Ultrasound-assisted Extraction of Bioactive Polyphenols from Cashew Testa (*Anacardium occidentale* L.) and Evaluation of Their Antioxidant and Antimicrobial Properties

Nguyen Thi Dung[1,*], Chau Hong Nhat Linh[2], Chu Hoang Chau Anh[2], Tran Gia Minh Tam[3], Nguyen Văn Toan[1], Nguyen Thi Nu Trinh[1]

[1]Biotechnology Center of Ho Chi Minh City, Ho Chi Minh City, Viet Nam
[2] Tran Dai Nghia High School for the Gifted, Viet Nam
[3] Vinschool Central Park, Viet Nam
[*]thuydung9810@gmail.com

Abstract

Cashew testa (*Anacardium occidentale* L.) is an underutilized by-product rich in bioactive compounds. This study aims to evaluate the polyphenol content and bioactivities of cashew nut testa in Vietnam using ultrasound-assisted extraction with different solvents. Methanol and ethanol were identified as the most effective solvents, yielding extracts with high polyphenol content of (484.06 ± 4.26) mg GAE/g and (465.33 ± 4.69) mg GAE/g, respectively. The results from antioxidants assay demonstrated that at the concentration of 100 µg/mL, methanol and ethanol extracts exhibited > 87% DPPH and > 99% ABTS inhibition In addition, both extracts showed pronounced antimicrobial activity against *Staphylococcus aureus* and *Candida albicans*, as indicated by inhibition zone diameters exceeding 11 mm and minimum inhibitory concentrations of 1.56 mg/mL. These results confirm the effectiveness of ultrasound-assisted extraction for producing polyphenol-rich extracts with antioxidant and antimicrobial potentials.

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Keywords

Antioxidant; antimicrobial activity; Cashew testa; polyphenols; ultrasound-assisted extraction.

1 Introduction

Viet Nam has remained the world's leading exporter of cashew nuts for 18 consecutive years, accounting for over 80% of global export volume. In 2024, the country exported more than 765,000 tons of cashew kernels and generated over 4.6 billion USD in revenue, which is a remarkable increase compared to previous year (WTO Center, Viet Nam) [1]. Binh Phuoc is often referred to as the "cashew capital" of Viet Nam, contributes nearly 50% of the national cultivation area and over 40% of the total raw cashew nut output [2].

Cashew nut testa is the thin reddish-brown skin surrounding the kernel that accounts for approximately (1-3)% of the total nut weight. It is generated in large quantities as a by-product of cashew nut processing with a rich source of polyphenols and flavonoids such as catechin, epicatechin, catechin gallate and procyanidins, along with other phytochemicals and nutrients which have demonstrated antioxidant and

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antimicrobial properties [3]. Despite the rapid growth of cashew industry, this valuable by-product is often discarded or utilized only as low-value fuel or fertilizers [4, 5]. This highlights the cashew testa extract as a valuable but underutilized resource in fields such as pharmaceuticals, cosmetics, and food technology.

The efficient recovery of bioactive compounds from plant-derived materials strongly depends on the extraction process which directly influences yield, chemical composition, and biological activity [5, 6]. Conventional extraction techniques, including maceration, reflux extraction, Soxhlet extraction, and steam distillation, are still widely employed, yet are often associated with long extraction times, high solvent consumption, and potential degradation of thermolabile compounds [5]. Consequently, increasing attention has been directed toward advanced extraction technologies such as ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), supercritical fluid extraction (SFE), and accelerated solvent extraction (ASE), which offer improved efficiency and reduced environmental impact [6]. Among these techniques, UAE has emerged as a promising approach for polyphenol recovery due to its ability to enhance mass transfer through acoustic cavitation, thereby improving extraction efficiency while reducing processing time and solvent usage. Furthermore, UAE is compatible with a wide range of solvents and is considered relatively safe and scalable for industrial applications. Research reported the optimization of UAE conditions for maximizing TPC from cashew testa, demonstrating the feasibility of this technique for phenolic recovery [7]. However, their study primarily focused on process optimization parameters and did not comprehensively evaluate the influence of solvent polarity on extraction efficiency, phytochemical profile, or biological activities of the resulting extracts. In addition, the antioxidant and antimicrobial properties of solvent-specific UAE extracts were not systematically compared.

Therefore, this study aims to evaluate the polyphenol content and bioactivities of cashew nut testa in Viet Nam using UAE with different solvents. By systematically assessing extraction efficiency, antioxidant capacity, and antimicrobial activity, this work seeks to provide scientific evidence supporting the valorization of cashew testa as a high-value natural resource, thereby contributing to sustainable agricultural by-product utilization and the development of functional ingredients for food, cosmetic, and pharmaceutical applications.

