

ORIGINAL RESEARCH ARTICLE

Development and Characterization of Eco-Friendly Bi-Herbal Dye from *Curcuma longa* and *Acacia nilotica* with Antimicrobial Properties

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ABSTRACT

The increasing environmental and health concerns associated with synthetic dyes have stimulated interest in sustainable natural alternatives with additional bioactive properties. This study investigated the extraction, characterization, and antimicrobial activities of a bi-herbal natural dye obtained from *Curcuma longa* and *Acacia nilotica* pods were extracted using ethanol through Soxhlet extraction technique. The bi-herbal dye product was prepared via recrystallization by mixing equal amounts of the extracted dyestuff (5 g each) in ethanol as solvent. The dye exhibited a percentage yield of 48%, melting point range of 119-122 °C, and a dark brown appearance. UV-Visible spectroscopic analysis showed a maximum absorption wavelength (λ_{max}) at 493 nm, indicating the presence of conjugated chromophoric compounds. FT-IR analysis revealed characteristic peaks at 3619.2 cm^{-1} , 3399.3 cm^{-1} , 1595.3 cm^{-1} , and 1517.0 cm^{-1} corresponding to phenolic O-H, N-H, and aromatic C=C functional groups. Antimicrobial evaluation using agar well diffusion method showed inhibition zones of 22 mm against *Staphylococcus aureus*, 19 mm against *Escherichia coli*, and 28 mm against *Candida albicans*, compared with standard drugs Sparfloxacin (37 mm and 35 mm) and Fluconazole (32 mm). The Minimum Inhibitory Concentration (MIC) values were 25 mg/ml for *Staphylococcus aureus*, 50 mg/ml for *Escherichia coli*, and 12.5 mg/ml for *Candida albicans*. Similarly, the Minimum Bactericidal/Fungicidal Concentration (MBC/MFC) values were 50 mg/ml for *Staphylococcus aureus*, 100 mg/ml for *Escherichia coli*, and 12.5 mg/ml for *Candida albicans*. The findings demonstrate that the bi-herbal dye possesses broad-spectrum antimicrobial activity with stronger antifungal potency against *Candida albicans*.

ARTICLE HISTORY

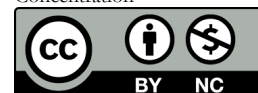
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KEYWORDS

Bi-Herbal Dye; Antimicrobial; Zone of Inhibition; Minimum Inhibitory Concentration; Minimum Bactericidal/Fungicidal Concentration



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INTRODUCTION

The search for sustainable and eco-friendly alternatives to synthetic dyes has increased significantly due to the environmental and health concerns associated with synthetic colorants. Synthetic dyes used in textile, cosmetic, pharmaceutical, and food industries are often non-biodegradable and may release toxic and carcinogenic substances into the environment during production and application processes. These pollutants contribute to water contamination and ecological imbalance, thereby necessitating the development of safer and renewable alternatives. Natural dyes derived from plants have therefore gained renewed scientific attention because of their biodegradability, low toxicity, renewable nature, and additional medicinal properties such as antimicrobial and antioxidant activities (Satruhan and Patel, 2023).

Among the numerous dye-yielding plants, *Curcuma longa* (turmeric) and *Acacia nilotica* have emerged as promising natural sources because of their rich phytochemical

compositions and therapeutic potentials. Turmeric belongs to the Zingiberaceae family and contains curcuminoids, particularly curcumin, which is responsible for its characteristic yellow coloration and strong biological activities. Previous studies have shown that turmeric possesses antibacterial, antifungal, antioxidant, and anti-inflammatory properties against several pathogenic microorganisms. A systematic review by Mehta et al. (2022) reported that turmeric extracts exhibited significant inhibitory effects against both Gram-positive and Gram-negative bacteria as well as fungal strains, thereby supporting its potential application as a multifunctional natural dye and antimicrobial agent (Fuloria et al., 2022).

Similarly, *Acacia nilotica*, a member of the Fabaceae family, is widely recognized for its medicinal and dyeing applications. The pods, bark, leaves, and gum of the plant are rich in tannins, flavonoids, phenolic compounds, and

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alkaloids which contribute to its coloring characteristics and pharmacological activities. Literature reports indicate that *Acacia nilotica* possesses strong antimicrobial, antioxidant, anti-inflammatory, and wound-healing properties. Ali et al. reviewed the phytochemical and pharmacological profile of *Acacia nilotica* and reported its effectiveness against several bacterial and fungal pathogens due to the presence of polyphenolic compounds and tannins (Zamfirache et al., 2025). Additional reviews have further confirmed the antimicrobial activities of species within the *Acacia* genus and highlighted their potential applications in medicinal and textile fields (Awode et al., 2023).

