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CHANGES IN TEXTURAL PROPERTIES AND COLOR DUE TO THE PROCESSING METHOD OF GREEN *COFFEA ARABICA*

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ABSTRACT

Choosing a suitable method of green coffee beans processing is one of the first steps that can significantly affect the final product. Thus, the objective of this study was to evaluate how the processing method affects the selected observed parameters (dry matter, water activity, pH, hardness, color). The postharvest processing of coffee cherries involves natural dry, semi-washed, or wet processing. On-farm postharvest coffee processing is essential for ensuring high quality of coffee cup and constitutes a chain of interlinked phases mainly aimed at removing the cherries' mucilage and drying the beans to a low moisture content of 10 to 12% (mass/mass). The coffee samples were of American origin *Coffea arabica*. A total of 12 samples from multiple regions were used. Samples of Coffea arabica were collected into three groups natural (dry), pulped natural (semi-washed), and wet processing (fully washed). The processing results, to some extent, influence the values of the monitored parameters. The highest dry matter value was indicated in dry processing, and the highest value of water activity was in wet processing. The average value of pH was 5.74. Natural processing showed the most significant differences between individual groups concerning color processing. On the other hand, wet and dry processing showed very similar colors. Values of hardness were in range 86549.05 - 100674.90 g. The final quality of the green coffee beans is thus dependent on the different agricultural, and farm practices applied, which depend on the coffee plant cultivar, geography, weather conditions, and available infrastructure.

Keywords: green coffee, post-harvest processing, textural parameters, *Coffea arabica*

INTRODUCTION

The quality of coffee beans depends on method of cultivation, post-harvest processing, ripe berries collection, and removal of the outer fruit layers **Gonzalez *et al*. (2007)**. It is assumed the especially lack of proper harvesting and processing methods are main factors to the poor quality of coffee **(Tassew *et al.*, 2020).**
Hosseni *et al.*, (2021); Bobková *et al.*, (2022); Iriondo-DeHond *et al.*, (2019); Ghosh and Venkatachalapathy (2014), confirmed that the coffee cherry has several different layers protecting the beans that must be removed to collect the green beans. The first outer layer is the skin (epicarp or exocarp), with waxy substance and has red or yellow color dependent of variety or cultivar. The second layer is the pulp (mesocarp), that is a slim layer of pectinaceous materials. The third layer is the parchment (endocarp), with polysaccharide covering. These layers together forming so called Cascara. The last layer, sticking to the seed, is named silverskin or chaff, which is formed during the roasting process.
After harvesting, the fruits required to undergo primary processing to separate the seeds from the rest of the fruit. Regardless the method of processing, coffee cherries must be dried to produce tradable standard green beans **(Das, 2021).**
According to the method used, for processing the well ripened coffee cherries, the world coffee bean production is classified as natural or dry, semi-washed or pulped natural, and fully washed method i.e., wet processing. Although these methods aim at removing the fruit outer, their principle differ in several steps. These processes begin just after the harvesting of coffee cherries, when these methods are applied to remove the mucilage and to reduce beans' moisture **(Poltronieri and Rossi, 2016; Hameed *et al.*, 2018).**
The dry method, generally used for *Coffea canephora* (Robusta), is technologically simpler than the wet method, which is generally used for *Coffea arabica* **(Gonzalez Rios *et al.*, 2007).** Dry method is the simplest, oldest, and cheapest process. In the dry method, the harvested cherries are first sorted and then sun-dried. Drying operation is the most important stage of this process, since it affects the final quality of green coffee obtained after husking **(Hamdouche *et al.*, 2016).** In general, harvested beans are parched by exposure the sun in open-air clean dry floor or on mats (other term is bed). Cherries are sun-dried with the pulp intact, for up to 3- 4 weeks, producing the so-called "natural" coffees. Coffee cherries should be raked frequently to prevent fermentation or discoloration. Other alternative is drying by air dryers until the moisture content decreased to 10-12% to prevent bacterial and fungal growth **(Das, 2021; Ghosh and Venkatachalapathy, 2014; Casal *et al.*, 2003; Kleinwächter *et al.*, 2016).** Subsequently after the drying followed by the separation of the hull (dried pulp and parchment) by hand using a pestle and mortar or in a mechanical huller **(Ghosh and Venkatachalapathy, 2014; Pittia *et al.*, 2007)**. On the contrary, the most serious problem related to natural (dry) method is dust and dirt blown onto the coffee cherries. Another problem are rainstorms, which can soak the product very quickly and increase the risk of microbiological contamination and problem with moisture (**Das, 2021).** The dried cherry is then hulled to remove the pericarp Dry processing is used often, especially in those areas where the climatic conditions favor drying in the sun **Kleinwächter *et al.*, 2016).**
In semi-dry processing, fruit pulp covering the beans is removed by a pulper, then, the mucilage coating the beans is washed before sun drying.
(Bonilla-Hermosa *et al.*, 2014; de Velasco and Hoyos, 2011; Esquivel and Jiménez, 2012). This method is an intermediate between dry and wet processes. During this method, the cherries are pulped, and the cherries are dried while surrounded by the mucilage, without the fermentation step for mucilage removal. Coffee beans resulting from this method are called pulped natural coffees **(Duarte *et al.*, 2010).**
Finally in the wet method, the outer fleshy material (mesocarp and exocarp) is removed by pulping with a machine or pestle and only a layer of slime remains on the top of the bean **(Ghosh and Venkatachalapathy, 2014).** Wet method requires the use of specific equipment to remove the pulp and substantial quantities of water. Moreover, beans treated by this process present better quality and higher cost when compared to beans processed by the dry method (**Cortés-Macías *et al.*, 2022).** In this process, skin, pulp, and mucilage are removed using water and fermentation **(Poltronieri and Rossi, 2016).** This method involves more stages than the dry process, it also has the largest number of variants (**Gonzalez-Rios, 2007**). However, wet processing exhibits some drawbacks, such as high amount of water usage, which generating excessive contents of organic pollutants, time-demanding, and uncontrolled fermentation on farms resulting in the lack of coffee quality predictability **(Ghosh and Venkatachalapathy, 2014).**
It is well known that post-harvest processing has pronounced effects on the chemical composition of coffee beans, being wet coffee considered to present superior quality because of its higher acidity and outstanding aroma than those obtained by the other methods **(Cortés-Macías *et al.*, 2022).** Choosing a suitable method of green coffee beans processing is one of the first steps that can significantly affect the final product. The final quality of the green coffee beans is