2 Material and Method

2.1 Material

Cashew testa samples were collected from cashew processing factories in Binh Phuoc, Dong Nai.

Chemicals: ethanol, methanol, Na_2CO_3, $AlCl_3$, CH_3COONa, ascorbic acid, Folin - Ciocalteu reagent, quercetin, gallic acid, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (St. Louis, MA, USA) and Merck (Germany). Brain Heart Infusion (BHI) media (Himedia) were also used.

Microbial strains: *S. aureus* ATCC 25923 and *C. albicans* ATCC 1023 were provided by Biotechnology Center of Ho Chi Minh City, Viet Nam.

2.2 Method

2.1.1 UAE procedure

Cashew testa was collected from Binh Phuoc, Dong Nai province. The raw material was cleaned and dried at 50 °C until the moisture content was below 12%, and ground into a fine powder. UAE was performed out using an ultrasonic bath (maximum power 600 W) with minor modifications [8]. Sample were extracted with different solvents (e.g. ethanol, methanol, and water) at a solid to solvent ratio of 1:10 for 180 min at 60 °C. The extracts were filtered, concentrated under reduced pressure at 40 °C using a rotary evaporator (Buchi, Switzerland), and freeze-dried to obtain powdered extracts. Extraction efficiency was calculated based on extraction yield.

2.2.2 Qualitative phytochemical analysis

Qualitative phytochemical characterization of cashew testa extracts was performed using established qualitative assays based on specific color reactions and precipitation

phenomena to detect major groups of secondary metabolites. Tannins were identified through gelatin precipitation reactions. Polyphenolic compounds were qualitatively detected using a 10% ferric chloride ($FeCl_3$) reagent, and flavonoids were identified by reaction with concentrated sulfuric acid (H_2SO_4) [9].

To further verify the occurrence of polyphenols and catechins, thin-layer chromatography (TLC) analysis was conducted [10]. Silicagel 60 F_{254} TLC plates (Merck, Germany) were activated at 110 °C for 30 min prior to analysis. Separation was achieved using a mobile phase consisting of chloroform: methanol: acetic acid (9:3:3 v/v/v). Extracts and reference standards (gallic acid and catechin, 10 g/L) were spotted onto the plates and developed for (25-30) min. After development, the plates were dried, sprayed with 1% $FeCl_3$ solution, and heated at (95-105) °C for (5-10) min. The presence of polyphenols and catechins was confirmed by comparing the color reactions and retention behavior of sample spots with those of the corresponding standards.

2.2.3 TPC determination

The TPC of cashew testa extracts was determined using the Folin-Ciocalteu method, with slight modifications [4]. Briefly, 1 mg of dried extract was dissolved in 1 mL of methanol to obtain a concentration of 1 mg/mL. An aliquot of 0.1 mL of this solution was mixed with 0.5 mL of 10% Folin-Ciocalteu reagent and allowed to react for 10 min. Subsequently, 0.4 mL of 7.5% Na_2CO_3 solution was added, and the mixture was incubated in the dark at 30 °C for 1 h. The absorbance was measured at 765 nm using ELISA reader (VersaMAX). All experiments were performed in triplicate. A calibration curve was prepared using gallic acid as a standard under the same experimental conditions, at concentrations of (500, 250, 125, 62.5, 31.25, and 15.625) µg/mL. TPC values of the extracts were expressed as milligrams of gallic acid equivalents per gram of extract (mg GAE/g).

2.2.4 Antioxidant activity

2.2.4.1 DPPH scavenging assay

The DPPH scavenging activity was measured as previously described with slight modifications [11]. Briefly, 400 µL of 0.1 mM DPPH solution prepared in methanol was added to 400 µL of extract solution at different concentrations (1.95-62.5) µg/mL. The mixtures were incubated in the dark for 30 min, then the absorbance was recorded at 517 nm using a UV-VIS spectrometer (UV-11 model,

Spectro, USA). Ascorbic acid at the concentrations of (1.95-62.5) µg/mL was used as the positive control, while methanol was used as the negative control. All experiments were performed in triplicate. The percentage of DPPH radical scavenging activity was calculated using the following equation. Radical scavenging activity (%) = $[1 - (Abs_{sample}/Abs_{control})] \times 100$. The IC_{50} value, defined as the extract concentration required to inhibit 50% of DPPH radicals, was determined from the linear regression equation obtained by plotting inhibition percentage against sample concentration.