Several researchers have investigated the extraction and application of individual plant dyes for textile coloration and antimicrobial finishing. Kamboja et al., 2022, reviewed the antimicrobial activities of natural dyes and observed that many plant-derived dyes possess inherent antimicrobial properties that can improve textile functionality. Other studies have focused independently on turmeric extracts or *Acacia nilotica* extracts for antimicrobial applications (Yildiz et al., 2024); however, there is limited information on the synergistic effects of combining these two plant materials as a bi-herbal dye system. Most available studies concentrate mainly on single herbal extracts without exploring the possible enhancement in antimicrobial efficiency, dye yield, and phytochemical interactions obtainable through combined herbal formulations (Wada et al., 2021).

Therefore, a significant knowledge gap exists regarding the extraction, characterization, and antimicrobial evaluation of bi-herbal natural dyes prepared from turmeric and *Acacia nilotica*. Furthermore, limited studies have investigated the possibility of utilizing these combined plant extracts as multifunctional natural dyes capable of simultaneously imparting coloration and antimicrobial protection. Addressing this gap may contribute to the development of sustainable, eco-friendly, and bioactive dye systems for textile and biomedical applications (Kamboja et al., 2022).

The aim of this study is to extract and evaluate the antimicrobial properties of bi-herbal natural dyes obtained from turmeric and *Acacia nilotica*. The specific objectives are to: extract natural dyes from turmeric and *Acacia nilotica* using soxhlet extraction method; characterize the extract and evaluate the antimicrobial activities of the combined dye extracts against selected microorganisms.

MATERIALS AND METHODS

Materials used includes ethanol, distilled water, sodium chloride, sodium carbonate, Mueller Hinton Agar (MHA), Mueller Hinton Broth (MHB), Potato Dextrose Agar (PDA) and Nutrient Agar (NA). Plant samples of turmeric root (*Curcuma longa*) and *Acacia nilotica* pods were collected and authenticated by Dr. Namadi Sunusi in Herbarium of the Department. of Biological Science from Ahmadu Bello University, Zaria with the voucher number ABU06805 for *Curcuma longa* and ABU01816 for *Acacia nilotica*, the clinical isolates of *Candida albicans* and

Staphylococcus aureus. were obtained from the Department of Microbiology, Ahmadu Bello University, Zaria, Nigeria.

Extraction of Dye

Powdered plant samples (50 g each of *Acacia nilotica* pods and *Curcuma longa* root) were subjected to Soxhlet extraction technique using ethanol as solvent for 6 hours. Extracts were concentrated and dried to obtain crude dye.

Preparation of Bi-herbal Dye

The bi-herbal dyestuff was prepared via recrystallization by mixing of equal amounts of the extracted dyestuff from turmeric root and acacia nilotica pods (5 g each) in ethanol and heated up with constant stirring. It was then filtered off while cooling using a Buchner funnel with a suction pump. The crystals were collected, washed several times with water and dried to obtain the bi-herbal dye product.

Characterization

Determination of Melting point: The melting point of the dye extract was determined via open capillary tube method with Gallenkamp melting point apparatus. Small amount of the bi-herbal dye was filled into a capillary tube and placed into the apparatus; the melting point of the sample was obtained by consistently focusing on the apparatus as the apparatus gradually heated the sample. The dye extract exhibited sharp and fairly well defined melting points characteristic of pure compounds.

Determination of UV-Vis spectroscopy: The Agilent CARY 300 UV-visible spectrophotometer was used. The cell used for the spectroscopic analysis was washed with distilled water and dried. Ethanol was put into the cell to take the blank. This was followed by taking 5.0 mL of the solution of the bi-herbal dye (0.00005 mol/L) in ethanol to reduce the concentration of the dye sample. The absorbance of dye samples was determined using spectrophotometer machine (UV-visible spectroscopy) within the visible region (i.e. 400-800 nm), in order to obtain the wavelength of maximum absorption.

Determination of FT-IR Spectroscopy: Agilent CARY 630 FT-IR spectrometer machine was used for the determination of IR-spectroscopy of the bi-herbal natural dye sample in order to ascertain the functional groups present.

