

Potencial funcional de la infusión de pulpa de café de cinco variedades: evaluación comparativa de la actividad antioxidante

Functional Potential of Coffee Pulp Infusion from Five Varieties: Comparative Evaluation of Antioxidant Activity

Flor Anita Palacios Adriano^{1*}, Patricia Elizabeth Torres Plasencia²

^{1*}National University of Trujillo. Faculty of Biological Sciences. fpalaciosad@unitru.edu.pe,

²National University of Trujillo. Faculty of Biological Sciences. ptorres@unitru.edu.pe,

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ABSTRACT

Coffee pulp, a by-product of the coffee agroindustry, represents a potential source of bioactive compounds with functional properties. The aim of this study was to characterize phytochemically and identify the antioxidant activity of infusions prepared with pulp from five coffee varieties (*Coffea arabica*): caturra, geisha, bourbon, catimor and marsellesa. Two kilograms of ripe fruits from each variety were processed, the pulp was extracted and dehydrated, and infusions were prepared under standardized conditions. Qualitative assays were conducted to identify secondary metabolites, and antioxidant capacity was determined using the free radical DPPH scavenging method, expressed as Trolox equivalents. Statistical analyses were performed through analysis of variance and Tukey test. Results showed the presence of flavonoids, tannins, alkaloids and reducing sugars in all varieties, while saponins were absent. The geisha variety presented the highest antioxidant activity (0.7202 ± 0.0028 mg Trolox equivalents/g infusion), significantly higher than the other varieties ($p < 0.05$), whereas the marsellesa variety showed the lowest antioxidant capacity. It was concluded that coffee pulp, particularly the geisha variety, constitutes a natural source of antioxidant compounds with potential applications in the food and pharmaceutical industries, adding value to an agricultural by-product and promoting sustainable practices.

Keywords: Agroindustry, Bioactivity, Herbal infusions, Secondary metabolites, Sustainability.



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Introduction

Coffee is one of the world's most traded crops and represents a key source of income for more than 50 countries, mainly in Latin America, Africa and Asia. More than 25 million people depend on this activity to survive, promoting jobs throughout the productive circuit, from the countryside to retail trade. Besides economic significance, it is a cultural icon in Colombia, Peru, Ethiopia and Brazil, where it is deeply connected with their national identity, family life and practises of the communities, and is a significant part of their history and tradition (García-Zavaleta et al., 2025).

Coffee is a critical economic activity of small farmers in Peru particularly in Cajamarca, Amazonas, San Martín and Cusco departments. This product creates jobs in the rural areas, develops the local economies and leads to a high level of agricultural exports in the country. In addition, Peruvian coffee is internationally acclaimed for its quality and flavors. Its production is linked to

sustainable practices and family traditions (Morales et al., 2022).

During the wet milling of coffee, there is a noticeable presence of pulp, which is equivalent to 40 or 50% of the weight of the fruit. This pulp is a perishable organic waste due to its moisture content, sugars and phenolic compounds. Currently, its potential to be transformed into fertilizers, biogas or functional foods, helps to contribute to the circular economy and agro-industrial sustainability (Serna-Jiménez et al., 2022).

Poor handling of coffee pulp is a big environmental issue in the areas where it is produced. Through direct dislocation into water or soil without prior treatment, this biomass having high organic matter produces a high biological oxygen demand (BOD), resulting in eutrophication and reduction in the oxygen supply to aquatic organisms (Ruiz-Nájera et al., 2021). Moreover, its fermentation emits gases like methane (CH₄) and nitrogen oxides (NO_x), which have an impact on climate change (Villa et al., 2024). Damage to the soil, the

increase in the number of insect vectors and changes in the local ecosystem have also been reported (Irawan et al., 2024).

