ORIGINAL PAPER

FROM BEAN TO BIOACTIVITY: ANALYZING MINERAL COMPOSITION AND EVALUATING ANTIOXIDANT AND ANTIMICROBIAL ACTIVITY OF ARABICA AND ROBUSTA COFFEE

LUIZA-MADALINA CIMA[1], GABRIELA STANCIU[2],*, ROXANA COLETTE SANDULOVICI[1], ANA-MARIA NECULAI[3], MAGDALENA MITITELU[4]

Manuscript received: 14.09.2024; Accepted paper: 20.11.2024;
Published online: 30.12.2024.

Abstract. *Coffee, one of the most consumed beverages globally, is a significant source of antioxidants. The present study investigated the mineral content, antioxidant, and antimicrobial activity of coffee extracts prepared by room temperature maceration and hot water infusion. The results showed the influence of the preparation method on the analyzed parameters, demonstrating that Robusta green coffee has a superior antioxidant activity to Arabica. However, after roasting, Arabica outperformed Robusta in antioxidant activity. Antimicrobial activity was effective against Gram-negative bacteria, moderate against Gram-positive bacteria, and weak against fungi for roasted coffee samples. Mineral content, performed by atomic absorption spectrometry, showed the presence of beneficial elements such as Fe, Zn, Ca, Mg, K, and Na, confirming that both types of green coffee contain only healthy substances without harmful metals.*

Keywords: *coffee; Arabica and Robusta; antioxidant activity; antimicrobial activity; mineral composition.*

1. INTRODUCTION

Coffee has been shown to reduce fatigue, increase concentration, increase productivity, and generally increase performance, making it one of the most preferred beverages globally [1-3]. For a significant number of people, drinking coffee is an integral aspect of their daily routine and lifestyle. About 40% of the global population – millions of people – start their day with a cup of coffee in the morning [4]. Coffee drinks are consumed for a variety of reasons, including their stimulating effects due to caffeine, the health benefits related to their rich phytochemical composition, and above all, their delightful taste and aroma. While the attractiveness of coffee is influenced by its aroma and caffeine (1,3,7-trimethylpurine-2,6-dione) content, it is important to note that coffee, comprising both beans and beverages, is a complex chemical mixture containing over a thousand different chemical compounds such as carbohydrates, lipids, nitrogen, vitamins, minerals, alkaloids, and phenolic compounds [5-7].

[1] Titu Maiorescu University, Faculty of Pharmacy, Department of Pharmaceutical Chemistry, 040314 Bucharest, Romania. E-mail: luiza.cima@prof.utm.ro; roxana.sandulovici@prof.utm.ro.
[2] Ovidius University of Constanta, Department of Chemistry and Chemical Engineering, 900470 Constanta, Romania.
E-mail: gstanciu@univ-ovidius.ro.
[3] Ovidius University of Constanta, Department of Biochemistry, Faculty of Medicine, 900470 Constanta, Romania. E-mail: anamneculai89@gmail.com.
[4] "Carol Davila" University of Medicine and Pharmacy, Department of Clinical Laboratory and Food Safety, Faculty of Pharmacy, 020956 Bucharest, Romania. E-mail: magdalena.mititelu@umfcd.ro.

https://doi.org/10.46939/J.Sci.Arts-24.4-b01

The chemical composition of green coffee is primarily influenced by internal factors, although external factors also contribute to these characteristics. Internal factors include coffee varieties and the stage of physiological maturity, which are the most important determinants of the quality of green coffee [2,8,9]. On the other hand, external factors such as agricultural practices, soil composition, climate changes, and storage conditions contribute to the variability in coffee quality. For example, ambient temperatures and CO_2 levels can impact its quality [10-12]. While soil minerals can cause sensory changes, their impact is generally minimal [13]. However, internal genetic factors remain the primary determinants of the unique characteristics of green coffee. In the case of roasted coffee, notable sensory attributes result from the blend of volatile compounds formed during the roasting process [14,15]. Additionally, roasting is a critical industrial process in which coffee undergoes numerous physical and chemical changes [16].

The article analyzes green and roasted coffee (i.e., Arabica and Robusta) to identify mineral composition, antioxidant, and antimicrobial activity. These analyses are essential because coffee is not only a popular beverage, but also an important source of nutrients and bioactive compounds that can influence human health. By determining the mineral composition, researchers can assess the intake of essential elements such as iron, manganese, and zinc, which are crucial for various biological functions.

