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Research article

Flavor precursors and sensory attributes of coffee submitted to different post-harvest processing

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Abstract: Post-harvest processing (PHP) modifies the quality of the coffee and increases the value of coffee production. The choice of PHP to apply depends primarily on the available infrastructure, local climatic conditions and the desired end-value. The objective of this study was to evaluate the influence of PHP on the physico-chemical characteristics of green and roasted coffee beans and their sensory attributes. Coffee cherries from IAPAR 59 cultivar were processed as natural coffee (CN), semi-dry coffee (CD), de-pulped coffee (CP) and floating coffee (CF). Total and reducing sugars, phenolic compounds, chlorogenic acids, lipids, proteins, caffeine and water content were determined in coffee beans collected during (10thday) and at the end of each processing. The roasted beans and their sensory attributes were also analyzed. The greatest changes at the ending point of the processes were found in total and reducing sugars, phenolic compounds, chlorogenic acids and lipids contents. The PHP presented different weight loss to achieve the same visual brown color and luminosity. Beverage sensory attributes were influenced by the PHP: CN and CP coffees presented similar intensities of coffee aroma, but higher intensity of green grassy aroma, and taste were found in CF and CN coffees. Aroma and taste precursors were modified during the PHP and these were associated to husk removal of the coffee beans, suggesting an activation of the germination metabolism during the PHP. This study allowed the characterization of the effects of the different

post-harvest processing on the roasted coffee beans and provides the foundations to monitor their efficiencies in the future.

Keywords: *Coffea Arabica*; chemical composition; post-harvest process; green coffee beans; roasted coffee beans

1. Introduction

Coffee beverage is appreciated worldwide and its consumption has been mainly attributed to sensory attributes and beneficial health effects. Continuous efforts throughout the production chain have provided better post-harvest techniques to improve the sensory quality of the beverage [1,2]. Additionally, identification of bioactive compounds in the beverage has constantly increased its consumption [3].

The coffee cherries develop after the main flowering that occurs in the first spring rains [4]. Due to the successive blossoms, it is possible to find cherries with different degrees of maturation in the same branch at the time of harvest.

After the coffee cherries are harvested, they are washed and sorted according to their maturation stage (dried vs immature beans). Then, the cherries are submitted to peeling, de-pulping and drying. This set of steps is called the post-harvest process and from the different combinations of these steps originate the different post-harvest processing [5].

Coffee post-harvest processing (PHP) vary according to their degree of removal of the exocarp (husk), mesocarp (pulp) and endocarp (parchment) before drying (Figure 1a). When after a first washing step, the intact coffee cherries are spread directly into the sun terrace to dry it is called natural coffee (CN). In semi-dry coffee processing (CD), the husk is removed and coffee cherries are dried with the mucilage remaining. In the de-pulped coffee processing (CP), besides the removal of the husk, the mucilage is removed by mechanical and/or fermentative methods before the drying [5].

The presence of immature coffee cherries beans in the coffee harvested impedes the good implementation of the different PHP. Indeed, in immature cherries, the husk is more attached than in mature ones. In addition, the presence of immature and dry cherries significantly alter the chemical composition of the coffee batches [6] and consequently cause multiple defects of aroma and flavor in the beverage [7].

Various coffee endosperm compounds are precursors of aromas and flavors [1]. These compounds are involved in the production of the volatile compounds through numerous reactions during the roasting of the coffee beans [8]. Endosperm carbohydrates such as cell wall carbohydrates, sucrose, glucose and fructose [9,10] are important aroma and taste precursors. Proteins, free amino acids, caffeine and trigonelline are the main nitrogenous compounds in coffee endosperm that contribute to aroma in the coffee beverage [3,6,11]. Additionally, lipids and free fatty acids are present in the green coffee beans and contribute to define the sensory attributes of the beverage [12,13]. Other compounds, such as the phenolic, sugars, organic acids ones, depend on the maturation stage [14] and they also have high influence on the sensory attributes of the beverage [15].

In all PHP, the coffee endosperm remains metabolically active and many compounds were altered significantly in the different processing. Studies have reported changes in the content of chlorogenic acids, trigonelline, sucrose [5] and reducing and total sugars contents too [10,16].

Many changes in composition during these PHP have been attributed to the fermentation and germination mechanisms [5,17], but these events are highly variable and can have different levels of influence on the final quality of beverage [11,18].

The natural microflora in the coffee beans develops on the surface of the coffee cherries in the CN process until the moisture conditions are still favorable to the growth of the microorganisms [19]. The succession of microorganisms that acts during the drying on the coffee cherries are governed by the water content in them. When the water content decreases down to 12%, few microorganisms are able to multiply [19], guaranteeing the stability of the product.

