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Extraction and Application of Natural Dye from African Locust Bean (*Parkia biglobosa*) Pod on Nylon Fabrics

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Abstract

Growing environmental and health concerns regarding synthetic dyes have increased interest in natural colorants as potentially more sustainable alternatives. This study aimed to extract and optimize a natural dye from *Parkia biglobosa* pods and evaluate its application to nylon fabrics. The dye was extracted through maceration, producing a yield of 23.76%. The optimum dyeing conditions for treated and untreated nylon were concentrations of 1% and 1.5%, temperatures of 60 and 70 °C, and dyeing times of 30 and 40 min, respectively. The extract was applied using pre-, meta-, and post-mordanting techniques with copper sulfate, ferrous sulfate, and potassium aluminum sulfate as mordants. The resulting fabrics exhibited shades ranging from light and dark brown to black, with pre-mordanting producing the most visually attractive shades. However, the dyed nylon fabrics demonstrated poor colorfastness to sunlight and washing, with ratings ranging from 1 to 3. Neither mordanted nor unmordanted fabrics exhibited antibacterial activity against *B. subtilis* or *S. Typhi* (inhibition zone: 0.00 ± 0.00 mm). In contrast, all

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dyed fabrics showed varying antifungal activity against *P. notatum*. Treated nylon dyed with copper sulfate produced the largest inhibition zone (1.0 ± 0.00 mm), whereas untreated nylon dyed with potassium aluminum sulfate produced the smallest (0.3 ± 0.00 mm). These findings demonstrate the potential of *P. biglobosa* pods as a source of natural dye for nylon fabrics, particularly when applied through pre-mordanting. Nevertheless, the poor colorfastness and limited antimicrobial performance indicate that further optimization is necessary before practical textile application.

Keywords: Antifungal Activity; Colorfastness; Mordanting; Natural Dye; *Parkia biglobosa*

INTRODUCTION

A colored material with an affinity for the surface it is applied on, is called a dye (Kumar *et al*., 2021). Natural dyes are substances from plants and animals that impart color to foods, cosmetics, drugs, hair, fiber, fur and polymers. Natural dyes may be obtained from several plant parts like flowers, roots, leaves, bark, insects' secretion and minerals (Nwoye and Ezema, 2017). In light of growing environmental consciousness, the significance of natural dyes has gained global attention. The usage of natural dyes has become more popular due to the negative consequences of synthetic dyes and dyeing agents. This is mostly because many nations have rigorous environmental regulations in place to prevent the health risks linked with synthetic textile dyes (Nwadiokwu *et al*., 2019). Because natural extracts contain strong, highly active agents including tannins, flavonoids, quinines, carotenoids, and alkaloids, the utilization of natural colorants holds promise for creating antimicrobial fabrics for aesthetic, hygienic, and medical uses (Verma *et al*., 2017).

Nigeria has abundant resources in terms of plants which contain dyes, they are found in leaves, bark, roots, seeds, fruits and flowers (Nwoye and Ezema, 2017). African locust bean also known as *Parkia biglobosa*, has long been acknowledged as a vital native multipurpose fruit tree with a variety of domestic uses, including manure, medicine, food, shade, windbreaks, bee food, stabilizing the environment, fuel, livestock feeds, fiber, fish poison, and many more (Sadiku, 2010).

Andema *et al*., 2026 reported that, the dye extract from African locust bean pod was dark brown, with a pH of 5.77, a melting point of 44 °C, a density of 0.54 g/mL, partial solubility in water, and complete solubility in methanol. The UV-Vis spectrum showed

distinct peaks, with the highest absorbance recorded at 287 nm (4.1000), likely associated with carbonyl (C=O) groups characteristic of hydrolysable tannins. Phytochemical screening revealed the presence of tannins, flavonoids, alkaloids, glycosides, phlabotannins, anthraquinones, quinones, terpenoids, steroids, carbohydrate, starch, proteins, and anthocyanins, while saponin was absent. The extract demonstrated antibacterial activity against *B. subtilis*, *E. coli*, *S. aureus*, *P. aeruginosa*, and *S. typhi*, and antifungal activity against *P. notatum*, but no antifungal activity was observed against *C. albicans* and *A. niger* at all concentrations (Andema *et al.*, 2026).

