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Research article

The influence of hot-air mechanical drying on the sensory quality of specialty Colombian coffee

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Abstract: The main aim of this study was to evaluate the impact of mechanical drying on the sensory quality of specialty coffee produced on three Colombian coffee farms. The technique involved a study of the coffee bean drying process parameters, such as temperature (35, 45 and 55 ℃), airflow (100 $m^3/min \cdot m^2$) and thickness (0.2 m) for mechanical drying, vs conventional drying in the open sun until 11% of moisture content was reached. For mechanical drying, the effective diffusion coefficient, electrical conductivity and drying kinetics were evaluated. A sensory test was performed for three storage periods (3, 6 and 9 months) using the Specialty Coffee Association (SCA) protocol. The results showed that the effective diffusion coefficient varied from 3.21 to 8.02 × 10^{-7} m^2/s for mechanical drying and from 4.21 × 10^{-11} m^2/s for drying in the open sun. The time drying time was established at 20.35 ± 0.06, 29.10 ± 0.09 and 71.52 ± 0.11 hours for mechanical drying at 55 ℃, 45 ℃ and 35 ℃ respectively and 54.48 ± 11.37 hours for drying in the open sun system. The average moisture content at the end of all drying operations was 12.5%. Electrical conductivity rose from 11.71 to 16.86 µS/cm·g at drying temperatures ranging from 35 to 55 ℃. The sensory test revealed that storage duration had no effect on the quality of the coffee drink when in touch with the drying process, with mechanical drying yielding higher sensory ratings. The coffee beans were dried at 55 ℃, yielding coffee samples with SCA scores more than 85 points. In overall, it is determined that the convective mechanical drying

method is a viable approach for the processing of specialty coffee beans since it allows for the retention of high-quality sensory qualities, allowing it to command higher market pricing.

Keywords: specialty coffee; drying kinetics; diffusivity coefficient; sensorial quality

1. Introduction

Coffee is one of the most popular beverages around the world and a rather relevant food commodity from an economic standpoint. In that sense, green beans are a largely produced and commercialized commodity worldwide, with an average global production of approximately 168.35 million 60-kg bags [1]. Botanically, coffee belongs to the genus *Coffea* of the *Rubiaceae* family, with the commercially relevant species being C. *arabica* and C. *canephora* and it is only produced in tropical regions that have specific soil and climatological characteristics [2]. A complex system has been related to the coffee supply chain, which involves several agents such as agricultural inputs firms, farmers, commodity traders, food industries, retailers, coffee shops and the final consumer [3]. Likewise, coffee fruit processing includes steps such as harvesting, postharvest process (dry, semi-wet and wet processing), dehulling, size grading, roasting, grinding, extraction and drying, the last step for industrial coffee factories.

With current changes in the preferences of consumers, who are increasingly aware of the ethical and environmental implications, the production processes and the people behind their food, the specialty coffee market has become one of the products with the highest growth and interest worldwide. Specialty coffee is defined as a beverage with unique and distinct sensorial attributes. It is derived from green coffee beans obtained by selective harvesting of ripe fruits (handpicking), which are free of primary defects (stones, sticks, black and sour beans). Specialty coffee is processed by a controlled fermentation, followed by a traditional open sun drying process [4]. The fermentation process has been previously examined by different authors, who define it as the process with a major impact on volatile compounds, composition, quality and value of the final product. These factors allow the product to reach higher market prices due to superior qualification values, as defined by the SCA scale (>85) [4,5].

After the fermentation process, the coffee beans must be dried to avoid bacterial or mold activity, thus preventing over fermentation of coffee beans. The drying process aims to evaporate the water, or the volatile constituents present in the food material and to reduce water activity (a_w) through a complex phenomenon that involves processes of heat and mass transfer [6,7]. Several authors have reported the use of drying as a method of processing agro-industrial products and by-products such as avocado [8], passion fruit [9] and coffee and coffee byproducts [6], among others. In the coffee industry, drying of green coffee beans is a critical step for the overall quality, since drying avoids damage and weight loss. Since green beans must be dried immediately due to the high moisture content derived from the washing and fermentation processes (>50%), coffee is considered a perishable product [10,11]. Overall, the drying process is associated with the country of the coffee's origin and can be performed by hot-air or open sun drying.

