Zoo Botanica
ISSN: 3007-2050 (E), 3007-2042 (P)

Check for updates

Research Article

Optimization of microwave assisted extraction (MAE) protocol and study of antimicrobial activity of Bergenia ciliata (Haw.) Sternb.

[1]Rida Ibrahim, [1]Amina Tariq, [1]Zeenat Fatima, [1]Maryam Asif
Department of Botany, Lahore College for Women University, Lahore, Punjab, Pakistan.

ABSTRACT

Bergenia ciliata is an effective medicinal plant since it contains a significant number of bioactive chemicals and has a broad spectrum of biological action. The current study was conducted to evaluate the antimicrobial activity of *Bergenia ciliata* rhizome extract using microwave-assisted extraction (MAE) with 1 g of plant material in 10 mL of solvent ratio. For extraction, several factors such as power level, time, ethanol and petroleum ether solvents were used. The highest extract weight of 0.957 g was discovered in ethanol, using a combination of 200 W (power) and 150 seconds (time). The phenolic content in the rhizome of *Bergenia ciliata* was also determined by measuring absorption at 765 nm with a UV spectrophotometer. The highest total phenolic content in *Bergenia ciliata* rhizomes extract with ethanol was reported to be 62.43063a ± 0.1 mg/g at a power level of 200 W after 150 seconds of microwave irradiation. Antimicrobial activity was tested using selected bacterial (*Escherichia coli*, *Salmonella enterica* and *Staphylococcus aureus*) and fungal (*Trichoderma harzianum*, *Alternaria alternata*, and *Fusarium oxysporum*) strains after extraction. Ethanol showed the highest antimicrobial action. By utilizing the anti-microbial properties of *Bergenia ciliata*, current research can be expanded to examine alternative drug discoveries.

Keywords: Antibacterial; antifungal; *Bergenia ciliata*; microwave-assisted extraction; MAE; phenolic compounds.

INTRODUCTION

The World Health Organization states that plants naturally produce phytochemicals, and about 80% of people worldwide still use traditional plant medicine. Phenolic compounds are a significant family of phytochemicals that plants naturally make. The majority of phenolic compounds are antioxidants, which can help prevent heart disease, inflammation, diabetes, cancer, and mutagenesis in humans. Antioxidants isolated from medicinal plants have risen in popularity over the last two decades due to their low toxicity and widespread application in scientific study and industry (Pekamwar et al., 2013).

As food preservatives, a range of synthetic antioxidants, including butyl hydroxyanisol and butyl hydroxytoluene, have been utilized. Butyl hydroxyanisol and butyl hydroxytoluene, on the other hand, have been shown in toxicological tests to influence blood coagulation in experimental animals. Because of the negative consequences of synthetic antioxidants, the use of naturally occurring antioxidants in dietary items, medicines, and beauty products has grown. More study is required to determine the antioxidant activity of naturally occurring substances and to create effective extraction and separation procedures (Zafar et al., 2019). *Bergenia ciliata*, also referred to as fringed elephant ears, hairy Bergenia, and, winter begonia belongs to the genus Bergenia. It contains bergenin, gallic acid, catechin, gallicin, beta-sitosterol, and catechin-7- O-glucoside. The benefits it has for health are recognized, including its use in Ayurveda. It is an extensively utilized medicinal herb

OPEN ACCESS

Correspondence
Amina Tariq
aminapal786@hotmail.com
Article History
Received: August 02, 2025
Accepted: August 22, 2025
Published: August 31, 2025

in the Himalayan area of Sikkim, which is located in Northeastern India for usage as a food, the plant is taken out of the wild (O'Neill et al., 2017).

Bergenia ciliata (Haw.) Sternb. is a significant Himalayan medicinal plant**.** A plant species' phenotypic features change with altitude in order to adapt to and overcome changing and challenging surroundings. Several environmental parameters, such as mean temperature, soil properties, precipitation, radiation intensity, etc, alter with altitudinal gradient and hence influence plant morphology. With increasing altitude, plant height, leaf breadth and length, inflorescence length, and petiole length all decrease significantly (Magray et al., 2022).