Evaluation of the Antimicrobial Activities of Bi-Herbal Dye

Determination of Zone of Inhibition (Sensitivity Test) using the Agar Well Diffusion Method

The standard inocula of both the bacteria and fungi isolates was streaked on sterilized Mueller Hinton Agar and Potato Dextrose Agar plate respectively with the aid of sterilized swab sticks. Four well was punched on each inoculated Agar plate with a sterilized cork borer. The wells were properly labelled according to the different concentration of the bi-herbal dye which were 100, 50, 25 and 12.5 mg/ml respectively. Each well was filled up with 0.2 ml of the bi-herbal dye solution and the inoculated

plates with the dye was allowed to stay on the bench for about 1 hour; this is to allow the dye sample to diffuse on the Agar. The plates were incubated at 37°C for 24 hours (plate of Mueller Hinton Agar) while the plate of Potato Dextrose Agar was incubated at room temperature (26-27°C) for about 3 days.

At the end of the incubation period, the plates were observed for any evidence of zone of inhibition which was appeared as a clear zone that is completely devoid of growth around the wells (zone of inhibition). The diameters of the zones were measured using a ruler calibrated in millimeters (Lykidou *et al.*, 2021).

Determination of Minimum Inhibitory Concentration (MIC)

The minimum inhibitory concentrations (MIC) of the bi-herbal dye extract was determined using Dilution Method with the Mueller Hinton Broth used as diluents. This was the lowest concentration of the dyes showing inhibition for each organism when the sample was tested during sensitivity test which was serially diluted in the test tubes containing Mueller Hinton Broth. The organisms were inoculated into each tube containing the Broth and the synthesized dyes. The inoculated tubes were thereafter incubated at 37°C for 24 hours.

At the end of the incubation period, the tubes were observed for the presence or absence of growth using turbidity as a criterion, the lowest concentration in the

series without visible sign of growth (turbidity) was considered to be the minimum inhibitory concentration (MIC) (Lykidou *et al.*, 2021).

Determination of Minimum Bactericidal/Fungicidal Concentration (MBC/MFC)

The result from the Minimum Inhibitory Concentration (MIC) was used to determine the Minimum Bactericidal/Fungicidal Concentration (MBC/MFC) of the bi-herbal dyes. A sterilized wire loop was dipped into the test tubes that did not show turbidity (clear) in the MIC test and loopful was taken and streaked on a sterile nutrient Agar plate. The plates will be incubated at 37°C for 24 hours. At the end of incubation period, the plate was examined for the presence or absence of growth. This was to determine whether the antimicrobial effects of the bi-herbal dyes are bacteriostatic/fungistatic or bactericidal/fungicidal (Lykidou *et al.*, 2021).

RESULTS AND DISCUSSIONS

Results

The physical properties of the bi-herbal dye extract is presented in Table 1. The UV-Visible spectrum (nm) of the bi-herbal dye extract is as presented in Figure 1 and the summary of the observed wavelength of maximum absorption is presented in Table 2. The FTIR peaks observed with the corresponding group present for the bi-herbal dye extract are shown in Table 3.

Table 1: Physical Properties

Sample	Melting point (°C)	% Yield	Appearance
Bi-herbal dye extract	119-122	48	Dark Brown