thus dependent on the different agricultural, and farm practices applied, which depend on the coffee plant cultivar, geography, weather conditions, and available infrastructure. Thus, the objective of this study was to evaluate how the processing method affects the selected observed parameters (dry matter, water activity, pH, hardness, color).

MATERIAL AND METHODS

Material

Samples of green *Coffea arabica* were distributed from Barzzuz Ltd. (Banská Bystrica, Slovakia). This company cooperates with coffee plantations, imports and processes coffee. We analyzed samples which originated in America. A total of 12 samples from multiple growing areas and regions were used for our analyses. Samples of green *Coffea arabica* were harvested in the year 2020 and delivered and analyzed in 2021. Samples were processed in the coffee plantage in home country. Samples of *Coffea arabica* were divided to three groups based on processing: natural (dry), pulped natural (semi washed), and wet processing (fully washed). Table 1 contains a detailed list of green samples.

Methodology

Determination of dry matter (DM), water activity (a_w)

To determine the parameter dry matter was used instrument by a moisture analyzer brand KERN DAB 100-3 (KERN & SOHN GmbH, Balingen, Germany). The value of this parameter was expressed in %. The weight of the samples used was 5g. The conditions and settings of the dry matter determination process were as follows. The drying program used a temperature of 110ºC. Next analyzed parameter was water activity. We used the Water Activity Meter Fast-Lab to determine a_w **(Bobková *et al.*, 2022).**

Table 1 List of analyzed samples

Samples	Country	Variety	Processing	Region/Area	Altitude (mamsl)
1A	Honduras	C1, C2, L, B	N	El Paraiso, Santa Barbara, Lempira	1300 - 1800
2A	Brazil	C1, C2, B		Minas Gerais, São Paulo	1000 - 1200
3A	Guatemala	C2, P, B		Mataquescuintla, Jalapa	1400 - 1800
4A	Brazil	B		Cerrado	1000 - 1100
1B	Brazil	B	PN	Minas Gerais	1200 - 1500
2B	Brazil	B		Cerrado	1100 -1300
3B	Brazil	B		São Sebastião da Grama,	1150 - 1350
4B	Costa Rica	C1,C2,P1		León Cortes	1100 - 1600
1C	Costa Rica	C1, C2	W	Tarrazu - La Pastora	1100 -1800
2C	Guatemala	C1,C2, B		Atitlan - San Juan La Laguna, Sololá	1500 - 1700
3C	Mexico	B, C3		Jaltenango Chiapas	1200 - 1600
4C	Nicaragua	C1		Nueva Segovia	1000 - 1300

