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Research Article

Assessment of Bioactive Properties and Nutritional Value of *Imperata Cylindrica* Rhizome Extract

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Abstract

This study evaluated the bioactive properties and nutritional composition of *Imperata cylindrica* rhizome extracts with a view to assessing its potential as a natural food preservative. Rhizomes were cleaned, dried, pulverized, and extracted using petroleum ether, acetone, methanol, and distilled water via Soxhlet extraction. Proximate and mineral compositions were determined using standard AOAC methods, while phytochemical constituents were quantified using established procedures. Proximate analysis showed carbohydrates predominated (up to 99.43 %). Antioxidant activity was assessed using the DPPH radical scavenging assay, and antimicrobial activity was evaluated using agar well diffusion and minimum inhibitory concentration (MIC) techniques. Results showed that aqueous (46.34 %) and methanolic (26.26 %) extracts yielded the highest extraction efficiencies. Phytochemical analysis revealed the presence of total phenols (up to 35.30 ± 0.10 mg GAE/g in acetone), tannins (up to 34.33 ± 0.03 mg TAE/g in acetone), saponins (up to 20.23 ± 0.58 mg/g in acetone), oxalates (up to 2.46 ± 0.11 mg/g in methanol), and alkaloids (up to 1.70 ± 0.07 g/100g in petroleum ether). Methanolic extract exhibited the highest antioxidant activity (36.73 ± 0.45 mg TAE/g). All extracts showed varying degrees of antimicrobial activity against the tested organisms. The findings indicate that *Imperata cylindrica* rhizome possesses significant antioxidant and antimicrobial properties based on in vitro assays and in situ raw cheese application, suggesting its potential as a natural food preservative.

Keywords: Antimicrobial activity, Antioxidant activity, *Imperata cylindrica*, Phytochemicals, Rhizome extract.

Introduction

Imperata cylindrica is a perennial grass widely distributed across tropical and subtropical regions. It is commonly regarded as an invasive weed that negatively affects agricultural productivity (MacDonald, 2004; Adeleke *et al.,* 2024). Despite its ecological impact, increasing scientific attention has been directed toward its rhizome due to reported medicinal and nutritional properties. Traditional applications of the rhizome include the treatment of gastrointestinal disorders, hypertension, and inflammatory conditions (Sahidin *et al.,* 2025). These traditional uses suggest the presence of bioactive compounds with significant therapeutic potential. Previous studies have identified various phytochemicals in medicinal plants that contribute to biological activity, thereby supporting continued investigation into under utilised plant species (Wink, 2015; Atanasov *et al*., 2021).

Growing concerns regarding the safety and environmental impact of synthetic food preservatives have intensified the search for natural alternatives derived from plant sources. Consumer preference for minimally processed foods with

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fewer chemical additives has further accelerated research into natural preservation strategies (Hassanien *et al.,* 2024). Bioactive compounds such as phenolics, flavonoids, tannins, and alkaloids have been widely reported to exhibit antioxidant and antimicrobial properties, making them suitable candidates for application in food systems. Sharma and Bhat (2009) demonstrated that phenolic-rich plant extracts exhibit strong radical scavenging activity, while Gouvea *et al.* (2017) highlighted the antimicrobial effectiveness of plant-derived compounds against foodborne pathogens.

Although previous studies have explored the general biological activities of *Imperata cylindrica*, existing research primarily focuses on crude baseline screenings without systematically evaluating how extraction solvent polarity affects specific phytochemical profiles and functional potency (Latha *et al.,* 2020; Dhianawaty *et al.,* 2024). Furthermore, there is a critical gap regarding the direct application and stability of these extracts within real food matrices. Given that solvent selection governs the solubility of specific active compounds, a rigorous comparative analysis of solvent-dependent extraction efficiency is essential to identify the optimal fraction for food preservation (Boeing et al., 2014; Duan *et al.,* 2021). Addressing this gap, this study systematically evaluates the impact of extraction solvents on the yield, phytochemical composition, and antioxidant and antimicrobial performance of *I. cylindrica* rhizome extracts, establishing their targeted application as natural bio-preservatives in raw cheese.

Limited studies have comprehensively evaluated the phytochemical composition, antioxidant activity, and antimicrobial potential of *Imperata cylindrica* rhizome using multiple solvent systems. Variation in solvent polarity significantly influences extraction efficiency and the types of compounds recovered, which ultimately affects biological activity (Ghasemzadeh *et al.,* 2025). Insufficient comparative data on solvent-dependent extraction limits the practical application of this plant in food preservation and nutraceutical development. Therefore, a systematic evaluation of its chemical composition and functional properties is required to establish its potential industrial relevance.

This study aimed to evaluate the nutritional composition, phytochemical constituents, antioxidant capacity, and antimicrobial activity of *Imperata cylindrica* rhizome extracts obtained using solvents of varying polarity. Emphasis was placed on understanding the relationship between extraction solvent and bioactive compound recovery, as well as the implications of these findings for food preservation and safety.

Materials and Methods

Sample collection and preparation

Rhizomes of *Imperata cylindrica* were collected from the Teaching and Research Farm of Ladoke Akintola University of Technology, Ogbomoso, Nigeria, and authenticated based on standard morphological characteristics and botanical keys. Collected samples were washed thoroughly under running tap water to remove adhering soil particles and debris, followed by rinsing with distilled water to eliminate residual contaminants. Cleaned rhizomes were air-dried under shade at ambient temperature (25 ± 2 °C) until constant weight was achieved in order to minimize enzymatic degradation and microbial activity.

