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# The decolourising potential of some laccase-producing *Curvularia* and *Paradictyoarthrinium* species

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**ABSTRACT**

Laccases are enzymes that break down lignin and are also useful in dye decolourisation. This study investigated laccase production by some laccase-producing fungi and evaluated their ability to decolourise dyes. Some fungi with laccase-producing potential were collected and identified using molecular techniques. They were cultivated on various substrates at pH 5 and 6. Laccase production was determined using 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) [ABTS] and guaiacol as indicators. The fungi were grown in fermentation media containing 1 g/L of dyes, and their decolourising capacity was determined. The fungi were identified as *Paradictyoarthrinium diffractum* AP3, *Paradictyoarthrinium diffractum* AP2, *Curvularia lunata* DPI, *Curvularia lunata* FESAMB, *Curvularia petersonii* K2, and *Curvularia verruculosa* K6. There was higher laccase activity in substrates containing lignin than in those without. The highest laccase production (39.62 U/mL) was recorded by *Curvularia lunata* DPI in maize straw-containing medium at pH 6 with ABTS as an indicator. In comparison, *Curvularia petersonii* K2 was the best producer of laccase (17.67 U/mL) when guaiacol was used. *Paradictyoarthrinium diffractum* AP2 decolourised methyl red, Congo red and safranin, whereas *Curvularia lunata* FESAMB achieved the highest decolourisation rate (63%) of Leishmann blue. *Curvularia* and *Paradictyoarthrinium* species used in this work produced laccase enzymes, and successfully decolourised dyes.

**Keyword:** laccase, 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid), guaiacol, decolourisation, lignin, fungi

**1. INTRODUCTION**

Laccases are lignin-degrading enzymes that break down lignin in lignin-containing substrates. They belong to the class of oxidoreductases and oxidise phenolic and non-phenolic compounds (Janusz et al., 2020; Fasiku et al., 2026). Laccases are produced by bacteria and fungi and play a major role in lignin degradation in plant cell walls. Lignin provides structural and mechanical support for plants (Morya et al., 2019). Lignin is not easily degradable; only microbes that produce lignin-degrading enzymes can break it down.

Bacteria and fungi produce lignin-degrading enzymes such as laccase, manganese peroxidase, lignin peroxidase, and versatile peroxidase, which work together to

degrade lignin in lignin-containing compounds (Morya et al., 2019; Fasiku et al., 2026). Some bacterial species used in laccase production include *Bacillus* (Khan et al., 2024), *Staphylococcus* (Oluwadamilola and Momoh, 2022), and *Enterobacter* (Hosseini et al., 2025). Many fungi have been utilised in laccase production, including *Penicillium* species, *Fusarium* species, *Pleurotus* species, and *Curvularia* species (Bello et al., 2020; Dai et al., 2020; Debnath and Saha, 2020; Fasiku et al., 2023a). Various *Curvularia* species, such as *Curvularia trifolii* (Zhang et al., 2010), *Curvularia clavata* (Neoh et al., 2015), *Curvularia lunata* (Bello et al., 2020; Yadav and Vivekanand, 2020), and *Curvularia kusanoi* L7 (Vazquez et al., 2020), have successfully produced laccase.

There is limited information on the production of laccase by *Paradictyoarthrinium*. Although some reports describe the use of *Curvularia* species in laccase production, there is a paucity of information on the decolourisation potentials of laccase produced by these species. Methyl red, Congo red, Leishmann blue, and safranin are industrial dyes released into wastewater from the textile, food and pharmaceutical industries causing environmental pollution (Periyasamy, 2024). The traditional method of removing dyes involved harsh chemicals prompting the use of an alternative approach through the use of laccase. Different cultures and environmental parameters affect enzyme production (Hassan et al., 2023; Odjogi et al., 2026). Laccases are utilised in biobleaching, dye decolourisation, degradation of lignin and pollutants, and clarification of juices (Guan et al., 2018; Debnath and Saha, 2020). This study investigated laccase production by some *Curvularia* and *Paradictyoarthrinium* species and examined their ability to decolourise dyes.

## 2. MATERIALS AND METHODS

### Collection and identification of organisms

Laccase-producing fungi isolated from soil samples were collected from the Department of Microbiology and Biotechnology, Ajayi Crowther University, Oyo, Nigeria. The fungi were identified using molecular methods based on the Internal Transcribed Spacer (ITS) region (Fasiku and Wakil, 2021). Their sequences were submitted to the National Center for Biotechnology Information for accession numbers, and their phylogenetic relationships were analysed using the maximum likelihood method (Kumar et al., 2018).

