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IMPACT OF SLOW DRYING IN A COLD ROOM ON COFFEE SENSORY, CHEMICAL, AND PHYSICAL PROPERTIES

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KEYWORDS

refrigerated storage, sensory attributes, colorimetry, chemical composition.

ABSTRACT

This study aimed to evaluate the duplicity and synergism of slow drying and storage processes at low temperatures, using a refrigerated room under suitable conditions for coffee fruit just after harvest. A cold room was prepared to receive and store coffee fruit in bulk directly from the field, perform slow drying, and maintain water content at approximately 12% during three months of storage. The room operated at temperatures between 7 and 14 ºC and relative humidity between 37 and 41%. The coffee variety used was the Conilon Yellow 62. The initial water content reduction period from 54% (wb) to 12% (wb) was two months. For comparison, coffee harvested from the same batch was dried on a covered suspended bed. Results showed that the coffee dried and stored in the cold room received a sensory score of 86.41, while that dried on a suspended bed obtained a sensory score of 84.16. Moreover, the coffee dried and stored in the cold room had a higher energy content. Colorimetric analysis showed that the dried grains stored in the cold room had a reduction in the "a" coordinate, indicating an approximation to the green color. The cold room also allowed for extended storage of the coffee grains.

INTRODUCTION

The loss of water from *in natura* products stored in cold rooms can result in considerable damage if preventive measures are not taken for mass transfer, which is related to the low vapor pressure of the air, resulting in dry conditions of low relative humidity (Zuo et al., 2021). For this reason, rooms used for storing fruits and vegetables need humidification systems (Ndukwu et al., 2023).

What constitutes a problem for products that need to be marketed with their natural characteristics as close as possible to their state at harvest—namely, the slow and gradual loss of water during storage (Souza et al., 2021)—can be desirable for sensitive products that require rapid water content reduction, such as coffee (Alves et al., 2020), which requires water removal for preservation and commercialization. Because coffee is a thermosensitive product, drying temperatures above 40 ºC are not recommended due to the risk of thermal damage to the cell membranes of the grains. Such damage can cause the chemical components to come into contact with hydrolytic and oxidative enzymes, affecting the color, flavor, and aroma of the beverage (Mesquita et al., 2021).

The volatile aromatic constituents present in coffee are overly sensitive to the drying process (Haile & Kang, 2019). The composition of these volatile substances and variations in their concentrations are related to the drying method and temperature used (Zhang et al., 2022). Thus, the relatively low temperature of cold rooms represents another advantage.

In the coffee production chain, storage is typically carried out under ambient conditions. Therefore, the drying stage immediately after harvesting is indispensable for preservation (Pazmiño-Arteaga et al., 2022), which is considered fundamental for the quality of the resulting beverage (Teshome et al., 2019; Carvalho et al., 2023). Energy consumption at this stage also impacts production costs (Franco et al., 2022).

Eliminating or adding steps to optimize the production process and reduce qualitative losses can be beneficial in the coffee production chain. There is an

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opportunity to increase the product's value by enhancing or maintaining the beverage's quality through an adequate drying and preservation process.

The production of specialty coffees in Brazil has grown in recent years (Volsi et al., 2019; Zarebska et al., 2022), stimulated by the increased consumption of high-quality beverages and higher market prices, which can be more than ten times the amount paid for common coffee. This justifies investment in post-harvest stages to ensure final product quality (Donovan et al., 2019).

Recently, in grain-producing countries like Brazil, refrigerated storage has started to be applied to grains, yielding significant economic and quality improvements, including reduced pest attacks and better preservation of oils and proteins. Although these products are not yet priced according to their qualitative attributes, as is the case with coffee (Chen et al., 2022).

Temperatures between 10 and 15 ºC reduce pest development and attacks during storage, decrease grain metabolism, lower respiration rates, and consequently reduce energy (carbohydrate) consumption (Aung Moon et al., 2022). Temperature reduction also minimizes lipid degradation, which can lead to undesirable flavors and odors, negatively affecting the nutritional and sensory quality of the product.

Contamination by microorganisms, color changes, and lipid oxidation during coffee storage are factors that reduce beverage quality (Figueroa-Hernández et al., 2021). In addition to sensory quality, color significantly influences the economic value of the product (Anastácio et al., 2023).