Coffee pulp includes numerous bioactive substances including polyphenols, flavonoid, and phenolic acid that possess antioxidant and health-promoting effects (Febrianto and Zhu, 2023). The compounds could be used to create useful products in the food, pharmaceutical and cosmetic sectors thereby facilitating a circular and sustainable economy (Urugo et al., 2024).

Rohaya et al., (2023) tested the antioxidant activity and the physicochemical composition of the coffee pulp of three varieties (Arabica, Robusta, and Liberica) which were cultivated in Aceh, Indonesia. The DPPH method was applied, and the IC₅₀ of the different varieties was determined to be between 33.95 and 44.94 ppm, and this represents a very high antioxidant property, as well. They also determined parameters like pH, moisture, total phenols and crude fibre showing the differences among the varieties. The research is useful in the valorisation of the pulp as a source of functional compounds. Nevertheless, their weakness was not to utilise the infusion technique (solid-liquid extraction) or to make comparisons under homogeneous conditions of experiment.

Woraprayote et al., (2023) they compared the chemical make-up and antioxidant properties of two coffee pulp-based ingredients, a flour (CPF) and an aqueous extract (CPE). Their high fibre content and antioxidant properties measured as gallic acid and 4-caffeoylquinic acid were found to be high and proved that these items could be used as functional ingredients. The research was however limited to a single coffee type and did not compare coffee types with each other, and also as a procedure of infusion was not compared with the extraction procedure, thus limiting its extrapolation in regard to varietal diversity and experimental settings.

Hu et al., (2025) They studied extraction of antioxidant-rich fractions of coffee pulp by using ethanol-modified supercritical carbon dioxide. The recovery of caffeine and phenolic acids like chlorogenic and protocatechuic were increased with the use of this solvent. An efficiency on the process was noted to be significantly better at high levels of ethanol. The extracts that were obtained were very active in free radicals. The study encourages utilisation of coffee waste as a useful source but did not consider the other varieties and methods.

Thus, in the context described, there is still a deficit of knowledge in the scientific literature on comparative studies that evaluate the antioxidant potential of infusions made from the coffee pulp of different varieties. This lack limits the optimal use of this by-product in the functional food and healthy beverage industry, where its application could represent a sustainable alternative with high added value. Therefore, the purpose of the study is to comparatively evaluate the antioxidant activity of infusions made from the pulp of five coffee varieties, in order to determine their functional potential.

This study acquires transcendence in the scientific field, since it provides comparative information that allows identifying which coffee varieties have greater

antioxidant activity, being essential for future applications. It is also of environmental importance by proposing the revaluation of agricultural waste such as coffee pulp to contribute to the reduction of the environmental impact associated with its inadequate disposal. From a socioeconomic perspective, the diversification of coffee products can generate income opportunities for producers, especially in coffee-growing regions where coffee is a main economic source.

Materials and methods

Material

2 kg of fruits in physiological maturity of each of the coffee varieties (*Coffea arabica*) were used: caturra, geisha, bourbon, catimor and marseillaise. The samples were obtained in the district of Tabaconas, province of San Ignacio, department of Cajamarca (Peru). The raw material was collected directly from a certified producer, guaranteeing the traceability and identification of the varieties.

Harvesting and processing of coffee pulp

The fruits were disinfected with 50% sodium hypochlorite and subjected to an extrusion process to separate the pulp from the almond. Subsequently, the mucilage was removed by washing with drinking water and left to drain at room temperature for an hour. The pulp was dehydrated in an oven at 60 °C for 90 minutes, until it reached 11% humidity.

The dried pulp was ground and sieved (≤ 2 mm), the moisture content was verified by automatic equipment (Santorius, range 40–160 °C), and finally packed in trilaminated bags for the preparation of the filters.

Preparation of infusions

The coffee pulp flour of each variety was packaged in filter bags, making three replicates per variety, obtaining a total of 15 experimental units. Each filter was infused in 50 mL of distilled water at 85 °C for 7 minutes.