The aim of this research is to extract dye from African locust bean pod, optimize the dyeing conditions on the nylon fabric, apply the dye with and without mordants, carry out antimicrobial study of the dyed cotton fabrics.



Plate 1: Dried Pod of the African Locust Bean (*Parkia biglobosa*)

METHODOLOGY

Extraction and Purification of the Dye

A container containing 200 g of the powdered stuff was filled with 500 ml of methanol. For efficient extraction, the mixture was left to stand for a week. Following that, it was filtered, the filtrate was dried off, and the solute was gathered and weighed (Leonard *et al.*, 2022).

Scouring of the Fabrics

3M sodium hydroxide was used during the scouring procedure. For every cotton fabric. The scouring procedure was conducted for one hour at 60^0C using 50 mls of the sodium hydroxide (Otutu *et al.*, 2012).

Bleaching of the Fabrics

Using a measuring cylinder, 3M of sodium hypochlorite was prepared. The bleaching process of every fabric was then carried out for an hour at 100^0C using 100 ml of the prepared solution (D'Cruz 2020).

Pre-mordanting, Meta and Post Mordanting

In order to perform the mordanting, 3% of the mordant was prepared. After being scoured, the cloth was submerged in 50 ml of the mordant solution for approximately half an hour at 60 ^{0}C. It was then removed, manually squeezed and submerged in the dye bath depending on the type of mordanting method employed (Khin and Yee, 2017).

Dyeing Process of the Fabrics

Using a fixed amount of liquor ratio (1:100), the fabrics were added to the dye solution in the bath and dyed at specific concentrations, temperatures, and times. To ensure that the dye molecules are well absorbed into the fabric, the fabric was agitated throughout this process. After dyeing, the dyed sample was carefully rinsed with cold water to remove the dye particles that are not absorbed and squeezed by hand then dried at room temperature and stored dried for further analysis (Wayama *et al.*, 2011).

Optimization of dyeing concentration

Several dye concentrations (0.5%, 1.0%, 1.5%, 2.0%, and 2.5%) were made in order to find the optimum dyeing concentration. A constant temperature and time were used to dye the cotton fabric. At the optimum wavelength, the absorbance of dye solutions was measured both before and after dyeing (Mahilrajan *et al.*, 2014).

Optimization of dyeing time

Dyeing was done for 20, 30, 40, 50, 60, and 70 minutes at the constant concentration and temperature in order to maximize dying time. At the optimum wavelength, the absorbance of dye solutions was measured both before and after dyeing.

The optimum time for dyeing was determined when the most dye was absorbed (Geetam *et al.*, 2017).

Optimization of dyeing temperature

The dyeing process was run at 50^0C, 60^0C, 70^0C, 80^0C, 90^0C, and 100^0C to maximize the dyeing temperature at constant time and concentration. At the optimum wavelength, the absorbance of dye solutions was measured both before and after dyeing. The optimum dyeing temperature was determined to be the one at which the most dye could be absorbed (Onyesm, 2017).

Color Fastness of the Dye Fabrics

To ascertain whether the dye is resistant to washing and sunshine, the dyed textiles were subjected to fastness tests.

Fastness to washing

All of the dyed fabrics were cleaned and rinsed with water after soaking in laundry soap for an hour. And the fabrics was allowed to air dry at room temperature (Ezeokonkwo *et al.*, 2018).

Fastness to sunlight

For two days, the dyed materials were exposed to sunlight for ten hours every day (Ezeokonkwo *et al.*, 2018).

Screening for Antimicrobial Activity of the Dyed Fabrics

Determination of Zone of Inhibition

The dyed fabric's antimicrobial property was tested using the hole-in-plate disc diffusion technique. After boring wells in the media with a 6 mm cork borer, the dyed fabric was placed within. The agar plate was then incubated at 37 ºC for 24 hours. Following incubation, a transparent meter rule was used to measure the diameters of each dyed fabric's zone of inhibition in millimeters. Every dyed fabric was examined three times (Usman *et al.*, 2018).

RESULTS AND DISCUSSION

Extraction and Purification of the Dye Extract

Table 1 showed the extraction of dye from African locust bean (*Parkia biglobosa)* pod via maceration method of extraction. 200 g each of the sample was use to carry out this extraction. The yield of the dye extract is 47.52g and percentage yield is 23.76%. According to Leonard *et al*., 2022, the percentage yield of 6.3% (12.93 yield) was obtained from the *Parkia biglobosa* tree bark when ethanol was used for the extraction.