Considering all these aspects, particularly for specialty coffees, this work aimed to evaluate the duplicity and synergism of slow drying and storage processes at low temperatures, using a refrigerated room under suitable conditions for coffee fruit just after harvest.

MATERIAL AND METHODS

The coffee fruit, Yellow Conilon 62, from Poços de Caldas, Minas Gerais (MG), was selectively harvested (only mature beans) on July 20, 2021. The harvested coffee was cooled to 16 ºC, placed in a thermal box, and transported to the experimental area within 24 hours. Upon arrival in Dourados, Mato Grosso do Sul (MS), the coffee was taken to the Laboratory of Thermodynamics, Refrigeration, and Energy (LTRE) at the Agricultural Sciences College of the Federal University of Grande Dourados (UFGD).

In the experiment, 15.74 kg of coffee was received at a temperature of 18.7 ºC. Four samples of approximately 55 g each were taken to determine the initial water content using the gravimetric method, with a forced-air circulation oven at 105 ºC for 24 hours. A 600 g sample was taken for chemical properties analyses.

The remaining coffee was evenly distributed in four perforated trays, with a mass of 3730 g per tray. The tray dimensions were 40 x 70 x 10 cm (width, length, height). The trays were placed on a trolley with four perforated shelves, each 35 cm apart, and then taken to a cold room (Figure 1). In each tray, a 90 g portion of coffee (control sample) was packed in mesh-5 polypropylene for weighing and monitoring the decrease in water content during the slow drying process at low temperatures.

A

B

FIGURE 1. (A) Cold storage trolley loaded with trays; (B) Cold room installation.

After drying, control samples were periodically weighed using a semi-analytical scale with a resolution of 0.01 g. The first weighing took place after 24 hours, with subsequent weighings at 7-day intervals. The water content during drying was determined by mass difference, based on the initial water content, until a final water content of at least 12 ± 1% (wb) was reached.

The cold room used in the experiment, designed for chilled products, had dimensions of 2.20 x 2.20 x 2.50 m (base, width, height). It was assembled with isothermal panels of expanded polystyrene, 100 mm thick, and equipped with a refrigeration system with a capacity of 2850 kcal/h at an evaporation temperature of 5 ºC. The system consisted of an Elgin evaporator unit model FXBN02426E with two fans and an Elgin UCM2200TTC condensing unit with a three-phase hermetic compressor and R22 refrigerant.

The cold room was pre-conditioned to achieve 10-12% equilibrium humidity using the modified Harkins-Jura model (Jordan et al., 2020a). At low temperatures, coffee drying can reach a storable moisture content of 12% (wb) within 2-3 months, based on prior research (Jordan et al., 2020b; Jordan et al., 2020c). Following pre-conditioning, the cold room's operating temperature was set to 10-15 °C. Evaporator fans in the cold room cycled on only for temperature reduction. To ensure equilibrium humidity within the desired temperature range, we used a 250 W mixed steam lamp, which was constantly switched on.

To ensure precise monitoring of the microenvironment, RHT sensors (Novus brand) connected to a Field Logger tracked temperature and humidity during cold room adjustment and the experiment. This approach aligns with the findings of Lovatto et al. (2020) and Cesca et al. (2021), who emphasize temperature and relative humidity as a crucial climatic binomial for accurate microenvironment representation.

Once the coffee reached the target moisture content, it was removed from all trays in the cold room, homogenized, and sampled for sensory and chemical analyses. For comparison, 20 liters of the same coffee batch were air-dried on a covered bed at night for 23 days, reaching 12% moisture (wb). After 20 days of rest in a wooden bin on-site, these beans underwent the same analysis as the cold-stored ones.

Sensory analysis, adhering to the American Specialty Coffee Association (SCA) protocol established by Lingle (2011), was performed by Q-Graders certified by the Coffee Quality Institute (CQI) at the IFSULDEMINAS Coffee Quality Center, Federal Institute of Southern Minas Gerais State - Campus at Machado. Chemical and physical analyses of the final product were conducted at the Research Laboratory for Products and Agro-industrial Processes of the Cerrado (LabGEPPAC) from UFGD.

