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Effects of Solvents on Phenolic Compounds and Bioactivities of Fig (*Ficus carica*) Leaf Extracts using Ultrasound-Assisted Method

(Kesan Pelarut terhadap Sebatian Fenol dan Aktiviti Biologi Ekstrak Daun Tin (*Ficus carica*) menggunakan Kaedah Berbantukan Ultrabunyi)

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ABSTRACT

Fig (*Ficus carica* Linn.) leaves are well-known for their abundant phytochemicals and various bioactivities, including antioxidant and antibacterial properties. The choice of solvent plays a crucial role in extracting these bioactive compounds. However, there are limited studies on comparing the effects of different solvents in fig leaf extraction using ultrasound-assisted methods. This research investigates the influence of 100% methanol, 80% methanol, and water on the bioactive potential of the fig leaf extracts. Total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity were determined using Folin–Ciocalteu, aluminium chloride, and 2,2-diphenyl-1-picrylhydrazyl radical scavenging assays, respectively, while antibacterial activity was tested through disk diffusion method. Results showed that the 100% methanol extract displayed the highest TPC (61.68 mg GAE/g) and TFC (166.52 mg QE/g) whereas the 80% methanol extract demonstrated the highest extraction yield (19.47%) and the strongest antibacterial activity against *Escherichia coli* and *Salmonella typhimurium*. The water extract exhibited the highest antioxidant activity (IC_{50}: 1343.83 µg/mL). In conclusion, the type of extraction solvent significantly influenced the extraction efficiency and biological activities of fig leaf extracts, with 80% methanol providing the highest yield and antibacterial activity while exhibiting moderate antioxidant performance. These findings highlight the importance of solvent selection in developing fig leaf extracts for potential food and pharmaceutical applications.

Keywords: Antibacterial activity; antioxidant activity; *Ficus carica* Linn.; total phenolic content; ultrasound-assisted extraction (UAE)

ABSTRAK

Daun tin (*Ficus carica* Linn.) terkenal dengan kandungan fitokimia yang kaya dan pelbagai aktiviti bioaktif, termasuk sifat antioksida dan antibakteria. Pemilihan pelarut memainkan peranan penting dalam pengekstrakan sebatian bioaktif ini. Walau bagaimanapun, kajian yang membandingkan kesan pelbagai pelarut dalam pengekstrakan daun tin dengan menggunakan kaedah berbantukan ultrabunyi adalah terhad. Penyelidikan ini mengkaji pengaruh pelarut 100% metanol, 80% metanol dan air terhadap potensi bioaktif ekstrak daun tin. Jumlah kandungan fenol (TPC), jumlah kandungan flavonoid (TFC) dan aktiviti antioksida masing-masing ditentukan melalui ujian Folin-Ciocalteu, aluminium klorida dan perencatan radikal bebas 2,2-difenil-1-pikrilhidrazil, sementara aktiviti antibakteria diuji melalui kaedah resapan cakera. Keputusan menunjukkan bahawa ekstrak 100% metanol menghasilkan nilai tertinggi TPC (61.68 mg GAE/g) dan TFC (166.52 mg QE/g), manakala ekstrak 80% metanol memberikan hasil pengekstrakan tertinggi (19.47%) dan aktiviti antibakteria terkuat terhadap *E. coli* dan *S. typhi*. Ekstrak air menunjukkan aktiviti antioksida yang paling kuat (IC_{50}: 1343.83 µg/mL). Kesimpulannya, jenis pelarut pengekstrakan mempengaruhi kecekapan pengekstrakan dan aktiviti biologi ekstrak daun tin dengan ketara dengan 80% metanol memberikan hasil dan aktiviti antibakteria tertinggi sambil menunjukkan prestasi antioksida yang sederhana. Penemuan ini menekankan kepentingan pemilihan pelarut dalam pembangunan ekstrak daun tin untuk potensi aplikasi makanan dan farmaseutikal.