In the first step, the green coffee powder was analyzed by flame atomic absorption spectrometry to determine the concentrations of metals and minerals, including Fe, Mn, Cu, Cr, Ni, Pb, Cd, Zn, Ca, Mg, K, and Na. These aspects were chosen given their high sensitivity and ability to provide accurate information on mineral content, important in evaluating the quality and safety of coffee.

In the second phase, six coffee extracts were derived - four from green coffee using varying extraction temperatures and two from roasted coffee. These extracts were then assessed for their antioxidant activity through the photochemiluminescence method. Assessing the antioxidant activity is essential because the antioxidant compounds found in coffee may aid in combating oxidative stress, which is a contributing factor in the development of several chronic diseases. This phase aimed to determine how different extraction methods affect the availability of these beneficial compounds and to compare green coffee beans with roasted ones.

The microdilution method was utilized to assess the antimicrobial activity of roasted coffee samples against pathogenic species, including *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923, and *Candida albicans* ATCC 10231. Investigating antimicrobial properties is crucial, as coffee could offer protective benefits against specific infections, and recognizing these attributes may encourage the inclusion of coffee in a healthy diet.

2. MATERIALS AND METHODS

2.1. MATERIALS AND ANALYTICAL EQUIPMENT

2.1.1. Mineral composition

The mineral concentration of samples was measured using the ContrAA-700 atomic absorption spectrometer manufactured by Analytik Jena AG, Germany. The apparatus includes a continuous background correction system and cavity cathode lamps matched to the

metals being analyzed. It is also equipped with a nebulizer-burner assembly compatible with an air-acetylene flame, ensuring accurate and reliable performance.

2.1.2. Antioxidant activity

To determine the total antioxidant property of coffee extracts, the Photochem apparatus, Analytik Jena AG, Germany, was used. The Photochem works based on the photochemiluminescence method, where the photochemical excitation of samples accelerates chemical reactions up to 100 times faster than normal conditions. The process is carried out using a mercury vapor lamp, coated with a phosphor layer, which emits light at a maximum wavelength of 351 nm. Detection of the results is provided by a photomultiplier tube (PMT) with multi-field performance, and the flow of substances is managed by high-flow peristaltic pumps. The equipment is integrated with a computer running specialized software designed to process and interpret the obtained results. Each analysis session was completed within 120 seconds.

2.1.3. Antimicrobial activity

Microbial strains and growth conditions: The antimicrobial activity was evaluated against two types of pathogenic microorganisms, namely bacteria, and fungi, utilizing reference strains from Sanimed, specifically the gram-positive *Staphylococcus aureus* ATCC 25923 and the gram-negative *Escherichia coli* ATCC 25922 for bacterial strains, along with the pathogenic fungal strain *Candida albicans* ATCC 10231. Culture media were sourced from Sigma-Aldrich, Germany. For culturing, *S. Aureus* and *E. Coli* were cultivated in Tryptone Soya Broth (TSB, 30 g/l) and Tryptone Soya Agar (TSA, 15 g/lL, while *C. Albicans* was cultured in Sabouraud 2% Dextrose Broth (SDB, 30 g/L) and Sabouraud 4% Dextrose Agar (SDA, 65 g/L).

2.1.4. Plant material

Samples of Arabica and Robusta coffees from India were purchased from a local distributor. The green coffee beans were finely ground with a professional dip grinder DK-30. They were roasted using a wood roaster, which ensures optimal control over the degree of roasting, achieving an average roasting of 209℃ , guaranteeing uniformity and avoiding the burning of the beans.

2.2. METHODS

2.2.1. Preparation of aqueous extracts from green and roasted Arabica and Robusta coffee

For extraction from green coffee, infusion and maceration methods were used. In the case of infusion, distilled water was heated to 85 ± 2℃ to which green coffee was added. The infusion was maintained in a water bath for 10 minutes at a ratio of 1:10 (g green coffee/ mL distilled water) and the extract was filtered hot to remove insoluble particles (CA1, CR1). The maceration method was carried out at room temperature (21 - 25℃) for 24 hours, protected from light in the same ratio of 1:10, and filtered through filter paper (CA2, CR2).

For the roasted coffee, each sample was extracted with hot distilled water (≈100°C) for 5-7 minutes, using a ratio of approximately 1:10 between roasted coffee powder and solvent (CA0, CR0).

