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Evaluation of physical parameters of green and roasted arabica coffee using the scilab® free software

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ABSTRACT

The physical and chemical parameters of coffee beans make it possible to assess beverage quality before and after the roasting process. Currently, the use of software as a tool provides the verification and compilation of graphics, resulting in a better visualization of techniques and data separation. The physical parameters of soft, hard and rio coffees were evaluated regarding type, sieve and color, and the chemical composition was represented by moisture content, ether extract, protein, ash, soluble solids and total titratable acidity. Different roasting levels were assessed for the beverages and the parameters color and mass loss were verified. The results were analyzed with the aid of the Sisvar software and graphics were plotted using the Scilab® free software. Rio coffees showed lower physical classifications in relation to type and showed a darker color; for sieving, all showed a higher percentage of flat coarse beans. The moisture content showed values according to the current legislation; ether extract, protein content and ash were as expected. The rio beverage had lower levels of soluble solids and higher total titratable acidity. After the roasting process, the parameters L*, b*, C* and H* showed a decrease, since the mass loss increased with the roasting level, but there was no difference between beverages. The samples were well located within the roasting scopes and L* was the parameter that best differentiated the samples, thus constituting an important factor for determining the roasting point.

Key terms: *Coffea arabica* L.; Quality; Roasting; Color.

1 INTRODUCTION

Coffee represents one of the main crops of economic importance in Brazil. It is estimated that production for this year will be approximately 46.88 million processed bags and, of this total, approximately 68% corresponding to Arabica coffee (Companhia Nacional de Abastecimento - CONAB, 2021).

Among the main producing and exporting states is the state of Minas Gerais, with emphasis on the Southern region (Alves et al., 2011). The region has climatic conditions, favorable water demand for plant development, in addition to the production of coffees with peculiar characteristics, and has dozens of coffee producing and processing farms, also constituting a pole of companies related to the coffee sector (Carvalho et al., 2007; Barbosa et al., 2010; Toledo, 2019).

Coffee quality is directly related to the physical characteristics and chemical composition of raw beans: through this factor, it is possible to infer about the behavior of these coffees during the roasting process (Borém, 2008; Oliveira et al., 2013).

The physical evaluation of coffee is described through Normative Instruction Nº8 (IN8) of the Ministry of Agriculture, Livestock and Supply (MAPA), which classifies coffee according to category, subcategory, group, subgroup, class, type, granulometry, aroma, flavor, beverage and color. Classification by type is performed by counting the beans containing extrinsic and intrinsic defects in a sample containing 300 grams of processed coffee. Defects are separated and counted using the Official Classification Table; equivalence is then made and the type of coffee is determined (BRASIL, 2003; Pimenta; Angélico; Chalfoun, 2018).

The classification regarding shape and size aims to guarantee a uniform roasting process by separating the beans before roasting. A set of sieves is used to separate the beans according to shape (mocha or flat) and size (large, medium or small) (BRASIL, 2003; Soares et al., 2019; Pimenta; Angélico; Chalfoun, 2018).

The classification for color is divided into eight classes: bluish green, sugarcane green, green, yellowish, yellow, brown, leaded, whitish and discrepant (BRASIL, 2003). As the color classification describes nuances very close to coloring, only a trained panelist can identify differences between the colors of the raw beans, but there are objective methods for these evaluations such as colorimeters. The three-dimensional color system of the *Commission Internationale de l'Eclairage* (Comission Internacionale de I'eclairage - CIE, 1986), called CIE Lab, is a noticeably uniform system, in which the Euclidean distance between two different colors corresponds approximately to the color difference perceived in the human eye (Hunt, 1991).

Through this system, color parameters are evaluated, such as L*, which represents sample luminosity, varying from 0 to 100; values close to zero are darker, while those close to 100 are lighter. Other chromatic components such as a* and b* range from +120 to –120 where, +a* indicates red and –a* green; for parameter +b*, it is yellow and –b*, blue. The chroma component C* indicates sample saturation and Hº corresponds to the tone or hue, which indicates color variation in the plane formed by the coordinates a* and b* (Bicho et al., 2012).

