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DEVELOPMENT AND PERFORMANCE ASSESSMENT OF A HERBAL HAIR DYE GEL FOR NATURAL HAIR COLOURING

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ABSTRACT

Conventional oxidative hair dyes dominate the global colourant market, yet their key ingredient p-phenylenediamine (PPD) is a leading cause of contact allergy and has been linked to systemic toxicity after severe exposure. This has driven sustained research into herbal hair colourants, and gels in particular have emerged as a convenient, ready-to-use dosage form that overcomes the messiness and poor rinsability of traditional plant pastes. The present review critically examines past work on the formulation and evaluation of hair dye gels containing herbal extracts, using a structured, meta-analytic style of synthesis. Studies were identified through searches of scholarly databases and journal archives, screened against explicit inclusion criteria, and compared with respect to botanical source, extraction method, gelling agent, additives, evaluation parameters and safety testing. Across the surveyed literature, henna (Lawsonia inermis), indigo, amla, walnut bark and madder were the most frequently used colourants, while Carbopol 934 was the dominant gelling polymer. Plant powders often outperformed hot extracts in dyeing intensity, and formulations typically showed near-neutral pH, acceptable spreadability, no visible change on short-term stability testing and no irritation in animal models. However, heterogeneity in hair substrates, dye concentration, contact time and outcome measurement prevented formal quantitative pooling of effect sizes. Important gaps include the absence of objective colorimetric data, limited wash-fastness testing, small sample sizes and a lack of human clinical safety trials. The review concludes with recommendations for standardised protocols that would allow robust meta-analysis in the future. Overall, the evidence supports herbal gels as promising but not yet clinically validated alternatives.

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1. INTRODUCTION

1.1 Background of Hair Colouration and Graying

Hair colour is one of the most visible features of human appearance, and the practice of altering it is among the oldest cosmetic traditions. Ancient civilisations used henna, indigo and walnut husk to tint hair, and the same plants remain in everyday use across South Asia, the Middle East and North Africa. Today hair colouring is a large commercial industry driven by fashion, personal preference and the wish to conceal grey hair [16], [17]. Graying arises when the melanocytes of the hair follicle gradually lose their ability to produce melanin. Genetics, stress, nutritional deficiency and disease are all recognised contributors, and the process is increasingly noticed at younger ages [3]. As a result, a growing number of consumers, including young adults, colour their hair regularly. Hair dyes are conventionally grouped into temporary, semi-permanent and permanent categories according to how deeply the colourant penetrates the hair shaft and how long the effect lasts [16]. Temporary dyes deposit large molecules on the cuticle surface and wash out within one or two shampoos, semi-permanent dyes use smaller direct dyes that partly enter the cortex, and permanent dyes rely on oxidative coupling of small precursors inside the fibre. Figure 1 summarises this classification and shows where herbal gels fit within it. Cultural practice matters as well. In many regions, traditional herbal colouring is associated with festivals and ceremonies, so consumers are accustomed to plant-based colour and are generally receptive to herbal products when these are made convenient, consistent and cosmetically elegant.

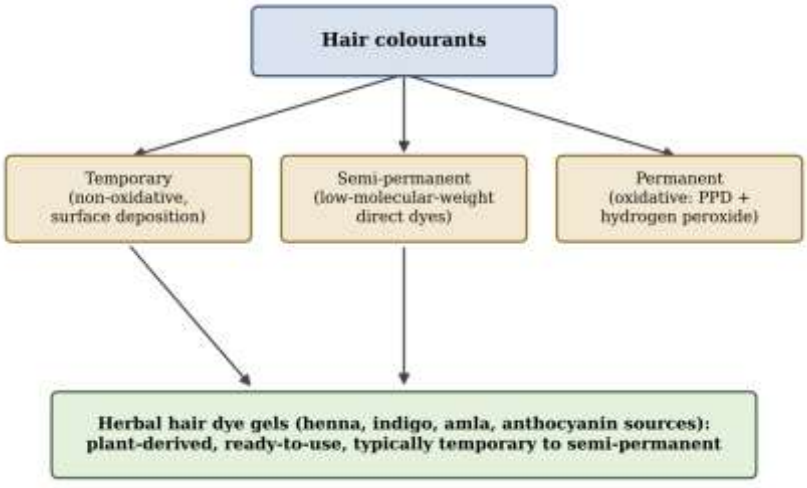


Figure 1. Classification of hair colourants and position of herbal hair dye gels.

