# QUALITY OF NATURAL AND PULPED COFFEE AS A FUNCTION OF TEMPERATURE CHANGES DURING MECHANICAL DRYING

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**ABSTRACT:** This research evaluated the sensory quality of processed and dried coffee beans in different ways. Two types of processing were used: dry and wet, besides seven drying methods: drying in yard and mechanical drying with heated air at 50 ºC until coffee reached 30% (w.b.) moisture content, followed by drying with air heated to 35 ºC until reaching 11% (w.b.) moisture content; drying in fixed-layer dryers with heated air at 45 °C until coffee reached 30% moisture content, followed by drying with heated air at 35 °C until reaching 11% (w.b.) moisture content; and drying in fixed-layer dryers with heated air at 40 °C until coffee reached 30% (w.b.) moisture content, followed by drying with heated air at 35 °C until reaching 11% (w.b.) moisture content; drying in fixed-layer dryers with heated air at 35 °C until coffee reached 30% (w.b.) moisture content, followed by drying with heated air at 50 °C until reaching 11% (w.b.) moisture content; drying in fixed-layer dryers with heated air at 35 °C until coffee reached 30% (w.b.) moisture content, followed by drying with heated air at 45 °C until reaching 11% (w.b.) moisture content; drying in fixed-layer dryers with heated air at 35 °C until coffee reached 30% (w.b.) moisture content, followed by drying with heated air at 40 °C until reaching 11% (w.b.) moisture content. The mechanical drying system consisted of three fixed-layer dryers, allowing the control of temperature and drying flow. Coffee was tasted according to the evaluation system proposed by the Specialty Coffee Association of America (SCAA). Physicochemical composition and physiological quality of the beans were analyzed, involving: grease acidity, potassium leaching, electrical conductivity, color and germination. The results show that pulped coffee is more tolerant to drying than natural coffee, regardless of how it was dried.

**Index terms**: Post harvest, sensory analysis, alternate drying.

# QUALIDADE DO CAFÉ NATURAL E DESPOLPADO EM FUNÇÃO DA ALTERNÂNCIA DE TEMPERATURA DURANTE A SECAGEM MECÂNICA

**RESUMO:** Objetivou-se neste trabalho avaliar a qualidade de grãos de café processados de duas formas diferentes (via seca e via úmida) e sete métodos de secagem: secagem em terreiro; e secagem mecânica com ar aquecido em secadores: a 50 ºC até o café atingir 30% de teor de água (TA), prosseguindo-se com ar aquecido a 35 ºC até atingir 11% (b.u) de TA; a 45 ºC até o café atingir 30% (b.u) de TA, prosseguindo-se com ar aquecido a 35 °C até atingir 11% (b.u) de TA; a 40 ºC até o café atingir 30% (b.u) de TA, prosseguindo-se com ar aquecido a 35 ºC até atingir 11% (b.u) de TA; a 35 ºC até o café atingir 30% (b.u) de TA, prosseguindo-se com ar aquecido a 50 °C até atingir 11% (b.u) de TA; a 35 ºC até o café atingir 30% (b.u) de TA, prosseguindo-se com ar aquecido a 45 °C até atingir 11% (b.u) de TA; a 35 ºC até o café atingir 30% (b.u) TA, prosseguindo-se com ar aquecido a 40 °C até atingir 11% (b.u) de TA. A análise sensorial foi realizada utilizando-se a metodologia proposta pela Associação Americana de Cafés Especiais (SCAA). As demais análises realizadas foram composição físico-química e acidez graxa, lixiviação de potássio, condutividade elétrica, cor e germinação. Para a análise estatística utilizou-se o programa computacional Assistat 4.0. A secagem em terreiro proporcionou melhor qualidade fisiológica e sensorial dos grãos de café, quando comparada com a secagem em secadores, mas o uso das temperaturas 35/40 °C e 40/35 °C apresentou resultados semelhantes à secagem em terreiro. Além disso, o café despolpado apresentou melhor qualidade fisiológica que o café natural.

**Termos para indexação:** Pós-colheita, análise sensorial, secagem alternada.

## 1 INTRODUCTION

Coffee is a product of great importance in global agribusiness. According to the International Coffee Organization - ICO (2016), raw coffee consumption was in the order of 145 million bags in 2016.