2.2.4.2 ABTS scavenging assay

The ABTS scavenging activity was determined as previously described with minor modifications [12]. The $ABTS^{\bullet+}$ radical cation was generated by mixing 7 mM $ABTS^{\bullet+}$ solution with 2.45 mM potassium persulfate ($K_2S_2O_8$) and allowing the mixture to stand in the dark at room temperature for (12-16) h. The solution was diluted with methanol to an absorbance of 0.70 ± 0.02 at 734 nm. Extracts solutions (1.95-62.5) µg/mL were mixed with 900 µL of the $ABTS^{\bullet+}$ working solution and incubated in the dark for 6 min, and absorbance was measured at 734 nm using a UV-VIS spectrometer (UV-11 model, Spectro, USA). Ascorbic acid at the concentrations of (1.95-62.5) µg/mL was used as positive control, methanol as negative control. All assays were performed in triplicate. ABTS radical scavenging activity was calculated as: Radical scavenging activity (%) = $[1 - (Abs_{sample}/Abs_{control})] \times 100$. IC_{50} values were determined from the linear regression of inhibition percentage versus concentration.

2.2.5 Antibacterial activity

2.2 5.1 Disc diffusion assay

The antibacterial activity of the cashew testa extract was evaluated using the disc diffusion method with minor

modifications [13]. *S. aureus* ATCC 25923 and *C. albicans* ATCC 1023 were cultured in Brain Heart Infusion (BHI) broth at 37 °C for 24 h, and microbial suspensions were adjusted to 10^6 CFU/mL. Sterile Mueller-Hinton agar plates were inoculated, and wells (6 mm diameter) were filled with 50 µL of extract (400 µg/mL). Gentamicin (100 µg/mL) served as the positive control. After incubation at 37 °C for 24 h, diameters of inhibition zones were measured. Antibacterial activity was expressed as the inhibition zone diameter (r, mm), calculated as $r = D - d$, where D is the total diameter including the well and d is the well diameter (6 mm). All experiments were performed in triplicate.

2.2.5.2 Minimum inhibitory concentration (MIC)

The MICs were determined by broth microdilution in 96-well method [18]. The extract was poured into a sterile 96-well plate at various concentrations (0.19-100) µg/mL. Subsequently, 100 µL of bacterial suspension cultured BHI medium for (16-18) h at a concentration of (1.5×10^6) CFU/mL was added. A bacterial suspension without extracts was used as a positive control, while negative control was made with only extracts and no bacterial suspension. The 96-well microplate was incubated at 37 °C for 24 h to 48 h. Afterward, 30 µL of 0.01% resazurin was added to each well and incubated further at 35 °C for 30 minutes. The MIC was determined as the lowest concentration of the extract at which the resazurin reagent did not turn pink, indicating the inhibition of microbial growth.

2.3 Data analysis

All experiments were performed in triplicate, and results are presented as mean ± standard deviation (S.D.). Statistical analyses were conducted using Statgraphics and Microsoft Excel 2013. Differences among treatments were evaluated by analysis of variance (ANOVA), with statistical significance defined at $p < 0.05$.

3 Results and Discussion

3.1 Extraction yield of cashew testa extracts

UAE was performed using ethanol, methanol, and water to assess the effect of solvent type on the extraction efficiency of cashew testa**.** As shown in Figure 1, the freeze-dried methanol (ME) and ethanol (EE) extracts exhibited a darker and more homogeneous appearance than the water extract (WE), indicating a higher recovery of phenolic-rich components. Methanol achieved the highest extraction yield (36.07 ± 1.70)%, followed by ethanol (26.53 ± 2.87)% and water (15.47 ± 0.31)% (Table 1). These findings indicate that solvent polarity plays a crucial role in the extraction process, with methanol demonstrating the most effective recovery of cashew testa constituents. This enhanced performance is likely due to its suitable polarity, which improves the solubility of a broad range of phenolic compounds compared with ethanol and especially water [15]. Under UAE conditions, acoustic cavitation enhances solvent penetration and mass transfer, thereby facilitating the Additionally, under UAE conditions, acoustic cavitation enhances solvent penetration and mass transfer, facilitating the release of intracellular phenolic compounds [12]. Consistent with previous reports, organic solvents generally yield higher phenolic recovery than aqueous systems under both conventional and ultrasound-assisted extraction conditions [8, 15].

Figure 1 Cashew testa extract powder from different extraction solvent

WE: Water extract, EE: Ethanol extract, ME: Methanol extract.

Table 1 Extraction efficiency (%) of different extraction solvents

Sample	Extraction efficiency (%)
EE	$26.53^b \pm 2.87$
ME	$36.07^a \pm 1.7$
WE	$15.47^c \pm 0.31$

Letter a, b, c: different letters indicate significant differences ($p < 0.05$).

