Quality of coffee dried on suspended terrace with different layers

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Abstract

Seeking to improve the final quality of coffee, producers began to improve and innovate in all stages of this segment to meet the demanding market. Hence, this study evaluated the physicochemical and sensory quality of dried unripe, cherry and over-ripe coffee cherries on suspended terraces in different layers. The experiment involved drying coffee in all layers of the suspended terraces, consisting of seven treatments and four replications as follows: T1– concrete terrace; T2 – conventional "single-layer" suspended terrace; T3 – first layer "suspended terrace with two layers"; T4 – second layer "suspended terrace with two layers"; T5 – first layer "suspended terrace with three layers"; T6 – second layer "suspended terrace with three layers"; and T7 – third layer "suspended terrace with three layers." All treatments used identical samples composed of a mixture of coffee cherries in the three different physiological maturation stages (unripe, cherry and over-ripe). Percentage of each stage was evaluated in a one-liter container with coffee. Physicochemical and sensory quality of unripe, cherry and over-ripe coffees is influenced by the terrace structure. Treatments T5 and T6, represented by the first layer "suspended terrace with three layers" and second layer "suspended terrace with three layers," presented the best results for the beneficial fermentation caused by the terrace structure, providing a more shaded environment and resulting in desirable sensory attributes.

Keywords: Sensory attributes. Beverage. Fermentation.

Introduction

Arabica coffee (*Coffea arabica* L.) represents a driving force for socioeconomic development in Brazil, its largest producer, exporter and one of the largest consumers worldwide (CARVALHO et al., 2017). According to the National Supply Company (CONAB, 2023), the 2022 harvest of this species represents, on average, 81 % (1,816.4 thousand hectares) of the country's total cultivated, with a growth of 3.3 % compared with the previous harvest. Consumption of specialty coffees has been growing significantly compared to commodity coffees, increasing 10 to 15 % per year whereas traditional consumption grows only 1 to 1.5 % per year (MATIELLO et al., 2020).

Obtaining quality coffees goes far beyond sensory issues, as it must involve good agricultural practices focused on social, environmental, and economic aspects, strengthening the stability of social groups and the integrity of the planet to ensure its economic growth (MATIELLO et al., 2020). Such quality is related to the remuneration of coffee and, therefore, all stages of the production chain are key in obtaining a profitable product. Consequently, coffee producers began to improve their knowledge to deliver consumers the quality required by the market, which has been ensuring increasingly more space (RUFINO; SILVA, 2015). For this purpose, they must adopt new technologies and innovations to optimize the available resources for maintenance or improvement of productivity and quality.

Coffee harvesting and post-harvesting are interconnected processes that directly influence the final quality. It is therefore essential that they are planned and professionally managed, focused on obtaining the best-quality grains for when poorly performed, they can generate losses to producers. Drying, for example, is used to reduce the beans' water content to a level that allow processing, storage and marketing without losing their qualitative characteristics as food and seeds (TEIXEIRA et al., 2015).

Borém (2008) states that coffee drying is an extremely important step that requires a careful and well-managed operation in terms of energy consumption and of being exempt from attacks by microorganisms and undesirable fermentations which deteriorate coffee quality.

Drying coffee can be achieved by several methods, one of which is the suspended terrace—a system that provides advantages in preserving quality, as the bean has no contact with possible impurities. This allows the lower part of the terrace to be ventilated and prevents interference from rainfall due to the use of plastic covering (MATIELLO et al., 2020). When it comes to space for drying, however, the suspended terrace has the disadvantage of not holding a large amount of beans compared to the superior capacity of other types of terraces, in addition to requiring high investment in construction (BORÉM; REINATO; ANDRADE, 2008).

Hence, this study evaluated the physicochemical and sensory quality of dried unripe, cherry and over-ripe coffee cherries on suspended terraces in different layers.

Material and methods

This study was conducted at the Federal Institute of Education, Science and Technology of the South of Minas Gerais (IFSULDEMINAS) – Inconfidentes Campus, at the School Farm in the Educational Production Unit (UEP) Coffee Growing, with latitude 22°19'00" S, longitude 46°19'40" W and average altitude of 869 meters. Local climate is defined as high-altitude tropical, with an average annual temperature of 18 °C and an average annual rainfall of 1,600 mm (GEOGRAFIA, 2022).