2.2.2. Mineral composition

The mineral composition was determined using atomic absorption spectroscopy (AAS) [17]. To analyze the metals, solutions were prepared by mineralizing 0.5 g of dried and ground sample in 5 mL of 69% HNO_3 and 40 mL of deionized water for 1 hour and 30 minutes at a temperature of 120℃. The clear solution obtained through filtration was transferred to 50 mL volumetric flasks and filled with deionized water. A multi-element standard solution (Certipur) purchased from Merck, containing 1 mg/mL of each metal, was used for calibration. Equation (1) was applied to express metal concentrations in mg metal/kg sample:

$$\text{Metal concentration [mg/kg sample]} = \frac{V_b \times c}{m_{sample}} \quad (1)$$

where V_b is the volume of the volumetric flask (50 mL) in which the sample solution was prepared, c is the metal concentration measured in mg/L and m is the mass of the sample added to the solution (m = 0.5 g).

To ensure the quality of the analytical data, the following performance parameters were evaluated: concentration range (µg/L), correlation coefficients of the calibration curve (R^2), limits of detection (LOD), and limits of quantification (LOQ) (Table 1).

Table 1. Performance parameters for AAS meters

Metals	Concentration range (mg/L)	R^2	LOD [mg/L]	LOQ [mg/L]
Fe	0.050-2000	0.9981	0.5084	0.1183
Mn	0.050-2000	0.9993	0.4704	0.0597
Cu	0.050-2000	0.9944	0.0426	0.0586
Cr	0.050-2000	0.9912	0.0488	0.0510
Ni	0.100-4000	0.9937	0.3425	0.1051
Pb	0.200-8000	0.9918	0.1375	1.0280
Cd	0.050-1000	0.9927	0.0610	0.0693
Zn	0.050-1000	0.9939	0.0423	0.1076
Ca	40.00-20000	0.9991	4.740	20.14
Mg	1.000-5000	0.9944	2.104	15.13
K	1.000-5000	0.9977	3.339	29.35
Na	5.000-2500	0.9995	1.241	4.712

2.2.3. Antioxidant activity

The total antioxidant capacity of lipophilic substances (ACL) in aqueous extracts of Arabica and Robusta coffee was evaluated by the photochemiluminescence method [18,19]. For this analysis, each extract was diluted in molar ratios of 1:1, 1:10, 1:100 and 1:200 with reagent R1 from the ACL kit (Analytik Jena AG). Aliquots of 5 µL of each sample (taken from the supernatant) were exposed to external radiation from a phosphor-coated Hg lamp emitting maximum energy at a wavelength of 351 nm in the presence of a photosensitive reagent. This interaction generates superoxide free radicals and initiates a photochemical reaction. The free radicals produced were partially neutralized by the antioxidants present in the sample. The remaining luminescence of these radicals was recorded as an electrical signal for 120 seconds and later converted to concentration values. The standard reagent kit (Analytik Jena, Germany) used for the ACL procedure included R1 (dilution solvent), R2 (buffer reagent), R3 (photosensitive reagent), and R4 (working reagent only for plotting the calibration curve). Mixtures were prepared according to the specifications in Table 2.

Table 2. Workflow for ACL analysis.

Reagents	R1 [µL]	R2 [µL]	R3 [µL]	R4 [µL]	Sample [µL]
Blank	2300	200	25	0	0
Calibration curve	2300	200	25	5	0
Measurement Sample	2300	200	25	0	5

A calibration curve for the Trolox standard was constructed using a series of Trolox standard solutions with concentrations of 0.5, 1.0, 1.5, 2.0, and 3.0 nmol/sample volume. A minimum of three blank tests were conducted. The resulting equation was $y = 1.59160x + 1.50449$, with a correlation coefficient of $R^2 = 0.9948$, demonstrating a linear relationship [19].

The recorded voltage (V) is directly proportional to the luminescence produced over time (in seconds). Initially, the samples were homogenized in a methanol phase using a Vortex magnetic stirrer from Velp Scientifica, Italy. For the measurements, 5 µL of extract was taken from the supernatant. The antioxidant activity was assessed for both the stock solution and its 1:100 dilution with reagent R1 for the hot green coffee extracts of Arabica and Robusta (CA1, CR1), as well as for the extracts at room temperature (CA2, CR2). The extract of roasted Arabica coffee (CA0) required a series of dilutions with reagent R1, specifically at 1:1, 1:100, and 1:200 ratios. In contrast, the roasted Robusta coffee extract (CR0) required dilutions of 1:10 and 1:100 with the same reagent R1.

2.2.4. Antimicrobial activity

This study aims to evaluate the effectiveness of these coffee extracts against specific Gram-positive bacterial strains, such as *Staphylococcus aureus* ATCC 25923, Gram-negative strains like *Escherichia coli* ATCC 25922, and pathogenic fungal strains, including *Candida albicans* ATCC 10231. By assessing the antimicrobial properties of biologically active compounds present in these extracts, we seek to explore their potential as natural antimicrobial agents. Building on our previous research [20], which mainly focused on the antimicrobial activity of green coffee extracts, this investigation turns its attention to roasted coffee extracts (CA0, CR0).