Dried rhizomes were milled into fine powder using a laboratory grinder (Kenwood, Kenwood Limited, Havant, Hampshire, UK) and passed through a 60-mesh sieve to obtain uniform particle size distribution. Powdered samples were stored in airtight polyethylene containers at 25 ± 2 °C prior to analysis. All reagents used were of analytical grade, and distilled water was used throughout the experimental procedures. All determinations were carried out in triplicate to ensure accuracy and reproducibility of results.

Extraction procedure

Bioactive constituents were extracted sequentially using a Soxhlet apparatus with organic solvents of increasing polarity, namely petroleum ether, acetone, and methanol. Due to the high boiling point of water, the aqueous extract was prepared separately by maceration: powdered rhizome sample was soaked in distilled water (1:10 w/v) at room temperature for 48 hours with continuous

stirring, filtered through Whatman No. 1 filter paper, and concentrated.

Fifty grams (50 g) of the powdered sample were placed in cellulose extraction thimbles and extracted with 100 mL of each solvent for a period of 6 h under controlled reflux conditions using a small-scale, rapid-cycling Soxhlet unit optimized for minimal solvent consumption. Temperature during extraction was maintained at the boiling point of each solvent to ensure efficient extraction.

Extracts obtained were concentrated using rotary evaporation and further dried in a hot air oven at 40 ^{0}C to constant weight following established parameters for this species (Sahidin *et al.*, 2025). Dried extracts were weighed using an analytical balance and stored in sterile containers at 4 ^{0}C until further analysis. Percentage yield of each extract was calculated using the expression described by Harborne (1998):

$$\text{Percentage yield (\%)} = \frac{W_2}{W_1} \times 100$$

Where:
W_1 = Initial weight of the powdered sample (g)
W_2 = Weight of the dried extract obtained (g)

Proximate analysis
Proximate composition of the samples, including moisture content, crude protein, crude fat, ash, and crude fibre, was determined using standard methods of the Association of Official Analytical Chemists (AOAC, 2023). Moisture content was determined by oven drying at 105 °C to constant weight. Crude protein was determined using the Kjeldahl method based on nitrogen determination and a conversion factor of 6.25.

Crude fat was determined using Soxhlet extraction with petroleum ether as solvent, while ash content was determined by incineration in a Carbolite muffle furnace (Model ELF 11/6, Carbolite Gero Ltd., Sheffield, UK) at 550 °C for 4 h**.** Crude fibre was determined using sequential acid and alkaline digestion methods as described by AOAC (2023). Carbohydrate content was calculated by difference using the expression:

$$\text{Carbohydrate (\%)} = 100 - (\text{Moisture} + \text{Protein} + \text{Fat} + \text{Ash} + \text{Fibre})$$

Mineral analysis
Mineral composition was determined using dry ashing and wet acid digestion prior to Atomic Absorption Spectrophotometry (AAS) according to standard procedures (AOAC, 2023). One gram (1 g) of the sample was subjected to dry ashing at 450 °C in a muffle furnace, followed by acid digestion using 6 M hydrochloric acid. Digested samples were filtered and diluted to a known volume with deionized water to ensure homogeneity. Elemental analysis for calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) was carried out using an atomic absorption spectrophotometer (Buck Scientific Model 210 VGP). Calibration curves were prepared using standard solutions of known concentrations, and appropriate reagent blanks were used to correct for background interference. All measurements were performed in triplicate to ensure precision and reliability.

Phytochemical analysis
Quantitative phytochemical determination was carried out using established analytical procedures. Tannins were determined using the Folin–Denis method, while total phenolic content was determined using the Folin–Ciocalteu reagent method, following profiling operations described by Duan *et al.* (2021). Absorbance for phenolics was measured at 765 nm and expressed as gallic acid equivalents (GAE).

- Alkaloids were extracted and quantified using gravimetric techniques described by Duan *et al*. (2021). Five grams (5 g) of the sample were extracted using 10 % v/v acetic acid in ethanol and precipitated with concentrated ammonium hydroxide. The precipitate obtained was filtered, dried, and weighed. Alkaloid content was calculated using the expression:

$$\text{Alkaloid (\%)} = \frac{W_2 - W_1}{W} \times 100$$

Where:
W_2 = weight of the filter paper and precipitate (g)
W_1 = weight of the empty filter paper (g)
W = initial weight of the sample (g)

Saponins were determined using the double solvent extraction gravimetric method described by

Harborne (1998) and referenced in similar species evaluations by Science Publishing Group (2023). Exactly 20 g of the ground rhizome sample was dispersed in 200 mL of 20 % v/v of aqueous ethanol in a conical flask. The mixture was heated over a hot water bath for 4 h at 55 °C with continuous, vigorous stirring, followed by filtration through Whatman No. 42 filter paper. The active residue was re-extracted with another 200 mL of 20 % v/v aqueous ethanol. Saponin content was calculated as:

$$\text{Saponin (\%)} = \frac{W_2 - W_1}{W} \times 100$$

Where:

W_2 =Weight of the filter paper and residue (g)
W_1 = Weight of the empty filter paper (g)
W = Weight of the initial sample (g)

Oxalate content was determined by titration with standard potassium permanganate following the method described by Duan *et al.* (2021). Two grams (2.0 g) of the powdered sample were extracted with 75 mL of distilled water and 25 mL of 6 mol L^{-1} hydrochloric acid. The mixture was digested at 90 °C for 1 h to ensure complete solubilisation of oxalate compounds. The digest was allowed to cool and filtered, and the filtrate was titrated against hot 0.05 mol L^{-1} potassium permanganate ($KMnO_4$) solution until a persistent faint pink endpoint was observed for at least 30 s. Oxalate content was calculated using the expression:

$$\text{Oxalate (\%)} = \frac{T \times 0.00225}{W} \times 100$$

Where:

T = Titre value (mL)
W = Weight of the sample (g)

Phytate content was determined using the standard titrimetric method described by Ifemeje *et al.* (2014). Two grams (2 g) of the sample were soaked in 100 mL of 2 % hydrochloric acid for 3 h with intermittent agitation and subsequently filtered. A 50 mL aliquot of the filtrate was mixed with 10 mL of 0.3 % ammonium thiocyanate solution and titrated against standard iron (III) chloride ($FeCl_3$) solution until a brownish-yellow colour persisted for approximately 5 min. Phytate content was calculated based on the titre value and expressed on a dry weight basis.

Carotenoids were extracted and quantified spectrophotometrically using standard plant matrix procedures as described by Lagnika *et al.* (2023). One gram (1.0 g) of the sample was homogenised with 10 mL of 100 % acetone, and the homogenate was filtered. The extract volume was adjusted to 25 mL with acetone, and absorbance was measured at 453 nm using a UV–visible spectrophotometer. Carotenoid concentration was determined using a β-carotene standard calibration curve and expressed as mg g^{-1} of sample.

Antioxidant activity

Total antioxidant capacity was evaluated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay based on the method described by Lagnika *et al.* (2023) with minor modifications. A solution of DPPH (0.004 % w/v, 0.1 mM) was prepared in pure methanol. Sample extracts were diluted in their respective solvents to a concentration of 1 mg/mL. Two millilitres (2 mL) of the DPPH solution was mixed with 2 mL of each extract solution. Methanol served as the blank/solvent control (A_0), while ascorbic acid (1 mg/mL) was evaluated under identical conditions as the positive reference standard.

Reaction mixtures were incubated in the dark for 30 min at room temperature to prevent photo-degradation of the DPPH radical. The absorbance was subsequently measured at 517 nm using a UV–visible spectrophotometer. Percentage inhibition of DPPH radicals was calculated using the equation:

$$\text{DPPH scavenging activity (\%)} = \left(\frac{A_0 - A_1}{A_0}\right) \times 100$$

where A_0 is the absorbance of the solvent control and A_1 is the absorbance of the extract sample. Total antioxidant capacity was reported as percentage radical scavenging activity.

Determination of microbial Counts (TPC, Mould/Yeast, and Coliforms)

The microbial load of the samples was evaluated using standard pour-plate enumeration techniques (AOAC, 2023; ISO, 2017).

***Total plate count (TPC)*:** Under aseptic conditions, 1 g of sample was homogenized in 9 mL of sterile distilled water to obtain a 10^{-1} dilution. Serial ten-fold dilutions were prepared up to 10^{-6}. Aliquots (1 mL) from appropriate dilutions were transferred into sterile Petri dishes, mixed with molten Plate Count Agar (PCA), and gently swirled. Blank control plates containing uninoculated media were prepared simultaneously to ensure sterility. Plates were incubated at 37 °C for 18--24 h, after which colonies were enumerated and expressed as CFU/g using the equation (ISO, 2013):

(i)

$$\text{CFU/g} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\text{Volume plated (mL)}}$$

***Total mould and yeast count*:** One gram (1 g) of sample was homogenized in 9 mL of sterile peptone water (10^{-1} dilution) and serially diluted up to 10^{-6}. Selected dilution aliquots (1 mL) were pour-plated onto Potato Dextrose Agar (PDA) supplemented with chloramphenicol (100 mg/L) to suppress bacterial growth (Tournas et al., 2001). Plates were incubated at 27°C for 3--5 days, and fungal colonies were counted after 4 days and reported as CFU/g.

Total coliform count: Aliquots (1 mL) of serial ten-fold dilutions (10^{-1} to 10^{-6}) prepared in sterile distilled water were pour-plated using molten MacConkey agar (Feng et al., 2020). Inoculated plates were incubated at 36 ± 1°C for 24--48 h, after which coliform colonies were enumerated as CFU/g.

Antimicrobial activity and agar well diffusion

Antimicrobial activity was evaluated using the agar well diffusion technique described by Lagnika *et al*. (2023) and CLSI (2018) guidelines with minor modifications. Prior to testing, all rhizome extract solutions were sterilized by filtration through a 0.22 μm membrane filter to prevent contamination (Balouiri *et al.,* 2016).