According to Ribeiro et al. (2011), color has a great economic importance, since discolored beans receive a lower market price. Oliveira et al. (2013) observed significant sensory differences between different coffee beverages. Better quality coffees retain their characteristic color, while poorer coffees undergo oxidative reactions, with consequent bleaching.

The chemical composition of Arabica coffee beans depends on genetic and environmental factors, besides pre- and post-harvest management conditions (Abrahão et al., 2008). The perceived acidity in coffee, for example, is influenced by climatic conditions during harvest and drying, place of origin, type of processing and ripening stage (Siqueira; Abreu, 2006). For Carvalho et al. (1994), the total titratable acidity of processed coffee beans has an inverse relationship with beverage quality.

Soluble solids are parameters capable of determining the content of solids in a coffee sample. According to Lopes et al. (2000), a high content of soluble solids can ensure beverage body, thus yielding a good quality beverage.

Other important chemical constituents for determining the characteristics of raw Arabica coffee beans are: moisture, lipid, protein and ash content. Moisture content is a relevant parameter that predicts processing and storage conditions. Coffees with very high moisture contents can allow the activity of microorganisms and enzymes, in addition to altering the sensory characteristics of the product (Morgano et al., 2008).

The lipids present in raw beans are precursors of the organoleptic characteristics of post-roasted coffee (Borém, 2008). Gourlart et al. (2007) observed that higher quality coffees have integral walls and membranes with a higher lipid concentration in these places whereas, for lower quality coffees, these concentrations were greater in the center of the cell. With regard to coffee bean proteins, these are free in the cytoplasm or may be linked to a cell wall polysaccharide (Toci; Farah; Trugo, 2006). For (Associação Brasileira da Indústria de Café - ABIC, 2016), the raw bean has a wide variety of minerals such as potassium, magnesium, calcium, sodium, iron, among others.

One of the most important processes in the formation of the aroma and flavor of coffee is roasting; during this process, the coffee beans are subjected to high temperatures in a controlled time. This process generates a series of physical, chemical and sensory changes (Gabriel-Guzmán et al., 2017; Schenker; Rothgeb, 2017; Caporaso et al., 2018; Craig et al., 2018).

For the determination of the end-point of roasting, some indicators are used to predict the roasting level, such as color, aroma, volume and temperature of the beans (Hernandez; Heyd; Trystram, 2008). The color can vary from light brown to dark, as a function of the level of pyrolysis reactions and malanoidin formation (Cid; Peña, 2016; Schenker; Rothgeb, 2017; Gabriel-Guzmán et al., 2017).

According to Cid and Peña (2016), the use of colorimeters to determine color using the color parameters L*, a*, b*, C* and H* provides a quick method of evaluating the roasting point. Another physical parameter for a quick verification of the roasting process is the calculation of mass loss, as darker roasted beans lead to a greater mass loss, compared to lighter roasted beans (Schenker; Rothgeb, 2017).

Currently, the use of software to detect physical parameters of coffees is gaining relevance. Leme et al. (2019) used the Matlab® software and compiled a mathematical model to identify roasting levels.

Free software has the advantage of not generating costs, such as the Scilab®, which corresponds to a software for scientific computing that presents a high-level programming language and provides an environment focused on the development of programs for solving numerical problems (Kwong, 2016; Campbell et al., 2006). It is a highly used tool in Engineering and provides easy data separation, in addition to providing a better understanding of methods and techniques (Kwong, 2016; Buksman et al., 2019; Sanches et al., 2013; Almeida; Medeiros; Frery, 2012).

This study aimed to identify the physical and chemical behavior of arabica coffees of different beverage types and analyze the physical parameters after the roasting process in order to distinguish the roasting types using the Scilab® Software.