Qualitative phytochemical analysis

Assays were performed to identify secondary metabolites:

- Flavonoids and flavones: Shinoda assay.
- Tannins: test with ferric chloride.
- Saponins: foam test.
- Alkaloids: Dragendorff and Wagner trials.
- Reducing sugars: Fehling test.

Determination of antioxidant activity

Antioxidant capacity was determined by the DPPH free radical scavenging method.

- A DPPH solution (1.95 mg in 50 mL of absolute ethanol) was prepared.
- A calibration curve was developed with Trolox at concentrations from 0.025 to 1.000 mg/mL.
- In microplates, 10 μ L of sample + 300 μ L of DPPH were added, incubated in darkness at 28 °C for 15 minutes.
- Absorbance was recorded at 517 nm in the SHIMADZU spectrophotometer.

- Antioxidant activity was expressed in mg Trolox equivalents/g infusion.

Statistical processing and analysis

The data obtained were processed in the SPSS version 25.0 software. Means and standard deviations were calculated. To evaluate significant differences in antioxidant activity between varieties, a one-factor analysis of variance (ANOVA) was applied, followed by Tukey's post hoc test with a significance level of $p < 0.05$.

Results

Table 1 Phytochemical compounds identified in coffee pulp infusions from five varieties using qualitative testing

Nº	Sample	Flavonoids	Tannins	Saponins	Alkaloids (Wagner)	Alkaloids (Dragendorff)	Reducing sugars
1	Bourbon (1)	(++)	(+)	(-)	(+++)	(+++)	(++)
2	Catimor (2)	(++)	(++)	(-)	(+)	(++)	(+)
3	Caturra (3)	(++)	(++)	(-)	(+++)	(+++)	(++)
4	Geisha (4)	(+++)	(+++)	(-)	(+++)	(+++)	(+++)
5	Marseillaise (5)	(+)	(+)	(-)	(+++)	(+++)	(+)

Note. Precipitate or coloration: very abundant, +++; abundant, ++; medium, +; not detected, - (the number of positive signs indicated the intensity of the color observed after the reactions).

The phytochemical compounds identified in coffee pulp infusion of the bourbon, catimor, caturra, geisha and marseillaise were observed in Table 1. Their presence of flavonoids, tannins, alkaloids and reducing sugars was determined, and all of them possess known antioxidant action, which validates the usefulness of this coffee by-product. In the case of flavonoid, the geisha type exhibited the highest concentration (+++), caturra, catimor and bourbon the moderate levels (++) and Marseillaise the lowest presence (+). As to tannins, here the geisha type showed the greatest concentration (++), followed by caturra (++), and bourbon and marseillaise showed low concentrations (+).

Compared with alkaloids, the levels of presence were abundant (+++) in geisha, caturra, bourbon and marseillaise, with the catimor variety showing a much lower level (+). Lastly, among the reducing sugars the geisha variety was the most concentrated (+++) with the next one being caturra and bourbon (++) and catimor and marseillaise (++) to a less extent. These findings indicate that despite the fact that all the types considered have compounds related with the antioxidant capacity, the geisha type always outscores the other types in the amount of flavonoids, tannins and reducing sugars and therefore has a greater potential of having antioxidant activity than the rest of the types considered.

Table 2 Antioxidant activity (mg Trolox equivalents/g infusion) in five coffee varieties

Repetitions	Bourbon	Catimor	Cockatiel	Geisha	Marseillaise
1	0,2960	0,5643	0,5991	0,7206	0,0530
2	0,3014	0,5729	0,5972	0,7196	0,0501
3	0,2898	0,5611	0,5940	0,7233	0,0497
4	0,3000	0,5624	0,6010	0,7158	0,0556
5	0,2910	0,5595	0,6025	0,7219	0,0547
PROM. ± D.S.	0,2956± 0,0052	0,5640± 0,0053	0,5988± 0,0033	0,7202± 0,0028	0,0526± 0,0027

Table 2 shows the values of antioxidant activity of the infusion using coffee pulp of the bourbon, catimor, caturra, geisha and marseillaise varieties. The outcomes indicate significant variation of the varieties tested. The type of geisha compound had the highest average antioxidant activity (0.7202 +0.0028mg Trolox equivalent/g infusion), and therefore, it is highly loaded with bioactive compounds. Comparatively, the

Marseille variety was the least active (0.0526 ± 0.0027 mg Trolox equivalents/g infusion), with lower antioxidant potential.