The extraction efficiency of phenolic compounds from cashew testa was strongly influenced by solvent polarity. Methanol and ethanol yielded significantly higher extraction efficiencies than water, consistent with previous reports highlighting the superior solubilization capacity of organic solvents for phenolic compounds [15]. Although methanol showed the highest extraction efficiency, ethanol is generally preferred for food and pharmaceutical applications due to its lower toxicity and regulatory acceptance [16]. Under UAE conditions, acoustic cavitation further enhanced mass transfer and facilitated the release of intracellular phenolic compounds [8].

3.2 Phytochemical screening and TPC

Qualitative phytochemical screening of the cashew testa extracts demonstrated the presence of major bioactive groups, including phenolics, tannins, and flavonoids, across all tested solvents (Table 2). The presence of phenolic compounds was further confirmed by thin-layer chromatography (TLC), which showed comparable migration behavior and color reactions among the extracts((Figure 2). These results confirm cashew testa as a rich source of natural bioactive compounds, particularly polyphenols. These metabolites are well known for their antioxidant and antimicrobial properties, contributing to the functional potential of the extracts. Moreover, UAE demonstrated effective recovery of phenolic constituents while preserving their native profiles, offering a practical advantage over conventional and enzyme-assisted extraction methods in terms of efficiency and process simplicity.

Table 2 Qualitative phytochemical results

Sample	tannin	flavonoid	polyphenol
EE	+	+	+
ME	+	+	+
WE	+	+	+

WE: Water extract, EE: Ethanol extract, ME: Methanol extract

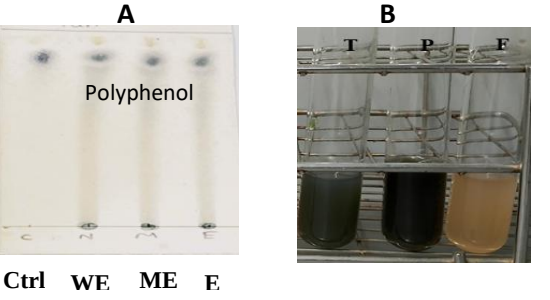

Figure 2 Qualitative phytochemical results (A. TLC method; B. classical biochemical reactions: T: Tanin, P: Pholyphenol, F: Flavonoid)

3.3 TPC

The TPC of cashew testa extracts is shown in Table 3. The ME exhibited the highest TPC (484.06 ± 4.26) mg GAE/g, followed by EE, (465.33 ± 4.69) mg GAE/g and WE (453.13 ± 0.65) mg GAE/g. The superior performance of methanol may be attributed to its polarity and hydrogen-bonding capacity which enhance the solubility of phenolic compounds. These results are consistent with previous studies in which lower TPC values was obtained from ethanol and methanol extracts of cashew testa under conventional and optimized UAE conditions [7]. The high TPC observed in this study confirms that methanol is an efficient solvent for phenolic recovery, while ethanol remains a more practical and safer option for large-scale food and pharmaceutical applications.

Table 3 TPC of cashew testa extract powder obtained from different extraction solvents.

Sample	EE	ME	WE
TPC (mg GAE/g extract)	465.33^{b} ± 4.69	484.06^{a} ± 4.26	453.13^{c} ± 0.65

Notes: Different letters indicate significant differences ($p < 0.05$).

3.4 Antioxidant activity

3.4.1 DPPH radical scavenging activity

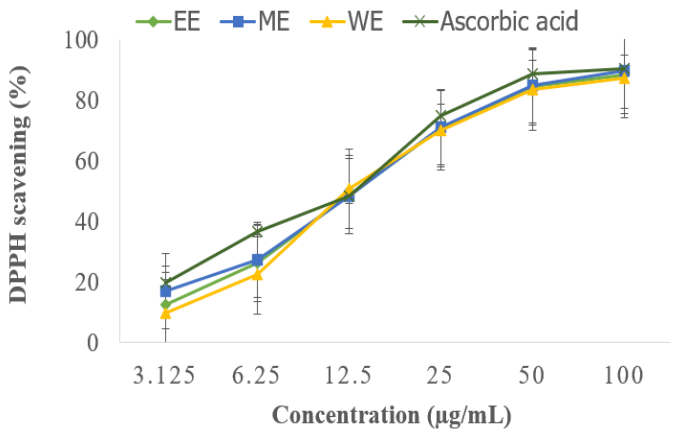

Figure 3 DPPH radical scavenging activity (%) of water extract (WE), ethanol extract (EE), and methanol extract (ME) at different concentrations (3.125-100) µg/mL.