Figure 1 presents the conventional classification of hair colourants into temporary, semi-permanent and permanent types. Temporary dyes act on the hair surface and wash out quickly, semi-permanent dyes use small direct dyes that partly enter the fibre, and permanent dyes depend on oxidative chemistry involving PPD and hydrogen

peroxide. The lower box places herbal hair dye gels in the temporary to semi-permanent region, because plant pigments such as lawsone mainly bind to the outer hair structure. The diagram explains why herbal gels offer milder action than oxidative dyes, but are not expected to equal them in durability.

1.2 Limitations of Conventional Hair Dyes

Permanent oxidative dyes owe their durability and natural-looking dark shades largely to PPD, which has been used in hair colour since the late nineteenth century [18]. The same chemistry creates problems. PPD is a well-established contact allergen that can produce acute, subacute or chronic dermatitis, and sensitisation may also follow exposure through dark temporary henna tattoos [18]. Hairdressers are at particularly high risk because of repeated occupational exposure [18], [22]. When oxidised, PPD can form reactive products such as Bandrowski's base, reported to be considerably more toxic than the parent compound, and severe cases involve angioedema, respiratory distress and renal injury [17], [19]. Consumer behaviour compounds the hazard. In a survey of female students, 58.5 percent reported using hair dye, yet knowledge about PPD was limited and nearly nine in ten had never performed an allergy test before application [17]. Epidemiological reviews confirm that PPD allergy is a significant public health concern [20], and cosmetovigilance programs now treat hair dye reactions as a priority area [19], [21]. Even products promoted as natural sometimes contain non-botanical colouring agents and added chemicals, which erodes consumer trust [3]. These observations explain the persistent search for safer colourants and delivery systems. Beyond individual health, environmental concerns have been raised, since commonly available oxidative dyes containing aromatic amines potentially pose specific environmental risks [17]. Together, health and environmental considerations have strengthened the case for plant-derived alternatives that avoid aromatic amines altogether.

1.3 Rationale and Aim of the Review

Herbal hair dyes are an attractive alternative because many colour-yielding plants have long histories of topical use and also provide conditioning, antidandruff or hair-strengthening effects. Traditional preparations, however, are usually applied as a freshly mixed paste that is messy, difficult to apply evenly and hard to rinse, and they require long contact times. Researchers have therefore sought to convert plant colourants into ready-to-use dosage forms such as creams, shampoos, oils and gels [1]-[3], [13]-[15]. Gels are especially suited to this purpose because they spread easily on hair, rinse off cleanly and can carry both dissolved and finely dispersed plant pigments. Numerous independent studies have reported such formulations over the past decade, but they differ widely in design and reporting, and no consolidated analysis exists. The present paper therefore reviews and synthesises past work on the formulation and evaluation of hair dye gels containing herbal extracts. Specifically, it surveys the botanical sources and formulation strategies used, describes the evaluation methods applied, appraises the strength of the evidence, and proposes directions that would make future studies comparable and suitable for formal meta-analysis. The review is organised as follows. Section II surveys the formulation literature, Section III describes the review methodology, Section IV offers a critical analysis of past work, and Sections V and VI discuss the implications and conclude with recommendations. Studies on shampoos and hair oils are consulted only where they illuminate gel formulation.

