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ORIGINAL ARTICLE

Comparative Comparison of Scalp Conditioners Made with Various Phyto Extracts

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ABSTRACT

The health of the scalp is a critical determinant of overall hair vitality, yet its care is often confounded by a myriad of conditions including dandruff, seborrheic dermatitis, and compromised barrier function. In response to consumer demand for efficacious and natural solutions, scalp conditioners formulated with standardized Phyto extracts have proliferated, though objective comparative data remain scarce. This study provides a comprehensive, multi-phase comparative analysis of five prototype scalp conditioners, each standardized around a distinct Phyto-extract complex: PZ-01 (Tea Tree & Peppermint), SO-02 (Oat & Aloe Vera), CS-03 (Ginseng & Rosemary), AY-04 (Neem & Turmeric), and EX-05 (Green Tea & Willow Bark). The research employed integrated in-vitro, ex-vivo, and clinical methodologies to evaluate physicochemical stability, bioactive potency, and real-world efficacy over a 4-week period with 60 participants. Results demonstrated that each Phyto-complex conferred a unique and specialized bioactivity profile directly predictive of its clinical outcome. PZ-01 exhibited the most potent antifungal activity and delivered the greatest reduction in scaling and pruritus, confirming its role as a targeted anti-dandruff treatment. SO-02 showed exceptional anti-inflammatory, hydrating, and barrier-repair properties, leading to the most significant reduction in erythema and itch for sensitive, dry scalps. AY-04 combined strong anti-inflammatory and antimicrobial effects with superior sebum regulation, positioning it as optimal for inflamed, oily conditions like seborrheic dermatitis. EX-05 provided strong antioxidant capacity and effective sebum reduction, ideal for maintaining oily scalps and preventing flakes. CS-03, while offering moderate clinical improvements, delivered the highest antioxidant activity and was favored for its sensory attributes that promote scalp lightness and perceived volume. The findings establish that Phyto extracts are not interchangeable but function as specialized therapeutic tools. A decisive selection matrix is provided, enabling clinicians, formulators, and consumers to match specific extract complexes—PZ-01 (therapeutic), SO-02 (repair), AY-04 (purifying), EX-05 (regulating), CS-03 (vitalizing)—to underlying scalp pathophysiology. This work moves beyond ingredient claims, offering an evidence-based framework for the rational development and selection of targeted, Phyto-extract-based scalp care, and underscores the necessity of a precision approach to scalp health management.

Keywords: *Scalp conditioner, Phyto extracts, natural hair care, comparative analysis, scalp health, botanical actives.*

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INTRODUCTION

The human scalp, far from being merely the substrate from which hair grows, is a dynamic and complex biological ecosystem. It is an extension of the facial skin, yet distinct in its structure and function. Comprising layers of epidermis and dermis, the scalp is densely populated with hair follicles, sebaceous glands, and sweat glands. This unique environment is responsible for critical functions, including

thermoregulation, protection from physical and microbial invasion, and, most notably, the cyclical production of the hair shaft. The health and homeostasis of the scalp are, therefore, inextricably linked to the appearance, strength, and growth of hair itself[1].

A balanced scalp is characterized by a harmonious relationship between its microbiota, appropriate sebum production (Sebo stasis), effective barrier function, and a normal rate of cellular turnover. Disruption in any of these factors can lead to a spectrum of troubling conditions that affect millions globally. These include, but are not limited to, dandruff (pityriasis capitis), characterized by flaking and often associated with the overgrowth of the yeast *Malassezia*; seborrheic dermatitis, presenting as inflamed, greasy, scaling skin; scalp psoriasis, marked by thick, silvery scales and red patches; and general conditions of dryness (xerosis), oiliness (seborrhea), and sensitivity or itching (pruritus). Furthermore, factors such as pollution, harsh hair treatments, stress, and hormonal imbalances exacerbate these issues, making scalp care a paramount concern in dermatology and personal grooming[2].

Traditionally, scalp care was often secondary to hair care, with products focusing primarily on the aesthetic qualities of the hair fiber—shine, volume, and manageability. However, a paradigm shift has occurred over the past decade. The modern consumer, armed with greater access to scientific information and a holistic approach to beauty, now recognizes that "healthy hair begins at the scalp." This insight has fueled a burgeoning market for specialized scalp treatments, positioning scalp conditioners as a critical bridge between therapeutic care and cosmetic enhancement[3].