Table 4 IC_{50} value of cashew testa extract powder obtained from different extraction solvents

Sample	Equation	IC_{50} value (µg/mL)
EE	$y = 22.787\ln(x) - 9.674$, $R^2 = 0.9683$	13.72 ± 0.50
ME	$y = 22.451\ln(x) - 7.7085$, $R^2 = 0.9759$	13.07 ± 0.35
WE	$y = 23.913\ln(x) - 14.249$, $R^2 = 0.9607$	14.68 ± 0.54
Ascorbic acid	$y = 22.05\ln(x) - 3.6337$, $R^2 = 0.9603$	11.39 ± 0.96

The antioxidant capacity of the cashew testa extracts was first evaluated using the DPPH radical scavenging assay. As shown in Figure 3, all extracts exhibited a clear concentration-dependent increase in radical scavenging activity from 7.61% to 88.56%. Importantly, no significant difference was observed between the extracts and the positive control (ascorbic acid) at higher concentrations. The calculated IC_{50} values were (13.07 ± 0.35) µg/mL, (13.72 ± 0.50) µg/mL, and (14.68 ± 0.54) µg/mL for ME, EE and WE, respectively, compared with (11.39 ± 0.96) µg/mL for ascorbic acid (Table 4). These results indicate that all extracts possess strong radical scavenging potential, with methanol slightly outperforming ethanol and water. The differences in activity may be related to solvent dependent differences in polyphenol concentration, as higher polyphenol yields generally enhance antioxidant capacity.

3.4.2 ABTS radical scavenging activity

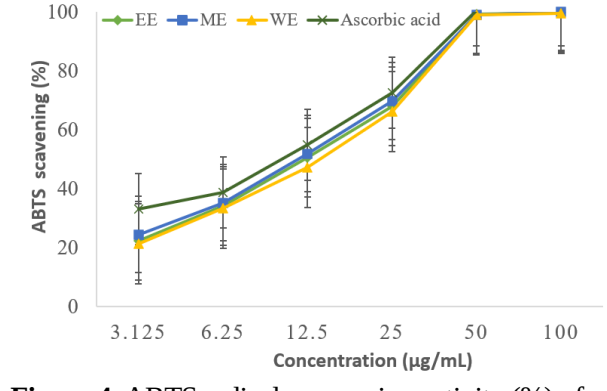

Figure 4 ABTS radical scavenging activity (%) of water extract (WE), ethanol extract (EE), and methanol extract (ME) at different concentrations (3.125-100) µg/mL.

Table 5 IC_{50} value of Cashew testa extract powder obtained from different extraction solvents

Sample	Equation	IC_{50} value (µg/mL)
EE	$y = 24.282\ln(x) - 6.9244$, $R^2 = 0.9545$	10.43 ± 0.27
ME	$y = 23.646\ln(x) - 4.7629$, $R^2 = 0.9462$	10.14 ± 0.31
WE	$y = 24.956\ln(x) - 10.874$, $R^2 = 0.9526$	11.36 ± 0.26

The ABTS assay further confirmed the antioxidant potential of cashew testa extracts. As shown in Figure 4, radical scavenging activity increased in a clear dose-dependent manner from 21.00% to 99.79%. The IC_{50} values were (10.14 ± 0.31) µg/mL, (10.43 ± 0.27) µg/mL, and (11.36 ± 0.26) µg/mL for ME, EE and WE, respectively, compared with 8.32 µg/mL for ascorbic acid (Table 5). Although less potent than ascorbic acid, both methanol and ethanol extracts exhibited significantly higher ABTS scavenging activity than water extract. The antioxidant performance closely corresponded to the TPC of the extracts, supporting the

established role of phenolic compounds as primary contributors to ABTS scavenging activity. Comparable antioxidant activities of cashew testa extracts have been reported demonstrating strong DPPH IC_{50} = (12.35 ± 1.48) µg/mL and ABTS IC_{50} = (33.77 ± 1.04) µg/mL scavenging capacities [4]. Furthermore, comparison with our previous work employing conventional maceration revealed higher IC_{50} values, indicating lower antioxidant activity. This highlights the critical influence of extraction methodology on bioactivity, with UAE providing enhanced polyphenol recovery and preservation, resulting in stronger antioxidant performance.