In Colombia, it is common that farmers apply open sun drying, which is carried out on flat ground, platforms or concrete terraces until the beans reach the desired water content (<12%). This method is used to reach the moisture content required by the Colombian standard. Open sun drying is a procedure that has not altered significantly since the beginning of coffee production in Colombia and it is unlikely to change in the future. This type of drying technique using solar energy, makes it an economical process that is advantageous mainly for small farmers. However, this process need at least 100 square meters of drying area, takes several days depending on the climatic conditions and the coffee beans need to be homogenized 3 times a day, Otherwise, it can be compromised the sensory characteristics of the final product [4,5,11,12]. Nowadays, for Colombian farmers, mechanical drying is a technology that is still unknown and viewed with suspicion and is frequently associated with high cost and low quality.

The mechanical drying of coffee is a technique that allows for a better utilization of the physical properties of coffee and is used to reduce the moisture content in coffee beans [13]. This technique involves the use of drying machines that apply heat and hot air to accelerate the process of water evaporation in the beans. Looking for to achieve a faster and more efficient drying process, [14] evaluated the influence of different drying techniques (direct sun exposure, cabinet sun drying, heat pump drying, hot air drying and freeze-drying) on the bioactive components, fatty acid composition, and volatile chemical profile of green robusta coffee beans. The authors reported that freeze-drying is an efficient way to preserve saturated and unsaturated fatty acids as well as organic acids as well as more than 62 volatile chemicals. According to the authors, the maximum concentration of volatiles was achieved with heat pump drying, while the highest quantity of volatiles was obtained with lyophilization. Finally, the drying techniques direct exposure to the sun were shown to have a tight association. However, the lyophilization and hot air-drying methods were notably different from the remainder of the drying process.

According to the above, the traditional method takes several days to process, requires large drying spaces and is an uncontrolled process based on the experience of the farmer. To the best of our knowledge, this is the first time to work about the effect of mechanical drying with different conditions over the sensorial quality of specialty green coffee beans. The objective of the present work was to evaluate the effect of the mechanical drying process on the sensorial quality of specialty coffee produced in three different Colombian coffee farms and compare the results with samples obtained by traditional open sun drying technique. This work provides a processing alternative to farmers in the coffee industry, aiming to reduce drying process time and produce coffee beans that can be sold in the international market as a specialty coffee.

2. Materials and methods

2.1. Materials

150 kg of Castillo® variety coffee was collected by handpicking in a state of optimum maturity from trees planted on three different farms located at 1700 meters above sea level in Valle del Cauca, Colombia. The farms are La Esmeralda farm (4°17'00"N; 75°49'15"W), La Morelia 2 farm (4°16'39"N; 75°48'40"W) and Villa Laura farm (4°16'07"N; 75°5'01"W). The collected coffee was processed by the wet method and the fermentation process was controlled with the Fermaestro® method.

2.2. Fermaestro® method

The Fermaestro® method has proven to be an effective tool in accurately determining the washing point when natural fermentation is carried out using a device that helps to determine the optimal washing point [15,16]. In this regard, the Fermaestro® implement consists of a truncated cone of half a liter with holes in the base and walls, which is filled with freshly depulped coffee and placed in the mass of coffee that is fermenting; this way, the coffee inside the Fermaestro® follows the same fermentation process as the coffee in the tank [16].

2.3. Drying process of the coffee samples

After washing, two drying processes were applied to coffee samples until 11% w.b of moisture content was reached (Figure 1).

Figure 1. (a) Diagram of the equipment used for drying coffee with hot air and (b) open sun.

The weight change over time was measured with a gravimetric method for both drying techniques [17,18]. The air-hot drying process (mechanical drying) was carried out in a static layer silo with a maximum capacity of 15 kg of coffee samples. The mechanical drying process was performed using a silo dryer equipped with a heat source, fan and devices based on Arduino technology. Specifically, the equipment consisted of a fan coupled to an electrical resistance for air heating, which passed through a tunnel with a height of 40 cm. The electrical resistance consisted of a 6-inch tubular plate with a working range of 110 to 120 volts (Haceb, Colombia). The temperature of the drying air was set at 35, 45 and 55 ± 1 °C, with data collection performed by a data acquisition system every 60 minutes. The air velocity rate was set at 100 ± 0.1 $m^3/min \cdot m^2$ and the maximum bed height of coffee was 0.20 m. The microcontroller of the Arduino mega board was programmed through a computer using serial communication via the RS-232 port available on the board. The firmware of the system was programmed to sense relative humidity using DHT11 sensors and to control the temperature using type K thermocouples. The signals from the sensors were sent to the computer software control and automation system, which consisted of a user interface (UI) developed using C# technology.