Table1: Extraction and Purification of the Dye Extract

Locust Bean Pod Powder (g)	Weight after Extraction and Purification (g)	Actual yield (g)	Percentage Yield (%)
200	152.48	47.52	23.76

Scouring of the Nylon fabrics

Table 2 showed the result of scouring of the nylon fabric. It was observed that, the fabrics lost weight after scouring. This may be due to removal of wax and other impurities as reported by Joshua *et al*., 2023.

Table 2: Scouring of the Nylon Fabrics

Weight of fabric before scouring (g)	Weight of fabric after scouring (g)	Weight Loss (g)
0.339	0.259	0.080

Bleaching of the Nylon fabrics

Table 3 showed the result of bleaching the nylon fabric. The results revealed that the fabrics lost weight after bleaching. This may be due to removal of wax and other impurities which causes the fabric to become whiter and brighter as reported by Joshua *et al*., 2023.

Table 3: Bleaching of the Nylon Fabrics

Weight of fabric before bleaching (g)	Weight of fabric after bleaching (g)	Weight Loss (g)
0.259	0.245	0.014

Dyeing Process

Optimization of the Dyeing Concentration

The results for the optimization of the dyeing concentration of treated and untreated nylon fabrics is presented in Figure 1. The optimum concentration of treated nylon fabric was 1.0% and the amount of dye absorbed was 17.51%. While the optimum

concentration of the untreated nylon was 1.5% and the amount of dye absorbed was 14.34. %. However, after 1% concentration, the amount of dye absorbed by the treated nylon decreases. While after 1.5% concentration, the amount of dye absorbed by the untreated nylon also decreases. According to Wayama *et al.*, 2014, the amount of dye absorbed increases as dying time increases. Higher absorbance is produced by longer dyeing times until dye exhaustion reaches equilibrium.

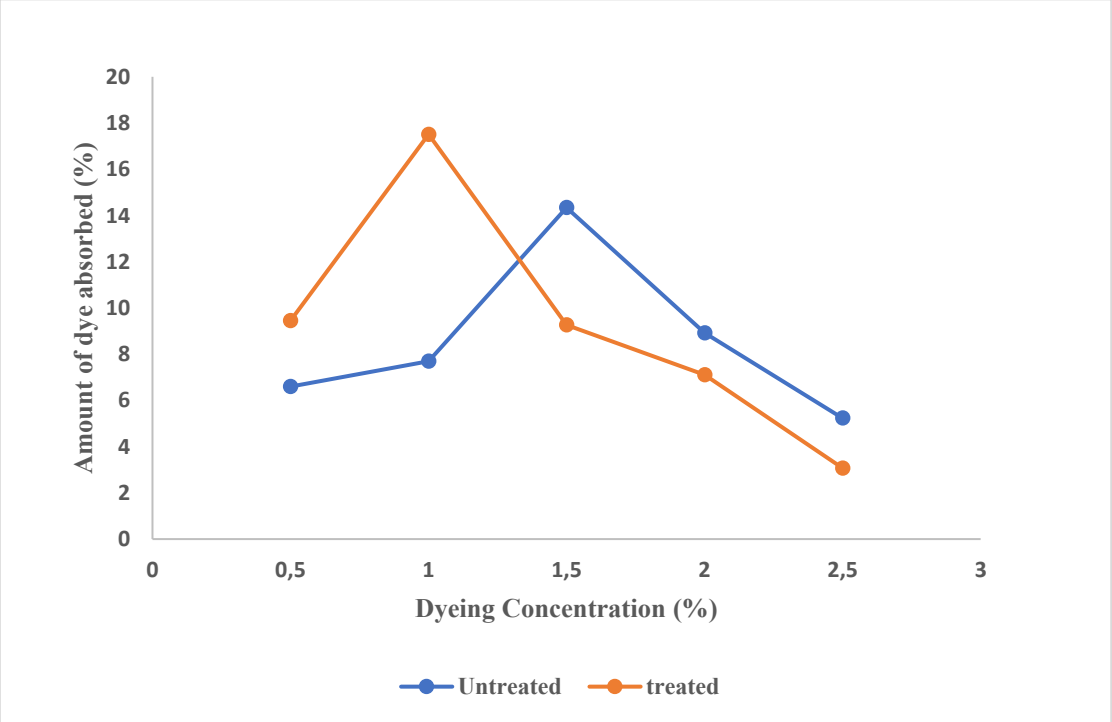


Figure 1: Optimization of the Dyeing Concentration of Treated and Untreated Nylon Fabric