2 MATERIAL AND METHODS

2.1 Collection and physical evaluation of samples

Commercial samples of soft, hard and rio coffees of the species *Coffea arabica* L., harvest 2019/2020, processed dry were acquired from Cooperativa Regional dos Cafeicultores de Poços de Caldas. Each treatment containing 20 samples of 3Kg.

The experiment was carried out at the Soil Analysis Laboratory of IFSuldeMinas - Inconfidentes Campus. The samples were homogenized and quartering was performed, obtaining 300g for the physical classification related to type. Thus, the samples were submitted to a new quartering, reducing them to 100g to determine the sieve based on Normative Instruction Nº8; the process was carried out in triplicate (BRASIL, 2003).

These samples were analyzed for color parameters (L*, a*, b*, C* and Hº) with the aid of a digital colorimeter CM-2300 Konica Minolta - Illuminant D65 (Konica Minolta, Japan) previously calibrated with a white dish. The samples were placed in a 60-mm Petri dish for reading and calculating the parameters according to the methodology described by Bicho et al. (2012). Readings were performed at 10 points in the samples to allow the calculation of the mean of these parameters.

2.2 Chemical evaluation of raw coffee beans

The moisture content was evaluated in an oven at 105 ºC, according to the Association of Official Analytical Chemists (AOAC 1995), with modifications. The analyses of ether extract, protein (using 6.25 as a correction factor) and ash were carried out according to the AOAC (1995).

An extract was prepared from 10g of sample in 100mL of distilled water; they were subjected to stirring for 15 minutes using a magnetic stirrer at 150 rpm. Subsequently, they were filtered through No. 3 Whatman filter paper. The content of soluble solids was read on a digital refractometer (Atago Pal-1 digital – Atago, USA). Total titratable acidity was determined according to the AOAC methodology (1995). All analyses were performed in quadruplicate.

2.3 Evaluation of the roasting process of the samples

For the roasting process, the samples of each beverage (soft, hard and rio) were divided into 20 plots containing 300 grams.

The samples were roasted in a laboratory roaster (T2BL Pinhalense) in different roasting degrees: light, medium and dark. The initial temperature of the thermometer coupled to the roaster was 150 ºC; subsequently, the beans were inserted in the cylinder, with a decrease of approximately 25 ºC due to the temperature difference between the beans and the interior of the roaster. Thermal equilibrium was achieved after a few minutes. The average roasting time was approximately 10 minutes for light roasting, 12 minutes for medium and 14 minutes for dark.

The shade of the final color of the beans was visually determined and subsequently measured with the aid of a colorimeter. Readings of color parameters were performed according to item (Collection and physical evaluation of samples).

At the end of the roasting process, the mass loss Δm was calculated to verify the roasting level, according to Bicho et al. (2012).

2.4 Statistical analysis and graph plotting

For statistical analysis, the software Sisvar version 5.6 (Ferreira, 2014) was used, and analysis of variance (Anova) was performed, when a difference was detected by the F test ($p < 0.05$); a Tukey test was then applied at 5% probability.

The software Scilab® 6.1.0. was used for the construction of three-dimensional and two-dimensional graphs, using color parameters as vectors. In addition, values of L*, a* and b* were determined to constitute scopes for each roast.

3 RESULTS

3.1 Physical analysis

The results obtained after classification regarding type are shown in Table 1.

The results obtained after the physical classification using the sieves are shown in Table 2 below.

The color parameters of the coffee beans obtained after evaluation are shown in Table 3.

3.2 Chemical analysis of raw coffee beans

Table 4 presents the results obtained after chemical analyses.

3.3 Roasting Process

Table 5 shows the results obtained through the analysis of colorimetry and mass loss after the roasting process.

Table 1: Physical classification for type.

	DEFECTS											
	Extrinsic					Intrinsic						
Samples	H	St	Bf	Co	S	Bl	G	So	B	Br	Bg	Sh	TYPE
SB	-	-	-	-	-	-	-	14	8	Clean= 2	-	-	2
HB	5	-	4	-	-	29	14	48	102	Clean= 8 Dirty= 12	19	23	6
RB	51	3	-	1	6	146	9	208	103	Clean= 41 “Rendado”= 3 Dirty= 40	-	-	Out of type

Caption: SB- soft beverage, HB- hard beverage, RB- rio beverage, H- husk, St= stick, Bf= bean fragment, Co= coconut, S= stone, Bl= black, G= green, So.= sour, B= broken, Br= brocade, Bg= badly grained and Sh= shell.