Nutritional composition was determined by measuring moisture content via oven drying at 105°C (AOAC, 2003), ash content by incineration in a muffle furnace at 55 °C, protein content by the micro-Kjeldahl method, lipid content by the Bligh and Dyer method, 1959), and carbohydrate content (calculated by difference). Total energy value (TEV) was calculated using established Atwater conversion factors, with proteins, lipids, and carbohydrates being four, nine, and four kcal/g (Merril & Watt, 1973). Additionally, pH (measured by digital potentiometer), titratable acidity (determined by titration with 0.1 N NaOH - AOAC, 1997), and grain color (analyzed using a Konica Minolta CR-400/CR-410 colorimeter at 10º and D65 light source with CIELab system - Connolly & Fleiss, 1997) were evaluated. The colorimeter provided L (brightness), a (red), and b* (yellow) values from at least nine sample replicates. Finally, the Folin-Ciocalteau colorimetric method quantified phenolic compounds, expressed as mg gallic acid equivalent (GAE) per gram of sample (Oliveira et al., 2021).

RESULTS AND DISCUSSION

Total refrigerated storage time was 112 days. It took 81 days to reduce the water content from 52% to 12% (FIGURE 2) under temperature conditions between 6.7 and 14.5 ºC and relative humidity between 39% and 55% (FIGURE 3), within the operating conditions determined by the cold room.

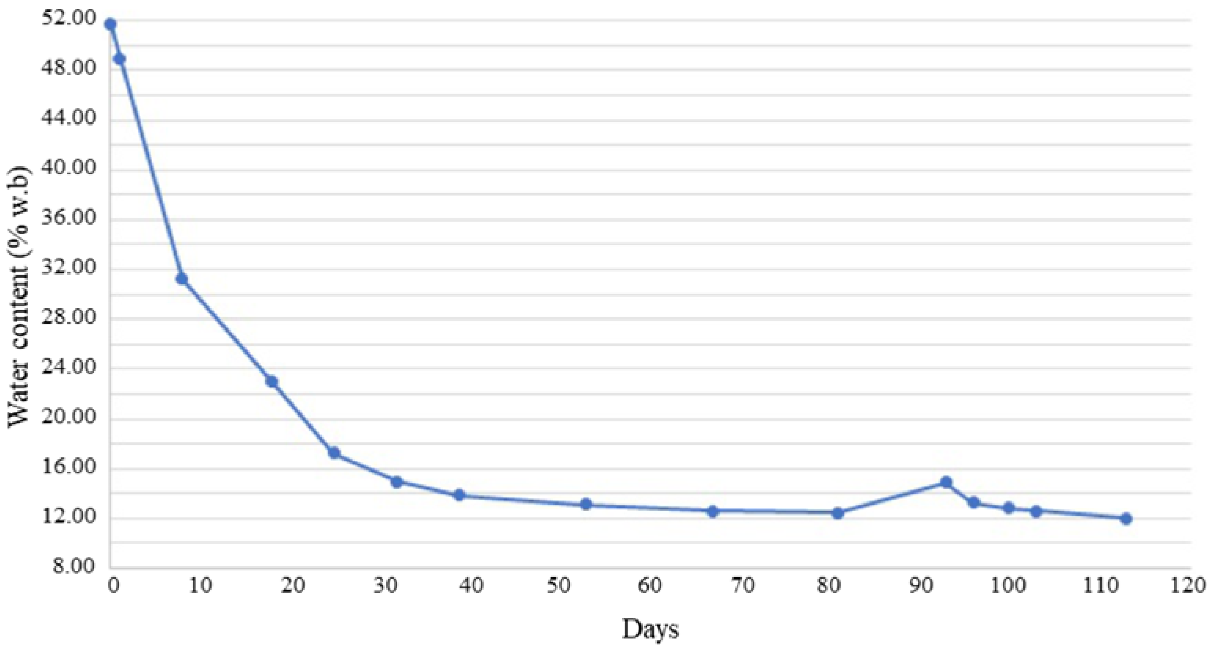

FIGURE 2. Changes in coffee water content over cold room storage time.