Optimization of the Dyeing Time

The results for the optimization of the dyeing time of treated and untreated nylon fabrics is presented in Figure 2. The optimum dyeing time of treated nylon fabric was 30 minutes and the amount of dye absorbed was 19.23%. While the optimum dyeing time of the untreated nylon was 40 minutes and the amount of dye absorbed was 19.14%. However, after 30 minutes, the amount of dye absorbed by the treated nylon begins to decrease. While after 40 minutes, the amount of dye absorbed by the untreated nylon also decreases. According to Wayama *et al.*, 2014, the amount of dye absorbed increases as dying time increases. Higher absorbance is produced by longer dyeing times until dye exhaustion reaches equilibrium.

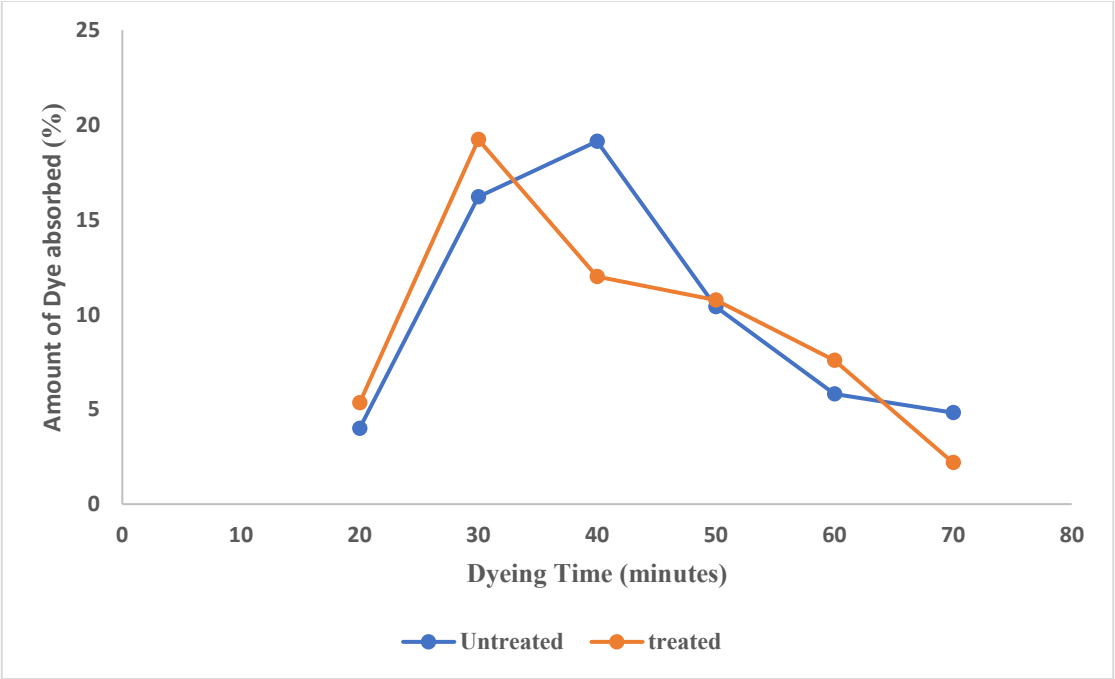


Figure 2: Optimization of the Dyeing Time of Treated and Untreated Nylon Fabric

Optimization of the Dyeing Temperature

The results for the optimization of the dyeing temperature of treated and untreated nylon fabrics is presented in Figure 3. The optimum dyeing temperature of treated nylon fabric was 60^0C and the amount of dye absorbed was 17.63%. While the optimum dyeing time of the untreated nylon was 70^0C and the amount of dye absorbed was 16.40%. However, after 60^0C, the amount of dye absorbed by the treated nylon begins to decrease. While after 70^0C, the amount of dye absorbed by the untreated nylon also decreases. According to Wayama *et al.*, 2014, the amount of dye absorbed increases as the dyeing temperature rises. Higher absorbance is produced by longer dyeing temperatures until equilibrium is reached by the dye.

