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Quality of *Coffea Arabica L.* beans that emit fluorescence when subjected to ultraviolet light

Qualidade de grãos de *Coffea Arabica L.* que emitem fluorescência quando submetidos à luz ultravioleta

Calidad de granos de *Coffea Arabica L.* que emiten fluorescencia cuando se someten a luz ultraviolet

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Abstract
The demand for specialty coffees on the world market is growing, and their commercial value is directly linked to their quality. When subjected to ultraviolet (UV) light, some raw coffee beans show a blue fluorescence. Around the world, producers and traders have used UV light as a quality analysis method to detect defects in beans that cannot be seen with the naked eye. Despite being a technique used for a long time, almost no scientific study has been done to confirm and clarify the matter. Therefore, the work aims to evaluate the quality of the beans that emit and do not emit fluorescence from the same batch. For this, a batch of natural specialty coffee was divided into treatments with different fluorescence concentrations and analyzed sensorially and physicochemically. It was observed that the increase in fully fluorescent beans concentration negatively affected the coffee final score and astringency, and the increase in partially fluorescent beans concentration negatively affected the final score, astringency, sweetness, acidity, bitterness, and aftertaste of the coffee. Furthermore, attributes such as fruity notes and sweetness were affected by the presence of fluorescence, thus changing the sensory profile. In the physicochemical analyses, a reduction in the coffee quality was observed for the parameters of potassium leaching, electrical conductivity, fatty acidity, polyphenols, titratable acidity, moisture and weight of 1000 seeds. Therefore, it was possible to observe that the use of UV light to assess the green coffee beans quality can be a viable method.
Keywords: Coffee; UV light; Quality control.

Resumo
A procura por cafés especiais, no mercado mundial, é crescente e seu valor comercial está diretamente ligado à sua qualidade. Quando submetidos à luz ultravioleta (UV), alguns grãos de café cru apresentam uma fluorescência azul. No mundo, produtores e comerciantes têm utilizado a luz UV como método de análise qualitativa para a detecção de defeitos nos grãos, que não é possível observar a olho nu. Apesar de já ser uma técnica utilizada há muito tempo, quase nenhum estudo científico foi realizado para confirmar e esclarecer o assunto. Portanto, o trabalho tem como

objetivo a avaliação da qualidade dos grãos que emitem e daqueles que não emitem fluorescência. Para isso, um lote de café especial natural foi dividido em tratamentos com diferentes concentrações de fluorescência e analisado sensorial e físico-químicamente. Observou-se que o aumento da concentração de grãos completamente fluorescentes afetou, de modo negativo, a nota final e a adstringência do café, ao passo que o aumento dos grãos parcialmente fluorescentes afetou a nota final, a adstringência, a doçura, a acidez, o amargor e a finalização do café. Além disso, atributos como notas frutadas e doçura foram afetados com a presença da fluorescência, mudando, assim, o perfil sensorial. Nas análises físico-químicas, observou-se uma redução da qualidade do café para os parâmetros lixiviação de potássio, condutividade elétrica, acidez graxa, polifenóis, acidez titulável, umidade e peso de 1000 grãos. Sendo possível, finalmente, observar que o uso da luz UV, para a avaliação da qualidade dos grãos de café verde, pode ser um método viável.
Palavras-chave: Café; Luz UV; Controle de qualidade.

Resumen
La demanda de cafés de especialidad en el mercado mundial está creciendo y su valor comercial está directamente relacionado con su calidad. Cuando se someten a luz ultravioleta (UV), algunos granos de café crudo muestran fluorescencia azul. En todo el mundo, los productores y comerciantes han utilizado la luz UV como método de análisis de calidad para detectar defectos que no se pueden ver a simple vista. A pesar de ser una técnica utilizada desde mucho tiempo, casi no se ha realizado ningún estudio científico que confirme y aclare el asunto. Por tanto, el trabajo tiene como objetivo evaluar la calidad de los granos que emiten y no emiten fluorescencia de un mismo lote. Para eso, un lote de café natural de especialidad se dividió en tratamientos con diferentes concentraciones de fluorescencia y se analizó sensorial y fisicoquímicamente. Se observó que el aumento en la concentración de granos completamente fluorescentes afectó negativamente el puntaje final y la astringencia, y el aumento en la concentración de granos parcialmente fluorescentes afectó negativamente el puntaje final, astringencia, dulzor, acidez, amargor y retrogusto. Además, atributos como notas afrutadas y dulzor se vieron afectados por la presencia de fluorescencia, cambiando el perfil sensorial. En los análisis fisicoquímicos se observó una reducción en la calidad para los parámetros lixiviación de potasio, conductividad eléctrica, acidez grasa, polifenoles, acidez titulable, humedad y peso de 1000 semillas. Por lo tanto, se pudo notar que el uso de luz UV para evaluar la calidad del café verde puede ser un método viable.
Palabras clave: Café; Luz UV; Control de calidad.

1. Introduction

The coffee trade is a multi-billion-dollar industry and coffee remains one of the most traded commodities being of great value economically for producing and consuming countries. To guarantee demand, it is of great importance to constantly maintain and, whenever possible, improve its quality.

The demand for specialty coffees on the world market is growing and in ever-increasing proportions (Guimarães et al., 2019; Ufer et al., 2019). The specialty coffee differentiation is related to its sensory characteristics and care during the production process, having a superior quality both in the beverage and appearance of the beans, as well as in the cultivation and processing history. The criteria used to evaluate the coffee beans quality include bean size, colour, shape, processing method, crop year, presence of defects and flavour or cup quality (Banks et al., 1999).

Under ultraviolet light (UV) with a wavelength around 365nm, known as black light, some green coffee beans emit a blue fluorescence. Many specialty coffee producers and traders use UV light to analyze coffee quality. Through experience and observations, they believe that beans that emit fluorescence when subjected to this radiation are beans of inferior quality compared to those that do not emit fluorescence, and that phenomenon can be due to defective beans, excessively fermentation, old coffee, phenolic coffee, and it can also be an indication of processing performed incorrectly or increase of microbial activity (Coffee Damage under UV Light, 2009; Bryman, 2019; Choi, 2019; Pate, 2019; Our Green Bean Quality, n.d.; Feran, 2020; Galova, 2020).

Through preliminary sensory analysis, it was observed that the flavor presented by the beans that emit fluorescence is different from the flavor presented by the beans that do not emit. The coffee quality perceived by the flavor and aroma in the cup is a reflection of the quantitative and qualitative content of the chemical components present in raw beans. These compounds are formed in the plant under the influence of several factors such as genotype (Scholz et al., 2013), environment

(Silva et al., 2005), agricultural practices (Vinecky et al., 2017), harvest maturation point (Farah & Donangelo, 2006), and post-harvest process (Duarte et al., 2010). It is important to emphasize that the coffee flavor and aroma directly influence the value and price of the coffee. The better the flavor and aroma, the greater its commercial value.