In developing this experiment, we worked with fruits at three different physiological maturation stages, namely: unripe, cherry and over-ripe. The fruits were homogenized in the same Arabica coffee sample from cultivar, in the 2021/2022 harvest. The experiment involved drying coffee in all layers of the suspended terraces, consisting of seven treatments and four replications as follows: T1 = concrete terrace; T2 = conventional "single-layer" suspended terrace; T3 = first layer "suspended terrace with two layers"; T4 = second layer "suspended terrace with two layers"; T5 = first layer "suspended terrace with three layers"; T6 = second layer "suspended terrace with three layers"; T7 = third layer "suspended terrace with three layers."

For T1, we used a 4 m^2 concrete terrace subdivided into four plots of 1 m^2 each. The other treatments were represented by three different suspended terrace structures, in which each layer had 3 m (length) × 2 m (width) dimensions, subdivided into four plots of 0.75 m (length) × 2 m (width).

The single-layer terrace was 0.81 m from the ground. For the suspended terrace with two layers, the first layer was 0.52 m from the ground whilst the second was 0.50 m above the first layer. For the three-layer suspended terrace, the first layer was 0.40 m from the ground, the second layer 0.40 m above the first, and the third layer 0.40 m above the second.

The coffee was selectively harvested on June 26, 2022, and transported directly to the terraces without undergoing hydraulic separation (washing). Each plot received 12 liters of coffee, totaling 336 liters. After harvesting the fruits, 15 ripe fruits were selected for brix measurement. Mucilage was removed from each grain and deposited in the refractometer individually; then, the value for each fruit was measured, obtaining the average.

Since the experiment was conducted with fruits at three different maturation stages, the percentage of each stage was evaluated in a one-liter container with coffee. Amount of total fruits present in the one-liter container was counted and the number of fruits was estimated for the

respective maturation stage: unripe, cherry and over-ripe. As soon as they were placed in thin layers on the terraces, the berries were sorted to remove the fruits that did not meet the three desired physiological ripening points.

On the first day of drying, there was no raking. After the second day, raking was conducted every 40 minutes or when the temperature of the fruits was close to 40 °C. When they no longer adhered to the hand, the "first fold" was conducted–in this case on July 1, 2022—, that is, the berries distributed in thin layers within each plot that occupied 100 % of the space started to occupy 50 %, in thicker layers. From that point onwards, the fruits began to be raked every hour to ensure greater homogeneity in receiving solar radiation and greater ventilation between the fruits. The second fold took place after observing a change in fruit color, which in this experiment was identified on July 5, 2022. Hence, the berries occupied only 25 % of each plot, positioned on the side of the terraces, maintaining raking from side to side every hour.

On July 11, 2022, the berries reached 28 % of water content, which is considered semi-dry. Consequently, we included plastic curtains in the suspended terraces. In the concrete terrace, at that time, the plots began to be covered by jute bags which were in turn covered by plastic bags. When the temperature inside the terrace approached 40 °C in the morning, always around 9:30 am, the curtains were raised. At 3:30 pm each day, the fruits were piled up and the curtains came down, closing the terraces. The same happened in the concrete terrace. When they reached 11.5 % of water content, the berries were removed from the terrace, separated by treatments and placed in raschel bags. Subsequently, they were placed in jute bags and taken to the storage bin for homogenization of drying.

Information was collected daily throughout the drying process, always at 1 pm, on relative humidity and ambient temperature, using a digital thermo-hygrometer positioned 1.5 m from the ground. Fruit mass temperature of each plot was also measured daily, using a Flir C2 thermal camera at 10 cm from the fruits. On July 13, when the fruits reached semi-dryness and the curtains were already employed, environment temperature and relative humidity and fruit mass temperature were assessed at 6 pm, and at 12 pm and 6 am on July 14, 2022, to measure the nocturnal variations for each terrace type.