The open sun drying process was carried out in a patio under direct exposure to the sun. The thickness of the coffee was 0.01 m, and the sample was mixed every 2 hours. At night, the coffee was packed to protect it from relative humidity and avoid re-moistening of the coffee.

After the coffee drying processes were completed, the parchment coffee was packed in GrainPro® Hermetic Pouch™ bags (GrainPro, USA) and stored for three, six and nine months at 23 ± 2 °C and 75 ± 3 relative humidity inside a darkroom.

2.4. Modeling of coffee beans drying process

A dimensionless moisture ratio (MR) was calculated from the drying curves as shown in Equation 1, where X_t is the moisture content at any time t (g water/g dry basis), X_e is the moisture content at the equilibrium (g water/g dry basis) and X_0 is the initial moisture content (g water/g dry basis).

$$MR = \frac{X_t - X_e}{X_0 - X_e} \quad (1)$$

values of X_e are considered relatively small compared to X_t or X_0 [6].

The effective diffusion coefficient (D_{eff}) was determined using Fick's second law for an infinite slab (open sun drying) and spherical geometry (mechanical drying), shown in equations 2 and 3, respectively [19,20]. Fick's law was used for one-dimensional transport with the assumptions that moisture migrates only by diffusion, negligible shrinkage occurs, and the diffusion coefficients and temperature are constant [21].

$$MR = \frac{8}{\pi^2}\sum_{i=1}^{\infty}\frac{1}{(2i-1)^2}e^{\left(\frac{-(2i-1)^2\,\pi^2\,D_{eff}\,t}{4L^2}\right)} \quad (2)$$

$$MR = \frac{6}{\pi^2}\sum_{i=1}^{\infty}\frac{1}{j^2}e^{\left[-j^2\,\pi^2\,D_{eff}\,\frac{t}{r^2}\right]} \quad (3)$$

However, for long drying times (MR < 0.6), only the first terms of equations 2 and 3 are relevant for the evaluation of MR and can be simplified as shown by equations 4 and 5, respectively.

$$MR = \frac{8}{\pi^2}e\left(\frac{-D_{eff}\times\pi^2\times t}{4L^2}\right) \quad (4)$$

$$MR = \frac{6}{\pi^2}e^{\left[\pi^2\,D_{eff}\,\frac{t}{r^2}\right]} \quad (5)$$

Deff is the effective moisture diffusion coefficient ($m^2.s^{-1}$), t is the drying time (s), L is the half-thickness of the slice (m) and r the radius of the sphere (m). Different semi-theoretical methods were used to provide an understanding of the transport processes and to demonstrate a better fit to the experimental data. All the temperatures were modeled, in that sense 55 °C was selected in order to show graphically the behavior of the mechanical drying process. The semi-theoretical models are shown in Table 1.

Table 1. Semi-theoretical models to describe drying kinetics.

No	Model	Equation	Reference
1	Page	MR = exp ($-kt^n$)	(Akoy, 2014) [22]
2	Henderson and Pabis	MR = a exp ($-kt$)	(Hashim, Daniel & Rahaman, 2014) [23]
3	Midilli et al.	MR = a exp ($-kt$) + bt	(Ayadi, Mabrouk, Zouari & Bellagi, 2014) [24]
4	Demir et al.	MR = a exp $(-kt)^n$ + b	(Demir, Gunhan & Yagcioglu) [25]

2.5. Moisture and electrical conductivity

The obtained coffee samples were tested for moisture according to the methodology described by the norma técnica colombiana NTC 2325/2005 [26]. The electrical conductivity was tested following the methodology described by [27] and a Hanna brand HI8733 portable conductivity meter was used (µS/cm·g).

2.6. Sensorial quality

Sensorial analysis of the coffee samples was carried out applying a methodology reported by [28,29]. Sensory evaluation was performed in different sessions involving a total of 15 expert panelists. The description of the sensory attributes and the score of the beverage was carried out according to the SCA protocol for specialty coffee. After carrying out the coffee roasting process according to SCA protocol, 50 grams of roasted coffee were ground, ensuring that 70–75% of the particles passed through a 20-mesh sieve (Retsch, Germany) and 5 cups of coffee were prepared with a ratio of (55 g coffee/1 L H_2O). Frag/aroma, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness and overall quality were tested. The total score of each coffee sample was converted into an SCA point scale and the average of the panelists' scores was calculated.