Note: Samples: A, - natural processing, B – pulped natural processing, C – wet processing; Variety: B – Bourbon, C1 – Caturra, C2 – Catuai, C3-Catimor, L – Lempira, P- Pache San Ramon; N (natural, dry), PN (pulped natural, semi washed), W (wet, fully washed); mamsl - meters above mean sea level

Determination of pH

The pH value was determined using portable pH meter, type Lab 845 SI Analytics, Germany. We performed the measurement in five repetitions for each sample of these parameters **(Bobková *et al.*, 2022).**

Determination of hardness

Parameter texture of green coffee samples was performed by the instrument TA. XT plus Texture Analyzer (Stable Micro Systems, Great Britain). For this analysis was using a Warner-Bratzler knife probe. We analyzed each sample in 10 repetitions. Principe of this analysis was that probe during analysis completely cut the sample, while the accrued maximum arm weight developed was recorded required for complete sample destruction **Pitia *et al.* (2007).**

Determination of color

Measurement color of our samples was conducted by spectrophotometer (Konica Minolta CM-2600d, Osaka, Japan) with the setting Specular Component Included (SCI). For this analysis was used the D65 light source and a 10° observer, with a port of 8 mm. Concrete conditions for this analysis was following: the temperature during calibration of white plate at 23°C. The results were coordinates in the color interface of CIELab, where L* represents lightness, a* represents redness-greenness, and b* represents yellowness-blueness. The obtained results calculated the chroma by the following equation: chroma = square root of ($a^{*2} + b^{*2}$) **(Jurčaga *et al.*, 2021).**

Statistical analysis

Descriptive statistic was used for the clearer summarizing of our results. To evaluate any possible differences within green and roasted coffee, ANOVA Duncan test and REGWQ was used. For the visualization of differences between roasted and green samples, PCA, LDA was used. All statistical analysis were performed using Microsoft Office Excel 365 for Windows (XLSTAT Addinsoft, statistical and data analysis solution, 2021, New York, NY, USA) **(Demianová *et al.*, 2022).**

RESULTS AND DISCUSSION

The specific changes in parameters the DM, a_w, and pH of green coffee beans in consideration of processing are shown in **Table 2**.

Table 2 Average value chemicals parameters of green coffee beans considering groups of processing

	Dry matter (%)	Water activity (a_w)	pH
PN	93.44 ^{b}	0.50 ^{a}	5.83 ^{a}
W	91.10 ^{a}	0.57 ^{b}	5.70 ^{a}
N	92.43 ^{ab}	0.46 ^{a}	5.70 ^{a}
Pr > F(Model)	0.01	0.08	0.11
Significant	Yes	Yes	No

Notes: a,b = groups within a column with different superscripts differ significantly at $p \leq 0.05$, ANOVA Duncan test, N (natural, dry), PN (pulped natural, semi washed), W (wet, fully washed)

Significant differences between individual processing of coffee beans were observed in DM and a_w parameters ($p < 0.05$). However, pH parameter values did not show significant differences between processing groups. Green beans reached an average DM of 92.21%. Our results indicated a relationship between processing and DM values. In pulped natural processing the highest values of DM were obtained, being on average 93.44%. On the other hand, the lowest values of DM were obtained in wet processing. **Bobková *et al.* (2017)** determined DM for green coffee beans origin from America, Asia, and Africa in the range 98.64 – 99.07% these values are higher compared to our results. According to **Pereira *et al.* (2019)** is important that the beans resulting from any type processing method must be dried to a final water content of 10–12%

Average value of water activity was 0.51, regardless the processing method. The value of a_w was highest in wet processing (0.57). **Pittia *et al.* (2007)** determined value of water activity in green coffee beans 0.52 ± 0.01 this is consistent with our findings. Value of a_w is one of the most important factors determining the quality of coffee. **Macías *et al.* (2022)** determined value of a_w natural processing coffee beans different origin 0.61 ± 0.10, wet processing coffee beans 0.63 ± 0.01, pulped natural 0.61 ± 0.02, our results are lower than this value.

Parameter pH is according **Trick *et al.* (2008)** defined such measure of the hydrogen ion concentration in solution and is also referred to as the degree of alkalinity or acidit.