To elucidate the shading issue, the intensity of available sunlight and reflectance in each layer of the suspended and concrete terraces were only quantified on July 21, 2022, using a digital luxmeter and measured at 9 am and 3 pm at nine points per plot.

Physicochemical analyses were conducted in the Soil and Bromatology Laboratories of IFSULDEMINAS – Inconfidentes Campus. We analyzed moisture, ether extract (gravimetric process), nitrogen and proteins (methodology 037/IV kjeldhal), soluble solids and hydrogen potential (pH) according to the Association of Official Agricultural Chemists (AOAC, 1990), electrical conductivity according to Prete (1992), and total titratable acidity (TTA) according to the Adolfo Lutz Institute (IAL, 2008).

Classification by type of coffee was conducted using 300 g of processed sample, counting defective cherries by black, green, broken beans and picking percentage according to the Official Brazilian Table of "Classification of Raw Bean Processed Coffee, according to defect/type," described by Normative Instruction No. 8, of June 11, 2003 (MAPA, 2003).

Cup tasting was performed for quality, with analysis of flavor, aroma, astringency, acidity, body, intensity and aftertaste by trained and qualified tasters with accreditation for evaluating specialty coffees (Q-Graders), using the methodology proposed by the Association of Specialty Coffees (SCA, 2016), in the Coffee Growing Laboratory of IFSULDEMINAS – Machado Campus.

Results of all variables underwent non-parametric analysis, using the Wilcoxon/ Mann-Whitney test ($p \leq 0.05$) for comparing means. Only variables with significant difference were presented in the results. Multivariate analysis was also used to interpret the data obtained. All analyses were performed using the Genes software (CRUZ, 2013).

Results and discussion

Fruits harvested at the three different maturation stages were represented by 58.81 % cherry, 30.95 % unripe and 10.24 % over-ripe, with a 28 % Brix degree for ripe fruits.

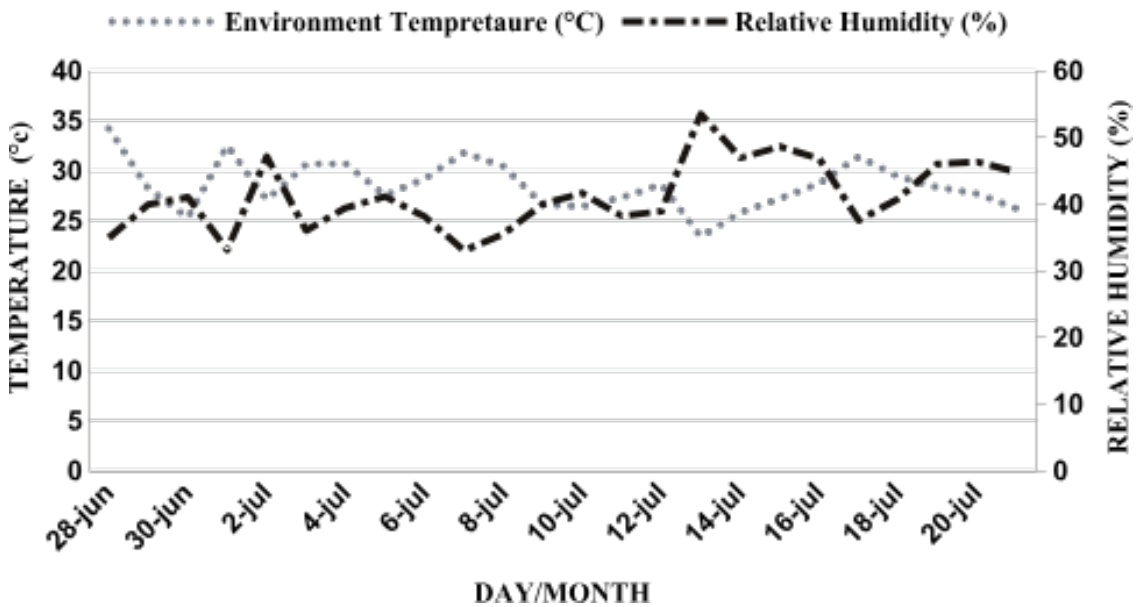
A period of drought during the drying process caused low variation in both environment temperature and relative humidity, with 28.4 °C and 41.3 % averages, respectively (Figure 1). High temperature values exceeding 30 °C (Figure 1) are due to measurements taken at the hottest times of the day, which could potentially damage the coffees.