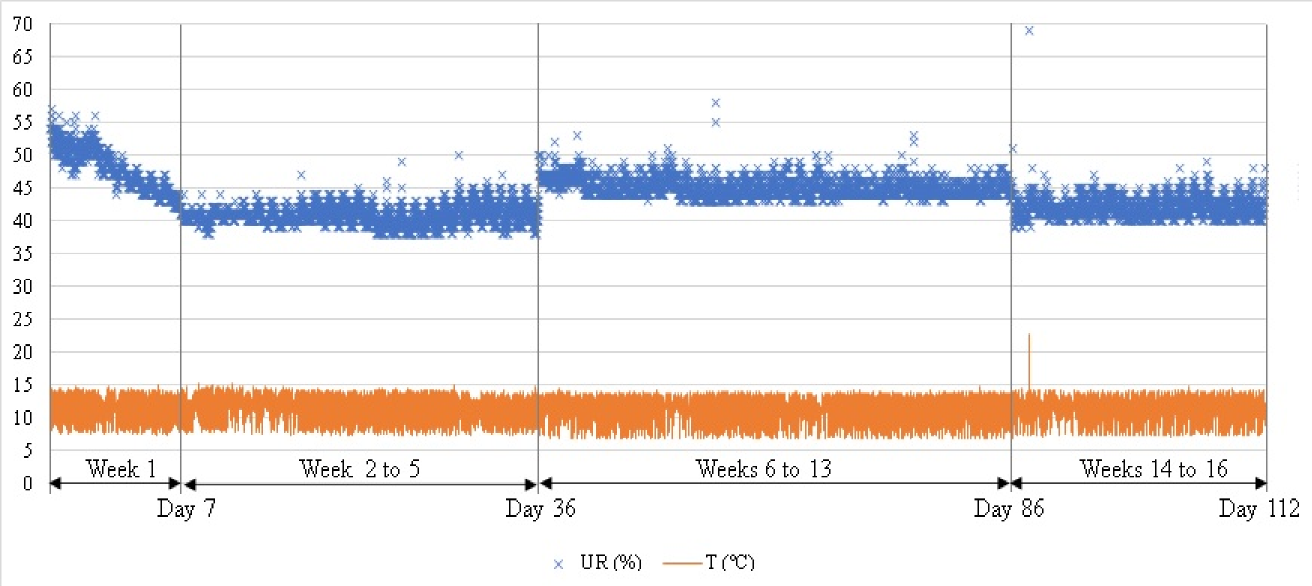

FIGURE 3. Variations in relative humidity and air temperature during cold room storage time.

During the storage period, a power outage caused a prolonged shutdown of the cold room operating system for about three days, which led to an increase in water content after the ninetieth day.

Regarding relative humidity and air temperature in the cold room, noticeable peaks occurred after day 86, reaching 20 ºC and 70% relative humidity. These peaks were caused by the cooling system shutdown due to the power outage. The data acquisition system also reset, leading to inaccurate temperature and relative humidity records. Between the sixth and thirteenth weeks (days 36 and 86), relative humidity increased because of an electrical problem that shut down the lamp used to reduce humidity.

The accidental shutdown of the heat source affected the water content reduction time, altering the operating conditions and equilibrium temperature. As shown in Figure 2, between the thirty-sixth and eightieth days, when the lamp was off, it took about 40 days to reduce the water content from 14% to 12%. After the lamp was turned back on, after the ninetieth day, it took only about 20 days to reduce the water content from 15% to 12%.

Jordan et al. (2020a) found that drying natural coffee at 15 ºC and 48% relative humidity with a constant air supply took 10 days to reduce the water content from 37% to 11% (wb). Increasing the temperature to 30 ºC and reducing the relative humidity to 20% reduced the pre-drying time to less than four days.

Mengistu et al. (2020) reported that in "cold" drying, which limits the temperature range to between 0 and 15 ºC, relative humidity is a critical factor in the water removal process.

Table 1 shows the results of the sensory analysis. Coffee subjected to slow drying and storage in the cold room had a sensory quality score of 86.41, while coffee dried on a suspended bed and stored in an uncontrolled environment scored 84.15.

TABLE 1. SCA sensory evaluation scores of coffee samples.