The next analyzed parameter was pH and the average value of this parameter was 5.74. Results by **Kim *et al.* (2007)** represent the value of pH of green beans in range 5.66 – 6.22, this claim is similar with our findings. **Macías *et al.* (2022)** determined value of pH natural processing 5.79 ± 0.04, wet processing 5.79 ± 0.05 and pulped natural coffee beans 5.83 ± 0.05. Out coffee samples were of American origin *Coffea arabica.* For this country **Demianová *et al.* (2022)** determined the measured pH values of coffee beverages prepared using green beans from 5.70 to 5.89 in South American samples, and from 5.73 to 5.78 in Central American green coffee beans these values are in accordance with our results. According to **Cortés-Macías *et al.* (2022)** the values of pH for natural processing were lower than those obtained for the wet and semi-dry samples, this claim agrees with our results. The main reasons for this claim author explain that the dry processing leads to a low pH, probably because to the absorption of acids produced during beans fermentation throughout the drying periods. Reasons contributing to change of pH of the final product is the accumulation of lactic acid and acetic acid generated by lactic acid bacteria. However, in the case of the dry processing, the incidence of yeast, mainly microorganism (*Saccharomyces*, *Candida*, and *Pichia*), lead to the production of specific acids (acetic, propionic, malic and citric) as metabolites, with a subsequent potential metabolites migration into the seed **(Cortés-Macías *et al.*, 2022).**

The roasting conditions also give rise to significant changes in the textural properties of the coffee bean and these changes are dependend on input raw material in this case green coffee beans and the method which was used for processing coffee cherries **(Pittia *et al*., 2001).**

The specific changes in the hardness of green coffee beans in consideration of processing are shown in **Figure 1**. We used ANOVA statistics for the visualization of differences between groups of green samples and processing.

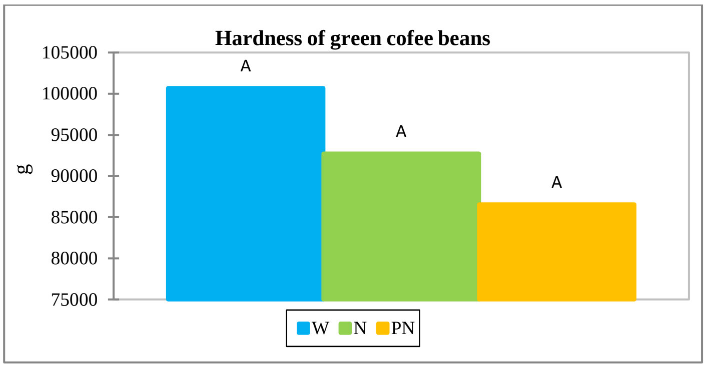

Figure 1 Statistical analysis ANOVA.

Notes: A = groups within a column with different superscripts differ significantly at p≤0.05, ANOVA Duncan test, N (natural, dry), PN (pulped natural, semi washed), W (wet, fully washed)

In a comparison hardness between dry, pulped natural, and wet processing samples were not significantly different (α = 0.05). The data obtained from measurement showed that green beans which were processed using the wet method had the highest value of hardness 100674.90 g. On the contrary pulped natural method showed the lowest values of the hardness of green coffee beans (86549.05 g). The value of hardness of natural processing sample was 92719.33 g. The results of a study of **Pitia *et al.* (2007),** showed that a higher value of water activity in green beans related to an increase in value of hardness. We can confirm this claim, given the highest value of a_w and the highest value of hardness was observed in wet processing. **Pitia *et al.* (2007)** also observed the effect of water content on the ability of the coffee bean to resist mechanical action and found that coffee beans with a higher water content (green) are more resistant to mechanical action than coffee beans with lower water content (roasted). A higher water content allows the coffee beans to absorb a higher level of mechanical strength energy, thus protecting them from breaking. This study defines modification of the cellular characteristics of the raw coffee matrix (porosity, cell size distribution, cell wall thickness) as such factors that could be implied in the different textural behavior of the raw and roasted beans) **Pitia *et al.* (2007).** The effect of post-harvest processing on the hardness parameter has not been studied much, so there are no clear connections.

Of the physical characteristics of green coffee beans, color has significant importance of coffee beans in the consideration of the economy because as discolored beans are associated with lower market prices **(de Oliveira *et al.*, 2016).** In foods, the appearance is a primary criterion in making purchasing decisions **(Wu and Sun, 2013).**

As we can see in Figure 2, the most significant differences between individual groups of processing with regard to color were shown by natural processing, on the other hand, wet and dry processing showed very similar color.

As stated by **Borém *et al.* (2016) and Cortés-Macías *et al.* (2022)** the color of green coffee beans is a strong indication of the occurrence of oxidative processes and natural enzymatic biochemical transformations.

Color of green beans is mainly influenced by origin and variety **(Cortés-Macías *et al.*, 2022).**

The CIE L*a*b*, an international color measurement standard adopted by the Commission Internationale d'Eclairage (CIE, 1986), has been used worldwide to measure food color because it has a uniform distribution and because it is a device independent. CIE method expresses various spectrum of colors, factor L* (D65) represents lightness, a* (D65) redness and b* (D65) yellowness **(Wu and Sun, 2013).** Our results showed that for wet processing is represented lightness, for pulped natural yellowness, and for natural processing redness.

