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Effect of processing methods (washed, honey, natural, anaerobic) of catimor coffee on physical and sensory quality in Alto Inambari, Peru

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ABSTRACT

Coffee cultivation is an important economic activity produced mainly by small producers and is a major exportation product in Peru. Among the coffee varieties grown in the Puno region, the Catimor variety predominates, mainly because of its resistance to yellow rust and productivity. We investigated the effect on the physical and sensory quality of four coffee processing methods (washed, honey, natural, anaerobic) and a control sample. Samples of three kilograms of Catimor coffee cherry were harvested for each benefit method, then the Specialty Coffee Association (SCA) methodology was applied to evaluate the physical and sensory quality, and the results were analyzed with analysis of variance and Tukey's multiple comparison. The results showed that yield, the main attribute of physical quality, grouped the treatments into two different groups: (1) control, 71.17%; washed, 75.83%; and honey, 75.24%; and (2) natural, 44.45%, and anaerobic, 45.70%, from the harvest of the coffee cherry to green coffee, only 13.01% to 15.13% is used for roasting, consumption or transformation. Regarding the sensory quality, of the sensory attributes, only fragrance and body were significantly different, and the total cup score was 82.50 (control), 84.00 (washed), 82.88 (honey), 85.75 (natural) and 87.38 (anaerobic). There is a significant difference between the treatments, despite the lower physical yields of the natural and anaerobic benefits, these benefit methods significantly improve sensory quality and therefore profitability. This study provides a reference for coffee producers on the processing method to generate greater profits, and the organic and volatile components related to the beneficial methods should be studied.

Key words: Anaerobic; coffee farmer; processing method; profitability; wet.

1 INTRODUCTION

Coffee is an important agricultural product in the world (Gutiérrez-Calle et al., 2021) and the most popular beverage in the world after water (Barbin et al., 2014; Mussatto et al., 2011). Peru is the eighth largest producer of coffee worldwide (International Coffee Organization - ICO, 2020). This product is produced in 10 regions of Peru from 600 to 2,200 meters above sea level (m.a.s.l.), with a harvested area of 375,000 ha (Junta Nacional del Café - JNC, 2019). Due to the different altitudes in production, Peru has diverse ecosystems or life zones, therefore, coffees of diverse qualities, and specialty coffees are an opportunity for economic and social improvement for small producers since the price of coffee is related to quality (Márquez et al., 2020; Rosas-Echevarría et al., 2019; Silva et al., 2014). The Catimor variety is resistant to yellow rust and of high productivity (Research World Coffee - RWC, 2020; Julca-Otiniano et al., 2018), which is why it is mostly cultivated in areas of medium and low altitudes, usually from 900 to 1600 m.a.s.l.

Postharvest processes determine the physical and sensory characteristics of the final product, regardless of the processing method, and fermentation has a great influence on the composition of beans and their quality (Velásquez; Banchón, 2022; Guevara-Sánchez et al., 2019; Rodrigues et al., 2020; Cândido et al., 2019). There are different coffee processing or processing methods: dry or natural methods and wet or washed methods (De Oliveira et al., 2018; Hamdouche et al., 2016; Borém et al., 2013). Additionally, the semidry or honey method combines previous methods (Aswathi et al., 2022; Karim; Wijayanti; Sudaryanto, 2019). The anaerobic method is also a recent alternative, in which fermentation is carried out without the presence of oxygen (Mulyara; Rahmadian, 2021). These methods add value to coffee (Nasution; Hasyim; Lubis, 2020).

In recent years, specialty coffees have become more required in the market, and the denomination of specialty coffees is strongly related to their physical and sensory qualities. Table 1 presents the classification of coffees according to the Specialty Coffee Association (SCA), which classifies specialty coffees from 0 to 100 points, resulting from a physical and sensory evaluation.

There is little literature on the influence of processing methods in different coffee varieties on quality, especially in Peru and South America. There are studies comparing washed, natural, and honey methods in China (Chen et al., 2019); in Korea, they studied the washed, natural, and anaerobic methods (Kim et al., 2022); in Colombia, the sensory quality was studied (Cruz-O'byrne; Piraneque-Gambasica; Aguirre-Forero, 2020) with the washed method.

Table 1: Scoring and classification for specialty coffees according to (Specialty Coffee Association - SCA, 2003).

Score	Quality	Classification
90-100	Outstanding	Specialty
85–89,99	Excellent	Specialty
80–84,99	Very good	Specialty
< 80	Below specialty quality	Not specialty

To generate greater alternatives for coffee producers, applying nontraditional processing methods, this research aims to evaluate the effect of four methods of processing coffee (Coffea arabica L.) variety Catimor de Alto Inambari on physical and sensory quality.

2 MATERIAL AND METHODS

2.1 Study area

The study was conducted at the Cari farm, Chillcayoc Sector, Pampayamayo Village Center, Alto Inambari district, Puno region (Peru; Latitude: -13.993249, Longitude: -69.237123; between 1200 and 1330 m.a.s.l.). The temperature during the study period was between 15.1 and 27 °C, and the relative humidity was between 47 and 78% (day and night), according to Folmer (2017) the climatic cluster is constant. These parameters were obtained with a data logger (TempU03, TZONE, Taiwan) from July to September 2022 (end of harvest season).