Table 2: Classification results for sieve.

Samples	Big flat (%)	Medium flat (%)	Small flat (%)	Mocha (%)	Bottom (%)
SB	86.630a	13.110a	0.190a	0.069a	0a
HB	58.145b	32.526b	7.448b	1.770b	0.111a
RB	55.119b	35.748c	7.691b	1.009b	0.433b

Caption: SB- soft beverage, HB- hard beverage, RB- rio beverage
*Means followed by the same letter, within the same column, do not differ by the Tukey test at 5% probability (P<0.05%).

Table 3: Color parameters of raw coffee beans.

Samples	L*	a*	b*	H*	C*
SB	47.560 ± 2,847a	5.183 ± 1,722a	30.400 ± 1,878a	80.433 ± 2,644a	30.864 ± 2,096a
HB	51.508 ± 4,135 a	2.530 ± 0,858b	26.685 ± 1,858b	84.661 ± 1,495b	26.812 ± 1,924b
RB	42.532 ± 4,935b	4.270 ± 1,565ab	28.925 ± 2,280ab	81.773 ± 2,571ab	29.262 ± 2,455ab

Caption: SB- soft beverage, HB- hard beverage, RB- rio beverage.
*Means(± standard deviation) followed by the same letter, within the same column, do not differ by the Tukey test at 5% probability (P<0.05%).

Table 4: Chemical composition of raw arabica coffee beans.

Samples	Moisture (%)	Ether extract (%)	Proteins (%)	Ash (%)	TTA (*)	SS (% dry matter)
SB	11.1960± 0.542a	16.8718±1.033a	8.87485±1.072a	4.3494±0.388a	133.4994±15.607a	42.8093±3.632a
HB	11.6622± 1.271ab	15.6447±0.631a	11.5408±0.567b	5.0535±1.202a	126.3643±20.003a	41.4961±4.601a
RB	12.4157± 3.533b	16.4239±1.219a	9.6845±1.629ab	4.8810±1.494a	159.3790±11.547b	36.3107±4.260b

Caption: SB- soft beverage, HB- hard beverage, RB- rio beverage.
*mL of 0.1 N NaOH /100 g sample.
**Means(± standard deviation) followed by the same letter, within the same column, do not differ by the Tukey test at 5% probability (P<0.05%).

Table 5: Results of color parameters after the roasting process

Samples	L*	a*	b*	C*	H*	Δm (%)
LRSB	30.4590±0.526a	20.6005±0.403ab	50.9225±0.473a	54.9413±0.494a	67.9881±0.494a	11.980±0.756a
LRHB	30.6340±0.342a	19.9275±0.476abc	50.1560±0.392a	53.9716±0.360a	68.3324±0.534a	13.127+0.362a
LRRB	30.5840±0.261a	20.5000±0.329ab	49.2980±0.078a	53.3908±0.137a	67.4558±0.332ab	13.125±0.678a
MRSB	26.6700±0.919b	21.6455±2.295b	43.6255±1.433b	48.7730±1.790b	63.6112±2.382bc	15.078±0.956b
MRHB	25.9505±1.658b	21.7710±1.973b	43.1545±2.784b	48.4012±1.861b	63.1289±3.435bc	14.519±1.023b
MRRB	26.7168±1.036b	17.7668±2.958c	43.9332±2.169b	47.4323±2.941b	68.0307±2.941a	15.641±0.319b
DRSB	20.4153±1.474c	19.2758±2.976ac	33.7811±3.828c	38.9560±2.746c	60.3090±6.347c	16.870±0.521c
DRHB	19.7570±1.771c	20.7720±3.271ab	31.4325±5.308c	38.1223±3.623c	55.7075±7.894d	18.909±2.071c
DRRB	20.1595±1.089c	19.0975±1.750ac	33.2585±3.703c	38.4637±2.572c	59.9648±4.958cd	16.693±0.251c