According to Borém (2008), temperatures above 40 °C and high levels of relative humidity harm the quality of the grains; in this regard, our findings indicate that these characteristics remained ideal during the experiment (Figure 1).

Borém (2008) states that keeping the night temperature around 25 °C reduces the moisture gain caused by dew formation. This justifies the fact that the coffee beans reached the ideal point of humidity for storage after 26 days, both in suspended and concrete terraces. We thus recorded 29 days less than the results obtained by Fulan (2021), who used the same terrace structure, but without curtains. Keeping coffees piled up and covered during the coldest hours was a crucial strategy to avoid significant variations in temperature and humidity gain at night, thus accelerating the drying process (Figure 2).

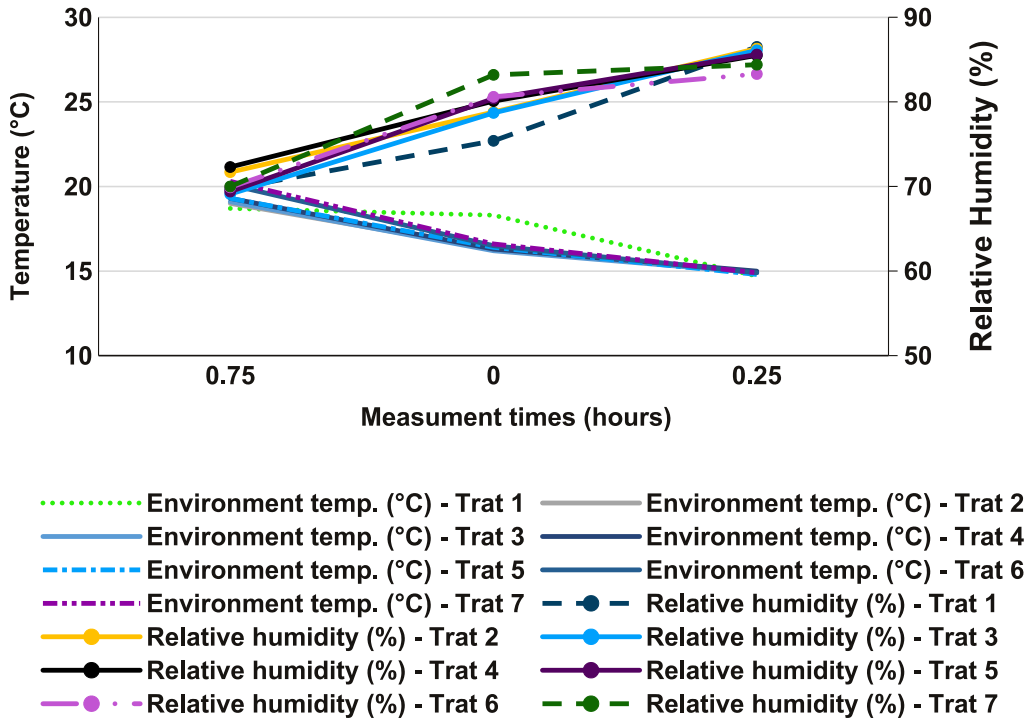
At 6 pm, the temperature remained at 19.4 °C on average. Temperature measurements at 12 pm obtained a small 16.4 °C average variation. Terrace treatment remained at a higher temperature, with 18.3 °C (Figure 2). At 6 am,

Figure 1. Variation of environment temperature (°C) and relative humidity (%) during the experiment, quantified at 1 pm. IFSULDEMINAS- *Inconfidentes* Campus. Inconfidentes, Minas Gerais, 2023



Source: Authors' own elaboration (2023).

Figure 2. Nocturnal variation of temperature (°C) and relative humidity (%) in each treatment. IFSULDEMINAS – *Inconfidentes* Campus. Inconfidentes, Minas Gerais, 2023



T1 = concrete terrace; T2 = single layer suspended terrace; T3 = first layer of suspended terrace with two layers; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers; and T7 = third layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

temperatures stabilized at 14.9 °C. We observed no significant variation in temperature loss from 6 pm to 6 am. Relative humidity behaved similarly; however, as the temperature dropped the relative humidity increased, maintaining a 15 % variation from 6 pm to 6 am.