There are two processing methods for coffee: dry and wet. In moist processing, three types of coffee can be produced. Peeled coffees, of which the remaining husk mucilage is not removed from the beans; pulped coffees, originating from mechanically peeled fruits, and the remaining mucilage is removed by fermentation; and

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those demucilated, in which the mucilage is mechanically removed. In dry processing, intact fruits are submitted to drying, without exocarp removal.

The chemical composition of raw coffee depends on the processing used (BORÉM, 2008; BYTOF et al., 2005; KNOPP; BYTOF; SELMAR, 2006). In general, natural coffees give rise to more full-bodied and sweet beverages compared to pulped coffees, which have more desirable acidity (SANTOS; CHALFOUN; PIMENTA, 2009). Acidity in coffee beans has been pointed out as a good indicator of product quality, in which small amounts of organic acids are necessary to confer essential acidity to the coffee beverage (DA SILVA et al., 2009).

The sensory evaluation method of the Specialty Coffee Association of America has been emphasizing the importance to evaluate the quality of special coffees. The method is based on a quantitative descriptive sensory analysis of the beverage, performed by a selected and trained team of panelists, using an unstructured scale from 6 to 10 for the evaluation of powder fragrance, defects, acidity, bitterness, flavor, residual taste, astringency and beverage body, with final evaluation of the overall quality and quality of coffee according to the terminology presented by Lingle (2011).

In addition to sensory evaluation, the physicochemical evaluation of coffee beans can become a valuable tool for assessing beverage quality. Taveira et al. (2015) observed biochemical changes during processing related to germination metabolism, whose extent depends on the treatment, whether wet or dry. The authors, however, did not correlate it with drying methods.

The drying rate has a significant effect on the quality of agricultural products and, according to Burmester; Eggers (2010), it is mainly influenced by drying air temperature, but also by drying air flow, relative humidity, among other factors. These parameters are not independent, simultaneously influencing the drying process.

Higher drying rates caused by high temperatures can lead to damage to coffee quality due to damage to cell membranes (MARQUES et al., 2008; BORÉM et al., 2008b). Borém et al. (2008b) verified, through ultrastructural scanning electron microscopy, that natural and pulped caffeine endosperm, during drying at 40 °C and in yard, maintained the integrity of the cell membranes and that these membranes were damaged only between moisture contents of 30% and 20% (w.b.), when natural and pulped coffee were dried at a temperature of 60 °C.

High water reduction rates are desirable in reducing the risk of fermentation in early drying stages, as well as energy consumption. However, when using the technology currently available for coffee drying, the increase in drying rate is obtained by increasing the temperature. However, it has been proven by several scientific reports that, when subjected to drying temperatures above 40 ºC, coffee suffers serious damage to the cell membrane system of the seed endosperm, with negative reflections on beverage quality, when these are used in the final stages of mechanical drying.

The objective of this study was to evaluate the effects of different processing and drying methods on the physiological and physicochemical quality of coffee beans, analyzing their interrelationship with beverage quality.

## 2 MATERIAL AND METHODS

### 2.1 Experimental procedure

The experiment was carried out with parchment coffee (*Coffea arabica* L. cv. Catuai 62), harvested on Santa Clara farm, which has an altitude of 1,270 meters, located 10 km from the city of Carmo de Minas (Latitude: 22 ° 4'14.80 "South; Longitude: 45 ° 7'17.77" West), in the mountain range of Mantiqueira. The harvested fruits were taken to the city of Lavras - Minas Gerais, and transportation took about 2 hours.

After arriving at the Federal University of Lavras, coffee was processed through dry (natural) and wet (pulped) methods, separating only the parchment fruits. After processing, coffee was dried under seven different conditions (Table 1).

After drying, physiological, physicochemical and sensory analyses were carried out at the Post-Harvest Technology Pole Laboratory of the Federal University of Lavras. Figure 1 summarizes the whole experimental process.

### 2.2 Dry processing

For dry coffee processing, which results in the natural coffees, the fruits were washed and separated hydraulically, by bulk density difference, for the removal of the float and dried fruits present in the plot. Subsequently, the ripe fruits were again manually selected to ensure sample uniformity with respect to the maturation stage. After this procedure, a portion of the natural coffee was taken to the yard for complete drying and the other portion was subjected to mechanical drying in the dryers.