Caption: LRSB- light roast, soft beverage, LRHB- light roast, hard beverage, LRRB- light roast, rio beverage, MRSB- medium roast, soft beverage, MRHB- medium roast, hard beverage, MRRB- medium roast, rio beverage, DRSB- dark roast, soft beverage, DRHB- dark roast, hard beverage and DRRB- dark roast, rio beverage.
*Means(± standard deviation) followed by the same letter, within the same column, do not differ by the Tukey test at 5% probability (P<0.05%).

Figure 1 shows the location of the samples after the roasting process. The samples showed good separation between the different roast, despite differences in the beverage.

It is important to observe that the color consists of the formation of the three parameters (L*, a* and b*); therefore, a three-dimensional view facilitates the verification of the correct roasting point.

For a better visualization of the separation between the samples in the different roasting processes, Figure 2 was constructed, expressing the parameter L* versus a*.

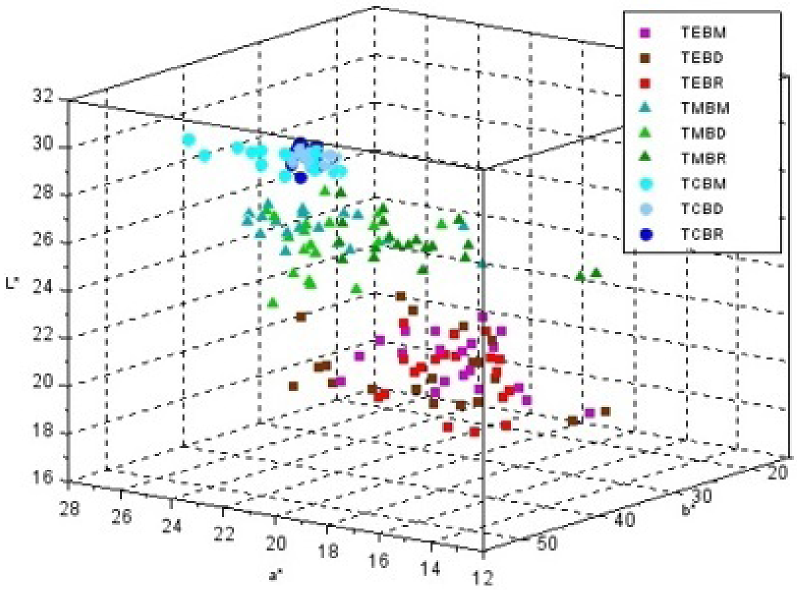

Figure 1: Samples of different beverages in light, medium and dark roasting.