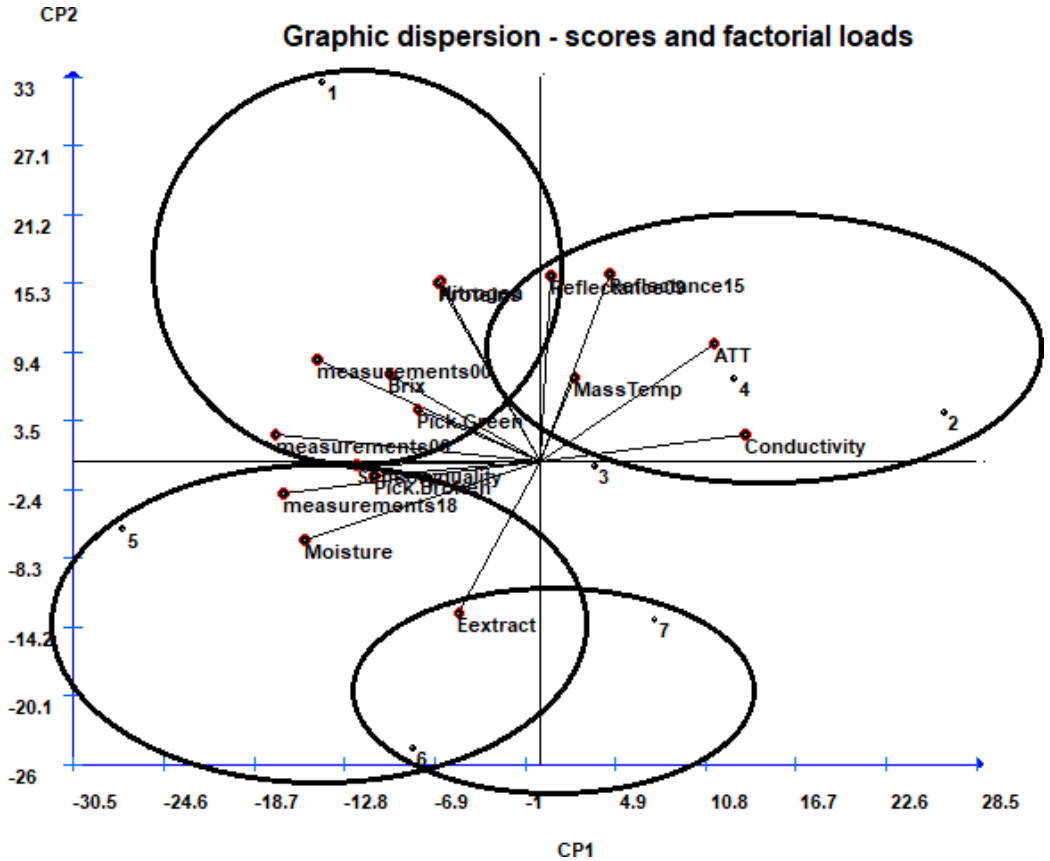
Principal component analysis (PCA), adopting clusters between the variables evaluated, demonstrated the greatest influence of these variables in each treatment (Figure 3).

Hongyu, Sandanielo, and Oliveira Junior (2016) described this analysis as a technique that allows generating indices and group individuals according to their defining characteristics. According to Regazzi (2000), multivariate analysis techniques can solve problems of grouping individuals through their similarities. Although we found no significant difference in the sensory analysis, results showed that the values ranged from 76.25 for T2 to 80.93 for T4.

Principal components 1 and 2 explained 66.29 % of all the observed variation. Treatments T5 and T6 were best related to the sensory analysis (Figure 3), and are represented by the two shaded layers of the three-layer structure, which hindered solar radiation on the fruits.