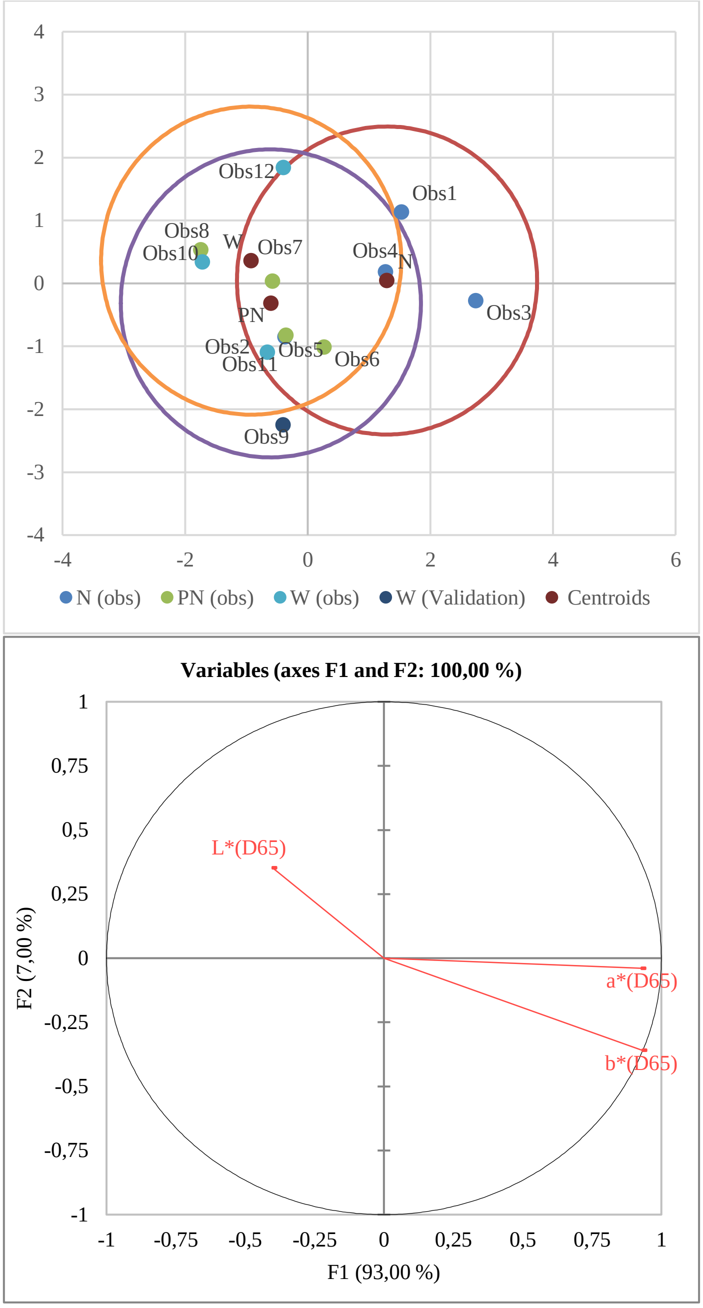

Figure 2 LDA map of color

Notes: N (natural, dry), PN (pulped natural, semi washed), W (wet, fully washed), L* (D65) lightness, a* (D65) redness, b* (D65) yellowness

CONCLUSION

The chemical composition of green coffee beans, as well as chemical changes that occur through postharvest processing, can have a direct impact on the quality and value of the final product. The aim of this review was to examine all types of coffee processing (dry, pulped natural and wet) on selected parameters (dry matter, water activity, pH, hardness and color. The results of the processing to some extent influence the values of the monitored parameters. The highest value of dry matter was indicated in dry processing and the highest value of water activity was in wet processing. Average value of pH was 5.74. The most significant differences between individual groups of processing with regard to color were shown by natural processing, on the other hand, wet and dry processing showed very similar color. Our results showed that for wet processing is represented lightness, for pulped natural yellowness, and for natural processing redness. Values of hardness was in range 86549.05 - 100674.90 (g). The wet method had the highest value of hardness, and on the other hand pulped natural processing had lowest value of harness. During postharvest, several metabolic activities occur, depending on the type of processing carried out. The chemical composition of coffee beans can change due to physical, biochemical, and physiological changes during the postharvest and drying process. Any changes in these compounds result in varying precursors and affect the coffee beverage's ultimate quality after roasting.

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