Fluorescence is a phenomenon that has been extensively studied since many processes and systems of biological interest involve molecules that absorb and emit radiation in the ultraviolet and visible range of the spectrum (Pavoni et al., 2014). According to Roshchina (2012), the compound's fluorescence intensity signal can be affected by several factors, such as the environmental conditions of the fluorophores inside the cell, including temperature, pH, water potential, light, the physiological state of the cell, and the absorption of light by other compounds, etc. By excitation, thanks to the specificity of the fluorescent signals emitted by plants, specific fluorescence analysis provides valuable information about physiological conditions, plant diseases, and many abiotic stresses such as nutritional deficiencies (García-Plazaola et al., 2015; Roshchina, 2012).

In specialty coffee, not many scientific studies have been done that address this phenomenon. One of the first mentions of the possibility of using UV light to identify defects in coffee that can not be seen with the naked eye was made in 1975, where the authors Gibson and Butty (1975) note that the phenomenon of fluorescence enables the identification and removal of over-fermented coffee beans (“stinkers”). A few years later, another study was published at the same event, International Scientific Colloquium Coffee at Hamburg, talking about experimental machines based on UV light excitation for defect separation. Unfortunately, the researcher did not achieve any sensory improvement in the results, and the explanation is that the experiment was carried out in an importing country and, therefore, the coffee was already a little aged (Carter, 1980).

Some recently published studies show that coffee beans subjected to the increase of water contents associated with high drying rates (Tavares et al., 2008), mechanical impacts suffered during processing and storage time (Pereira et al., 2008) are related to fluorescence emission and, therefore, the application of UV light can help to verify the integrity of raw coffee bean (Oliveira et al., 2011).

Based on the above, it is notorious the importance of studying this phenomenon of fluorescence observed in raw coffee beans. The use of UV for qualitative coffee analysis is attractive, as it is a simple, non-destructive, fast, and low-cost method compared to other analytical methods. All that is needed is representative samples of the coffee batch and a UV light lamp. However, the method still requires many scientific studies to prove its efficiency.

Thus, the goal of this work is an exploratory study, aiming to evaluate the sensory and physicochemical quality of beans that emit fluorescence when subjected to ultraviolet light.

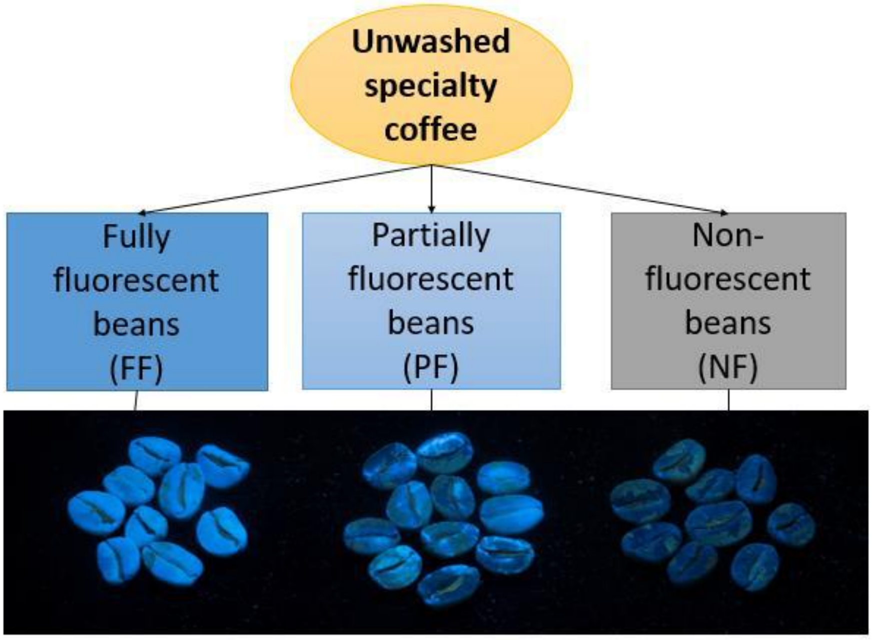
2. Methodology

2.1 Sample characterization and standardization

For this research, a natural specialty coffee (Coffea arabica L.), specifically the floaters cherries from the 2020 crop, was analyzed. The coffee was supplied by the coffee exporter company, Bourbon Specialty Coffees S/A, located in Poços de Caldas – Minas Gerais. The coffee was a Mundo Novo variety from Cachoeira da Grama Farm. This coffee batch was sieve 16 above without visible physical defects and had a final score of 83 points being classified as a specialty according to the criteria described by the Specialty Coffee Association – SCA (Lingle, 2011).

To characterize the percentage of fluorescence in the batch, 100g of sample was taken and placed under UV light for analysis. Within the same coffee batch, beans can fluoresce in different ways when exposed to UV light. Some beans fluoresce partially, in other words, just in some parts of the bean, and others fluoresce in their entirety. Therefore, to assess the incidence of fluorescence, the beans were separated into three groups according to its fluorescence: non-fluorescent beans (NF), fully fluorescent beans (FF), and partially fluorescent beans (PF), as shown in Figure 1.

Figure 1 - Schematic representation of the groups separation according to its fluorescence.



Source: Authors (2020).