***Inoculum preparation*:** Test bacterial strains (*Staphylococcus aureus* and *Escherichia coli*) were subcultured in Nutrient Broth at 35--37°C. Inoculum density was standardized against a 0.5 McFarland turbidity standard [prepared by mixing 0.5 mL of 0.048 M $BaCl_2 \cdot 2H_2O$ with 99.5 mL of 0.18 M H_2SO_4] (CLSI, 2018). Suspensions were adjusted with physiological saline to an optical density matching 1×10^8 CFU/mL (verified against a black-and-white grid background and confirmed spectrophotometrically at 600 nm).

Agar well assay: Sterile Mueller–Hinton agar plates were inoculated with standardized bacterial suspensions using a sterile cotton swab to produce a uniform lawn. Wells (6 mm) were punched using a sterile cork borer, and 100 μL of the rhizome extract (20% w/v) was introduced. Pure extraction solvent served as the negative/solvent control, while tetracycline hydrochloride (for *S. aureus*) and amoxicillin (for *E. coli*) served as positive control standards (CLSI, 2018). Plates were held at 4°C for 30 min to facilitate extract pre-diffusion into the agar before incubating at 37°C for 24 h for bacterial strains (and 24°C for 72 h for fungal strains). Zones of inhibition were measured in millimeters (mm) using a calibrated ruler.

Minimum inhibitory concentration (MIC) determination

The Minimum Inhibitory Concentration (MIC) of the rhizome extract was determined using the broth microdilution method in sterile 96-well microtiter plates as described by Wiegand et al. (2008) and Lagnika *et al*. (2023).

Wells were filled with sterile Mueller–Hinton broth, and two-fold serial dilutions of the filtered extract were prepared across the plate. Bacterial inoculum was diluted in physiological saline to achieve a working cell density of approximately 5×10^5 CFU/mL (EUCAST, 2021). Each microtiter well received 100 μL of the standardized bacterial suspension. Tetracycline hydrochloride (*S. aureus*) and amoxicillin (*E. coli*) were included as positive antibiotic controls, while wells containing broth and inoculum without extract served as negative growth controls. Microplates were incubated at 37°C for 24 h. Growth was determined by visual inspection of turbidity and confirmed by measuring optical density at 600 nm using a UV–Visible spectrophotometer. The MIC was defined as the lowest concentration of rhizome extract that completely inhibited visible bacterial growth. All assays were conducted in triplicate, and extracts demonstrating MIC values below 5 mg/mL were

considered to possess strong antibacterial activity (Gibbons, 2005).

Data analysis

All experimental analyses were conducted in triplicate, and results were expressed as mean ± standard deviation. Data obtained were subjected to one-way analysis of variance (ANOVA) to determine significant differences among treatments. Fisher's Least Significant Difference (LSD) test was used for mean separation at a significance level of $p \leq 0.05$. Statistical analysis was performed using SPSS software (version 13.0) to ensure accuracy and reliability of the results.

Results and Discussion

Extraction yield

The extraction yield of Imperata cylindrica rhizome varied significantly based on solvent polarity (Table 1). The aqueous extract produced the highest yield (46.34 %), followed by methanol (26.26 %), acetone (0.36 %), and petroleum ether (0.02 %). This higher recovery in aqueous and methanolic extracts indicates that polar constituents predominate within the rhizome matrix. Solvent polarity enhances extraction efficiency through improved solute–solvent interactions. Hydrogen bonding and dipole interactions specifically facilitate the dissolution of phenolics, flavonoids, and glycosides (Zhang *et al.,* 2018).

Sahidin *et al.* (2025) and Konan *et al.* (2023) confirmed that polar solvents significantly improve the extraction of bioactive compounds from *I. cylindrica* organs, validating the trends observed in this study. Water-soluble carbohydrates and inorganic constituents likely contribute to the overall extract mass, explaining the higher aqueous yield recorded. Lagnika *et al.* (2023) noted similar results, stating that extraction efficiency depends heavily on the chosen solvent system and the specific plant organ. Previous studies (Atanasov *et al.,* 2021; Rajauria, 2019) highlighted that traditional Soxhlet extraction remains a gold-standard comparative method due to its high mass-transfer efficiency, even as newer green technologies emerge.

The low yield obtained with petroleum ether suggests that lipophilic constituents, such as fats, waxes, and non-polar terpenoids, are limited in the rhizome. Reduced extraction efficiency of non-polar solvents occurs commonly in plant matrices dominated by hydrophilic compounds (Rajauria, 2019). This variation highlights the necessity of careful solvent selection when optimising the recovery of functional compounds for food and pharmaceutical applications.

Proximate composition

Proximate composition values for the various extracts are presented in Table 2. The proximate composition analysis revealed low concentrations of crude protein (0.28—0.52 %), crude fat (0.11—0.19 %), ash (0.08—0.87 %), and carbohydrate (98.48—99.43 %) across all extracts. This marked predominance of total carbohydrates in the extract fractions is attributed to the selective dissolution of polar low-molecular-weight non-structural carbohydrates, free sugars, and carbohydrate-containing secondary metabolites (such as glycosides and polysaccharides) during solvent extraction (Sankaranarayanan et al., 2021). Furthermore, crude fibre was absent (0.00 %) across all extract fractions because crude fibre analysis specifically quantifies acid- and alkali-resistant insoluble structural cell-wall polymers (cellulose, hemicellulose, and lignin). During Soxhlet extraction, these high-molecular-weight structural polymers do not dissolve in the extraction solvents and are completely retained in the solid plant filter residue during filtration (Adu-Gyamfi *et al*., 2023). Consequently, the evaporated liquid extract contains only solvent-soluble constituents, yielding 0.00 % insoluble crude fibre.