**TABLE 1 -** Experimental design.

| Processing | Drying Method |
|---|---|
| NATURAL/ PULPED | OnGround |
| | 35*/40 °C** |
| | 35*/45 °C** |
| | 35*/50 °C** |
| | 40*/35 °C** |
| | 45*/35 °C** |
| | 50*/35 °C** |

*Initial drying temperature of each treatment.**Drying temperature from the moment the sample reached the mass relative to the moisture content of 30% ± 2% (w.b.), remaining the same until coffee reached 11% (w.b.).

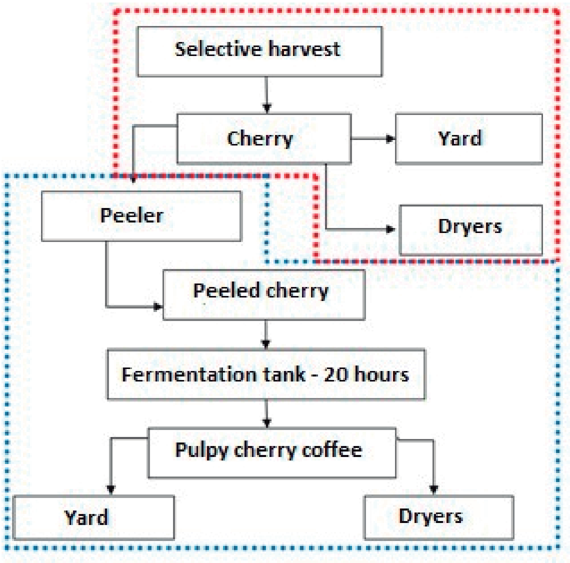


**FIGURE 1 -** Flowchart used to obtain the raw material (Dotted lines in red indicate dry processing; Dotted lines in blue indicate wet processing).

## 2.3 Wet processing

For the processing of wet coffee, mature fruits from selective harvesting were again manually selected and mechanically peeled in a green separator (Pinhalense Ltda., Eco – 6). After peeling, the coffee was submitted to fermentation in water to remove the mucilage, under ambient conditions, with an average temperature of 20 ºC, for 20 hours. After this period, the parchment coffees were washed with water until the mucilage was completely removed. When the mucilage was completely removed, a portion of the parchment coffee was taken to the yard for complete drying and the other portion was subjected to mechanical drying in the dryers.

## 2.4 Drying on ground

For drying on ground, coffee remained under ambient conditions after processing. One type suspension was used for drying on ground. These coffees were sprayed in fine grain-to-grain layers and, with drying, the layer was folded, according to the methodology proposed by Borém et al. (2008).

During the drying period, the maximum temperature was 31.8 ºC, the minimum temperature was 13.15 ºC, average room temperature was 18.85 ºC, precipitation was 1.4 cm and relative humidity was 58.6 %, which lasted from August 16 to 27, 2013. Both natural and pulped coffees remained under these conditions until reaching the moisture content of 11 ± 0.2% (w.b.).

## 2.5 Drying in dryer

The mechanical drying plots were made to three dryers (Figure 2) with a fixed layer, which allow flow and temperature (T) control of the drying air with precision, through an electronic panel. The bean layer reached the thickness of 30 cm for natural coffee and 20 cm for pulped coffee.

The air flow was controlled at 20 m³ $min^{-1}$ $m^{-2}$, corresponding to a speed of 0.33m $s^{-1}$ (SILVA, 2000).

The transition from one temperature to the next, in the case of treatments with heated air at 50/35 °C, 45/35 °C, 40/35 °C, 35/50 °C, 35/45 °C and 35/40 °C, was determined as follows:

The moisture content of the beans during drying was controlled from the initial moisture content of coffee on ground, which made it possible to monitor the mass variation in the respective samples. The moisture content of coffee was determined when the fruits were subjected to a constant temperature of 105 °C for a period of 24 hours (BRASIL, 2009). After this period, their humidity was determined by the difference of the initial and final people.

To determine the time of transition of the air temperature, each tray containing the experimental plot was weighed every hour, and the moisture content was determined by mass difference applying equations 1 and 2. When each drawer reached the relative mass at the moisture content of 30% ± 2% (w.b.), the temperature was changed, remaining until the coffee reached 11% (w.b.).

$$Mf = Mi - \left(\frac{Mi \times PQ}{100}\right) \quad 1$$

$$PQ = \left[\frac{(Xi - Xf)}{(100 - Xf)}\right] \times 100 \quad 2$$

Where:
Mf: final mass (kg);
Mi: initial mass (kg);
PQ: percentage of break (%);
Xi: initial moisture content (% w.b.);
Xf: final moisture content (% w.b.).

