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Extraction yield, phytochemical profile, and antibacterial activity of *Curcuma longa* rhizomes using polar and non-polar solvents

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Abstract
Background: *Curcuma longa* (turmeric) contains diverse secondary metabolites with reported antibacterial activity. Extraction solvent strongly influences yield, phytochemical spectrum and bioactivity (Hewlings & Kalman, 2017; Kocaadam and Şanlier, 2017; Fuloria *et al*., 2022; Prasad *et al*., 2014; Anand *et al*., 2021) [5, 6, 2, 9, 1].
Objective: To determine extraction yields, qualitatively screen phytochemicals, and evaluate in-vitro antibacterial activity of ethanol, petroleum ether, and aqueous extracts of *Curcuma longa* rhizomes.
Methods: Authenticated rhizomes were Soxhlet-extracted with ethanol, petroleum ether and distilled water. Crude yields were recorded post-evaporation. Qualitative tests screened for tannins, flavonoids, phenols, saponins, carbohydrates, anthraquinones, alkaloids, and terpenoids. Antibacterial activity against *Staphylococcus aureus*, *Klebsiella* spp., and *Escherichia coli* was assessed by agar-well diffusion on Mueller-Hinton agar; ciprofloxacin (5 µg) and DMSO served as positive and negative controls.
Results: From 1,440 g powdered rhizome, total crude was 11.58 g (0.80%). By solvent: ethanol 4.25 g (0.89%), petroleum ether 3.80 g (0.79%), aqueous 3.53 g (0.74%). Ethanol extract displayed the broadest phytochemical profile. Zones of inhibition (mm): *S. aureus* 12.0 (ethanol), 9.0 (petroleum ether), 6.0 (aqueous); *Klebsiella* 10.0, 7.0, 5.0; *E. coli* 8.0, 6.0, 2.0; ciprofloxacin 17.5/18.0/14.5; DMSO 0.0.
Conclusion: Ethanol provided richer phytochemicals and stronger antibacterial activity than petroleum ether and water. Findings support quantitative phytochemistry and MIC/MBC confirmation to progress standardized antimicrobial preparations.

Keywords: *Curcuma longa*, turmeric, Soxhlet extraction, phytochemical screening, agar-well diffusion, antibacterial activity, *Staphylococcus aureus*, *Klebsiella* spp., *Escherichia coli*

Introduction
Medicinal plants provide structurally diverse bioactives. *Curcuma longa* (turmeric) is notable for anti-inflammatory, antioxidant, and antimicrobial properties attributed to curcuminoids and essential oils (Hewlings & Kalman, 2017; Kocaadam and Şanlier, 2017; Prasad *et al*., 2014; Fuloria *et al*., 2022) [5, 6, 2, 9]. With rising antimicrobial resistance, plant-derived agents are explored as complements (Anand *et al*., 2021; Ghosh *et al*., 2015) [1, 3]. Extract composition and activity depend on solvent polarity and process parameters. This study reports yields, phytochemical profiles, and antibacterial activity of ethanol, petroleum ether, and aqueous extracts of *C. longa* rhizomes to aid replication and standardization.

Materials and Methods
Study Design and Authentication
Experimental laboratory study. Mature rhizomes were collected at Fourah Bay College Botanical Garden (Freetown, Sierra Leone), authenticated at the Department of Botany; voucher IDs recorded (FTWA d.2,3:70; UPWTA ed.1,473) (Nguyen Thi *et al*., 2021; Srivastava, Ripanda and Mwanga, 2022) [8, 11].

Soxhlet Extraction and Crude Yield
Rhizomes were washed, shade-dried, milled, and portioned (480 g per solvent; total 1,440 g). Soxhlet extraction used ethanol, petroleum ether, or distilled water. Typical durations: ~3.5 h (petroleum ether), 4-6 h (ethanol), ~6 h (water). Solvents were removed by rotary evaporation; aqueous residue concentrated at 40-50 °C. Crudes were weighed and % yield calculated per 480 g and overall.

Qualitative Phytochemical Screening
Standard tests: Molisch/ Fehling/ Benedict (carbohydrates/ reducing sugars); Dragendorff/ Mayer (alkaloids); froth test (saponins); ferric chloride (tannins); magnesium/HCl (flavonoids); Bornträger (anthraquinones); Salkowski (terpenoids). Presence recorded as ++ (strong), + (present), - (absent).

Microorganisms and Culture Conditions
Test organisms: *Staphylococcus aureus*, *Klebsiella* spp., and *Escherichia coli*. Isolates were sub-cultured on Nutrient Agar to confirm viability.

Agar-Well Diffusion Antibacterial Assay
Mueller-Hinton agar (38 g/L; 9.5 g in 250 mL) was prepared, sterilized (121 °C, 15 min), cooled to 45 °C, and poured. Inocula were adjusted to 0.5 McFarland. Wells (7 mm) were bored in seeded plates; wells received crude extracts or controls. Plates incubated at 37 °C for 24 h; zones measured (mm).

Controls and Data Handling
Ciprofloxacin (5 µg) served as positive control; DMSO was negative control. Descriptive summaries were used to compare activity across solvents and organisms.

Results

Table 1: Percentage Yield of *Curcuma longa* Extracts by each solvent

Extract	Weight (g)	% Yield (compared to 480 g)
Ethanol extract	4.25	0.89%
Petroleum ether extract	3.80	0.79%
Aqueous extract	3.53	0.74%

Table 2: Phytochemical Composition of *Curcuma longa* Extracts

Phytochemical Component	Ethanol Extract	Petroleum Ether Extract	Aqueous Extract
Tannin	++	-	+
Flavonoid	++	+	++
Phenol	++	+	++
Saponin	+	+	+
Carbohydrate	+	+	++
Anthraquinones	+	+	+
Alkaloids	+	+	+
Terpenoids	++	++	-

Key: ++ = strongly present, + = present, - = absent

Table 3: Zones of Inhibition (mm) for *Curcuma longa* Extracts and Controls

Isolate	Positive Control ciprofloxacin (5 µg)	Negative Control Dimethyl Sulfoxide (DMSO)	Ethanol Extract	Petroleum Ether Extract	Aqueous Extract
Staphylococcus aureus	17.5	0.0	12.0	9.0	6.0
Klebsiella	18.0	0.0	10.0	7.0	5.0
Escherichia coli	14.5	0.0	8.0	6.0	2.0

Discussion
Ethanol delivered the highest yield and the broadest phytochemical profile, aligning with expectations for an intermediate-polarity solvent capable of extracting phenolic and terpenoid classes (Mahmood *et al*., 2022; Rathi *et al*., 2021) [7, 10]. Superior antibacterial zones for ethanol extract against *Staphylococcus aureus*, *Klebsiella* spp., and *Escherichia coli* are consistent with prior reports (Goudarzi *et al*., 2022; Ghosh *et al*., 2015) [3, 4]. Ciprofloxacin confirmed assay validity; DMSO showed no activity.

Methodologically, standardized Mueller-Hinton conditions, 0.5 McFarland inocula, and defined well size support replication. Limitations include qualitative rather than quantitative phytochemistry, absence of MIC/MBC determinations, and a limited organism panel. Future work should quantify key classes (e.g., total phenolics/flavonoids), determine MIC/MBC, expand to resistant isolates, optimize extraction parameters, and assess stability/toxicity.

Conclusion
Curcuma longa rhizome extracts exhibited solvent-dependent yields, phytochemical spectra, and antibacterial effects. Ethanol performed best across yield, phytochemical richness, and inhibition zones. Findings support further standardization with quantitative phytochemistry and MIC/MBC confirmation as next steps.

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