2. SURVEY OF PAST WORK

Plant-derived colourants used in hair dye gels fall into a limited number of chemical families. The most frequently studied is henna, the powdered leaf of Lawsonia inermis, whose principal pigment lawsone binds to keratin and yields orange to reddish-brown shades. Henna appears, alone or in combination, in almost every herbal dye formulation reviewed here [3]-[5], [11]. Indigo, obtained from Indigofera leaves, is used after or together with henna to deepen the shade toward brown and black. One polyherbal pack combined henna at 50 percent and indigo at 30 percent with coffee and amla at 4 percent each, and the resulting colour on blonde hair strings resembled natural black hair [4]. Other colour sources include amla (Emblica officinalis), madder (Rubia cordifolia), belleric myrobalan (Terminalia belerica) and walnut bark (Juglans regia), all of which were incorporated alongside henna in a gel-based natural hair colorant [3]. Calendula officinalis has also been explored as a pigment source in the form of a nano-sized dispersion [9]. Besides colour, several of these plants are traditionally valued for conditioning and anti-dandruff properties, so a single product may colour and care for hair at the same time [4].

Dyeing studies share a common experimental logic. Plant powders are first tested alone on hair samples to determine the concentration at which the colour becomes appealing, and the powders are then carried into a gel. In one study, dyeing trials on human hair were used to optimise the amount of henna required in combination with the other plant powders, and the preparation was applied as a paste in distilled water with evaluation carried out after three hours of contact [3]. This stepwise approach separates the question of pigment performance from the question of dosage form, and it is a useful template because it allows the contribution of the gel to be judged against a simple paste. Contact times in the literature remain relatively long compared with conventional oxidative dyes, which typically act within minutes, and this is one of the practical disadvantages of plant-based systems.

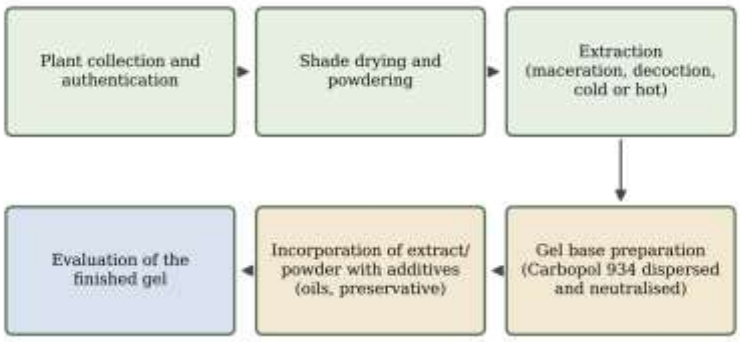


Figure 2. General workflow for formulating a herbal hair dye gel.

Figure 2 shows the typical sequence followed in the surveyed formulation studies. Plant material is first collected and authenticated, then shade dried and powdered. Pigments are extracted by maceration or decoction, or the powder is used directly, since cold extract and whole powder performed better than hot extract in comparative work. A gel base, usually Carbopol 934 dispersed in water and neutralised, is prepared separately. The plant material is blended into the base with additives such as oils and preservatives, and the finished gel proceeds to evaluation. The flow chart emphasises that every stage affects colour intensity and stability.

Extraction strategy is the next major design variable. One recent study prepared a semisolid herbal dye by the decoction method using henna and indigo among its botanical ingredients [5]. In a more systematic comparison, hot extracts and gels prepared from them gave a poor dyeing effect, whereas a cold extract and the whole plant powder dispersed in a 2 percent Carbopol 934 gel produced a good, appealing reddish-brown colour on human hair [3]. The same investigators incorporated powder, cold extract and hot extract into the gel in a ratio of 1 to 4, and reported that combinations of cold and hot extracts did not give encouraging results [3]. This finding suggests that heat may degrade or fail to carry pigments efficiently, and that unextracted powder retains more colourant than a simple aqueous extract. Comparative work on the dyeing efficiency and retention capacity of herbal hair dyes [6], on herbal hair oils against marketed dyes [7], and on herbal dyes compared with commercial formulations [10] shows that extraction and delivery choices are consistently treated as determinants of performance.