After drying and cooling, parchment and natural coffee remained stored in polyethylene bags in an environment with a temperature of 10 °C and 50% relative humidity, and it was only used when the physiological, physicochemical and sensory to evaluate the quality of coffee, which happened after a minimum of 90 days of rest, minimum time for coffee to have consolidated its sensory attributes (BORÉM, 2008).

## 2.6 Characterization of coffee quality

### 2.6.1 Sensory analysis

The sensory analysis was performed at the Nutrade Quality Laboratory, located in the city of Varginha/MG. For this purpose, portions of the bean samples classified in the above 16 sieves were used, with discs of malted and defective grains, according to Normative n°8 (BRASIL, 2003).

Sensory analysis was performed by two Certified Special Coffee Panelists (SCAA-Certified Cupping Panelists). The sensory analysis protocol of the SCAA was used, according to the methodology proposed by Lingle (2011), for the sensory evaluation of special coffees, with the assignment of scores, in the range of 6 to 10 points for fragrance, acidity, body, taste, sweetness, uniformity, clean cup, balance and finish. The roast was made with coloration corresponding to 58 points of the Agtron scale, for the whole bean, and 63 points for the ground bean, with a tolerance of ± 1 point. To obtain the ideal toasting point, the samples were standardized for weight (110 g), bean size (sieve 16 and above), as well as temperature and toasting time (between 8 and 12 minutes), according to Normative n° 8 (BRASIL, 2003).

At each sensory evaluation, five representative cups of coffee were sampled, and a sensory analysis session was conducted for each replicate, totaling three replicates for each treatment. Due to the presence of different sensory characteristics, the sensory analysis of natural and pulped coffee was carried out separately, in order to minimize any possible negative or positive interference. The final results of the sensory evaluation were constituted by the sum of all the attributes.

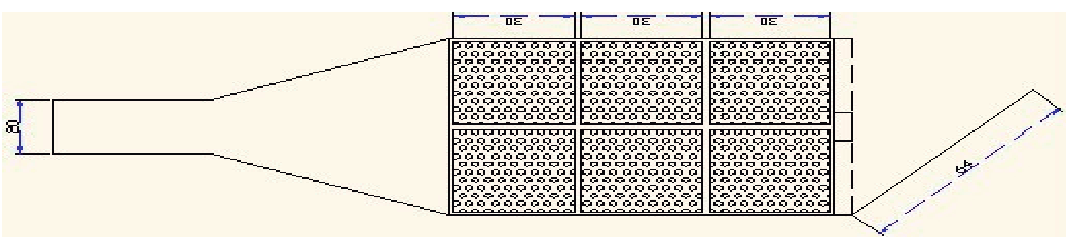

**FIGURE 2 -** Top view of the dryers used in the experiment.

**2.6.2 Physiological and physicochemical analyses**

Physiological and physicochemical analyses were performed in the Laboratory of Seed Analysis of the Department of Agriculture of the Federal University of Lavras. For the physiological analyses, four sub-samples of beans with no apparent defects were used, for each replication of the respective treatments.

**2.6.2.1 Germination test**

It was carried out with four sub-samples of 50 seeds, distributed in germinated paper with water equivalent to two and a half times the mass of the dry substrate and placed to germinate at 30 ºC. The evaluations were performed 30 days after sowing, according to the Rules for Seed Analysis (BRASIL, 2009), and the results were expressed as a percentage.

**2.6.2.2 Electrical Conductivity**

The electrical conductivity of the raw beans was determined by the methodology proposed by Krzyzanowski et al. (1991). Four replicates of 50 beans of each plot were used, which were weighed to an accuracy of 0.001g and immersed in 75 mL of distilled water inside 180 mL plastic cups. These containers were then taken to BOD with forced ventilation regulated to 25 °C for five hours, and the electrical conductivity of the soaking water in BEL W12D was read. With the data obtained, the electrical conductivity was calculated by Equation 3, expressing the result in μS $cm^{-1}$ $g^{-1}$ of beans.