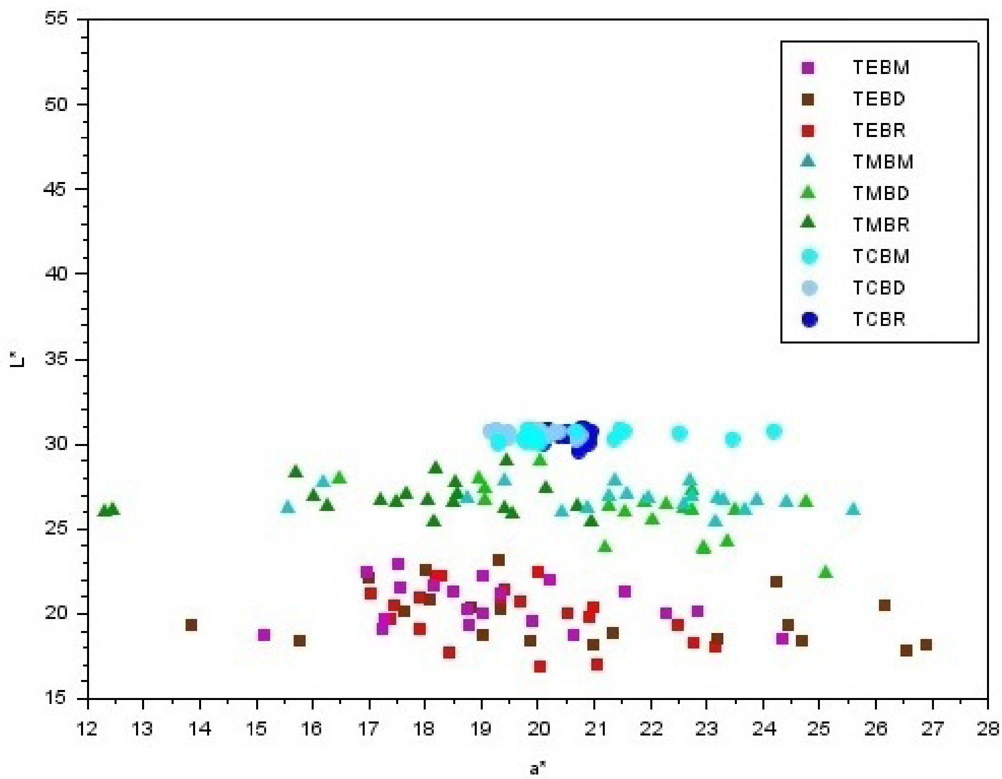

Figure 2: Color parameters L* and a* of roasted coffee samples.

4 DISCUSSION

4.1 Physical analysis

As presented in Table 1, soft coffees did not present extrinsic defects (husk, stick, bean fragment, coconut and stone); for intrinsic defects, the presence of defects sour, broken and brocade was observed, but there was an absence of defects black and green. When making the equivalence using the Official Brazilian Classification Tables according to IN8, the soft beverage presented type 2. For hard coffees, the extrinsic defects found were husk and bean fragment, and the intrinsic ones corresponded to black, green, sour and broken, in addition to brocade and, when performing the defect equivalence, the result obtained was type 6. The rio beverage presented extrinsic (husk, stick, coconut and stone) and intrinsic (black, green, sour, broken and brocade) defects, and the number of beans exceeded the limit of 50 black beans and 100 sour beans and coffee was, therefore, classified as out of type (BRASIL, 2003).

The presence of a high number of defects in the samples of rio beverage indicates problems during pre- and post-harvest handling. The black and sour beans defects that are in high concentration in these samples are indicative of complications: for sour unripe fruit harvest, delayed harvest and fruit contact with the ground and for blacks delayed harvest and fruit contact with the soil (Malta, 2011).

According to Giomo and Borém (2011), the presence of beans that present some type of defect, such as green, black and sour beans, are considered abnormalities, since they are related to some problem that occurred during the production process. Defects such as brocade, broken, impurities and foreign matter also present a high risk to coffee quality.

In general, coffee quality can be affected by several factors, but the presence of defective beans, especially black, green and sour, have an extremely negative influence during roasting and on beverage quality (Coelho; Pereira, 2002; Malta; Pereira; Chaga, 2005; Malta, 2011). According to Farah et al. (2006), the addition of these defects leads to a reduction in coffee quality, also changing the chemical and sensory composition after the roasting process.

Soft, hard and rio coffees showed a higher percentage of flat beans (Table 2), which shows a good physical parameter of these coffees. However, the samples belonging to soft beverage were statistically different from hard and rio beverages, which were the same. Soft, hard and rio coffees of medium sieve were statistically different; however, for the flat small beans and mocha, the soft samples were different from hard and rio beverages at 5% significance. The bottom was the same for soft and hard beverages, and statistically different from rio.

In botany, the coffee fruit is considered a drupe, arising from the growth of a bilocular ovary. When mature, it has two stores that normally contain two plano-convex seeds that, in practice, are called flat-type grains. For genetic or environmental reasons one or two seeds may fail to develop or abort, resulting later in fruit with one or two empty stores. When this occurs in only one store and early in fruit development, the other store, which contains a normal embryo and endosperm, develops and occupies the entire volume of the ovary. Consequently, it results in a fruit that contains only an ovoid grain known as a mocha grain (Malta, 2011).