In the CD and CP processing, the fermentation process takes place in fermentation tanks for the removal of the mucilage that adhered to the coffee beans. Depending on environmental conditions, the microflora degrades the mucilage in 20 to 40 hours, leading to an acidification through the production of organic acids (mainly lactic acid) [20]. The metabolites produced by the indigeneous microflora may have beneficial or detrimental effects on the sensory attributes of the green beans [2].

Changes in coffee beans composition are also associated with germination mechanisms. PHP pioneering studies by [21], have demonstrated that the removal of inhibitors present in the husk activates the germination of coffee beans. Initiation of the germination mechanisms depends on a large extent of the water content of the coffee beans. Germination in the wet methods occurs in the first two days of fermentation, while in the dry processing the highest activity is observed between 4 and 5 days after the start of the processing [17,22].

The changes caused by PHP influence the amount and quality of flavor and flavor precursors determining the aromatic profile of the beverage [8]. In general, CN coffee has a beverage with a strong aroma, moderate acidity, intense body and a natural sweetness. In CD coffee beverage, the aroma and body presented medium intensities whereas the acidity and sweetness intensities are lower. CP coffee beverage is acidic, it presents a body of low intensity and the aroma is quite weak [11].

Despite several studies on the effect of PHP on coffee quality, few of them compare the sensory quality among them. Therefore, the consequences of the applied processing in the flavor precursors need to be investigated to understand their involvement and contribution in the sensory quality of the coffee.

The objective of this study was to evaluate the influence of natural (CN), semi-dry (CD) and de-pulped coffee (CP) PHP on the chemical composition of the green coffee beans, on the roasted beans characteristics and on the sensory attributes of the coffee beverage originating from each processing.

2. Material and methods

2.1. Coffee samples

About 500 kg of coffee cherries of *C. arabica* cv. Iapar 59 were harvested at the experimental station of the Instituto de Desenvolvimento Rural do Paraná—IAPAR-EMATER (IDR) located in Londrina (23°18'S, 51°10'W) in the state of Paraná (Brazil), in May 2006. In the Figure 1, the different post-harvest processing that the harvested coffee batches were submitted are described.

The washing tank has two outputs for the separation of the ripe coffees cherries. At first output, the fruits dried naturally in the plant and floating beans in the water were separated. These coffee beans were spread directly in suspended yards to dry in the sun. The coffee cherries dried were denominated floating coffee (CF).

In the second output the immature and ripe coffee cherries were discharged. After manual removal of the immature coffee cherries, the ripe cherries were divided into three parts.

The first ripe coffee cherry fraction was taken directly to drying in suspended yard and resulted in natural coffee (CN).