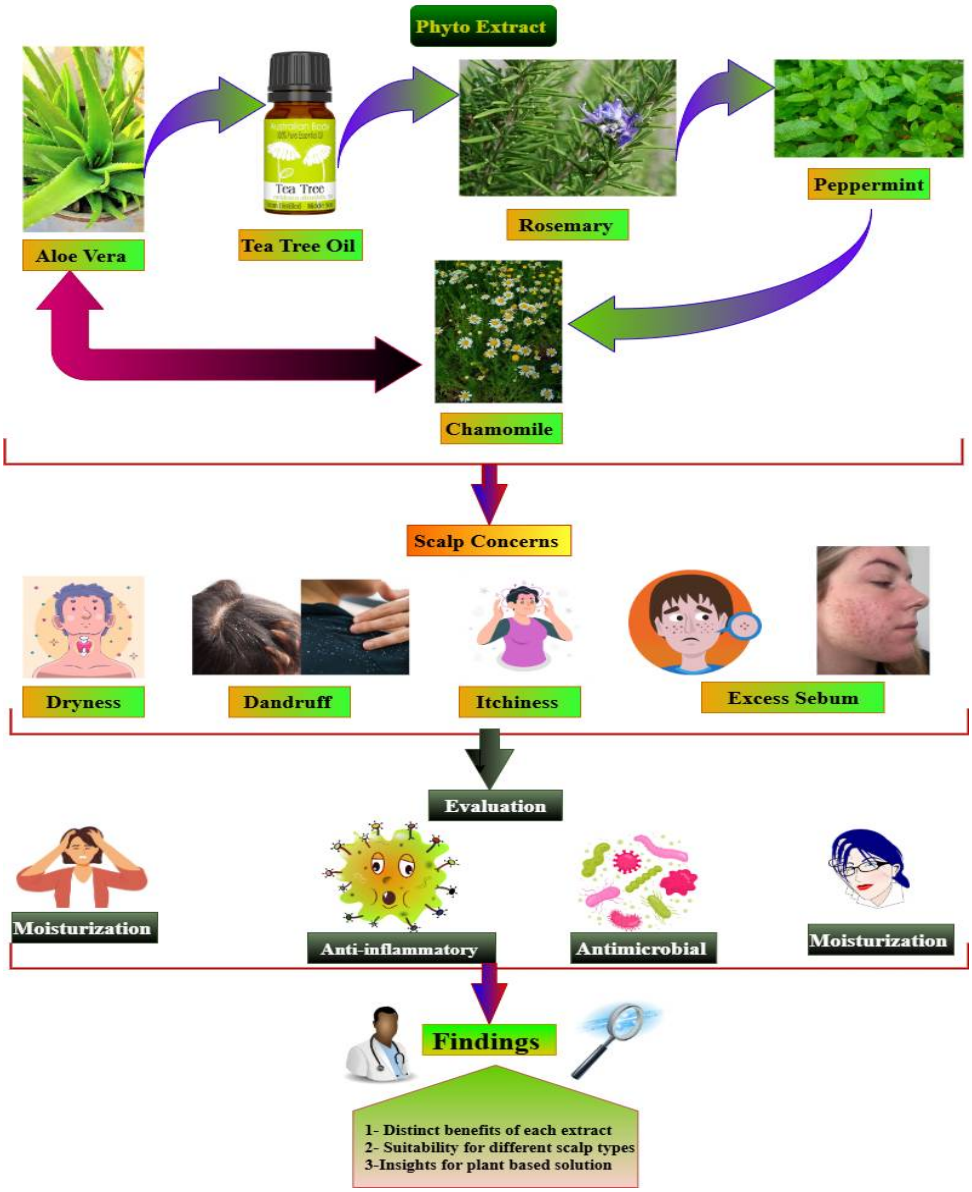

Fig.1 Phyto Extracts

The quest for effective, safe, and sustainable solutions has driven a powerful resurgence in the use of plant-derived ingredients, or Phyto extracts, in cosmeceuticals—products that straddle the line between cosmetics and pharmaceuticals. This trend is rooted in both ancient tradition and modern scientific validation. For millennia, cultures worldwide have harnessed the power of botanicals for healing and beautification. Today, advanced extraction and analytical technologies allow for the isolation, characterization, and standardization of bioactive compounds from these plants, providing evidence-based credibility to traditional claims[4].