### Production of laccase using a compounded medium

The laccase production media were compounded as described below in either a 0.1 M sodium acetate buffer at pH 5.0 or a 0.1 M sodium phosphate buffer at pH 6.0 to assess the effect of initial media pH on enzyme production. The fermentation medium contained (g/L): Glucose 10, CaCl<sub>2</sub> 1, KCl 0.25, NH<sub>4</sub>NO<sub>3</sub> 2.5, MgSO<sub>4</sub> 0.25, MnSO<sub>4</sub> 0.005, and FeSO<sub>4</sub> 0.005. Three treatments were employed: one supplemented with 1% maize straw, another with 1% sawdust, and the third without any lignin-containing substrate (control). Media (10 mL each) were sterilised at 121°C for 15 minutes, cooled, and aseptically inoculated with two 7 mm circular plugs from a young culture of the isolate. The inoculated media were incubated at 28°C for 4 days. After incubation, the fermentation media were filtered through Whatman No. 1 filter paper and centrifuged at 1790 g for 15 minutes. The supernatant was used as the crude laccase extract.

### Enzyme assays

The crude enzyme was assayed for laccase activity using 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) and guaiacol as substrates to compare the enzyme activity under different conditions.

### Laccase activities with 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) – ABTS

Laccase activity was determined following the modified method of Mongkolthanasarak et al. (2012). The oxidation of ABTS (AK Scientific, Union City, CA 94587, USA) was measured using a BOSCH UV-visible spectrophotometer 721G. The reaction mixture contained 60 µL ABTS solution (1 mM), 1.5 mL sodium acetate buffer pH 5.0 (0.1 M), and 0.5 mL enzyme. After 10 minutes of incubation, the reaction was stopped by adding 20 µL of 5 % Trichloroacetic acid (TCA). The blank contained all components except the crude enzyme, which was substituted with sterile distilled water. The oxidation of ABTS was quantified by measuring absorbance at 420 nm, with a molar extinction coefficient of 36,000 M<sup>-1</sup>cm<sup>-1</sup>. One unit of enzyme activity is the amount of enzyme that oxidises 1 mmol of ABTS per minute.

$$\text{Laccase activity (U/mL)} = \frac{\text{Change in absorbance per min} \times \text{final volume of reaction mixture} \times \text{dilution factor}}{\text{Extinction coefficient } (\epsilon) \times \text{sample volume}}$$

### Laccase activities using guaiacol

Guaiacol (2mM) in sodium acetate buffer (10 mM, pH 5.0) was used to determine laccase activity (Desai et al., 2011). The reaction

mixture contained 0.5 mL of crude enzyme, 0.5 mL of guaiacol, and 1.5 mL of acetate buffer, and was incubated at 30°C for 30 minutes. Absorbance was read at 450 nm using the same spectrophotometer. The formation of a brown colour due to guaiacol oxidation was used as an indicator of enzyme activity. One unit of enzyme activity is the amount of enzyme required to oxidise 1 µmol of guaiacol per minute. Laccase activity (U/mL) was calculated using the extinction coefficient of guaiacol (12,100 M<sup>-1</sup> cm<sup>-1</sup>) at 450 nm.

$$\text{Laccase Activity (U/mL)} = \frac{\text{Absorbance at 450 nm} \times \text{Total volume of reaction mixture}}{\text{Incubation time (min)} \times \text{Extinction Coefficient} \times \text{enzyme volume}}$$

### Decolourisation of Dyes by laccase-producing fungi

The fermentation medium contained (g/L) glucose 10, CaCl<sub>2</sub> 1, KCl 0.25, NH<sub>4</sub>NO<sub>3</sub> 2.5, MgSO<sub>4</sub> 0.25, MnSO<sub>4</sub> 0.005, and FeSO<sub>4</sub> 0.005, with dyes at 1 g/L (methyl red, Congo red, Leishmann blue, and safranin). Three treatments were set up: one and two with dye but no lignin-containing substrate, and three with dye plus 1% lignin-containing substrate. They were all sterilised and allowed to cool. The first treatment was not inoculated with any organism and set as control. Ten millilitres of the second and third treatments were inoculated with two 7 mm plugs of each fungus. They were all incubated for 4 days and filtered with Whatman No. 1 filter paper. Dye decolourisation was assessed by measuring absorbance at 520 nm for methyl red, Congo red, and safranin; and 595 nm for Leishmann blue.