These findings align closely with previous proximate evaluations on rhizomatous grass and herbal extracts. While raw, unextracted *Imperata cylindrica* biomass naturally contains significant levels of insoluble crude fibre (~ 28—46 %) and mineral ash in its raw state (Feedipedia, 2020), liquid solvent extraction isolates the soluble organic components, concentrating carbohydrates as the major fraction. Similar carbohydrate-dominant profiles in solvent-extracted rhizomes were reported by Lagnika *et al.* (2023) and Suručić *et al*. (2025), who noted that polarity-driven solvent extraction of rhizomes primarily isolates soluble non-structural carbohydrates alongside bioactive phytochemicals, while excluding insoluble structural fiber.

These values also indicated that *Imperata cylindrica* rhizome is not a significant source of macronutrients. Previous evaluations on grass rhizomes documented similar results (Feedipedia, 2020), showing low nitrogenous and lipid content

in rhizome samples from tropical regions. Bioactive composition, rather than nutritional macronutrient contribution, provides the primary functional relevance of this plant material.

Rhizomes function primarily as storage organs rather than metabolically active tissues, which explains the lower protein values compared to edible plant materials. The low-fat values observed in this study support the suitability of such materials for low-fat food formulations. Sun *et al.* (2025) noted that plant extracts with minimal lipid content are increasingly prioritised in the development of weight-management nutraceuticals. Ash content in the aqueous extract suggests that polar solvents improve mineral solubility and recovery. The limited carbohydrate contribution further indicates that the rhizome is not a major energy source. Duan *et al.* (2021) established that health-promoting properties are prioritised over caloric density in functional food development using this species.

Mineral composition

The mineral composition of *Imperata cylindrica* rhizome extracts is detailed in Table 3. Calcium and magnesium emerged as the predominant elements across all solvent systems. The aqueous extract exhibited the highest calcium content (99.03 ± 0.22 mg/L), whereas the acetone extract contained the lowest amount (57.52 ± 0.26 mg/L). Significant differences ($p < 0.05$) in calcium levels occurred between the aqueous extract and the other solvent systems. Calcium remains essential for physiological processes including bone mineralisation and blood clotting. Recent evidence by Ahn *et al.* (2021) further links adequate calcium intake to the management of chronic metabolic conditions.

Magnesium levels followed a similar trend, with values ranging from 33.13 ± 0.16 mg/L in acetone to 52.42 ± 0.77 mg/L in the aqueous extract. Costello *et al.* (2021) established that magnesium is critical for calcium absorption and enzymatic activation. Higher mineral recovery in the water extract suggests that these elements exist in highly soluble forms within the rhizome matrix. Sahidin *et al.* (2025) recently confirmed that polar extraction significantly improves the bioavailability of essential divalent cations in *I. cylindrica* roots.

Iron and zinc concentrations remained lower in comparison to the macro-minerals. Iron levels ranged from 3.42 ± 0.37 mg/L to 5.03 ± 0.01 mg/L, while zinc levels peaked in water at 0.81 ± 0.02 mg/L. Both minerals contribute to haemoglobin formation and immune function. Zinc recorded the lowest concentration across all samples, indicating that dietary requirements should be supplemented by other sources. Omoba and Omogbemile (2023) noted that plant-based functional ingredients often require fortification to meet daily zinc targets. These findings indicate that while the rhizome provides moderate mineral support, it serves best as a supplementary source in functional food systems (Rodriguez *et al.*, 2024).

Phytochemical composition

Phytochemical analysis confirmed the presence of tannins, phenols, alkaloids, saponins, oxalates, and carotenoids across the rhizome extracts (Table 4). Semi-polar solvents facilitated the efficient recovery of these bioactive compounds. The concentrations of tannins (34.33 ± 0.03 mg TAE/g) and phenols (35.30 ± 0.10 mg GAE/g) reached their maximum levels in the acetone extracts. Ghasemzadeh *et al.* (2025) recently demonstrated that methanolic and acetone systems provide superior efficiency for phenolic extraction in *Imperata cylindrica*. These phenolic compounds contribute significantly to antioxidant activity by donating hydrogen and stabilising free radicals. Sahidin *et al.* (2025) observed similar trends, noting that the concentration of these metabolites directly influences the anti-inflammatory potential of the rhizome.

Saponin content showed marked variation across the different solvents, with the highest level attained significantly in the acetone extract (20.23 ± 0.58 mg/g). This elevated concentration enhances the functional potential of the extract because saponins form complexes with cell membrane sterols. Sun *et al.* (2025) established that saponin recovery remains a critical factor for the development of plant-based antimicrobial agents.