Carbopol 934 emerges as the most widely used gelling polymer in the surveyed work. A 2 percent Carbopol 934 gel served as the vehicle for the colorant mixture in [3], and Carbopol-934 gel was again used in a polyherbal study that prepared eight shades in both gel and cream forms, with almond oil, coconut oil and beeswax added to ease penetration [2]. In that study, gel formulations F5 and F6, together with cream formulations F1 to F4, F7 and F8, showed good staining and better colour intensity, and accelerated stability testing revealed no change in physical properties and no microbial contamination [2]. Another group prepared five different gel formulations containing herbal extract and plant-derived additives and identified formulation G5 as the most promising on hair colour [1]. A henna leaf gel was also evaluated for skin irritation in albino rats [11]. Taken together, these reports indicate that the gel format is technically straightforward and compatible with a wide range of botanical inputs.The role of additives and of the gel matrix deserves separate comment. Carbopol is a cross-linked polyacrylic acid that must be dispersed in water and neutralised before it forms a clear, viscous gel, and the neutralisation step also brings the product toward a skin-compatible pH. The finished gel in [3] showed a pH of about 7 after three months of storage. Natural oils and waxes were added in [2] to ease penetration of the colourant, and the authors also checked microbial stability, which matters because water-rich gels containing plant material are susceptible to contamination. Preservative selection and its effect on pigment stability are rarely discussed in the surveyed literature, even though they could influence both safety and shelf life.

Evaluation protocols can be grouped into four families, shown in Figure 3. Physicochemical testing covers organoleptic properties, pH, homogeneity, viscosity and spreadability. Dyeing performance is assessed by applying the gel to human or animal hair swatches and judging the colour obtained after a fixed contact time, often against sunlight exposure and repeated washing. Stability testing follows International Council for Harmonisation style storage conditions and records appearance, pH and microbial growth. Finally, safety testing relies on skin irritation studies in animals and, rarely, on human patch testing. A representative gel evaluated for three months showed no change in appearance, a pH of about 7 and spreadability of 8 to 9 g.cm/s [3]. The same work assessed wash fastness by washing dyed hair on alternate days for 30 days with a 10 percent w/v aqueous dispersion of reetha (Sapindus mukorrossi), and examined colour retention under sunlight exposure for two hours a day [3]. Skin irritation testing of the optimised gel in rats produced no irritation [3].

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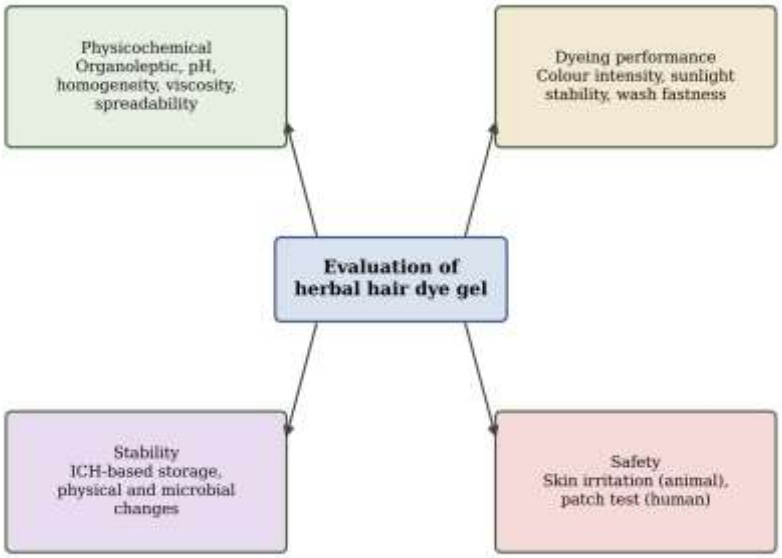


Figure 3. Evaluation parameters applied to herbal hair dye gels.

Figure 3 groups the evaluation methods reported in the literature into four families around the finished gel. Physicochemical tests include organoleptic assessment, pH, homogeneity, viscosity and spreadability. Dyeing performance covers colour intensity on hair swatches, stability toward sunlight and fastness to repeated washing. Stability studies examine physical and microbial changes under controlled storage in the manner of ICH guidance. Safety testing relies on skin irritation in animals and, ideally, human patch tests. The figure makes clear that a complete assessment needs all four components, and that the safety branch is the one least often supported by human data.