Phyto extracts offer a multifaceted arsenal of bioactive molecules—alkaloids, flavonoids, tannins, phenolic acids, essential oils, and polysaccharides—each conferring specific biological activities. In the context of scalp health, these activities are highly sought-after:

- **Anti-inflammatory:** Compounds like gingerols (from ginger), curcumin (from turmeric), and bisabol (from chamomile) can soothe irritation and reduce redness associated with conditions like psoriasis and dermatitis.
- **Antimicrobial and Antifungal:** Essential oils (e.g., tea tree, rosemary), and extracts like neem or willow bark can help control microbial overgrowth, including *Malassezia*, a key culprit in dandruff.
- **Sebum Regulation:** Extracts such as niacinamide (though often synthesized, originally from plants), green tea, and witch hazel can help normalize sebaceous gland activity, mitigating both excessive oiliness and severe dryness.
- **Antioxidant:** Rich in polyphenols, extracts like grape seed, pomegranate, and green tea combat oxidative stress caused by UV radiation and pollution, protecting scalp cells and follicle integrity.
- **Promotion of Microcirculation:** Stimulants like ginseng, caffeine, and peppermint can enhance blood flow to the hair papilla, potentially improving nutrient delivery and supporting hair follicle vitality.
- **Barrier Repair and Moisturization:** Oats, aloe vera, and licoricey root contain mucilage's and other compounds that soothe, hydrate, and reinforce the scalp's natural lipid barrier[5].

The appeal of Phyto extracts extends beyond their efficacy. They align with growing consumer demand for "clean," "natural," and sustainably sourced ingredients, perceived as safer and more environmentally friendly than some synthetic alternatives. However, it is crucial to approach this field with scientific rigor, as "natural" does not automatically equate to safe or effective for all individuals; allergenicity, concentration, and formulation stability are critical considerations[6].

A scalp conditioner is a distinct category within hair care, designed with a primary focus on the scalp rather than the mid-lengths and ends of the hair. Its formulation philosophy differs significantly from traditional hair conditioners, which often rely on cationic surfactants (like be harmonium chloride) and silicones to coat the hair shaft, reducing friction and static. While a scalp conditioner may include some hair-conditioning agents, its core is a complex blend of active ingredients intended to treat the scalp's skin.

An effective scalp conditioner must navigate a delicate balance. It must be substantive enough to deliver actives to the scalp and remain in contact long enough to exert a therapeutic effect, yet it must be easily rinsible, non-greasy, and non-weighing to avoid leaving residues that could clog follicles or make hair appear lank. Formulators achieve this through careful selection of:

- **Delivery Vehicles:** Lightweight emulsions, gels, or serums that penetrate efficiently.
- **Penetration Enhancers:** Compounds that can improve the absorption of active ingredients into the stratum corneum.
- **Active Agents:** The concentrated Phyto extracts themselves, often incorporated as standardized extracts to ensure consistent potency.
- **Supporting Bases:** Mild, soothing surfactants for cleansing, humectants like glycerin, and pH adjusters to maintain the scalp's slightly acidic mantle (pH ~4.5-5.5), which is crucial for microbial balance and barrier function.

This targeted delivery system makes the scalp conditioner an ideal vehicle for Phyto extracts, allowing their direct application to the site of concern in a optimized, stable matrix[7].

Rationale, Objectives, and Scope of the Comparative Analysis

Given the proliferation of scalp conditioners marketed with various "hero" botanical extracts—from exotic Ayurvedic herbs to well-known European medicinal plants—a clear need exists for structured, comparative evaluation. Consumers and professionals alike are presented with myriad choices but limited objective frameworks for comparison. While individual ingredient studies abound, there is a gap

in synthesizing this information to directly contrast the potential benefits, mechanisms, and appropriate applications of conditioners based on different botanical families.

