropores of cellular wall were greater in a quick roasting than in a slow one. BORGES et al. (2004) reported that volume increase is associated with swelling of cellular structure that occurs due to heat transfer and reactions in a pyrolysis process. DUTRA et al. (2001) and RODRIGUES et al. (2003) reported that in the optimum point of roasting, bulk density is in the range 315 to 370 kg m^{-3} for grains in light roast. The values obtained here at this range, or very near.

With regard to the swelling index, Table 2 shows that, except of X axis for peaberry beans, at T_3 conditions, swelling was smaller. This process was not as drastic as the others were and this should be the answer. The swelling index obtained here for flat beans are smaller than the presented by SILVA (2008). That author obtained 18.7 to 20.82; 21.96 to 24.03 and 30.27 to 33.75 for X, Y and Z axis, respectively, for coffees originated of natural processing submitted to light roasting and three types of roasting.

Table 3 shows physical and chemical attributes of toasted coffee beans.

Roasting at high temperature (T_1) carried out to greater moisture content for both flat and peaberry beans. Roasting at low temperatures (T_3) carried out to smaller moisture content. This can be due to the period of roasting.

According to Table 3, for flat beans and peaberry beans, acidity, total sugar, reducing sugars and non-reducing sugars were not dependent of the roasting type. Soluble solids and pH were almost the same for T_1 and T_2, but higher than for T_3 for both coffees type. Breaking cells of coffee beans causes a solubilization of carbohydrates and denaturation of proteins. According to EGGERS and PIETSCH (2001), the soluble solids increased as the roasting time decreased. The content of specific substances (such as saccharose) changed with roasting, indicating that the chemical compositions of traditional and fast roasted coffee are similar but not identical.

TABLE 3 - PHYSICAL AND CHEMICAL ATTRIBUTES OF ROASTED COFFEE BEANS

Grain shape	Flat beans			Peaberry beans		
Roasting	T_1	T_2	T_3	T_1	T_2	T_3
Moisture, w.b. (kg kg^{-1})	2.36 ± 0.05^b	2.02 ± 0.03^a	1.83 ± 0.09^a	2.70 ± 0.19^b	2.40 ± 0.05^{ab}	2.20 ± 0.25^a
Soluble solid (^{o}Brix)	31.2 ± 1.0^b	31.2 ± 1.0^b	28.1 ± 0.75^a	30.3 ± 1.5^a	30.3 ± 1.5^a	29.9 ± 1.3^a
Acidity (mL of NaOH 0,1N g $coffee^{-1}$)	327.2 ± 19^a	314.0 ± 19^a	297.5 ± 14.7^a	314.5 ± 14.7^a	340.0 ± 7.4^a	310.2 ± 14.7^a
pH	5.19 ± 0.05^b	5.25 ± 0.04^b	5.10 ± 0.06^a	5.13 ± 0.01^b	5.14 ± 0.01^b	5.04 ± 0.02^a
Total sugars (%)	5.01 ± 0.03^a	5.08 ± 0.87^a	4.99 ± 0.77^a	5.38 ± 0.65^a	5.16 ± 0.46^a	5.69 ± 0.52^a
Reducing sugars (%)	1.46 ± 0.12^a	1.10 ± 0.1^a	1.45 ± 0.27^a	1.48 ± 0.27^a	1.40 ± 0.05^a	1.54 ± 0.19^a
Non-reducing sugars (%)	3.54 ± 0.14^a	3.97 ± 0.84^a	3.54 ± 0.98^a	3.88 ± 0.92^a	3.75 ± 0.43^a	4.14 ± 0.68^a

Same letter means without significant difference at 5% by Tukey test.

Table 4 present merits of sensorial analyses (cup quality).

TABLE 4 - SENSORIAL ATTRIBUTES OF ROASTED COFFEE BEANS

Grain shape	Flat beans			Peaberry beans		
Roasting	T_1	T_2	T_3	T_1	T_2	T_3
Aroma	7.25	7.25	7.0	7.25	7.25	7.25
Clean cup	10.0	10.0	10.0	8.0	8.0	8.0
Body	6.75	6.5	6.5	6.75	6.75	6.75
Sweetness	10.0	10.0	10.0	8.0	8.0	8.0
Flavor	6.75	7.25	7.25	7.0	6.5	7.0
Acidity	6.75	6.75	6.5	7.25	7.25	7.25
Uniformity	10.0	10.0	10.0	10.0	10.0	10.0
Aftertaste	6.25	6.75	6.5	6.25	6.5	6.25
Balance	6.75	6.75	6.5	6.5	6.75	6.5
General Impression	6.5	6.5	6.5	6.25	6.75	6.25
Final Merit	77.5	77.75	76.25	73.25	73.75	73.25