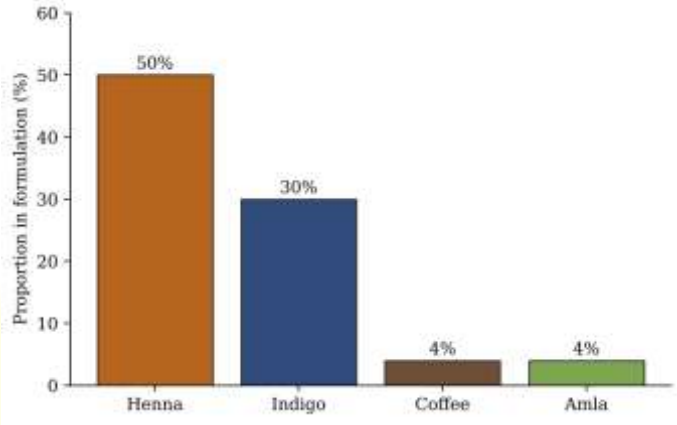


Figure 4. Colourant composition of a henna-based herbal dye pack (data from [4]).

Figure 4 plots the proportions of the four colouring ingredients reported for one henna-based herbal dye pack: henna at 50 percent, indigo at 30 percent, coffee at 4 percent and amla at 4 percent. Henna supplies the orange-red base shade, while indigo darkens it toward brown and black. Coffee and amla are present in small amounts and contribute tone and hair-care benefits. The chart shows that performance depends mainly on the ratio between

a few key pigments. It also illustrates the quantitative composition data that future studies should report consistently so that formulations can be compared across laboratories.

Several of the surveyed studies are also notable for what they show about formulation composition. Figure 4 plots the proportions of the four colourants used in a henna-based herbal dye pack, in which henna and indigo account for the great majority of the mixture while coffee and amla contribute small amounts for tone and hair benefit [4]. The authors observed that the colour obtained on blonde hair was similar to natural black, but noted that application on other hair shades remains to be examined before the full range of benefits can be established [4]. A polyherbal study likewise emphasised that its products are not permanent dyes and are therefore suitable for a wide range of consumers, with severe side effects expected to be reduced because only natural sources were used [2]. Studies of related dosage forms add context. Herbal dye shampoos [13], herbal shampoos [14] and polyherbal hair oils [15] show that researchers are exploring many carriers for the same colourants, and the comparison of a herbal hair oil with a marketed dye [7] illustrates a useful design in which the plant-based product is benchmarked against a commercial standard. The comparison of herbal hair dye with a marketed formulation [10] follows the same logic. In general, the geographical origin of the work is also informative. Much of it comes from pharmacy departments and colleges in India, with additional contributions from Malaysia, which reflects both the strong tradition of herbal medicine in these regions and the commercial interest in natural cosmetics [2], [3], [5].

The safety context for herbal products deserves attention. PPD allergy is confirmed by epicutaneous patch testing, and manufacturers recommend an open test behind the ear 48 hours before each application [18]. These checks are equally relevant to herbal dyes, because products sold as natural may contain undeclared artificial colouring agents [3] and individual plant ingredients can themselves be sensitising. Safety studies of herbal gels in the literature are largely limited to animal skin irritation tests [3], [11], which is an encouraging but incomplete foundation. The wider herbal cosmetics literature shows the same pattern of rapid product development with limited toxicological depth, as seen in herbal shampoos [13], [14] and polyherbal hair oils [15], and in studies that synthesise and evaluate herbal dye bases [12] or claim formulations that are fully herbal [8]. In summary, the survey shows a coherent technical picture. Henna and indigo supply the dominant pigments, Carbopol 934 supplies the gel structure, powders and cold extracts outperform hot extracts, and short-term physical stability and animal skin tolerance are consistently favourable [1]-[3], [11]. At the same time, reporting is uneven. Hair type, contact time, dye concentration and scoring methods vary from one study to the next, and most outcomes are described qualitatively. These characteristics shape both the methodology chosen for this review and the conclusions that can safely be drawn from it, as discussed in the following sections. It is also worth noting that the strongest claims in the literature concern physical quality and tolerability, whereas claims about lasting colour on grey hair are supported mainly by small qualitative demonstrations. Readers should therefore treat the surveyed results as proof of concept rather than as definitive performance data for commercial products.