Table 2: UV-Visible Analysis

Sample	Wavelength (nm)
Bi-herbal Dye Extract	493.0

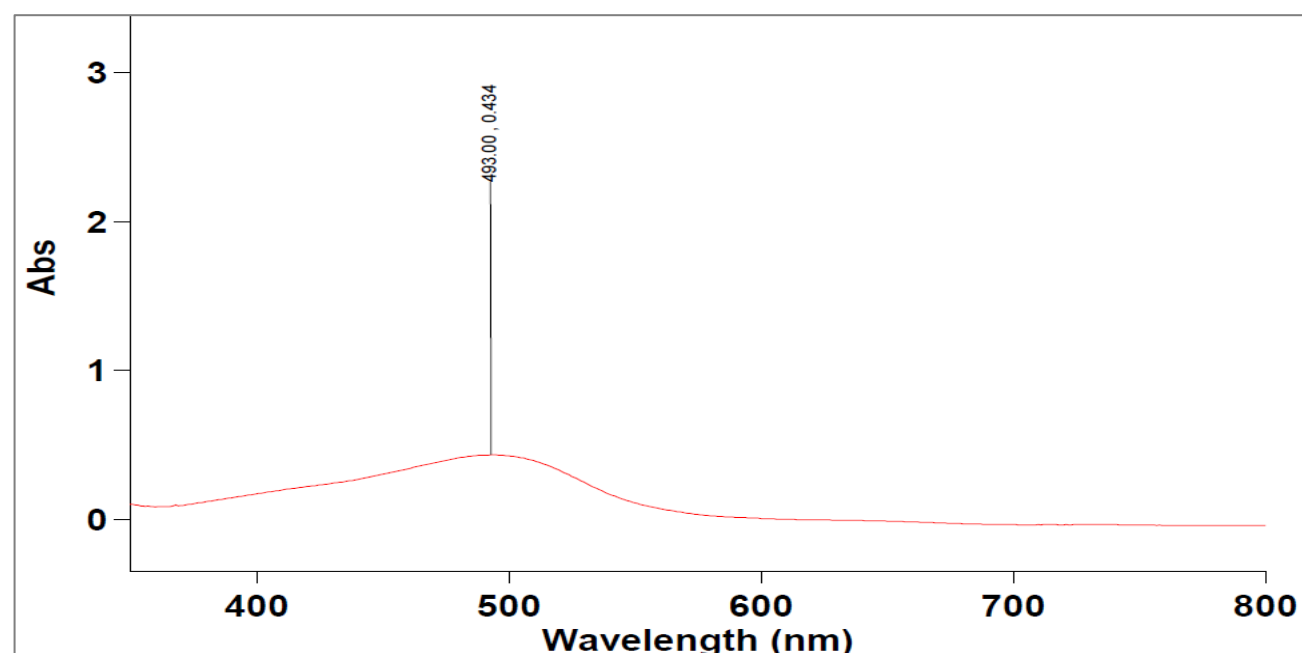


Figure 1: UV-Visible Absorbance of Bi-Herbal Dye Extract

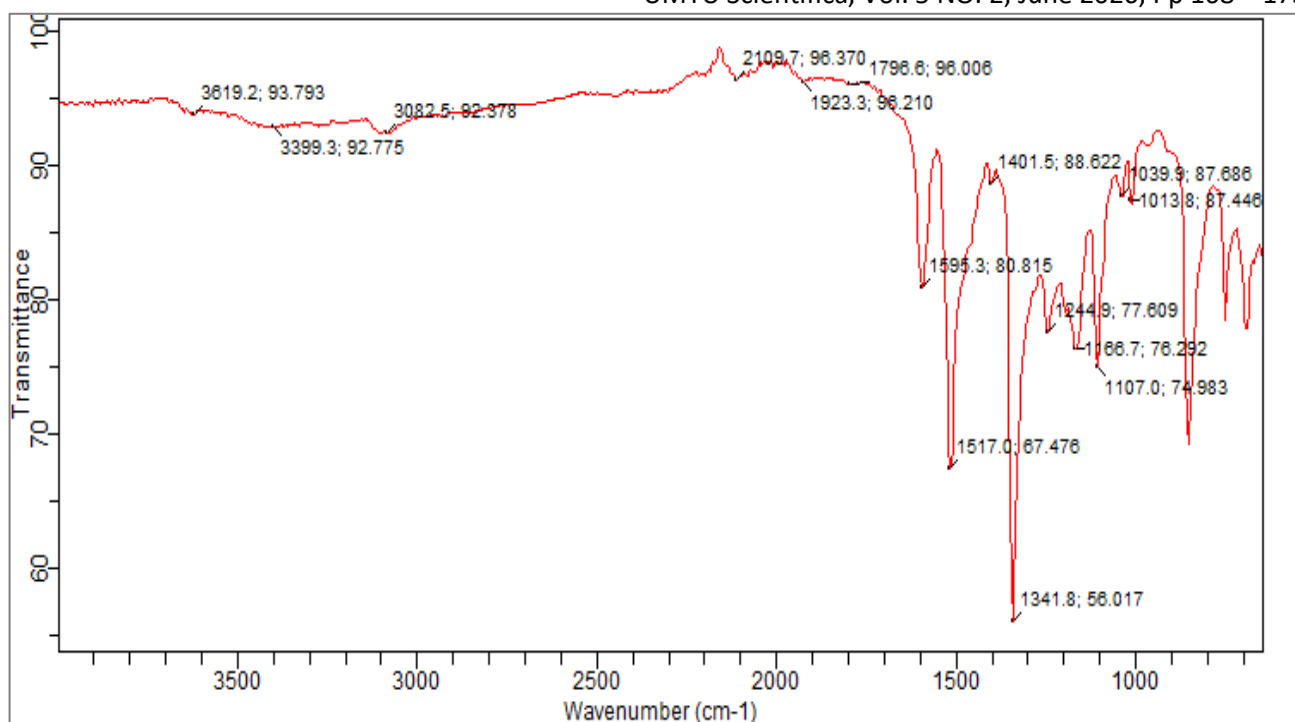


Figure 2: FT-IR Spectra of Bi-Herbal Dye Extract

Table 3: FT-IR Analysis

Wave number (cm ⁻¹)	Assigned vibration(s)	Functional group(s)
3619.2	O-H stretching (sharp, free)	Free (non H-bonded) phenolic O-H or isolated alcohol O-H
3399.3	O-H / N-H stretching (broad)	H-bonded alcohols/phenols and/or N-H of amines/amides
3082.5	=C-H stretching	Aromatic =C-H or =C-H of alkenes
2109.7	C≡C or C≡N stretching (or combination/overtone)	Terminal/internal alkyne or nitrile (less likely), or combination band
1923.3	Overtone / combination band or conjugated carbonyl-related	Possible carbonyl overtone or weak conjugation-related band
1798.6	C=O stretching (high frequency)	Anhydride, γ-lactone, or highly strained/ conjugated ester carbonyl
1595.3	C=C aromatic ring stretching	Aromatic ring vibrations (aromatic C=C)
1517.0	Aromatic C=C / N-O asymmetric stretch	Aromatic ring vibrations; could also correspond to NO ₂ asymmetric if nitro present

Table 4: Zone of Inhibition (mm) of the Bi-Herbal Dye Extract Against the Test Organisms

Test Organism	Bi-Herbal Dye Extract	Sparflo	Fluco
<i>Staphylococcus aureus</i>	22	37	-
<i>Escherichia coli</i>	19	35	-
<i>Candida albicans</i>	28	-	32

Key:

Sparflo: Sparfloxacin = 5µg/ml (Positive control drug for bacteria)

Fluco: Fluconazole = 5µg/ml (positive control drug for fungi)

Table 5: Minimum Inhibitory Concentration (MIC) in mg/ml of the Bi-Herbal Dye Extract Against the Test Organisms

Test Microbes	Concentration of Bi-Herbal Dye Extract (mg/ml)			
	100	50	25	12.5
<i>Staphylococcus aureus</i>			MIC	-
<i>Escherichia coli</i>		MIC	-	-
<i>Candida albicans</i>				MIC

Keys:

Absent of turbidity

+ presence of turbidity

MIC: Minimum Inhibitory Concentration