Overall, both DPPH and ABTS assays demonstrated that all cashew testa extracts are capable of effectively scavenging free radicals. Flavan-3-ols such as catechin, epicatechin, and procyanidins act as effective antioxidants by donating electrons or hydrogen atoms to neutralize free radicals, while the resulting phenoxyl radicals are stabilized through resonance structures, thereby terminating oxidative chain reactions [17]. Phenolic-rich extracts have been reported to reduce intracellular reactive oxygen species (ROS), protect biomolecules from oxidative damage, and activate endogenous antioxidant defense pathways, including Nrf2-mediated signaling, in cellular models [18]. From an application standpoint, these properties support the use of cashew testa extracts as natural antioxidants in food, cosmetic, and pharmaceutical formulations. While ME and EE were more efficient in recovering bioactive phenolics, EE represents a safer and more sustainable solvent for industrial-scale applications. Collectively, these findings highlight cashew testa as a valuable phenolic-rich by-product with strong antioxidant potential. The ME and EE extracts consistently exhibited higher activities than the water extract, reflecting their greater efficiency in extracting phenolic compounds. These results are consistent with previous studies in which cashew testa contained catechin, epicatechin, and procyanidins that exhibited strong free radical scavenging activities. These findings confirm cashew testa as a valuable source of natural antioxidants, with solvent selection (particularly methanol and ethanol) as a critical factor in maximizing antioxidant efficiency.

3.5 Antibacterial activity

The antimicrobial assays demonstrated that all cashew testa extracts exhibited inhibitory effects against *S. aureus* and *C. albicans* (Figure 5). Among them, EE and ME showed the strongest activity, as indicated by inhibition zones exceeding 11 mm (Table 6). Specifically, the ME produced the largest inhibition zone against *S. aureus* (13.5 ± 0.5) mm, followed by EE (12.5 ± 0.5) mm and WE (11.17 ± 0.29) mm. For *C. albicans*, both EE and ME demonstrated inhibition zones greater than 11 mm, whereas WE displayed the weakest effect (10.5 ± 0.5) mm. The MIC assay further supported these observations (Figure 6). Both EE and ME exhibited strong antimicrobial effects, with MIC values of 1.56 mg/mL and 0.78 mg/mL, respectively. These findings suggested that ME and EE are more effective than water in recovering antimicrobial compounds from cashew testa, likely due to their favorable polarity.

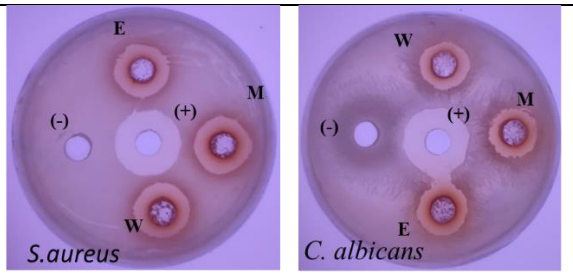

Figure 5 Antibacterial activity of WE, EE and ME against *S. aureus* and *C. albicans* by disk diffusion

Table 6 Measurement of inhibition zone diameters (mm) of WE, EE and ME against *S. aureus* and *C. albicans*

Sample	Diameter of inhibition zone of (mm)	
	S.aureus	***C.albicans***
EE	12.5^{a} ± 0.5	11.17^{a} ± 0.29
ME	13.5^{a} ± 0.5	11.33^{a} ± 0.58
WE	11.17^{b} ± 0.29	10.5^{a} ± 0.5

Different letters indicate significant differences ($p < 0.05$).

The antimicrobial activity observed for cashew testa extracts is consistent with previous studies reporting strong antibacterial and antifungal properties of polyphenol-rich extracts. In the present study, EE and ME extracts produced significantly larger inhibition zones (> 11 mm) against *S. aureus* and *C. albicans* and exhibited lower MIC values (0.78 - 1.56) mg/mL than WE, indicating superior antimicrobial potency.

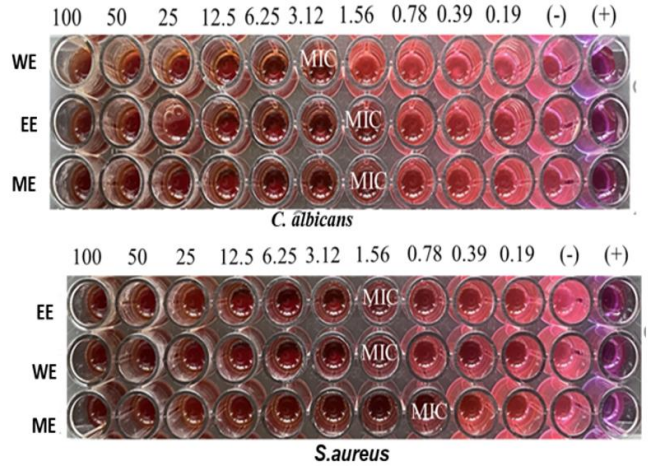

Figure 6 MIC results of WE, EE and ME.

This enhanced activity is closely associated with their higher polyphenol content and more efficient recovery of bioactive compounds. Polyphenols, particularly catechins, flavonoids, and coumarin derivatives, are known to disrupt microbial cell membranes, interfere with essential metabolic enzymes, and inhibit cell division. Moreover, synergistic interactions among these phenolic constituents may further amplify antimicrobial efficacy. The solvent-dependent differences in inhibition zones and MIC values underscore the critical role of extraction solvent polarity in maximizing the recovery and biological effectiveness of antimicrobial compounds from cashew testa.