3. METHODOLOGY

This review followed a protocol modelled on the PRISMA reporting guidelines for systematic reviews and meta-analyses [24], [25]. Searches targeted scholarly databases and open journal archives using combinations of the terms herbal hair dye, natural hair colorant, hair dye gel, Lawsonia inermis, henna, indigo and Carbopol. Records

were considered eligible if they reported the formulation of a gel (or a closely related semisolid) containing a plant extract or powder as the colouring agent and described at least one evaluation parameter, whether physicochemical, dyeing-related, stability-related or safety-related. Review articles, focusing exclusively on conventional chemical-based hair dyes and reports that gave no formulation detail were excluded. Titles and abstracts were screened first, and full texts were then assessed for eligibility, as illustrated in Figure 5. Reference lists of retrieved papers were also hand-searched to find additional studies, and reports in English from 2010 to 2026 were prioritised, although earlier foundational work on PPD allergy and on meta-analytic methods was consulted for context. Duplicate records were removed before screening.

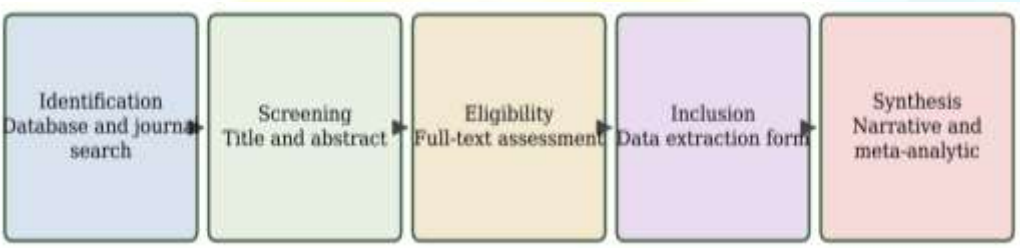


Figure 5. Review workflow from identification of studies to synthesis.

Figure 5 illustrates the five stages of the review process adopted in this paper. Identification involves searching databases and journal archives with defined terms. Screening removes irrelevant records on the basis of titles and abstracts, and eligibility assessment applies the inclusion and exclusion criteria to full texts. Eligible studies pass to inclusion, where data are extracted and quality is appraised. Synthesis combines narrative and, where possible, meta-analytic methods. The figure follows the logic of PRISMA reporting guidance and shows how the review moved from a broad pool of records to a focused set of comparable studies.

A standardised extraction form was used to record the botanical source, plant part, extraction method, gelling agent and its concentration, additives, hair substrate, contact time, evaluation tests, stability conditions, safety model and principal findings of each study. Methodological quality was appraised qualitatively, with attention to whether a control or marketed comparator was used, whether replicates were reported, and whether outcome assessment was objective. For animal skin irritation studies, risk of bias was considered using the domains of the SYRCLE tool [30]. Because many of the identified studies were published in regional pharmaceutical journals, particular care was taken to judge reporting completeness rather than to rely on journal reputation. Where a study reported several formulations, each was recorded separately, but the study was treated as a single unit to avoid giving undue weight to one report. Disagreements in data extraction were to be resolved by discussion and re-reading of the source. No study was excluded solely because of low quality, but quality was considered when interpreting results. The synthesis plan had two layers. First, a narrative and tabulated comparison allowed the frequency of each botanical source, gelling agent and evaluation method to be summarised. Second, a quantitative meta-analysis was planned for continuous outcomes such as pH and spreadability, using a random-effects model [26], heterogeneity assessed by the Q statistic and I-squared [27], [28], and small-study effects examined by the Egger regression test [29]. In practice, outcome definitions, hair substrates and reporting formats differed so strongly that formal pooling of effect sizes was not justified, and the results are therefore presented as a structured

qualitative synthesis. This limitation is itself treated as a finding and is carried into the critical analysis. Subgroup comparisons were planned by extraction method (powder, cold extract and hot extract) and by gelling polymer, and a sensitivity analysis would have excluded studies at high risk of bias. Findings are reported in line with the PRISMA checklist so that the review can be reproduced and updated as new studies appear.