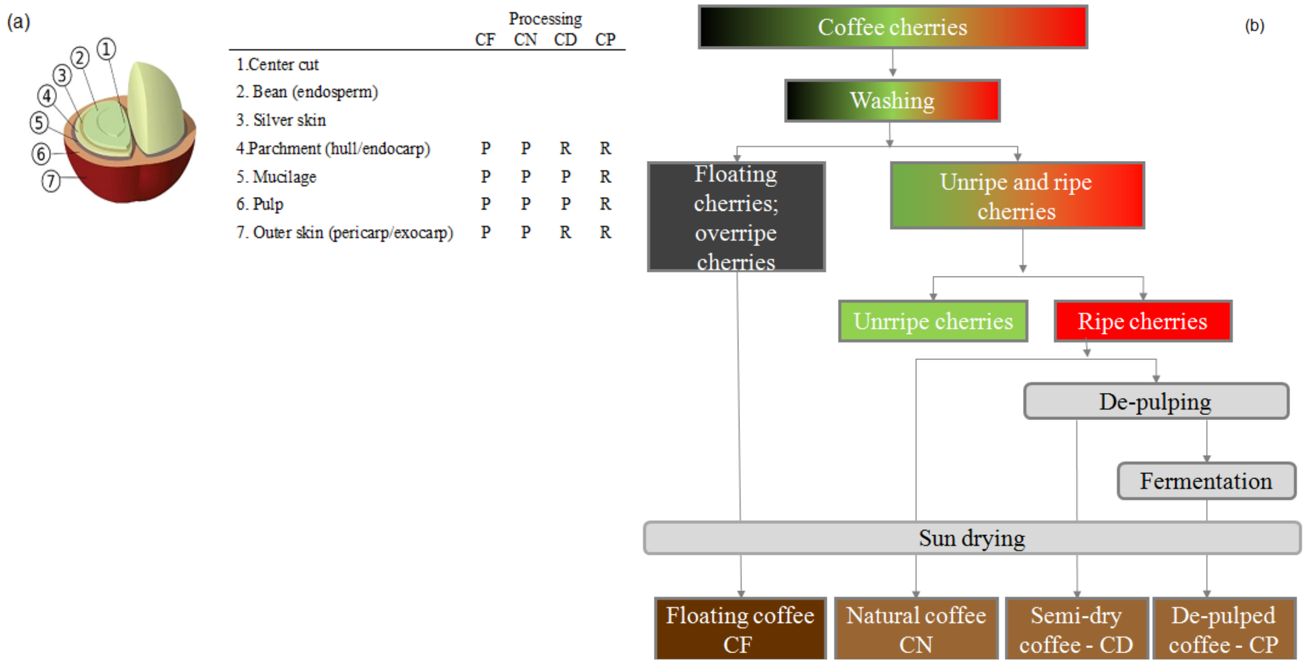

Figure 1. Schematic description of the tissue coffee cherry and presence (P) or removal (R) parts in each process (a), and schematic description of the different processes. Adapted from: http://redberrycoffee.co.id/anatomy-of-a-coffee-bean/ (b).

The other two coffee cherry fractions were peeled in pulper (Pinhalense, Brazil) with an appropriate regulation to remove the husk of the ripe coffee. Half of these peeled coffee cherries were then spread on suspended yards for drying and corresponded to the semi-dry coffee (CD).

The other half fraction was placed in a plastic drum and covered with water for the fermentation process. When the water of the fermentation reached pH 4.3, the coffee beans were washed intensively for removing residual mucilage and pulp, and were spread on suspended yard for drying. This coffee is the so-called de-pulped coffee (CP).

During the fermentation process of the CP coffee, each 12 hours, 50 mL of the water from the fermentation tanks were collected to control pH (digital pHmeter Metrohm, model 744).

2.2. Procedures for drying coffee beans on the suspended yard

During the drying period, the coffee beans were moved at 30 minutes intervals, between 10 h a.m. and 4 h p.m. every day and coffee beans were heaped and covered with plastic sheets daily. This procedure was repeated every day until 12% water content of the beans was achieved.

During the first 10 days of drying, 600 g of coffee beans were collected in each PHP to follow the changes in chemical composition. These samples were dried in air circulation oven at 60 ℃, until constant weight and were then stored at −18 ℃.

2.3. Preparation of coffee beans dried for the physico-chemical and sensory analyses

At the drying end, about 50 kg of dried coffee beans were available for each PHP. The dried coffee beans were packed in plastic bags and stored in ventilated place. For 2 kg of dried coffee beans from each processing the husk and parchment were removed and broken and defective beans were separated. These green coffee beans were packed in paper bags and kept in a dry place.

2.4. Physico-chemical analyses of green coffee beans

For the physico-chemical determinations, the green coffee beans were frozen with liquid nitrogen and ground (disc mill PERTEN 3600). Coffee beans grounded were packed in plastic bottles and kept in −18 ℃.

Protein, lipids and phenolic compounds contents were evaluated by the respective methods described in [23]. The chlorogenic acid and caffeine contents were evaluated by the method described in [24], and [25], respectively. Total and reducing sugars content was determined by Nelson-Somogyi method described in [26]. All biochemical determinations were performed in duplicates and the results were expressed on a dry weight basis.

2.5. Physical analyses of roasted coffee beans

Luminosity (L*), red-green (a*) and yellow-blue (b*) color components of the roasted and grounded coffee beans were determined in a Minolta CR 410 portable colorimeter, employing D65 illuminator (natural daylight), 10 ° angle and CIE standard observer. The density and the volume expansion of the roasted coffee beans were evaluated by the method described in [7].

2.6. Sensory analyses

Green coffee beans (100 g) were roasted in experimental roaster (Rod Bel) at temperature between 200–240 ℃, for 8–10 minutes. The final point of roasting was determined by the visual coloration of the roasted coffee beans.

The panel of candidates received information about the subject of the study and participated in testing procedures assessing their ability to recognize basic odors and tastes. The candidates with odor recognition scores above 70% and who exhibited 100% accuracy in recognizing basic tastes were selected for the panel analysis. Details about procedure used for selecting and trained assessors, attribute identification and quantification and panel performance evaluation were clearly described in [26].

The beverage was prepared with 70 g of roasted and ground coffee beans to which 1000 mL of boiling water (96–98 ℃) were added. After 5 min of extraction, the beverage was filtered on filter paper (Melitta filter paper). Coffee was served in disposable cups of 50 mL of capacity and coded with three-digit numbers. Eight trained tasters evaluated four samples in two sessions [26].

Attributes generally employed to evaluate coffee beverage [15,26] were used to evaluate the sensory profile of the beverages of each PHP. The intensity of the attributes turbidity, coffee aroma, sweet aroma, green grassy aroma, body, sweet taste, acid taste, green grassy taste, bitter taste and astringency were evaluated using an unstructured 10 cm scale, anchored to one cm of the extremes corresponding to the minimum and maximum limits of attribute intensity [26].