4 Conclusion

This study demonstrated that UAE is an effective method for recovering polyphenols from cashew testa, yielding extracts with strong antioxidants and antimicrobial activities. Among the tested solvents, the ME and EE exhibited the highest bioactivity, as evidenced by its superior radical scavenging capacity and inhibitory effects against *S. aureus* and *C. albicans*. These findings highlighted the influence of extraction methods on the biological efficacy of cashew testa extracts and underscore their potential as sustainable value added products derived from agricultural by-products.

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Tài liệu tham khảo

1. WTO Center Vietnam. (2024). Cashew nut export performance of Vietnam in 2024. WTO Center Viet Nam. https://wtocenter.vn/tin-tuc/26895-cashew-industry-and-new-export-record (accessed: 22 April 2025).
2. Vietnam Cashew Association (VINACAS). (2023). Annual report of the Vietnam cashew industry. VINACAS. Available at: https://vinacas.com.vn (accessed: 22 April 2025).
3. N. Chandrasekara, F. Shahidi. (2011). Effect of roasting on phenolic content and antioxidant activities of whole cashew nuts, kernels, and testa. *Journal of Agricultural and Food Chemistry* 59(9), 5006-5014. https://doi.org/10.1021/jf2000772

4. P. Sruthi, C. Roopavathi, M.M. Naidu. (2023). Profiling of phenolics in cashew nut (Anacardium occidentale L.) testa and evaluation of their antioxidant and antimicrobial properties. *Food Bioscience* 51, 102246. https://doi.org/10.1016/j.fbio.2022.102246.

5. R.M. Smith. (2003). Before the injection-modern methods of sample preparation for separation techniques. *Journal of Chromatography A* 1000(1–2), 3–27. https://doi.org/10.1016/S0021-9673(03)00511-9.

6. S. Sasidharan, Y. Chen, D. Saravanan, K.M. Sundram, Y.L. Latha. (2011). Extraction, isolation and characterization of bioactive compounds from plants' extracts. *African Journal of Traditional, Complementary and Alternative Medicines* 8(1), 1–10. https://www.ajol.info/index.php/ajtcam/article/view/60483.

7. T.N. Nguyen, M.D. Doan, D.V. Nguyen, T.Q.P. Le. (2024). Optimizing conditions for total phenolic contents using ultrasound-assisted extraction from cashew testa (*Anacardium occidentale* Linn.). *Journal of Science and Technology, Industrial University of Ho Chi Minh City* 72(6), 45–54.

8. F. Chemat, N. Rombaut, A.G. Sicaire, A. Meullemiestre, A.-S. Fabiano-Tixier, M. Abert-Vian. (2017). Ultrasound assisted extraction of food and natural products: Mechanisms, techniques, combinations, protocols and applications. *Ultrasonics Sonochemistry* 34, 540-560. https://doi.org/10.1016/j.ultsonch.2016.06.035.

9. P. Tiwari, B. Kumar, M. Kaur, G. Kaur, H. Kaur. (2011). Phytochemical screening and extraction: A review. *International Pharmaceutica Sciencia* 1(1), 98-106.

10. V. Rastija, A. Mornar, I. Jasprica, G. Srečnik, M. Medić-Šarić. (2004). Analysis of phenolic components in Croatian red wines by thin-layer chromatography. *Journal of Planar Chromatography - Modern TLC* 17(1), 26-31. https://doi.org/10.1556/jpc.17.2004.1.6

11. İ. Gülçin, S.H. Alwasel. (2023). DPPH radical scavenging assay. *Processes* 11(8), 2248. DOI:10.3390/pr11082248

12. R.A.M. de Sena Andrade, V.B.V. Maciel, R.R. Pereira, F.H.A. Rodrigues, D.C. Rodrigues, A.L. Oliveira, L.P.S. Cassiano, E.K. Silva, M.A.A. Meireles. (2023). Microencapsulation of phenolic compounds from cashew apple (Anacardium occidentale L.) agro-food waste: Physicochemical characterization, antioxidant activity, bioavailability and stability. *Food Chemistry Advances* 3, 100364. https://doi.org/10.1016/j.focha.2023.100364

13. P. Ngamsurach, P. Praipipat. (2022). Antibacterial activities against Staphylococcus aureus and Escherichia coli of extracted Piper betle leaf materials by disc diffusion assay and batch experiments. *RSC Advances* 12(40), 26435–26443. https://doi.org/10.1039/D2RA04064A.