4. CRITICAL ANALYSIS OF PAST WORK

The body of past work on herbal hair dye gels shows several clear strengths. First, there is notable agreement on the basic formulation concept. Independent groups have converged on henna and indigo as principal pigments and on Carbopol 934 as a practical, inexpensive gelling agent, and each has reported that the resulting products are easy to apply and rinse [1]-[3]. Second, a few studies go beyond simple colour assessment. One tested the stability of a gel for three months and examined skin irritation in rats [3], another subjected eight shades in two dosage forms to accelerated stability checks including microbial examination [2], and another evaluated a henna gel for irritation in albino rats [11]. These design elements bring herbal cosmetic research closer to the expectations applied to pharmaceutical dosage forms. Nevertheless, the weaknesses are substantial and recur across studies. The most serious is that dyeing performance is usually judged by eye. Colour intensity, shade and fastness are described in words such as good or promising, and objective measurements such as CIE L*a*b* colorimetry or spectrophotometric reflectance are rarely reported. Without numerical colour data, results cannot be pooled, compared across laboratories or linked statistically to variables such as dye concentration or contact time. A second weakness concerns the hair substrate. Experiments are carried out on swatches of different origin, such as human hair of unspecified natural colour or man-made and natural fibres, and the one study that reports results on blonde hair itself concedes that other shades have not been tested [4]. Colour obtained on pale hair says little about performance on grey, dark or chemically treated hair.

The meaning of success also differs from study to study. Some reports treat a visible colour change on a hair swatch as sufficient proof of effectiveness, others require the colour to resist washing, and still others compare against marketed products [7], [10]. These are different standards, and the same label of good performance can conceal very different levels of evidence. In addition, many reports describe the preparation of several candidate formulations and then select the best by inspection [1], [2], so that the selected formulation is evaluated by the same criterion that was used to choose it. This practice inflates apparent performance and illustrates the value of independent validation on fresh hair samples, which is almost never reported. Third, the evidence base is limited in scale and duration. Stability studies typically last from a few weeks to three months [2], [3], which is short in relation to the shelf life expected from a commercial cosmetic. Wash-fastness is generally evaluated for about 30 days, and only in a small number of reports [3]. Sample sizes are small and replicate numbers often unstated, so differences between formulations may reflect noise rather than genuine effects. Fourth, plant material is rarely standardised. Henna and indigo vary in pigment content with cultivar, harvest and processing, yet few studies quantify lawsone or indigotin content in the raw material or in the finished gel. Contamination with heavy metals, pesticides or undeclared artificial colouring agents, which has been recognised as a concern for products labelled natural [3], is almost never screened.

Fifth, safety evaluation is thin. Animal irritation tests provide useful screening information [3], [11], but they cannot substitute for human patch testing, particularly when the stated purpose of herbal dyes is to serve people who react to PPD. Cross-reactivity, photosensitisation and long-term exposure are not addressed. By contrast, the PPD literature offers a model of rigorous clinical characterisation, with defined patch test protocols and large epidemiological datasets [18], [20]. Sixth, publication and reporting biases are likely. Almost all published studies conclude that the formulation is effective and safe, a pattern that is difficult to reconcile with the technical challenges of colouring grey hair with plant pigments, and unfavourable or null results are seldom reported. Finally, the absence of marketed comparators in many studies limits claims of superiority over conventional dyes, whereas the few studies that include a comparator, as suggested by [7] and [10], provide the most useful benchmarks. Taken together, these shortcomings explain why quantitative meta-analysis was not feasible.

External validity is a further concern. A product that colours a laboratory swatch under controlled temperature may perform differently on a consumer's head, where scalp sebum, prior chemical treatment, hair porosity and the humidity of the environment all influence uptake and retention. Cosmetic use also demands attributes that are seldom measured in the academic literature, including odour, staining of skin and clothing, ease of removal from the scalp, packaging compatibility and microbial preservation over months of use. The long contact time needed by plant dyes is a practical barrier to adoption, yet it is mentioned more as a limitation than studied as an optimisation target. Regulatory aspects, such as permitted preservatives and labelling of botanical ingredients, are likewise rarely addressed in laboratory-scale reports.