Total carotenoids were also most abundant in the acetone extract (1.43 ± 0.36 mg/mL), providing added nutritional value through provitamin A activity. The concentrations of antinutritional factors (oxalates and phytates) observed across all solvent systems were within acceptable daily intake levels reported in the literature. Specifically, oxalates were within the safe dietary upper limit of <250 mg/100 g (<100 mg/day) (Mitchell *et al.,* 2020). The phytate content of the plant extract ranged from 0.78 mg/100 g to 0.98 mg/100 g, showing no significant difference ($p < 0.05$) across the solvent systems and remaining far below the maximum allowable threshold of 250–500 mg/100 g (<1000 mg/day) for human consumption (Petroski & Minich, 2020). Although traditionally

classified as an antinutrient because of its high affinity to chelate essential minerals like zinc and iron, phytate at these low concentrations exhibits beneficial bioactivity, including anti-inflammatory and cholesterol-lowering effects, as well as acting as a potent antioxidant and protective metal chelator (Grases & Costa-Bauza, 2019). Generally, this study recorded small quantities of phytate across all samples, confirming its nutritional safety.

Antioxidant activity

The antioxidant capacity of *Imperata cylindrica* extracts was evaluated through the DPPH radical scavenging assay, with results expressed as total antioxidant equivalents (TAE). Measurable activity was recorded only in the polar extracts. The methanolic extract exhibited significantly higher activity (36.73 ± 0.45 mg/TAE) compared to the aqueous extract (26.49 ± 0.43 mg/TAE) (Table 4). Petroleum ether and acetone extracts yielded "nil" results, suggesting that the radical scavenging constituents are concentrated in the polar fractions. Lagnika *et al.* (2023) observed a similar trend, reporting that polar solvents are more efficient at extracting the phenolic and flavonoid compounds responsible for hydrogen donation and free radical stabilisation.

Antimicrobial properties and food safety implications

Antimicrobial properties of the aqueous, petroleum ether, acetone, and methanol extracts were evaluated against foodborne pathogens, specifically *Escherichia coli* and *Salmonella typhi*. This assessment focused on their effectiveness within raw cheese samples, which are particularly susceptible to microbial contamination due to poor storage (Hassanien *et al.*, 2024). As illustrated in Figure 1, all four extracts significantly reduced the total plate count, coliforms, and fungal growth within the samples. The methanolic extract demonstrated the highest reduction in microbial load, which may be attributed to the high concentration of phenolics and tannins identified in the phytochemical profile (Table 4). These compounds are known to disrupt microbial cell membranes and precipitate essential proteins. Moussa *et al.* (2023) supports these findings, highlighting the significant antibacterial potential of *Imperata cylindrica* as a natural preservative in dairy products.

Bacterial sensitivity varied significantly across the solvent systems (Table 5 and Table 6). Both *E. coli* and *S. typhi* exhibited sensitivity to the extracts, though potency levels differed based on the solvent used. Bactericidal effects on *E. coli* were observed across various concentrations, ranging from 11.11 % to 100 % for the methanolic extract and 1.23 % to 100 % for the aqueous extract. The Minimum Inhibitory Concentration (MIC) values provided in Table 7 further quantify this potency, where lower percentage values indicate higher antimicrobial efficiency. For *S. typhi*, the methanolic extract was the most potent with a remarkably low MIC of 1.23 %, suggesting high efficacy even at low concentrations. In contrast, the petroleum ether extract required a 100 % concentration to inhibit *S. typhi*, indicating a lower susceptibility of this pathogen to non-polar constituents.

Interestingly, for *E. coli*, the aqueous extract showed superior potency with an MIC of 1.23 %, outperforming the methanolic extract (11.11 %). This variation suggests that the specific antibacterial metabolites active against Gram-negative bacteria are partitioned differently according to solvent polarity. The lower MIC values recorded for the polar extracts (water and methanol) compared to the non-polar extracts (acetone and petroleum ether) indicate that the primary antimicrobial agents in *I. cylindrica* rhizome are hydrophilic in nature. Ahmad (2021) noted that variations in antibacterial performance likely stem from the specific secondary metabolites present in the crude extracts and their respective solubilities.

Antifungal analysis indicated that the aqueous and petroleum ether extracts successfully inhibited the growth of yeast and moulds. Suppression of fungal growth by these extracts highlights their potential to prolong the shelf life of dairy products by preventing spoilage. Consumers increasingly favour such natural preservation strategies over synthetic chemical additives (FDA, 2024). Plant extracts from species like rosemary and thyme have demonstrated similar *in vitro* antimicrobial activity against pathogens typically found in cheese (Hassanien *et al.*, 2024). These findings demonstrate that the bioactive profile of *I. cylindrica* rhizome makes it a suitable candidate for the formulation of natural preservatives.

Conclusion

This study demonstrates that water is the most efficient solvent for extracting bioactive constituents from the rhizome of *Imperata cylindrica*, yielding a maximum of 46.34 % w/w. Methanol follows with a yield of 26.26 % w/w,

while acetone and petroleum ether produce significantly lower recoveries. These results confirm that solvent polarity is a decisive factor in extraction efficiency. Proximate analysis reveals that the rhizome is not a significant source of macronutrients, as protein, fat, and ash levels remain very low. Mineral profiling shows a notable presence of calcium and magnesium across the extracts. Phytochemical screening indicates that acetone and methanol extracts contain the highest concentrations of tannins and phenols. Methanolic extracts exhibit superior antioxidative and antimicrobial properties, particularly against the foodborne pathogens *Escherichia coli* and *Salmonella typhi*. Based on these findings, it is recommended that advanced analytical techniques like HPLC and LC-MS be used to pinpoint specific bioactive compounds. Furthermore, future research should focus on the toxicological assessment and the development of standardized dosage forms to facilitate the practical application of these extracts in the food and pharmaceutical industries.