Kata kunci: Aktiviti antibakteria; aktiviti antioksida; *Ficus carica* Linn.; jumlah kandungan fenol; pengekstrakan berbantukan ultrabunyi

INTRODUCTION

Medicinal plants are promising alternative and sustainable sources for improving human health and treating diseases owing to their diverse bioactive constituents, widespread availability, and low toxicity (Stéphane et al. 2021). They have been explored as active products in various applications such as food, pharmaceutical, and cosmetic industries. Among them, *Ficus carica* Linn., usually known as a common fig, has long gained attention for its flavorful fruit, health benefits, and esthetic value. *Ficus carica* is under the Moraceae (mulberry) family, widely cultivated in tropical and subtropical regions due to its adaptability and ease of growth, and a popular choice among consumers given its richness in minerals, vitamins, carbohydrates, and antioxidants (Alzahrani et al. 2024; Fazel et al. 2024). Worldwide, including in Malaysia, fig products exist in various forms, such as fresh fruits, beverages, jams, cakes, and confectioneries (Rasool et al. 2023).

According to the Food and Agriculture Organization of the United Nations (FAO) (2025), global fig production in 2024 has remained stable exceeded one million tons, with Mediterranean countries such as Turkey, Egypt, Algeria, and Morocco contributing around 50% of the overall output. Its demand continues to rise, reflecting the growing popularity of figs. Parts of *Ficus carica*, including fruits, leaves, peels, latex, and seeds, have demonstrated antioxidant, antimicrobial, antidiabetic, anti-inflammatory, and anticancer effects, highlighting their potential for various applications (Ayuso et al. 2022). Fig leaves have recently studied as natural sources of bioactive compounds for food preservation and packaging applications as strategies to prevent food quality deterioration during various stages of production, which is mainly caused by microbial growth and oxidation (Abdel-Aziz et al. 2020; Alzahrani et al. 2024; Haider et al. 2023). This growing interest is closely related to the wide range of phytochemicals in fig leaves such as phenolic acids, flavonoids, coumarins, and organic acids, thereby emphasizing the need for efficient extraction of these compounds (Li et al. 2021).

Previous studies have shown that differences in the bioactive constituents of fig leaf extracts are influenced by intrinsic factors (cultivar, location, and harvest season) as well as processing conditions, including extraction method and solvent type (Ayuso et al. 2022; Petruccelli et al. 2018; Radwan et al. 2020). Common extraction process for *Ficus carica* includes conventional techniques (decoction, maceration, and Soxhlet extraction), and modern approaches such as microwave-assisted and ultrasound-assisted extraction (Fazel et al. 2024; Rasool et al. 2023). Ultrasound-assisted extraction, which uses mechanical bubble action to disrupt cell walls and improve solvent penetration, has gained increasing attention due to enhanced mass transfer, improved extraction efficiency, energy-saving advantages, and minimal degradation of thermolabile compounds (Akhtar et al. 2019; Alara, Abdurahman & Ukaegbu 2021; Khound et al. 2023). Despite that, the choice of solvent remains a critical role in determining the solubility and recovery of bioactive compounds.

Earlier investigations showed that solvent systems significantly affected the resulting phytochemical content and biological properties of fig leaf extracts, primarily due to differences in solvent polarity (Merzic et al. 2021; Renda et al. 2023; Weli, Al-Blushi & Hossain 2015). These studies employed a range of solvents, including polar solvents (water, methanol, and ethanol), medium-polar solvents (acetone and ethyl acetate), non-polar solvents (hexane), and a mixture of organic solvent and water. Water is a highly polar, environmentally friendly, most safest solvent suitable for extracting hydrophilic compounds. Methanol and aqueous methanol are commonly used for extracting both hydrosoluble and liposoluble antioxidant and antibacterial compounds effectively, while offering practical advantages in laboratory extraction (low cost, readily available, and easy removal) (Stéphane et al. 2021; Xu et al. 2017). In particular, the incorporation of 20-75% water into alcoholic solvents has been shown to improve the diffusion and solubilization of phenolic and flavonoid compounds from plant tissues, resulting in enhanced biological effects of fig leaf extracts (Merzic et al. 2021; Plaskova & Mlcek 2023; Radwan et al. 2020).