Drying/storage	Average Score Obtained
Cold room	86.41
Suspended bed / environment	84.16

Significant differences were observed in the attributes (FIGURE 4): body, aroma, flavor, acidity, aftertaste, and balance. According to Barbosa et al. (2021) and Ribeiro et al. (2020), fruit classified as mature can have a wide range of properties. Attributes such as acidity, body, and sweetness are essential for the sensory quality of coffee.

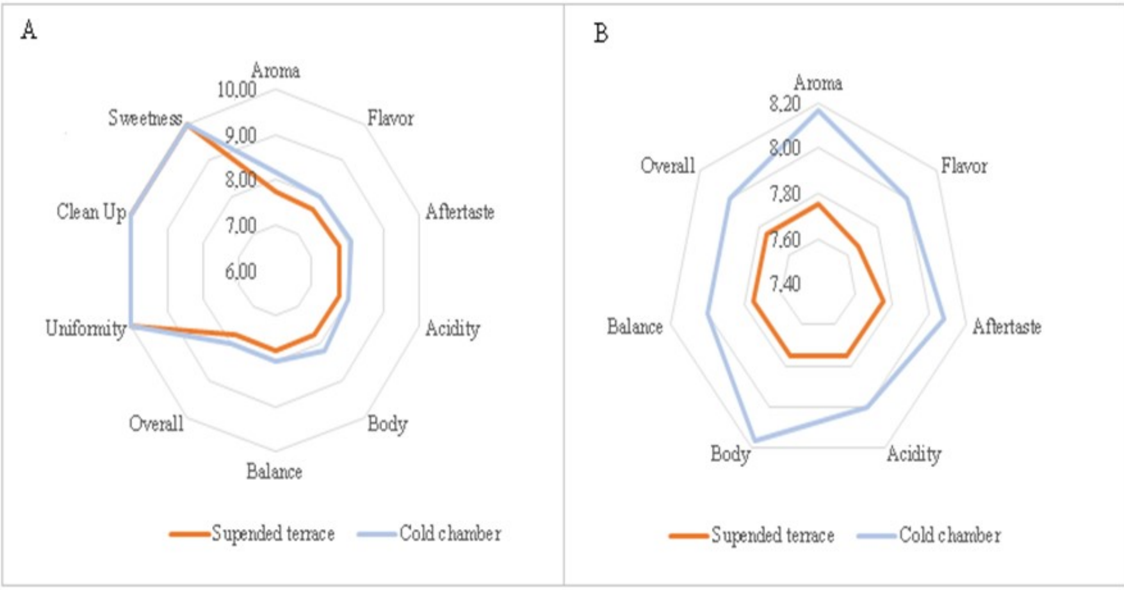

FIGURE 4. Sensory evaluation of coffee samples: general attributes (A) vs. differentiating attributes (B).

Lima et al. (2021) stated that using low temperatures in coffee drying (below 30 ºC) improves its sensory quality. Natural coffees are physiologically more sensitive to long-term drying conditions. Therefore, one beneficial effect of drying at low temperatures is the reduction of drying time.

Jordan et al. (2020c) evaluated the quality of coffee dried at low temperatures (15, 30, 35, and 40 ºC) and obtained the best sensory score—85 points—for coffee dried at 15 ºC and 48% relative humidity, the condition with the lowest drying rate. An increase in the drying rate at low temperatures negatively affects coffee quality. Conversely, lower drying rates and higher relative humidity at low temperatures positively impact the coffee score (Martins et al., 2022).

Zarebska et al. (2022), evaluating the influence of storage conditions, temperature (-10, 5, 10, 18, and 20 ºC), and packaging (GrainPro and jute), observed that after three months, natural coffees kept at 10 ºC in jute bags showed the smallest decreases in sensory score compared to the initial condition. Losses of flavor quality were more significant for coffees stored at 18 and 20 ºC, where aroma, acidity, body, and general attributes showed the most substantial decreases. Aftertaste, flavor, and balance exhibited minor decreases.

Regarding the chemical and physical analyses (FIGURE 5), considering the standard deviation, no differences were observed in the mean values of protein and carbohydrate contents, pH and acidity values, and phenolic compounds between the coffee samples dried on the suspended bed and in the cold room.