2.7. Experimental design and statistical analysis

A 4 × 3 randomized factorial experimental design was performed with two independent variables: drying process temperature (55 ℃, 45 ℃, 35 ℃ and solar drying) and storage time (3, 6 and 9 months), with a block factor (3 farms). The responses that were measured included diffusivity coefficient (D_{eff}), moisture content, electrical conductivity and sensorial test. Data were expressed as mean ± SD of three replicates. The data and RMS were analyzed and performed using R software (R Development Core Team, 2004). An analysis of variance (ANOVA) was applied where the effects were considered significant when $p < 0.05$. The FactoMineR package in R language was used for the factorial analysis of mixed data (FAMD) to find the similarities between the quantitative and qualitative results in the analyzed variables [30,31].

3. Results and discussion

3.1. Effect of mechanical drying process conditions on effective diffusion coefficient analysis of green coffee beans

The influence of drying conditions (35 ℃, 45 ℃, 55 ℃ and open sun drying) on drying time, moisture content (MC), diffusivity coefficient (D_{eff}) and electric conductivity (EC) of the coffee samples is presented in Table 2.

According to the data shown in Table 2, the drying time required to get an MR = 0.1 (Equiation1) varied from 20.35 to 71.52 hours. Increasing the process temperature results in lower process time. The Diffusivity value (D_{eff}), based on Fick's second law, presented significant differences ($p < 0.05$) for all drying processes. The D_{eff} ranged from 3.21 to 8.02 × 10^{-7} m^2/s for mechanical drying and values of R^2 ranged between 0.83 to 0.96. On average, open sun drying showed diffusivity of 4.21 × 10^{-11} m^2/s.

In general, the previous values are in accordance with those reported by [32], who related that overall, the diffusivity values for food matrices are between 10^{-11} and 10^{-8} m^2/s. The values obtained for Deff from mechanical drying were lower than these values, indicating a faster water evaporation process in mechanical drying compared to sun drying. This is because mechanical drying is a controlled process, whereas open sun drying depends on climatic conditions (temperature and relative humidity). These conditions are not constant in tropical regions like Colombia, where the climate is characterized by rainy seasons, cloudiness and limited hours of sunlight. Likewise, the effective diffusivity values increased greatly with increasing drying temperature, as an elevated heating energy leads to an increase in the activity of water molecules, thus higher moisture diffusivities [22].

Table 2. Results for drying process (mechanical and solar drying) applied to specialty Colombian coffee samples.

Drying process	Variable			
	Drying time (h)	MC (% db)	D_{eff} (m^2/s)	EC (µS/cm·g)
35 °C	71.52 ± 0.11 [a]	12.67 ± 0.03 [ab]	3.21E-07 ± 4.96E-10 [a]	11.71 ± 0.10 [a]
45 °C	29.10 ± 0.09 [b]	12.59 ± 0.22 [ab]	6.32E-07 ± 1.79E-09 [b]	14.40 ± 0.09 [b]
55 °C	20.35 ± 0.06 [c]	12.42 ± 0.02 [a]	8.02E-07 ± 1.61E-08 [c]	16.86 ± 0.13 [c]
Open sun drying	58.48 ± 11.37 [d]	12.79 ± 0.24 [b]	4.21E-11 ± 5.37E-12 [d]	11.87 ± 0.08 [d]

Note: Values are expressed as the mean ± standard deviation. Means in same column with different superscript letters are significantly different ($p \leq 0.05$) by Fisher's LDS test.

Figure 2 shows the drying curves obtained using the operating conditions that produced the dehydrated product in 20 h (55 °C), 29 h (45 °C) and 72 h (35 °C).

