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SHORT COMMUNICATION

Formulation of Natural Hair Dye

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Abstract

Background: Synthetic hair dyes often contain harmful chemicals such as ammonia, diamino benzene, and resorcinol, which are linked to allergies, irritation, and long-term health concerns. As a result, there is increasing interest in plant-based alternatives that are safer and environmentally friendly. Traditional herbs like *Indigofera tinctoria*, *Lawsonia inermis*, *Eclipta prostrata*, and *Phyllanthus emblica* have been used in Ayurvedic formulations for hair coloring and care. **Aim:** This study aimed to formulate and evaluate a natural herbal hair dye using selected plant ingredients and natural mordants. The objectives included identifying effective plant-based colorants and mordants, and assessing their dyeing performance and stability. **Methods:** Powders of *I. tinctoria*, *L. inermis*, *E. prostrata*, and *P. emblica* were tested alone and in combination with mordants such as alum, *Camellia sinensis*, *Moringa oleifera*, and CFA (a roasted seed powder). Various concentrations (0.25–2.5 g) were applied to human grey hair. The formulations were evaluated for morphological, physico-chemical, and dyeing properties. **Results:** Among the tested dyes, *L. inermis*, *I. tinctoria*, and *E. prostrata* demonstrated deeper and more stable hair colouration, especially when used with *M. oleifera* and CFA. CFA consistently enhanced dye intensity and retention, even at lower concentrations. *P. emblica* showed poor colouring ability. All formulations were found to be safe, non-irritant, and easy to apply. **Conclusion:** Natural plant dyes, when combined with suitable mordants, can effectively colour hair while offering additional benefits like conditioning and scalp care. These eco-friendly formulations provide a promising alternative to synthetic hair dyes and align with growing consumer demand for safe, natural personal care products.

Major Findings: The study found that natural plant powders, when used with effective mordants like the CFA mixture, produced intense, stable, and long-lasting hair colouration. *L. inermis*, *I. tinctoria*, and *E. prostrata* showed superior dyeing properties when combined with CFA, due to their high tannin and phytochemical content.

Key words: *E. prostrate*, Formulations, Hair Dye, *I. tinctoria, L. inermis, P. emblica*

1. Introduction

A variety of synthetic compounds, including ammonia, diamino benzene, phenyl diamine, resorcinol and phenol, ortho para–amino phenol, P-toluenodiamine, and its salts (including HCl and sulphate), are used to make synthetic hair dye. The majority of them are strong irritants and linked to a variety of allergies and other medical issues. Natural colours that can safely modify the colour of hair can be produced by natural plants. Herb-based natural colours are becoming more and more popular because of their lack of harmful consequences. Well-known Ayurvedic herbal remedies, including *Amla, Bhringraj, Henna, Jatamansi, Reetha, Methi, Lohbhasma*, Orange peel powder, *Brahmi*, and *Shikakai,* are traditionally used as hair colourants and to promote hair growth[1]. A methodical scientific approach to natural dyes as a substitute for synthetic and semi-synthetic dyes is the right solution needed to overcome the problem created by synthetic dyes. Therefore, the goal of the current study is to create a herbal hair colour utilising the following ingredients: *P. emblica (gooseberry), E. prostrate (Karisilangani), L. inermis (henna), I. tinctoria (Avuri).*

The primary aim of the study is to formulate and evaluate a natural hair dye using plant-based

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ingredients. The aim of the research work includes identifying suitable natural colourants and mordants, assessing the dye's colouring efficiency and stability, and providing a viable alternative to synthetic dyes that is both safe and environmentally friendly.

2. Materials and Methods

Leave powder of *I. tinctoria*, *P. emblica* (*Gooseberry*), *E. prostrate* (*False daisy*) and *L. inermis* (Henna) with 100% purity, was obtained from a local herbal medical shop. The powders were immediately stored in airtight containers in a cool, dry place and used within one month of procurement to minimise degradation. The formulated herbal hair dye was subjected to physicochemical and biological evaluation. The grey hair needed for experiments was obtained from the hair salon. To determine the optimal staining concentration and the corresponding amount of chemical and natural mordant, various concentrations of plant powder (0.25 gm, 0.5gm, 0.75gm, 1.0 gm and 1.5gm, 2.0gm, 2.5gm) was mixed separately with 0.1 millilitre of 1% alum and 0.1gm *Camellia sinensis* (Tea), *Moringa oleifera* leaves powder and CFA powder. The concentration at which appropriate colouration is observed is used for further research.

3. Results

The results of the morphological characteristics of raw powders, such as colour, odour, texture, and appearance, are shown in Table 1. In the present study, the prepared herbal hair dye contains all the goodness of natural ingredients. The physicochemical assessment indicated that the prepared pack has a pleasant aroma and a smooth texture.