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Ethics Issues
This study did not involve the use of human or animal subjects; therefore, informed consent for experimentation was not required. Inclusive language has been used throughout the manuscript to ensure it is free from bias, stereotypes, or cultural assumptions. The authors further declare that the manuscript makes no assumptions about the beliefs of any reader and contains no content implying superiority of any individual based on age, gender, race, ethnicity, culture, sexual orientation, disability, or health condition.

Declaration of Competing Interest
The authors have no relevant financial or non-financial interests to disclose.

Authors' Contributions
Oyedemi, G. I. conceptualised the study, designed the experiments, and performed the laboratory analyses. Akande, E. A. supervised the research, reviewed the data, and edited the final manuscript. Both authors have participated in the research preparation and have approved the final article for submission.

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Here is your updated reference list, alphabetized and formatted without numbering or bullets, fully matching every in-text citation:

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Table 1: Percentage yield of *Imperata cylindrica* rhizome extracts using different solvents

Extract	Wt of sample (g)	Qty Recovered (g)	% Yield (w/w)
Water	50	21.82	46.34[d]
Pet. ether	50	0.10	0.02[c]
Acetone	50	0.18	0.36[b]
Methanol	50	13.13	26.26[a]

Values are expressed as mean ± SD (n=3). Means within the same column with different superscripts are significantly different ($p<0.05$).

Table 2: Proximate composition of *Imperata cylindrica* rhizome extracts (%)

Extract	Protein	Fat	Ash	Carbohydrate	Fibre
Water	0.52 ± 0.01[b]	0.13 ± 0.02[a]	0.87 ± 0.02[a]	98.48 ± 0.02[a]	0.00 ± 0.00[a]
Pet. Ether	0.28 ± 0.08[a]	0.11 ± 0.01[ab]	0.36 ± 0.46[a]	99.25 ± 0.47[a]	0.00 ± 0.00[a]
Acetone	0.30 ± 0.03[a]	0.19 ± 0.02[b]	0.08 ± 0.06[a]	99.43 ± 0.07[a]	0.00 ± 0.00[a]
Methanol	0.43 ± 0.10[b]	0.16 ± 0.06[ab]	0.25 ± 0.09[a]	99.16 ± 0.12[a]	0.00 ± 0.00[a]

Values are expressed as mean ± SD (n=3). Means within the same column with different superscripts are significantly different ($p<0.05$).
*Carbohydrate calculated by difference: $100 - (\text{Protein} + \text{Fat} + \text{Ash})$. Crude fibre was absent (0.00%) across all extracts as insoluble structural cell-wall polysaccharides were removed during extract filtration

Table 3: Mineral composition of *Imperata cylindrica* rhizome extract (mg/L)

Extract	Calcium	Magnesium	Iron	Zinc
Water	99.03 ± 0.22[b]	52.42 ± 0.77[b]	4.48 ± 0.47[a]	0.81 ± 0.02[c]
Pet. Ether	68.60 ± 0.45[a]	35.82 ± 0.25[a]	3.88 ± 0.12[a]	0.14 ± 0.08[a]
Acetone	57.52 ± 0.26[a]	33.13 ± 0.16[a]	5.03 ± 0.01[a]	0.16 ± 0.03[a]
Methanol	58.70 ± 0.89[a]	37.47 ± 0.12[a]	3.42 ± 0.37[a]	0.49 ± 0.01[b]

Values are expressed as mean ± SD (n=3). Means within the same column with different superscripts are significantly different ($p<0.05$).

Table 4: Phytochemical composition of *Imperata cylindrica* rhizome extracts

Phytochemical	Water	Pet. ether	Acetone	Methanol
Tannins (mg TAE/g)	25.03 ± 0.03[a]	27.48 ± 0.37[b]	34.33 ± 0.03[d]	30.20 ± 0.18[c]
Phytates (mg/100g)	0.78 ± 0.00[a]	0.88 ± 0.10[a]	0.78 ± 0.19[a]	0.98 ± 0.01[a]
Total Phenols (mg GAE/g)	26.25 ± 0.05[a]	28.65 ± 0.25[b]	35.30 ± 0.10[d]	31.20 ± 0.20[c]
Alkaloids (g/100g)	1.61 ± 0.07[a]	1.70 ± 0.07[a]	1.48 ± 0.34[a]	1.48 ± 0.30[a]
Oxalate (mg/g)	1.54 ± 0.01[ab]	1.75 ± 0.22[b]	1.43 ± 0.11[a]	2.46 ± 0.11[c]
Saponin (mg/g)	1.11 ± 0.61[a]	16.71 ± 0.63[c]	20.23 ± 0.58[d]	7.88 ± 0.01[b]
Total Antioxidant (mg TAE/g)	26.49 ± 0.43[b]	ND	ND	36.73 ± 0.45[c]
Total Carotenoid (mg/g)	0.58 ± 0.01[a]	0.24 ± 0.33[a]	1.43 ± 0.36[b]	0.55 ± 0.08[a]

Values are expressed as mean ± SD (n=3). Means within the same row with different superscripts are significantly different ($p < 0.05$). ND = Not Detected. TAE = Tannic Acid Equivalent; GAE = Gallic Acid Equivalent.