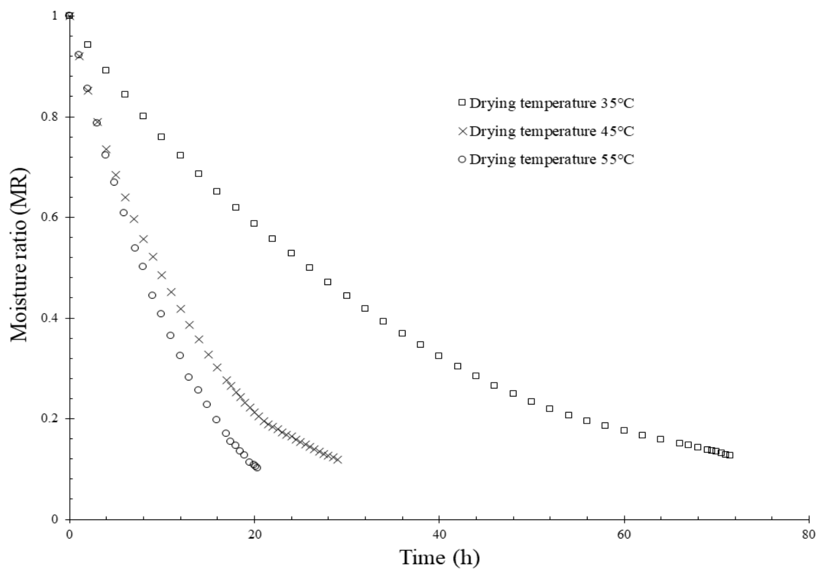

Figure 2. Convective drying curve obtained from the operating drying conditions.

Subsequently, an Arrhenius-type adjustment was made of the Deff values obtained as a function of the inverse of the temperature to establish the activation energy (Ea) of the process. On average, the Ea of the mechanical process was 900.6 J/mol. However, when the Ea was calculated for each farm, the following values were obtained: 892.29 J/mol (La Esmeralda farm), 886.30 J/mol (La Morelia 2 farm) and 922.55 J/mol (Villa Laura farm). The differences in the values could be explained by the geographical location of each farm, as that can have an influence on the behavior of the process.

The final moisture content was between 12.42 and 12.79 g/100 g d.b, in the sense that a moisture content of 10 to 11% (wet basis) was obtained to commercialize parchment coffee. The electric conductivity varied between 11.71 to 16.86 µS/cm/g. The drying temperature (T) significantly influences the electric conductivity ($p < 0.05$), with higher values of temperature correlating to an increase in the electric conductivity. This behavior indicates that the cell membrane of coffee beans is affected by the temperature, which favors the diffusivity process and hence the loss of water. Likewise, higher temperature is related to an increase in the enthalpy of the system, which increases the transfer of mass and energy, thus accelerating the migration of water [6,22]. The results found in this work are like those reported by [33] and lower than those reported by [27].

Table 3 shows values of the drying constants and drying coefficients of the selected models.

Table 3. Results for the drying kinetics described by semi-theoretical models.

Model	Parameters	35 °C	45 °C	55 °C
1	R^2	0.9926	0.9696	0.9927
	k	9.05E−05	5.94E−04	1.57E−04
	n	1.2531	1.1534	1.3926
	Standard error	0.0265	0.0481	0.0276
2	R^2	0.9809	0.9645	0.9706
	a	1.0594	1.0348	1.0874
	k	6.54E−04	1.71E−03	2.12E−03
	Standard error	0.0419	0.0521	0.0556
3	R^2	0.9991	0.9692	0.9994
	a	1.0008	1.0050	1.0142
	b	0.0000	0.0000	−0.0002
	k	4.90E−04	1.49E−03	1.37E−03
	Standard error	0.0087	0.0491	0.0081
4	R^2	0.9994	0.9710	0.9999
	a	1.1529	0.9809	1.2436
	b	−0.1664	−0.0192	−0.2489
	k	4.42E−04	1.47E−03	1.28E−03
	n	1.0496	1.1800	1.1055
	Standard error	0.0072	0.0483	0.0033

From the Table, the drying constant (k) is a function of temperature, where an increase in drying temperature leads to an increase in the drying constant. In all cases, the R^2 values for the models were greater than 0.95, indicating a good fit and varied between 0.9696 and 0.999. These values show that the tested drying models predict the drying process of coffee beans adequately. Figure 3 shows the plotting of the experimental data with the predicted values using Page, Henderson, Midilli and Demir models for coffee samples processed at 55 °C by mechanical drying.