Table 6: Minimum Bactericidal/Fungicidal Concentration (MBC/MFC) in mg/ml of the Bi-Herbal Dye Extract Against the Test Organisms

Test Microbes	Concentration of Bi-Herbal Dye Extract (In mg/ml)			
	100	50	25	12.5
<i>Staphylococcus aureus</i>		MBC	+	+
<i>Escherichia coli</i>	MBC	+	+	+
<i>Candida albicans</i>			+	MFC

Keys:

Absent of Growth

+ Present of Growth

MBC Minimum Bactericidal Concentration

MFC Minimum Fungicidal Concentration

Discussion

The results of the physical properties in Table 1 show that the bi-herbal dye extracted from *Curcuma longa* and *Acacia nilotica* possessed good physical properties suitable for eco-friendly dye applications. The melting point range of 119-122 °C indicates moderate thermal stability and relative purity of the dye extract. The 48% yield obtained suggests efficient extraction of bioactive coloring compounds such as curcumin, tannins, and phenolic substances from the plant materials. The dark brown appearance resulted from the combination of turmeric pigments and tannin-rich components of *Acacia nilotica*. This coloration indicates successful blending of the herbal constituents.

The UV-Visible spectrum (nm) Figure 1, of the bi-herbal dye extract is as summarized in Table 2. The results reveals that the bi-herbal dye extract exhibited a maximum absorption wavelength (λ_{max}) at 493.0 nm in the visible region. This indicates the presence of chromophoric and conjugated compounds such as curcuminoids, tannins, and flavonoids responsible for the dye coloration. The strong absorption suggests good color intensity and effective light absorption properties suitable for textile applications. The result also confirms successful interaction of the phytochemical constituents from both plant sources. The observed absorbance may contribute to enhanced stability and antimicrobial activity of the dye due to the presence of phenolic compounds (Mehta et al., 2022).