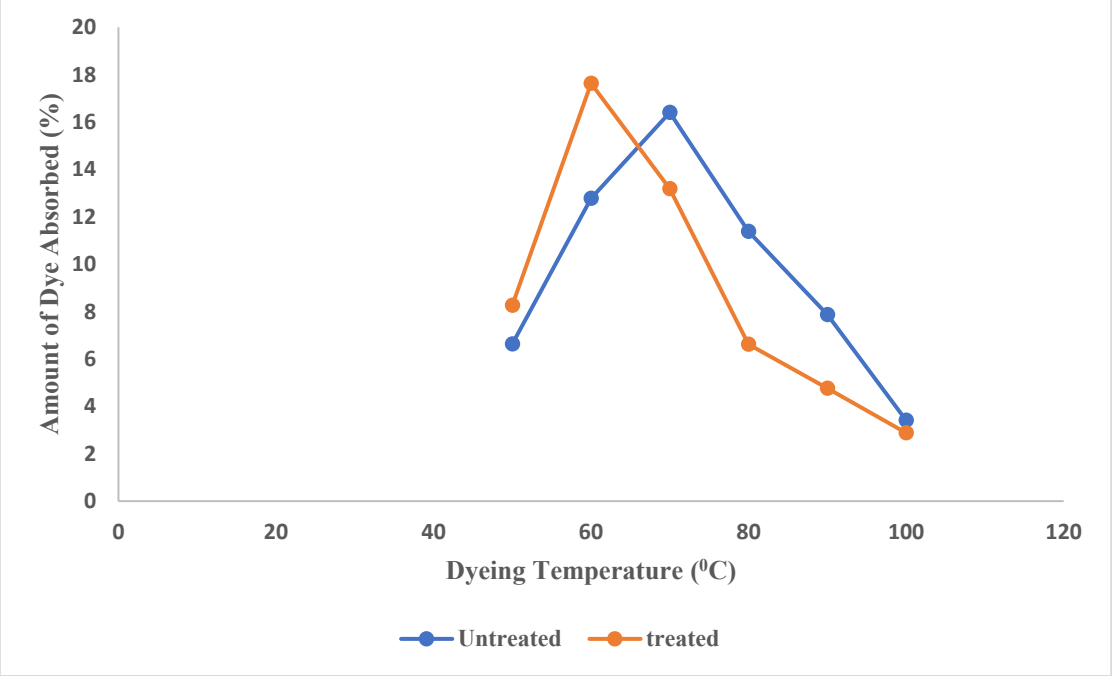


Figure 3: Optimization of the Dyeing Temperature of Treated and Untreated Nylon Fabric

It was observed that the treated nylon fabrics absorbed more dye than the untreated cotton and nylon fabrics at optimum concentration, time and temperature. This may likely be due to, the effects of fiber swelling that improve dye diffusion. Secondly, it can be explained by the relationship between treated cotton fibers and dye structure (Mansour and Ali, 2019).

Dyeing of the Nylon fabric with and without mordant

The results of dyeing treated and untreated cotton are presented in Plate 2 to 9. It was observed that all the treated and untreated nylon fabrics dyed without and with mordants showed varying degree of shades. The treated and untreated fabrics dyed with mordants using copper sulphate, iron sulphate and aluminum sulphate produced darker shades than those without mordants. This may likely be as a result of the interaction between the dye's chromophore and the various metals in the mordants, which may be responsible for these different shades, which also promote better dye absorption and retention on the fabric fibers (Islam *et al.*, 2024). The metal salt utilized determines the effects of color strength. Iron forms strong coordination tendency. The auxochrome may change the dye's fastness, but the chromatophore protects it against photochemical damage. One of the dye chromophore's intrinsic characteristics is its resilience to chemical or photochemical attack (Kanchana *et al.*, 2013). Locust bean pod dye is naturally a brown

color. However, when reacted with $CuSO_4$ the color changes to dark brown, $FeSO_4$ changes the color to blue black or black while $KAl(SO_4)_2$ changes the color light brown. The pre-mordanted treated fabrics produced the best attractive shades. The treated fabrics have a little darker shade than the untreated. This is likely because the treated fabrics absorb more dye due to the chemical pre-treatment. Generally, it was also observed that all the dyed nylon fabrics showed lighter shades. This may be because nylon is a hydrophobic synthetic material (Dhir, 2022).