The antimicrobial properties of the extracts were evaluated using a modified Kirby-Bauer disk diffusion method and a quantitative microdilution technique to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC). This method involves making serial dilutions (1/2, 1/4, 1/16, etc.) of the extract in a liquid medium, which is then exposed to fixed amounts of bacterial culture. The mixtures are incubated for 18-24 hours at 37 °C to identify the lowest concentration of extract that inhibits bacterial growth. Subsequently, a fixed amount from tubes in which no microbial growth has occurred is transferred to a solid culture medium. After a further incubation of 18-24 hours at 37 °C, the lowest concentration at which bacteria have not grown is recorded as the minimum bactericidal concentration (MBC). Both extracts were filtered through sterile PES filters (0.22 µm) for purification before testing for antimicrobial activity [21].

The results are interpreted by visually assessing the color intensity, turbidity, and population density of the cultures in each well compared to a growth control. In addition, after inoculation of the solid medium, the growth of the microorganisms is assessed at the appropriate MIC dilution.

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1. Mineral composition

Analysis of two green coffee samples by flame atomic absorption spectrometry revealed the concentrations of 12 metals (Fe, Mn, Cu, Cr, Ni, Pb, Cd, Zn, Ca, Mg, K, and Na). The concentrations of these metals were determined in Arabica and Robusta green coffee samples as shown in Table 3.

Table 3. Metal concentration (mg/kg) in Arabica and Robusta green coffee samples.

Metal	Coffee Arabica [mg/kg]	Coffee Robusta [mg/kg]
Ca	3334.00±0.51	5320.00±0.42
Cd	<DL	<DL
Cr	<DL	<DL
Cu	15.88±0.11	22.22±0.25
Fe	81.82±0.22	79.02±0.44
K	4004.00±0.31	4020.00±0.37
Mg	886.00±0.14	810.60±0.18
Mn	17.80±0.16	<DL
Na	1086.60±0.55	1135.00±0.66
Ni	<DL	<DL
Pb	<DL	<DL
Zn	62.44±0.24	80.40±0.28

Each value shown is the mean value ± standard deviation; <DL means below detection limit

3.1.2. Antioxidant activity

The total antioxidant capacity for the extracts derived from both green and roasted Arabica and Robusta coffees was evaluated for the stock solution as well as for different dilutions of the stock solution, in particular in ratios of 1:10, 1:100 and 1:200, using reagent R1. This evaluation was carried out according to the ACL method. The findings are presented in Table 4.

Table 4. Total antioxidant capacity (TEAC) obtained for diluted solutions of green and roasted coffee extracts

No.	Sample/Dilution	Free Radicals Max. Inhibition	Total Antioxidant Capacity [nM TE/μL]	TEAC Quantity Means [g TE/100 g d.w.]
1.	CA0 Stock solution	0.999	15.122	0.757
2.	CA0 / 1:1	0.964	14.021	0.702
3.	CA0 / 1:100	0.820	10.292	51.519
4.	CA0 / 1:200	0.680	7.525	75.337
5.	CR0 Stock solution	0.999	15.123	0.757
6.	CR0 / 1:10	0.864	11.304	5.658
7.	CR0 / 1:100	0.567	5.731	28.688
8.	CA1 Stock solution	0.999	15.106	0.756
9.	CA1 / 1:100	0.645	6.939	34.735

No.	Sample/Dilution	Free Radicals Max. Inhibition	Total Antioxidant Capacity [nM TE/μL]	TEAC Quantity Means [g TE/100 g d.w.]
10.	CR1 Stock solution	0.999	15.124	0.757
11.	CR1 / 1:100	0.585	6.001	30.039
12.	CA2 Stock solution	0.999	15.127	0.757
13.	CA2 / 1:100	0.618	6.496	32.517
14.	CR2 Stock solution	0.999	15.118	0.756
15.	CR2 / 1:100	0.689	7.688	38.484

3.1.3. Antimicrobial activity

The results of the tests performed to evaluate the antimicrobial properties of roasted coffee extracts are presented in Table 5.

Table 5. Antimicrobial activity of coffee extracts by microdilution method.