2.7. Statistical Analyses

Analyses of variances and Tukey's test were performed to estimate the effects of the different post-harvest processes on the physico-chemical compositions and sensory attributes of the beverages. PCA analyses were developed for chemical and sensorial analyzes. Statistical analyzes were performed using XLstat [27].

3. Results and discussion

3.1. Control of fermentation process and moisture in CP coffee

The peeled coffee beans were placed into tanks with water for the fermentation step in order to promote the mucilage removal. The natural microflora on the coffee cherries is mainly formed by lactic bacteria and yeasts and rapidly ferments the pulp that recovers the coffee cherries. The fermentation process decreases the pH of the medium and inhibits undesirable microorganisms multiplication [20,28]. These conditions were efficient for the control of fermentative processes that can compromise the final quality coffee and allowed the complete pulp removal.

In the present study, the pH of the water in the fermentation tank was used to control the fermentation process in CP coffee. The fermentation occurred normally and after 40 h a pH of 4.2 was achieved (Figure 2a). Similar results were found by [29] in wet processing coffee when the pH decreased from 6.27 to 4.00 after 48 h of fermentation.

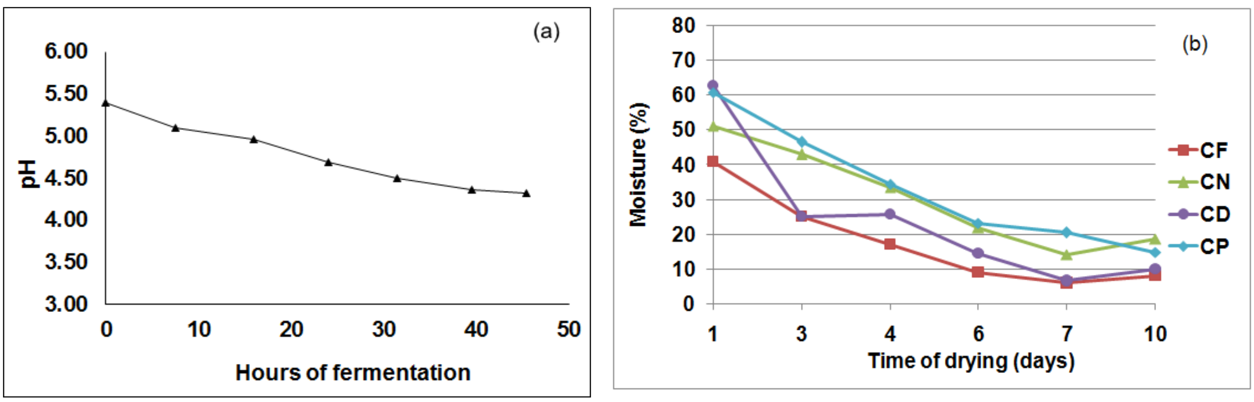

Figure. 2. Evolution of the pH in the water of the fermentation tank of de-pulped coffee CD: (a) and evolution of the water content of natural coffee (CN), floating coffee (CF), semi-dry coffee (CD) and de-pulped coffee (CP) (b) during the drying period.

The water content of the harvested ripe coffee cherries is relatively high (60–64%) and must be reduced to avoid the development of undesirable fermentative processes [2]. In CN processing, water removal may require from 25 to 35 days to reach the recommended moisture content (12%) ensuring a safe storage, depending on the movement of the coffee mass and climatic conditions [2,19].

The degradation of the chemical compounds and the formation of new compounds are proportional to water existing in the coffee beans. At the beginning of the drying process, the reactions are very rapid, but when the water content achieves critical limits (<20%) these reactions can cease or develop very slowly [2].

The Figure 2b shows the drying evolution for all processing. A great variability in the water content was observed in the coffee cherries at the beginning of the different processes. At this time, moisture content of CF and CN coffee beans were 44.3 and 51.1%, respectively, while it was around 60% in the CD and CP coffee beans. The CD and CF coffee beans showed faster drying than the CN and CP coffees beans in the first days of the PHP (Figure 2b). The CF and CD processing required fewer days to achieve the 12% moisture content than the two others PHP.

3.2. Physico-chemical compositions of the green coffee beans from different PHP

The composition of the coffee beans at the end of each PHP showed significant differences for the contents of total sugars, reducing sugars, chlorogenic acids, lipids and caffeine. Final phenolic compounds and proteins were similar in the four PHP (Table 1).

Table 1. Mean value (g 100 g^{-1}) of total sugars (TS), reducing sugars (RS), phenolic compounds (PC), chlorogenic acids (CGA), proteins (PRO), lipids (LIP), and caffeine (CAF) from the coffees beans of different post-harvest processing (PHP).