14. V. Caso Coelho, A.M.C. Pereira, A.M.C. Coelho, R.B. Pedroso, D. Silveira, T.F.F. Magalhães, A.L. Mattos-Guaraldi. (2021). Evaluation of antimicrobial susceptibility testing of Nocardia spp. isolates by broth microdilution with resazurin and spectrophotometry. *BMC Microbiology* 21(1), 331. https://doi.org/10.1186/s12866-021-02357-6.

15. M. Pinelo, M. Rubilar, M. Jerez, J. Sineiro, M.J. Núñez. (2008). Effect of solvent, temperature, and solvent-to-solid ratio on the total phenolic content and antiradical activity of extracts from grape pomace. *Journal of Agricultural and Food Chemistry* 56(6), 2111-2117. https://doi.org/10.1021/jf073366b.

16. J. Dai, R.J. Mumper. (2010). Plant phenolics: Extraction, analysis and their antioxidant and anticancer properties. *Molecules* 15(10), 7313–7352. https://doi.org/10.3390/molecules15107313.

17. R.L. Prior, X. Wu, K. Schaich. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. *Journal of Agricultural and Food Chemistry* 53(10), 4290-4302. https://doi.org/10.1021/jf0502698.

18. H.-K. Na, Y.-J. Surh. (2008). Modulation of Nrf2-mediated antioxidant and detoxifying enzyme induction by the green tea polyphenol (-)-epigallocatechin-3-gallate. *Food and Chemical Toxicology* 46(4), 1271-1278. https://doi.org/10.1016/j.fct.2007.11.006.

Ứng dụng phương pháp siêu âm trong chiết xuất polyphenol từ vỏ lụa hạt điều (*Anacardium occidentale* L.) và đánh giá hoạt tính chống oxy hóa, kháng khuẩn

Nguyễn Thị Dung[1,*], Châu Hồng Nhật Linh[2], Chu Hoàng Châu Anh[2], Trần Gia Minh Tâm[3], Nguyễn Văn Toàn[1], Nguyễn Thị Nữ Trinh[1]

[1]Trung tâm Công nghệ Sinh học Thành phố Hồ Chí Minh
[2]Trường chuyên Trần Đại Nghĩa
[3]Vinschool
thuydung9810@gmail.com

Tóm tắt Vỏ lụa hạt điều (*Anacardium occidentale* L.) là phụ phẩm của ngành công nghiệp chế biến hạt điều, chứa nhiều hợp chất có hoạt tính sinh học. Nghiên cứu này nhằm đánh giá hàm lượng polyphenol và hoạt tính sinh học của cao chiết từ vỏ hạt lụa điều tại Việt Nam bằng phương pháp chiết xuất hỗ trợ siêu âm với các dung môi khác nhau. Kết quả nghiên cứu cho thấy dung môi methanol và ethanol tỏ ra hiệu quả nhất, cho hàm lượng polyphenol tổng số cao nhất lần lượt là 465,33 mg GAE/g và 484,06 mg GAE/g, xác định theo phương pháp Folin - Ciocalteu. Hoạt tính chống oxy hóa của các chiết xuất được đánh giá bằng phương pháp DPPH và ABTS. Ở nồng độ 100 µg/mL, cao chiết methanol và ethanol thể hiện khả năng bắt gốc tự do mạnh, với % ức chế > 87 % (DPPH) và > 99 % (ABTS). Giá trị IC_{50} tương ứng là 13,07 và 10,14 µg/mL đối với cao methanol, và (13,72 và 10,43) µg/mL đối với cao ethanol. Hoạt tính kháng khuẩn của chúng được đánh giá đối với *Staphylococcus aureus* và *Candida albicans*. bằng phương pháp khuếch tán đĩa thạch và phương pháp Nồng độ ức chế tối thiểu. Kết quả cho thấy cao chiết methanol và ethanol đều cho hiệu quả ức chế rõ rệt, với đường kính vòng vô khuẩn > 11 mm và nồng độ ức chế tối thiểu đạt 1,56 mg/mL. Nhìn chung, kết quả cho thấy chiết xuất hỗ trợ siêu âm kết hợp với lựa chọn dung môi phù hợp là giải pháp hiệu quả để thu nhận cao chiết giàu polyphenol từ vỏ lụa hạt điều, góp phần định hướng ứng dụng phụ phẩm này như nguồn chất chống oxy hóa và kháng khuẩn tự nhiên cho các lĩnh vực thực phẩm, mỹ phẩm và dược phẩm.

Từ khóa Chống oxy hóa; kháng khuẩn; vỏ lụa hạt điều; polyphenols; chiết xuất hỗ trợ siêu âm.