2.2 Biological material

Mature coffee fruits (selective harvest) of the Catimor variety were harvested, and a control sample of the same variety was also harvested (as is usually done in the study area, without selective harvest). The plantations were cultivated for 6 years under the agroforestry system. Then, the float test was performed, removing immature fruits and debris. Three kilograms were washed and selected for each experimental unit to carry out coffee processing. The fruits were between 13 and 18 °Brix, measured with an optical refractometer (M80, ATC, China), and the color was measured with a colorimeter (Basic, VINCKOLOR, China). In the CIELab measurement system, three repetitions were made by measuring 30 cherry coffee fruits harvested with selective harvesting, similar to the methodology used by Buitrago-Osorio et al. (2022) and Rincon-Jimenez et al. (2021). The average values for L, a, and b were 28.95 ± 5.12, 11.22 ± 3.33 and 7.04 ± 4.40, respectively.

2.3 Coffee processing

Four coffee processing methods were applied: washed, honey, natural and anaerobic, applying methodologies by Karim, Wijayanti and Sudaryanto (2019), Alomia and Untiveros (2021), and Mulyara and Rahmadian (2021). For each method, three replicates were performed. Figure 1 shows the methodology used for coffee processing.

The washed processing method was also used for the control sample (traditional method) and T1, the fermentation time was 15 hours, and drying was carried out for 10 days. The honey process - T2 (yellow honey) was carried out by drying the samples after pulping, and the drying time was 15 days.

The natural method - T3 was carried out by drying the samples after conditioning, and the drying time was 23 days. The anaerobic method - T4 was carried out by fermenting the sample in a Grain Pro bag without presence of air, inside a hermetically sealed 15-liter container, the drying time was 23 days.

In all the processing methods, fermentation was also carried out under ambient conditions and drying was carried out until the recommended moisture content of 10 to 12% (dry) was reached (Anokye-Bempah et al., 2022).

Drying was carried out in a solar dryer with wooden pallets, mesh and windows as ventilation system, under natural conditions, at temperatures between 15 and 40 °C and a relative humidity of 29 to 91%. Storage was carried out under shade in Ziplock bags at ambient conditions of 12 to 18 °C and 39.8 to 58% relative humidity. These parameters were obtained with a data logger (TempU03, TZONE, Taiwan).

2.4 Physical and sensory quality

SCA methodology was used for coffee quality, samples were evaluated separately according to process method, for the physical analysis (the grading green coffee protocol), the following parameters were considered: moisture (NTP ISO 11294:2001), granulometry and yield, mass balance was calculated according with methodology used by Karim, Wijayanti and Sudaryanto (2019). Figure 2 summarizes the methodology used in the research. The sensory quality analysis was performed in the quality control laboratories of the Central de Cooperativas Agrarias Cafetaleras de los Valles de Sandia CECOVASA LTDA (accredited as SCA Premier Training Campuses) and of the coffee trading company CANDELARIA. The analyses were carried out by two professional tasters with international certification Q Arabica Grader granted by the Coffee Quality Institute (CQI), using the methodology SCA (2003) used as an international standard that considers 10 attributes (fragrance, flavor, residual flavor, acidity, body, balance, uniformity, clean cup, sweetness, taster's score), and the total score.