PHP	TS	RS	PC	CGA	PRO	LIP	CAF
CF	6.68 d	0.39 ab	5.14 a	6.58 b	16.51a	14.99 b	1.35 b
CN	7.55 b	0.48 a	5.15 a	6.93 a	16.21 a	15.16 ab	1.45 a
CD	7.22 c	0.29 bc	5.11 a	6.85 ab	16.74 a	14.66 c	1.32 c
CP	7.77 a	0.26 c	5.11 a	6.79 ab	17.04 a	15.37 a	1.47 a

Note: Mean value of the process followed by equal letters in the column do not differ by the Tukey test at the 5% probability level.

The final chemical composition of coffee beans was influenced by PHP. The total sugars content (TS) differed significantly among the different PHP. The highest content was observed in the CP coffee beans (7.77 g 100 g^{-1}) and lower in the CF coffee beans (6.68 g 100 g^{-1}). The highest value of reducing sugars was found in the CN coffee beans (0.48 g 100 g^{-1}) and the lowest in the CP coffee (0.26 g 100 g^{-1}) (Table 1). Similar sugars contents were observed by [16,30] in coffees beans prepared by similar processes.

CD and CP coffees beans, both with husk removal, presented similar RS contents at the end of drying. The reductions observed in both PHP cannot be attributed to sugars solubilization or fermentation because the CD coffee was not submitted to fermentation (Table 1) and presented a reduction too.

In the PHP, where the husks were removed (CD and CP) the decrease of reducing sugars occurred more intensely. In addition to the leaching during peeling and fermentation, this reduction could be attributed to the concomitant activation of the germination process with the husk removal [16,31]. During germination, various reserve polymers (lipids, proteins and carbohydrates) are mobilized to generate simple assimilates for the embryo.

Phenolic compounds content in CN, CD and CP coffees were similar, indicating that these compounds are scarcely influenced by PHP (Table 1). CF coffee has the lower amount of chlorogenic acids possibly because exposure to sun in the plant [32] and the full ripeness at harvest [33] have reduced the content of these compounds.

PHP had a significant effect on coffee lipids: the lowest lipid content was found in CD coffee and the highest value was observed in CP coffee (Table 1). Similarly, Leloup et al. [11] found significantly higher lipid values in de-pulped coffee than in processed coffees without husk removal, such as CF and CN coffees.

Conversely to other studies [5,11], the caffeine content showed significant differences between the processes and the highest values were observed in CN and CP coffees (Table 1). No significant difference in protein content among the processes was observed (Table 1).

3.3. Physical characteristics of roasted coffee beans from different PHP

The roasted characteristics and sensory attributes of the coffee beverage (mainly sour and bitter taste) are strongly influenced by the roasting intensity which must be strictly controlled [6,34].

The coffees of all PHP presented nearly the same degree of roasting (Table 2). Although weight loss varied significantly between 15.31% (CD coffee) and 14.21% (CN coffee), no significant difference in the luminosity (L*) of the roasted coffee was observed.

In these conditions of luminosity and weight loss, greater production of volatile compounds was observed [8], and these parameters are normally used to evaluate the quality of coffee beverage. The luminosity and component a* (red-green) are similar between the PHP, but CF and CP coffees showed higher intensity of component b* (yellow) than the CD and CN coffees.

The heating of green coffee beans during roasting promotes the evaporation of water and volatile substances with changes in weight and color of the beans [7,8]. Usually, the value of weight loss range between 15% [3,8] to 16% [34] to achieve dark brown color and developing typical coffee flavor.

In the present study, the different PHP presented different weight loss to achieve the similar visual color. This coloration depends on the presence of compounds (precursors) in the green coffee beans to produce the responsible compounds for the color of roasted coffee [8,30]. Thus, these results suggest that coffees from each processing had different precursors in quality and quantity, which then required different roasting intensities to achieve similar coloration.

During the roasting, gas formation promotes the expansion of the coffee beans, and the resistance of the cell walls to the expansion determining the volume of the roasted beans [34]. The volume expansion of the coffee beans was related to the porosity, the easiness of grinding and beverage percolation [7]. In the present study, volume expansion was similar for CD and CN coffees, but different in CF and CP, which presented the lowest and highest volume expansion, respectively (Table 2).

Coffees beans from all PHP showed similar density reduction in relation to green coffee beans (Table 2). These results contrast with the [7] who observed a variability of the density of green coffee beans varies according to species and coffee beans quality.

Table 2. Mean value of color parameters (L*, a*, b*), weight loss (PP), volume expansion (EV), density of green (DV) and roasted coffee beans (DT) from coffees of different post-harvest processing (PHP).