	Roasted coffee samples					
	CA0			CR0		
Pathogens / CFU/mL	*S. aureus*	*E. coli*	*C.albicans*	*S. aureus*	*E. coli*	*C.albicans*
1/2	8	0	>100	0	0	>100
1/4	>100	>100	>100	>100	>100	>100
1/8	>100	>100	>100	>100	>100	>100
1/16	>100	>100	>100	>100	>100	>100
1/32	>100	>100	>100	>100	>100	>100
1/64	>100	>100	>100	>100	>100	>100
1/128	>100	>100	>100	>100	>100	>100
1/256	>100	>100	>100	>100	>100	>100
1/512	>100	>100	>100	>100	>100	>100
1/1024	>100	>100	>100	>100	>100	>100
MC*	>100	>100	>100	>100	>100	>100
MS*	Steril	Steril	Steril	Steril	Steril	Steril

**MC = growth marker (positive marker); MS = sterility marker (negative marker); CFU = colony forming units*

This article focuses on examining the antimicrobial properties of roasted Arabica and Robusta coffees, as our previous research has not revealed any antibacterial activity of green coffee extracts against the tested pathogens [20]. Extract CR0, at a volume of 50 μL, showed complete inhibition of *Staphylococcus aureus* and *Escherichia coli* cultures, along with partial inhibition of *Candida albicans* cultures. In contrast, the CA0 extract showed complete inhibition of *E. coli* and partial inhibition of both *S. aureus* and *C. albicans*, as illustrated in Figs. 1-3. These results suggest that, while both roasted coffee extracts exhibit antimicrobial characteristics, Robusta may provide a more pronounced inhibitory effect against specific pathogenic bacteria.

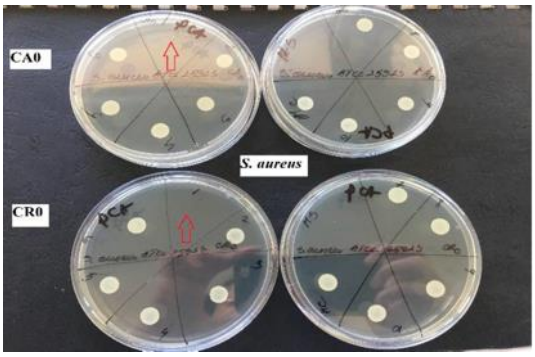

Figure 1. Antimicrobial effect of CA0 and CR0 extracts tested on Gram-positive strains of *Staphylococcus aureus*

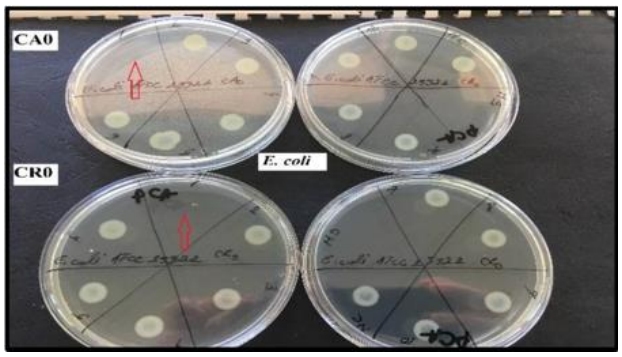

Figure 2. Antimicrobial effect of CA0 and CR0 extracts tested on Gram-negative strains of *Escherichia coli*

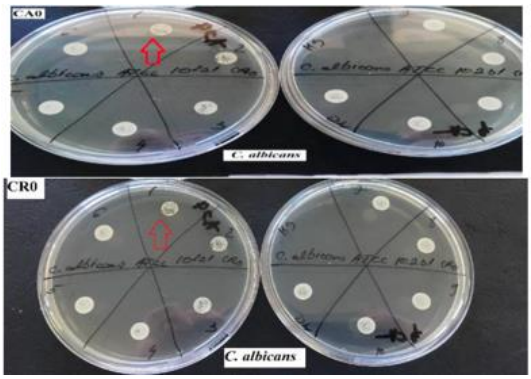

Figure 3. Antimicrobial effect of CA0 and CR0 extracts tested on yeast strains of *Candida albicans*

3.2. DISCUSSIONS

Coffee is one of the most popular beverages in the world and is valued by many coffee lovers for its sensory properties [22]. Previous studies have shown that coffee is generally safe for most social groups and can have positive effects on health [23-25]. However, the preparation method and type of coffee have a significant impact on the properties of the resulting product. For example, these can affect flavor profile, acidity, fatty acid composition, caffeine, and other antioxidant compounds. The biochemical properties of coffee beverages are also affected by factors such as brewing temperature, extraction time, and coffee powder size [26-29].

