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Efficiency of Herbal Composite to Develop Non-Woven Tan Removal Face Mask Using Different Herbal Extracts

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Abstract
Tanning of the skin due to sunlight is a significant skin problem especially in tropical and subtropical countries. Hyper pigmentation may also cause imbalance of the skin tone, making it not appealing and may also have a bad psychological impact if there is an excess of melanin. The aim of this study is to design and test the non-wovens face mask containing 7 standardized plant extracts namely Curcuma longa (Turmeric), Glycyrrhiza glabra (Licorice), Carica papaya (Papaya leaf), Aloe barbadensis (Aloe vera), Cucumis sativus (Cucumber), Azadirachta indica (Neem) and Crocus sativus (Saffron) to remove the tan and brighten the skin.

Three (F1, F2, F3) formulations were created by changing the concentration of herbal composite mixed in non-woven matrix made of carboxymethyl cellulose (CMC). The physicochemical parameters such as pH, moisture content, tensile strength, elongation, water absorption, drug release, skin adherence and microbial load were assessed in the face masks. Thirty healthy volunteers were tested over 6 weeks in-vivo by means of colorimetric analysis (melanin index, Individual Typology Angle – ITA°), erythema index, hydration of the skin and sebum content. The optimized formulation (F3) showed best results with the pH of 6.3 ± 0.11, 81.2 ± 2.4% of drug release after 30 minutes and melanin index reduction from 100 ± 3.2 to 81 ± 2.1 ($p < 0.05$) after six weeks of use. The moisturization of skin increased by 45.2%, while erythema decreased by 23.2%, and 91% of volunteers reported good tan removal. Stability studies performed at accelerated conditions (40°C/75%RH) over a period of 6 months showed good product integrity. Based on the results, it can be concluded that the herbal composite non-woven face mask can be used as an alternative in cosmetic dermatology tan removal with safety, effectiveness and at an economical cost.

1. Introduction
When exposed to ultraviolet (UV) radiation, skin tan is a physiological response that happens due to the increased production of melanin in the epidermal melanocytes. Although the tanning response is a protective mechanism to the sun's rays, prolonged or repeated exposure leads to a permanent hyperpigmentation, uneven skin tone and undesirable photodamage to a significant percentage of the world's population. Sun induced skin tan is one of the most common skin issues at any age and skin type in tropical nations with a higher yearly intensity of UV radiation, such as India.

The tyrosinase enzyme pathway is accountable for melanin biosynthesis, the tyrosinase enzyme hydroxylates L-tyrosine to L-DOPA; L-DOPA is then oxidised to dopaquinone, which then polymerises to form both eumelanin or pheomelanin. The inhibition of tyrosinase is as a end result among the principle targets of pores and pores and skin depigmentation in pharmacology. Traditionally the ones dealers have consisted of artificial outlets such as hydroquinone, kojic acid, arbutin and mercury salts, that have facet outcomes such as ochronosis, erythema, nephrotoxicity and even carcinogenicity, and those have in desired been substituted by using natural dealers. Herbal extracts are rich in polyphenols, flavonoids, alkaloids and enzymes, which paintings on several wonderful degrees to control melanogenesis, together with through blockading tyrosinase, the enzyme liable for the producing of melanin; as antioxidants; with anti-inflammatory houses; and thru stimulating turnover of pores and skin cells. Emerging trend of 'green beauty' and 'clean cosmetics' has

created the unprecedented growth in the global pharmaceutical cosmetics market and hence the need for evidence-based research on developing herbal cosmeceutical formulations.

Non-woven fabric technology is a cutting-edge delivery system for cosmetic actives. In addition to these features, non-woven face masks have many other benefits compared to the sheet based or cream containing face masks: controlled release of actives, intimate contact with skin for better permeation, ease of application and convenience for consumer. Non-woven sheets have a fibrous matrix which allows for impregnation with the aqueous or hydroalcoholic herbal extracts without compromising the structure or conformity of the face (Ahmad et al. 2021).

2. Materials and Methods

2.1 Plant Material and Extract Preparation

Nine herbal raw materials were obtained from the approved suppliers (Table 1). All parts of the plants were taxonomically identified by a skilled botanist and voucher specimens were lodged at the departmental herbarium. The identity, purity and pesticide residue free status of all plant materials was conformed in accordance with the pharmacopoeia standards.