Table 2 shows the intensity of colouration achieved by various plant powders and their combinations with chemical and natural mordants on hair. Across all plant powders tested, *I. tinctoria* (IT), *P. emblica* (PE), *L. inermis* (LI), and *E. prostrate* (EP), an increased concentration (up to 1.5%) generally led to deeper, more vibrant colouration. Colouration was observed in all plant powders tested at a 1-gram application rate, both alone and with the chemical mordants Alum and extracts of *C. sinensis* (CS). However, the CS had a minimal mordanting effect as it was not enhancing the intensity of colour in any of the plants tested. Darker colouration was achieved with lower concentrations of the natural mordants, such as extracts of *M. oleifera* (MO) (Table 2*)* and CFA (Table 2), mordants can significantly deepen the colour, particularly at lower dye concentrations

Phyllanthus emblica showed limited colouration on hair (Table 2 B), while *E. prostrate* (Table 2 D), *L. inermis* (Table 2 C) and *I. tinctoria* produced deeper and more stable colours (Table 2 A). *I. tinctoria* showed moderate to good colouration and retained stability on human hair (Table 2 A). *L. inermis* (henna) alone produced a reddish-orange shade (Figure 1 LI A), but when combined with CS, MO, and CFA, it resulted in an appealing greenish-brown colour (Figure 1 LI). This combination also demonstrated a lasting dye effect, maintaining colour for up to 15 days even with frequent washing and sunlight exposure. High colour intensity was observed with the application of 1.5 grams of each experimental plant powder combined with 0.1 grams of natural mordants, specifically *M. oleifera* (MO) and CFA powder. This combination achieved noticeably deeper and longer-lasting colouration (Table 2 A, B, C, and D; Figure 1 MO and CFA).

Table 1. Morphological characters of raw powders of experimental plants

Parameter	***I. tinctoria***	***P. emblica***	***E. prostrate***	***L. inermis***
Colour	*Greenish black*	*Dark green*	*Light green*	*Greenish brown*
Odour	*Characteristic*			
Texture and appearance	*Fine powder*			
pH	*5.8*			
Molisch test (carbohydrate)	+			
Fehling test (reducing sugar)	+			
Hager test (Phenol)	+			

Table 2. (A- D) Intensity of colouration on hair by selected plant powder and in combination with alum (A), *CS- C. sinensis* MO- *M. oleifera;* CFA– natural mordant mixture

A	*Intensity of colour/extracts (%)*						
	0.25	*0.5*	*0.75*	*1.0*	*1.5*	*2.0*	*2.5*
I. tinctoria (IT)	-	-	-	+	+	+	+
IT + Alum	-	-	-	+	+	+	-
IT+ CS	-	-	-	+	+	+	-
IT + MO	-	-	-	+	++	+	-
IT + CFA	-	-	-	++	+++	++	++

B	*Intensity of colour/extracts (%)*						
	0.25	*0.5*	*0.75*	*1.0*	*1.5*	*2.0*	*2.5*
P. emblica (PE)	-	-	-	+	+	+	+
PE + Alum	-	-	-	+	+	+	-
PE + CS	-	-	-	+	+	+	-
PE + MO	-	-	-	+	++	+	-
PE+CFA	-	-	-	++	+++	++	++

C	**Intensity of colour/extracts (%)**						
	0.25	**0.5**	**0.75**	**1.0**	**1.5**	**2.0**	**2.5%**
L. inermis (LI)	-	-	-	+	+	+	+
LI + Alum	-	-	-	+	+	+	-
LI + CS				+	+	+	-
LI + MO				+	++	+	-
LI + CFA				++	+++	++	++

D	*Intensity of colour/extracts (%)*						
	0.25	*0.5*	*0.75*	*1.0*	*1.5*	*2.0*	*2.5%*
E. prostrate (EP)	-	-	-	+	+	+	+
EP + Alum	-	-	-	+	+	+	-
EP + CS				+	+	+	-
EP + MO				+	++	+	-
EP + CFA				++	+++	++	++