5. DISCUSSION

The synthesis suggests that herbal hair dye gels are a technically mature but scientifically under-characterised product class. On the technical side, the combination of a henna-indigo pigment system with a Carbopol 934 gel base yields products that spread easily, remain stable under short-term storage and cause no irritation in rodent skin [2], [3]. The finding that whole plant powder and cold extract outperform hot extract in dyeing is practically important because it simplifies manufacturing, avoids heating steps and retains the particulate pigment that provides most of the colour [3]. Oils and waxes such as almond oil, coconut oil and beeswax appear to add conditioning and may aid penetration without compromising gel structure [2]. The main scientific limitation is the gap between the claim of colouring ability and the evidence offered for it. Herbal dyes work chiefly by depositing or bonding pigment to the outer layers of the hair and therefore behave as temporary to semi-permanent colourants, as one polyherbal study itself stressed [2]. Consumers expecting permanent coverage of grey hair equal to oxidative dyes may be disappointed, and expectations should be communicated honestly. The trade-off between permanence and safety is real, and it is for this reason that objective, quantitative colour retention data are so important. Instrumental colorimetry, standardised grey-hair swatches and defined washing cycles would make the performance of herbal gels directly comparable with that of marketed products.

For consumers, the safety message is two-sided. Herbal dyes may be a useful option for people who have developed allergy to PPD, but natural origin is not a guarantee of tolerance, and the discovery that some natural-labelled products contain undeclared chemical colouring agents underlines the need for authenticity testing [3]. Open patch testing before use remains sensible advice for any hair product [18]. For researchers and

manufacturers, priorities include standardising raw plant material, screening for contaminants, running human patch tests, and testing in multiple hair shades. Emerging technologies such as nano-sized plant dispersions [9] may improve pigment uptake and uniformity, but they also require dedicated safety assessment. Finally, a shared minimum reporting standard, covering hair type, dye concentration, contact time, colour measurement method and stability duration, would allow future reviews to carry out the quantitative meta-analysis that the present body of work could not support. Looking ahead, three themes appear especially promising. The first is quantitative colour science, in which instrumental measurement replaces visual judgment and allows dose-response relationships between pigment concentration, contact time and colour change to be established. The second is formulation technology, including nano-sized dispersions [9], film formers and improved natural preservative systems, which could increase colour uptake, reduce contact time and extend shelf life. The third is clinical validation, in which small human studies with defined patch testing protocols establish the tolerability of herbal gels in volunteers, including those with a history of PPD allergy. Progress along these lines would turn a literature of promising laboratory formulations into a body of evidence capable of supporting product claims and regulatory acceptance.

6. CONCLUSION

This review examined past work on the formulation and evaluation of hair dye gels containing herbal extracts. The literature converges on a consistent formulation strategy in which henna, indigo and related botanical colourants are dispersed or incorporated into a Carbopol 934 gel, often with natural oils, to give ready-to-use products that apply easily, rinse cleanly and appear stable and non-irritating in short-term studies [1]-[3], [11]. Powders and cold extracts generally performed better than hot extracts, and gels have been prepared in a range of shades. At the same time, the evidence is limited by subjective colour assessment, small and heterogeneous hair samples, short stability and wash-fastness periods, unstandardised plant material and an absence of human safety trials. These weaknesses prevented a formal quantitative meta-analysis and mean that claims of superiority over conventional oxidative hair dyes remain unproven. Future studies should adopt instrumental colorimetry, standardised hair substrates, characterised raw materials, longer stability programs and human patch testing, and should report results in a common format. With such improvements, herbal hair dye gels could become a credible, safer alternative for consumers seeking to avoid PPD and other non-botanical colouring ingredients. Until then, herbal hair dye gels should be described as promising, mild and consumer-friendly colourants rather than proven replacements for permanent dyes. Overall, the field has moved from empirical recipe-building toward systematic evaluation, but it has not yet produced the quantitative, clinically relevant evidence needed for confident recommendations. Coordinated, well-reported studies are now the most valuable contribution that researchers can make.

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