Un-dyed Without Mordant

Plate 2: Treated Nylon without mordant and un-dyed Fabrics



$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 3: Pre-mordanted Treated Nylon Fabrics



$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 4: Meta-mordanted Treated Nylon Fabrics



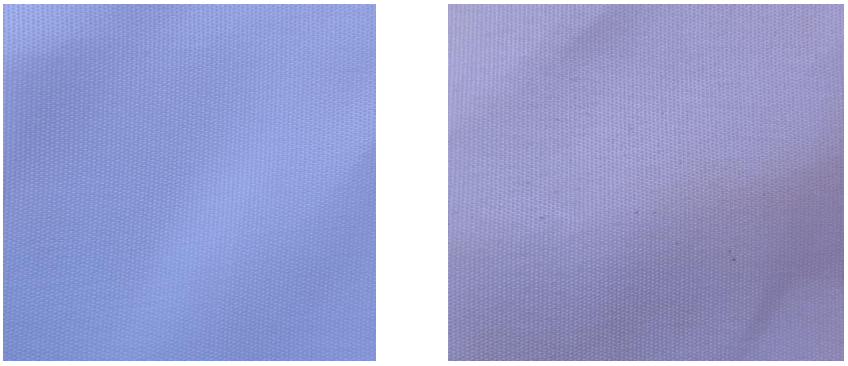
$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 5: Post-mordanted Treated Nylon Fabrics



$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 6: Pre-mordanted Untreated Nylon Fabrics



Undyed Without Mordant

Plate 7: Untreated Nylon without mordant and un-dyed Fabrics



$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 8: Meta-mordanted Untreated Nylon Fabrics



$CuSO_4$ $FeSO_4$ $KAl(SO_4)_2$

Plate 9: Post-mordanted Untreated Nylon Fabrics

Sunlight Fastness Test

The results of the sunlight test of the treated and untreated nylon dyed with extract from the locust bean pod is presented in Table 4. It was observed that the treated nylon fabrics dyed with mordants showed fair colorfastness (2-3) than the control (without mordant) which is slightly fair. Similarly, the untreated nylon fabrics with mordants showed poor colorfastness (1-2) than the control which is very poor. The pre-mordanted treated nylon showed better results than the rest of the nylon fabrics. The interaction between the dye, mordant, and fiber is responsible for this enhancement, which could lead to improved color stability and retention when exposed to light (Islam *et al.*, 2024). The nylon fibers' poor affinity with the mordant or the mordant's poor bonding to the dye could be the cause of the color loss in most of the fabrics (Ibrahim, 2013).

Table 4: Sunlight test of Treated and Untreated Nylon

Mordant	Pre		Meta		Post	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
$CuSO_4$	2-3	2	2	1-2	2	1
$FeSO_4$	2-3	1-2	2-3	1-2	2	1
$KAl(SO_4)_2$	2-3	1-2	2	1-2	2	1
Without (Control)	1	1	-	-	-	-

Ratings:1= very poor, 1–2= poor, 2= slightly fair, 2–3= fair, 3= moderate, 3–4= good, 4= very good, 4–5= excellent, and 5= outstanding

The treated nylon fabrics showed fair color fastness in the presence of sunlight than the untreated nylon fabrics.

Washing Test

The results of the washing test of the treated and untreated nylon dyed with extract from the locust bean pod is presented in Table 5. It was observed that the treated nylon

fabrics dyed with mordants showed fair colorfastness (2-3) than the control (without mordant) which is slightly fair. Similarly, the untreated nylon fabrics with mordants showed poor colorfastness (1-2) than the control which is very poor. The pre-mordanted treated nylon showed better results than the rest of the nylon fabrics. The presence of metals in the mordants may likely affect the interaction with the dye-fiber during washing, which explains the rise in the rate of color change in the mordanted fabrics (Islam *et al*., 2024) The fibers' poor affinity with the mordant or the mordant's poor bonding to the dye could be the cause of the color loss (Ibrahim, 2013).