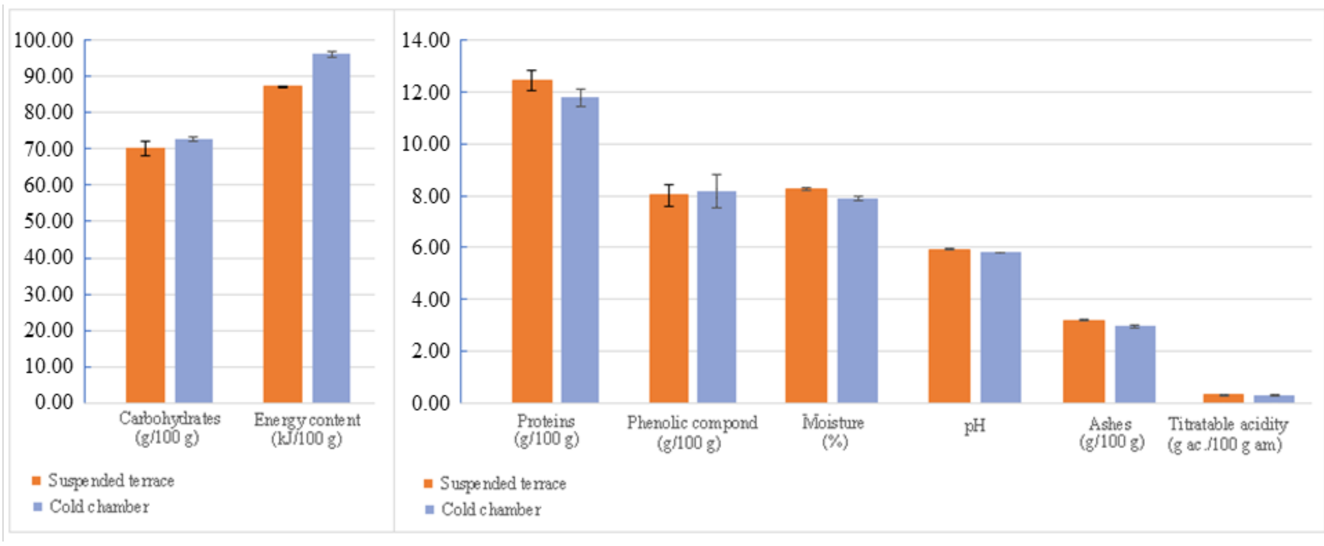

FIGURE 5. Chemical and physical analyses of coffee samples.

Protein concentrations averaged between 12.13 and 12.43 g 100 g^{-1}, while carbohydrate contents ranged from 70.29 to 72.67 g 100 g^{-1}. These values are close to those found by Barbosa et al. (2019) and Degefa et al. (2022), who reported protein contents between 11 and 13 g 100 g^{-1} and carbohydrates from 62.67 to 71.96 g 100 g^{-1}.

Averages of phenolic compounds varied between 8.02 and 8.19 g 100 g^{-1}, which are higher than those reported by Kulapichitr et al. (2022), who observed a range from 4.31 to 5.33 g 100 g^{-1}. According to Jiang et al. (2023), chlorogenic acids (CGA), the predominant form of phenolic compounds in green coffee beans, can reach a concentration of 14 g 100 g^{-1} and play a fundamental role in coffee flavor quality.

Averages of ash contents for coffees dried on the bed were slightly higher (3.18 g 100 g^{-1}) than that of coffee dried and stored in the cold room (2.94 g 100 g^{-1}). Both coffees had ash levels well below the maximum established by the current Brazilian legislation, which is 5 g 100 g^{-1} (BRASIL, 2010).

The average energy content of coffee dried and stored in the cold room was higher (96.17 kJ 100 g^{-1}) than that of ground-dried coffee (87.3 kJ 100 g^{-1}). This difference is not solely explained by the small difference in average water content: 8.26 g 100 g^{-1} for bed-dried coffee and 7.9 g 100 g^{-1} for cold room coffee. Considering the slight differences in average carbohydrate and protein contents, the difference in energy content can be attributed to a higher concentration of lipids in coffee stored in the cold room. This may result from the beneficial effect of low temperatures on the conservation of lipids, as verified by Silva et al. (2022).