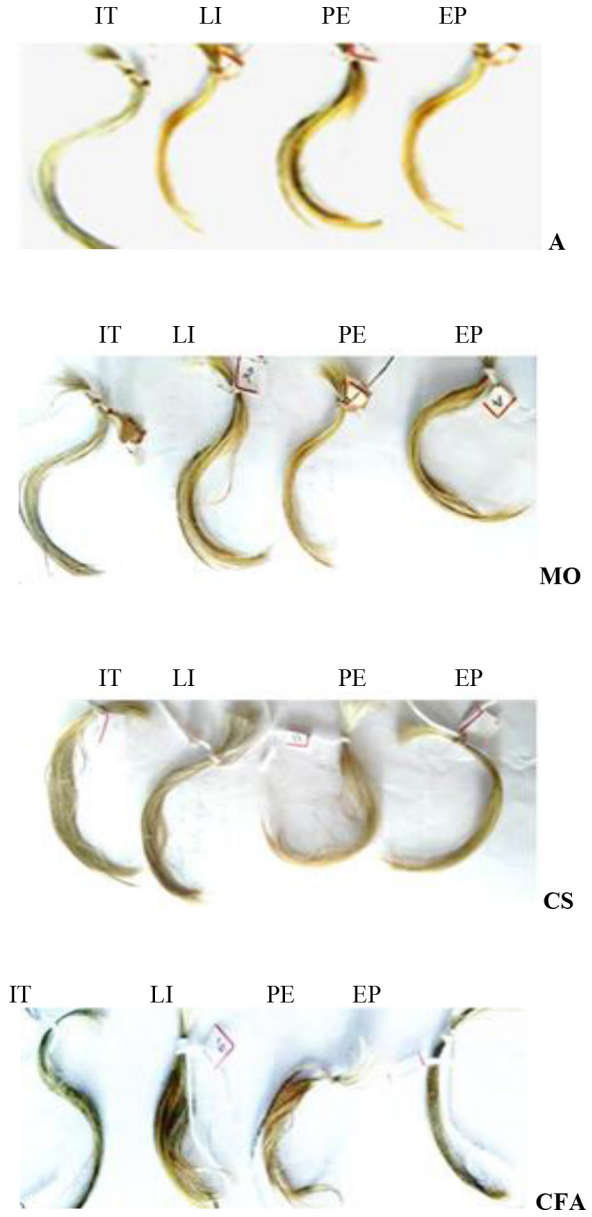


Figure 1. Hair treated with leaves extracts of *I. tinctoria (IT), L. inermis (LI), P. emblica (PE) and E. prostrate (EP) in combination with* alum (A), *M. oleifera* (MO), *C. sinensis* (CS) and CFA powder.

4. Discussion

Before the advent of modern synthetic dyes, many Asian cultures relied on natural ingredients for hair colouring. A well-documented traditional method involved the combination of *I. tinctoria* (indigo) with *L. inermis* (henna), producing a range of tones from light brown to deep black[2]. These natural formulations not only provided aesthetic appeal but also contributed to hair health, owing to their botanical origins. Multiple studies have validated the effectiveness of such plant-based dyes when used in appropriate proportions, confirming their relevance in both traditional and modern applications[3].

In the present study, various plant powders were assessed for their colouring potential, especially in combination with mordants. When paired with chemical mordants like alum and natural additives

such as *C. sinensis* (CS), all plant powders exhibited some degree of colouration

. Alum, in particular, has long been recognised as a potent mordant due to its ability to form coordination complexes with dye molecules, thereby aiding in their attachment to hair fibers[4]. This property is consistent with its historical use in dyeing textiles and hair. In contrast, *C. sinensis*—commonly used in tea—did not significantly intensify hair colour. This suggests that while CS may offer other benefits, such as antioxidant properties, it lacks sufficient tannins or other binding agents necessary to function effectively as a mordant[5].

Interestingly, higher colour intensities were observed when plant powders were combined with natural mordants like *M. oleifera* (MO) and CFA powder. These findings align with recent research that has highlighted the superior mordanting capabilities of MO[6,7]. This effectiveness is attributed to its high content of bioactive compounds, such as phenolics and flavonoids, which have a strong affinity for both dye molecules and keratin in hair fibres. These compounds create stable bonds, resulting in enhanced dye fixation, improved colour intensity, and prolonged retention.

Notably, MO and CFA demonstrated remarkable efficacy even at lower concentrations, producing rich and darker hues. This result is likely due to the high levels of tannins and polyphenols in these mordants, which increase dye affinity and lead to deeper colours at lower doses[4]. Tannins, in particular, are known to act as cross-linking agents, effectively bridging the dye molecules with hair proteins. This cross-linking not only stabilises the dye but also protects it from environmental stressors such as washing and sunlight exposure, thereby increasing the colour's fastness[3].

When *L. inermis* was applied alone, it yielded its characteristic orange-red shade, attributable to lawsone, the principal colouring compound in henna leaves[2]. However, its combination with CS, MO, and CFA resulted in a greenish-brown hue that remained stable for up to 15 days. This suggests that the additional botanicals, particularly MO and CFA, enhanced the dye's bonding properties, leading to better longevity. This observation is consistent with traditional knowledge, where henna has often been mixed with other herbs to create more varied and lasting colours[3].