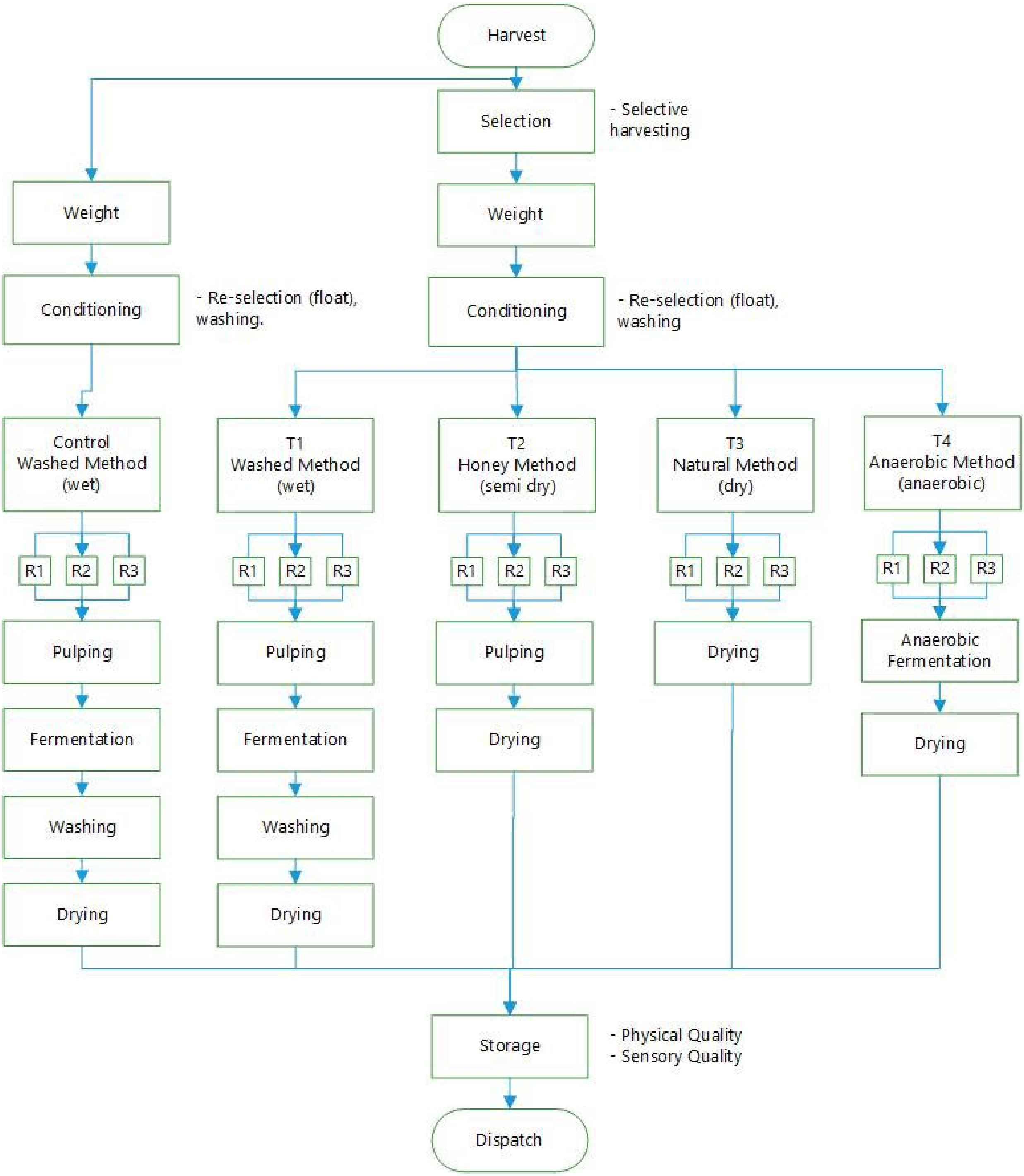

Figure 1: Methodology applied for the processing of Catimor coffee.

Profitability

To determine the profitability of the coffee processing methods, profitability was determined according to the prices per quintile of parchment coffee (coffee season 2021-2022), which the central cooperative CECOVASA LTDA pays to the coffee producer. This organization has been operating since 1970 and is the main exporter of coffee in the study region.

2.5 Statistical design and data analysis

A completely randomized experimental design (CRD) with four treatments and three replications was used, using analysis of variance (ANOVA). For the comparison of treatments, Tukey's multiple comparison methodology was used with a significance level Pr≤ 0.05, and the data were analyzed with R 4.2.2.2 software and RStudio Desktop 2022.12.0.

3 RESULTS

3.1 Physical quality

Moisture values are within the range of 10 to 12% recommended for optimum storage (Anokye-Bempah et al., 2022; ITC, 2022; SCA, 2003). Table 2 details the physical attributes of Catimor variety coffee subjected to four processing methods.

The yield of the treatments (Figure 3) shows a significant difference ($p<0.05$) according to Tukey's test, grouping into two groups with similar yields, but different between groups: processing method (control, washed, honey) and (natural and anaerobic), this is attributable to the similarity of processes of each group, given that in the natural and anaerobic processing methods drying and storage is performed with the whole coffee fruit without the removal of the husk and mucilage, unlike the washed and honey methods.

The mass balance of the main coffee processing processes (Table 3) shows that from harvest (coffee cherry), only 13.01% to 15.13% is used for roasting and consumption, and the difference is waste that is discarded in each process.

3.2 Sensory quality

The results of the sensory quality are presented in Table 4, which indicate that there is a significant difference between the processing methods ($p<0.05$). The sensory quality attributes fragrance and body are different for each treatment, affirming that the processing method influences the organoleptic attributes proposed by Várady et al. (2022) and Worku et al. (2018). The attributes (flavor, residual flavor, acidity, balance, uniformity, clean cup, sweetness and taster score) do not present significant differences, which is attributed to the fact that the treatments were performed on a single coffee variety.

The total score of sensory quality attributes, description and classification are presented in Table 5. The treatments presented significant differences ($p<0.05$), and the statistical test grouped the processing methods into three groups: (1)