### Dye Decolourisation (%)

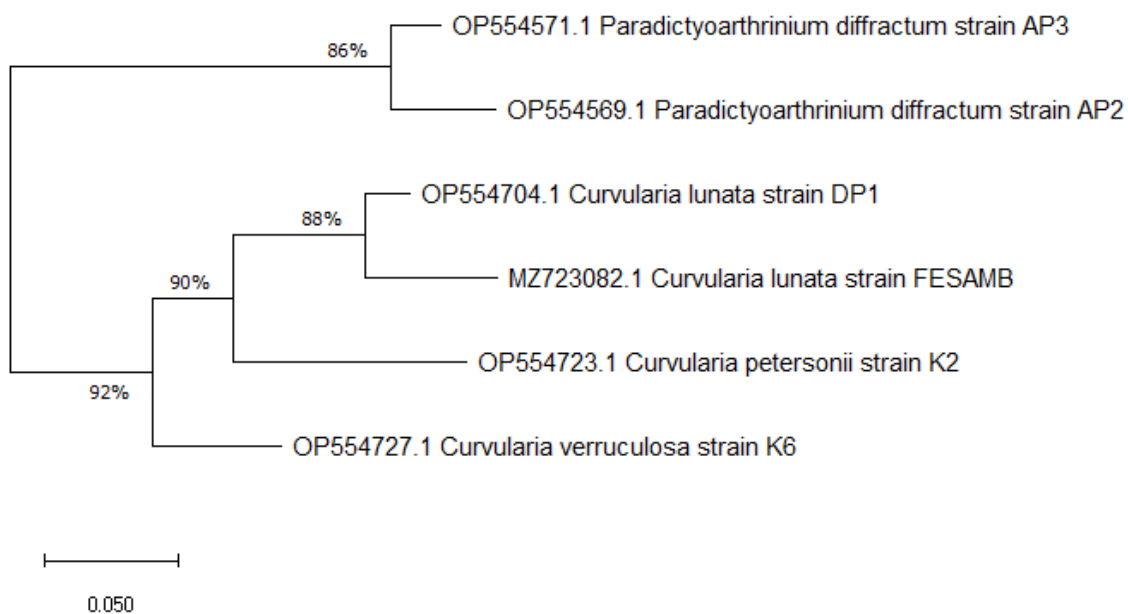
$$= \frac{\text{Absorbance of filtrate from dye medium inoculated with organism}}{\text{Absorbance of filtrate from dye medium not inoculated}} \times 100\%$$

### Statistical Analysis

All experiments were carried out in duplicate and analysed using analysis of variance (ANOVA) to determine the means, and the level of significance was set at  $P \leq 0.05$ .

## 3. RESULTS

### Identification of organism and phylogenetic analysis



**Figure 1** Phylogenetic analysis of some laccase-producing *Curvularia* and *Paradietioarthrinium* species

The fungi were molecularly identified as *Paradietioarthrinium diffractum* AP3, *Paradietioarthrinium diffractum* AP2, *Curvularia lunata* DP1, *Curvularia lunata* FESAMB, *Curvularia petersonii* K2, and *Curvularia verruculosa* K6 with accession numbers OP554571, OP554569,

OP554704, MZ723082, OP554723, and OP554727, respectively. Phylogenetic analysis of these fungi is displayed in Figure 1. *Paradictyoarthrinium diffractum* AP3 and *Paradictyoarthrinium diffractum* AP2 are closely related, while *Curvularia lunata* DP1 and *Curvularia lunata* FESAMB are more closely related compared to other *Curvularia* species.

#### Laccase activities using 2, 2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) – ABTS

The activities of laccase produced by some fungi, using 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) [ABTS] as an indicator, are shown in Table 1. Laccase activity by *Paradictyoarthrinium diffractum* AP2 was higher at pH 5 than at pH 6. The highest laccase activity (38.89 U/mL) of *Paradictyoarthrinium diffractum* AP2 was recorded with medium containing maize straw at pH 5, followed by activity (30.28 U/mL) observed when sugarcane bagasse was in the production medium at pH 5. *Paradictyoarthrinium diffractum* AP2 had the lowest laccase activity (2.24 U/mL) in a medium without lignin-containing substrates at pH 6. Laccase activity of *Paradictyoarthrinium diffractum* AP3 ranged from 0.00 U/mL (in medium without lignin-containing substrate at pH 5 and 6) to 2.87 U/mL (in medium containing maize straw at pH 6). Lignin-containing substrates (sugarcane bagasse and maize straw) increased laccase production of *Curvularia verruculosa* K6 from 2.49 U/mL (in a medium without lignin-containing substrate) to 29.68 U/mL and 20.37 U/mL, respectively, at pH 5. At pH 6, the presence of sugarcane bagasse and maize straw in the fermentation medium increased laccase yields of *Curvularia verruculosa* K6 from 0.00 U/mL to 9.38 U/mL and 11.45 U/mL, respectively. At pH 5, *Curvularia petersonii* K2 produced the highest laccase (29.51 U/mL) in a medium containing maize straw and the least laccase (7.53 U/mL) in a sugarcane bagasse-containing medium. In comparison, the highest laccase production (21.35 U/mL) at pH 6 by *Curvularia petersonii* K2 was recorded in a medium with sugarcane bagasse. *Curvularia lunata* DP1 had the highest laccase yield (39.62 U/mL) in maize straw-containing medium at pH 6. Maize straw-containing medium supported the highest laccase yield (33.99 U/mL and 31.75 U/mL) by *Curvularia lunata* FESAMB at pH 5 and 6, respectively, when compared with other media of production. The substrate type and pH significantly affected laccase production.