The Caturra, Bourbon and Catimor types had middle values, between both extremes above, which indicates that differences noted are related to the specific chemical composition of each type.

Table 3 Analysis of variance

Fountain	GL	SC Ajust.	MC Ajust.	F-Value	p-value
Factor	4	1.44915	0.362288	22413.11	0.000
Error	20	0.00032	0.000016		
Total	24	1.44947			

Statistical analysis (ANOVA, $p < 0.005$) showed that there were significant differences in varieties, and therefore, differences in antioxidant activity cannot be explained by chance, but by the inherent nature of the

coffee pulp based on the genetic variety. These findings support the significance of coffee pulp, particularly of the geisha type, as a possible source of antioxidants of the functional and nutraceutical value.

Table 4 Tukey Test

Factor	N	Media	Grouping			
Geisha	5	0.72024	A			
Cockatiel	5	0.59877		B		
Catimor	5	0.56403			C	
Bourbon	5	0.29563				D
Marseillaise	5	0.05263				E

Table 4 of the tukey test shows that there is a statistical difference in the antioxidant activity of the coffee pulp infusion in the five varieties.

Discussion

The evidence of this study proves that coffee pulp, which is usually regarded as an agricultural by-product, possesses a topical phytochemical profile with sulphuric content of flavonoids, tannin, alkaloids and reducing sugars, which are linked to a high antioxidant capability. Geisha emerged as the most active type of the varieties considered, and it was characterised by the superior concentration of bioactive compounds and the highest antioxidant activity (0.7202 ± 0.0028 mg Trolox equivalents/g infusion), unlike Marseillaise variety that introduced much lower values. These results align with those of (Mesa et al., 2024), who reported the occurrence of the same secondary metabolites in coffee pulp and those of Silva et al., (2021), who found an enrichment of phenolic compounds and flavonoids under various extraction conditions.

The genetic and biochemical differences between varieties are attributed to the fact that they are specialised in the synthesis of secondary metabolites, which are the ones that explain the difference that is observed between varieties (Mengesha et al., 2024). Particularly, flavonoids and tannins are the most notable in neutralising the free radicals, because of the capacity of their hydroxyl groups to donate electrons (Šamec et al., 2021; Zhang et al., 2023). This possibility is reinforced by alkaloids, which are compounds, commonly found in the types, and have established uses in neuroprotection and pharmacology (Rajput et al., 2022). Similarly, the lowering of sugars, which is typically linked to energy activities, also serves as electron donors, which add to the overall activity of the antioxidant properties of infusions (Vegas et al., 2024). The ANOVA test ($p < 0.005$) confirms that there are significant differences in the antioxidant capacity of varieties, which agrees with the findings of Ahmed Ali et al., (2022), that found significant changes in the antioxidant performance of six coffee varieties. Equally, the test conducted by Tukey revealed that geisha is distinctly different with the rest of the varieties indicating its high level of functional possibility. The findings indicate that geisha coffee pulp can become a potential source of the nutraceutical compounds that can be used in the food and the pharmaceutical industry.

One of the advantages of this research is the comparative analysis of five varieties of coffee in homogeneous conditions of experimental conditions, which makes it possible to determine the difference that can be explained primarily by the genetic factor. Similarly, the joint qualitative phytochemical tests with quantitative analyses of the antioxidant activity work in support of the validity of the results. Nevertheless, the limitation of using aqueous infusions exclusively has been stated, thus limiting generalisation to other types of extraction that may alter the bioavailability of bioactive compounds (Silva et al., 2021). Further studies need to include chromatographic methods in identification and accurate quantification of the metabolites and in vivo experiments that confirm the activities of these in methods of biological models.