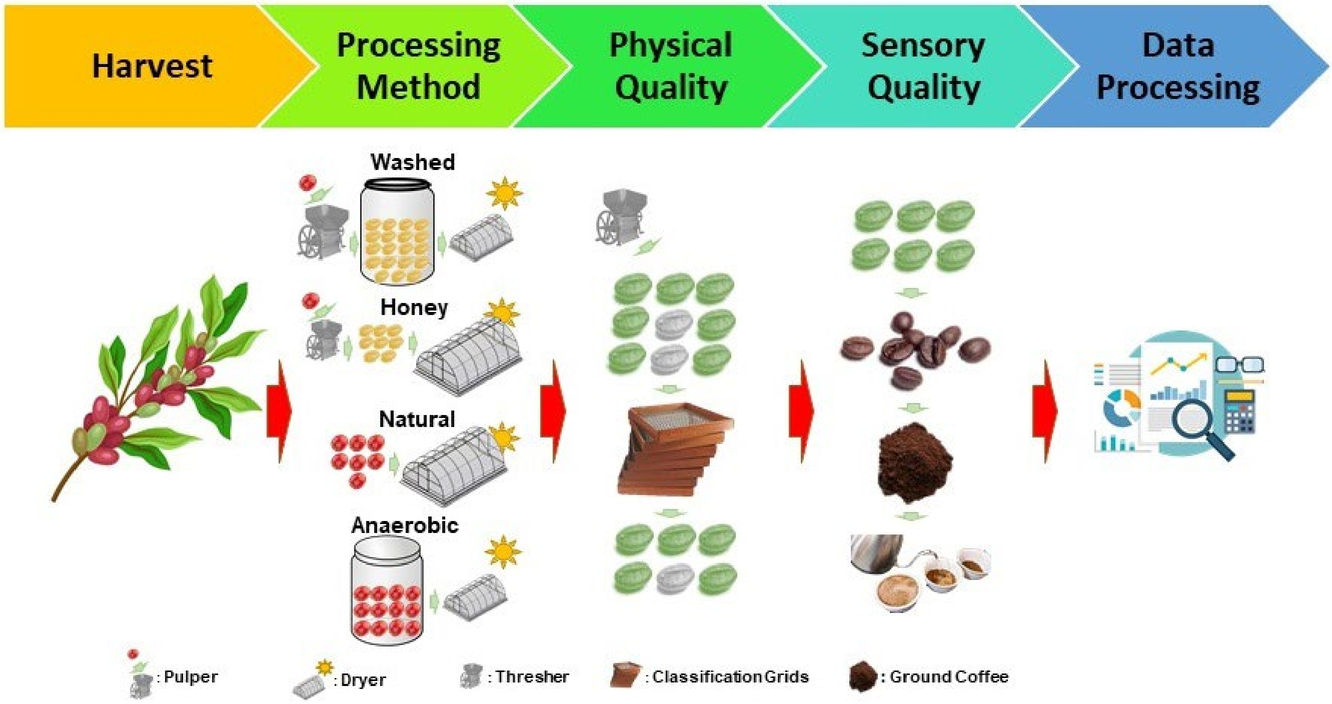

Figure 2: Summary of research methodology.

Table 2: Physical quality of Catimor coffee subjected to four processing methods.

	Processing Method				
	Control* (wet)	Washed (wet)	Honey (semidry)	Natural (dry)	Anaerobic
Moisture	10.00%	10.50%	10.80%	11.00%	11.40%
Grain size (N° grid)	14 (9%). 15 (91%)	14 (3%). 15 (97%)	14 (5%), 15 (95%)	14 (4%). 15 (96%)	14 (3%). 15 (97%)

* Without selective harvesting

control, washed, and honey; (2) washed, honey, and natural; and (3) natural and anaerobic.

3.3 Profitability

Profitability for coffee producers is related to quality (Silva et al., 2014). In the production zone, sensory quality is prioritized, unlike other regions where physical quality is also taken into account. This is why it would be worthwhile to carry out coffee processing with anaerobic and natural methods, since according to the collection prices, the producer would obtain per quintal of parchment coffee of 46 kilograms the following income per processing method as a minimum: S/600 (control), S/750 (washed), S/600 (honey), S/850 (natural), and S/950 (anaerobic), the last treatment being the most profitable, followed by the natural beneficiation method.