**Table 1.** Laccase activities (U/mL) of some laccase-producing *Curvularia* and *Paradictyoarthrinium* species using 2,2'-azino-bis (3-ethylbenzthiazoline-6-sulphonic acid) as an indicator

Isolates	pH/Substrate					
	pH 5			pH 6		
	NL	SB	MS	NL	SB	MS
<i>Paradictyoarthrinium diffractum</i> AP2	22.40 <sup>c</sup>	30.28 <sup>e</sup>	38.89 <sup>f</sup>	2.24 <sup>a</sup>	18.48 <sup>b</sup>	26.71 <sup>d</sup>
<i>Paradictyoarthrinium diffractum</i> AP3	0.00 <sup>a</sup>	0.70 <sup>b</sup>	0.88 <sup>c</sup>	0.00 <sup>a</sup>	2.10 <sup>d</sup>	2.87 <sup>e</sup>
<i>Curvularia verruculosa</i> K6	2.49 <sup>b</sup>	29.68 <sup>f</sup>	20.37 <sup>e</sup>	0.00 <sup>a</sup>	9.38 <sup>c</sup>	11.45 <sup>d</sup>
<i>Curvularia petersonii</i> K2	20.83 <sup>c</sup>	7.53 <sup>a</sup>	29.51 <sup>e</sup>	20.72 <sup>c</sup>	21.35 <sup>d</sup>	12.85 <sup>b</sup>
<i>Curvularia lunata</i> DP1	4.17 <sup>a</sup>	4.76 <sup>b</sup>	29.47 <sup>e</sup>	5.88 <sup>c</sup>	25.97 <sup>d</sup>	39.62 <sup>f</sup>
<i>Curvularia lunata</i> FESAMB	15.82 <sup>d</sup>	4.94 <sup>b</sup>	33.99 <sup>f</sup>	4.38 <sup>a</sup>	14.70 <sup>c</sup>	31.75 <sup>e</sup>

#### Keys

NL: Medium with no lignin-containing substrate

SB: Medium with sugarcane bagasse

MS: Medium with maize straw

Laccase activities with different superscripts across the row are significantly different.

#### Laccase activities using guaiacol

Table 2 shows the activities of laccase produced by some fungi using guaiacol as an indicator in different media and varying pH. The laccase produced by *Paradictyoarthrinium diffractum* AP2 ranged from 0.00 U/mL (no lignin-containing medium, pH 5) to 1.82 U/mL (sugarcane bagasse-containing medium, pH 6). Guaiacol, as an indicator, detected laccase produced by *Paradictyoarthrinium diffractum* AP3 in a medium with no lignin-containing substrate (0.21 U/mL) and sugarcane bagasse-containing medium (0.24 U/mL) at pH 5. The highest laccase activity (1.66 U/mL) observed with guaiacol as an indicator by *Curvularia verruculosa* K6 was in a medium of production which contained maize straw at pH 5. With guaiacol as an indicator, *Curvularia petersonii* K2 had better laccase yield at pH 5 than at pH 6 with different substrates. In maize straw-containing medium, *Curvularia lunata* DP1 had higher laccase activity at pH 6 (4.79 U/mL) than at pH 5 (3.99 U/mL). Maize straw had a positive influence on *Curvularia lunata* FESAMB laccase. The presence of maize straw in the fermentation medium increased laccase activity from 1.01 U/mL (no lignin-containing medium) to 6.94 U/mL at pH 5 and from 0.64

U/mL (no lignin-containing medium) to 4.40 U/mL at pH 6.