$$CE = \frac{Value\ read\left(\frac{\mu S}{cm}\right)}{Mass(g)} \quad (3)$$

**2.6.2.3 Potassium leaching**

The leaching of potassium ions was carried out in the raw beans, according to the methodology proposed by Prete (1992). After the electrical conductivity reading, the solutions were subjected to the determination of the amount of leached potassium. The reading was carried out in a flame photometer (Digimed NK-2002). With the obtained data, the amount of potassium leached was calculated according to Equation 4, and the results were expressed in ppm.

$$LK = \frac{Value\ read \times dilution \times 1{,}56}{Mass\ (g)} \quad (4)$$

**2.6.3 Grease acidity**

For this analysis, coffee samples stored for 3 months were used (MARQUES et al., 2008) in a cold room with a temperature of 10 °C. The acidity of the grease was determined by titration, according to the method described by the American Association of Cereal Chemists - AACC (1995): 40g of ground coffee samples were weighed and 100 mL of toluene were added to stir for 1 hour and 30 minutes. It was then filtered, using filter paper; 25 mL of the filtered solution were mixed in a conical flask with 25 mL of ethanol (95% $v.v^{-1}$) over phenolphthalein (0.04% $w.v^{-1}$) and the solution was titrated with (KOH) at a concentration of 0.025 mol $L^{-1}$ until it reached the turning point. The result of the acidity content of the grease was expressed in mL of KOH.100 $g^{-1}$ DM, calculated according to Equations 5 and 6.

$$PS = [1 - U(b.u.) \times PC(g)] \quad (5)$$

$$AG = \frac{[V(ml) \times 100]}{PS(g)} \quad (6)$$

Where:
PS: mass of the dry sample (g);
PC: coffee weight (g);
U (w.b.): moisture content on a wet basis (%);
V: KOH volume spent in the titration (extract + indicator), in mL;
AG: grease acidity (mL KOH.100 $g^{-1}$ DM).

**2.7 Statistical analysis**

The experimental design consisted of a factorial scheme 2x7, completely randomized, with two processing forms (natural and pulped) and seven drying treatments. Three replicates were performed for each treatment.

The data obtained from the physiological, physicochemical and sensory analysis of coffee were also submitted to analysis of variance, using the Assistat 4.0 software and the means were grouped by the Scott-Knott test, at 1% significance.

## 3 RESULTS AND DISCUSSION

**3.1 Characterization of drying conditions**

Table 2 shows the average moisture content values at the beginning and at the end of mechanical drying and the total drying time, for dry and wet processed coffee. It can be observed from Table 2 that the drying treatment with higher temperatures at the end of the process had a lower total drying time, when compared to the other mechanical drying treatments. This fact results from the greater difficulty in water removal when the fruits are at lower moisture contents.

**TABLE 2** - Average moisture content values and total drying time, for each drying and processing treatment - Lavras - 2013.

| Drying Treatment | Processing | Average moisture content (% w.b.) | | Average drying time (h) | |
|---|---|---|---|---|---|
| | | Initial | End | Before Half dry (w.b.) | Total |
| 35/40 °C | Pulped | 46.5 | 11.6 | 20.0 | 32.0 |
| 35/40 °C | Natural | 65.0 | 11.4 | 48.0 | 113.0 |
| 35/45 °C | Pulped | 46.5 | 11.7 | 20.0 | 29.0 |
| 35/45 °C | Natural | 65.0 | 11.1 | 48.0 | 97.0 |
| 35/50 °C | Pulped | 46.5 | 11.3 | 20.0 | 28.0 |
| 35/50 °C | Natural | 65.0 | 11.1 | 48.0 | 91.0 |
| 40/35 °C | Pulped | 48.0 | 11.5 | 18.5 | 37.0 |
| 40/35 °C | Natural | 64.4 | 11.2 | 40.0 | 139.0 |
| 45/35 °C | Pulped | 48.0 | 10.7 | 15.5 | 35.5 |
| 45/35 °C | Natural | 64.4 | 11.0 | 28.0 | 117.0 |
| 50/35 °C | Pulped | 48.0 | 10.8 | 12.0 | 34.5 |
| 50/35 °C | Natural | 64.4 | 11.0 | 20.0 | 107.0 |
| On Ground | Pulped | 46.5 | 10.9 | - | 145.0 |
| On Ground | Natural | 64.4 | 11.8 | - | 251.0 |

It can also be observed that the higher total drying times of coffee beans occurred in the treatment on ground, due to the lower exposure time of these coffees to high temperatures and greater relative humidity of the ambient air, to which these coffees were submitted.