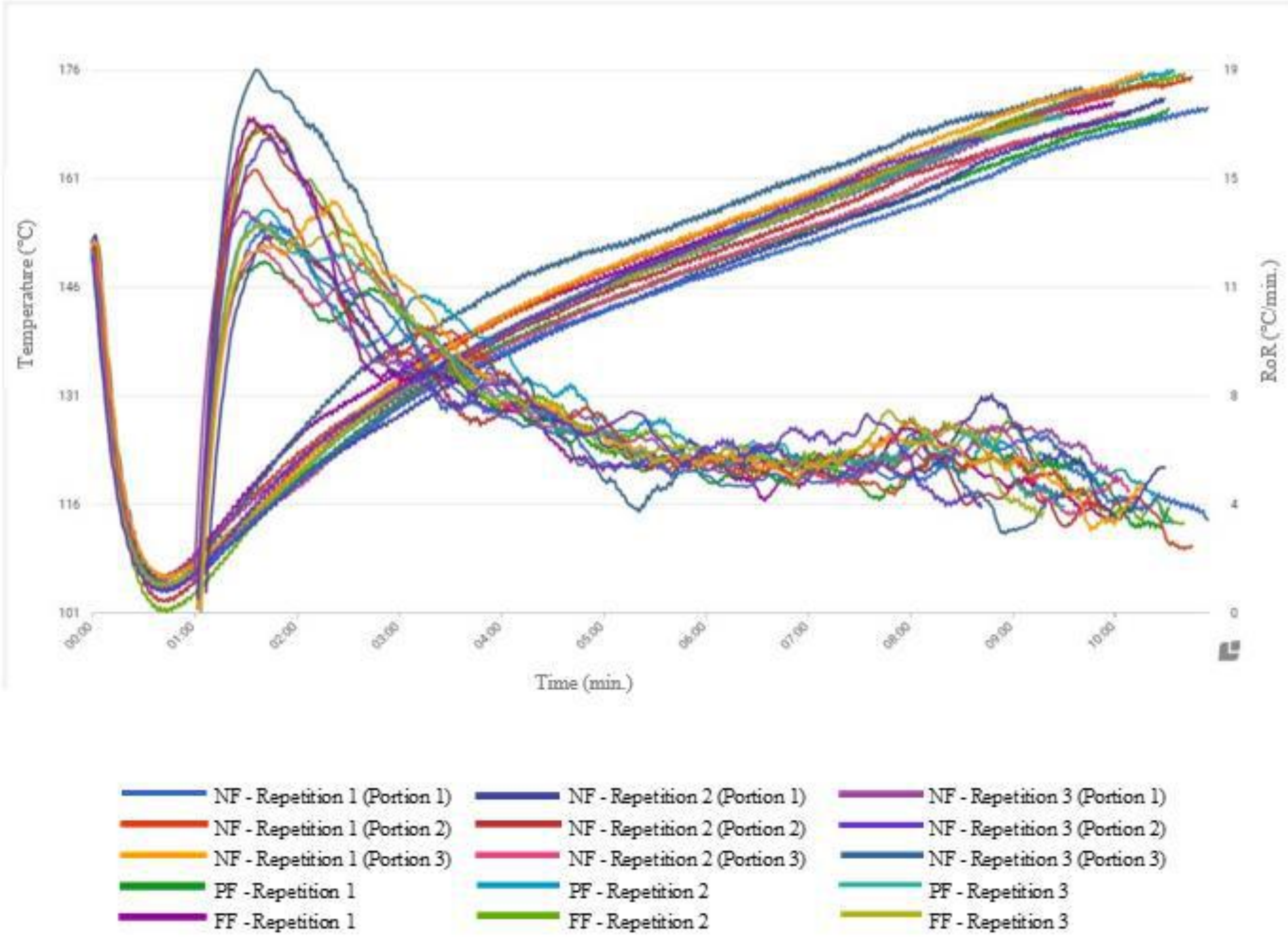
The coffee batch was characterized with 16% of fully fluorescente, 24% of partially fluorescent beans and 60% of non-fluorescent beans.

For the sensory analysis and for the physical-chemical analysis, 6 bags of 30 kg from that batch were separated in the 3 large groups mentioned above according to its fluorescence. The separation was manual using a PeeDar 2.0 UV light lamp with a wavelength of 380 – 385nm. The lamp was placed on a support to be at 20 cm distance from the coffee that allowed a good visualization of the fluorescence of the beans. In a dark room, the beans were spreded out on a black surface (mat), and with the help of the lamp, was performed the manual separation of the 3 groups.

2.2 Sensory analysis

The sensory analysis was performed on treatments with different concentrations of FF beans versus different concentrations of PF beans. But before prepare the treatments, the 3 groups were roasted separately. For each of the 3 replications were used 660g of PF beans, 660g of FF beans, and 1920g of NF beans. For homogenization during roasting, the group of NF beans were divided into 3 portions of 640g. Each of these parcels was roasted separately in a Probatino Leogap roaster with a capacity of 1000g, monitoring the temperature, the roasting time and final color following the guidelines of the SCA Procotols (SCA, 2018). Thus, the roasting time was not less than 8 minutes nor more than 12 minutes, the roast color was Agtron "Gourmet" 63, and all groups were roasted at least 8 hours before cupping. The roasts were made using the Cropster software to monitor the temperature and roasting time, seeking to maintain standardization and consistency during the process, as seen in Figure 2.

Figure 2 - Temperature Kinetics of the bean mass and the temperature rate progression (RoR) during the coffee roasting.



Source: Study data.

After roasting, for the preparation of the treatments, 5 concentrations (0, 5, 10, 25 and 50%) of FF beans were added versus 5 concentrations (0, 5, 10, 25 and 50%) of PF beans on NF beans aiming to structure 25 different combinations. In order to also evaluate the sensory effect of only PF beans and only FF beans, two additional treatments were added: a portion with 100% PF beans and another portion with 100% FF beans.

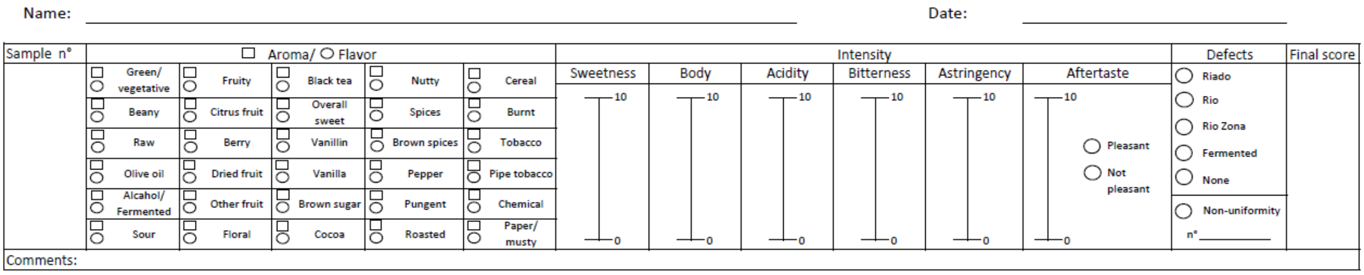
The experiment was installed in a randomized block design (RBD) in a 5 x 5 + 2 factorial scheme [5 concentrations of FF and 5 concentrations (0, 5, 10, 25, 50%) of PF] and 2 additional (100% of FF and 100% PF). The block was considered each coffee taster and 3 replications were performed.

The concentration preparation of each treatment was carried out by weighing the coffee from each group in each cup, with a total of 5 cups per treatment to assess the uniformity of the sample.

Soon after, the samples were ground using a Mahlkonig EK43 mill. Clean and odor-free water was used. The water was brought to approximately 92–94 °C and poured directly into the ground coffee. The proportion was 8.25 g of coffee per 150 ml of water or 5.5% w/v. Sensory analysis was carried out according to the recommendations of SCA cupping protocol (SCA, 2018). To reduce the number of samples cupped in a single day, sensory analyzes were divided into 2 days of testing, with 1 replication performed on the first day and 2 replications on the following day.

The evaluation was carried out by a panel composed of 6 licensed Q-graders who received all coded samples. The sensory evaluation form was according to the one used by Rabelo et al. (2021). The only adaptation made in order to facilitate the description was the change of the aroma and flavour descriptors according to the terms pointed at Coffee Taster's Flavor Wheel (Spencer et al., 2016) as seen in Figure 3.

Figure 3 - Sensory evaluation form.



Source: Adapted of Rabelo et al. (2021).