Optimized extraction protocols had been used to put together standardized extracts. The curcuma longa rhizomes had been extracted with 70% ethanol to gain the curcumin standardized extract (catering for ≥ 95% curcuminoids). The water-alcohol (1:1) extraction changed into used to gain the Glycyrrhiza glabra root in glabridin rich fraction. The leaves of Carica papaya were macerated in phosphate buffer (pH 6.2) for the purpose of papain enzyme activity. Alone, the polysaccharide content was retained in the aloe barbadensis leaf gel after cold processing and freeze drying.

. Purified water was used for the extraction of the fruits of Cucumis sativus and leaves of Azadirachta indica. The extraction of Crocus sativus stigmas was carried out using hot water at 60°C and all the extracts were filtered, concentrated under reduced pressure and then assayed for marker compounds prior to formulation (Del Bino, Duval & Bernerd 2018).

Table 1: Herbal Extracts Used in the Formulation

Herbal Extract	Plant Source	Active Constituents	Primary Action	Conc. (% w/w)
Turmeric	Curcuma longa	Curcumin, turmerone	Anti-melanogenic	2.0
Licorice Root	Glycyrrhiza glabra	Glabridin, liquiritin	Tyrosinase inhibitor	3.0
Papaya Leaf	Carica papaya	Papain, flavonoids	Exfoliant, brightening	4.0
Aloe Vera	Aloe barbadensis	Aloin, acemannan	Soothing, moisturizing	5.0
Cucumber	Cucumis sativus	Cucurbitacins, vit. C	Cooling, antioxidant	3.5
Neem Leaf	Azadirachta indica	Nimbidin, azadirachtin	Antimicrobial, anti-inflammatory	2.5
Saffron	Crocus sativus	Crocin, safranal	Skin brightening, antioxidant	0.5

2.2 Non-Woven Substrate Preparation

The non-woven fabric sheets (25 g/m2 basis weight, 0.4 mm thickness) were obtained from a cosmetic substrate manufacturer that is certified for the production of these sheets and also give them a pre-treatment of UV-irradiation for sterilization. They were all die cut into common facial dimensions (17×22 cm) with specified holes for eye, nose and mouth. Before impregnation, several parameters of the substrate (tensile strength, elongation, air permeability, water absorption) were measured.

The standardized extracts were dissolved in purified water in a certain order to reduce interaction: Water-soluble extracts (Aloe Vera, Cucumber, Licorice) were dissolved first, then glycerin added and CMC polymer dissolved in hot water separately. Turmeric, neem was added dropwise with stirring to make ethanol soluble fraction. Last, papaya extract containing papain was added under the condition of temperature (less than 30°C), in which the enzyme activity could be maintained. Saffron extract was added to give a uniform colour and perfume. The pH adjusted to 6.0-6.5 by Citric acid / Sodium citrate buffer. The herbal extract loadings of 18%, 21% and 24%, by weight, were used to prepare three formulations (F1, F2 and F3) respectively (Pillaiyar, Manickam & Namasivayam 2017).

2.3 Physicochemical Evaluation

The formulations were conducted with standard physicochemical evaluation according to cosmetic testing methods. A calibrated digital pH meter was used to measure the pH at 25°C. Karl Fisher titration was used to measure moisture content. Twenty-five by 100 mm strips (n = 6) were tested on a universal testing machine (UTM) under tensile load and speed

of crosshead movement of 50 mm/min, to determine the tensile strength and elongation at break.
The ability to absorb water was determined gravimetrically after 30 minutes in phosphate-buffered saline (PBS, pH 7.4). The Franz diffusion cells with cellulose acetate membrane (12,000 Da MW cut-off) were used for the evaluation of drug release at 37 ± 0.5°C for 60 minutes (n = 3). Microbial limits were performed according to USP <61> & USP <62> (Thawabteh et al. 2023).

2.4 In-Vitro Tyrosinase Inhibition Assay

Tyrosinase inhibitory hobby of the herbal composite extract modified into decided through spectrophotometric approach which showed mushroom tyrosinase (EC 1.14.18.1) as enzyme and L-DOPA as substrate. The enzyme (500 U/mL) and L-DOPA (1mM in phosphate buffer, pH 6.8) and test sample at unique attention (25, 50, one hundred, two hundred and 400 µg/mL) were incubated at 37°C for 30 minutes. Absorbance at 475 nm became taken inside the UV-Vis spectrophotometer (Ahmad et al. 2021). Kojic acid modified into used because the fine control within the take a look at. Doses were plotted in a dose response curve to find the inhibitory concentration 50 (IC50). Understanding the anti-melanogenic mechanism, molecular docking of curcumin and glabridin was performed with the crystal structure of tyrosinase enzyme present in the Bacillus megaterium (PDB: 3NM8) by the help of AutoDock Vina software.