The extraction method utilized in the extraction procedure has a substantial impact on the successful and focused extraction of physiologically active chemicals from plant material. Organic solvents including methanol, ethanol, and acetone are frequently employed to extract bioactive compounds (Tilburt et al., 2008).

Microwave extraction of plant components has gained significant attention and potential in recent years. A more recent extraction technique called microwave-assisted extraction (MAE) blends conventional solvent extraction with microwave technology. The term "microwave-assisted extraction" describes the method of heating solvents and plant tissues with microwaves to increase the extraction rate. If sufficient study is conducted, this technology has the potential to replace other traditional ways of plant extraction on a large scale because it offers several advantages over previous methods of extraction. Some of the benefits include reduced solvent and energy usage, shorter extraction times, and protection of thermolabile chemicals (Tariq et al., 2017; Akhtar et al., 2020). It is now one of the most widely used and economical extraction techniques available today, with a number of sophisticated MAE instruments and methodologies available, such as solvent-free microwave-assisted extraction (SFMAE) and pressurized microwave-assisted extraction (PMAE) (Mandal et al., 2007).

According to studies conducted in numerous countries, the antibacterial capabilities of plant extracts and phytochemicals, can be highly beneficial in treatments. Many plant's microbiological traits are derived from secondary metabolites known as phenolic chemicals, which are components of essential oils and tannins (Negi et al., 2014).

Bergenia ciliata has yielded a variety of beneficial secondary metabolites such as tannic acid, glucose, gallic acid, mucilage, stigmasterol, bergenin, arbutin, phytol, *β*-sitosterol, 3 methyl-2 buten-1-ol, and others. Various parts of these plants contain antiviral, antilithic, diuretic, antipyretic, anti-bradykinin, anti-bacterial, anti-inflammatory, insecticidal, hepatoprotective, and *α*-glycosidase activities and are used to eliminate urinary bladder stones. *Bergenia ciliata*, one of the three Bergenia species reported, is widely used in folk medicine and contains antitussive, antiulcer, antioxidant, antibacterial, hypoglycemic, toxicological anticancer, and anti-adiabatic qualities (Kanth et al., 2019).

MATERIALS AND METHODS

The current study was conducted in the Botany Department's Plant Tissue Culture Lab at Lahore College for Women University in Lahore. Microwave-assisted extraction of *Bergenia ciliata* for polyphenol extraction was completed in this study. The rhizome of *Bergenia ciliata* was obtained from Azad Kashmir. *Bergenia ciliata* rhizomes were air-dried, ground into a fine powder, and extracted to promote solvent penetration and release of active components. This powder was kept in an airtight container and then extracted.

Preparation of Plant Extract

An electronic scale was used to weigh the rhizome powder in order to prevent solvent evaporation and control the solvent's boiling pressure after microwave heating. A calibrated solvent (10 mL) was poured, along with 1g plant material, and covered with a perforated polyethylene bag. Whatman filter paper No. 1 was used to filter the extract, resulting in the crude extract.

Parameters for Microwave Assisted Extraction

The Extraction parameters to be studied were as follows;

Solvents: Ethanol and petroleum ether were used as solvents for extraction from powder. The solvent-to-plant material ratio of 10 mL/1 gram was used respectively.

Power levels: 200, 400, 600, and 800 Watts of power level of microwaves were used during the experimental work.

Time duration: 30, 60, 90, 120, 150 seconds time intervals were used.

Spectrophotometric Analysis of Phenolics

Spectrophotometric methods are semi-quantitative methods used to estimate phenolic content in plant extracts. 1 g of plant material was homogenized with 1 solvent and filtered using Whatman filter paper no. 4. The Folin-Ciocalteu (FC) assay was used to analyze response 1, or phenolic content. The sample 125, 500 and 125 µL of Folin-Ciocalteu reagent was combined with distilled water, 1.25 mL of 7% Na_2CO_3, and 3 mL distilled water, incubated in the dark for

90 minutes. The absorbance at 760 nm was measured, and gallic acid was produced in various concentrations to create a standard curve (Rebey et al., 2012).

Figure 1. MAE extract of *Bergenia ciliata.*

Figure 2. Spectrophotometer.