For the statistical analysis of the sensory attributes (Final Score, Sweetness, Acidity, Body, Astringency, Bitterness and Aftertaste), the results were first tabulated. Then, the assumptions of normality were tested by the Shapiro-Wilk test, and homoscedasticity by the F-maximum. The interaction and the additionals were also tested. As there was no violation of the assumptions and no significance was detected for the interaction and for the additionals, the results of sensory attributes were submitted to analysis of variance (ANOVA) and, when significant differences in the F test were detected, regression analyzes were performed. The statistical tests were performed according to Ferreira (2011) and with the use of spreadsheets.

For the terms describing the aroma and flavor, it was contructed relative frequency histograms using the Microsoft Office® Excel 2019. In order to facilitate the data visualization, the 30 descriptors were first grouped into 9 large categories following the order described at the Coffee Taster's Flavor Wheel (Spencer et al., 2016) as shown in Table 1. The histograms were compared in the same factors analyzed for the physicochemical parameters, that is, in the 3 groups FF, PF and NF.

Table 1 - Grouping the aroma and flavor descriptors.

Green/ vegetative	Green/ vegetative	Floral	Floral	Spices	Spice
Beany		Black tea		Brown spices	
Raw		Overall sweet	Sweet	Pepper	
Olive oil		Vanillin		Pungent	
Alcohol/ Fermented	Sour/ fermented	Vanilla		Roasted	Roasted
Sour		Brown sugar		Cereal	
Fruity	Fruity	Cocoa	Cocoa/ nutty	Burnt	
Citrus fruit		Nutty		Tobacco	
Berry				Pipe tobacco	
Dried fruit				Chemical	Other
Other fruit				Paper/ musty	

Source: Authors.

2.3 Physicochemical analysis

In order to evaluate the bean quality based on the presence of the fluorescence, the physicochemical analysis was done only in the three groups according to its fluorescence: non-fluorescent beans (NF), fully fluorescent beans (FF), and partially fluorescent beans (PF).

The moisture, water activity (Aw), color, pH, total dissolved solids (TDS), weight of 1000 seeds, and titration acidity analysis were done at Food Science and Technology Laboratory of the Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas (IFSULDEMINAS) - Machado campus. The potassium leaching, fatty acidity and polyphenols analysis were done at Central Laboratory of Chemical Analysis of the IFSULDEMINAS - Pouso Alegre campus. The electric conductivity analysis was done at Phytopathology Laboratory of IFSULDEMINAS - Machado campus. Lastly, the bulk density analysis was done at Bourbon Specialty Coffee's Lab.

The coffee moisture, expressed in % of wet basis (w.b.), was determined by the oven method, at 105±1 °C, for 16 hours, according to the standard method of ISO 6673 (International Organization for Standardization, 2003). The determination of Aw was carried out directly in the Aqualab equipment, Decagon brand 4TE model, at 25°C±1. According to the analysis procedure some amount of coffee was placed in plastic capsules until reaching 50% of the capsule capacity and taken directly to Aqualab for reading.

The bulk density, expressed in $Kg.m^{-3}$, was determined using a Motomco brand hectoliter weight scale, with a capacity of 250mL (Santos, 2011). The weight of 1000 seeds (g) was determined according to Brasil (2009).

The color was determined in a Minolta® CR 310 colorimeter (illuminant C and angle 10º), measuring the parameters: "L" (luminosity), "a" and "b" (chromaticity coordinates). The samples were placed in petri dishes and for each repetition, five readings were performed, at the four cardinal points and one at the central point of the petri dish.

The total titratable acidity was determined by titration with NaOH 0.1N, adapting to the methodology cited by Association of Official Analytical Chemists (AOAC) (1990). The result was expressed in mL of NaOH 0.1N per 100g of sample (dry matter). In the same extract, the pH was measured with a pHmeter and the TDS content determined in a refractometer (AOAC, 1990).

The electrical conductivity of raw beans, expressed in $\mu S.cm^{-1}.g^{-1}$, was determined by the methodology adapted by Malta, Pereira, e Chagas (2005). After reading the electrical conductivity, the solutions were cooled and taken to the Central Laboratory of Chemical Analyzes at IFSULDEMINAS to determine the amount of leached potassium, according to the methodology proposed by Prete (1992) with the reading in a flame photometer. With the data, the amount of leached potassium was calculated, expressing the result in ppm.

Fatty acidity, expressed in mL of KOH per 100g of coffee (dry matter), was determined by titration, according to the method described by the American Association of Cereal Chemists (1995).

Colorimetric assay by spectrophotometry (UV-VIS Spectrum SP-2000 UV, Biosystems) was used to determine the total polyphenol content by the Follin – Ciocalteau methodology according to Singleton and Rossi (1965) with minor modifications. In brief, for extraction, 2.75g of ground green coffee was extracted with distilled water at 90°C to complete 50mL of extract. It was homogenized 0.5mL of coffee extract, 2.5 mL of Folin–Ciocalteau reagent (10%) and 2.0 mL of Na_2CO_3 (4% w/v) and incubated at room temperature, in the dark for 120 min. The absorbance of the samples was measured at 750 nm. Through the standard curve of gallic acid (ranging from 10 to 100 µg/mL) the polyphenol concentrations were calculated and expressed as milligrams of gallic acid equivalents per gram of ground coffee (mg GAE/g).

The physico-chemical determinations were performed in two replicates. The experimental design used was randomized block with seven replications, with a factorial (3 x 7). It was used the Scott-Knott test at 5% level.

3. Results and Discussion

3.1 Sensory analysis

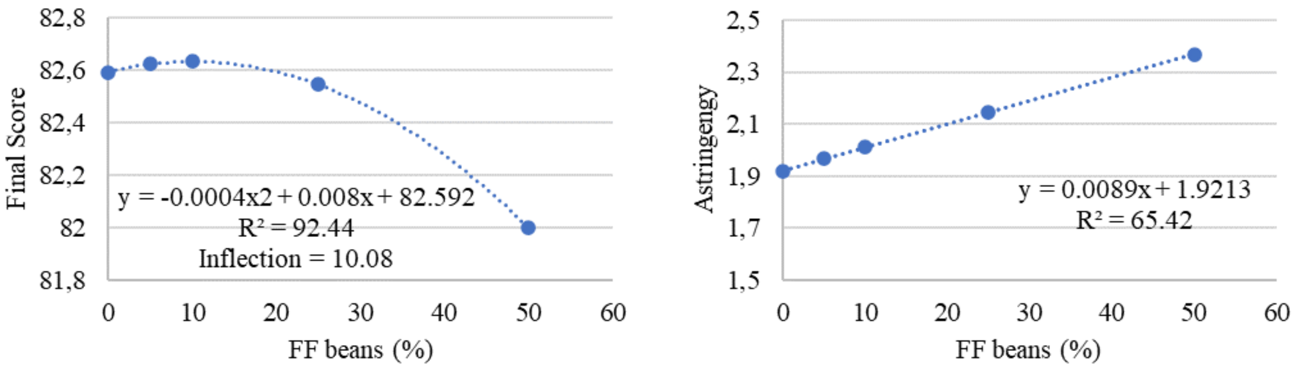
3.1.1 Sensory attributes evaluation

There was no interaction between FF and PF for any attribute analyzed, so the split was not performed. Therefore, the regression analysis was performed separately for the FF and PF.