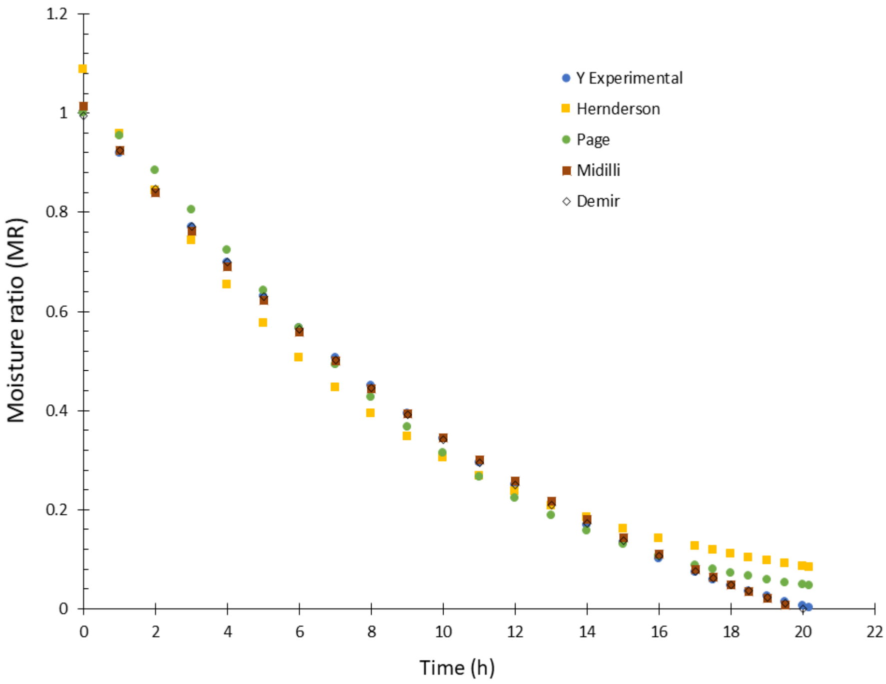

Figure 3. Predicted MR_t versus Experimental MR by Page, Henderson, Midilli and Demir models at 55 °C.

The diagram shows that the observations are clustered along the linear regression line, which demonstrates the adequacy of the selected models in describing the drying characteristics of coffee beans.

3.2. Sensory analysis of dried coffee beans

The scores obtained for fragrance/aroma, flavor, aftertaste, acidity, body, uniformity, balance, clean cup, sweetness and overall quality for samples coffee evaluated as presented in Table 4.

The total score of each coffee sample was converted into an SCA point scale and all samples were given a score higher than eighty. Overall, the drying process presented a significant effect ($p < 0.05$) for all the coffee samples, while storage time did not present a significant effect ($p > 0.05$) over the sensory attributes evaluated.

The uniformity, clean cup, and sweetness of the beverages scored a value of 10 in all the samples, which indicates that the storage conditions and drying processes produced coffee beans with the minimum quality requirements for the specialty coffee market. On the other hand, the samples produced at 55 °C and for the entire storage time reached higher scores for fragrance/aroma, flavor, residual flavor, acidity, body and balance. The results obtained for global score (Table 4) indicate that coffee samples dried at 55 °C and 45 °C benefit the sensorial characteristics of coffee samples and reach the SCA requirement to be selected for the specialty coffee market. According to the results obtained in the sensorial test, it can be inferred that shorter drying time and higher temperature favors the sensory profile of the samples. These factors favor the concentration of important chemical compounds in the formation of flavor and aroma during the roasting process, as reported by additional authors [14,34,35].

Table 4. Sensory attributes evaluated in specialty coffee samples for the drying process.

Sensory attributes	Drying process			
	35 °C	45 °C	55 °C	Open sun drying
Fragrance/aroma	8.03 ± 0.19[a]	7.96 ± 0.29[ab]	8.50 ± 0.17[c]	7.83 ± 0.14[b]
Flavor	7.78 ± 0.12[a]	7.80 ± 0.12[ab]	8.11 ± 0.18[b]	7.63 ± 0.25[a]
Aftertaste	7.50 ± 0.21[a]	7.78 ± 0.20[b]	7.94 ± 0.18[b]	7.50 ± 0.20[a]
Acidity	7.78 ± 0.19[ab]	7.67 ± 0.19[a]	7.89 ± 0.13[b]	7.76 ± 0.13[ab]
Body	7.52 ± 0.18[a]	7.75 ± 0.22[b]	7.97 ± 0.15[c]	7.53 ± 0.18[a]
Uniformity	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]
Balance	7.66 ± 0.06[a]	7.79 ± 0.14[b]	7.97 ± 0.15[c]	7.62 ± 0.14[a]
Clean cup	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]
Sweetness	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]	10 ± 0[a]
Overall	7.80 ± 0.14[a]	7.86 ± 0.14[a]	8.08 ± 0.36[b]	7.73 ± 0.18[a]
Total score SCA	84.00 ± 0.48[ab]	84.60 ± 0.80[b]	86.50 ± 1.00[c]	83.60 ± 0.74[a]