**Table 2.** Laccase activities of some laccase-producing *Curvularia* and *Paradictyoarthrinium* species using guaiacol as an indicator

Isolates	pH/Substrate					
	pH 5			pH 6		
	NL	SB	MS	NL	SB	MS
<i>Paradictyoarthrinium diffractum</i> AP2	0.00 <sup>a</sup>	0.07 <sup>b</sup>	0.66 <sup>d</sup>	0.06 <sup>b</sup>	1.82 <sup>e</sup>	0.46 <sup>c</sup>
<i>Paradictyoarthrinium diffractum</i> AP3	0.21 <sup>b</sup>	0.24 <sup>c</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>	0.00 <sup>a</sup>
<i>Curvularia verruculosa</i> K6	0.00 <sup>a</sup>	0.00 <sup>a</sup>	1.66 <sup>d</sup>	0.00 <sup>a</sup>	0.78 <sup>b</sup>	1.22 <sup>c</sup>
<i>Curvularia petersonii</i> K2	3.64 <sup>c</sup>	14.37 <sup>e</sup>	17.67 <sup>f</sup>	0.16 <sup>a</sup>	1.60 <sup>b</sup>	4.42 <sup>d</sup>
<i>Curvularia lunata</i> DP1	0.76 <sup>b</sup>	0.77 <sup>b</sup>	3.99 <sup>d</sup>	0.39 <sup>a</sup>	2.22 <sup>c</sup>	4.79 <sup>e</sup>
<i>Curvularia lunata</i> FESAMB	1.01 <sup>c</sup>	0.26 <sup>a</sup>	6.94 <sup>f</sup>	0.64 <sup>b</sup>	1.42 <sup>d</sup>	4.40 <sup>e</sup>

Keys

NL: Medium with no lignin-containing substrate

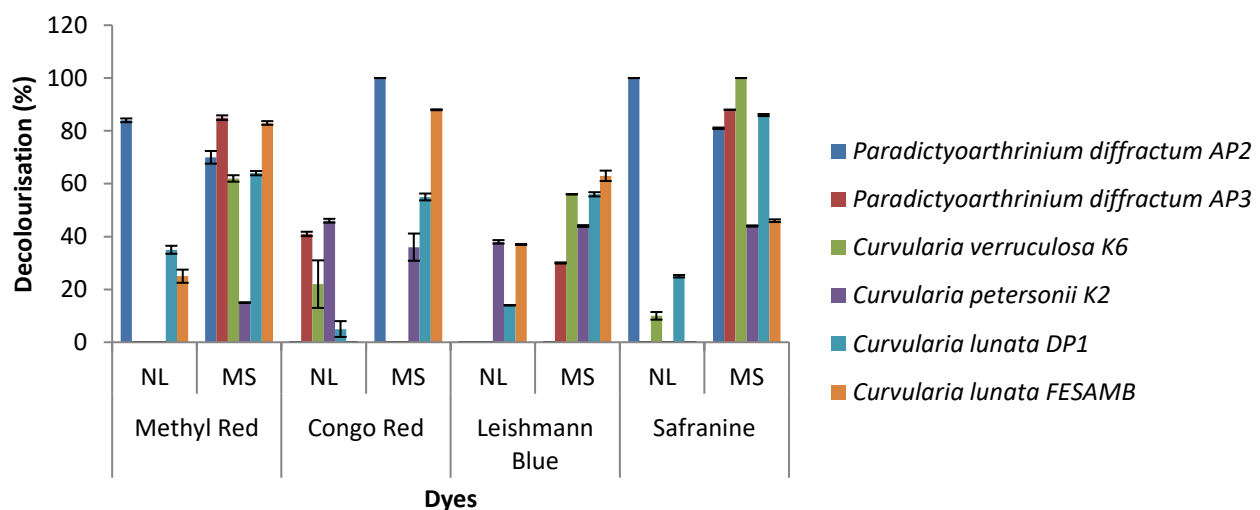
SB: Medium with sugarcane bagasse

MS: Medium with maize straw

Laccase activities with different superscripts across the row are significantly different.

### Decolourisation of Dyes by laccase-producing fungi

Decolourisation ability of some laccase-producing *Curvularia* and *Paradictyoarthrinium* species is shown in Figure 2. *Paradictyoarthrinium diffractum* AP3 showed the highest reduction in methyl red dye (85%) when grown in maize straw-containing medium, which was followed by *Paradictyoarthrinium diffractum* AP2 (84%) when grown in non-lignin-containing medium. *Paradictyoarthrinium diffractum* AP3, *Curvularia verruculosa* K6, and *Curvularia petersonii* K2 did not decolourise methyl red dye when grown in a non-lignin-containing medium. The highest decolourisation of Congo red (100 %) was by *Paradictyoarthrinium diffractum* AP2 in maize straw-containing medium. Leishmann blue was decolourised by 63 % when *Curvularia lunata* FESAMB was grown on maize straw-containing medium. In contrast, *Paradictyoarthrinium diffractum* AP2, *Paradictyoarthrinium diffractum* AP3, and *Curvularia verruculosa* K6 could not decolourise Leishmann blue when grown in a no-lignin-containing medium. *Paradictyoarthrinium diffractum* AP2, grown in a no-lignin-containing medium, and *Curvularia verruculosa* K6, cultivated in maize straw-containing medium, decolourised safranine completely (100 %). Generally, there was more decolourisation of dyes in maize straw-containing media than in non-lignin-containing media.