3.1.1.1 Fully fluorescente

The concentration increases of fully fluorescent beans changed the final score and the astringency of the coffee, as can be seen in Figure 4.

Figure 4 - Coffee final score and astringency as a function of the fully fluorescent beans concentration.



Souce: Authors (2021).

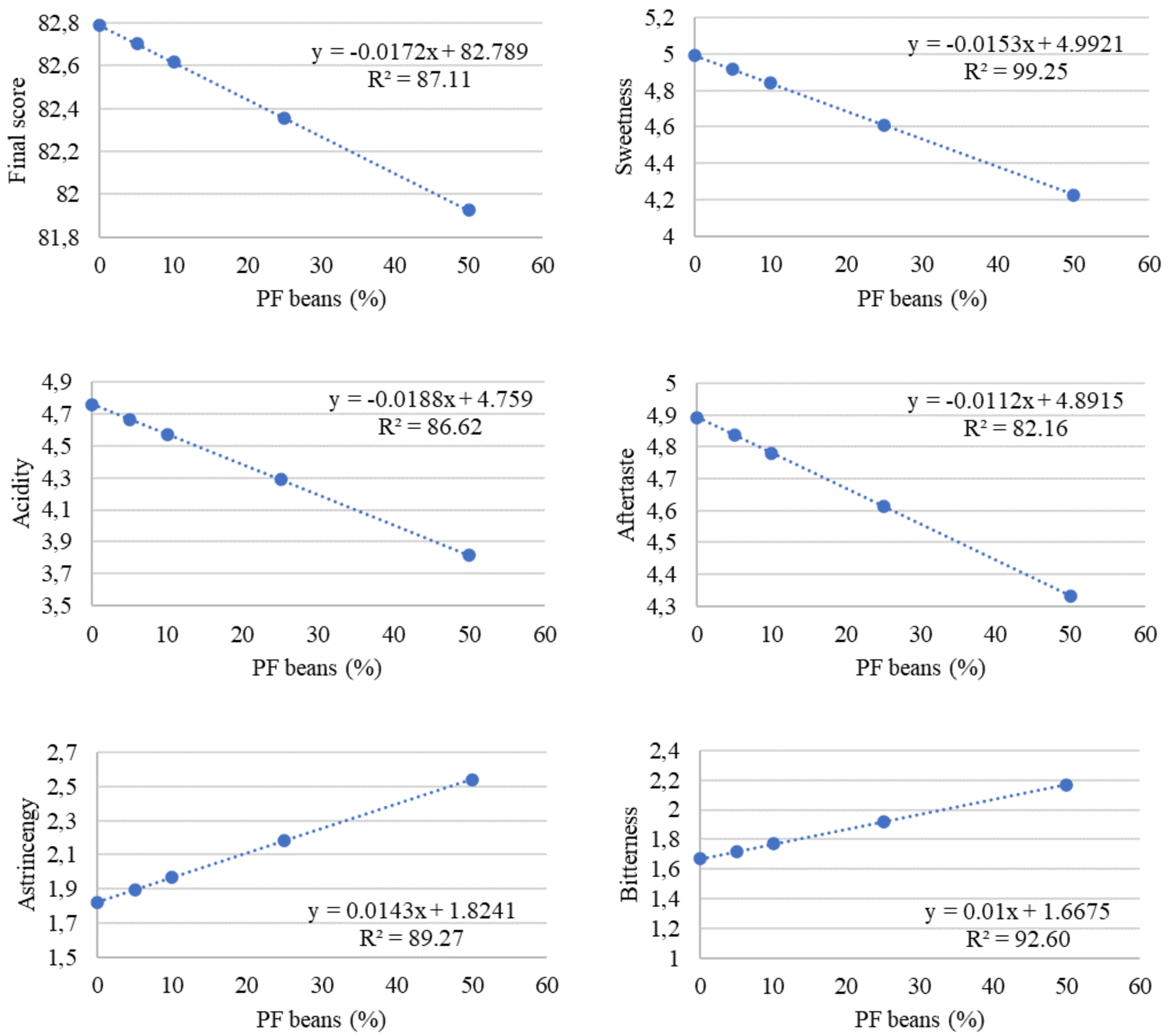
The presence of fully fluorescent beans concentration from 10% started to negatively affect the final score of the natural specialty coffee. The final score takes into account all the attributes of coffee and the lower its value, the lower the coffee value in the market (Ribeiro et al., 2011).

The results also show that the coffee astringency increased as the percentage of fully fluorescent beans increased (Figure 4). Astringency is an undesirable attribute in coffee, and when present devalues the quality of the coffee. According to Kreuml, Majchrzak, Ploederl, e Koenig (2013), the presence of phenolic compounds in coffee in larger amounts is responsible for astringency, coffee pigmentation and formation of aroma.

3.1.1.2 Partially fluorescent

The increase in partially fluorescent beans altered the final score, sweetness, acidity, bitterness, astringency and aftertaste of the coffee, as can be seen in Figure 5.

Figure 5 - Coffee final score, sweetness, acidity, bitterness, astringency, and aftertaste as a function of the partially fluorescent beans concentration.



Souce: Authors (2021).

The increase of PF beans altered the coffee final score. The coffee final score is a very important parameter for specialty coffees, as it is one of the main factors that will indicate the commercial value of the coffee (Borém et al., 2019).

In the sensory evaluation of specialty coffees, besides the final score, the scores obtained in each of the sensory attributes that composes the beverage quality are important in order to identify distinct sensory characteristics, and at the same time, describe the specific notes or nuances of aroma and flavor found in a given sample (Figueiredo, 2010). From the data, it is possible to observe that the coffee sweetness and acidity decreased as the percentage of PF beans increased. Sweetness is an appreciated parameter in specialty coffee (Lingle, 2011). As reported by Siqueira and Abreu (2006), the acidity perceived in coffee is an important attribute for the sensory analysis of the product, knowing that its intensity varies depending on the stage of fruit maturation, place of origin, type of harvest, methods of processing, type of drying and weather conditions during harvest and drying.

The coffee aftertaste received lower scores as the percentage of partially fluorescent beans increased. When tasting a coffee, the taster is always looking for a coffee with a long and pleasant finish, and the result shows that the increase in PF beans affects this characteristic. Coffee bitterness and astringency, which are negative attributes, increased as the percentage of partially fluorescent beans increased.

Summarizing, the increase of FF beans negatively affected the final score and astringency attributes, and the increase of PF beans negatively affected the final score, the astringency, the sweetness, the acidity, the bitter and the aftertaste coffee attributes. The attribute that was not significantly affected by FF and PF beans was the body.