To ensure the quality and safety of coffee beverages, it is essential to assess the mineral composition of the coffee plants under study. Table 3 presents the average values of three measurements for the metals analyzed in both Arabica and Robusta coffee samples. The results revealed that Arabica and Robusta species contain varying amounts of minerals that are crucial for optimal body function [12]. Specifically, Arabica coffee was found to have higher concentrations of Fe, Mn, and Mg compared to Robusta coffee. Magnesium plays a critical role in plant physiology, as it is a central component of chlorophyll molecules but also contributes to the overall health and productivity of the coffee plant. Interestingly, manganese was absent in the Robusta sample (CR), which may indicate differences in soil composition or agricultural practices that affect the mineral absorption of these coffee plants [30]. On the other hand, Robusta coffee exhibited relatively higher values for the following elements: Ca and Zn. Calcium, an essential element for many plant-based products, was found to have a concentration of 5320±0.2 mg/kg in the Robusta sample and 3334±0.01 mg/kg in the Arabica sample. Similarly, zinc was present in higher amounts in the Robusta coffee (80.4±0.02

mg/kg). Zinc is vital for the structural integrity of plant ribosomes, and it also acts as a constituent or activator of numerous enzymes, playing a crucial role in membrane integrity [12]. Potassium and sodium exhibited similar values in both coffee samples. Another finding is the presence of Cu in normal concentrations ranging from 15 to 22 mg/kg in both coffee samples. Copper is a vital micronutrient for plants, contributing to normal growth and development [31,32]. Interestingly, out of the 12 elements studied, only four—Cr, Ni, Pb, and Cd - were found to have concentrations below the detection limit. This observation is significant as it suggests that green coffee beans are relatively low in potentially harmful heavy metals, which is important for consumer safety and the overall health benefits of coffee consumption [33,34].

Antioxidants represent the most significant health-promoting compounds present in coffee, thus establishing this beverage as a substantial source of these beneficial elements [35]. According to Vicente et al. [36], coffee beverages may play a role in mitigating the impacts of oxidative stress within the body, suggesting a potential health benefit. The photochemiluminescence analysis revealed that the tested extracts exhibited a broad spectrum of antioxidant activity, highlighting their diverse potential in neutralizing free radicals. Thus for roasted Arabica coffee extract (CA0) the values ranged from 0.757-75.337 g TE/100 g d.w. following progressive dilution 1:1, 1:100, 1:200 of the stock solution (CA0) with reagent R1. This sample showed very good antioxidant activity for the 1:200 dilution, where a value of 75.337 g TE/100 g d.w. was obtained. For the roasted Robusta coffee extract (CR0), antioxidant values ranged from 0.757-28.688 g TE/100 g d.w. following progressive dilution at 1:10 and 1:100 with reagent R1. This sample showed particularly strong antioxidant activity at the 1:100 dilution (28.688 g TE/100 g d.w.). Diluting the sample at molar ratios of 1:10, 1:100, and 1:200, along with using a minimum working volume of 5 μL, led to a decrease in maximum free radical inhibition. This effect was attributed to an increase in the amount of TEAC (g TE/100 g d.w.). Green coffee extracts also exhibited strong antioxidant activity, with the best value observed in macerated Robusta (CR2) at 38.484 g TE/100 g d.w. at the 1:100 dilution. This was followed by Arabica green coffee (CA1) with 34.735 g TE/100 g d.w. at the same dilution. These results are similar to those obtained in previous studies with respect to the antioxidant activity achieved by the DPPH method [21]. The observed variations in antioxidant activity may be attributed to differences in the concentration of polyphenols, chlorogenic acids, and other antioxidant compounds that vary depending on the coffee variety and processing methods [37,38].

This study explored the antimicrobial properties of roasted coffee extracts (CA0, CR0) against three microbial strains commonly associated with human infections: *S. aureus*, *E. coli*, and *C. albicans*, each characterized by distinct cell wall structures. Among the strains tested, the Gram-negative *E. coli* was the most sensitive, with complete growth inhibition in both roasted coffee extracts. Gram-positive *S. aureus* showed the highest sensitivity to the CR0 extract, which completely inhibited its growth, while the CA0 extract also exhibited some activity. *C. albicans* demonstrated the highest resistance, with yeast cells protected by their robust cell wall. Previous research [20] has shown that green coffee extracts did not exhibit antimicrobial activity against these pathogens. The results suggest that roasting, which induces significant structural, chemical, and physical changes in coffee, plays a key role in enhancing the antimicrobial properties of the extracts, likely due to the formation of compounds such as melanoidins [39,40]. This highlights the potential of roasted coffee not only as a popular beverage but also as a natural source of antimicrobial agents, offering potential benefits in food safety and public health [41].