**Figure 2** Decolourisation ability of some laccase-producing *Curvularia* and *Paradictyoarthrinium* species

Error bar: Standard error of the mean

## 4. DISCUSSION

Laccase produced by different organisms on various substrates demonstrated distinct properties. The activities of enzymes from different cultivation media varied. The substrates (maize straw and sawdust) added to the fermentation media during the laccase production contain lignin, which enhances the production of lignin-degrading enzymes. Variation in the lignin content of these substrates could be responsible for the different activities of the enzymes produced. The addition of lignin-rich substrates influences the production of lignin-degrading enzymes (Mongkolthanasarakul *et al.*, 2012). Neoh *et al.* (2015) utilised agro-wastes for the production of laccase and manganese peroxidase by *Curvularia* sp. Lignin-containing substrates and the pH of the fermentation medium affected the laccase yield by different laccase-producing organisms used in this work. Substrates (Fasiku *et al.*, 2023b; 2023c) and pH (Onilude *et al.*, 2015; Boran and Yesilada, 2022; Jafari *et al.*, 2023; Odjogi *et al.*, 2026) significantly influence enzyme production. The production of laccase by *Curvularia lunata* has been established by some researchers (Bello *et al.*, 2021; Hamed *et al.*, 2024), but to the best of our knowledge, this is the first report of laccase production by *Curvularia verruculosa*, *Curvularia petersonii*, and *Paradictyoarthrinium* species isolated from any source.

Better decolourisation of dyes in media supplemented with maize straw than in media not supplemented with lignin-containing substrates may have been influenced by the presence of lignin in maize straw. The lignin or lignin-containing substrate in the fermentation medium might have acted as an inducer for the production of lignin-degrading enzymes. One of the applications of laccase is its ability to decolourise dyes, which has been confirmed (Yang *et al.*, 2020). Yang *et al.* (2020) reported that laccase produced by *Trametes trogii* could decolourise dye. Lignin-containing substrates improve laccase production, which in turn directly affects dye decolourisation. Yang *et al.* (2013) reported that an inducer influences laccase production by *Trametes velutina*. Lignin-containing substrates in the fermentation media could be considered inducers, and they had a positive influence on laccase production by most organisms used in this work. Riffat *et al.* (2024) achieved 82% maximum decolourisation of Remazol dye, whereas in this work, 100% decolourisation of safranin and Congo red dyes was recorded by *Curvularia verruculosa* K6 and *Paradictyoarthrinium diffractum* AP2, respectively, in maize straw-containing media. Riffat *et al.* (2024) utilised laccase enzyme to decolourise; however, laccase-producing organisms were used for decolourisation in this work. The variation in the rate of decolourisation by the organisms employed might have been influenced by the differences in the redox potentials and suitability of the steric structure with the active site of the laccases produced by these organisms (Tavares *et al.*, 2008; Afreen *et al.*, 2018). The source of enzymes and the chemical structure of dyes affect the decolourisation rate (Afreen *et al.*, 2018). Laccases from different organisms have diverse properties depending on the media. From this work, some organisms with high laccase activities could not decolourise certain dyes, but effectively decolourised others.

## 5. CONCLUSION

*Curvularia verruculosa* K6, *Curvularia petersonii* K2, *Curvularia lunata* DP1, *Curvularia lunata* FESAMB, *Paradictyoarthrinium diffractum* AP2, and *Paradictyoarthrinium diffractum* AP3 produced laccase. Lignin-containing substrates and the pH of the production medium had a significant effect on laccase production, and the decolourisation of dyes by laccase-producing *Curvularia* and *Paradictyoarthrinium* species. These organisms have potential application in treating dye-contaminated water.

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### Author Contributions

Samuel Adedayo Fasiku: Conceptualisation, design, investigation, data acquisition, data analysis and interpretation, writing original draft, review and editing/critical revision

Godwin Adeoluwa Akinrinsade: investigation, data acquisition, writing original draft, data analysis and interpretation

Seun Angel Aregbesola: investigation, data acquisition, writing original draft

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Femi Johnson Afolabi: writing original draft, review and editing/critical revision

Gboyega Ebenezer Adebami: writing original draft, review and editing/critical revision.

**Informed consent**

Not applicable.

**Conflicts of interests**

The author declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

**Ethical approval & declaration**

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors.

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**Data and materials availability**

Data that support the findings of this study are embedded within the manuscript.