Analyzing the treatments more carefully to try to understand the reason many atributes were negatively affected as PF beans percentage increased, it was observed that some partially fluorescent beans had slight physical damage that went unnoticed during classification, such as beans with small cuts, beans with a few insect damages (perforation from border beetle) and scratched beans, as can be seen in Figure 6.

Figure 6 - Partial fluorescent beans with slight physical damage.

Souce: Authors (2021).

This may be an indication that partial fluorescence can help the identification of beans with slight physical damage and flaws.

Overall, it was possible to observe that the increase of fluorescent beans decreases the coffee sensory quality.

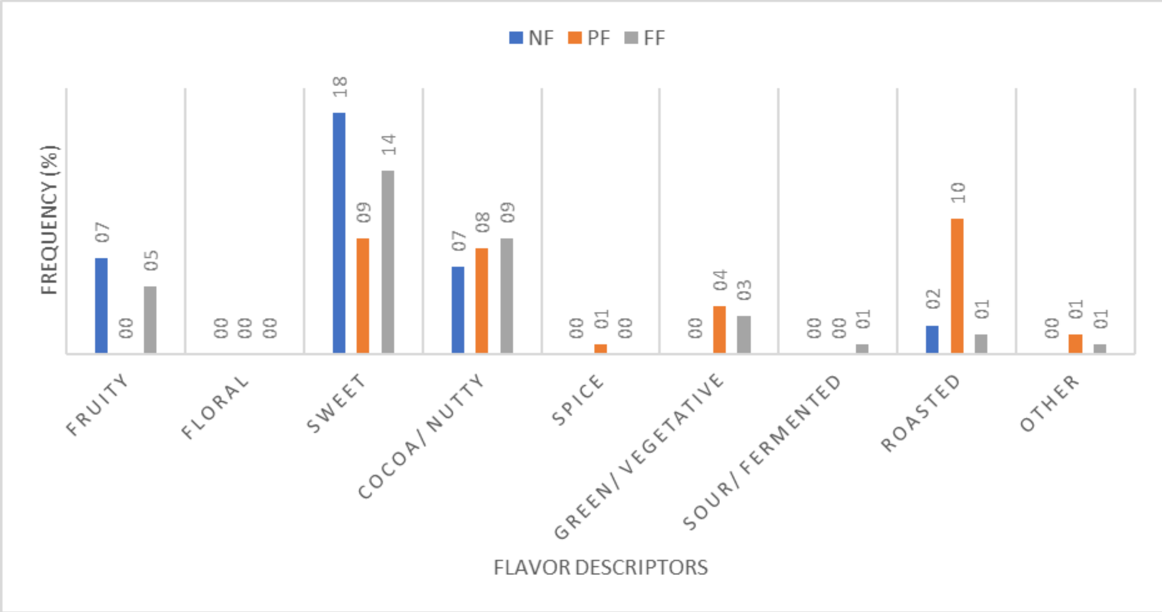
3.1.2 Aroma and flavor analysis

The analysis of the terms describing the coffee flavor can be seen in Figura 7.

From Figure 7, it is possible to observe that the tasters described the NF coffee as a very sweet coffee, with fruity and cocoa/nutty notes and slightly roasted.

According to the data, the presence of fluorescence changed the flavor of the coffee. The FF coffee had its fruity and sweet notes reduced compared to NF. In addition, it was observed a slight increase in cocoa/nutty perception and the appearance of negative notes such as green/vegetative that were not described in NF coffee.

Figure 7 - Relative frequency histograms for the terms describing the coffee flavor for the NF, PF and FF beans.



Souce: Authors (2021).

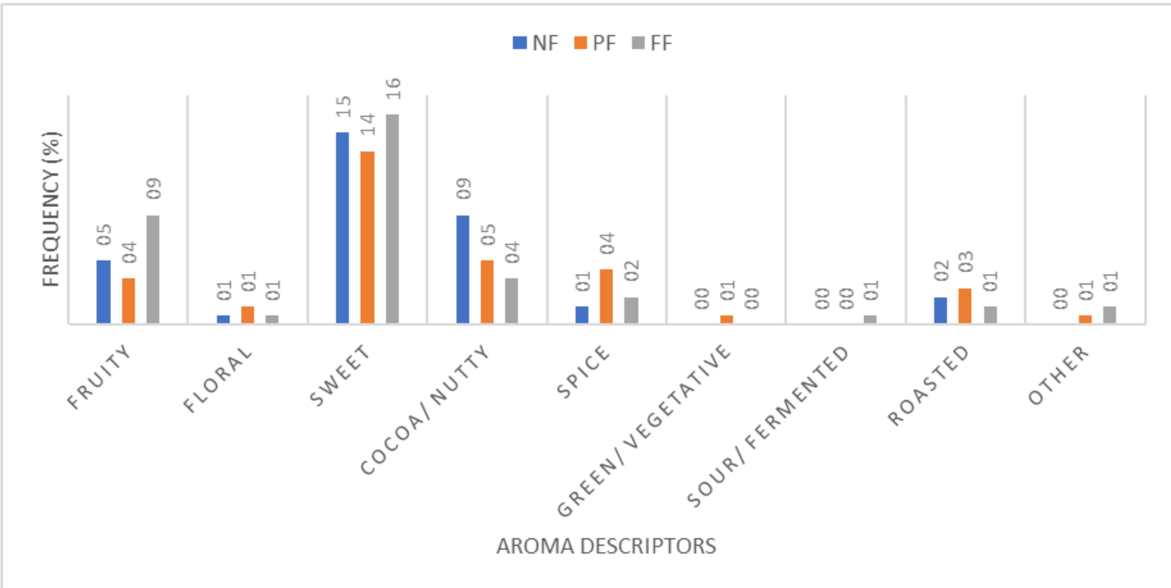
As for PF coffee, the sensorial change was greater. It is possible to notice that the coffee did not have fruity notes and had reduced sweetness compared to NF. In addition, tasters described an increase in cocoa/nutty and roasted notes, and the appearance of negative flavors such as green/vegetative and other.

The descriptors floral, spice, and sour/fermented were not or almost not pointed by the tasters to describe the coffees.

As mentioned by Farah et al. (2006), flavor and aroma are the most important attributes for evaluating coffee quality, as they are the main motivations for consumer preferences.

Therefore, it can be concluded that the presence of fluorescence changed the coffee flavor profile. For the aroma analysis, the terms describing the coffee can be seen in Figura 8.

Figure 8 - Relative frequency histograms for the terms describing the coffee aroma for the NF, PF and FF beans.



Souce: Authors (2021).