Conclusions

The current research illustrates the fact that coffee pulp is indeed a source of antioxidant compounds, in particular flavonoid compounds, tannins, alkaloids and reducing sugars, with considerable differences among the varieties, which are examined. The geisha type was the one that was characterised by the increased levels of bioactive metabolites and the highest levels of antioxidant activity, which places it as a highly functional and nutraceutical prospective candidate. The Marseille variety was however low in antioxidant compounds and antioxidant activity. These findings contribute in an original way to the knowledge of the added value of coffee pulp, proposing its use as a raw material in the development of functional beverages and antioxidant supplements. At the same time, they reinforce the need to promote a sustainable approach in the coffee production chain, transforming an agricultural by-product into a resource of biotechnological and nutritional interest.

Bibliographic references

1. Ahmed Ali, A. M., Yagi, S., Qahtan, A. A., Alatar, A. A., Angeloni, S., Maggi, F., Caprioli, G., Abdel-Salam, E. M., Sinan, K. I., & Zengin, G. (2022). Evaluation of the chemical constituents, antioxidant and enzyme inhibitory activities of six Yemeni green coffee beans varieties. *Food Bioscience*, 46, 101552. <https://doi.org/10.1016/j.fbio.2022.101552>
2. Febrianto, N. A., & Zhu, F. (2023). Coffee bean processing: Emerging methods and their effects on