Antimicrobial Activity

The antibacterial activity of *Bergenia ciliata* extracts produced through various extraction processes was tested using the agar well diffusion method against various bacterial strains and fungal strains (Singh et al., 2017). Bacterial (*Escherichia coli*, *Staphylococcus aureus* and *Salmonella enterica*) and fungal (*Fusarium oxysporum*, *Trichoderma harzianum* and *Alternaria alternata*) strains were obtained from Lahore College for Women University's Botany Department.

Preparation of Media Plates

The culture medium was prepared by dissolving 3.9 g of Potato Dextrose Agar (PDA) in 100 mL of distilled water, sterilizing it using autoclave (temperature 121 °C and the pressure 151b2/inch). After cooling the autoclaved medium was placed into sterilized petri plates under aseptic conditions, and 20 mL of Agar medium was poured into each plate.

Culturing of Bacterial Strains

The bacterial strains were subcultured on solidified agar plates after being kept at 4 °C. Bacterial cultures were transferred from agar plates to freshly produced agar plates using a sterilized red-hot inoculating needle. After that, the plates were incubated for at 37 °C for full day.

Preparation of Inoculum

Isolated colonies were diluted in a saline solution and then transferred to fresh agar plates. After that, the plates were incubated at 37°C for 24 hours. The solution's turbidity indicated bacterial colony expansion.

Inoculation of Plates

The study involved placing 100 mL of bacterial inoculum on agar plates, keeping the flask close to the flame, heating the opening to prevent contamination, and allowing the inoculums to solidify. Then, in each Petri plate, four 9 mm diameter wells were created using a sterile cork borer. All of the plates were appropriately labeled before applying plant samples.

Sample Application and Inoculation

https://doi.org/10.55627/zoobotanica.003.02.1452

Each well received 100 L of the corresponding sample by micropipette. The plates were then placed in a 37 °C incubator (UNB-400). The results were obtained after a 24-hour incubation period.

Measurements of the Zone of Inhibition

The zone of inhibition, indicating bacterial growth inhibition, was determined by measuring the diameter of a clean region surrounding the well. A transparent mm ruler was used to measure the zone's diameter (mm), and the results were noted as the mean zone of inhibition. All tests were isolated in duplicate.

Statistical Analysis

The resulting data were analyzed using One Way ANOVA, and the treatment means were compared for significance using Duncan's New Multiple Range Test at a 5% level of significance using SPSS computer software.

RESULTS AND DISCUSSION

Microwave Assisted Extraction (MAE)

Extraction was performed with microwave-assisted extraction. For extraction, 1 g of plant material (*Bergenia ciliata* rhizomes) powder and 10 mL of solvent (Ethanol and Petroleum ether) were taken. Different power levels of 200, 400, 600, and 800 Watts and times 30, 60, 90, 120, 150 seconds were used. After filtering the extract with Whatman filter paper No. 1 the filtrate was poured into glass vials and it was air dried, extract weight was calculated by formula:

Extract weight= initial weight-final weight

Effect of various Power Levels on Weight of Ethanolic Extract of *Berginia ciliata*

Comparison of a maximum and minimum amount of yield (extract of *Bergenia ciliata*) was obtained through microwave-assisted extraction using two different solvents (Ethanol and Petroleum ether).

As shown in Table (1), with ethanol the maximum extract (0.95g ± 0.1) was yielded at 200 W when the mixture was heated for 150 seconds. The minimum amount of extract (0.06g ± 0.01) however was obtained at 800 W but the time was just 30 seconds.

With petroleum ether at 200 W maximum amount of extract was observed (0.48 g ± 0.01) at 60 sec, whereas the minimum in (0.02 g ± 0.01) at 120s. At 400 W power maximum amount of extract (0.79 g ± 0.01) was observed at 90s, whereas the minimum (0.19 g ± 0.01) at 120s. At 600 W maximum amount of extract was observed (0.42 g ± 0.01) at 150s, whereas the minimum (0.02 g ± 0.01) at 30s. At 800 W power maximum amount of extract was observed (0.68 g ± 0.01) at 120s, whereas the minimum (0.04 g ± 0.01) at 90s.

The results showed that ethanol showed better results in terms of extraction of plant extract as compared to petroleum ether when all the other factors were kept similar.