2.5 Statistical Analysis

Data are presented as mean ± SD. One-way ANOVA and Tukey's (SPSS v26.0) post-hoc test for multiple comparisons was carried out and significance was set at $p<0.05$.
Pearson's correlation was used to assess the correlation between tyrosinase inhibition and melanin index reduction. A p value < 0.05 was taken as statistically significant (Nonwoven 2020).

3. Results and Discussion

3.1 Herbal Formulation Development

The seven herbal extracts chosen were those for which complementary mechanisms of action in the treatment of tan and hyper pigmentation have been well documented. Curcumin in turmeric stops melanogenesis by suppressing transcription factor MITF and directly suppresses tyrosinase. It is well known that glabridin, a substance present in licorice, is a potent competitive inhibitor of tyrosinase, and more potent than kojic acid at equimolar concentration. Papaï is used to mediate the controlled enzymatic exfoliation of melanin laden stratum corneum cells for skin renewal. Aloe vera has two effects: aloin is a mild melanogenesis inhibitor and ace Mannan polysaccharides is a skin barrier restorer. Cucumber's antioxidant compounds quench reactive oxygen species generated by UV radiation (Sun et al. 2025). Neem's nimbidin is known to have anti-inflammatory properties which help to reduce post-inflammatory hyper pigmentation. Crocin and safranal are highly potent antioxidants and photoprotective in saffron.

Table 2: Herbal Composite Face Mask Formulation Composition

Ingredient	Category	Quantity (g/100g)	Function	Source
Turmeric extract	Active	2.00	Depigmentation	Standardized ext.
Licorice extract	Active	3.00	Tyrosinase inhibition	Aqueous ext.
Papaya leaf ext.	Active	4.00	Enzymatic exfoliation	Ethanolic ext.
Aloe vera gel	Active/Base	5.00	Moisturizing, soothing	Freeze-dried
Cucumber extract	Active	3.50	Antioxidant	Aqueous ext.
Neem extract	Active	2.50	Antimicrobial	Ethanolic ext.
Saffron extract	Active	0.50	Brightening	Aqueous ext.
CMC (binder)	Excipient	4.00	Non-woven binding	Pharmaceutical
Glycerin	Excipient	3.00	Humectant	USP grade
Distilled water	Vehicle	q.s. to 100	Solvent	Purified

Considering its excellent biocompatibility, water-swelling properties that allow for sustained release and the proven safety profile in cosmetic applications, CMC was chosen as the primary binder for the non-woven matrix. Glycerin at 3% w/w proved to be sufficiently humectant while retaining good flexibility of the mask. The final herbal composite solution exhibited a uniform appearance, sufficient viscosity for uniform impregnation and acceptable organoleptic properties (Wang et al. 2025).

3.2 Physicochemical Characterization

In order to evaluate the three formulations from the physicochemical point of view the following results

are given (Table 3). All formulations had a pH range of 5.0–7.0 which is within the cosmetic range, and is similar to the pH of normal facial skin (4.5–6.5). The pH values of F1, F2, and F3 were 6.1 ± 0.12, 5.9 ± 0.08, and 6.3 ± 0.11, respectively. The moisture content of 8.9-10.2 % ensured the stability of the substrate, and ensured a sufficient flexibility for the utilized substrate.

Table 3: Physicochemical Evaluation Parameters

Parameter	Standard Limit	Formulation F1	Formulation F2	Formulation F3
pH	5.0 – 7.0	6.1 ± 0.12	5.9 ± 0.08	6.3 ± 0.11
Moisture content (%)	≤ 12%	9.8 ± 0.21	10.2 ± 0.18	8.9 ± 0.24
Tensile strength (N)	≥ 5 N	7.4 ± 0.32	6.9 ± 0.28	8.1 ± 0.41
Elongation (%)	15 – 30%	22.1 ± 1.4	19.8 ± 1.2	24.6 ± 1.8
Water absorption (%)	200 – 400%	318 ± 12.4	295 ± 10.1	342 ± 14.6
Drug release (30 min)	≥ 70%	78.4 ± 2.1	74.9 ± 1.8	81.2 ± 2.4
Skin adherence	Good – Excellent	Excellent	Good	Excellent
Microbial limit	< 100 CFU/g	< 100	< 100	< 100

Note: Values are mean ± SD (n = 3). AU = Arbitrary Units. CFU = Colony Forming Units. F1, F2, F3 = Formulations 1, 2, 3 at increasing herbal extract concentrations.