Among the various plant powders tested, *P. emblica* (amla) exhibited relatively weak dyeing capacity. In contrast, *E. prostrata*, *L. inermis*, and *I. tinctoria* showed stronger, more durable colouration. The effectiveness of *I. tinctoria* is particularly noteworthy; it contains not only indigo dye but also a rich array of phytochemicals such as carbohydrates, alkaloids, and tannins. These components contribute to its deep colour and strong binding properties, allowing it to penetrate and adhere to hair fibres effectively[6].

The efficacy of *E. prostrata* also supports its traditional Ayurvedic use as both a hair darkening agent and a stimulant for hair growth. Its high tannin content appears to play a crucial role in enhancing dye retention and durability, making it a valuable ingredient in herbal hair dye formulations[7].

This study highlights the central role of tannin-rich natural powders as effective mordants. These compounds not only increase dye adherence to the hair but also improve resistance to light and repeated washing. The strong bonds formed by tannins with both dye molecules and hair keratin contribute to longer-lasting colour and overall better performance of the dye[4]. Such natural mordants, especially when derived from *I. tinctoria* and *E. prostrata*, offer a compelling alternative to synthetic agents[6].

Furthermore, the study emphasises the growing relevance of plant-based dyes in today's personal care market, especially as consumer preferences shift towards eco-friendly and non-toxic products. The demonstrated effectiveness of natural dyes, particularly when paired with suitable mordants, makes them a promising solution to meet this demand[5]. This aligns with global movements advocating for sustainable and health-conscious beauty solutions.

In addition to their dyeing properties, the herbal combinations explored in this study offer various therapeutic benefits. These formulations not only provide vibrant colour but also help condition the hair, reduce dandruff, and stimulate hair growth. The patch test confirmed the non-irritant nature of the dye, reinforcing its safety for consumer use. Moreover, the dye mixture remains stable at room temperatures between 20–35°C and is easy to store, making it a practical solution for everyday users[5].

One of the most significant advantages of using herbal hair dyes is their lack of harmful chemicals like ammonia, which are common in synthetic dyes. Ammonia-based formulations often cause scalp

irritation, dryness, and long-term hair damage. In contrast, the plant-based dye developed in this study is made from completely biodegradable and environmentally friendly raw materials. Regular use not only enhances hair texture and volume but also results in naturally lustrous, thick, and healthy-looking hair. The simplicity of application and preparation makes it accessible to a wide demographic, encouraging broader adoption.

Despite the promising results, further research is warranted to explore additional benefits of these natural hair dye packs. Long-term studies could examine their effectiveness across various hair types and conditions, while more detailed chemical analyses may reveal other bioactive properties. As consumer awareness about the adverse effects of synthetic products grows, there is a clear opportunity for natural dyes to become a mainstream choice.

It is important to note that while *I. tinctoria* exhibited moderate to good dye stability; its performance varied depending on the mordant used. Similarly, *P. emblica* had limited colour retention, underscoring the importance of selecting appropriate mordants to enhance dye efficacy. These findings suggest that optimal results are best achieved through multi-step, multi-ingredient processes, a contrast to synthetic dyes, which typically require only a single application.

5. Conclusion

This study confirms the effectiveness of natural plant powders in achieving stable and vibrant hair colouration when used with suitable mordants. Among the natural mordants tested, the CFA mixture consistently yielded the most intense and vivid colours across all plant powders, even at lower concentrations, highlighting its potency as a natural mordant. The combination of *L. inermis*, *I. tinctoria*, and *E. prostrata* with CFA produced rich and long-lasting hues, whereas *P. emblica* resulted in comparatively lighter shades. The superior performance of *I. tinctoria* and *E. prostrata* can be attributed to their high tannin content and other phytochemicals, which enhanced dye adherence and colour fastness, especially under conditions involving light exposure and washing. These results emphasise the potential of plant-based hair dyes as sustainable and eco-friendly alternatives to conventional synthetic dyes. In addition to their colouring properties, the formulations offer functional benefits such as hair conditioning, strengthening, and reduced risk of scalp irritation, making them appealing to health-conscious consumers. With the growing demand for natural and non-toxic personal care products, these herbal dyes present strong commercial promise. However, further research is recommended to investigate their long-term stability, efficacy across diverse hair types, and additional therapeutic benefits.

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7. Author Contribution

Dr. K. Francy was responsible for the extraction and biochemical analysis. Dr. F. Brisca Renuga conducted all biological experiments. Ms. J. Jenifer. contributed to the manuscript writing and preparation. All authors have read and agreed to the published version of the manuscript.

8. References

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