- chemical, biological and sensory properties. *Food Chemistry*, 412. <https://doi.org/10.1016/j.foodchem.2023.135489>
3. García-Zavaleta, J., Quintero-Fuentes, M. P., Bautista-Sánchez, R., & Mendoza-Loyo, O. I. (2025). Agronomic factors in the cultivation and production of arabica coffee in Zongolica, Veracruz. *Digital Publisher CEIT*, 10, 652–667. <https://doi.org/https://doi.org/10.33386/593dp.2025.1.2848>
4. Hu, S., Martín-Cabrejas, M. Á., Hernández, D. M., Martín-Trueba, M., Cañas, S., Rebollo-Hernanz, M., Aguilera, Y., Benítez, V., & Gil-Ramírez, A. (2025). Tailored recovery of antioxidant fractions enriched in caffeine and phenolic compounds from coffee pulp using ethanol-modified supercritical carbon dioxide. *Food Research International*, 200. <https://doi.org/10.1016/j.foodres.2024.115433>
5. Irawan, A., Rabemanolontsoa, H., & McLellan, B. C. (2024). Comprehensive Environmental Impact Analysis of Dry Processing Methods for Specialty Coffee Beans in Bondowoso, Indonesia Using Life Cycle Assessment. *Biomass (Switzerland)*, 4(3), 843–864. <https://doi.org/10.3390/biomass4030047>
6. Mengesha, D., Retta, N., Woldemariam, H. W., & Getachew, P. (2024). Changes in biochemical composition of Ethiopian Coffee arabica with growing region and traditional roasting. *Frontiers in Nutrition*, 11. <https://doi.org/10.3389/fnut.2024.1390515>
7. Mesa, D., Figueroa, J. P., Leyes, E. A., Castillo, C. R., Collazo, A., Núñez, H. A., Viltres, D., Mirabal, Y., & Coll, Y. (2024). Preliminary Physical and Chemical Characterization of By-Products from Cuban Coffee Production. *Foods*, 13(21). <https://doi.org/10.3390/foods13213348>
8. Morales, L. V., Robiglio, V., Baca, M., Bunn, C., & Reyes, M. (2022). Planning for Adaptation: A System Approach to Understand the Value Chain's Role in Supporting Smallholder Coffee Farmers' Adaptive Capacity in Peru. *Frontiers in Climate*, 4, 1–23. <https://doi.org/10.3389/fclim.2022.788369>
9. Rajput, A., Sharma, R., & Bharti, R. (2022). Pharmacological activities and toxicities of alkaloids on human health. *Materials Today: Proceedings*, 48, 1407–1415. <https://doi.org/10.1016/j.matpr.2021.09.189>
10. Rohaya, S., Anwar, S. H., Amhar, A. B., Sutriana, A., & Muzaifa, M. (2023). Antioxidant activity and physicochemical composition of coffee pulp obtained from three coffee varieties in Aceh, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1182(1). <https://doi.org/10.1088/1755-1315/1182/1/012063>
11. Ruiz-Nájera, R. E., Medina-Meléndez, J. A., Carmona-De la Torre, J., Rincón-Enriquez, G., Sánchez-Yáñez, J. M., & Raj-Aryal, D. (2021). Effect of the disposal of residues resulting from the wet processing of coffee on the physical and chemical characteristics of the natural running water. *Terra Latinoamericana*, 39. <https://doi.org/https://doi.org/10.28940/terra.v39i0.884>
12. Šamec, D., Karalija, E., Šola, I., Vujčić Bok, V., & Salopek-Sondi, B. (2021). The role of polyphenols in abiotic stress response: The influence of molecular structure. *Plants*, 10(1), 1–24. <https://doi.org/10.3390/plants10010118>
13. Serna-Jiménez, J. A., Siles, J. A., de los Ángeles Martín, M., & Chica, A. F. (2022). A Review on the Applications of Coffee Waste Derived from Primary Processing: Strategies for Revalorization. *Processes*, 10(11), 1–24. <https://doi.org/10.3390/pr10112436>
14. Silva, M. de O., Honfoga, J. N. B., de Medeiros, L. L., Madruga, M. S., & Bezerra, T. K. A. (2021). Obtaining Bioactive Compounds from the Coffee Husk (*Coffea arabica* L.) Using Different Extraction Methods. *Molecules*, 26(1). <https://doi.org/10.3390/MOLECULES26010046>
15. Urugo Makiso, M., Bekele Tola, Y., Ogah, O., & Lisben Endale, F. (2024). Bioactive compounds in coffee and their role in lowering the risk of major public health consequences: A review. *Food Science and Nutrition*, 12(2), 734–764. <https://doi.org/10.1002/fsn3.3848>
16. Vegas Niño, R. M., Acosta Arteaga, Y., & Fernández Segura, C. (2024). Obtaining, purifying and using reducing sugars from lignocellulosic materials. *Bolivian Journal of Chemistry*, 41(2). <https://doi.org/10.34098/2078-3949.41.2.2>
17. Villa Herrera, A., Bolaños-González, M. A., Salvador Castillo, J. M., & Ramírez Armas, L. M. (2024). *Coffee pulp management strategies to mitigate greenhouse gas emissions*. <https://doi.org/10.13140/RG.2.2.14441.10083>
18. Woraprayote, W., Janyaphisan, T., Adunphatcharaphon, S., Sonhom, N., Showpanish, K., Rumjuankiat, K., Visessanguan, W., Elliott, C. T., & Petchkongkaew, A. (2023). Bacteriocinogenic lactic acid bacteria from Thai fermented foods: Potential food applications. *Food Bioscience*, 52, 1–9. <https://doi.org/10.1016/j.fbio.2023.102385>
19. Zhang, X., Kang, J., Hu, H., Wang, H., Liu, Z., Zhou, W., & Zhang, X. (2023). Impacts of tannin inclusion on fabrication, characterization and antioxidant activity of sodium alginate-silk fibroin-tannin films and their application on fresh-cut apple packaging. *Food Bioscience*, 54, 102897. <https://doi.org/10.1016/j.fbio.2023.102897>