4. CONCLUSIONS

The mineral content determined through atomic absorption spectroscopy revealed the presence of Fe, Cu, Zn, Ca, Mg, K, and Na in both green coffee samples, while Mn was absent in Robusta. This indicates that both Arabica and Robusta green coffee are important sources of beneficial elements such as Ca, Mg, K, Na, and Zn. The analysis also showed concentrations of Cr, Ni, Cd, and Pb below detection limits, confirming that green coffee contains elements that are advantageous for human health. Additionally, photochemiluminescence results confirm that the analyzed coffee samples are rich in antioxidant compounds. Favorable antioxidant activity values determined by the ACL method were within the limits of the standard curve and were recorded at the highest dilutions: 1:200 for CA0, 1:100 for CR0, 1:100 for CA1, 1:100 for CR1, 1:100 for CA2, and 1:100 for CR2. The antioxidant activity of Robusta green coffee extracted by maceration (CR2 - 38.484 g TE/100 g d.w.) was observed to be higher than that of Arabica green coffee obtained through the same method (CA2 - 32.517 g TE/100 g d.w.). Interestingly, roasted Arabica (CA0) exhibited significant antioxidant activity, surpassing that of roasted Robusta (28.688 g TE/100 g d.w.) with a value of 75.337 g TE/100 g d.w. Moreover, the antimicrobial activity analysis indicated that both Arabica and Robusta medium-roast extracts (CA0, CR0) could serve as potential natural antimicrobial agents, offering possible applications in medical, food, and cosmetic industries. Overall, this research underscores the nutritional and bioactive potential of both green and roasted coffee as valuable natural sources of essential minerals, antioxidants, and antimicrobial compounds.

REFERENCES

[1] Torquati, L., Peeters, G., Brown, W.J., Skinner, T.L., *International Journal of Environmental Research and Public Health*, **15**(9), 1812, 2018.
[2] Wu, H., Gu, J., Amrit, B.K., Nawaz, M.A., Barrow, C.J., Dunshea, F.R., Suleria, H.A. R. *Food Bioscience*, **46**, 101373, 2022.
[3] Wachamo, L.H., *Medicinal Aromatic Plants*, **6**, 4, 2017.
[4] Gaascht, F., Dicato, M., Diederich, M., *Genes Nutrition*, **10**, 51, 2015.
[5] Gebrewold, F., Gosaye, G., *Chemistry and Materials Research*, **10**(1), 23, 2018.
[6] Zain, M.Z.M., Shori, A.B., Baba, A.S., *European Journal of Clinical and Biomedical Sciences*, **3**(5), 97, 2017.
[7] Janda, K., Jakubczyk, K., Baranowska-Bosiacka, I., Kapczuk, P., Kochman, J., Rębacz-Maron, E., Gutowska, I., *Foods*, **9**(2), 121, 2020.
[8] Palmieri, M.G.S., Cruz, L.T., Bertges, F.S., Hngaro, H.M., Batista, L.R., da Silva, S.S., Fonseca, M.J.V., Rodarte, M.P., Vilela, F.M.P., da Penha do Amaral, M., *Biocatalysis and Agricultural Biotechnology*, **16**, 43, 2018.
[9] Somporn, C., Kamtuo, A., Theerakulpisut, P., Siriamornpun, S., *International Journal of Food Science and Technology*, **46**(11), 2287 2011.
[10] Bertrand, B., Boulanger, R., Dussert, S., Ribeyre, F., Berthiot, L., Descroix, F., Joet, T., *Food Chemistry*, **135**(4), 2575, 2012.
[11] Aytar, E.C., Aydın, B., *Food Bioprocess Technol*, 2024.
[12] Barbes, L., Barbulescu, A., Stanciu, G., *Romanian Reports in Physics*, **72**(2), 705, 2020.