Differences in solvent properties highlight the importance of understanding their effects on the phytochemical profile and biological performance of plant extracts. However, comparative information on the influence of different extraction solvents under ultrasound-assisted extraction, particularly for fig leaves grown in Malaysia, remains limited. Therefore, this study aimed to evaluate the effects of water, methanol, and aqueous methanol on the recovery of phenolic and flavonoid compounds, as well as the antioxidant activity of fig leaf extracts. Antibacterial effects were also tested against *E. coli* and *S. typhi*, both common foodborne pathogens of food safety concern. The study outcomes provide preliminary insights into solvent selection for ultrasound-assisted extraction of bioactive compounds from fig leaves, with potential applications in food and pharmaceuticals.

MATERIALS AND METHODS

REAGENTS

Methanol, dimethyl sulfoxide (DMSO), sodium nitrite ($NaNO_2$), sodium carbonate (Na_2CO_3), sodium hydroxide (NaOH), aluminum chloride ($AlCl_3$), gallic acid, quercetin, Folin-Ciocalteu's (FC) phenol reagent, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma-Aldrich (USA). All the chemicals were analytical reagents or HPLC grades. Mueller-Hinton agar (MHA) and Mueller-Hinton broth (MHB) were supplied by Himedia (India), and ciprofloxacin disks (5 µg/disk) were procured from Oxoid (UK). Whatman filter papers (USA) were used for sample separation (No. 1) and antibacterial assay (antibiotic assay disk). Milli-Q ultrapure water (Germany) was used to prepare extract and dilute materials.

PLANT SAMPLES

Fresh fig leaves were collected from Mutiara Figs Garden, Shah Alam, Selangor, Malaysia. Herbarium of Universiti Kebangsaan Malaysia (UKM) Bangi, Selangor, Malaysia, conducted species identification and assigned the specimen voucher (ID070/2023). The leaves were cleaned, dried in an oven at 50 °C, and then pulverized into powder using a blender.

EXTRACTION PROCESS

Fig leaf extracts were prepared according to the method by Merzic et al. (2021), with some modifications. Fig leaf powder (10 g) was mixed with 100 mL of solvents (100% methanol, 80% methanol (in water), and water) and sonicated in an ultrasonic bath (S60H, Elmasonic, Germany) at room temperature for 30 min. The extracts were filtered, and the solids were subjected to two additional rounds of sonication. The solvents were evaporated using a rotary evaporator (RE600, Yamato Scientific, Japan), and the extracts were frozen at -30 °C for 24 h before being dried in a freeze dryer (BTP-9EGE0X, SP Scientific, USA) to complete dryness. The dry green extracts were weighed, stored in a secured glass vial, and placed in a freezer until analysis. The extraction yield (%) was calculated as follows:

$$\text{Extraction yield (\%)} = \frac{\text{Weight of dry extract (g)}}{\text{Weight of leaf powder (g)}} \times 100$$

TOTAL PHENOLIC CONTENT

The total phenolic content (TPC) of the extracts was determined using the FC method with some modifications (Mopuri et al. 2018). The extract was dissolved in methanol to a concentration of 1 mg/mL. Then, 0.5 mL of the sample was mixed with 2 mL of 10% (v/v) FC reagent for 5 min before adding 2 mL of 7.5% (w/v) Na_2CO_3 and incubated for 30 min. The absorbance was measured using a spectrophotometer (DR 3900, Hach Company, USA) at 760 nm. The TPC was determined from the gallic acid standard curve (0.02-0.10 mg/mL) and expressed as milligram gallic acid equivalent per gram of extract (mg GAE/g).

TOTAL FLAVONOID CONTENT

The total flavonoid content (TFC) was quantified using previous methods with some changes (Mopuri et al. 2018). The sample was mixed with 0.3 mL of 5% (w/v) $NaNO_2$, 0.3 mL of 10% (w/v) $AlCl_3$, and 2 mL of 4% (w/v) NaOH and incubated for 30 min. The absorbance was measured at 510 nm, and the TFC was obtained from the quercetin standard curve (0.1-0.5 mg/mL) and written as milligram quercetin equivalent per gram of extract (mg QE/g).