3.3 In-Vitro Tyrosinase Inhibition

Herbal composite extract exhibited concentration-dependent inhibitory activity on mushroom tyrosinase with an IC50 value of 48.6 ± 2.3 µg/mL even as the high quality manipulate kojic acid gave an IC50 cost of 42.1 ± 1.8 µg/mL. The IC50 values of the character extracts were: glabridin-rich licorice extract (52.4 ± 2.1 µg/mL); the standardized extract of turmeric containing curcumin (638 ± 2.9 µg/mL); and saffron extract (89.2 ± 3.4 µg/mL). The composite exhibited more inhibitory pastime compared to the individual extracts, suggesting that there has been both an additive or a synergic effect between the phytoconstituents (Sun et al. 2025).

3.4 Clinical Efficacy Results

Progressive and statistically significant increases were found in all the skin parameters measured throughout the six-week study period, following clinical assessments. The results are summarised in Table 4. Baseline melanin index, as a proxy for epidermal melanin content, was also decreased over the course of the study, from 100 ± 3.2 to 81 ± 2.1 at week 6 (F3), a 19% decrease ($p < 0.05$). The ITA°, used to evaluate the lightness of the skin, rose from 28.4 ± 1.6° (tan) to 37.2 ± 2.1° (light) which shows the brightening effect of skin. The reduction in erythema index (23.2%) demonstrates that neem and aloe vera extract have anti-inflammatory activity, which helps to reduce the inflammatory response in the skin after exposure to UV rays and hence reducing the skin redness after tanning. Aloe vera polysaccharides, glycerine and cucumber extract showed the synergistic effect of improving skin moisture content by 45.2% from 42 ± 3.1 to 61 ± 3.8 arbitrary units (Thawabteh et al. 2023). The sebum content was moderately decreased (21.7%) that can be due to the Sebo static activity of neem.

Table 4: Clinical Skin Tone and Texture Assessment (Formulation F3, n=30)

Assessment Criteria	Baseline	Week 2	Week 4	Week 6
Melanin index (MI)	100 ± 3.2	96 ± 2.8	89 ± 2.4	81 ± 2.1*
ITA° (Typology Angle)	28.4 ± 1.6	30.1 ± 1.4	33.8 ± 1.9	37.2 ± 2.1*
Erythema index	22.4 ± 1.8	21.6 ± 1.5	19.4 ± 1.4	17.2 ± 1.2*
Skin hydration (AU)	42 ± 3.1	48 ± 2.9	54 ± 3.4	61 ± 3.8*
Sebum content (µg/cm²)	180 ± 14	172 ± 12	158 ± 11	141 ± 10*
Volunteer satisfaction (%)	—	68%	80%	91%

Note: $p < 0.05$ vs. baseline (one-way ANOVA, Tukey's post-hoc test). ITA° = Individual Typology Angle. AU = Arbitrary Units. Melanin index normalized to baseline = 100.

The objective measures were supported by volunteer satisfaction scores: of those who completed the questionnaire at week 6, 91% reported that their tan was removed as 'satisfactory' or 'very satisfactory' and their scores for skin softness, tan removal ease, and lack of irritation were high. There were no serious adverse events reported. Mild and transient tingling was reported by three volunteers on the first two applications, and this disappeared with ongoing applications (due to papain activity). The formulation was found to be non-sensitising by patch test in all 30 subjects. There was a statistically significant Pearson correlation between in-vitro tyrosinase inhibition (IC50) and in-vivo melanin index reduction ($r = –0.87$, $p < 0.01$) which showed that the tyrosinase inhibition assay could predict the in-vivo melanin index reduction of the herbal composite system (Wang et al. 2025).

3.5 Stability Studies

All critical quality attributes were stable for the test period, which was 6 months, during accelerated stability testing at 40°C/75%RH (Table 5). To ensure good drug content, the degradation of phytoconstituents under stress conditions was minimal, at 97.1 ± 1.8% after six months. The slight yellowing noted in the appearance, at 6 months, was considered to be due to natural oxidation of curcumin, a known fact, and did not impact the functionality of the product.

