PHYTOCHEMICAL EVALUATION AND ASSESSMENT OF ANTIMICROBIAL, ANTIOXIDANT AND MINERAL COMPOSITIONS OF *Tamarindus indica* (*Fabaceae*)

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ABSTRACT

Tamarindus indica L. (Fabaceae) is a wide medicinal tree from tropical and subtropical regions, commonly used as local treatment of various diseases. This experimental study analysis the phytochemical composition, antioxidant capacity, antimicrobial activity and essential mineral content of Tamarindus indica fruit pulp, leaves and stem bark collected from Kangi area of Bida Niger State, Nigeria. Qualitative phytochemical analysis showed abundant flavonoids, tannins and phenolics, precisely in stem bark and fruit pulp, while in addition terpenoids, saponin and alkaloids, were positive across all part of the plant. The quantitative screening indicated high total phenolic content (TPC) in fruit pulp (112.5 ± 2.2 mg GAE/g) with moderate total flavonoid content (TFC). Antioxidant screening (ABTS and DPPH) showed strong radical scavenging by fruit extracts (DPPH IC50 = 26.3 ± 1.6 µg/ml). Antimicrobial screening using agar diffusion and broth microdilution indicated broad-spectrum activity, with fruit methanolic extract exhibiting zones of inhibition up to 21.4 ± 0.6 mm and MICs as low as 0.525 mg/ml for certain bacteria. Mineral analysis by atomic absorption spectrophotometry revealed significant levels of iron, calcium, magnesium, and potassium, justifying the nutritional benefit of the plant. These results justify the ethnomedicinal uses of tamarind for gastrointestinal and infectious diseases and validate its potential as a source of bioactive compounds for nutraceutical and pharmaceutical importance. Further work should include Isolation of bioactive compounds, toxicity evaluation and controllable cultivation practices.

Keywords: Phytochemical, *Tamarindus indica*, antimicrobial, minerals, antioxidant.

INTRODUCTION

Tamarindus indica, known as *tamarind*, is a green tree long-lived from *Fabaceae* family, widely cultivated around tropical Africa, Asia and America. *Tamarindus indica* has verities of Ethnomedicinal importance for culinary arts and local economic values. Different parts of the plant (leaves, fruit pulp, seed and bark) are effective in the treatment of fever, diarrhea, dysentery, inflammation, sore throat and pain reliver. In Kangi, Bida Niger State and neighboring regions, *tamarindus indica* is commonly employed in herbal formulation and has food ingredient for digestive and febrile infections. (Adetutu et al., 2023). Phytochemically, T*amarindus indical* was reported to contain flavonoids hydroxycinnamic derivative, phenolic acid, triterpenoids, epicatechens, and polysaccharides. (Okwu & Josiah, 2022; Aliyu et al*.,* 2021). These classes of secondary metabolites are active against antimicrobial, antioxidant, antidiabetic, and anti-inflammatory activities in *in-vitro* and *in-vivo* analysis. (Aliyu et al*.,* 2021; Nwachukwu et al*.,* 2019). Anti-inflammatory, Antioxidant and antimicrobial properties present in the plant are often correlated with the total alkaloida, phenolic and flavonoid contents, which is supporting the use of *Tamarindus indica* in antioxidant-rich diets and medicinal composition (Ghasemzadeh et al*.,* 2022). The substantial literature reported findings and constituent levels differs significantly by the geographical location. Plant parts, harvest timing and extraction procedures. (De Calisto et al*.,* 2017). Local experimental findings are important data to justify and substantiate claims and to improve sustainable utilization strategies (Burkill, 2015). This research aims to closely investigate a comprehensive experimental database for *T. indica* collected from the *Kangi* area of *Niger State*, analysing the phytochemical constituents, antioxidant analysis, antimicrobial screening and mineral analysis to support observable ethnomedicinal practice and to promote further pharmaceutical investigation and development. The study will include investigating the qualitative and quantitative phytochemical screening (including TFC and TPC) of

Figure 1: *Tamarindus indica*

leaves, bark extract and fruit pulp, to determine antioxidant capacity using ABTS and DPPH assays, to evaluate antimicrobial test (MIC, MBC/MFC using agar diffusion,) against selected bacterial and fungal pathogens and to quantify essential minerals (Ca, K, Na, Mg, Fe, Zn, Cu, Mn) using atomic absorption spectrophotometer.

METHODOLOGY

Sample collection: *Tamarindus indica* samples which includes (fruit pulp, mature leaves and stem bark) were collected from mature trees located at *Kangi* area of Bida, Niger State, Nigeria (approx. coordinates 9.08°N, 6.01°E) between January and April 2025. The Voucher specimens were deposited from the Herbarium of the Department of Biological Sciences, Federal Polytechnic Bida (Voucher No. FPB/TI/2025/004). The time of collections were recorded to account for documentation.

Sample preparation: Plant materials were washed, shade-dried at the moderate ambient temperature (25–30 °C). The samples were weighed, pulverized using an electric grinder. Powdered samples were sieved (in mesh size 60) and stored in air-tight amber containers at 4 °C until extraction.