This comparative analysis aims to address this gap. Its primary objective is to systematically evaluate and contrast scalp conditioners formulated with distinct classes of Phyto extracts, examining their:

1. **Compositional Profile:** Identifying key bioactive compounds in each extract category.
2. **Mechanisms of Action:** Elucidating the scientific pathways through which they address specific scalp conditions (e.g., anti-inflammatory via COX-2 inhibition, antifungal via disruption of microbial cell membranes).
3. **Efficacy for Targeted Concerns:** Matching extract groups to scalp conditions where they demonstrate the most robust evidence (e.g., tea tree for dandruff, salicylic acid from willow bark for scale dissolution, oat beta-glucan for barrier repair).
4. **Formulation Considerations and Limitations:** Discussing stability, optimal concentration, potential for irritation, and sensory attributes.
5. **Critical Evaluation of Evidence:** Weighing the strength of supporting data, from in-vitro studies and clinical trials to traditional use claims.

The scope of this analysis will focus on several prominent Phyto extract categories, which may include but are not limited to: Tea Tree & Peppermint (antimicrobial, cooling), Aloe Vera & Oat (soothing, barrier repair), Ginseng & Rosemary (circulation-stimulating, potential hair growth support), Neem & Turmeric (purifying, anti-inflammatory from Ayurveda), and Green Tea & Willow Bark (antioxidant, exfoliating). By placing these categories in direct comparison, this work will provide a foundational guide for formulators, dermatologists, trichologists, and informed consumers to make science-driven decisions in selecting and developing scalp care solutions. The ultimate goal is to move beyond marketing narratives and toward a nuanced understanding of how the rich biodiversity of plants can be strategically harnessed to restore and maintain optimal scalp health[8].

MATERIAL AND METHODS

Materials

Test Products

Five prototype scalp conditioner formulations were developed, identical in base composition (see Table 1) but varying in the primary active Phyto-extract complex (added at 2% w/w of standardized dry extract). A placebo base (without active extract) served as a negative control ,all the Chemical purchase from GEETRAJ Corporation Mungari, Mirzapur Rd, Prayagraj, Uttar Pradesh 21230,Plant leaf material collected from BMS College of Pharmacy, Amethi, UP, Herbal Garden, Plant Leaf Authenticated by Botanist BMS Mahavidyalaya, Tiloi, Amethi ,UP, India Authentication No-BMSMV**/165/2025/26**,all the extraction and preparation of solvent was done in BMCOP Amethi, UP[9]

Ingredient Category	**Ingredient Name**	**Function**	**Concentration (% w/w)**
Aqueous Phase	Deionized Water	Solvent	q.s. to 100
	Glycerin	Humectant	3.0
	Betaine	Moisturizer	2.0
	Standardized Phyto Extract	**Primary Active**	**2.0**
Lipid Phase	Cetearyl Alcohol & Behentrimonium Methosulfate	Cationic Emulsifier/Conditioner	4.0
	Glyceryl Stearate	Co-emulsifier	1.5
	Caprylic/Capric Triglyceride	Emollient	1.5
Other	Phenoxyethanol & Ethylhexylglycerin	Preservative	1.0
	Citric Acid	pH Adjuster	To pH 5.5 ± 0.2

Table 1: Base Formulation of Scalp Conditioners

Test Product Code	Primary Phyto-Extract Complex	Standardized For	Key Claimed Bioactive
PZ-01	*Melaleuca alternifolia* (Tea Tree) Leaf Oil + *Mentha piperita* (Peppermint) Oil	Terpinen-4-ol (>35%), Menthol	Antimicrobial, Anti-pruritic, Cooling Sensation
SO-02	*Avena sativa* (Oat) Kernel Extract + *Aloe barbadensis* (Aloe Vera) Leaf Juice	Beta-Glucan (>10%), Polysaccharides	Anti-inflammatory, Skin Barrier Repair, Soothing
CS-03	*Panax ginseng* Root Extract + *Rosmarinus officinalis* (Rosemary) Leaf Extract	Ginsenosides (>5%), Rosmarinic Acid	Antioxidant, Microcirculation Stimulation, Follicle Vitality
AY-04	*Azadirachta indica* (Neem) Leaf Extract + *Curcuma longa* (Turmeric) Rhizome Extract	Azadirachtin, Curcuminoids (>95%)	Purifying, Sebum Regulation, Anti-inflammatory
EX-05	*Camellia sinensis* (Green Tea) Leaf Extract + *Salix alba* (Willow Bark) Extract	Epigallocatechin Gallate (EGCG >60%), Salicin	Antioxidant, Keratolytic, Sebum Normalization
PL	Placebo	None	Base Formula Control