Table 5: Washing test of Treated and Untreated Nylon

Mordant	Pre		Meta		Post	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
$CuSO_4$	3	1-2	2-3	2	2	1-2
$FeSO_4$	3	2	2-3	2	2-3	1-2
$KAl(SO_4)_2$	2-3	1-2	2	2	2-3	1-2
Without (Control)	2	1	-	-	-	-

Ratings:1= very poor, 1–2= poor, 2= slightly fair, 2–3= fair, 3= moderate, 3–4= good, 4= very good, 4–5= excellent, and 5= outstanding

Antimicrobial Study of the Dyed fabrics

The result of the antimicrobial study of the dyed fabrics is presented in Table 6. From the results, it was observed that all the bacteria (*B. subtilis*, *S. typhi*) showed no zone of inhibition against all the fabrics dyed with and without mordants. This may likely be due to resistance developed by the bacteria against the antimicrobial agent. This ability of microorganisms such as bacteria to develop resistance to antimicrobial agent is called antimicrobial resistance (AMR) This resistance means that the antimicrobial agent is no longer as effective or entirely ineffective in killing or inhibiting the growth of the microorganisms (Mahizhchi *et al*., 2024).

Table 6: Zone of Inhibition (mm) of Dyed fabrics

S/N	Fabrics	Mordants	B. subtilis	S.typhi	P.notatum
1.	Treated Nylon	$CuSO_4$	00.00 ± 0.00^a	00.00 ± 0.00^a	1.0 ± 0.00^a
		$FeSO_4$	00.00 ± 0.00^a	00.00 ± 0.00^a	0.9 ± 0.00^a
		$KAl(SO_4)_2$	00.00 ± 0.00^a	00.00 ± 0.00^a	1.8 ± 0.00^a
		Without	00.00 ± 0.00^a	00.00 ± 0.00^a	0.7 ± 0.00^a
2.	Untreated Nylon	$CuSO_4$	00.00 ± 0.00^a	00.00 ± 0.00^a	0.9 ± 0.00^b
		$FeSO_4$	00.00 ± 0.00^a	00.00 ± 0.00^a	0.8 ± 0.00^b
		$KAl(SO_4)_2$	00.00 ± 0.00^a	00.00 ± 0.00^a	0.3 ± 0.00^b
		Without	00.00 ± 0.00^a	00.00 ± 0.00^a	0.6 ± 0.00^b

Values of mean across columns with different alphabetical superscripts are statistically different ($p<0.05$) n=3

It was also observed that all the dyed fabrics inhibited the growth of *P.notatum*. This confirms the antifungal activity of the *parkia biglobosa* pod dye extract. The different mordants used result in varying dye fixation levels, which is also responsible for the various inhibition zones. The treated nylon dyed with copper sulphate mordant showed the highest zone of inhibition of 1.0 ± 0.00^{a} mm while the untreated nylon dyed with potassium aluminum sulphate mordant showed the lowest zone of inhibition of 0.3 ± 0.00^{b} mm. Interestingly, all the fabrics dyed with copper sulphate mordant showed good zone of inhibitions, this may be primarily because copper ions (Cu^{2+}) ions act as a potent non-specific fungicide that disrupt essential cellular functions, leading to a metabolic failure and death. It is known that copper sulfate damages the cell wall of *penicillium* species, preventing their growth. Copper is a multisite fungicide that mostly inhibits central catabolic and metabolic processes by displacing iron atoms in iron-sulfur clusters of dehydratases and targeting thiolate groups (Farahmand *et al.*, 2023). Also, the treated cotton and nylon fabrics showed high zone of inhibitions than the untreated. This may likely be as a result of the more dye absorbed by the treated fabrics than the untreated fabrics. Musinguzi *et al.*, 2019 reported that, the cotton and silk fabrics dyed with $FeSO_4$ exhibited the highest antibacterial activity on *S. aureus* and *P. aeruginosa*. This is accurate since different mordants employed under appropriate conditions result in varying dye fixation levels, which in turn generate variable inhibition zones.

CONCLUSION

The research concludes that *Parkia Biglobosa* pod is a viable and sustainable source of natural dye with promising industrial potential. Using maceration method of extraction, dye extracts were successfully obtained from plant pod, demonstrating good extraction yields and stability. It also reveals the optimum dyeing temperature, concentration and time of the African locust bean pod dye extract on nylon fabrics. The dyed fabrics produced different beautiful shades with different mordants and mordanting methods. Pre-mordanting emerged as the most effective dyeing method. The dyed fabrics exhibit poor color fastness during washing and on exposure to sunlight likely due to the poor bonding

between the fabric and the mordant or the mordant and the dye. The dyed nylon fabrics possessed notable antimicrobial activity.

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