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Evaluation of the Antimicrobial Activity of the Bark Extracts of *Tamarindus indica*, *Adansonia digitata* and *Vitellaria paradoxa*, and their Combinations against Some Selected Clinical Pathogens

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Abstract

The emergence of antibiotic resistance poses a significant threat to global health, necessitating the exploration of alternative antimicrobial agents. This study investigates the antibacterial activities of the bark extracts of *Tamarindus indica, Adansonia digitata,* and *Vitellaria paradoxa* against Escherichia coli, Staphylococcus aureus, Streptococcus pneumoniae, and Salmonella typhi, using hot aqueous, methanol, and ethanol as solvents for extraction. The antimicrobial activity was analysed by agar well diffusion assay, and their phytochemical properties were assessed using various standard phytochemical methods. A 0.5ml of hundred percentage (100%) concentration of each extract was used against each bacterial isolate at 370C for 24 hours. For positive control, 0.5mg/mL of Ciprofloxacin and 0.5ml of water were used as negative control. The findings reveal substantial antibacterial activity, particularly from the hot aqueous extract of *Tamarindus indica, Adansonia digitata*, and *Vitellaria paradoxa*; and combined extracts exhibited the highest zones of inhibition, ranging from 23.0 to 31.5mm. The combinations of these plant extracts demonstrated enhanced antimicrobial efficacy, indicative of synergistic interactions among the constituents. The phytochemical results of all the extracts showed the presence of mostly Saponins, Tannins, Flavonoid, Phenol, Glycosides and partly Alkaloids. This research highlights the potential of these plant-derived extracts as alternative sources for new antimicrobial agents to combat resistant strains of bacteria.

Keywords: Antimicrobial, *Tamarindus indica, Adansonia digitata, Vitellaria paradoxa*, clinical bacteria, Plant extracts.

Introduction

Plants serve as vital sources of natural compounds beneficial for human health and are instrumental in the development of novel pharmaceutical molecules [1]. Many modern medicines are directly or indirectly derived from plants, which contain active metabolites used to treat various diseases [2]. The use of medicinal plants is deeply rooted in human history, with ancient cultures relying on them for treating ailments [3-5]. Plant resources play a crucial role in combating diseases, as natural plant products rich in nutrients, fibre, antioxidants, and bioactive compounds can reduce the risk of conditions like colorectal cancer, diabetes, and heart disease [6,7]. Despite not being fully explored, medicinal plants hold significant therapeutic potential [8]. Traditional medicine, which combines knowledge, skills, and beliefs from various cultures, has utilized medicinal plants for approximately 5000 years across China, India, and Egypt [9-13]. In Asia, Latin America, and Africa, 80% of the population relies on traditional medicines, which are perceived to have minimal side effects [14]. Traditional herbs are often used alongside modern chemical drugs to prevent and treat diseases [15-18]. Plants remain a significant source of biologically active metabolites for developing new medications [19]. This is attributed to the presence of bioactive chemicals, such as saponins, flavonoids, alkaloids, and polyphenols, which act as defense mechanisms [20, 21]. With the rise of antibiotic resistance threatening global health, finding new antimicrobial compounds is essential [14, 22]. Harnessing the potential of plant-based antimicrobials, which are both inexpensive and environmentally friendly, could provide a solution to drug resistance [23]. Therefore, investigating the antibacterial activities of medicinal plant extracts like Adansonia digitata, Vitellaria paradoxa, and Tamarindus indica against infections caused by Salmonella typhi, Streptococcus pneumoniae, Staphylococcus aureus, and Escherichia coli is critical.

Materials and Methods

Study Area

The study was carried out at Navrongo, located in the Kassena-Nankana Municipality of the Upper East Region of Ghana. This region is characterized by its unique biodiversity and is home to various medicinal plants, making it an ideal location for this research.