**REFERENCES**

1. Afreen S, Answer R, Singh RK, Fatma T. Extracellular laccase production and its optimization from *Arthrspirira maxima* catalyzed decolorization of synthetic dyes. *Saudi Journal of Biological Sciences*, 2018; 25(7): 1446-1453. doi: 10.1016/j.sjbs.2016.01.015
2. Bello A, Ameh JB, Machido DA, Mohammed-Dabo AI. Screening and identification of Laccase producing fungi from environmental samples. *UMYU Journal of Microbiology Research*, 2021; 6(1): 91-98. doi: 10.47430/ujmr.2161.012
3. Bello A, Machido DA, Mohammed-Dabo AI, Ado SA. Optimization of laccase production by *Curvularia lunata* using maize cob as substrate. *FUDMA Journal of Sciences*, 2020; 4(4): 460-468.
4. Boran F, Yesilada O. Laccase production by newly isolated *Ganoderma lucidum* with solid state fermentation conditions and its using for dye decolorization. *ADYU Mühendislik Bilimleri Dergisi*, 2022; 17: 458-470.
5. Dai X, Lv J, Yan G, Chen C, Guo S, Fu P. Bioremediation of intertidal zones polluted by heavy oil spilling using immobilized laccase-bacteria consortium. *Bioresource Technology*, 2020; 309: 123305.
6. Debnath R, Saha T. An insight into the production strategies and applications of the ligninolytic enzyme laccase from bacteria and fungi. *Biocatalysis and Agricultural Biotechnology*, 2020; 26: 101645.
7. Desai SB, Gururaj, Tennali N, Channur AC, Anup G, Deshpande GBP, Azhar M. Isolation of laccase producing fungi and partial characterization of laccase. *Biotechnology Bioinformatics Bioengineering*, 2011; 1(4), 543-549.
8. Fasiku SA, Afolabi FJ, Egbeleke TA, Fashogbon RO. Applications of Microbial Enzymes in Industries. *Journal of Multidisciplinary Science: MIKAILALSYS*, 2026; 4(1): 26 – 40. doi: 10.58578/mikailalsys.v4i1.8137
9. Fasiku SA, Wakil SM. Pretreatment of maize straw with *Pleurotus ostreatus* and *Lentinus squarrosulus* for bioethanol production using *Saccharomyces cerevisiae*. *Novel Research in Microbiology*, 2021; 5(6): 1480-1493. doi: 10.21608/nrmj.2021.209731
10. Fasiku SA, Bello MA, Odeniyi OA. Production of xylanase by *Aspergillus niger* GIO and *Bacillus megaterium* through solid-state fermentation. *Access Microbiology*, 2023c; 5:000506.v5. doi: 10.1099/acmi.0.000506.v5
11. Fasiku SA, Wakil SM, Alao OK. Screening for lignocellulolytic enzymes-producing white rot fungi. *Asian Journal of Research in Botany*, 2023a; 9(2): 1-7.
12. Fasiku SA, Wakil SM, Alao OK. Degradation of lignocellulosic substrates by *Pleurotus ostreatus* and *Lentinus squarrosulus*. *The Asia Journal of Applied Microbiology*, 2023b; 10(1): 10-20. doi: 10.18488/33.v10i1.3354
13. Guan Z, Luo Q, Wang H, Chen Y, Llao X. Bacterial laccases: promising biological green tools for industrial applications. *Cellular and Molecular Life Sciences*, 2018; 75: 3569–3592.
14. Hamed AA, Abd-Elaziz AM, Ghanem ME, ElAwady ME, Abdel-Aziz MS. Production of laccase enzyme from *Curvularia lunata* MY3: purificaion and characterization. *Folia Microbiologica*, 2024; 69: 221-234. doi: 10.1007/s12223-023-01088-2
15. Hassan S, Anwar Z, Khalid W, Afzal F, Zafar M, Ali U, Refai MY, Afifi M, AL-Farga A, Aljobair MO. Laccase production