The IR spectrum (IR ν_{max} cm^{-1}) Figure 2, as summarized in Table 3, shows that the FT-IR analysis of the bi-herbal dye revealed the presence of important bioactive functional groups. The peaks at 3619.2 cm^{-1} and 3399.3 cm^{-1} indicate hydroxyl and amine groups associated with phenols, alcohols, and amides. Peaks at 3082.5 cm^{-1} , 1595.3 cm^{-1} , and 1517.0 cm^{-1} confirm the presence of aromatic and conjugated compounds responsible for dye coloration and stability. The carbonyl peak at 1798.6 cm^{-1} suggests the presence of ester or lactone compounds that may improve dye-fiber interaction. These functional groups are linked to the antimicrobial and antioxidant activities of the dye due to the presence of polyphenolic compounds (Mari et al., 2015).

The bi-herbal natural dye extract demonstrated significant antimicrobial activity against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans* (Table 4). The dye

produced inhibition zones of 22 mm, 19 mm, and 28 mm respectively, indicating broad-spectrum antimicrobial potential. The strongest activity was observed against *Candida albicans*, suggesting excellent antifungal properties. The antimicrobial effects are attributed to phytochemicals such as curcuminoids, tannins, flavonoids, and phenolic compounds present in both plants. Gram-positive *Staphylococcus aureus* was more susceptible than Gram-negative *Escherichia coli* due to differences in cell wall structure. Although the activity of the extract was lower than the standard drugs Sparflo and Fluco, the results remain significant because the extract was a crude natural product (Emeruwa, 2012).

The Minimum Inhibitory Concentration (MIC) results in Table 5, showed that the bi-herbal dye possesses significant antimicrobial activity against the tested microorganisms. The MIC values were 25 mg/ml for *Staphylococcus aureus*, 50 mg/ml for *Escherichia coli*, and 12.5 mg/ml for *Candida albicans*. This indicates that *Candida albicans* was the most susceptible organism, while *Escherichia coli* was the least susceptible due to its protective outer membrane. The antimicrobial activity is attributed to bioactive compounds such as curcuminoids, tannins, flavonoids, and phenolic compounds present in both plants. The lower MIC value against *Candida albicans* suggests strong antifungal potential of the extract. The higher MIC for *Escherichia coli* reflects the natural resistance of Gram-negative bacteria (Rajkowska et al., 2015).

The Minimum Bactericidal/Fungicidal Concentration (MBC/MFC) results in Table 6, reveals a significant bactericidal and fungicidal activities against the tested microorganisms. The MBC values were 50 mg/ml for *Staphylococcus aureus* and 100 mg/ml for *Escherichia coli*, while the MFC value for *Candida albicans* was 12.5 mg/ml. The low MFC value indicates that *Candida albicans* was the most susceptible organism, showing strong fungicidal sensitivity to the extract. *Escherichia coli* exhibited the highest resistance due to the protective outer membrane characteristic of Gram-negative bacteria. The antimicrobial activity is attributed to phytochemicals such as curcuminoids, tannins, flavonoids, and phenolic compounds present in both plants. The findings demonstrate that the combined extracts exert synergistic antimicrobial effects. The extract showed stronger fungicidal than bactericidal activity, especially against *Candida albicans*. These results suggest that the bi-herbal dye could serve as a natural antimicrobial agent for textile,

pharmaceutical, cosmetic, and biomedical applications (Agho *et al.*, 2020).

CONCLUSION

This study successfully extracted and characterized a bi-herbal natural dye from *Curcuma longa* and *Acacia nilotica* using Soxhlet extraction with ethanol as the solvent. The extracted dye showed a good yield of 48%, melting point range of 119-122 °C, and a maximum absorption wavelength of 493 nm, confirming the presence of conjugated chromophoric compounds responsible for coloration. FT-IR analysis further revealed important functional groups such as phenolic O-H, N-H, and aromatic C=C associated with curcuminoids, tannins, and flavonoids. The bi-herbal dye demonstrated significant antimicrobial activity against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*, with the strongest activity observed against *Candida albicans*. The MIC and MBC/MFC results confirmed both inhibitory and bactericidal/fungicidal potentials of the bi-herbal dye extract. The findings indicate that the combined plant extracts possess synergistic antimicrobial properties and could serve as eco-friendly multifunctional natural dyes with promising applications in textile, pharmaceutical, cosmetic, and biomedical industries.