Sample Collection

Matured fresh barks of *Tamarindus indica, Adansonia digitata,* and *Vitellaria paradoxa* were collected aseptically from Navrongo into polyethylene bags, each using a sterile cutlass. Plant samples were identified and validated by a botanist at the Department of Applied Biology at C.K. Tedam University of Technology and Applied Sciences. The selected plant materials were based on the plant's health, maturity, and accessibility.

Collection of Pathogens

Clinical isolates of E. coli, S. aureus, S. pneumoniae, and S. typhi were procured from the microbiology laboratory at the Department of Applied Biology, C. K. Tedam University of Technology and Applied Sciences. These pathogens were selected based on their clinical relevance and prevalence in public health settings.

Plant Extracts Preparation

The bark samples of *Tamarindus indica, Adansonia digitata,* and *Vitellaria paradoxa* collected were air-dried, independently crushed into powder using an electric grinder, and extracted using hot aqueous water, methanol (70%) and ethanol (70%) as solvents.

Approximately, 50g of the powdered leaves was weighed using a balance and dissolved in 500ml of water, methanol, and ethanol separately (i.e., in the ratio 1:10). The mixtures were agitated for 3 hours and then for 3 days. The soaked materials were filtered into clean containers using Whattman's No.1 filter paper. The resulting filtrates were evaporated to dryness using a boiling water bath. The yields were separately weighed and kept in a refrigerator for further use.

Hot Aqueous Extracts: Ten grams of finely ground bark powder were weighed and placed in separate conical flasks con-

taining 90 mL of distilled water. The mixtures were heated to boiling in a water bath, cooled to room temperature, filtered through Whatman No. 1 filter paper, and stored at 4 °C.

Ethanolic Extracts: The bark powder was mixed with 90 mL of 70% ethanol in separate flasks and allowed to rest for 24 hours. Following filtration, the extracts were concentrated and stored at 4 °C.

Methanolic Extracts: Similar to the ethanolic process, the bark powder was mixed with 90 mL of 70% methanol and allowed to rest for 24 hours. The resulting extracts were filtered, concentrated, and stored at 4 °C.

Antimicrobial Sensitivity Testing

The bacteria strains were sub-cultured on Mueller Hinton Agar (MHA) and incubated at 37 °C for 48 h. Fresh sub cultures were used in the antimicrobial activity assays as described below.

Agar well diffusion assay was used to determine the zone of inhibition for the different plant extracts and extract combinations. Mueller-Hinton agar plates were prepared, and clinical isolates were spread uniformly across the surface. Wells were created using a sterile cork borer, and 100 µl of the standardized bacterial inoculum was inoculated onto the surface of Mueller-Hinton Agar plates under aseptic conditions. The inoculum was spread evenly using a sterile swab to ensure uniform bacterial growth. A 0.5 mL of each plant extract was injected into each well and allowed to stand and settle for some minutes. For positive control, 0.5mg/mL of Ciprofloxacin and 0.5ml of water were used as negative control. These were incubated at 37°C for 24 hours, and after incubation, the zones of inhibition were measured using a transparent ruler, and the results were recorded in millimeters. The experiments were done in duplicates and the mean values are presented.

Phytochemical Screening of the Plants

Qualitative screening for the presence of the following phytochemicals; alkaloids, flavonoids, phenols, saponins, tannins and glycosides using aqueous hot water, methanol and ethanol extracts were done, following the standard methods of [24-28].

Data Analysis

The data was analysed statistical using SPSS Statistics version 25. The data were presented as mean ± standard deviation in the form of tables. A One-Way ANOVA analysis was used to analyse for statistical differences in the mean zones of inhibition of the different extracts and combinations against the test microorganisms. All statistical tests were carried out at a 5% level of significance ($p \leq 0.05$).

Results

In all the antibacterial activity tables, the hot aqueous extract exhibited significantly higher antibacterial activity than all the other extracts against S. aureus, E. coli, S. typhi and S. pneumonia at $p < 0.05$. Although methanolic and ethanolic extract although showed slightly larger inhibition zones, the differences were not statistically significant ($p > 0.05$). The results indicate that hot aqueous extract may possess stronger antimicrobial constituents, possibly due to floral source variations or contents.