PHP	L*	a*	b*	PP (%)	EV(%)	DV**	DT**
CF	27.83 a	12.44 a	20.43 a	14.59 ab	57.15 b	0.65a	0.41 a
CN	26.79 a	12.36 a	19.56 b	14.21 b	60.26 ab	0.64a	0.40a
CD	26.78 a	12.41 a	19.76 b	15.31 a	61.41 ab	0.65a	0.40 a
CP	26.96 a	12.39 a	19.85 ab	14.36 b	61.86 a	0.64a	0.40 a

Note: L*: luminosity, a*: red-green color component, b*: yellow-blue color component, ** (g mL^{-1}).

3.4. Sensory analysis of the coffees from different PHP

The volatile compounds formed during the roasting are responsible for the aroma and flavor of the coffee beverage [8,30]. The sensory attributes of the beverage depends on the quantity and quality of these compounds [11].

In the present study, the descriptive sensory evaluation showed that the attributes coffee aroma, green grassy aroma and green grassy taste presented significant differences in beverages from the different PHP (Table 3).

CN coffee presents the highest coffee aroma, while the CF and CD coffees presented the lowest intensity of this attribute. The aroma intensity is associated with the presence of products derived from reactions between carbonyl and nitrogen compounds and between lipids and phenolic compounds and with the presence of lipids (coffee aroma). Therefore, the higher total sugars content in green coffee beans can be associated to the higher formation of coffee aroma. Studies of Leloup [11] have identified higher precursor content in CN coffee than in CP coffee.

Table 3. Mean value of the intensity scores of the coffee beverage attributes of the different post-harvest processing (PHP).

	Turb	Arc	Arv	Ado	Body	Sdo	Sac	Sv	Sam	Sads
CF	4.19 a	3.90 b	1.81 a	3.14 a	3.55 a	2.04 a	4.40 a	2.14 a	4.11 a	3.28 a
CN	4.51 a	4.64 a	1.46 ab	3.67 a	3.73 a	2.27 a	4.34 a	1.68ab	4.12 a	2.80 a
CD	4.28 a	3.89 b	1.37 b	3.16 a	3.56 a	1.99 a	4.25 a	1.48 b	4.16 a	3.42 a
CP	4.40 a	4.27 ab	1.36b	3.52 a	3.77 a	2.29 a	4.08 a	1.31 b	3.30 a	2.69 a

Note: Turb: turbidity; Arc: coffee aroma; Arv: aroma of green grassy; Ado: sweet aroma; Sdo: sweet taste; Sac: acid taste; Sv: green grassy taste; Sam: bitter taste; Sads: astringent taste.

Principal component analysis (PCA) was used to associate biochemical compounds and processes, and sensory attributes were used as supplementary variables (Figure 3). The first-two components retained 83.19% of the initial variability. The reducing sugars and protein showed higher correlation as F1, whereas total sugar, chlorogenic acid, lipids and caffeine had higher correlation with F2.

CF coffee beans showed higher intensities of green grassy aroma and green grassy taste and they were associated to high content of phenolic compounds (Table 1, Figure 3), but no significant differences between CN, CD and CP coffees were found (Table 3). These attributes are described as aroma and taste reminiscent of green grassy and they are chemically associated with phenolic compounds (green grassy aroma) as described [6,7].

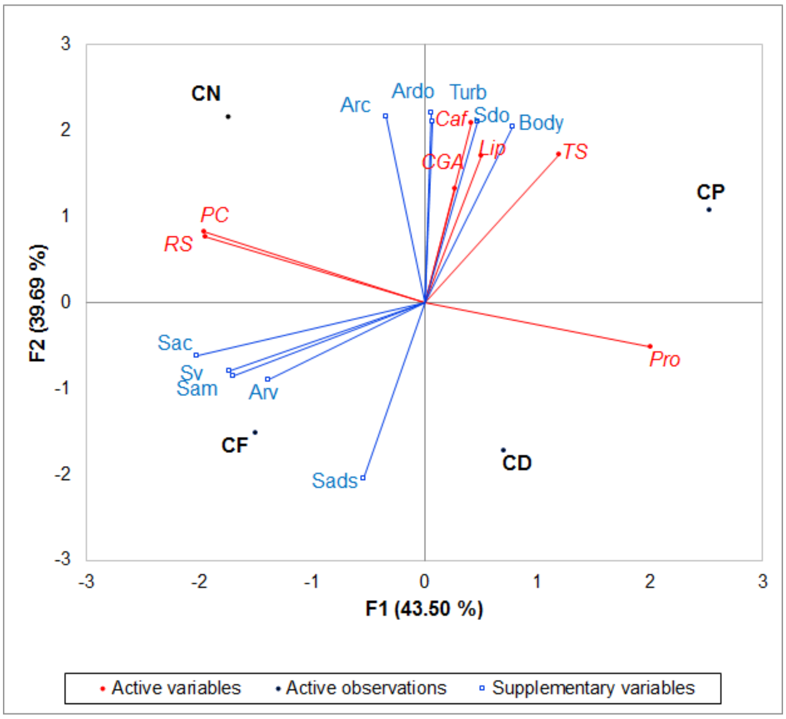

Figure 3. Chemical composition and sensory attributes dispersion in F1 and F2 of biplot of principal components analysis.