ANTIOXIDANT ACTIVITY

The antioxidant activity was evaluated using a modified DPPH free radical scavenging method (Akhtar et al. 2019). Fig leaf extract solutions were prepared in methanol, mixed with 0.1 mM DPPH in methanol, and incubated in the dark for 60 min. The absorbance was measured at 517 nm, and the antioxidant activity was expressed as IC_{50}, the inhibition concentration required to decrease the DPPH free radical by 50%. IC_{50} was derived from the linear regression graph of radical scavenging activity (RSA) against the concentration of samples. The RSA of the sample was calculated as follows:

$$\text{RSA (\%)} = \frac{A_0 - A_1}{A_0} \times 100$$

A_0 = Absorbance of the DPPH control and A_1 = Absorbance of the sample mixture.

ANTIBACTERIAL ACTIVITY

The Faculty of Science and Technology, UKM provided laboratory-isolated *E. coli* and *S. typhi* strains, maintained as glycerol stock cultures at -40 °C. The antibacterial activity was assessed using the disk diffusion method (Weli, Al-Blushi & Hossain 2015). The fig leaf extracts at 10, 50, 100, and 150 mg/mL concentrations were prepared in 10% DMSO and filtered with 0.22-µm filters. Sterile 6-mm antibiotic assay disks were impregnated with 200 µL of extracts and air-dried under laminar flow before placing them on MHA plates inoculated with *E. coli* and *S. typhi*. The plates were then incubated at 37 °C for 24 h. Antibacterial activity was recorded by measuring the diameter of the inhibition zone surrounding the disks in millimeters (mm). The positive and negative controls were ciprofloxacin and 10% DMSO, respectively.

STATISTICAL ANALYSIS

All the experiments were performed in triplicate, and results were expressed as the mean values ± standard deviation. Statistical comparisons were performed using Pearson's correlation analysis and one-way analysis of variance (ANOVA) with Tukey's test, with a significance level set at $p < 0.05$. Microsoft Excel 2016 (Microsoft Corporation, USA) and XLSTAT (Addinsoft, France) software were used to conduct the data analysis.

RESULTS AND DISCUSSION

EXTRACTION YIELD

The extraction yields (Table 1) followed the order: 80% methanol > 100% methanol > water. The yield obtained with 80% methanol was higher than that of 100% methanol, consistent with findings on *Limnophila aromatica*, where aqueous methanol system outperformed absolute methanol (Do et al. 2014). This supports the role of methanol as a strong organic solvent in metabolite extraction, with the addition of water improving solid yield (Alara, Abdurahman & Ukaegbu 2021; Do et al. 2014). In contrast, some fig leaf studies reported higher yields

with 100% alcohol compared to hydroalcoholic solvent, highlighting that solvent efficiency may vary depending on plant variety and extraction parameters (Qodriah et al. 2023; Radwan et al. 2020).

Furthermore, the present study shows that aqueous extraction resulted in lower yields compared to methanol-based solvents, in agreement with previous studies on fig leaves and Bulung Sangu, where 50-100% methanol extracts exceeded the yield obtained with water alone (Radwan et al. 2020; Sasadara & Wirawan 2021). These yields likely reflect the recovery of metabolites with varied polarity and solubility, with aqueous methanol capable of extracting hydrophilic and moderately polar phenolic compounds, whereas water primarily recovers highly polar constituents such as sugars and amino acids (Plaskova & Mlcek 2023; Stéphane et al. 2021). Plus, the incorporation of water facilitates cell wall swelling and improves the diffusion of phytochemicals. The extraction yields obtained in this study fall within the range (8-23%) reported for fig leaf extracts using various extraction techniques and solvent systems (water, alcohol, and aqueous alcohol), emphasizing the strong influence of extraction parameters and solvent on plant metabolite recovery (Mahmoudi et al. 2016; Radwan et al. 2020; Reveny, Maha & Laila 2023).