Table 1 shows the antibacterial activities of shea bark extracts. The hot aqueous extract exhibited significantly higher antibacterial activity against S. aureus (31.5 mm) while the methanolic extract showed notable inhibition against S. typhi (28.5 mm), E. coli (30.5 mm) and S. typhi (30.5 mm). The ethanolic extract had the least antibacterial activity (17.5mm), showed slightly larger inhibition zones, the differences were not statistically significant.

Table 1: Antibacterial Activities of Vitellaria paradoxa (Shea) Bark Extract (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	30.5 ± 0.71	20.0 ± 0.00	17.5 ± 3.54	47.5 ± 3.54
S. aureus	31.5 ± 1.41	25.0 ± 0.00	24.5 ± 0.71	55.0 ± 14.14
S. pneumoniae	28.5 ± 0.71	26.0 ± 1.41	24.0 ± 1.41	55.0 ± 7.07
S. typhi	30.5 ± 0.71	28.5 ± 2.12	24.5 ± 0.71	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 2 shows the Antibacterial Activities of *Tamarindus indica* (Tamarind) Bark Extract. Tamarind bark extracts revealed significant antibacterial properties, particularly with hot aqueous extracts, which demonstrated the highest efficacy against S. typhi (25.5 mm). The hot aqueous extract exhibited significantly higher antibacterial activity against S. aureus (31.5 mm) ($p < 0.05$), while the methanolic extract showed notable inhibition against S. typhi (28.5 mm). The ethanolic extract had the least antibacterial activity (17.5mm), showed slightly larger inhibition zones, the differences were not statistically significant ($p > 0.05$).

Table 2: Antibacterial Activity of *Tamarindus indica* (Tamarind) Bark Extract (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	23.0 ± 1.41	14.0 ± 1.41	20.0 ± 0.00	47.5 ± 3.54
S. aureus	24.5 ± 0.71	15.5 ± 0.71	13.0 ± 2.83	55.0 ± 14.14
S. pneumoniae	22.0 ± 1.41	16.0 ± 2.88	11.5 ± 0.71	55.0 ± 7.07
S. typhi	25.5 ± 0.71	18.5 ± 0.71	13.0 ± 2.83	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 3 shows the Antibacterial Activities of Adansonia digitata (Baobab) Bark Extract. The baobab bark extracts also showed promising antibacterial effects. Notably, the hot aqueous extract exhibited the highest inhibition against S. typhi (26.5 mm).

Table 3: Antimicrobial Activity of the Adansonia digitata (Baobab) Bark Extract (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	20.5 ± 0.71	15.0 ± 0.00	22.0 ± 1.41	47.5 ± 3.54
S. aureus	20.0 ± 0.00	14.5 ± 0.71	17.5 ± 3.54	55.0 ± 14.14
S. pneumoniae	23.5 ± 0.71	21.0 ± 0.00	11.0 ± 1.41	55.0 ± 7.07
S. typhi	26.5 ± 0.71	17.5 ± 3.54	17.0 ± 4.24	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 4 shows the antibacterial activities of the combination of *Vitellaria paradoxa* and *Tamarindus indica* extract. The hot aqueous extract achieved the strongest inhibitory effect against S. typhi with a mean inhibition zone of 30.0 mm, indicating potent antibacterial properties. S. aureus also showed significant susceptibility with a zone of 27.5 mm. These results suggest that the synergistic action of the constituents from both plant sources enhances their antibacterial efficacy.