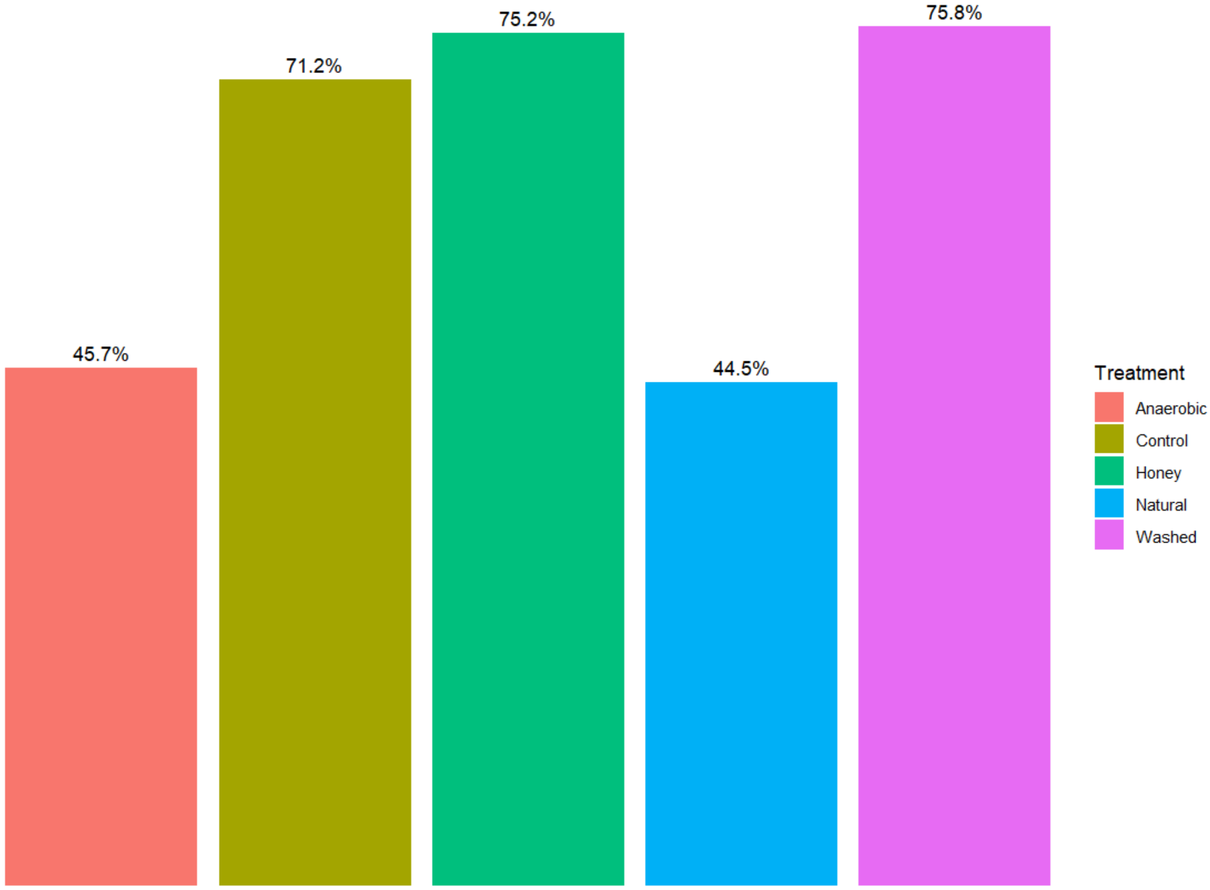

Figure 3: Performance of processing methods for Catimor coffee.

Table 3: Mass balance by processing method for Catimor coffee.

	Processing Method				
	Control* (wet)	Washed (wet)	Honey (semidry)	Natural (dry)	Anaerobic
Harvesting	100.00%	100%	100.00%	100.00%	100%
Conditioning	85.94%	89.29%	89.33%	89.52%	89.52%
Pulping	42.41%	44.64%	47.23%	-	-
Demucilaging	39.73%	40.85%	-	-	-
Drying	18.28%	18.48%	19.86%	34.04%	32.88%
Hulling and grading	13.01%	14.02%	14.95%	15.13%	15.03%
Bagging	13.01%	14.02%	14.95%	15.13%	15.03%

* Without selective harvesting

Table 4: Sensory quality attributes for Catimor coffee by processing method.

	Processing Method				
	Control* (wet)	Washed (wet)	Honey (semidry)	Natural (dry)	Anaerobic
Aroma	7.63	7.88	7.75	8.25	8.50
Flavor	7.50	7.88	7.63	8.13	8.38
Aftertaste	7.38	7.50	7.38	7.75	8.25
Acidity	7.38	7.75	7.63	7.88	8.25
Body	7.50	7.63	7.50	7.88	8.00
Balance	7.63	7.63	7.50	8.13	8.00
Uniformity	10.00	10.00	10.00	10.00	10.00
Clean Cup	10.00	10.00	10.00	10.00	10.00
Sweetness	10.00	10.00	10.00	10.00	10.00
Overall	7.50	7.75	7.50	7.75	8.00

* Without selective harvesting

Table 5: Total score, classification and description of Catimor coffee by processing method.

Processing Method	Score	Quality - Classification	Description
Control* (wet)	82.50	Very Good - Specialty	Chocolate, barley, panela, green banana, astringent rough finish, medium citric acidity, juicy body
Washed (wet)	84.00	Very Good - Specialty	Sweet chocolate, chamomile, molasses, caramel, short smooth finish, medium citrus acidity, smooth juicy body
Honey (semidry)	82.88	Very Good - Specialty	Caramel, honey, chocolate, cereal, dried cane, mild citric acidity, smooth body
Natural (dry)	85.75	Excellent - Specialty	Red wine, grape, malt, short sweet finish, apple caramel, cognac, medium citric acidity, creamy and long lasting body
Anaerobic	87.38	Excellent - Specialty	Pineapple, apricot, pomegranate, red apple, sweet wine, caramel, butter, black raisins, blackberries, capulin, acetic and phosphoric acidity, effervescent, creamy and long-lasting body

* Without selective harvesting

4 DISCUSSION

4.1 Physical quality

Regarding granulometry, the bean size for all treatments meets the export criteria that coincide with the values of Guevara-Sánchez et al. (2019) and ITC (2022), which indicate that exportable coffee beans are larger than the size of mesh No. 14-5. 60 mm in diameter (INACAL, 2021), attributable to selective harvesting, the results of the control sample present a lower percentage of exportable beans, possibly because this was harvested without selective harvesting, and overripe, ripe, semiripe, and green beans were processed, coinciding with research that concludes that the stages of maturity influence physical properties (Buitrago-Osorio et al., 2022; Rincon-Jimenez et al., 2021).

The yield values of the washed beneficiation method coincide with the results of research conducted in the study area (Quispe, 2020; Ramos et al., 2019), and they also resemble values reported by Alomia and Untiveros (2021) in Satipo (80.83%) and Julca-Otiniano et al. (2018) in Chachamayo (73. 62%), the yields of the honey and natural processing methods coincide with the results of Alomia and Untiveros (2021), 75.19% and 47.33%, respectively, because the yields of the anaerobic and natural methods are similar since the coffee cherry remains intact until the moment of processing to obtain green coffee, where husk, mucilage and parchment are discarded. The mass balance shows that on average, only 14.43% of the harvested coffee is roasted, 85.57% are residues (husk, mucilage, grain husk, defects, among others), and the results are similar to the results reported by Karim, Wijayanti and Sudaryanto (2019), but there are differences because they conducted the study with robusta coffee.