TOTAL PHENOLIC AND FLAVONOID CONTENTS

As shown in Table 1, the bioactive compound levels of fig leaf extracts varied significantly across the three solvents, with TPC and TFC ranked as follows: 100% methanol > 80% methanol > water. The methanol and aqueous methanol extracts contained higher TPC and TFC than the aqueous extract, consistent with previous reports on fig leaves (Ergül et al. 2019; Radwan et al. 2020). These results may be due to the combination of hydroxyl groups and aromatic conjugated structures that gives phenolic compounds a broad polarity range, enhancing their extraction in methanol and aqueous methanol systems (Alara, Abdurahman & Ukaegbu 2021). Additionally, methanol-based solvents efficiently extract polar to medium polar phenolic compounds, which likely contribute more significantly to the TPC and TFC values than highly water-soluble polyphenols (Fazel et al. 2024; Plaskova & Mlcek 2023).

The 100% methanol extract also exhibited higher phenolic and flavonoid contents than the aqueous methanol extract, suggesting that certain compounds are more compatible with lower-polarity alcohols, enhancing their solubility (Khound et al. 2023; Radwan et al. 2020). Previous studies using ultrasound-assisted extraction of fig leaves have reported contrasting results, with phenolic and flavonoid contents higher in water and aqueous methanol than absolute methanol, emphasizing the strong influence of solvent selection on bioactive compound recovery (Ivanov et al. 2015; Merzic et al. 2021). In addition, the present TPC and TFC values were comparable to or higher than those reported previously for water and methanol-based fig leaf extracts obtained using ultrasound-assisted extraction, maceration, and Soxhlet extraction (Mahmoudi et al. 2016; Mopuri et al. 2018; Petruccelli et al. 2018; Radwan et al. 2020; Reveny, Maha & Laila 2023). Variations among studies are likely related to differences in extraction techniques, solvent systems, and experimental conditions. Overall, these findings highlight the importance of solvent selection in extracting bioactive compounds.

ANTIOXIDANT ACTIVITY

As shown in Table 1, there were significant differences in the IC_{50} among all three extraction solvents, with antioxidant activity ranked as follows: water > 80% methanol > 100% methanol. The positive control, gallic acid (IC_{50} = 16 µg/mL), exhibited the strongest antioxidant activity, as lower IC_{50} values indicate higher radical scavenging effects. The antioxidant activity observed in fig leaf extracts is likely contributed by bioactive compounds such as phenolics and flavonoids, as shown by the TPC and TFC results. These compounds are capable of neutralizing free radicals through hydrogen atom or electron donation, which is supported by their phenolic hydroxyl groups (Xu et al. 2017).

The present study shows that the water extract demonstrated the strongest DPPH radical scavenging activity despite its lowest TPC and TFC. This may be attributed to the presence of reactive hydrophilic antioxidants or other reducing compounds in fig leaves, recovered through aqueous extraction (Li et al. 2021). Similar trends were reported in previous fig leaf studies, where water extract exhibited stronger antioxidant activity than methanol-based extract (Ivanov et al. 2015). In addition, the 80% methanol extract demonstrated stronger antioxidant activity than the 100% methanol extract, consistent with reports on fig leaves, *Salvia hispanica*, and *Stemona curtisii*, where aqueous alcohol systems enhance the solubility and structural compatibility of antioxidant compounds (Merzic et al. 2021; Morales-Olán et al. 2020; Ting, Jusoh & Hashim 2024).

Conversely, other studies have reported higher antioxidant activity in absolute alcohol extracts compared to aqueous alcohols and water, showing the strong influence of solvent composition on antioxidant performance (Ergül et al. 2019; Khound et al. 2023; Renda et al. 2023). The IC_{50} observed in this study was generally close to previously reported values (Ergül et al. 2019; Petruccelli et al. 2018), although some studies have reported higher activities, likely due to differences in solvent systems, extraction techniques, and plant varieties (Abdel-Aziz et al. 2020; Mahmoudi et al. 2016; Merzic et al. 2021).