Table 4: Antibacterial Activity of the Combination of *Vitellaria paradoxa* and *Tamarindus indica* Extract (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	23.5 ± 0.71	22.5 ± 3.54	15.0 ± 0.00	47.5 ± 3.54
S. aureus	27.5 ± 3.54	24.5 ± 0.71	19.0 ± 1.41	55.0 ± 14.14
S. pneumoniae	25.0 ± 0.00	23.0 ± 2.83	17.5 ± 2.12	55.0 ± 7.07
S. typhi	30.0 ± 0.00	19.0 ± 1.41	16.5 ± 2.12	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 5 displays the results for the antibacterial activity of the combined extracts from *Adansonia digitata* (baobab) and *Vitellaria paradoxa* (shea tree). The hot aqueous extract notably inhibited S. typhi with a mean zone of 30.0 mm, similar to the table 4. Additionally, the combined effects on other pathogens like S. aureus and S. pneumoniae demonstrated substantial zones of inhibition, indicating that the combination of these two plant extracts can effectively combat a range of bacteria.

Table 5: Antibacterial Activity of the Combination of Adansonia digitata and Vitellaria paradoxa Extracts (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	24.5 ± 0.71	19.5 ± 2.12	20.5 ± 0.71	47.5 ± 3.54
S. aureus	25.0 ± 0.00	25.0 ± 0.00	20.0 ± 0.00	55.0 ± 14.14
S. pneumoniae	26.0 ± 1.41	20.0 ± 0.00	20.5 ± 0.71	55.0 ± 7.07
S. typhi	30.0 ± 0.00	22.5 ± 0.00	20.5 ± 0.00	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 6 shows the antibacterial activity of the combination of *Adansonia digitata* and *Tamarindus indica* extracts. The hot aqueous extract exhibited the most significant effect against S. typhi (23.5 mm). The results suggest that while both baobab and tamarind individually possess antibacterial properties, their combination enhances their overall inhibitory effects, particularly against pathogens like E. coli and S. aureus.

Table 6: Antibacterial Activity of the Combination *of Adansonia digitata* and *Tamarindus indica* Extracts. (Mean ± SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	20.5 ± 0.71	18.0 ± 4.24	13.0 ± 1.41	47.5 ± 3.54
S. aureus	20.5 ± 0.71	20.5 ± 0.71	13.5 ± 0.71	55.0 ± 14.14
S. pneumoniae	21.5 ± 0.71	14.0 ± 2.83	12.0 ± 0.00	55.0 ± 7.07
S. typhi	23.5 ± 0.71	17.5 ± 3.54	13.0 ± 1.41	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 7 shows the antibacterial activities of the combinations of extracts of *Vitellaria paradoxa, Tamarindus indica,* and *Adansonia digitate* extracts. The hot aqueous extract demonstrated the strongest inhibition against multiple pathogens, particularly S. typhi (27.5 mm), illustrating the efficacy of the synergistic effects amongst the three extracts. The results indicate that combining these plant extracts not only improves their individual antimicrobial activities but also supports the concept of multi-ingredient herbal remedies in fighting bacterial infections

Table 7: Antibacterial Activities of the Combinations of Extracts of *Vitellaria paradoxa, Tamarindus indica,* and *Adansonia digitate* extracts. (Mean ±SD).

Clinical Pathogens	Hot Aqueous (mm)	Methanol (mm)	Ethanol (mm)	Positive Control (Cipro)
E. coli	25.0 ± 0.00	13.5 ± 0.71	20.0 ± 7.07	47.5 ± 3.54
S. aureus	25.5 ± 0.71	20.5 ± 0.71	20.0 ± 0.00	55.0 ± 14.14
S. pneumoniae	24.5 ± 2.12	19.5 ± 0.71	17.0 ± 1.41	55.0 ± 7.07
S. typhi	27.5 ± 0.71	17.5 ± 0.71	16.0 ± 2.83	55.0 ± 0.00

Negative control (water) showed 0.00 ± 0.00 mm for all the bacterial isolates.

Table 8 shows the phytochemical screening of the bark extracts of Tamarind. The hot aqueous extract, ethanol extract, and methanol extract of Tamarind were tested for various phytochemicals. Flavonoids, saponins, tannins, phenols, and glycosides were present in the extracts, while alkaloids were present in only one extract.