The proportions of aroma precursors, such as sugars, amino acids and chlorogenic acids present in green coffee beans can generate different aromas and flavors [15,30]. Then the sensory attributes of the beverage results from the reactions of several possible combinations of precursors existing in the coffee green beans. Studies [15,26,35] have shown that high content of chlorogenic acids in the presence of high total sugars produces coffee with high intensity coffee aroma. On the other hand, low coffee aroma intensity was obtained in the presence of low sucrose content combined with high chlorogenic acid content. This fact justifies a higher intensity of coffee aroma in the CN and CP coffees, which despite the high content of chlorogenic acids present coffee aroma (Table 1, Figure 3). However, when there is a lower content of these compounds (TS and CGA) as in CF and CD coffees, there was less production of volatiles that were insufficient to cover the CGA degradation products and as a consequence the green grassy flavor are stronger (Figure 3).

The other attributes did not show differences between the PHP, suggesting that the precursors for these attributes were little influenced by the post-harvest processing.

The sensory differentiation among PHP has great importance because these attributes are easily perceived by consumers who will identify the coffee that can effectively fill/match their expectations.

3.5. Evolution of coffee chemical composition from different PHP

Significant differences in the chemical compounds of the coffee beans at the beginning and end of each process were observed due to the specific reactions developed in each of them.

The correlation plot based on the first-two principal components of PCA of chemical compounds was noted and explained 68% of the variability (Figure 4a). It is interesting to highlight that CGA and lipids are highly correlated (0.84) and that the proteins are negatively correlated with them (−0.88 and −0.71, respectively) (Supplementary Table 1). Pearson correlation between CGA isomers and lipid was also found in the study of coffee cultivars submitted to different cultural practices and plant arrangements [35]. In the same way, lipids and protein showed correlations in different coffee genotypes of three consecutive harvests as demonstrated by [36].

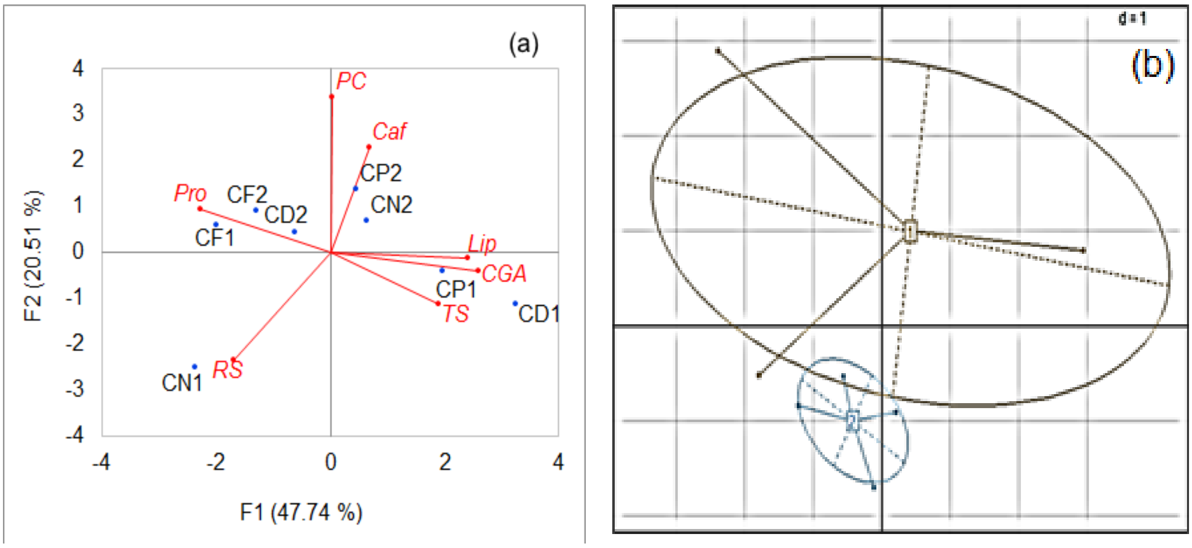

Figure 4. Biplot of principal components analysis in F1 and F2: (a) chemical compounds dispersion and (b) comparative projections of chemical variability in the PHP beginning (1) and the end (2).