Mocha fruits occur most frequently on the tips and ends of the branches. The percentage of mocha also varies with the year, with the production, nutritional status and even with the variety (Medina Filho; Bordignon, 2003).

It is important to emphasize that large beans normally have preference in the market, as this characteristic is an indicator of bean development, since environmental factors that cause stress to plants, such as lack of water and unbalanced nutrition, interfere with bean size and, for this reason, large coffee beans can yield a better beverage (Giomo; Borém, 2011).

The parameter L*, corresponding to luminosity (Table 3), presented higher values for soft and hard beverages, indicating lighter tones, whereas the rio beverage presented lower values, suggesting it to be darker. The color parameters a*, b*, C* and H° were the same between soft and rio beverages and between hard and rio beverages, but soft and hard beverages were statistically different at 5% significance. The values of parameters a* and b* positive and H* in the first quadrant indicate that all samples had orange tones.

The color of raw grains is quite variable, depending on the place of production, processing system (natural, peeled, pulped or demucilated), drying, storage time and conditions, presence of defects, among others (Pimenta; Angélico; Chalfoun, 2018; Giomo; Borém, 2011). The results regarding the darkening of the samples of rio beverage may have occurred due to several factors, but the high amount of defects present in the samples of rio beverage indicate that this may have been the primary factor. Defects of an intrinsic nature such as black, burnt, black green, brocades and extrinsic such as bark, sticks and stones can lead to darkening of the sample and appear due to improper conduction of processes during crop management at harvest and post-harvest (Malta, 2011).

According to Silva et al. (2008) the physical classification based on color, type and cup proof can be complemented with the adoption of chemical and physico-chemical methods that facilitate the evaluation of the condition of the coffees.

4.2 Chemical analysis of raw coffee beans

Raw arabica coffee beans (Table 4) showed an equal moisture content between soft and hard beverages, and hard and rio beverages. However, soft and rio samples were statistically different. The moisture content of processed raw coffee beans cannot exceed the maximum tolerance limits of 12.5% (twelve and a half percent); thus, the samples were within the limits established by Nº8 (BRASIL, 2003).

For ether extract and ash content (Table 4), the samples were equal through the statistical test. The content of ether extract in arabica coffee varies according to the geographical origin of the plants, but it should be between 12 and 16% (Mazzafera et al., 1998; Folstar, 1985; Martinez et al., 2014). According to Goulart et al. (2007), better quality coffees, such as soft coffees, may have a higher lipid content if they have integral walls and membranes, and poorer coffees if they have any break in the walls or membranes and may express lower contents, in addition to greater concentration in the center of the cell.

The ash content is directly related to the type of processing, soil conditions and the use of fertilizers; the total ash values of the samples had similar results, close to 4% as reported by Clarke (1985).

The results obtained for proteins (Table 4) showed that the rio beverage was statistically equal to soft and hard, but there was a difference between soft and hard beverages. According to Toci; Farah and Trugo (2006), the protein content in the beans can vary from 8.7 to 16%; the majority is soluble in water. For Oliveira (2006), there is no evidence to indicate that the protein content of coffees of different qualities must be significantly different. It is important to observe that the results were based on the determination of raw nitrogen and multiplication by the factor 6.25, thus including caffeine and trigonelline nitrogen.

Regarding the total titratable acidity and content of soluble solids (Table 4), the soft and hard samples had statically equal values, but they were different from rio samples.

The higher levels of total titratable acidity present in samples of rio beverage are due to the high level of defects (Pimenta; Angélico; Chalfoun, 2018). In fact, problems related to poor conditions used throughout the production process can trigger the appearance of defects, which lead to increased acidity and consequent loss of quality (Borém et al., 2008). Thus, acidity can be influenced by several factors such as unfavorable weather conditions during harvesting and drying, place of origin, type of processing and stage of maturation (Siqueira, Abreu, 2006).