- from local biomass using solid state fermentation. *Fermentation* 2023; 9(2): 179. doi: 10.3390/fermentation9020179
16. Hosseini SM, Sepahi AA, Razavi MR, Saffarian P. Optimizing laccase production from halotolerant *Enterobacter* sp. GR18 for hydrocarbon bioremediation. *Remediation Journal*, 2025: 35(2): e70006. doi: 10.1002/rem.70006
  17. Jafari A, Aghebati S, Khayati G. Decolorization of azo dyes by produced laccase enzyme in solid-state fermentation using biphenyl as an inducer. *Biocatalysis and Agricultural Biotechnology*, 2023: 52: 102814.
  18. Janusz G, Pawlik A, Swiderska-Burek U, Polak J, Sulej J, Jarosz-Wilkolazka A, Paszczynski A. Laccase properties, physiological functions and evolution. *International Journal of Molecular Sciences*, 2020: 21: 966. doi: 10.3390/ijms21030966
  19. Khan SI, Sahinkaya M, Colak DN, Zada NS, Uzuner U, Belduz AO, Çanakçı S, Khan AZ, Khan S, Badshah M, Shah AA. Production and characterization of novel thermostable CotA-laccase from *Bacillus altitudinis* SL7 and its application for lignin degradation. *Enzyme and Microbial Technology*, 2024: 172: 110329. doi: 10.1016/j.enzmictec.2023.110329
  20. Kumar S, Stecher G, Li M, Knyaz C, Tamura K. MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. *Molecular Biology and Evolution*, 2018: 35: 1547-1549. doi: 10.1093/molbev/msy096
  21. Mongkolthananuruk W, Tongbopi S, Bhoonobtong A. Independent behaviour of bacterial laccases to induce and metal ions during production and activity. *African Journal of biotechnology*, 2012: 11(39): 9391-9398. doi: 10.5897/AJB11.3042
  22. Morya R, Kumar M, Singh SS, Thakur IS. Genomic analysis of *Burkholderia* sp. ISTR5 for biofunneling of lignin-derived compounds. *Biotechnology Biofuels*, 2019: 12: 277. doi: 10.1186/s13068-019-1606-5
  23. Neoh CH, Lam CY, Yahya A, Ware I, Ibrahim Z. Utilization of Agro-Industrial Residues from Palm Oil Industry for Production of Lignocellulolytic Enzymes by *Curvularia clavata*. *Waste Biomass Valor*, 2015: 6: 385-390. doi: 10.1007/s12649-015-9357-4.
  24. Odjoi EA, Fasiku SA, Alao OK, Salawu KO, Dada MT, Odeniyi OA, Wakil SM. Amylase production by *Streptomyces* species and its application in orange juice clarification. *Trakya University of Journal of Natural Sciences*, 2026: 27(1). doi: 10.23902/trkjnat.202562
  25. Oluwadamilola EO, Timinibefi Z, Momoh AO. Production and characterization of thermostable lignolytic enzymes produced from *Staphylococcus saprophyticus* exposed to low-density polyethylene (LDPE). *Journal of Biochemistry International*, 2022: 9(4): 18-27.
  26. Onilude AA, Adekoya AO, Wakil SM, Fasiku SA, Ja'afaru, IM. Isolation and identification of thermophilic cellulolytic yeast from cassava waste dump. *Journal of Science Research*, 2015: 14: 131-143.
  27. Periyasamy AP. Recent Advances in the remediation of textile-dye-containing wastewater: prioritizing human health and sustainable wastewater treatment. *Sustainability*, 2024: 16(2): 495. doi: 10.3390/su16020495
  28. Riffat A, Anwar Z, Zafar M, Nadeem F, Mehmood T. Optimization of physiochemical parameters and characterization laccase enzyme produced by a novel strain of *Fomes fomentarius* through solid-state fermentation. *Biomass Conversion and Biorefinery*, 2024: 14: 3999-4006. doi: 10.1007/s13399-022-02621-y
  29. Tavares APM, Cristovao RO, Loureiro JM, Boaventura RAR, Macedo EA. Optimisation of reactive textile dyes degradation by laccase-mediator system. *Journal of Chemical Technology and Biotechnology*, 2008: 83: 1609-1615. doi: 10.1002/jctb.1952
  30. Vazquez MA, Cabrerias EC, Torta L, Laudicina A, Mirabile G. Lignolytic potential of *Curvularia kusanoi* L7 laccases for animal production. *Cuban Journal of Agricultural Science*, 2020: 54(2): 1-11.
  31. Yadav M, Vivekanand V. Biological treatment of lignocellulosic biomass by *Curvularia lunata* for production. *Bioresource Technology*, 2020: 306: 123151.
  32. Yang X, Wu Y, Zhang Y, Yang E, Qu Y, Xu H, Chen Y, Irbis C, Yan J. A Thermo-Active Laccase Isoenzyme From *Trametes trogii* and Its Potential for Dye Decolorization at High Temperature. *Frontiers in Microbiology*, 2020: 11: 241. doi: 10.3389/fmicb.2020.00241
  33. Yang Y, Wei F, Zhuo R, Fan F, Liu H, Zhang C, Ma L, Jiang M, Zhang X. Enhancing the laccase production and laccase gene expression in the white-rot fungus *Trametes velutina* 5930 with great potential for biotechnological applications by different metal ions and aromatic compounds. *PLoS ONE*, 2013: 8(11): e79307. doi: 10.1371/journal.pone.0079307
  34. Zhang J, Ren J, Yu Y, Wang B. Purification and characterization of laccase from *Curvularia trifol*. *Advanced Materials Research*, 2010: 2215-2219.