Note: Values are expressed as the mean ± standard deviation. Means in same row with different superscript letters are significantly different ($p \leq 0.05$) by Fisher's LDS test.

For a better understanding of the effect of temperature the sensory profiles of the cup based on the 10 attributes during the storage time are shown in Figure 4.

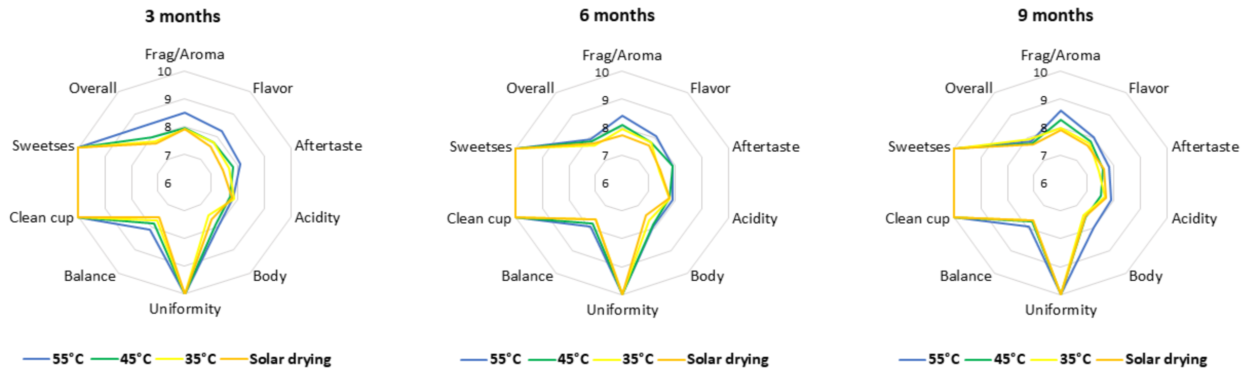

Figure 4. Sensory radar profiles of coffee samples according to SCA protocol for the different drying processes and storage time.

It is observed that the sensory profiles retain their tendency as time passes, while the coffee dried at 55 °C differs from the rest of the drying processes in the fragrance/aroma, flavor, residual flavor, body, balance and overall. These results show the importance of guaranteeing adequate storage conditions for coffee using packaging that protects the grain from moisture, oxygen and light. This can allow low impact on the chemical composition of the grain, leading to preserved sensory attributes over time. In general, higher cup scores are obtained in samples handled with mechanical drying procedures. Because this sort of technique eliminates or decreases the effects of exposure to light, air, humidity and environmental conditions as well as microbiological, enzymatic and oxidative processes, which standard drying samples are subjected to.

Figure 5 shows the factor analysis of mixed data (FAMD) for the quantitative variables (sensory attributes and drying time) evaluated during storage for all drying processes. FAMD was chosen as an appropriate multivariate approach for explaining the link between sensory qualities and drying time in relation to drying procedures and storage duration. The first two primary dimensions (Dim1 and Dim2) explain 59.4% of the variation in the observed variables, where the drying processes and drying time are clearly separated from the sensory qualities. This form of study is used to describe how drying methods affect sensory, chemical and physical properties [35].