Table 1**.** Extract weights of samples of MAE**.**

Power (Watts)	Ethanol		Petroleum ether	
	Time (seconds)	Weight (g)	Time (seconds)	Weight (g)
200 W	30	0.74 ± 0.1	30	0.38 ± 0.1
	120	0.08 ± 0.1	120	0.02 ± 0.01
	150	0.95 ± 0.1	150	0.47 ± 0.1
400 W	90	0.81 ± 0.1	90	0.79 ± 0.01
	120	0.17 ± 0.1	120	0.46 ± 0.1
	150	0.68 ± 0.1	150	0.33 ± 0.1
600 W	30	0.38 ± 0.1	30	0.02 ± 0.01
	60	0.04 ± 0.01	60	0.24 ± 0.1
	150	0.71 ± 0.01	150	0.42 ± 0.01
800 W	30	0.06 ± 0.01	30	0.10 ± 0.1
	60	0.61 ± 0.1	60	0.13 ± 0.1
	150	0.81 ± 0.01	150	0.15 ± 0.1

Total Phenolic Content Determination by using the Folin Ciocalteu Method

The total phenolic content of the extracts of different solvents was evaluated by the Folin Ciocalteu colorimetric method. A powdered rhizome extract of *Bergenia ciliata* was employed for the analysis of polyphenols. The absorbance of the treated sample was contrasted with the standard curve (equation) of Gallic acid.

At 200 W, total phenolic content using MAE with the time interval of 30, 60 90, 120, and 150 seconds were estimated with Ethanol. It is shown in the table that the maximum amount of total phenolic content was present in the 150s (62.43063 ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 60s (16.20841 ± 1.0 mg/g). At 400 W, the maximum amount of total phenolic content was present in the 150s (34.52715 ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 60s (8.975482 ± 1.0 mg/g). At 600 W, the maximum amount of total phenolic content was present in the 90s (34.71103 ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 150s (8.003503 ± 1.0 mg/g). At 800 W, the maximum amount of total phenolic content was present in the 60s (23.92294 ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 120s (15.91068 ± 1.0 mg/g).

When total phenolic content using MAE were estimated with Petroleum ether at 200 W, with the time interval of 30, 60, 90, 120, and 150 seconds, as shown in the Table (2), the maximum amount of total phenolic content was present in the 150s (16.34851a ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 90s (6.781086d ± 1.0 mg/g). At 400 W, the maximum amount of total phenolic content was present in the 30s (24.29947a ± 0.1 mg/g) while the minimum amount of total phenolic content was present in the 120s (3.949212e ± 0.1 mg/g). At 600 W, the maximum amount of total phenolic content was present in the 30s (17.78459a ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 90s (4.168126c ± 1.0 mg/g). At 800 W, the maximum amount of total phenolic content was present in the 90s (7.495622a ± 1.0 mg/g) while the minimum amount of total phenolic content was present in the 60s (4.063047c ± 1.0 mg/g). Thus, the maximum amount of total phenolic content (62.43063 ± 0.1 mg/g) was obtained in ethanol through MAE at a low power level (200 W) and maximum time (150 s).

Table 2. Total phenolic content of samples of MAE.

Power (Watts)	Ethanol		Petroleum ether	
	Time (seconds)	Total phenolic content mg/g	Time (seconds)	Total phenolic content mg/g
200 W	60	$16.20841^{e} \pm 1.0$	60	$7.338004^{cd} \pm 1.0$
	90	$33.17863^{b} \pm 1.0$	90	$6.781086^{d} \pm 1.0$
	150	$62.43063^{a} \pm 1.0$	150	$16.34851^{a} \pm 1.0$
400 W	30	$12.17163^{c} \pm 1.0$	30	$24.29947^{a} \pm 0.1$
	120	$15.70928^{b} \pm 1.0$	120	$3.949212^{e} \pm 0.1$
	150	$34.52715^{a} \pm 1.0$	150	$4.649737^{d} \pm 0.1$
600 W	30	$34.34326^{a} \pm 1.0$	30	$17.78459^{a} \pm 1.0$
	90	$34.71103^{a} \pm 1.0$	90	$4.168126^{c} \pm 1.0$
	150	$8.003503^{d} \pm 1.0$	150	$6.663748^{b} \pm 1.0$
800 W	60	$23.92294^{a} \pm 1.0$	60	$4.063047^{c} \pm 1.0$
	90	$16.07706^{b} \pm 1.0$	90	$7.495622^{a} \pm 1.0$
	120	$15.91068^{b} \pm 1.0$	120	$5.59544^{bc} \pm 1.0$