Table 5: Effect of different concentration of the extracts on *Salmonella typhi*

Conc. of Extract (%)	Methanol	Pet. Ether	Acetone	Water
100 (3^0)	Bactericidal	Bactericidal	Bacteriostatic	Bactericidal
33.33 (3^{-1})	Bactericidal	Bacteriostatic	Bacteriostatic	Bactericidal
11.11 (3^{-2})	Bactericidal	Bacteriostatic	No Effect	Bactericidal
3.70 (3^{-3})	Bactericidal	No Effect	No Effect	Bactericidal
1.23 (3^{-4})	Bactericidal	No Effect	No Effect	Bacteriostatic
0.41 (3^{-5})	Bacteriostatic	No Effect	No Effect	Bacteriostatic
0.14 (3^{-6})	Bacteriostatic	No Effect	No Effect	Bacteriostatic
0.04 (3^{-7})	No Effect	No Effect	No Effect	No Effect
0.015 (3^{-8})	No Effect	No Effect	No Effect	No Effect
0.01 (3^{-9})	No Effect	No Effect	No Effect	No Effect

Table 6: Effect of different concentration of the extracts on *Escherichia coli*

Conc. of Extract (%)	Methanol	Pet. Ether	Acetone	Water
100 (3^{0})	Bactericidal	Bactericidal	No Effect	Bactericidal
33.33 (3^{-1})	Bactericidal	Bactericidal	No Effect	Bactericidal
11.11 (3^{-2})	Bactericidal	Bactericidal	No Effect	Bactericidal
3.70 (3^{-3})	Bacteriostatic	Bactericidal	No Effect	Bactericidal
1.23 (3^{-4})	No Effect	No Effect	No Effect	Bactericidal
0.41 (3^{-5})	No Effect	No Effect	No Effect	Bacteriostatic
0.14 (3^{-6})	No Effect	No Effect	No Effect	Bacteriostatic
0.04 (3^{-7})	No Effect	No Effect	No Effect	No Effect
0.015 (3^{-8})	No Effect	No Effect	No Effect	No Effect
0.01 (3^{-9})	No Effect	No Effect	No Effect	No Effect

Table 7: Minimum Inhibitory Concentration (MIC) of the four extracts

Organism	Methanol (%)	Pet. Ether (%)	Acetone (%)	Water (%)
Salmonella typhi	1.23	100	-	3.70
Escherichia coli	11.11	3.70	-	1.23

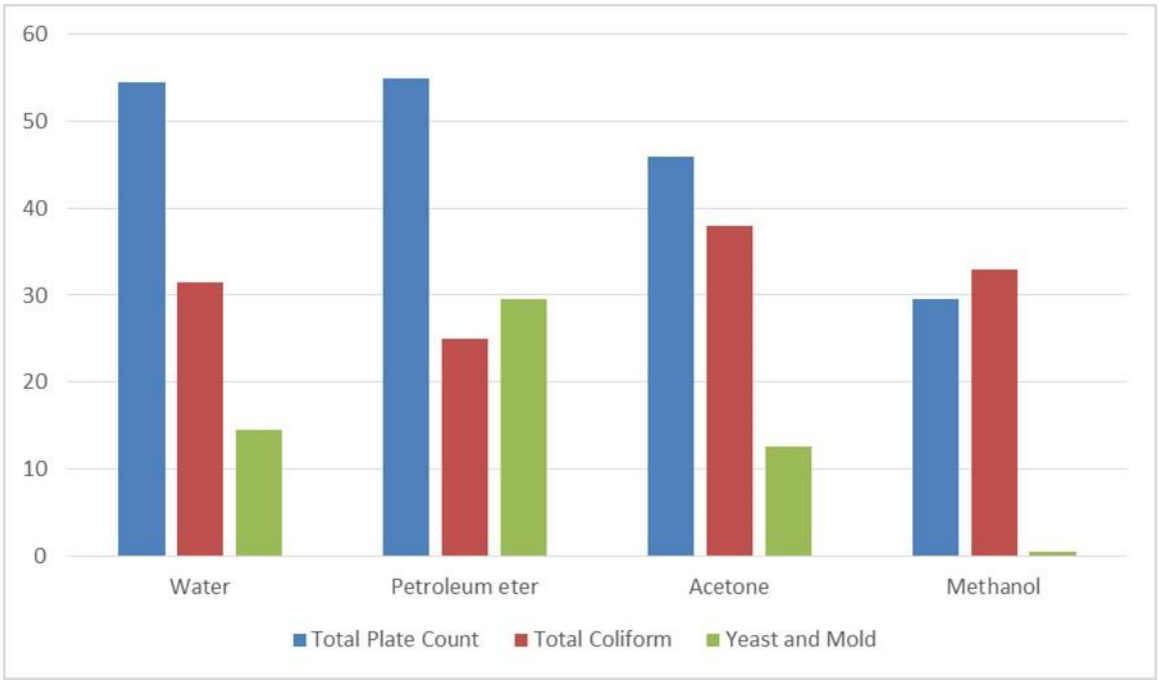

Figure 1. Antimicrobial effect of *Imperata cylindrica* extracts on the microbial load of raw cheese samples.

Blue bar = Total Plate Count

Red bar = Total Coliform

Green bar = Yeast and Mold