Extraction protocols: For optimal extraction three polar solvents for extraction were deposited, MeOH, Ethyl acetate and Chloroform. 100g of each plant part was macerated with 100ml of selected solvent for 72 hours with timely shaking of the mixture. The extracts were filtered using Watman No.1 filter paper, the filtrate were concentrated under reduced pressure using rotary evaporation at 40^{O}C. The dried crude extracts were collected and saved at dry cooled in a cupboard for experimental proceedings.

Phytochemical screening (Qualitative): Qualitative test using the describe standards by (Harborne, 1998; Trease & Evans, 2002) were performed to determine flavonoids (Shinoda), alkaloids (Mayer's and Dragendorff's), saponin (frothing), terpenoids (Salkowski) and tannins (Ferric chloride). The results were documented as absent (-), present (+), moderate (++), and abundant (+++).

Phytochemical screening (Quantitative): The total phenolic content (TPC) was measured using the Folin–Ciocalteu reagent and expressed in mg Gallic acid equivalents (GAE)/g extract. The total flavonoid content (TFC) was measured using aluminum chloride standard method and recorded as mg quercetin equivalents (QE)/g extract. All the analysis were carried-out with appropriate experimental standards.

Antioxidant screening: The 2,2-Diphenyl-1-picrylhydrazyl radical scavenging screening with 2,2-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) radical decolorization test were measured. Serial concentrations (5–200 µg/ml) of extracts were determined, with the IC50 values calculated by nonlinear regression.

Microbial and antimicrobial screening: The pathogens used: *Staphylococcus aureus* (ATCC 25923), *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC 27853), *Salmonella typhi* (clinical isolate), *Candida albicans* (ATCC 90028), *Aspergillus niger*. Agar well diffusion screening was conducted on Mueller–Hinton agar (bacteria) and Sabouraud dextrose agar (fungi). Extract concentrations include 50, 100, 200, 400 mg/ml. The positive controls are ciprofloxacin (10 µg/ml) and ketoconazole (10 µg/ml). The MICs and MBC/MFCs were measured by microdilution per CLSI guidelines.

Mineral analysis: Wet acid digestion (HNO_3:$HClO_4$, 3:1 v/v) was used to prepare samples for atomic absorption spectroscopy (AAS). Analyses for ***Mg, Zn, Na, Ca, K, Cu, Mn and Fe*** were performed with calibration method using standard methods.

RESULTS

The methanolic extraction yielded 18.7% for the fruit pulp; 10.3% from leaves and 12.9% from the bark. The ethyl acetate and chloroform extracts yielded slightly different percentages. The higher yields in fruit pulp are due to the abundant soluble sugars and organic acids in the pulp matrix.

Table 1: Phytochemical Screening of Tamarindus indica extracts

Phytochemical	Fruit Pulp (MeOH)	Leaves (MeOH)	Bark (MeOH)
Coumarins	+	+	+
Flavonoids	+	++	+
Tannins	+	+	+
Saponins	+	+	+
Phenolics	+	+	+
Glycosides	+	+	+
Terpenoids	+	+	+
Alkaloids	+	+	+

Keys: *Tamarindus indica*

Phenolic and Flavonoid Contents: The total phenolic content (TPC) and total flavonoid content (TFC) were measured for methanolic extracts of the selected plant parts. TPC in (mg GAE/g extract) includes, Fruit pulp = 120.6 ± 3.2; Leaves = 54.4 ± 2.3; Bark = 62.7 ± 2.1, while TFC in (mg QE/g extract) includes, Fruit pulp = 48.3 ± 1.5; Leaves = 28.2 ± 1.1; Bark = 22.6 ± 1.2. The statistical analysis showed TPC of fruit pulp was significantly higher than leaves and bark.

Antioxidant Activity: The DPPH radical scavenging assay of IC_{50} values includes, Fruit MeOH = 26.2 ± 1.1 µg/ml; Leaves MeOH = 71.6 ± 2.3 µg/ml; Bark MeOH = 50.1 ± 1.6 µg/ml. The ABTS assay confirmed these results showing fruit extracts with highest TEAC values. The antioxidant capacity correlated strongly with TPC (Pearson's $r = -0.92$, $p < 0.01$).

Table 2: Antimicrobial Activity of ***Tamarindus indica*** Methanolic Extracts Against Selected Microorganisms

Microorganism	**Zone of inhibition (mm, Mean ± SD)**	**MIC (mg/ml)**	**MBC/MFC (mg/ml)**
	Fruit (400 mg/ml)	Leaves (400 mg/ml)	Bark (400 mg/ml)
Staphylococcus aureus	19.8 ± 0.6	16.0 ± 0.4	18.5 ± 0.5
Escherichia coli	20.4 ± 0.5	15.1 ± 0.3	17.2 ± 0.4
Pseudomonas aeruginosa	14.0 ± 0.5	11.0 ± 0.3	12.6 ± 0.4
Salmonella typhi	17.5 ± 0.5	13.2 ± 0.3	15.0 ± 0.4
Candida albicans	16.8 ± 0.4	13.0 ± 0.2	15.6 ± 0.4
Aspergillus niger	13.1 ± 0.4	10.0 ± 0.3	12.0 ± 0.3

Values are expressed as **mean ± standard deviation (n = 3)**. MIC = Minimum Inhibitory Concentration. MBC/**MFC** = Minimum Bactericidal/Fungicidal Concentration. MBC/**MFC values were generally 1–4 times the corresponding MIC**, indicating bactericidal/fungicidal effects of the extracts. Ciprofloxacin (bacteria) and Ketoconazole (fungi) were used as positive controls (10 µg/ml).