According to Borém et al. (2006) and Ribeiro et al. (2003), the exposure time, the drying air temperature and flow, the initial and final moisture content of the product, the ambient air temperature, are factors that affect the drying dynamics, and have a significant effect on the quality of agricultural products. The removal of exocarp and mesocarp in the wet processing of coffee contributes to the drying time of these coffees.

The increase in air temperature results in a greater difference between the vapor pressure of the drying air and the product, making the water easier and faster to remove (SIQUEIRA; RESENDE; CHAVES, 2012). The increase in temperature reduces the viscosity of the water, directly influencing the resistance of the fluid to the flow. The decrease in viscosity facilitates the diffusion of the water molecules in the capillaries of the product, besides providing an increase in the vibration level of the water molecules, which also contributes to the increase in the drying rate (CORRÊA et al., 2010).

### 3.2 Sensory analysis

Considering this type of evaluation, the analysis of variance of the data was performed for the overall score.

The overall score for each type of processing is shown in Table 3 and the overall score for each drying method is in Table 4.

It is observed that processing had no significant effect on the overall score. However, if each attribute that comprises the overall score is analyzed, it was observed by panelists that natural coffees have higher scores, in terms of body and sweetness. Pulped coffees presented higher scores for acidity and finishing. This fact is directly related to the type of processing used. As the overall score is the sum of all attributes, there were no significant differences for these coffees, even though it was known that, for our taste, the coffee was different.

**TABLE 3** - Mean values of the overall score for each drying treatment - Lavras - 2013.

| Processing | Overall score |
|---|---|
| Natural | 80.50 A |
| Pulped | 79.60 A |

Means followed by distinct letters, upper case in columns, belong to the same cluster by Scott-Knott's test at 1% probability.

**TABLE 4** - Mean values of the overall score for each drying treatment - Lavras - 2013.

| Drying treatment | Overall score |
|---|---|
| On Ground | 82.70 A |
| 35/40 °C | 81.20 A |
| 35/45 °C | 78.83 B |
| 35/50 °C | 77.55 C |
| 40/35 °C | 81.54 A |
| 45/35 °C | 79.42 B |
| 50/35 °C | 80.04 B |

Means followed by distinct letters, upper case in columns, belong to the same cluster by Scott-Knott's test at 1% probability.

Regarding drying treatments 50/35 °C and 35/50 °C, there were differences between the average values of the overall score, regardless of the type of processing used, whether it is pulped or natural. The highest overall score values were found in the drying treatment 50/35 °C. It is noted that the use of heated air at 50 ºC after half-dry was extremely detrimental in maintaining its sensory characteristics, indicating a higher sensitivity of these coffees to the increase in the drying temperature at the end of the drying process. According to Borém et al. (2008) and Saath et al. (2012), the cell membranes of coffee beans are especially damaged when the moisture contents of coffee are between 30% to 20% (w.b.), using a constant drying temperature of 60 °C for pulped and natural coffee.

The highest values for the total score were found in the coffees dried on ground, 35/40 °C and 40/35 °C, when compared to the other drying treatments with heated air. This fact indicates a possibility of new managements that reduce costs, since there will be a greater final quality of the product. For specialty coffees, some producers are using lower temperatures.

It can also be observed that the increase in drying temperature, before or after half-dry, was detrimental to the sensory attributes of these coffees. Borém et al. (2006), Coradi et al. (2007) and Marques et al. (2008), studying the effect of bean mass temperature on sensory quality, reported that the increase in drying temperature was detrimental to the maintenance of sensory quality of parchment and natural coffee.

### 3.3 Physiological and physicochemical analyses

#### 3.3.1 Electrical conductivity, potassium leaching and germination

Table 5 reveals that the type of coffee processing and drying had a significant influence on the physiological evaluations. Lower germination values were found in natural coffees, indicating that more intense physiological damage occurred in these coffee beans, due to the longer exposure period to high temperatures. A similar result was observed by Taveira (2009), indicating the higher tolerance of these coffees to high drying temperatures, when compared to natural coffees. For natural coffees, only the coffees dried in yard presented values indicative of the presence of physiological activity in the beans. For the drying treatments with heated air, the values were low, indicating embryo death of natural coffee beans during the drying process, reinforcing the sensitivity of these coffees to drying at high temperatures (TAVEIRA, 2009).