The soluble solids content was lower in the river beverage, which indicates bad conditions during processing, since higher amounts of solids are desired for coffees, for industrial yield and to guarantee a full-bodied beverage. This solid fraction is composed of water and soluble compounds such as sugars, acids, vitamin C and some pectins, which may vary according to the type of processing, cultivar (different cultivars submitted to the same type of processing) and stage of maturation (Borém et al., 2008; Pimenta; Angélico; Chalfoun, 2018).

According to Pinto et al. (2002), the best beverages, such as strictly soft, soft, just soft and hard, have higher contents of soluble solids, while lower-quality coffees such as rio and "riado" exhibit greater acidity. For Abrahão et al. (2010), the final quality of the coffee beverage has a high correlation with the chemical composition of the green bean, suggesting that lower quality coffees have lower levels of sugars and higher total titratable acidity. According to Franca et al. (2005), the low quality of coffee provides a high acidity and this factor can be probably due to fermented beans.

4.3 Roasting Process

Through the statistical evaluation (Table 5), it is possible to observe that the different types of roasting were well identified even in beverages that present a difference in quality, and this is possible to visualize mainly through the parameters L*, b* and C*.

According to Schenker and Rothgeb (2017), for an average roast, the value of L* should be close to 26, indicating an average roast. It is possible to that, for lighter roast, these values tend to increase and the opposite will occur for darker roast.

The parameters L*, b*, C* and Hº (Table 5) suffered a significant decrease with the increase in the intensity of the roasting process and were similar in the different beverages. The values of the parameter a* were close among the samples; this is an important factor to highlight, as it shows that beverages of different qualities showed a similar behavior during the roasting process.

The obtained results corroborate with Bicho et al. (2012) for the parameters L*, b*, C* and Hº, which also decreased as roasting intensity increased.

The mass variation (Table 5) of coffees caused by the roasting process can vary between approximately 12 and 20%, as a function of factors such as genetic origin, initial moisture, type of storage and, mainly, the roasting level. In general, a greater loss occurs at the beginning of the process due to bean dehydration and evaporation, while the loss of organic matter will happen at more advanced stages (Bicho et al., 2012; Schenker; Rothgeb, 2017).

Sivetz (1963) reports that the percentages of mass loss vary between 13% for light roast; 15% for medium roast and 17% for dark roast.

The samples in light roast were closer; however, in medium and dark roast, the samples were more spaced. Through Figure 1, it is clear to demonstrate the positioning of the samples and the difference between the roasting processes, facilitating the visualization of the samples in the color space.

In clear roast, all plots were positioned within the scope; in medium roast, two plots of rio beverage and one of hard beverage were outside the scope. In dark roast, although more widely spaced, only two hard beverage samples were positioned outside the scope.

Figure 2 yielded better sample allocation with regard to the roasting process, as the values of parameter a* are close between the samples, the parameter L* became determinant for a better identification of the roasting point. Therefore, it is possible to recognize that, although the color space facilitates color identification and the scope reached by the samples, parameter L* indicates the roasting point reached and, through this point, it is possible to discern the roasting level regardless of beverage quality. The obtained results corroborate those of Bicho et al. (2012), who describe that L* and Hº are reliable and easy to use parameters in the study of color changes that occur during roasting.

5 CONCLUSION

The physical and chemical behavior of coffees showed differentiation mainly between beverages with high quality difference. Samples of different beverages showed a similar behavior when the same roasting level was applied, revealing that color and mass loss are decisive physical parameters of in roasting.

The free software Scilab® proved to be an effective tool in the compilation of graphics for detecting the roasting point. In addition, the parameter L* proved to be decisive in the identification of the roasting level.

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7 AUTHRS' CONTRIBUTION

EMO wrote the manuscript and performed the experiment, HTG supervised the experiment and co-work the manuscript, and EMO review and approved the final version of the work, EMO conducted all statistical analyses.

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