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Biodegradation of Azo Dyes Congo Red and Eriochrome Black T by Fungal Isolates from Textile Mill Effluent

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Abstract:

Synthetic azo dyes are extensively used in textile industries and represent a major source of environmental pollution due to their toxicity, recalcitrance, and potential carcinogenic effects. The present study evaluates the biodegradation potential of fungal isolates obtained from textile mill effluent for the decolorization of two azo dyes, Congo red and Eriochrome Black T. Three fungal isolates were identified based on morphological characteristics: Aspergillus niger (AS-I), Rhizopus spp. (AS-II), and Penicillium spp. (AS-III). Decolorization studies were conducted in liquid medium supplemented with 0.2% dye concentration over 24 days, and absorbance was measured at 530 nm. For Congo red, A. niger exhibited maximum decolorization (63.82%), followed by Rhizopus spp. (55.55%), Penicillium spp. (50.12%), and the consortium (54.05%). For Eriochrome Black T, Penicillium spp. showed highest decolorization (63.15%), followed by A. niger (60.25%), consortium (60.52%), and Rhizopus spp. (52.05%). The findings demonstrate the potential application of fungal isolates in eco-friendly treatment of textile dye effluents.

Keywords: Azo dyes, Biodegradation, Textile effluent, Decolorization, Congo red, Eriochrome Black T.

Introduction:

Dyes are colored substances that impart color to substrates by selective absorption of visible light. They may be classified as natural or synthetic. Synthetic dyes dominate industrial applications due to their stability, brightness, and cost-effectiveness.

Azo dyes constitute more than 50% of commercially used dyes and are characterized by one or more azo (-N=N-) bonds. While they produce vibrant shades such as red, yellow, and orange, their breakdown products aromatic amines are toxic and potentially carcinogenic.

Environmental Impact of Azo Dyes:

Textile effluents containing azo dyes: Reduce light penetration in aquatic systems, decrease photosynthetic activity, introduce toxic and mutagenic compounds, Persist due to complex aromatic structures. Complete detoxification requires not only azo bond cleavage but also aromatic ring degradation.

Selected Dyes:

Congo Red:

- Molecular formula: $C_{32}H_{22}N_6Na_2O_6S_2$
- Molecular weight: 696.66 g/mol
- Type: Secondary diazo dye
- Maximum absorption: 498 nm
- Water-soluble and toxic

Eriochrome Black T:

- Molecular formula: $C_{20}H_{12}N_3O_7SNa$
- Molecular weight: 461.38 g/mol
- Used as complexometric indicator
- Forms blue complex with metal ions

Biological Treatment Approaches:

Biological treatment using microorganisms is cost-effective and eco-friendly compared to physicochemical methods. Fungi, especially ligninolytic species, degrade dyes using extracellular enzymes such as: Lignin peroxidase, Manganese peroxidase, Laccase.

Aim of the Study:

To isolate fungi from textile effluent and evaluate their individual and consortium potential for decolorization of Congo red and Eriochrome Black T.

Materials and Methods:

Sample Collection: Effluent samples were collected from a textile mill and transported to the laboratory under sterile conditions.

Isolation of Fungi: Serial dilutions were prepared and plated on Saburou's agar medium. Plates were incubated at room temperature (≈28°C) for 4 days. Distinct colonies were subculture and preserved.

Identification of Isolates: Identification was based on macroscopic morphology.

Table 1. Morphological characteristics of fungal isolates

Sr. No.	Isolate	Size	Shape	Mycelial Color	Margin	Opacity	Elevation	Spore Color
1	AS-I (*Aspergillus niger*)	8 mm	Filamentous	Black	Entire	Opaque	Flat	Black
2	AS-II (*Rhizopus* spp.)	4 mm	Filamentous	White	Entire	Opaque	Flat	Green
3	AS-III (*Penicillium* spp.)	4 mm	Filamentous	White	Entire	Opaque	Flat	White

Medium Composition:

Liquid medium (per liter): Sucrose – 50 g/L, ammonium sulfate – 5 g/L, Yeast extract – 17 g/L, asparagine – 10g/L, distilled water – 1 L and P^H adjusted to 4.5

Decolorization Assay:

- Spores from 6-day-old cultures were inoculated into dye-containing medium (0.2%).
- Flasks incubated under static conditions at room temperature.
- Absorbance measured at 530 nm at 6-day intervals up to 24 days.
- Consortium flasks contained all three isolates.

