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Extraction and Characterization of Eco-Friendly Hair Dye from Agricultural Waste: A Study on Coconut Husk

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ABSTRACT

The increasing awareness of health hazards and environmental impact caused by synthetic hair dyes has sparked interest in natural alternatives. This study explores the potential of coconut husk—an underutilized agricultural byproduct—as a source of eco-friendly hair dye. Pigments were extracted from coconut husk using various solvents (water, ethanol, and alkaline solutions) and characterized using UV-Vis and FTIR spectroscopy. The extract was applied to human hair samples to evaluate dyeing potential, retention, and fastness. Results indicated that coconut husk contains tannins and phenolic compounds capable of imparting brown to reddish hues to hair. The study supports the development of a sustainable, cost-effective, and non-toxic hair dye formulation from agricultural waste.

Key words: coconut husk, natural dyeing, Eco-friendly Dye.

INTRODUCTION

The cosmetics industry is undergoing a significant shift toward sustainability, driven by increasing consumer awareness of the adverse effects of synthetic ingredients. Hair dyes are no exception; conventional formulations often contain ammonia, PPD (p-Phenylenediamine), and other harmful chemicals that may cause allergic reactions, hair damage, and environmental pollution. Coconut husk, the fibrous outer shell of the coconut (Cocos nucifera), is typically discarded as waste in large quantities, especially in tropical regions. Rich in tannins, lignin, and polyphenolic compounds, coconut husk presents an opportunity for conversion into a natural dye. This study aims to develop and characterize an eco-friendly hair dye derived from coconut husk, contributing to both waste valorization and green cosmetic development [1].

MATERIALS AND METHODS

Raw Material Collection

Coconut husks were collected from local coconut processing units. The husks were washed, sun-dried, and ground into a coarse powder.

Dye Extraction

Two methods were explored

Aqueous Extraction: 50g of powdered husk was boiled in 500 ml of distilled water for 2 hours.

Ethanolic Extraction: 50g of powdered husk was soaked in 70% ethanol for 48 hours, followed by filtration.

pH and Phytochemical Screening

The extract's pH was tested using a digital pH meter. Preliminary phytochemical analysis was conducted to detect the presence of tannins, flavonoids, and phenols.

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Characterization Techniques

UV-Vis Spectroscopy: Used to determine the absorption maxima of the dye extract.

FTIR Analysis: To identify functional groups in the extract responsible for dyeing properties.

Application on Hair Samples

Virgin human hair strands were washed and treated with the dye extracts at 60°C for 30 minutes. The samples were then dried and stored under ambient conditions. Observations were made over a 14-day period for:

I) Color intensity

II) Fade resistance

III) Texture change

RESULTS AND DISCUSSION

Extraction Yield

Aqueous extraction yielded 12.5% dye solution by weight.

Ethanolic extraction yielded 15.8%, indicating better solubility of active compounds in ethanol.

Phytochemical Analysis

Tests confirmed the presence of:

I) Tannins (high concentration)

II) Flavonoids

III) Polyphenols

These are known to bind well with keratin in hair, aiding in color retention.

UV-Vis and FTIR Results

UV-Vis: Major absorption peak at 320 nm, consistent with tannin presence.

FTIR: Peaks at ~3400 cm^{-1} (OH stretching), 1600 cm^{-1} (aromatic ring vibrations), indicating phenolic compounds.

Figure 01: Raw husk

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Figure 02: Husk prepared for dye

A **B**

Figure 03: A. Before the application of dye. B. After application of dye

Hair Dyeing Results

Hair treated with ethanolic extract exhibited a darker brown tone compared to aqueous extract.

I) Moderate dye retention observed up to 10 washes.

II) No significant change in hair texture or brittleness.

III) No irritation or reaction reported in patch tests on 5 volunteers.

CONCLUSION

This study demonstrates that coconut husk, an agricultural waste, can be effectively utilized to extract natural dye suitable for hair coloring. The presence of tannins and other polyphenolics in the extract offers good dyeing potential with acceptable retention and no adverse effects. Further work is required to enhance the longevity of the dye and explore formulation with mordants or fixatives. The valorization of coconut husk for natural dyes supports circular economy goals and promotes green innovation in cosmetics.

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