Table 8: Phytochemical Screening of Bark Extracts of Tamarind.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Tamarind Hot Aqueous (TH)	+	+	+	+	+	+
Tamarind Ethanol (TE)	-	+	+	+	+	+
Tamarind Methanol (TM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

The hot aqueous extract, ethanol extract, and methanol extract of the shea tree were tested for various phytochemicals (Table 9). Alkaloids, flavonoids, saponins, tannins, phenols, and glycosides were present in the extracts except the methanol extract that flavonoids were absent

Table 9: Phytochemical Screening of Bark Extracts of Shea Tree.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Shea Hot Aqueous (SH)	+	+	+	+	+	+
Shea Ethanol (SE)	+	+	+	+	+	+
Shea Methanol (SM)	+	-	+	+	+	+

Legend: + denotes presence; - denotes absence.

The analysis of *Adansonia digitata* (Baobab) extracts demonstrated varying profiles of phytochemicals (Table 10). Flavonoids, saponins, tannins, phenols, and glycosides were present in all the extracts, while alkaloid was present in only one extract.

Table 10: Phytochemical Screening of Bark Extracts of Baobab.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Baobab Hot Aqueous (BH)	+	+	+	+	+	+
Baobab Ethanol (BE)	-	+	+	+	+	+
Baobab Methanol (BM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

The combined extracts of Baobab and Shea were analyzed for their phytochemical content (Table 11). The following phytochemicals mostly alkaloids, flavonoids, saponins, tannins, phenols, and glycosides, were present in all the extracts except methanol extract that alkaloid was absent

Table 11: Phytochemical Screening of Combined Bark Extracts of Baobab and Shea.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Baobab and Shea Hot Aqueous (BSH)	+	+	+	+	+	+
Baobab and Shea Ethanol (BSE)	+	+	+	+	+	+
Baobab and Shea Methanol (BSM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

Table 12 shows the phytochemical screening of the combined bark extracts of baobab and tamarind. Flavonoids, saponins, tannins, phenols, and glycosides were present in all the extracts while alkaloids were absent in all.

Table 12: Phytochemical Screening of the Combined Bark Extracts of Baobab and Tamarind.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Baobab and Tamarind Hot Aqueous (BTH)	-	+	+	+	+	+
Baobab and Tamarind Ethanol (BTE)	-	+	+	+	+	+
Baobab and Tamarind Methanol (BTM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

Table 13 shows the results of the phytochemical screening of the combined bark extracts of shea and tamarind. Alkaloids, flavonoids, saponins, tannins, phenols, and glycosides were present in all the extracts except the methanol extract that alkaloids were absent

Table 13: Phytochemical Screening of the Combined Bark Extracts of Shea and Tamarind.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Shea and Tamarind Hot Aqueous (STH)	+	+	+	+	+	+
Shea and Tamarind Ethanol (STE)	+	+	+	+	+	+
Shea and Tamarind Methanol (STM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

The combined extracts of all three plants (Baobab, Tamarind, and Shea) were analyzed for their phytochemical content. Flavonoids, saponins, tannins, phenols, and glycosides were present in all the extracts, while alkaloids were absent in all the extracts.

Table 14: Phytochemical Screening of the Combined Bark Extracts of Baobab, Tamarind, and Shea.

Plant Extracts	Alkaloid	Flavonoid	Saponins	Tannins	Phenol	Glycoside
Baobab, Tamarind, and Shea Hot Aqueous (BTSH)	-	+	+	+	+	+
Baobab, Tamarind, and Shea Ethanol (BTSE)	-	+	+	+	+	+
Baobab, Tamarind, and Shea Methanol (BTSM)	-	+	+	+	+	+

Legend: + denotes presence; - denotes absence.

Discussion

This study examined the antibacterial efficacy of extracts from *Vitellaria paradoxa* (shea tree), *Tamarindus indica* (tamarind), and *Adansonia digitata* (baobab) against clinical isolates, including Staphylococcus aureus, Streptococcus pneumoniae, Escherichia coli, and Salmonella typhi. Most isolates demonstrated susceptibility to the plant extracts, suggesting broad-spectrum antibacterial action, although some showed intermediate responses.