4.2 Sensory quality

The effect of the washed processing method improves sensory quality to a greater extent than the honey method in the Catimor variety by generating higher values of flavor and taster appreciation. The sensory quality attributes of greater value were obtained with the anaerobic and natural processing methods. Since the processing, drying and storage in both methods are carried out with the coffee cherry intact, there is migration of simple and complex molecules to the coffee bean, which would be attributed to the improvement of the sensory quality, confirming that there are differences between processing methods (Várady et al., 2022; Tassew et al., 2021; Alomia; Untiveros, 2021).

The similarity between processes (1) washed and honey and (2) natural and anaerobic is attributable to the similarity of processes and total score between groups, coinciding with that proposed by Rodriguez, Guzman and Hernandez (2020), which indicates that there is no chemical or sensory difference between the washed and honey methods. The natural beneficiation method in comparison with the washed and honey method presents higher values, coinciding with the results of Dharmaputra et al. (2021) and Tassew et al. (2022). The significant increase in the total score of the anaerobic and natural methods is attributed to the metabolites that generate complex sensory descriptors, resulting from the presence of microorganisms (mainly bacteria and yeasts) during the fermentation process and migration of molecules during fermentation and drying.

In the control processing method (traditional in the production zone), barley, green banana and astringency descriptors were found, which diminish its sensory quality (Paredes-Espinosa et al., 2022). This is attributed to the fact that the harvest is carried out without selective harvesting, processing unripe and pinto fruits that generate these descriptors.

The anaerobic processing method presents higher scores, highlighting fruity descriptors, dried fruits, red fruits, acetic acidity, phosphoric acidity, and effervescence, coinciding with the values obtained by Jimenez et al. (2023), presenting greater complexity (Figure 4), being classified according to the international SCA standard as a specialty coffee of excellent quality, as is the case with the natural processing method.

The results indicate that there are significant differences between the coffee processing methods and the control sample. The washed and honey methods have better physical quality than the natural and anaerobic methods but contrast in sensory quality where the last abovementioned methods present higher values than the washed and honey methods. These differences are mainly attributed to the selective harvesting, the processes of each processing method, especially fermentation and drying, the migration of simple and complex chemical substances to the coffee bean, and the metabolites resulting from the metabolic activity of the microorganisms present during these processes. Finally, the anaerobic method presents the highest sensory values due to the complexity of sensory attributes that it generates, attributed to metabolites generated by microorganisms that develop in the absence of oxygen in the fermentation process.

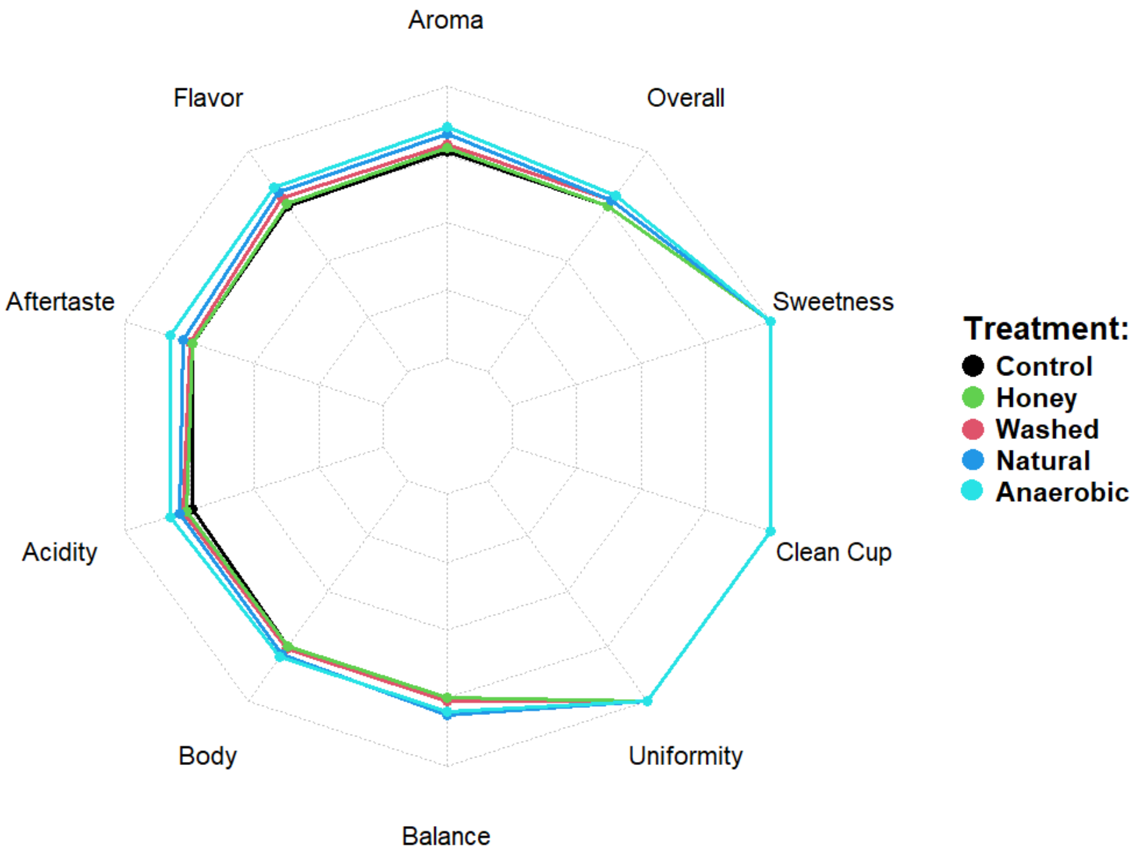

Figure 4: Sensory diagram of Catimor coffee by processing method.