**TABLE 5 -** Mean values of physiological and physicochemical evaluations for the interaction drying treatment and type of processing, data in percentage (%) - Lavras - 2013.

| Drying Treatment | Electrical conductivity | | Potassium leaching | | Germination | |
|---|---|---|---|---|---|---|
| | Natural ($\mu S.cm^{-1}.g^{-1}$) | Pulped ($\mu S.cm^{-1}.g^{-1}$) | Natural ($mg.kg^{-1}$) | Pulped ($mg.\ kg^{-1}$) | Natural (%) | Pulped (%) |
| On Ground | 2.06 aC | 1.38 aC | 15.85 aB | 8.68 bA | 70.25 aA | 72.75 aB |
| 35/40 °C | 4.82 aA | 3.75 bA | 20.26 aA | 12.02 bA | 50.50 bB | 93.34 aA |
| 35/45 °C | 5.10 aA | 3.91 bA | 14.00 aB | 14.80 aA | 8.17 bD | 92.67 aA |
| 35/50 °C | 5.21 aA | 4.12 bA | 15.18 aB | 12.02 aA | 0.00 bD | 76.33 aB |
| 40/35 °C | 3.47 aB | 2.32 bB | 12.13 aB | 10.99 aA | 35.33 bC | 94.5 aA |
| 45/35 °C | 3.66 aB | 2.71 bB | 8.81 aC | 13.64 aA | 37.33 bC | 92.66 aA |
| 50/35 °C | 3.85 bB | 3.10 bB | 9.13 aC | 9.87 aA | 31.00 bC | 81.50 aB |

Means followed by same lowercase letters in the rows and capitals in the columns belong to the same cluster by Scott-Knott's test at 1% probability.

The drying treatments 35/40 °C, 40/35 °C, 35/45 °C and 45/35 °C for pulped coffees, are presented as a good alternative for seed drying of wet processed coffee, in order to maintain their physiological quality (germination and EC). According to Taveira et al., (2015) wet processed coffee has a greater tolerance to drying than those which underwent the dry process, due to the greater activity of antioxidant enzymes, found in wet processed coffee.

For natural coffees, the increase in drying temperature before reaching the moisture content of 30% or later, significantly reduced the germination percentage, being more intense in the drying treatments 35/45 °C and 35/50 °C.

The use of high temperatures allows faster drying; however, it can lead to a very large moisture content difference between the periphery and the bean center, generating a high pressure gradient, which can cause disruption in the cellular membranes of coffee beans, resulting in a reduction in seed vigor, related to the emergence and potential development of normal seedlings, or even the total loss of viability, defined as the ability to produce normal seedlings.

It can be confirmed from Table 5, that there were significant differences between the types of processing and drying used in the experiment, in relation to the electrical conductivity. The highest values of electrical conductivity, regardless of the drying treatment, were found in natural coffees, when compared to pulped coffees, indicating that this form of processing contributed to the electrical conductivity values being smaller, with consequent maintenance of the cellular structures and product quality. Another fact that may have contributed would be the shorter exposure time of these coffees to the high temperatures, when compared to the natural coke exposure times (PRETE, 1992).

Regarding drying treatments, it was noticed that the increase in drying temperature resulted in higher electrical conductivity values, both for coffees processed dry and wet. This fact corroborates what was reported by Borém et al. (2008) and Coradi et al. (2007), who verified that the increase in drying temperature causes damage to the cell membrane system of coffee beans, increasing the electrical conductivity of the bean exudate.

It is also seen in Table 5 that the drying treatment that caused the least damage to cell structures was on ground. This fact may be related to the lower exposure time to high temperatures, lower bean mass temperatures and lower drying rates. Regarding the mechanical drying treatments, drying temperatures of 35/40 °C, 35/45 °C and 35/50 °C resulted in the highest values of EC, LK and Germination, indicating a higher compromise of coffee quality, compared to drying at temperatures 50/35 °C, 45/35 °C and 40/35 °C. This increase in the electrical conductivity of coffees processed through drought and drought, when using higher temperatures after half-drought, compared to using the same temperatures before half-drought, can be explained by the longer exposure time and greater disruption of cell membranes when using high temperatures at the time the product was at a lower moisture content. Similar phenomena were observed by Saath et al. (2012), who analyzed the damage caused by the drying temperature in the cellular structures of coffee beans, found that they occur more intensively between moisture contents ranging from 30% (w.b.) to 20% (w.b.), when using the temperature of 60 °C in drying.