Antifungal Activity of *Bergenia ciliata* Rhizome Extracts

Analysis of variance showed the significant effect of *Bergenia ciliata* and its different concentrations on Bacterial (*Escherichia coli*, *Salmonella enterica* and *Staphylococcus aureus*) and fungal (*Trichoderma harzianum*, *Fusarium oxysporum* and *Alternaria alternata*) strains.

Ethanolic extracts of *Bergenia ciliata* remarkably retarded the growth of *Trichoderma harzianum* (test fungus). At a power level of 200 W, the maximum antifungal activity against strain *Trichoderma harzianum* was 19.5 mm at 150 seconds while the minimum activity was 16 mm at 60 seconds. At a power level of 400 W, the maximum antifungal activity against strain *Alternaria alternata* was 26 mm at 120 seconds while the minimum activity was 19.5 mm at 60 seconds. At a power level of 800 W, the maximum antifungal activity against strain *Fusarium oxysporum* was 25 mm at 150 seconds while the minimum activity was 18 mm at 30 seconds.

Petroleum ether extracts of *Bergenia ciliata* significantly slowed the growth of *Trichoderma harzianum* (test fungus). At a power level of 200 W, the maximum antifungal activity against strain *Trichoderma harzianum* was 17.5 mm at 150 seconds while the minimum activity was

13.5 mm at 90 seconds. At a power level of 400 W, the maximum zone of inhibition against strain *Alternaria alternata* was 24 mm at 30 seconds while the minimum activity was 18 mm at 120 seconds. At a power level of 800 W, the maximum antifungal activity against strain *Fusarium oxysporum* was 21 mm at 90 seconds while the minimum activity was 16 mm at 30 seconds. Comparison of *Trichoderma harzianum* growth on *Bergenia ciliata*. Ethanolic and Petroleum ether extract are shown in Table (3).

Table 3. Comparison of *Trichoderma harzianum* growth on *Bergenia ciliata* ethanolic and petroleum ether extract.

Power (Watts)	Time (Seconds)	Zone of inhibition (mm)	
		Ethanol	Petroleum Ether
200 W	90	15.5^{de}± 1.0	13.5^{e}± 1.0
	120	18^{bc}± 1.0	15.5^{cd}± 1.3
	150	19.5^{a}± 1.0	17.5^{ab}± 1.0
400 W	60	17.5^{c}± 1.0	14^{e}± 1.0
	120	19.5^{a}± 1.0	16.5^{b}± 1.7
	150	20^{a}± 1.0	18^{a}± 1.0
600 W	30	18^{b}± 1.0	17^{b}± 0.76
	60	15^{e}± 1.0	15^{d}± 1.0
	120	19^{b}± 1.0	18^{a}± 1.0

Antibacterial Activity of *Bergenia ciliata*

The applied concentration of Ethanolic extracts of *Bergenia ciliata* inhibited the growth of test bacteria (*Escherichia coli, Salmonella enterica*, and *Staphylococcus aureus*). Ethanolic extracts of *Bergenia ciliata* remarkably retarded the growth of E. coli (test bacteria). At a power level of 200 W, the maximum antibacterial activity against strain E. coli was 25 mm at 120 seconds while the minimum activity was 18 mm at 60 seconds. At a power level of 600 W, the maximum antibacterial activity was 21 mm at 90 seconds while the minimum activity was 15 mm at 30 seconds. At a power level of 800 W, the maximum antibacterial activity was 23 mm at 150 seconds while the minimum activity was 18.5 mm at 30 seconds.