ANTIBACTERIAL ACTIVITY

Table 2 and Figure 1 present the diameter of the zone of inhibition (ZOI) of the fig leaf extracts against *E. coli* and *S. typhi*. The antibacterial activity of the extracts followed this trend: 80% methanol > 100% methanol > water (no ZOI). The 80% methanol and 100% methanol extracts,

TABLE 1. Extraction yield, TPC, TFC, and IC_{50} (DPPH) of the fig leaf extracts

Solvent	Extraction yield (%)	TPC (mg GAE/g)	TFC (mg QE/g)	IC_{50} (DPPH) (µg/mL)
100% Methanol	$16.16 \pm 1.72^{a,b}$	61.68 ± 2.74^{a}	166.52 ± 2.75^{a}	2036.64 ± 32.89^{a}
80% Methanol	19.47 ± 1.89^{a}	47.45 ± 1.18^{b}	145.66 ± 4.54^{b}	1880.02 ± 32.93^{b}
Water	12.00 ± 3.44^{b}	39.68 ± 1.79^{c}	106.28 ± 3.83^{c}	1343.83 ± 41.20^{c}

Values expressed as mean ± SD (n = 3), different superscript letters ($^{a-c}$) within the same column indicate significant differences based on Tukey's test ($p < 0.05$)

at concentrations 100 and 150 mg/mL, demonstrated antibacterial activity against both bacteria, showing more significant activity against *E. coli* than *S. typhi*. The negative control (10% DMSO) exhibited no antibacterial activity, while the positive control, ciprofloxacin, produced larger inhibition zones than the fig leaf extracts. Phytochemicals, such as phenolic and flavonoid compounds, are known to inhibit bacterial growth (Bubonja-Šonje, Knezević & Abram 2020) and have been identified in fig leaves, including quercetin, gallic acid, and hydroxycoumarin (Fazel et al. 2024; Li et al. 2021). According to Takó et al. (2020), the hydroxyl group of these compounds may interact with the bacterial cell membrane and disrupt its cellular metabolism, eventually leading to cell deterioration or death.

The present study showed that *E. coli* was more susceptible to fig leaf extracts than *S. typhi*, with the 80% methanol extract showing the highest inhibition zone against *E. coli*. The greater resistance of *S. typhi* towards fig leaf extracts aligns with findings on *Seriphidium Oliverianum*, likely due to *S. typhi*'s more complex outer membrane structure and stronger resistance mechanisms (Abbas et al. 2021), as well as differences in bacterial physiology that affect sensitivity to bioactive compounds (Monte et al. 2014). Previous studies also have reported varying antibacterial responses of fig leaf extracts against different microorganisms, indicating dissimilarity in bacterial sensitivity (Mahmoudi et al. 2016).

Apart from that, the largest ZOI against *E. coli* was recorded at 100 mg/mL, not the maximum concentration tested (150 mg/mL), indicating that excessively higher concentrations may limit the diffusion of phytochemicals into bacterial cell walls, thereby reducing antibacterial potential for certain extracts (Ali et al. 2018). A similar concentration-dependent trend was observed for the 80% methanol extract against *S. typhi*. In contrast, the 100% methanol extract showed its highest antibacterial activity at 150 mg/mL against both bacteria, suggesting that for this solvent composition, higher levels of bioactive compounds enhanced interactions with bacterial cells, leading to stronger antibacterial effects. These findings indicate that antibacterial performance is affected by extraction solvent and extract concentration, which influence bioactive compound recovery and activity (Weli, Al-Blushi & Hossain 2015).

No inhibition zone towards *E. coli* and *S. typhi* was observed for the aqueous extract, suggesting that fig leaf antibacterial effect is highly dependent on solvent system, consistent with previous studies reporting greater efficacy in alcoholic extracts (Ergül et al. 2019; Radwan et al. 2020). Despite higher polyphenol content and antioxidant activity in the 100% methanol and aqueous extracts, the 80% methanol extract exhibited stronger antibacterial activity against *E. coli* and *S. typhi*, suggesting selective extraction of antibacterial compounds in aqueous methanol systems. Furthermore, fig leaf extracts produced inhibition zones around 6 to 8 mm, which were close to or lower than that reported in previous ultrasound-assisted and conventional extraction studies with similar solvents, reflecting the combined influence of solvent system and extraction technique on antibacterial activity of fig leaf extracts (Al-Ogaili et al. 2020; Ali et al. 2018; Belattar, Himour & Yahia 2021; Radwan et al. 2020; Salem & Fatimh 2023).