Temperatures measured at 6 pm showed concentration of humidity, heat and high sugar content, responsible for the broken grains found that, in this case, instead of deteriorating the beverage, contributed to a positive, balanced and desired fermentation, attributing quality to the coffee. Treatments 6 and 7 had the best values correlated with the ether extract (Figure 3).

Figure 3. Biplot of principal component analysis. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023



T1 = concrete terrace; T2 = single layer suspended terrace; T3 = first layer of suspended terrace with two layers; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers; and T7 = third layer of suspended terrace with three layers; measurements00 (temperature measurement at 12 pm); measurements06 (temperature measurement at 6 am); measurements18 (temperature measurement at 6 pm); Pick.Green (green coffee picking); Pick.Broken (broken bean picking); Eextract(ether extract); MassTemp (temperature in the coffee mass); Reflectance09 (Reflectance at 9 am); Reflectance15 (Reflectance at 3 pm)

Source: Authors' own elaboration (2023).

Nakayama et al. (2020) concluded that fruits dried with the peel have a very sugary pulp from the mucilage, creating a culture medium that, when exposed to heat with the presence of water, favors the action of bacteria and yeasts that cause possible lactic, alcoholic or acetic fermentations.

Arabica coffee contains 12 to 18 % oil in its composition. These oils are responsible for the taste and aroma. Inadequate handling during drying favors the oxidation of lipid compounds, which cause changes in flavor and aroma, promoting loss of quality (ANGÉLICO, 2008).

Saath et al. (2010) reinforced that possible stresses suffered by the grains cause various metabolic processes that may be related to ether extract levels. Nascimento (2006) stated that coffee quality is related to the ether extract content present in the beans, as coffees with low quantities have compromised aroma and flavor. This justifies T5 and T6 having similar ether extract content, with 12.82 % and 12.35 % averages, respectively, and remaining within the ideal levels for coffee.

T2 and T4 showed greater interactions with the variables reflectance, mass temperature,

electrical conductivity and total titratable acidity (Figure 3). These treatments were more exposed to intense light which contributed to the higher mass temperatures, a variable linked to cell membrane integrity indicated by electrical conductivity (ALVES et al., 2011) (Figure 3).

Alves et al. (2011) noted that higher temperatures during coffee drying are related to higher electrical conductivity results, indicating presumed damage to the fruits' cell membrane system. Lopes, Pereira, and Mendes (2000) found that total titratable acidity is influenced by thermal decomposition due to high temperatures, promoting higher values of perceptible acidity.

T1 was associated with the temperature measurements at 12 pm and 6 am, proteins, nitrogen and soluble solids content (Brix) in the laboratory, according to the principal component analysis (Figure 3). This treatment provided direct contact with the concrete floor, which retains heat during the day and contributes to less loss of temperature of the grains in the coldest hours. Green bean picking also stood out in this treatment, explained by the difficulty in raking due to the more accelerated loss of water at the beginning compared with other treatments, which hindered sorting due to rapid husk darkening.

Treatments T3 and T7 were neither positively nor negatively influenced by any of the variables analyzed (Figure 3). Comparison of the significant averages for moisture content in the laboratory, measurements at 6 pm and picking broken beans occurred with greater prominence and significant difference for treatments T5 and T6, with T5 presenting the best results in picking broken beans, as shown in Tables 1, 2 and 3.

Table 1. Comparison of average moisture content (%) between treatments. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023

Treatment	Moisture (%)	Treatment	Moisture (%)	p-value (<0.05)
2	7.45	5	9.15	0.02857*
2	7.45	6	8.71	0.02857*

*Treatments differed from each other by the Wilcoxon/Mann-Whitney test, significant at p<0.05.

T2 = single-layer suspended terrace; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

Table 2. Comparison of average temperature at 6 pm (Tª 6 pm) in degrees Celsius (ºC) between treatments. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023

Treatment	Tª 6 pm (ºC)	Treatment	Tª 6 pm (ºC)	p-value (<0.05)
2	19.37	5	22.35	0.02857*
2	19.37	6	22.42	0.02857*
4	20.50	5	22.35	0.02857*
4	20.50	6	22.42	0.02857*
5	22.35	7	20.92	0.04207*

*Treatments differed from each other by the Wilcoxon/Mann-Whitney test, significant at p<0.05.