Cong et al. (2020) mentioned that lipid degradation negatively affects the nutritional and sensory quality of stored products and that the rate of degradation depends on factors such as temperature and storage time. According to Barbosa et al. (2019), lipids contribute to aroma formation during the roasting process, being associated with better quality of the “cup.”

Regarding the colorimetric analysis (FIGURE 6), there was an increase in the “L” parameter for both coffees (terrain and cold room), indicating the occurrence of bleaching of the stored product, which was more significant for dry coffee kept in the cold room. According to Figueroa-Hernández et al. (2021), using cooled air during storage reduces the bleaching of coffee beans. Thus, it is possible that the lamp used to control relative humidity was the cause since, according to Borém et al. (2019), exposure to light is one of the factors that leads to the loss of coffee quality.

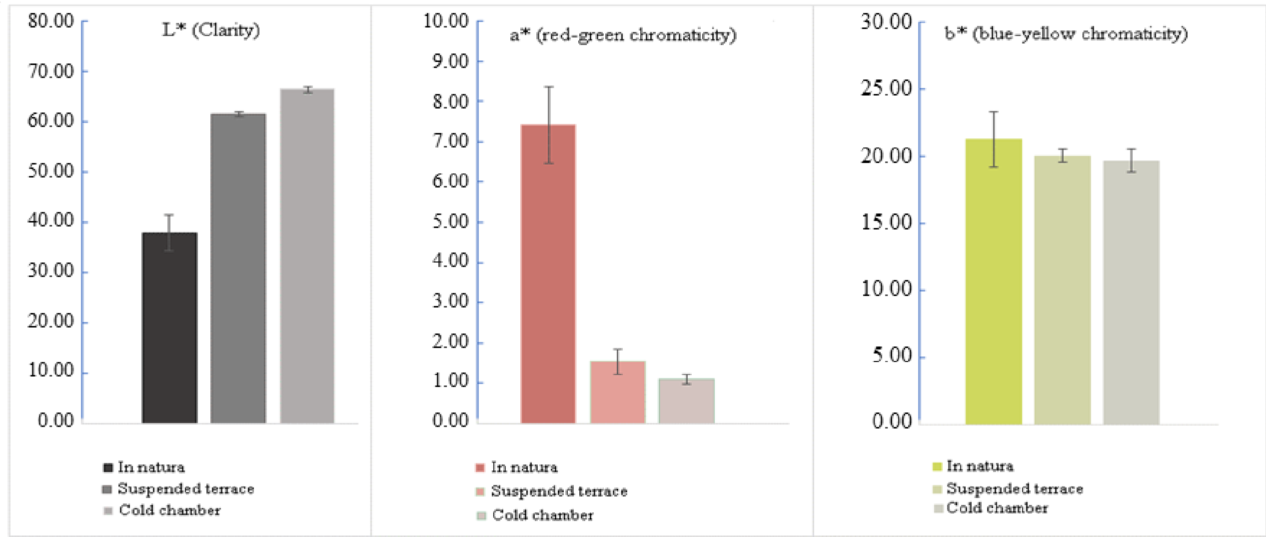

FIGURE 6. Colorimetric analysis of coffee samples before drying (*in natura*) and after drying on suspended bed and in cold room.

On the other hand, according to the colorimetric analysis, the coffee from the refrigerated room showed a reduction in the 'a' coordinate, indicating a closer approximation to green, and a slight reduction in 'b,' indicating a shift away from the unwanted yellow and toward the desired blue color. According to Gomes et al. (2023), a blue-green color in coffee beans indicates a product of better quality. These authors also note that, in addition to lighting, factors such as temperature and relative humidity influence the color of the beans, with changes being less frequent in environments with low temperature and relative humidity.

CONCLUSIONS

Coffee dried and stored in cold room had a higher energy content and a closer approximation to the green color. The cold room enabled longer preservation of the coffee.

Through operational adjustments, it was possible to use a cold room for slow drying and conservation of coffee during storage. This approach improved the preservation of important attributes, contributing to the good sensory quality of the beverage.

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