The applied concentration of Petroleum ether extracts of *Bergenia ciliata* inhibited the growth of test bacteria (*Escherichia coli, Salmonella enterica*, and *Staphylococcus aureus*). Petroleum ether extracts of *Bergenia ciliata* remarkably retarded the growth of *E. coli* (test bacteria). At a power level of 200 W, the maximum antibacterial activity against strain *E. coli* was 25 mm at 150 seconds while the minimum activity was 16.5 mm at 30 seconds. At a power level of 600 W, the maximum antibacterial activity against strain *S. enterica* was 20.5 mm at 30 seconds while the minimum activity was 15 mm at 120 seconds. At a power level of 800 W, the maximum antibacterial activity against strain S. aureus was 21 mm at 150 seconds while the minimum activity was 15 mm at 30 seconds. On Comparison of *Bergenia ciliata* Ethanolic and Petroleum ether extract, Ethanolic extracts of showed better antibacterial activity, as shown in Table 4.

It is well recognized that *Bergenia ciliata* has significant therapeutic value. The medicinal properties of its several portions are the subject of conflicting claims. Its rhizomes are employed in various Ayurvedic formulations and are used to treat bladder stones and disorders related to the urinary tract. Locals in the Himalayan region make tea from dried *B. ciliata* rhizomes and use them as a tonic to treat muscle soreness, diarrhea, and fever (Khan et al., 2012). In various parts of Jammu & Kashmir, samples of *B. ciliata* leaves, roots, and rhizomes are used ethnomedically as a tonic for fever, headache, skin conditions, abrasions, wound healing, digestive disorders, diarrhea, kidney and bladder stones, irregular menstruation, pulmonary infections, and asthma. (Gairola et al., 2014)

This study was conducted for optimization of microwave assisted extraction of phenolics from rhizomes of *Bergenia ciliata*. Extraction of *Bergenia ciliata* was performed with two solvents, Ethanol, and Petroleum ether, different power levels (200, 400, 600, and 800W) and time (30, 60, 90,120 and 150 seconds) were used for extraction. In the present study, maximum amount of extract was obtained from ethanol using MAE, at 400 W and 30 seconds while the minimum

amount of extract was obtained from petroleum ether at 800 W and 150 seconds. Earlier a study reported the maximum percentage of extract obtained from ethanol in microwave-assisted extraction (Bagade and Patil, 2021).
Extraction using MAE gave a high value of extraction yields. High power level in MAE was a reason for the abrupt splitting of cells and in a short time extract was obtained while in soxhlet long-term exposure to heat break down of phytochemicals, MAE has a higher potential for extraction of phytochemicals from plants (Akhtar et al., 2019).

Table 4. Comparison of solvents.

Power (Watts)	Time (Seconds)	Zone of inhibition (mm)	
		Ethanol	Petroleum Ether
200 W	90	18^{cd}± 1.0	16.5^{d}± 1.0
	120	25^{a}± 1.0	20^{b}± 1. 0
	150	22^{b}± 1.0	25^{a}± 1.0
400 W	60	17.5^{d}± 1.0	14^{e}± 1.0
	120	19.5^{c}± 1.0	16.5^{cd}± 1.0
	150	20^{bc}± 1.0	18^{c}± 1.0
800 W	30	18^{c}± 1.0	16^{d}± 1.0
	60	20.5^{b}± 1.0	21^{b}± 1.0
	90	23^{b}± 1.0	19^{b}± 1.0

Table 5. Comparison of solvents.

Power (Watts)	Time (Seconds)	Zone of inhibition (mm)	
		Ethanol	Petroleum Ether
200 W	60	16^{e}± 1.0	16^{d}± 1.0
	90	15.5^{e}± 1.0	15^{d}± 1.0
	120	18^{d}± 1.0	19.5^{b}± 1. 0
	150	20^{b}± 1.0	17.5^{c}± 1.0
400 W	60	17.5^{c}± 1.0	14^{de}± 1.0
	120	19.5^{bc}± 1.0	16.5^{c}± 1.0
	150	20^{b}± 1.0	18^{b}± 1.0
800 W	30	18.5^{d}± 1.0	15^{d}± 1.0
	90	21^{b}± 1.0	18^{b}± 1.0
	150	23^{a}± 1.0	21^{a}± 1.0