As in the electrical conductivity test, the highest values of potassium leaching were found in coffees processed dry, again indicating that the exposure time of these coffees to drying, both in terrarium and in dryers, may have been one of the causers of this phenomenon. The same phenomenon was observed by Taveira et al. (2012), studying temperature changes during the drying process.

The high temperature at the beginning of drying, before the half-dry, at the treatment of 50 / 35 ºC, and at the end of drying, after the half-dry in the treatment 35/50 °C, could have been harmful to the physiological integrity of the beans, indicated by high potassium leaching values, compared to drying on ground. The highest potassium leaching values were found in natural and pulped coffees dried at temperatures of 35/45 °C and 35/50 °C, indicating the higher sensitivity of the membranes to low moisture contents. At this moment, there was a very large energy accumulation inside the bean, which can, depending on the temperature used in drying, compromise the cellular structures with consequent solute leaching.

There is agreement that degeneration of cell membranes and subsequent loss of permeability control is one of the early events that characterize deterioration. According to Malta et al. (2005), any factor that changes the structure of the membrane, such as the attack of insects and microorganisms, physiological changes, mechanical and thermal damage, cause a rapid deterioration of coffee beans. These changes cause chemical reactions that modify the original chemical composition of coffee beans and, consequently, their sensory and physiological properties.

### 3.4 Grease acidity

Table 6 presents the results of the effect of the drying treatment for each type of bean processing on the acidity of the grease.

Significant differences were observed in the acidity content of the grease between drying and processing treatments. These results are related to membrane stabilization and cell wall integrity, indicating that a greater cell membrane degradation will give rise to a greater amount of free fatty acids (MARQUES, 2008). According to Coradi and Lemes (2018), the reduction in lipid content and the increase in free fatty acid contents during storage are directly correlated with the speed and intensity of the bean deterioration process, and it is possible to use the free fatty acid content as an indicator of bean deterioration.

In relation to the processing of coffee beans, Table 6 reveals that the highest values were found in coffees processed dry. It is assumed that the higher exposure of these coffees to high temperatures caused the rupture of cell membrane structures, extravasating oils and compromising coffee quality with oxidation processes, demonstrating the higher sensitivity of these coffees at high temperatures (OLIVEIRA et al., 2012).

**TABLE 6**- Average grease acidity values for the interaction between drying and processing treatments Lavras - 2013.

| Drying treatment | Grease Acidity | |
|---|---|---|
| | Natural | Pulped |
| | (mL KOH.100 $g^{-1}$ DM) | (mL KOH.100 $g^{-1}$ DM) |
| On Ground | 3.39 aD | 3.13 bB |
| 35/40 °C | 3.49 aC | 3.04 bB |
| 35/45 °C | 3.71 aB | 3.23 bB |
| 35/50 °C | 3.91 aA | 3.40 bB |
| 40/35 °C | 3.32 aD | 3.16 bB |
| 45/35 °C | 3.53 aC | 3.35 bB |
| 50/35 °C | 3.66 aB | 3.48bB |

Means followed by same lowercase letters in the rows and capitals in the columns belong to the same cluster by Scott-Knott's test at 1% probability.

It can be observed that the results for pulped coffee with mechanical drying were satisfactory, since the value of its grease acidity was statistically equal to that of drying on ground, a phenomenon that indicates a greater maintenance potential of the quality of these coffees when stored, suggesting that husk removal in pulped coffees decreased the amount of free fatty acids. The drying treatments 35/50 °C and 50/35 °C were those that yielded the highest grease acidity values, suggesting that this drying treatment damaged the cellular structures of the coffee beans, giving rise to a greater number of free fatty acids.

## 4 CONCLUSIONS

Drying on ground for the climatic conditions during the experiment provided the best physiological sensory quality of coffee beans, when compared with drying with heated air.

Pulped coffee has better physiological quality.

The temperatures of 35/50ºC and 50/35 °C were the ones that yielded the worst germination results.

The use of higher temperatures after half-dry was more damaging than when used before half-dry in terms of electrical conductivity.

The use of lower temperatures (35/40 °C and 40/35 °C) showed similar results to drying on ground.

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