Calculation of Percentage Decolorization:

$$\frac{\text{Initial absorbance (Ao)-observed absorbance (At)} \times 100}{\text{Initial absorbance (Ao)}}$$

Where:

A_o = Initial absorbance

A_t = Absorbance at time t

Result:

Decolorization of Congo Red:

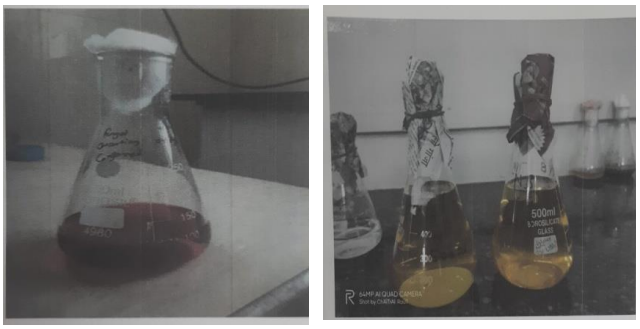

Figure 1. Percentage decolorization of Congo red by fungal isolates over 24 days. *A. niger* demonstrated maximum decolorization efficiency (63.82%).

Table 2. Optical density and percentage decolorization of Congo Red

Sr. No.	Fungal Isolate	Initial O.D.	Final O.D. (24 days)	% Decolorization
1	AS-I (*A. niger*)	0.94	0.34	63.82%
2	AS-II (*Rhizopus* spp.)	0.81	0.36	55.55%
3	AS-III (*Penicillium* spp.)	0.82	0.41	50.12%
4	Consortium	0.74	0.34	54.05%

Decolorization of Eriochrome Black T:

Figure 2. Percentage decolorization of Eriochrome Black T by fungal isolates over 24 days.

Sr. No.	Fungal Isolate	Initial O.D.	Final O.D. (24 days)	% Decolorization
1	AS-I (*A. niger*)	0.78	0.31	60.25%
2	AS-II (*Rhizopus* spp.)	0.73	0.35	52.05%
3	AS-III (*Penicillium* spp.)	0.76	0.28	63.15%
4	Consortium	0.78	0.32	60.52%

Table 3. Optical density and percentage decolorization of Eriochrome Black T by fungal isolates. *Penicillium spp*. showed highest efficiency (63.15%).

Discussion:

Fungal biodegradation of azo dyes is primarily enzymatic. The superior performance of *Aspergillus niger* in Congo red degradation may be attributed to high ligninolytic enzyme production. *Penicillium* spp. demonstrated greater affinity toward Eriochrome Black T, possibly due to structural compatibility and enzymatic specificity. The consortium did not outperform individual isolates, likely due to nutrient competition, antagonistic interactions, enzyme inhibition. Optimal pH (4.5) and static incubation favored decolorization. Similar findings have been reported in previous studies. Compared to bacterial systems, fungi: Produce higher biomass, secrete extracellular enzymes Tolerate harsh conditions. These advantages make fungi suitable for large-scale effluent treatment.

However, it is important to note that decolorization does not necessarily imply complete detoxification. Further studies involving metabolite analysis, toxicity assays, and enzyme characterization are required to confirm complete mineralization of the dyes.

Overall, the findings align with previous studies highlighting fungal biodegradation as an efficient and eco-friendly approach for textile effluent treatment.

Conclusion:

The present study confirms that fungal isolates recovered from textile mill effluent possess significant biodegradation potential against azo dyes. *Aspergillus niger* demonstrated maximum decolorization efficiency for Congo Red (63.82%)., *Penicillium* spp. showed highest degradation efficiency for Eriochrome Black T (63.15%). The fungal consortium exhibited moderate but not superior performance compared to individual isolates.

These results suggest that specific fungal strains may be selectively applied depending on dye type for improved bioremediation efficiency. The study highlights the potential application of fungal biotechnology as an economical and environmentally sustainable alternative to conventional physicochemical methods for textile wastewater treatment.

Future research should focus on:

- Optimization of environmental parameters (pH, temperature, aeration)
- Enzyme purification and characterization
- Identification of degradation intermediates
- Toxicity assessment of treated effluents
- Scale-up studies for industrial application

The integration of fungal-based bioremediation strategies could significantly

contribute to sustainable textile effluent management.

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