T2 = single-layer suspended terrace; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers; T7 = third layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

Table 3. Comparison of average broken bean picking in percentage (PI %) between treatments. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023

Treatment	PI (%)	Treatment	PI (%)	p-value (<0.05)
1	0.11	5	0.41	0.02857*
1	0.11	6	0.17	0.04083*
2	0.08	5	0.41	0.02857*
3	0.07	5	0.41	0.02857*
4	0.09	5	0.41	0.0294*
4	0.09	6	0.17	0.03961*
5	0.41	7	0.06	0.02857*
6	0.17	7	0.06	0.0294*

*Treatments differed from each other by the Wilcoxon/Mann-Whitney test, significant at $p<0.05$.

T1 = concrete terrace; T2 = single-layer suspended terrace; T3 = first layer of suspended terrace with two layers; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers; and T7 = third layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

Tables 4 and 5 show the significant differences between treatments T2 and T4 by comparing means with the other treatments regarding electrical conductivity (EC) and total titratable acidity (TTA), corroborating the PCA results (Figure 3).

Regarding TTA (Table 5), treatments T5 and T6 best stood out in quality since the 26.62 and 26.75 % levels were best indicated for quality, differing statistically from the others, with greater similarity of variances with sensory analysis (Figure 3).

Sensory analysis found no significant difference between treatments. Treatment 2 presented the lowest value, with a 76.25 score. All other treatments had scores ranging from 80.13 to 80.94, conferring a score of specialty coffee.

Table 4. Comparison of means of Electrical Conductivity (EC) ($\mu S\ cm^{-1}\ g^{-1}$) between treatments. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023

Treatment	EC ($\mu S\ cm^{-1}\ g^{-1}$)	Treatment	EC ($\mu S\ cm^{-1}\ g^{-1}$)	p-value (<0.05)
1	9.41	2	12.60	0.02857*
1	9.41	4	13.25	0.02857*
2	12.60	5	10.52	0.02857*
2	12.60	6	9.10	0.02857*
4	13.25	5	10.52	0.02857*
4	13.25	6	9.10	0.02857*
5	10.52	6	9.10	0.02857*

*Treatments differed from each other by the Wilcoxon/Mann-Whitney test, significant at $p<0.05$.

T1 = concrete terrace; T2 = single-layer suspended terrace; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

Table 5. Comparison of means of total titratable acidity (TTA) in percentage (%) between treatments. FSULDEMINAS – Inconfidentes Campus. Inconfidentes, Minas Gerais, 2023

Treatment	TTA %	Treatment	TTA %	p-value (<0.05)
1	29.00	4	31.12	0.02940*
1	29.00	5	26.62	0.04083*
1	29.00	6	26.75	0.03961*
2	29.00	4	31.12	0.04083*
3	29.12	4	31.12	0.04207*
4	31.12	5	26.62	0.02857*
4	31.12	6	26.75	0.02940*
4	31.12	7	28.25	0.02843*

*Treatments differed from each other by the Wilcoxon/Mann-Whitney test, significant at $p<0.05$.

T1 = concrete terrace; T2 = single layer suspended terrace; T3 = first layer of suspended terrace with two layers; T4 = second layer of suspended terrace with two layers; T5 = first layer of suspended terrace with three layers; T6 = second layer of suspended terrace with three layers; and T7 = third layer of suspended terrace with three layers.

Source: Authors' own elaboration (2023).

Optimizing the suspended terrace structure, making use of curtains after semi-dry and working with cherry, unripe and over-ripe fruits is an economically viable alternative for producers, since it reduces the need to assemble several structures, accelerates the drying time and maintains the quality of the beans, as well as improves sensory quality through the attributes arising from a beneficial fermentation as long as the more shaded terraces are managed carefully.

Conclusion

Physicochemical and sensory quality of unripe, cherry and over-ripe coffees is influenced by the terrace structure. Treatments T5 and T6, represented by the first layer "suspended terrace with three layers" and second layer "suspended terrace with three layers," stood out for the beneficial fermentation caused by the terrace structure, providing a more shaded environment and resulting in desirable sensory attributes.

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