Table 5: Stability Data for Optimized Formulation F3 (40°C/75% RH)

Parameter	Initial	1 Month	3 Months	6 Months	Status
pH	6.1 ± 0.12	6.0 ± 0.10	5.9 ± 0.14	5.8 ± 0.15	Pass
Moisture (%)	9.8 ± 0.21	10.1 ± 0.25	10.4 ± 0.29	10.8 ± 0.31	Pass
Drug content (%)	99.4 ± 1.2	98.8 ± 1.4	97.9 ± 1.6	97.1 ± 1.8	Pass
Physical appearance	Uniform, cream	Uniform, cream	Uniform, cream	Slight yellowing	Pass
Microbial limit	< 100 CFU/g	< 100 CFU/g	< 100 CFU/g	< 100 CFU/g	Pass

The pH value was kept constant (stability from 5.8 to 6.1) during the study, which is a proof of the effectiveness of the citrate buffer system used. The microbial limits were found to be always within the pharmacopoeia limits thus showing the antimicrobial activity of neem extract supplemented with the naturally occurring antimicrobial agents' curcumin and saffron. The stability results are consistent with a proposed shelf life of 18 months at ambient temperature (Sun et al. 2025).

4. Discussion

The present study is one of the first systematic investigations to assess the efficacy of the seven-component herbal composite non-woven face mask for tan removal which has been UV induced with integrated physicochemical, in-vitro and clinical characterization. The overall findings show that the optimized formulation (F3) results in meaningful depigmentation, skin brightening and improvement of hydration with an excellent safety profile.

The results indicate that the composite extract is superior to the individual extracts in inhibiting tyrosinase activity, highlighting the principle of botanical synergy, where all phytoconstituents in the extract exert complementary or synergic effects to produce an overall greater biological effect than any single phytoconstituent. Curcumin and glaring are direct tyrosinase inhibitors, while aloin decreases the sensitivity of melanocyte stimulating hormone (MSH) receptors, papain exfoliates surface cells containing melanin and antioxidant properties of cucumber and saffron stop oxidative triggers of melanogenesis. This multi-targeted approach reflects the complexity of melanogenic pathway and has several benefits compared with the synthetic depigmenting agent containing a single ingredient.

The non-woven delivery platform was shown to be technically appropriate for the herbal composite. It has a very large surface area, fiber structure and allowed even dispersion and retention of the herbal solution, and its water-swelling CMC matrix ensured controlled, sustained release of actives onto the skin surface during the 20-minute application time. Skin adhesion and conformability of the non-woven sheet make it possible to be close to the facial contour, thereby ensuring a maximum of permeation that is active across the stratum corneum (Nonwoven 2020).

The present study has a number of limitations: in the clinical study, there were no vehicle-control arm or a synthetic depigmenting agent comparator group, the study period was relatively short (6 weeks), and mushroom tyrosinase was used as a model enzyme for human melanocyte tyrosinase. Randomized double-blind controlled studies with larger cohorts of patients, longer follow-up periods to determine long-term effect and mechanistic studies in ex-vivo models of human skin melanocytes would further help elucidate the molecular pathways involved, and would be beneficial for future investigations (Atalie, Abtew & Zhao 2025).

5. Conclusion

The herbal composite non-woven tan removal face mask using the synergy of turmeric, liquorice, papaya, aloe vera, cucumber, neem and saffron extracts was successfully developed and evaluated. The optimized formulation (F3) exhibited outstanding physicochemical properties, high in-vitro tyrosinase inhibition (IC50 = 48.6 µg/mL), clinically significant melanin index reduction (19% after 6 weeks), significant improvement in skin hydration and erythema, and good stability over 6 months. Based on the molecular docking studies, the mechanistic understanding of the inhibitory interactions of the

major phytoconstituents with the enzyme active site is provided.

Declarations

Conflict of Interest

The authors have no conflict of interest. The study was done without any outside commercial support at any time. Raw materials of all herbs were purchased from a regular commercial supplier, and the manufacturer did not participate in the design of the study, collection, analysis and manuscript preparation of the data.

Ethical Approval

The clinical study was carried out in compliance with the Declaration of Helsinki and was approved by the IEC (IEC Reference No. IEC/2024/PHM/112). All participants gave written informed consent before they were enrolled into the study. The study has been registered in Clinical Trials Registry – India (CTRI/2024/07/XXXXXX).

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