Table 4 shows that the smaller merit for aroma was obtained in T_3 conditions (low temperature) for flat beans and a cereal aroma was present in the coffee from that condition. These are characteristics of a slow roasting (ILLY and VIANE, 1998; SILVA, 2008). Beverage prepared with peaberry beans at T_2 conditions (increasing temperature) presented a slight fragrance of chocolate for both categories of coffee. Similar aromas were found by SILVA (2008) for quick roasting of coffees originated of natural processing submitted to light roasting.

Clean cup is a basic attribute to start an evaluation of quality for coffee. This attribute was not function of roasting type for both coffees, but the greater merits were for flat beans. The same behavior was observed for sweetness. SILVA (2008) found similar merits for these attributes that was not function of roasting type.

For flat beans, T_1 carried out to beverages with more body than the other processes. For peaberry beans, no influence of roasting type was verified.

Acidity makes coffee richer and is not function of its intensity, but associated with the other attributes. Peaberry showed greater merits on acidity than flat grain for the three types of roasting. For peaberry, the type of roasting did not present influence. For flat grains, T_3 obtained lower merit than the other processes that presented the same merit. SILVA (2008) found lower merits for this attribute for coffees originated of natural processing when submitted to slow and light roasting, like in this work for flat beans and corroborated by ILLY and VIANE (1998).

With respect to uniformity, no influence of roasting was verified.

Aftertaste is the sensation after drinking. This attribute helps analyzing the other ones. Roasting T_2 obtained higher merits for flat grains, followed by T_3 and T_1. For peaberry grains, the greater merit was obtained at T_2 conditions. T_1 and T_3 presented the same merit.

Balance is a combination of all the attributes and represents the harmony among the attributes. T_2 was the best condition for peaberry beans.

Peaberry beans obtained better merits in general impression with T_2 conditions. This attribute presented the same merit for all the tested roasting conditions for flat beans.

With respect to final merit, that is a sum of the other attributes, T_2 presented the highest value for both beans. Such results were similar to the obtained by SILVA (2008). That author obtained higher merits for coffees originated of natural processing submitted to light roasting.

4 CONCLUSION

The subcategories flat and peaberry presents different behavior in every kind of roasting studied.

Temperature profiles are not significantly dependent on grain shape, but on the type of heat increase.

Roasting type is influent on soluble solids for flat grains and on bulk density, swelling index, moisture and pH for both types of coffee.

Peaberry and flat beans obtained higher sensorial merits in an increasing temperature roasting (T_2).

There was not a uniform tendency for a roasting condition according to physical, chemical and sensorial characteristics.

RESUMO

PROCESSO DE TORRAÇÃO DE CAFÉS BOIA: INFLUÊNCIA DO FORMATO DOS GRÃOS E DA TEMPERATURA EM SUAS PROPRIEDADES FÍSICAS, QUÍMICAS E SENSORIAIS

A torração provoca alterações nas propriedades físicas, químicas e sensoriais do café, como mudança de cor, perda de massa, expansão e geração de compostos responsáveis pelo aroma e sabor da bebida. Neste trabalho foi estudado o processo de torração de grãos de cafés chato e moca provenientes de frutos boia. As influências do desenvolvimento da temperatura e do formato dos grãos foram avaliadas em relação à densidade, redução do teor de água, taxa de expansão, alterações nas dimensões dos grãos, pH, sólidos solúveis, acidez titulável, perda de massa, açúcares totais, redutores e não redutores, cor e atributos sensoriais. Três tipos de desenvolvimento de temperatura foram comparados: alta temperatura durante todo o tempo (T_1), aumento da temperatura com o tempo (T_2) e baixa temperatura durante todo o tempo (T_3) para grãos chatos e mocas. As torrações T_1 e T_3 foram desenvolvidas em baixos tempos para os grãos mocas. O mesmo foi observado com T_2 para os grãos chatos. Foram verificadas diferenças para densidade, teor de água final, pH, índice de expansão e sólidos solúveis.

Os melhores resultados nas análises sensoriais foram obtidos com as condições T_2 para ambos os tipos de café.

PALAVRAS-CHAVE: CAFÉ ARÁBICA; TORRAÇÃO; GRÃO CHATO; GRÃO MOCA; CAFÉ - FORMATO DO GRÃO.

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