The inhibition zones of ciprofloxacin fell within the Clinical and Laboratory Standards Institute (CLSI) (2020) susceptible range, validating the assay, whereas the fig leaf extracts exhibited weak inhibition against *E. coli* and *S. typhi*. Previous studies also reported that Gram-positive bacteria are generally more susceptible to methanolic fig leaf extracts than Gram-negative bacteria (Belattar, Himour & Yahia 2021; Mahmoudi et al. 2016; Radwan et al. 2020). This reduced susceptibility of Gram-negative bacteria is likely due to their peptidoglycan layer and lipopolysaccharide-rich outer membrane, which can limit the penetration of certain bioactive compounds, particularly hydrophobic, less polar, or high-molecular-weight molecules (Mahmoudi et al. 2016; Shahbazi 2017). Plus, the diffusion of these compounds through solid agar may be slower, causing the weak inhibition observed (Bubonja-Šonje, Knezević & Abram 2020). Nonetheless, these results highlight the potential of fig leaf extracts and support further studies to optimize extraction conditions and antibacterial efficacy.

PEARSON CORRELATION ANALYSIS

The correlation coefficients for fig leaf extraction results are shown in Table 3 and relationships can be highlighted between extraction yield, phenolic and flavonoid contents, antioxidant potential, and antibacterial activity. Correlations (r) were categorized as strong ($0.7< r \leq 1$), moderate ($0.4< r \leq 0.7$), and weak ($0< r \leq 0.4$). Positive linear correlations were observed among all parameters with several demonstrating significantly strong associations ($p < 0.05$).

TABLE 2. Diameters of the ZOI (mm) of fig leaf extracts against *E. coli* and *S. typhi*

Extraction solvent	Concentration (mg/mL)	*E. coli*	*S. typhi*
100% Methanol	10	ND	ND
	50	ND	ND
	100	6.7 ± 0.3	ND
	150	6.8 ± 0.3	6.5 ± 0.5
80% Methanol	10	ND	ND
	50	ND	ND
	100	7.7 ± 0.3	7.2 ± 0.8
	150	7.2 ± 0.8	6.8 ± 0.6
Water	10	ND	ND
	50	ND	ND
	100	ND	ND
	150	ND	ND
Ciprofloxacin (5 µg)		34.0 ± 2.6	42.3 ± 2.5
10% DMSO		ND	ND

Values expressed as mean ± SD (n = 3)
ND: Not detected, SD: Standard deviation, ZOI: Zone of inhibition