The hot aqueous extract of shea bark exhibited superior inhibitory activity compared to methanol and ethanol extracts. These inhibitions could be attributed to the presence of metabolites such as alkaloids, tannins, flavonoids, phenols, saponins and glycosides in the extracts. This aligns with findings by [29], who noted that hot water extracts often yield higher phytochemical concentrations. Conversely, [30] indicated that certain plants may exhibit stronger antibacterial properties with methanol or ethanol extracts, highlighting variability based on the specific pathogens and extraction methods used [31]. [32] reveal that the antibacterial activity of medicinal plants was revealed to be due to bioactive chemicals present in the V. paradoxa and other extracts

The results for tamarind extracts showed significant antibacterial activity against all tested pathogens, with hot water extracts outperforming methanol and ethanol extracts. This indicates that the presence of phytochemicals in hot water extracts provides enhanced antibacterial efficacy, which is consistent with previous research that suggests secondary metabolites serve as defenses against microbial threats [33]. Similarly, for baobab extracts, hot water extracts demonstrated the highest antibacterial activity. However, the methanol and ethanol extracts showed only intermediate inhibition against some pathogens, which contrasts with [34] who found ethanol extracts more effective against E. coli and S. typhi.

The combinations of extracts revealed increased antibacterial activity when different extracts were mixed, potentially due to synergistic effects among phytochemicals. The presence of common metabolites in all extracts, such as tannins, alkaloids, flavonoids, saponins, phenols, and glycosides, could be the cause of the inhibitory zone presented by the extracts [33]. When plant extracts are combined, they are able to act on the bacteria in different structures to inhibit them [32]. [35] noted that combining plant extracts may increase the various antimicrobial metabolites and subsequently make it more difficult to develop resistance, and may also boost the bioavailability of the single metabolites that would have higher chances of locating the targets. The combination of antimicrobial substances can be used to reduce the chances of developing resistance. This synergism could enhance the efficacy of these extracts against bacterial pathogens, supporting claims by Van [36] regarding the benefits of combining plant extracts to improve antimicrobial activity. Some extracts exhibited limited efficacy due to potential resistance mechanisms in bacterial isolates or insufficient concentrations of bioactive compounds to inhibit bacterial growth effectively [23, 37]. The specificity of the metabolite of each extract and the sensitivity of the organisms used could be explained by the physiological characteristics of the pathogens and active components of the extracts that are left as an inactive form [38]. More so, some mixed plant extracts cannot inhibit some bacterial isolates due to the development of resistance mechanisms, such as efflux pumps or hydrolysis by enzymes, by the antimicrobial chemicals in the plant extracts [23] Staphylococcus aureus, Streptococcus pneumoniae, Escherichia coli and Salmonella typhi are the tested bacterial isolates. Few of them were intermediate to the plant extracts, whereas the majority were more vulnerable to them. This suggests that the plant extracts have broad-spectrum action.

Conclusion

This study demonstrated that all clinical isolates tested were susceptible to the hot water, ethanol, and methanol extracts of *Vitellaria paradoxa* (shea tree), *Tamarindus indica* (tamarind), and *Adansonia digitata* (baobab). This supports their use in alternative medicine to treat infections caused by these pathogens. The hot aqueous extracts particularly showed substantial efficacy against E. coli, S. typhi, S. pneumoniae, and S. aureus. Although some pathogens displayed intermediate sensitivity to the ethanol and methanol extracts, the results indicate that these plant extracts possess potent antimicrobial properties comparable to conventional antibiotics. The phytochemicals present in the barks could be harnessed for developing new antimicrobial agents, particularly for battling antibiotic-resistant bacterial infections. Overall, this study highlights the importance of phytochemicals in mediating antibacterial effects and demonstrates that combining extracts can enhance these properties.

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