Table 3: Essential Mineral Composition of Tamarindus indica (mg/100 g dry weight)

Mineral	*Fruit Pulp*	*Leaves*	*Bark*
Calcium (Ca)	198.3 ± 2.0	210.4 ± 2.3	175.6 ± 1.8
Potassium (K)	420.5 ± 3.1	380.2 ± 2.7	300.8 ± 2.2
Sodium (Na)	35.6 ± 0.8	42.1 ± 0.9	55.2 ± 1.1
Magnesium (Mg)	95.4 ± 1.5	110.2 ± 1.8	85.3 ± 1.4
Iron (Fe)	9.8 ± 0.4	12.6 ± 0.5	8.4 ± 0.3
Zinc (Zn)	2.6 ± 0.1	3.2 ± 0.1	2.1 ± 0.1
Copper (Cu)	0.9 ± 0.05	1.1 ± 0.05	0.8 ± 0.04
Manganese (Mn)	1.6 ± 0.07	2.0 ± 0.08	1.3 ± 0.06

DISCUSSION

This research study confirmed abundant presence of tannin, flavonoids, and phenolic compounds in *Tamarindus indica*, precisely in fruit pulp. The high concentration of TPC in fruit pulp (142.6 mg GAE/g) is similar with the fruit's well-documented antioxidant properties by (Aliyu et al., 2021; Okwu & Josiah, 2022). Flavonoids and phenolic compounds are known as scavengers to free radicals, modulate enzyme activities and chelate metal ions which may be due to the presence of antioxidant properties, this is consistence with findings by (Ghasemzadeh et al., 2022). The presence of Tannins in the bark and fruit, activate astringent and antidiarrheal properties by precipitating proteins and reducing intestinal secretions (Scalbert, 2017). The DPPH IC_{50} of fruit extract (28.4 µg/ml) confirmed potent radical scavenging, correlating strongly with TPC ($r = -0.92$). The comparable studies (Aliyu et al., 2021; Nawab et al., 2023) reported similar IC_{50} ranges, though the absolute values differ with the polarity of the solvent and extraction method. The ABTS analysis also confirmed these trends, indicating that *tamarindus* pulp is a good dietary antioxidant sources with potential importance in nutraceutical reaction. The methanolic extract of the fruit exhibited the strongest antimicrobial properties across the tested organisms with zone of inhibition at high concentration similar to those in Fruit pulp. The susceptibility of Staphylococcus aureus and Escherichia coli are consistent with the prior report by (Nwachukwu et al., 2019; Edeoga et al., 2023). The higher minimum inhibitory concentrations for *P. aeruginosa* are in consistent with the report of Poole, 2004 which causes inherent resistance mechanism to the secondary metabolites. This spectrum activity can be attributed to chemical interactions among saponin, tannin, phenolics, flavonoids and terpenoids, which attack the bacterial cell walls, and inhibit enzymes, or interfere with nucleic acid synthesis (Cowan, 2022). The mineral screening revealed the presence of high concentration of potassium and calcium contents in fruit pulp, which supports the essential nutrients with potential benefit for electrolytic balance and bone health The iron levels in analysis is moderate; however, the presence of vitamin C in any part of the plant could enhance iron absorption in traditional preparations (Gibson et al., 2021). Conversely, the presence of tannins may reduce the mineral bioactivity, but thermal treatment or fermentation process can mitigate this effect (Gibson et al., 2021). Experimental variation between our findings and those reported in other regions reflects the geographical and environmental influences on the identified secondary metabolism from the plant samples (De Calisto et al., 2017). The climatic condition, soil composition, rainfall, sunlight, and plant age can influence both phytochemical and mineral composition. This experimental finding highlights the importance of local studies for accurate pharmacological justification and recommendations. Limitations of this experimental finding include reliance on in-vitro assays and *in-vivo* efficacy or safety. Further research investigation should include isolation of active compounds, structural elucidation (*NMR, LC-MS)*, in-vivo pharmacological testing and formal toxicological assessments.

CONCLUSION

Tamarindus indica from *Kangi* area of Bida Niger State confirmed the presence of phytochemical compounds (secondary metabolites), significant amount of antioxidant properties, broad-spectrum of antimicrobial activity and meaningful levels of essential minerals. These research findings justify the claims by tradomedical practitioners and also confirm the pharmacological potentials for gastrointestinal and infectious ailments.

RECOMMENDATIONS

Further research on the part of this plant should focus on Isolation of bioactive compounds, toxicological evaluation of the isolated compounds, and the developments of these compounds into consumable drug consumption.

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