According to the data, it is possible to observe that the difference in the coffee aroma in relation to the presence of fluorescence was smaller than the change in the coffee flavor. For NF coffee, tasters described the aroma as sweet, with notes of cocoa/nutty and fruity, and slightly spicy and roasted. For FF coffee, it was possible to observe an increase in the perception of fruity and sweet notes, which are positive characteristics in coffee. However, there was a slight reduction in cocoa/nutty notes. For PF coffee, the change in aroma was also not big, but it was in a negative way. There was a slight reduction in fruity, sweet and cocoa/nutty notes. In addition, tasters noticed an increase in spice and roasted notes.

As mentioned by Kreuml et al. (2013), aromatic components are crucial in coffee beverages because they are the main components of the coffee consumer's sensory experience.

These sensory analysis results confirm the hypothesis that the increase in fluorescence on the coffee bean decreases the cup quality changing the sensorial profile. Thus, it can be inferred that the use of ultraviolet light for qualitative evaluation of green coffee beans is a viable method.

3.2 Physicochemical analysis

The results of the physicochemical analysis were summarized in Table 2. It is possible to observe in the Table 2 that there is a significant effect of treatments for potassium leaching, electrical conductivity, TDS, titratable acidity, moisture, 1000 beans weight, fatty acidity, polyphenols, and color "a" at 5% probability level by Scott Knott Test. For the other variables, no differences were detected between FF, PF and NF beans.

Table 2 - Physicochemical results of different parameters for fully, partially and non-fluorescent coffee.

Coffee	Potassium leaching (ppm)	Electric conductivity ($\mu S.cm^{-1}.g^{-1}$)	Fatty acidity (mL of KOH/100g)	Polyphenols (mg GAE/g)	Titratable acidity (mL of NaOH/100g)	pH	TDS (%)
NF	69.24 c	103.4 c	9.55 c	7.03 b	193.55 c	5.91 a	28.6 b
PF	119.49 b	204.32 b	13.03 b	7.38 a	237.24 b	5.91 a	34.12 a
FF	124.17 a	224.58 a	15.49 a	7.41 a	292.48 a	5.99 a	33.91 a

Coffee	Moisture (%)	Aw	Bulk density (kg/m^3)	Weight of 1000 seeds (g)	Color		
					L	a	b
NF	9.14 a	0.5224 a	664.3 a	149.72 a	47.04 a	1.83 a	15.76 a
PF	7.84 b	0.5200 a	657.1 b	138.55 b	47.73 a	1.59 b	15.69 a
FF	6.76 c	0.5271 a	668.6 a	137.78 b	48.20 a	1.13 c	15.10 a

NF = Non-fluorescent, PF = Partially fluorescent, FF = Fully fluorescent. Means followed by the same letters do not differ from each other by the Scott knott test at 5% significance. Source: Authors (2021).

3.2.1 Potassium leacing and eletric conductivity

Potassium leaching and electrical conductivity are parameters that indicate the condition of the cell membrane integrity, since ruptured membranes leach a greater amount of solutes (Gourlart et al., 2007). Studies show that the greater the results of potassium leaching and electrical conductivity, the worse the sensory quality of the coffee (Borém et al., 2008; Ribeiro et al., 2011). In this study, the beans that presented the highest leaching and conductivity values were the fully fluorescent ones, showing to be beans with the most disorganized cells, followed by partially fluorescent and finally, with the lowest values, the non-fluorescent beans (Table 2). According to Reinato, Borem, Cirillo, e Oliveira (2012), the loss of cell membrane selectivity is associated with several factors, such as damage suffered by coffee during the processing and drying stages. This loss of permeability control and solute leakage promote oxidative or catalytic reactions, causing undesirable products and harmful to the coffee sensory quality (Borém et al., 2008). This data corroborates the sensory analysis results that revealed a lower final score given to coffee as the percentage of fully or partially fluorescent beans increases.

In seeds, the increase in electrical conductivity is accompanied by loss of vigor and germination potential, which is therefore a method used to infer deterioration processes in beans (Vieira et al., 2001). Thus, the results show that the fluorescent beans have an inferior quality if compared to the non-fluorescent beans.

3.2.2 Fatty acids

Fatty acids are an important element to measure the coffee quality (Tsegay et al., 2020). As mentioned by Oliveira et al. (2013), fatty acidity values are inversely proportional to the quality of the coffee beverage. The results show that the FF beans had the higher values with of KOH/100g of coffee (dry matter), followed by the PF beans and NF beans as can be observed in the Table 2.

According to Marques et al. (2008) and Soares (2003), when coffee beans are under adverse conditions during post-harvest, one of the first reactions that occurs is the release of fatty acids derived from triglyceride hydrolysis. This reaction is the result of damage that compromises cell membrane stability and cell wall integrity, which is common in poorer quality coffees (Coradi et al., 2008). Fatty acids released from the hydrolysis of triglycerides, in the presence of oxygen, can be oxidized, originating other compounds, such as volatile aldehydes, which are related to the unpleasant taste and aroma in coffee (Ribeiro, 2013).

3.2.3 Polyphenols

In coffee, the polyphenols make a highly significant contribution to the taste and aroma of the final product (Pimenta, 2003). Polyphenols are responsible for the coffee astringency flavor and there is evidence of their greater concentration in poorer quality (Abrahão et al., 2010; Ferreira, 2010).

In this study, there was a significant difference between the NF beans to the PF and FF (Table 2). The PF and FF beans presented high polyphenol values above the average of the NF beans, which may explain the increase in astringency in the flavor as the concentration of PF and FF beans increased.

This increase in polyphenols may be related to possible stresses suffered by the beans, since according to Farah and Donangelo (2006), phenolic compounds as secondary plant metabolites usually involve in defense against ultraviolet radiation or aggression by pathogens.

Furthermore, the increase in ruptured cell membranes, as evidenced by the electrical conductivity and potassium leaching analysis, favors the activity of the polyphonoloxidase enzyme that acts on phenolic compounds (Santos et al., 2009).

In their study Abrahão et al. (2010) had a significant variation in the levels of phenolic compounds between the different standards of beverages analyzed, with the “rio” drink standing out with the highest content of phenolic compounds in the green beans and the soft drink had a lower content of total phenolic compounds.

As stated by Figueiredo et al. (2007), phenols generally show blue autofluorescence at UV light.

3.2.4 Titratable acidity, pH and total dissolved solids

Titratable acidity can vary according to the levels of fermentation occurring in the cherries and also the different maturation stages of the cherries (Pimenta, 2001). Some studies indicate that higher titrable acidity values have been associated with poorer quality flavors (Barbosa et al., 2019; Carvalho et al., 1994; Franca et al., 2005; Pimenta, 2001). In their study, Franca et al. (2005) observed significant differences between the levels of total titratable acidity in coffees of different beverage qualities. These authors found mean values of 207.2; 229.7; 219.7; 263.3 mL of NaOH/100g of sample for soft, hard, “riado” and “rio” coffees, respectively, as the Brazilian arabic coffee classification. Pimenta (2001), when analyzing the titratable acidity of coffees harvested in cloth and on the ground, identified higher values for coffee harvested from the ground and reports that these variations may have occurred due to the fact that eventually high microbiological contamination is occurring, which in turn, may contribute for the increase of fermentation levels, which increases the titratable acidity indices.