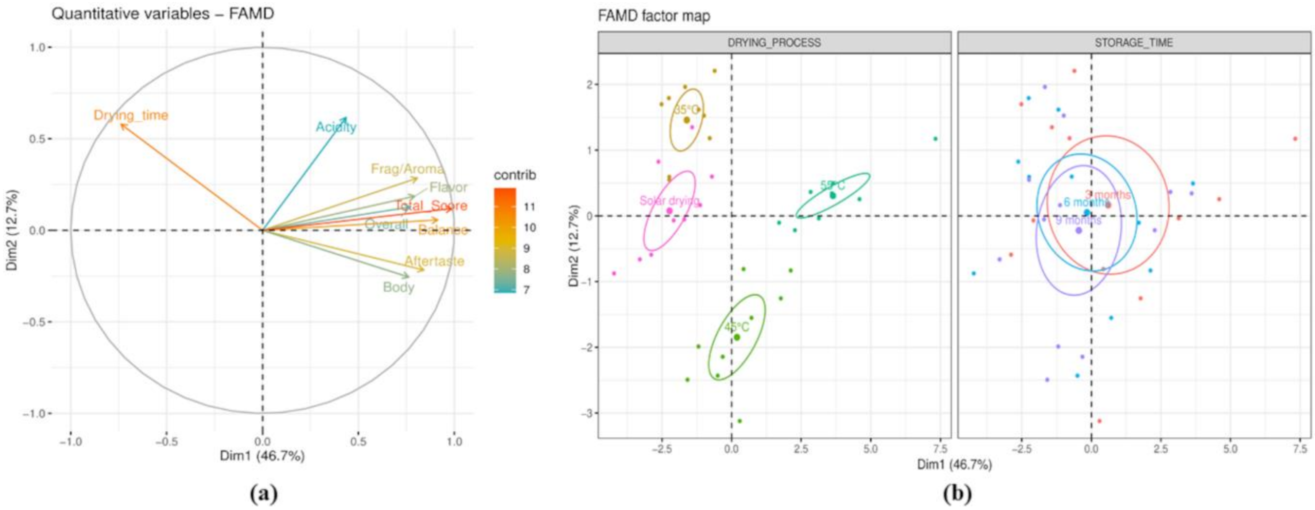

Figure 5. Factor analysis of mixed data (FAMD) for (a) quantitative variables and (b) map with drying process and storge time in months.

In Figure 5 (a) it is observed that there is a negative correlation between sensory attributes and drying time, indicating that drying processes with less time favor the sensory attributes evaluated in roasted coffee. This tendency could be due to longer drying times causing changes in the concentration of chemical components, which affect the sensory profile of the coffee drink [36]. The drying time effect may be related to different physicochemical and microbiological processes that occur inside and outside the coffee beans during drying. Water activity (a_w) is an important attribute in coffee quality preservation and when it is slow dried, the a_w is higher in the grains, enabling microbiological growth phenomena, oxidation processes, hydrolysis processes and enzymatic activity [37].

Figure 5 (b) shows the differences between the drying processes with the confidence ellipses and their centers of gravity. The drying procedures used on green coffee beans have an impact on the values obtained for sensory characteristics and evaluated variables. It is reasonable to believe that the drying procedures used have an effect on the amounts of chemical components in coffee beans. When performing the coffee roasting process, the concentration of these chemical components permits the development of scents and tastes, influencing the sensory profile of the coffee drink. According to current study, the drying technique utilized can ensure a higher or lower concentration of chemical components in the coffee beans after drying [14,35,38].

The opposite is observed for the storage time where all the ellipses are intercepted, indicating that the sensory attributes are preserved over time. The FAMD results confirm the ANOVA results in that storage time had no influence on the tested variables. This may be due to the fact that the packaging utilized helps the stability and conservation of the physicochemical qualities of the coffee. In this regard, the packaging used to keep parchment coffee must be very resistant to water vapor, oxygen and light.

4. Conclusions

In general, it can be concluded that the hot-air drying was a suitable technique for processing green coffee beans since the mechanical drying is a controlled process. This regulated environment yields a product with strong sensory qualities that has the potential to be commercialized in the specialty coffee market. The sensory quality of the coffee enhanced when the air temperature was elevated during mechanical drying. When compared to direct sun drying, a drying air temperature of 55°C led in greater ratings for the characteristics fragrance/aroma, flavor, aftertaste, body and balance. The mechanical drying technology that we examined provides a value-added option for Colombian coffee farmers, allowing them to produce high-quality green coffee beans while also opening up new financial prospects. Finally, the greatest coffee cup score was obtained at a temperature of 55 ℃, which can be attributed to a quicker drying period as compared to direct sun drying. In this context, technologies such as microwave drying, heat pump drying, and dehumidified air drying can achieve faster drying periods. These technologies have the potential to improve the coffee cup score.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declared that there is no conflict of interest.

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