REFERENCES

- Agho, O. B., Obadahun, J., Feka, D. P., Magaji, I. Y., Susanna, A. O., & Enyeribe, C. C. (2020). Synthesis and application of azo dyes derived from the methanolic extract of *Cissus populnea* as the coupling component on nylon 6,6. *International Journal of Research and Scientific Innovation (IJRSI)*, VII(XII), 43-48.
- Alaa, S. A., & Tarek, H. A. (2006). Novel azo disperse dyes derived from aminothiophenes: Synthesis and UV-visible studies. *Dyes and Pigments*, 7, 8-17. [Crossref]
- Awode, A. U., Dalyop, G. M., Olatidoye, S. D., Tijani, S., Kalu, I. H., & Adeyanju, O. (2023). Extraction, chemical modification and characterization of turmeric dye (*Curcuma longa*) and its application on cotton fabric. *International Journal of Research and Innovation in Applied Science*, 8(7), 115-123. [Crossref]
- Emeruwa, A. I. (2012). Antibacterial substance from *Carica papaya* fruit extracts. *Journal of Natural Products*, 45(2), 123-127. [Crossref]
- Fuloria, S., Mehta, J., Chandel, A., Sekar, M., Rani, N. N. I. M., Begum, M. Y., Subramanian, V., Chidambaram, K., Thangavelu, L., Nordin, R., Wu, Y. S., Sathasivam, K. V., Lum, P. T., Meenakshi, D. U., Kumarasamy, V., Azad, A. K., & Fuloria, N. K. (2022). A Comprehensive Review on the Therapeutic Potential of *Curcuma longa* Linn. in Relation to its Major Active Constituent Curcumin. *Frontiers in pharmacology*, 13, 820806. [Crossref]
- Kamboja, A., Jose, S., & Singh, A. (2022). Antimicrobial activity of natural dyes - A comprehensive

review. *Journal of Natural Fibers*, 19(13), 5380-5394. [Crossref]

- Lykidou, S., Pashou, M., Vouvoudi, E., & Nikolaidis, N. (2021). Study on the dyeing properties of curcumin on natural and synthetic fibers and antioxidant and antibacterial activities. *Fibers and Polymers*, 22(12), 3336-3342. [Crossref]
- Mari Selvam, R., Athinarayanan, G., Nanthini, A. U. R., Singh, A. J. A. R., Kalirajan, K., & Selvakumar, P. M. (2015). Extraction of natural dyes from *Curcuma longa*, *Trigonella foenum-graecum* and *Nerium oleander* plants and their application in antimicrobial fabric. *Industrial Crops and Products*, 70, 84-90. [Crossref]
- Mehta, A., Jain, A., & Jain, S. (2022). Antimicrobial activity of turmeric: A systematic review. *Nepalese Medical Journal*, 5(2), 311-315. [Crossref]
- Rajkowska, K., Kunicka-Styczyńska, A., & Maroszyńska, M. (2015). *In vitro* antimicrobial properties of essential oils against *Candida albicans* and *Candida krusei*. *Mycopathologia*, 179, 1-8.
- Satruhan, A. P., & Patel, D. K. (2023). A review on a medicinal tree *Acacia nilotica* Linn. *Journal of Pharmacognosy and Phytochemistry*, 12(6), 345-348. [Crossref]
- Wada, N. M., Ambi, A. A., Ibrahim, A. A., Bello, S. K., Umar, A., & James, D. T. (2021). Antimicrobial activity of extracts of turmeric (*Curcuma longa*) and garlic (*Allium sativum*) against selected bacterial clinical isolates. *Mediterranean Journal of Infection, Microbes and Antimicrobials*, 10(1), 1-6. [Crossref]
- Yildiz, S., Karadag, R., & Yavas, A. (2024). Eco-friendly dyestuffs prepared with *Curcuma longa* extracts and their antimicrobial activities. *Green Technologies and Sustainability*, 2(1), 100-141.
- Zamfirache, M. M., Tuchilus, C., & Aprodu, I. (2025). Eco-friendly extraction of curcumin from turmeric and dyeability of textile fibers. *Fibers*, 13(6), 73. [Crossref]