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FORMULATION AND EVALUATION OF HERBAL AROMATHERAPY HYDROGEL PATCH USING ORANGE PEEL ESSENTIAL OIL

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ABSTRACT

Aromatherapy is a complementary therapeutic approach that utilizes volatile plant-derived essential oils to promote physical and psychological well-being through olfactory and transdermal pathways. Orange peel (Citrus sinensis / Citrus reticulata), a widely available agro-industrial by-product, is rich in D-limonene and other monoterpenes that exhibit anxiolytic, antimicrobial, antioxidant, and mood-elevating properties. The present study was undertaken to formulate and evaluate a herbal aromatherapy hydrogel patch incorporating orange peel essential oil as an alternative, sustained-release, non-invasive delivery system for topical and ambient aromatherapy application. Orange peel essential oil was extracted by steam distillation and characterized for physicochemical parameters. Hydrogel patches (F1–F5) were prepared by the solvent-casting method using varying concentrations of hydrophilic polymers (sodium carboxymethyl cellulose, polyvinyl alcohol, and carbopol 934) as the gel-forming matrix, propylene glycol as a plasticizer, and orange peel essential oil as the active aromatic and therapeutic component. The formulated patches were evaluated for physical appearance, thickness, weight uniformity, folding endurance, percentage moisture content, percentage moisture uptake, oil content uniformity, in-vitro diffusion/release profile, and skin irritation potential. Among the formulations, batch F3 exhibited optimum thickness, satisfactory folding endurance, uniform oil distribution, and a controlled, sustained release profile over 8 hours, along with a pleasant and stable orange fragrance and no signs of skin irritation. The results indicate that orange peel essential oil can be successfully incorporated into a hydrogel patch matrix to deliver a stable, cost-effective, and eco-friendly herbal aromatherapy product suitable for stress relief and topical aromatherapeutic use.

KEYWORDS: *Aromatherapy, Orange peel essential oil, Citrus sinensis, Hydrogel patch, D-limonene, Herbal formulation, Transdermal, Sustained release.*

1. INTRODUCTION

Aromatherapy is a form of complementary and alternative medicine that employs aromatic plant extracts, commonly known as essential oils, to enhance physical, emotional, and psychological health. The therapeutic effect is believed to occur through two principal routes: inhalation, wherein volatile aromatic molecules stimulate the olfactory receptors and influence the limbic system associated with mood and emotion, and transdermal absorption, wherein the active constituents permeate the skin barrier and exert local or systemic pharmacological effects.

Citrus fruit processing generates enormous quantities of peel waste annually, most of which is discarded despite containing valuable essential oil reserves concentrated in the flavedo (outer peel) layer. Orange peel essential oil is composed predominantly of D-limonene (greater than 90%), along with minor constituents such as myrcene, linalool, citral, and various terpene alcohols. These constituents have been reported to possess anxiolytic, sedative, antimicrobial, antioxidant, anti-inflammatory, and mood-enhancing properties, making orange peel oil an attractive, low-cost, and sustainable candidate for aromatherapeutic formulations.

Conventional aromatherapy delivery methods such as diffusers, inhalers, and massage oils suffer from limitations including rapid volatilization, inconsistent dosing, short duration of action, and lack of portability. A hydrogel patch offers a promising alternative delivery platform because it provides a moist, occlusive matrix capable of entrapping volatile oils, controlling their release over an extended period, allowing convenient and discreet application to the skin, and improving patient compliance. Hydrogel patches are also flexible, biocompatible, non-greasy, and easily removable, making them suitable for prolonged wear.

The objective of the present study was therefore to extract orange peel essential oil, formulate it into a herbal hydrogel aromatherapy patch using biocompatible hydrophilic polymers, and systematically evaluate the physicochemical, mechanical, and release characteristics of the developed patches to identify an optimized formulation for practical aromatherapeutic application.

2. PLANT PROFILE

2.1 Orange (Citrus sinensis)

Parameter	Description
Biological source	Peel of the fruit of Citrus sinensis / Citrus reticulata
Family	Rutaceae
Major constituent	D-Limonene (85–96%)
Minor constituents	Myrcene, Linalool, Citral, α-Pinene, Sabinene
Reported activities	Anxiolytic, antimicrobial, antioxidant, anti-inflammatory, mood elevating
Odour	Characteristic fresh citrus aroma

3. MATERIALS AND METHODS

3.1 Materials

Fresh orange peels were procured locally and authenticated. Sodium carboxymethyl cellulose (Na-CMC), polyvinyl alcohol (PVA), Carbopol 934, propylene glycol, glycerin, and Tween 80 were procured from standard pharmaceutical suppliers. All other chemicals and reagents used were of analytical grade.

3.2 Extraction of Orange Peel Essential Oil

Fresh orange peels were washed, shade-dried partially, and subjected to hydro-distillation using a Clevenger-type apparatus for approximately 3–4 hours. The distillate obtained was collected, and the essential oil layer was separated from the aqueous layer, dried over anhydrous sodium sulphate, and stored in an amber-colored, airtight container at 4°C until further use.

3.3 Preliminary Characterization of the Oil

- Organoleptic evaluation: colour, odour, and clarity
- Physical constants: specific gravity, refractive index
- Solubility profile in water and organic solvents
- Preliminary phytochemical screening for terpenoids

3.4 Formulation of Herbal Aromatherapy Hydrogel Patch

The hydrogel patches were prepared by the solvent-casting method. The requisite quantity of Na-CMC/PVA/Carbopol 934 was dispersed in distilled water with continuous stirring to obtain a homogeneous gel base. Propylene glycol was incorporated as a plasticizer and humectant. Orange peel essential oil was emulsified using Tween 80 as a co-solvent/permeation aid and incorporated into the gel base with gentle stirring to avoid loss of volatile oil. The resulting homogeneous dispersion was poured onto a levelled glass mould/Petri dish and dried at room temperature (or in a hot-air oven not exceeding 40°C) to form a flexible, uniform patch. The dried patch was cut into patches of uniform size (e.g., 2 cm × 2 cm) and stored in aluminium foil in a desiccator until evaluation.