MAE, a larger ratio can result in lesser recoveries, which might be caused by insufficient solvent stirring. Therefore, in MAE, careful adjustment of this value is crucial (Truong et al., 2019). In the current study, it was observed that with increasing time MAE resulted in a decrease in the amount of plant extracts.
In MAE solvent and plant material interact with each other. If the dielectric constant of the solvent is high then it can absorb microwave energy and fast dissipation of energy occurs between solvent and plant material. Based upon dipole rotation and ionic conduction, microwave energy causes the transformation of the sample and solvent. When electromagnetic energy hits polar molecules they start moving with a changing electric field. This process occurs several million times and internal pressure is created which ruptures the cell wall of plant material and substances enclosed in the cell wall come out rapidly (Seoane et al., 2017). As reported earlier a high yield of phenolics from *Bergenia ciliata* using MAE was observed (Choudhary et al., 2023).
In *Bergenia ciliata* rhizomes extract with ethanol, the maximum amount of total phenolic content was found to be 62.43063a ± 0.1 mg/g obtained at power level 200 W after 150 seconds of microwave irradiation. The minimum total phenolic content was found to be 8.003503d ± 1.0 mg/g obtained at power level 400 W after 120 seconds of microwave

irradiation. In contrast to Petroleum ether, the maximum amount of total phenolic content was found to be 24.29947a ± 0.1 mg/g obtained at power level 400 W after 30 seconds of microwave irradiation. The minimum total phenolic content was found to be 3.949212e ± 0.1 mg/g obtained at power level 400 W after 90 seconds of microwave irradiation. Total phenolic content was increased with an increase of time but when time reached above 150 seconds phenolic content might be decomposed. It was concluded that ethanol could absorb components at low power levels and gave a maximum amount of phenolic content.

In the present research work, it is also evident that MAE did not affect the antimicrobial activity of extract from *Bergenia ciliata* when extracted under optimized conditions, as has also been reported earlier (Akhtar et al., 2019).

Ethanolic extract of plant *Bergenia ciliata* was found to be more effective than petroleum ether extract against Bacterial (*Escherichia coli*, *Staphylococcus aureus*, and *Salmonella enterica*) and fungal (*Trichoderma hazarium*, *Fusarium oxysporum*, and *Alternaria alternata* strains. At a power level of 400 W, the maximum antifungal activity shown against strain *Alternaria alternata*, was 26a ± 1.0 at 120 seconds while the minimum antifungal activity shown against strain *Fusarium oxysporum*, was 16d ± 1.0 at 30 seconds.

At a power level of 200 W, the maximum antibacterial activity against strain *E. coli* was 25a ± mm at 120 seconds while the minimum activity was 18cd ± 1.0 mm at 60 seconds. These findings demonstrate that the most antifungal and antimicrobial activity in *Bergenia ciliata* was observed in the bacterial strain of *E. coli* and the fungus strain of *Fusarium oxysporum*. According to the current research, the ethanol extract of *B. ciliata* has the potential to yield natural antibacterial chemicals that might be exploited in the food and pharmaceutical industries.

CONCLUSION

It was concluded from the present research that microwave-assisted extraction can be used for the extraction of compounds (phenolics) from the extract of dry rhizomes of *Bergenia ciliata*. Through MAE, considerable amount of extract can be obtained within short time duration. The rhizomes of *Bergenia ciliata* contained phytochemicals that might serve as a medicine for the treatment of persistent illnesses and for other purposes. Therefore, the study would further help to correlate the presence of phenolic content in other parts. It was concluded from conducted research work that *Bergenia ciliata* has significant antimicrobial activity against different bacterial and fungal strains.

AUTHOR'S CONTRIBUTION

RI carried out the experimental work, analyzed the data, and wrote the manuscript. AT, supervised the project, wrote and reviewed the manuscript. ZF and MA, wrote and reviewed the manuscript.

FUNDING

The project was supported by the Department of Botany, Lahore College for Women University, Lahore.

AVAILABILITY OF DATA AND MATERIAL

Not Applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

This study does not include any personal data from individuals in any capacity. All authors have consented to its publication.

CONFLICT OF INTERESTS

All authors attest to the validity of manuscript contents and agree for submission.

ACKNOWLEDGEMENT

Authors acknowledge Lahore College for Women University, Lahore for research support.