5 CONCLUSION

There is a significant difference between the following processing methods: washed, honey, natural and anaerobic in physical and sensory quality. The washed and honey methods present similar physical quality but are superior to the natural and anaerobic processing methods. The washed, natural and anaerobic processing methods improve the sensory quality of Catimor variety coffee, and the honey processing method is not recommended for the processing of Catimor variety coffee. Despite the lower physical yields of the natural and anaerobic methods, it is recommended to use these processing methods because of the significant increase in sensory quality, therefore, they are more profitable. This increase is attributed to selective harvesting, the presence and interaction of molecules and metabolites during the fermentation and drying processes, and the types of microorganisms present. The anaerobic processing method is attributed to the greater complexity of sensory quality with respect to other methods due to the development of microorganisms in the absence of oxygen during the fermentation process, constituting together with the natural processing method an alternative for coffee growers to generate greater income and make coffee cultivation more profitable. There are also processing methods such as red honey, black honey, lactic fermentation, malic fermentation, and carbonic fermentation that could improve the physical and sensory quality of coffee, and the related organic and volatile components should also be studied.

AUTHORS' CONTRIBUTION

RNVA wrote the manuscript and performed the experiment, GILM supervised the experiment and co-work the manuscript, and GILM review and approved the final version of the work, RNVA conducted all statistical analyses.

REFERENCES

ALOMIA, J. M.; UNTIVEROS, C. M. Beneficios con lavado, honey y natural de granos de *Coffea arábica* L. variedad catimor en la calidad física y organoléptica, Satipo - Perú. **Revista Investigación Agraria**, 3(2):27-42, 2021.

ANOKYE-BEMPAH, L. et al. The use of desiccants for proper moisture preservation in green coffee during storage and transportation. **Journal of Agriculture and Food Research**, 11:100478, 2022.

ASWATHI, K. N. et al. Metagenomics and metabolomic profiles of *Coffea canephora* processed by honey/pulped natural technique. **Innovative Food Science & Emerging Technologies**, 79:103058, 2022.

BARBIN, D. F. et al. Application of infrared spectral techniques on quality and compositional attributes of coffee: An overview. **Food Research International**, 61(1):23-32, 2014.

BORÉM, F. M. et al. Microscopia electrónica de verredura de graos de café submetidos a diferentes formas de processamento e secagem. **Coffee Science**, 8(2):218-225, 2013.

BUITRAGO-OSORIO, J. et al. Physical-mechanical characterization of coffee fruits *Coffea arabica* L. var. Castillo classified by a colorimetry approach. **Materialia**, 21:101330, 2022.

CÂNDIDO, T. A. et al. Effect of induced biological fermentations on coffee sensory quality. **Coffee Science**, 14(4):473-476, 2019.

CHEN, Y. L. et al. Influence of different primary process on the quality of arabica coffee in yunnan province. **Modern Food Science and Technology**, 35(2):146-156, 2019.

CRUZ-O'BYRNE, R.; PIRANEQUE-GAMBASICA, N.; AGUIRRE-FORERO, S. Physicochemical, microbiological, and sensory analysis of fermented coffee from Sierra Nevada of Santa Marta, Colombia. **Coffee Science**, 15:e151797, 2020.

DE OLIVEIRA, P. D. et al. Quality of natural and pulped coffee as a function of temperature changes during mechanical drying. **Coffee Science**, 13(4):415-425, 2018.

DHARMAPUTRA, O. S. et al. Assessment of the quality of arabica coffee beans from three processing methods and two types of packaging materials. **Biotropia**, 28(3):193-203, 2021.

FOLMER, B. **The craft and science of coffee**. London, Elsevier, 2017. 22p.

GUEVARA-SÁNCHEZ, M. et al. Efecto de la altitud en la calidad del café (*Coffea arabica* L.): Comparación entre secado mecánico y tradicional. **Scientia Agropecuaria**, 10(4):505-510, 2019.

GUTIÉRREZ-CALLE, S. A. et al. Capillary electrophoresis as a tool for genotyping SH3 mediated coffee leaf rust resistance. **Scientia Agropecuaria**, 12(1):91-99, 2021.

HAMDOUCHE, Y. et al. Discrimination of post-harvest coffee processing methods by microbial ecology analyses. **Food Control**, 65:112-120, 2016.

INACAL. Guía de Implementación de la Norma Técnica Peruana 209.027:2018. **Instituto Nacional de Calidad**, 2021. Available in: https://www.gob.pe/institucion/

inacal/informes-publicaciones/2187944-gip-101-guia-de-implementacion-de-la-norma-tecnica-peruana-ntp-209-027-2018-cafe-cafe-verde-requisitos. Access in: May 24, 2023.

INTERNATIONAL COFFEE ORGANIZATION - ICO. **Historical data on the global coffee trade 2020 data base**. 2020. Available in: http://www.ico.org/new_historical.asp. Access in: May 23, 2023.

ITC. **La Guía del Café Cuarta Edición**. Ginebra, Centro de Comercio Internacional, 2022. 12p. Available in: https://intracen.org/es/recursos/publicaciones/la-guia-del-cafe-cuarta-edicion. Access in: May 24, 2023.

JIMENEZ, E. J. M. et al. Influence of anaerobic fermentation and yeast inoculation on the viability, chemical composition, and quality of coffee. **Food Bioscience**, 51:102218, 2023.