In the Figure 4b, the PC1 and PC2 shows the chemical composition variability between the PHP was large at in the beginning (date 1), but it is highly reduced at the end of the processes (date 2). All chemical compounds showed changes during the drying processes, but different variations in each PHP were found. In the CF and CD coffee showed reduction in TS content and minor reduction were observed in CN and CP coffee beans. However, the reducing sugar (RS) content showed a marked reduction in all the processes (Figure 5). In the CN coffee beans, the reductions reached 34.25 % of the initial reducing sugars content. In CD, CP and CF coffees beans the variation in RS was 20.41%, 19.27% and 19.44%, respectively (Figure 5, Supplementary Table 2).

CGA content also showed modifications in the PHP coffees (Figure 5). An increase in CF (+1.86%) and CN (+7.78%) coffee was noted but in CD (−7.81%) and in CP (−5.21%) these values were decreased. These results suggest that CGA were mainly located in the coffee husk because the reductions happened in CD and CP where the husk and pulp were completely removed. Phenolic compounds present also variations: an increase in CN coffee (+4.67%) and in CD coffee (0.39%) was observed, but CF coffee (−0.39%) and CP (2.67%) presented a decrease.

Positive variations in lipids content in the CD coffee (+10.01%), in CN coffee (+4.41) and CF coffee (+3.67) were found and a minor change was noted in CP (−1.49%). Caffeine content showed variable increase in all PHP coffees (Figure 5). The highest increase was observed in coffee CN and the lowest CF coffee.

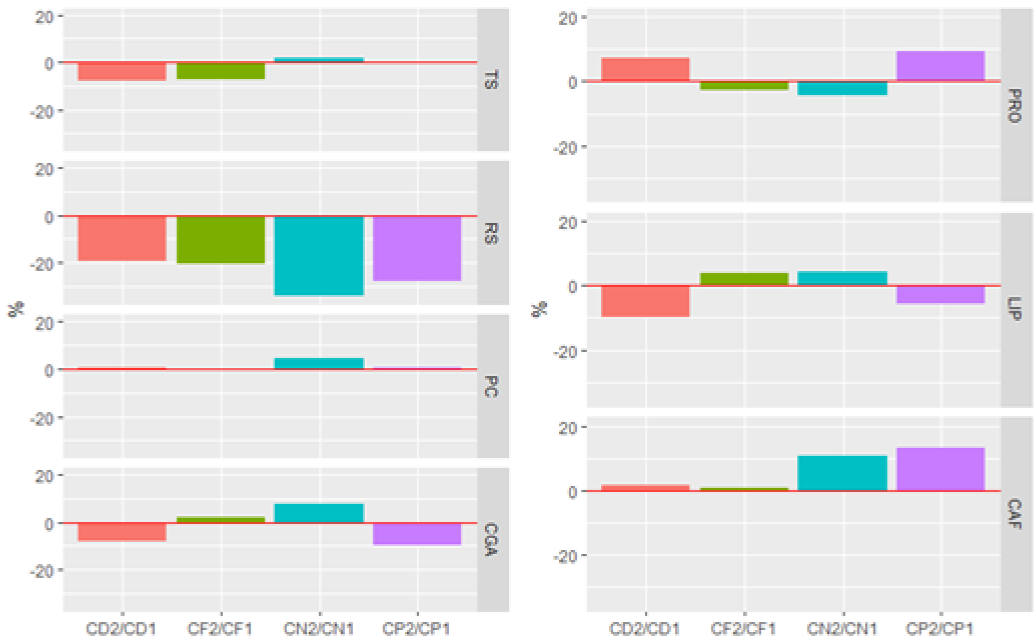

Figure 5. Total sugars (TS), reducing sugars (RS), phenolic compounds (PC), chlorogenic acids (CGA), protein (PRO), lipids (LIP) and caffeine (CAF) of the coffee beans at the beginning and end of the floating (CF), natural (CN), semi-dried (CD) and de-pulped (CP) coffees during the first ten days of drying.

4. Conclusion

Many aroma and tastes precursors were influenced by PHP. The greatest changes were found in total sugars, reducing sugars, phenolic compounds, chlorogenic acids and lipids. Interestingly the main changes in chemical composition of the coffee beans occurred with husk removal, suggesting the start of germination metabolism in this occasion.

The changes in the green coffee beans were reflected in the physico-chemical characteristics of the roasted coffee beans, mainly in the roasting intensity to achieve the same visual and instrumental color.

PHP resulted in beverages with different sensory attributes, which were associated with the presence or not of the husk during the process. This effect is less intense when the coffee has ripen and partially dried in the plant as occurred with the CF coffee.

To ensure the production of high quality coffee it is necessary that the harvested coffee beans provide the main precursors in quantity and quality. Then, the coffee producer could achieve the economic beneficial effects provide for different PHP.

Finally, this study provided a better understanding of the drivers of coffee quality for the different post-harvest processes.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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