REFERENCES

Akhtar, I., Javad, S., Ansari, M., Ghaffar, N. & Tariq, A. (2020). Process optimization for microwave assisted extraction of Foeniculumvulgare Mill using response surface methodology. Journal of King Saud University-Science, 32(2): 1451-1458.

Akhtar, I., Javad, S., Yousaf, Z., Iqbal, S. & Jabeen, K. (2019). Microwave assisted extraction of phytochemicals an efficient and modern approach for botanicals and pharmaceuticals. Pakistan Journal of Pharmaceutical Sciences, 32(1).

Tariq, A, Javad, S, Batool, S, Javeed, A & Jabeen, K. (2017). A rapid protocol for extraction of Podophyllotoxin (an anticancerous compound) from Podophyllumhexandrum royle. Biologia (Pakistan). 63 (1), 73-78.

Bagade, S. B. & Patil, M. (2021). Recent advances in microwave assisted extraction of bioactive compounds from complex herbal samples: a review. Critical Reviews in Analytical Chemistry, 51(2): 138-149.

Gairola, S., Sharma, J. & Bedi, Y. S. (2014). A cross-cultural analysis of Jammu, Kashmir and Ladakh (India) medicinal plant use. Journal of Ethnopharmacology, 155(2): 925-986.

Kanth, M., Hussain, A., Srivastava, P. K., Sharma, M., Tripath, J., & Khan, M. A. (2019). Extraction, qualitative and quantitative determination of secondary metabolites of bergeniaciliata (How) sternb rhizome. Journal of Drug Delivery and Therapeutics, 9(3): 407-411.

Khan, M. A., Khan, M. A., Mujtaba, G. & Hussain, M. (2012). Ethnobotanical study about medicinal plants of Poonch valley Azad Kashmir. Journal of Animal & Plant Sciences, 22: 493-500.

Magray, J. A., Zargar, S. A., Islam, T. & Nawchoo, I. A. (2022). Impact of habitat variability on growth dynamics of Bergeniaciliata (Haw.) Sternb. along an altitudinal gradient in Kashmir Himalaya. Plant Science Today, 9(1): 144-149.

Mandal. V., Mohan, Y. & Hemalatha, S. (2007). Microwave Assisted Extraction-An Innovative & Promising Extraction Tool for Medicinal Plant Research. Pharmacognosy Reviews, 1(1): 7-18.

Negi, D. S., Semwal, A., Juyal. V. & Rana, A. J. (2014). Antibacterial and Antifungal Activity of Centrotherumanthelminticum seeds Asterscene (Compositae). International Journal of Pharmaceutical and Medicinal Research, 2(5): 136-139.

O'Neill, A. R., Badola, H. K., Dhyani, P. P. & Rana, S. K. (2017). Integrating ethnobiological knowledge into biodiversity conservation in the Eastern Himalayas. Journal of Ethnobiology and Ethnomedicine, 13: 1-14.

Pekamwar, S. S., Kalyankar, T. M. & Kokate, S. S. (2013). Pharmacological activities of Cocciniagrandis. Journal of Applied Pharmaceutical Science, 3(5): 114-119.

Rebey, I. B., Jabri-Karoui, I., Hamrouni-Sellami, I., Bourgou, S., Limam, F. & Marzouk, B. (2012). Effect of drought on the biochemical composition and antioxidant activities of cumin (Cuminumcyminum L.) seeds. Industrial Crops and Products, 36(1): 238-245.

Singh, M., Pandey, N., Agnihotri, V., Singh, K. K. & Pandey, A. (2017). Antioxidant, antimicrobial activity and bioactive compounds of BergeniaciliataSternb. A valuable medicinal herb of Sikkim Himalaya. Journal of Traditional and Complementary Medicine, 7(2): 152-157.

Tilburt, J. C. & Kaptchuk, T. J. (2008). Herbal medicine research and global health: an ethical analysis. Bulletin of the World Health Organization, 86: 594-599.

Zafar, R., Ullah, H., Zahoor, M. & Sadiq, A. (2019). Isolation of bioactive compounds from Bergeniaciliata (haw.) Sternb rhizome their antioxidant and anticholinesterase activities. BMC Complementary and Alternative Medicine, 19(1): 1-13.