[13] Ahmed, S., Brinkley, S., Smith, E., Sela, A., Theisen, M., Thibodeau, C., Warne, T., Anderson, E., van Dusen, Giuliano, P., Ionescu, K.E., Cash, S.B., *Frontiers in Plant Science*, **12**, 708013, 2021.
[14] Campuzano-Duque, L.F., Blair, M.W., *Agriculture*, **12**(10), 1576, 2022.
[15] De Paula, J., Farah, A., *Beverages*, **5**(2), 37, 2019.
[16] Martinez-Tome, M., Jimenez-Monreal, A.M., Garcıa-Jimenez, L., Almela, L., Garcıa-Diz, L., Mariscal-Arcas, M., Murcia, M.A., *European Food Research and Technology*, **233**, 497, 2011.
[17] Stanciu, G., Rotariu, R., Popescu, A., Tomescu, A., *Revista de Chimie*, **70**(4), 1173, 2019.
[18] Popov, I., Lewin, G., *Methods in Enzymology.* In *Oxidants and Antioxidants*, Academic Press: New York, NY, USA, 437, 1999.
[19] Neculai, A.M., Stanciu, G., Mititelu, M., *Molecules (Basel)*, **28**(15), 5667, 2023.
[20] Cima, L.M., Stanciu, G., Stefan-Van Staden., R.I., Mititelu, M., *Farmacia*, **7**(5), 1059, 2024.
[21] Caracostea, L., Sirbu R., Lepadatu, A.C., *European Journal of Medicine and Natural Sciences*, **4**(1), 83, 2021.
[22] Grosso, G., Godos, J., Galvano, F., Giovannucci, E.L., *Annual Review of Nutrition*, **37**, 131, 2017.
[23] Schepici, G., Silvestro, S., Bramanti, P., Mazzon, E., *International Journal of Molecular Sciences*, **21**(13), 4766, 2020.
[24] Ikram, M., Park, T.J., Ali, T., Kim, M.O., *Antioxidants (Basel)*, **9**(9), 902, 2020.
[25] Yamagata, K., *Antioxidants (Basel)*, **7**(2), 26, 2018.
[26] Grembecka, M., Malinowska, E., Szefer, P., *Science of the Total Environment*, **383**(1-3), 59, 2007.
[27] Caprioli, G., Cortese, M., Sagratini, G., Vittori, S., *International Journal of Food Sciences and Nutrition*, **66**(5), 505, 2015.
[28] Gloess, A.N., Schönbächler, B., Klopprogge, B., D`Ambrosio, L., Chatelain, K., Bongartz, A., Strittmatter, A., Rast, M., Yeretzian, C., *European Food Research and Technology*, **236**, 607, 2013.
[29] Stanciu, G., Dobrinas, S., Birghila, S., Popescu, M., *Environmental Engineering and Management Journal*, **7**(6), 661, 2008.
[30] Rebeca, C., Simone, M., Susana, C., *Mineral Composition Variability of Coffees: A Result of Processing and Production* In *Processing and Impact on Active Components in Food*, Academic Press, Massachusetts, United States, pp. 549-558, 2015.
[31] Wachamo, H.L., *Medicinal and Aromatic Plants*, **6**(4), 1, 2017.
[32] Park, K., *Biomolecules and Therapeutics*, **23**(3), 207, 2015.
[33] Berego, Y.S., Sota, S.S., Ulsido, M., Beyene, E.M., *PeerJ*, **11**, e14789, 2023.
[34] Sandulovici, R.C., Gălăţanu, M.L., Cima, L.M., Panus, E., Truţă, E., Mihăilescu, C.M., Sârbu, I., Cord, D., Rîmbu, M.C., Anghelache, S.A., Panţuroiu, M., *Molecules*, **29**(9), 2128, 2024.
[35] Caporaso, N., Genovese, A., Canela, M.D., Civitella, A., Sacchi, R., *Food Research International*, **61**, 152, 2014.
[36] Vicente, S.J.V., Queiroz, Y.S., Davidson Gotlieb, S.L., Ferraz da Silva Torres, E.A., *Brazilian Archives Biology and Technology*, **57**(1), 110, 2014.
[37] Nosal, B.M., Sakaki, J.R., Kim, D.O., Chun, O.K., *Food Science and Biotechnology*, **31**(8), 1081, 2022.
[38] Stanciu, G., Aonofriesei, F., Lupsor, S., Popescu, A., Sirbu, R., *Revista de Chimie*, **70**(5), 1800, 2019.

[39] Pruthviraj, P.P., Suchita, S.B., Kurhade, S.K.S., Kadbane, S.K.K., *International Journal of Research in Ayurveda and Pharmacy*, **2**(4), 1354, 2011.
[40] Fiore, A.G., Severini, C., Romaniello, R., Peri, G., *Study of physical properties of coffee beans during roasting. Application of hyperspectral image analysis*. In Proceed. 21st International Conference on Coffee Science Montpellier, France, pp. 573-581, 2006.
[41] Mueller, U., Sauer, T., Weigel, I., Pichner, R., Pischetsrieder, M., *Food Function*, **2**(5), 265, 2011.