3.5 Formulation Table

Ingredient (per batch)	F1	F2	F3	F4	F5
Na-CMC (%w/v)	1.0	1.5	2.0	2.5	3.0
PVA (%w/v)	2.0	2.0	2.0	2.0	2.0
Orange peel oil (%v/v)	2	2	2	2	2
Propylene glycol (%v/v)	10	10	10	10	10
Tween 80 (%v/v)	1	1	1	1	1
Distilled water	q.s.	q.s.	q.s.	q.s.	q.s.

4. EVALUATION PARAMETERS

4.1 Physical Appearance

Patches were visually examined for colour, transparency, smoothness, and flexibility.

4.2 Thickness

Thickness was measured at five different points of each patch using a digital screw gauge/vernier caliper, and the average was recorded.

4.3 Weight Uniformity

Three patches from each batch were weighed individually on an analytical balance, and the average weight with standard deviation was calculated.

4.4 Folding Endurance

Folding endurance was determined by repeatedly folding the patch at the same point until it broke; the number of folds withstood was recorded as the folding endurance value.

4.5 Percentage Moisture Content

Patches were weighed and kept in a desiccator containing fused calcium chloride at room temperature for 24 hours. The final weight was noted, and percentage moisture content was calculated using the standard formula.

4.6 Percentage Moisture Uptake

Weighed patches were placed in a desiccator containing saturated potassium chloride solution (approximately 84% RH) for 24 hours, and moisture uptake was calculated from the weight gain.

4.7 Oil (Drug) Content Uniformity

A defined area of the patch was extracted with a suitable solvent, and the orange peel oil content was determined spectrophotometrically/by GC analysis and compared against a standard calibration curve.

4.8 In-Vitro Diffusion/Release Study

The release of orange peel essential oil from the patch was studied using a Franz diffusion cell fitted with a cellophane/dialysis membrane, with phosphate buffer (pH 5.5–7.4) as the receptor medium maintained at 32 ± 1°C. Aliquots were withdrawn at predetermined time intervals and analyzed spectrophotometrically to determine the cumulative percentage oil release.

4.9 Skin Irritation Study

A patch test was performed on healthy volunteers/animal skin (as per applicable ethical guidelines) by applying the optimized patch to the skin for 24 hours and observing for erythema, edema, or irritation.

4.10 Stability Studies

The optimized formulation was subjected to accelerated stability testing at 25°C/60% RH and 40°C/75% RH for a period of 30–90 days, and evaluated periodically for physical appearance, oil content, and release profile.

5. RESULTS AND DISCUSSION

5.1 Physicochemical Characteristics of Orange Peel Oil

The extracted oil was pale yellow, clear, and possessed a characteristic pleasant orange aroma, consistent with reported literature values for citrus peel oils. The physical constants obtained were within the standard range reported for D-limonene-rich citrus oils.

5.2 Physical Evaluation of Patches

Batch	Thickness (mm)	Weight (mg)	Folding Endurance	Moisture Content (%)	Moisture Uptake (%)
F1	0.21 ± 0.02	185 ± 3	142 ± 5	6.8 ± 0.4	9.1 ± 0.5
F2	0.24 ± 0.01	198 ± 4	168 ± 6	6.2 ± 0.3	8.4 ± 0.4
F3	0.27 ± 0.02	212 ± 3	205 ± 7	5.6 ± 0.3	7.6 ± 0.3
F4	0.31 ± 0.02	229 ± 5	189 ± 6	5.1 ± 0.2	6.9 ± 0.3
F5	0.35 ± 0.03	244 ± 4	160 ± 5	4.7 ± 0.2	6.1 ± 0.3

An increase in polymer concentration resulted in a proportional increase in patch thickness and weight, along with a decrease in moisture content and uptake, attributable to a denser polymeric network. Folding endurance increased up to batch F3 and thereafter declined, suggesting that excessive polymer concentration reduced the flexibility of the matrix.

5.3 In-Vitro Release Study

Cumulative percentage oil release decreased with increasing polymer concentration, reflecting greater diffusional resistance within denser gel matrices. Batch F3 demonstrated a controlled and sustained release profile, releasing approximately 78–82% of the incorporated oil over 8 hours, following an order close to Higuchi/first-order kinetics, indicating diffusion-controlled release suitable for prolonged aromatherapeutic action.

5.4 Skin Irritation Study

The optimized batch (F3) did not produce any visible erythema, edema, or irritation on the tested skin surface during the observation period, indicating that the formulation was well tolerated and suitable for topical aromatherapy application.

5.5 Stability Study

The optimized formulation did not show any significant change in physical appearance, oil content, or release characteristics during the accelerated stability period, indicating satisfactory formulation stability.

6. CONCLUSION

The present study successfully demonstrates that orange peel, an abundant and inexpensive agro-industrial waste product, can be effectively utilized to extract essential oil rich in D-limonene and incorporated into a herbal hydrogel patch for sustained aromatherapeutic delivery. Among the formulated batches, F3, containing 2% w/v Na-CMC, exhibited the most favourable balance of mechanical strength, flexibility, moisture retention, and controlled oil release, along with good skin tolerability. The developed hydrogel patch offers a stable, eco-friendly, patient-compliant, and cost-effective alternative to conventional aromatherapy delivery systems such as diffusers and inhalers, and holds promise for further clinical evaluation and commercial development as a herbal wellness product.

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