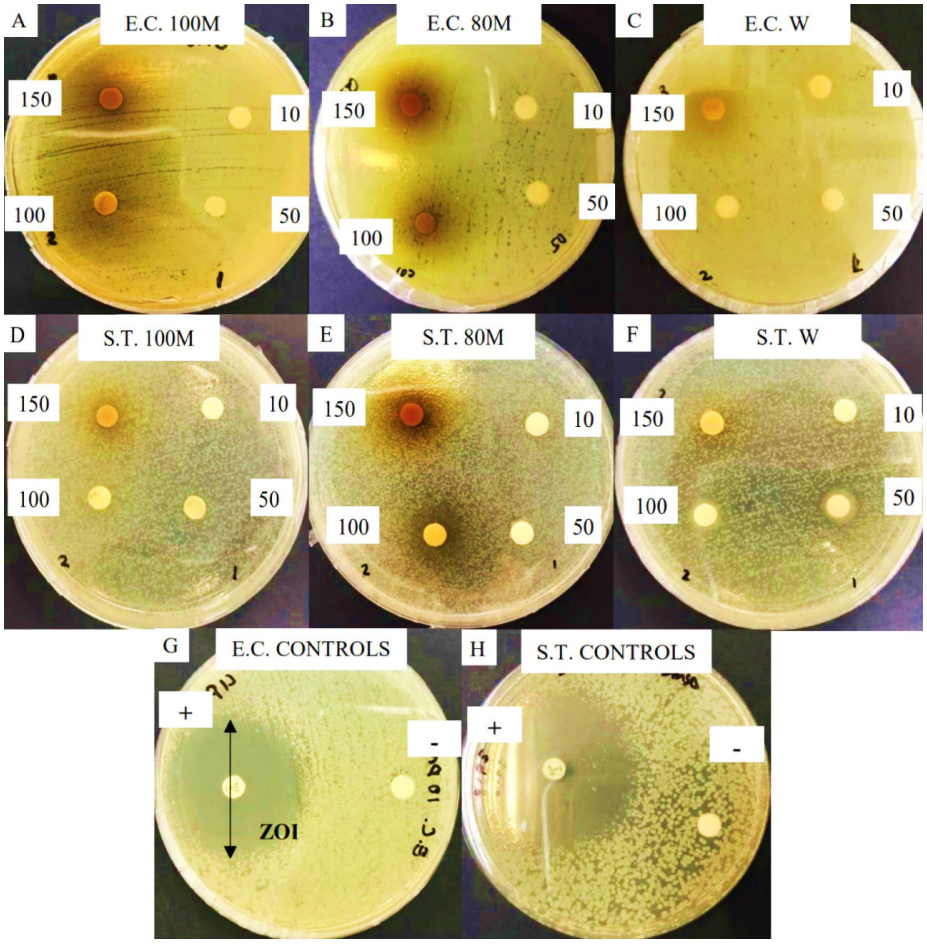

FIGURE 1. Antibacterial activity of the fig leaf extracts (10, 50, 100, and 150 mg/mL) and controls against *E. coli* and *S. typhi* (A–C and G) samples tested against *E. coli* (D–F and H) samples tested against *S. typhi*. 100M: 100% methanol, 80M: 80% methanol, W: Water, ZOI: Zone of inhibition, +: Positive control, −: Negative control

TABLE 3. Pearson correlation coefficients among various parameters of fig leaf extracts

	Extraction yield	TPC	TFC	IC_{50} (DPPH)	*E. coli*	*S. typhi*
Extraction yield	1					
TPC	0.354	1				
TFC	0.568	0.906*	1			
IC_{50} (DPPH)	0.651	0.861*	0.984*	1		
E. coli	0.872*	0.304	0.638	0.724*	1	
S. typhi	0.766*	0.181	0.414	0.533	0.753*	1

*Indicate significant correlation at $p < 0.05$

The extraction yield strongly correlated with antibacterial activity, highlighting that increasing extractable materials such as phytochemicals may yield more antibacterial compounds (Sartini, Djide & Nainu 2019). Another strong correlation was between the antibacterial effects against *E. coli* and *S. typhi*, indicating that the antibacterial compounds or mechanisms against one bacterium are likely effective against the other. Besides that, a highly significant correlation between TPC and TFC suggests that the extraction process effectively yielded both phenolic and flavonoid compounds together.

TPC and TFC were also strongly correlated with IC_{50}, consistent with previous findings (Wairata et al. 2022). This suggests that even small quantities of phenolic compounds can produce higher antioxidant effects, while higher concentrations may correspond to weaker antioxidant activities (Sartini, Djide & Nainu 2019). Conversely, several studies have shown a significant negative correlation between bioactive content and IC_{50} values, indicating that higher concentrations of these compounds may enhance antioxidant activity (Hmamou et al. 2022; Suleiman & Ateeg 2020). Furthermore, a correlation between IC_{50} and antibacterial activity suggests that fig leaf extracts with lower antioxidant activity have stronger antibacterial effects, and vice versa, implying that some bioactive compounds may act as effective antibacterial agents regardless of antioxidant strength. In summary, the findings of this study confirm strong correlations between the bioactive compounds in fig leaves and their biological properties, emphasizing their potential for functional applications.

CONCLUSIONS

This study shows that different extraction solvents (100% methanol, 80% methanol, and water) significantly influence the recovery of phenolic and flavonoid compounds, antioxidant activity, and antibacterial effects of fig leaf extracts using ultrasound-assisted extraction. Among the solvents, 80% methanol provided the highest solid yield and strongest antibacterial activity, while performed moderately in antioxidant assays. The better performance of 80% methanol likely reflects its intermediate polarity, which enhances solubility of both polar and moderately polar bioactive compounds. However, the fig leaf extracts showed weak inhibition against *E. coli* and *S. typhi*. Future investigations should focus on identifying active compounds, optimizing extraction parameters, and assessing toxicity to support potential applications of fig leaf extracts in food and pharmaceutical industries.

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