JUNTA NACIONAL DEL CAFÉ - JNC. **El cafetalero**: La caficultura peruana está en riesgo por bajos precios y altos costos de producción. Lima, Junta Nacional del Café, p. 10-12, 2019.

JULCA-OTINIANO, A. et al. Behavior of three cultivars of coffee (Catimor, Colombia and Costa Rica 95) in the valley of el Perené, Junín, Perú. **Chilean Journal of Agricultural and Animal Sciences**, 34(3):205-215, 2018.

KARIM, M. A.; WIJAYANTI, F.; SUDARYANTO, A. Comparative studies of coffee processing methods for decision making in appropriate technology implementation. **AIP Conference Proceedings**, 2114(1):020015, 2019.

KIM, C. et al. Interactive effect of post-harvest processing method, roasting degree, and brewing method on coffee metabolite profiles. **Food Chemistry**, 397:133749, 2022.

MÁRQUEZ, F. et al. Relación entre las características del suelo y altitud con la calidad sensorial de café cultivado bajo sistemas agroforestales en Cusco, Perú. **Scientia Agropecuaria**, 11(4):529-536, 2020.

MULYARA, B.; RAHMADIAN, Y. Non-volatile compounds of unwashed Gayo Arabica coffee (Coffea arabica) with anaerobic fermentation process. **IOP Conference Series: Earth and Environmental Science**, 828:012022, 2021.

MUSSATTO, S. et al. Production, composition, and application of coffee and its industrial residues. **Food Bioprocess Technology**, 4(5):661-672, 2011.

NASUTION, W. I.; HASYIM, H.; LUBIS, S. N. Analysis of value added of Arabica Coffee in central aceh regency (case of Indi Gayo Coffee business unit). **IOP Conference Series: Earth and Environmental Science**, 454:012006, 2020.

PAREDES-ESPINOSA, R. et al. **Cosecha y benefcio húmedo para cafés especiales**. Lima-Perú: Instituto Nacional de Innovación Agraria - INIA, 2022. 40p.

QUISPE, M. Estudio de calidad física y calidad de taza de café (Coffea arabica L.) de dos zonas de cultivo de la provincia de Sandia cosecha 2019. **Revista Científica I+D Aswan Science**, 1(1):1-7, 2020.

RAMOS, E.; LIMA-MEDINA, I.; CORNEJO-CONDORI, G. Comparativo de calidad organoléptica de café (Coffea arabica L.) en Puno - Perú y La Paz – Bolivia. **Revista de Investigaciones Altoandinas**, 21(4):283-292, 2019.

RESEARCH WORLD COFFEE - RWC. **Variety catalog**. Variety Catimor, 2020. Available in: https://varieties.worldcoffeeresearch.org/varieties/catimor-129. Access in: May 24, 2023.

RINCON-JIMENEZ, A. et al. Ripeness stage characterization of coffee fruits (*Coffea arabica* L. var. Castillo) applying chromaticity maps obtained from digital images. **Materials Today**, 44(1):1271-1278, 2021.

RODRIGUES, S. D. et al. Sensory Q-Grader evaluation of fermented arabica coffees by yeast (*Saccharomyces cerevisiae*) and lactic bacteria (*pediococcus acidilactici*) cultures. **Coffee Science**, 15:e151690, 2020.

RODRIGUEZ, Y. F. B.; GUZMAN, N. G.; HERNANDEZ, J. G. Effect of the postharvest processing method on the biochemical composition and sensory analysis of arabica coffee. **Engenharia Agrícola**, 40(2):177-183, 2020.

ROSAS-ECHEVARRÍA, C. W.; SOLÍS-BONIFACIO, H.; CERNA-CUEVA, A. F. Sistema eficiente y de bajo costo para la selección de granos de café: Una aplicación de la visión artificial. **Scientia Agropecuaria**, 10(3):347-351, 2019.

SILVA, S. A. et al. Coffee quality and its relationship with Brix degree and colorimetric information of coffee cherries. **Precision Agriculture**, 15(5):543-554, 2014.

SPECIALTY COFFEE ASSOCIATION - SCA. **Protocols & best practices**. 2003. Specialty Coffee Association Available in: https://sca.coffee/research/protocols-best-practices. Access in: May 23, 2023.

TASSEW, A. A. et al. Influence of location, elevation gradients, processing methods, and soil quality on the physical and cup quality of coffee in the Kafa Biosphere Reserve of SW Ethiopia. **Heliyon**, 7(8):e07790, 2021.

TASSEW, A. A. et al. Location, production systems, and processing method effects on qualities of kafa biosphere reserve coffees. **Agrosystems, Geosciences and Environment**, 5(2):1-10, 2022.

VÁRADY, M. et al. Effect of method of processing specialty coffee beans (natural, washed, honey, fermentation, maceration) on bioactive and volatile compounds. **LWT**, 172:114245, 2022.

VELÁSQUEZ, S.; BANCHÓN, C. Influence of pre-and post-harvest factors on the organoleptic and physicochemical quality of coffee: a short review. **Journal of Food Science and Technology**, 60(1):1-13, 2022.

WORKU, M. et al. Effect of altitude on biochemical composition and quality of green arabica coffee beans can be affected by shade and postharvest processing method. **Food Research International**, 105(1):278-285, 2018.