In the present work the presence of fluorescent beans increased the titratable acidity, and that result reflected in the beverage quality, since the final score decreased as the concentration of fluorescent beans increased. The highest titratable acidity was observed in the FF beans and the lowest in the NF beans.

The result showed that the total titratable acidity had a high relation with the quality of the beverage, but it had no relation with the perceptible acidity evatuated in the sensory analyses. According to Freitas et al. (2020), this may be explained by the titrable acidity being related to occurrence of undesirable fermentation in the coffee due to the presence of fatty acids. In opossition, the perceptible acidity is associated to desirable acidity, suggesting the presence of acids that favor beverage flavor, such as citric, malic, and chlorogenic acids (Ramos et al., 2016; Sunarharum et al., 2014). To know the relation of the desirable acids with the presence of fluorescence, a more detailed analysis is recommended.

Unlike titratable acidity, there was no significant difference for pH as a function of the fluorescent beans presence (Table 2). The values found in this study are in the range of pH described in other works as of Ramalakshmi, Kubra, e Rao (2007), who found values ranging from 5.74 to 6.10. In the same study, the authors comparing defective and nondefectives beans from India did not find statistical differences for the pH parameter, however, like this work, they found differences in the values of titratable acidity that were higher for defective beans compared to nondefective.

Total dissolved solids measured by refractometry are used as an index of total sugars in fruits, indicating the degree of maturity. They are made up of water-soluble compounds, such as carbohydrates (for example, sucrose), caffeine and polyphenols (Gadelha et al., 2009; Ramalakshmi et al., 2007). They are directly related to the body of the coffee flavor and are desirable constituents in high amounts in coffee (Angélico, 2008). Table 2 shows that the presence of fluorescent beans increases the total dissolved solids. This result was probably affected by the high amount of polyphenols found in the PF and FF beans, but a more detailed analysis of the soluble solids would help to know which one influenced this result.

3.2.5 Moisture and Aw

Moisture is an important parameter because it affects coffee beans shelf life and its quality, ensuring safe transport and storage (Caporaso et al., 2018; Wintgens, 2008). Besides that, quantification of the moisture content is necessary because the foods’ composition is usually reported based on dry matter (Ozbekova & Kulmyrzaev, 2019). According to the Ministry of Agriculture (MAPA), regardless of its classification, the moisture content of green coffee cannot exceed the maximum tolerance limits of 12.5% (Brasil, 2003). The ideal moisture content based on fresh matter, is 8-12.5% (Coffee Quality-Improvement Programme – Modifications, 2004; Reh et al., 2006).

Conforming to the results obtained (table 2), there was a significant difference in moisture content among the different treatments. The FF beans had the lowest moisture with 6.76%, followed by the PF beans with 8.84% and lastely the NF beans with 9.14% Amoung all treatments, the NF and PF, although statistically different, are within the recommended range, but the FF had a very low moisture value, compromising their quality.

Different from the result obtained in the moisture analysis, in the water activity analysis there was no significant difference for any treatment at 5% probability level by the Scott Knott test (table 2).

Thus, it was possible to observe that the fluorescence presence decreases the coffee moisture but does not alter the coffee Aw.

3.2.6 Bulk density and weight of 1000 seeds

The bulk density of agricultural products generally decreases with the increased water content (Ribeiro, 2013).

As can be seen in Table 2, the PF beans, with 657.1Kg/m^3, obtained a significantly different result from the FF and NF beans with 668.6 and 664.3Kg/m^3, respectively.

As reported by Brooker et al. (1992) the increase in the bulk density depends on the percentage of damaged beans, the initial water content, the temperature reached during drying, the final water content and the coffee variety. Since the 3 treatments are from the same variety/ batch and, according to the moisture analysis, the PF beans had moisture value between NF and FF moisture value, it is believed that one of the factors that may have contributed to the lower bulk density value of PF beans is the presence of damaged beans in the partial fluorescent beans. Therefore, what may be caused the decrease in bulk density was not the fluorescence itself but those slight damaged beans that went unnoticed during classification, such as, slight insect damage and beans with small chips, as presected at the section 3.1.1.2. In this case, partial fluorescence may help in the identification of the defective beans.

This result corroborates the sensory analysis that showed a worse sensory result for PF compared to FF.

Regarding the weight of 1000 seeds, the non-fluorescent beans stand out, with an average value of 149.72g, which differed significantly from the completely and partially fluorescent, with an average of 138.17g.

The seed weight is important as it is one of the indicators of yield and quality of the final product, and it can be affected, according to Angélico (2008), by several factors, among them, the fruit maturation stage. Thus, the presence of fluorescent beans can become a decisive factor for production yield.

3.2.7 Color

The coffee beans color is influenced by numerous factors, such as, relative humidity of the air, light in the storage place, injuries suffered by the beans, maturation stage at which the fruits are harvested, and others (Pimenta, 2001). The coffee color preservation during storage is extremely important, being a visual characteristic that often determines the acceptance or rejection of the product during marketing (Ribeiro, 2013).

In the measured system, “L” indicates luminosity (0 = black and 100 = white) and “a” and “b” indicate the directions that the color can take (+“a” = red and –“a” = green; +“b” = yellow and – “b” = blue) as described by Nobre (2005). Conforming Afonso Júnior and Corrêa (2003), the increase in luminosity (L) indicates the beans whitening (discoloration), whereas the increase in coordinates (a) and (b) indicates a loss, respectively, of the green and bluish color of the beans.

For luminosity values and for coordinate “b” there was no statistically significant difference between treatments, which presented similar values regardless of beans fluorescence. It indicates that there was no whitening in the beans regardless of the treatments.

On the other hand, for coordinate “a”, the treatments had significant differences, where FF beans had the lowest average, followed by PF and finally NF, being 1.13, 1.59 and 1.83, respectively (Table 2). The results indicates that the presence of fluorescent beans caused a tendency towards the approximation of the green color.

As noted, the fluorescent bean’s presence affects several physicochemical parameters, proving to be beans of poorer quality. These results indicate the potential of using UV light for qualitative coffee analysis.

4. Conclusion

The presence of FF beans from 10% negatively affects the coffee final score and the increase of these beans increases the coffee astringency.

The increase in PF beans negatively affects the final score, sweetness, acidity, after taste, bitterness and astringency.

The presence of fluorescence affected the parameters of potassium leaching, electrical conductivity, fatty acidity, polyphenols, titratable acidity, total dissolved solids, moisture and weight of 1000 seeds.

The green coffee beans that fluoresce under UV light have lower sensorial and fisico-chemical quality if compared to the green coffee that do not fluoresce under UV light.

The use of ultraviolet light for qualitative evaluation of green coffee beans may be a viable method.

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