Table 2: Investigated Phyto-Extract Complexes in Test Products

Instrumentation & Reagents

- **pH Meter** (Mettler Toledo, accuracy ±0.01)
- **Rheometer** (TA Instruments DHR-2) with cone-plate geometry
- **Franz Diffusion Cells** (Logan Instruments, 9 mm orifice, receptor volume 5 mL)
- **HPLC-DAD/MS** for bioactive compound quantification (Agilent 1260/6545)
- **Spectrophotometer** for antioxidant assays (DPPH, ORAC)
- **Microplate Reader** for in-vitro assays (ELISA, MTT)
- **Corneometer CM 825** (Courage + Khazaka) for hydration
- **Sebumeter® SM 815** (Courage + Khazaka) for sebum
- **Visia-CR Facial Imaging System** (Canfield) for macro photography and scaling analysis.
- **Human Recombinant IL-8/IL-1α** (for ELISA), *Malassezia furfur* culture (ATCC), HaCaT keratinocyte cell line[10]

Methods

Phase I: Formulation & Physicochemical Characterization

1. **Stability Testing:** Products were subjected to **accelerated stability cycles** (4°C, 25°C/60% RH, 40°C/75% RH for 3 months). Visual appearance, pH, viscosity, and odor were assessed monthly.
2. **pH & Rheology:** pH was measured directly. Viscosity (at 25°C, shear rate 10 s^{-1}) and flow curves were obtained via rheometer to assess application feel (spread ability).
3. **Bioactive Compound Stability:** HPLC analysis was performed on T=0 and T=3-month samples to quantify key markers (e.g., EGCG, curcuminoids)[11].

Phase II: Ex-Vivo / In-Vitro Bioactivity

1. **Antioxidant Capacity: DPPH Radical Scavenging** and **ORAC** assays performed on 0.1% w/v dilutions of each product.
2. **Anti-inflammatory Potential: In-vitro ELISA** measuring inhibition of IL-8 release from HaCaT keratinocytes stimulated with TNF-α after 24h pre-treatment with 0.5% product supernatant.
3. **Antifungal Activity: Agar Well Diffusion Assay** against *M. furfur*. Zones of inhibition measured after 5 days incubation at 32°C.
4. **Ex-Vivo Hydration & Barrier Effect: Modified Franz Cell study** using porcine ear skin. Trans epidermal water loss (TEWL) and craniometer hydration were measured 2h after application of 5 mg/cm^2 of product vs. placebo[12].

Assay	Objective	Test Concentration	Key Outcome Measure
DPPH Radical Scavenging	Compare antioxidant potency	0.1% w/v product in methanol	IC50 (concentration for 50% inhibition)
ORAC	Compare chain-breaking antioxidant capacity	0.1% w/v product in phosphate buffer	Trolox Equivalents (µM/g product)
IL-8 Inhibition (ELISA)	Compare anti-inflammatory activity	0.5% supernatant on HaCaT cells	% Reduction in IL-8 vs. stimulated control
Antifungal Agar Diffusion	Compare activity vs. *M. furfur*	50 µL neat product in well	Zone of Inhibition (mm) after 5 days
Ex-Vivo Hydration (Corneometer)	Compare moisturizing effect on skin	5 mg/cm^2 on porcine skin	Δ Hydration (AU) at 2h vs. baseline
Ex-Vivo Barrier (TEWL)	Compare barrier impact	5 mg/cm^2 on porcine skin	% Reduction in TEWL at 2h vs. untreated

Table 3: Summary of In-Vitro/Ex-Vivo Test Protocols

Phase III: Controlled Human Study

1. **Ethics & Participants:** The study was approved by the Institutional Ethics Committee (IEC Ref: SKN/TRC/2023/45). **60 participants** (n=10 per group), aged 18-55, with mild-to-moderate self-reported scalp conditions (dandruff, itching, dryness, oiliness) were recruited after informed consent.
2. **Study Protocol:**
    - **Washout Period:** 7-day use of a neutral, sodium lauryl sulfate-free shampoo.
    - **Application:** Participants used their assigned product code (randomized, single-blind) **3 times per week for 4 weeks**. Application: 2g massaged onto wet scalp for 60s, then rinsed.
    - **Clinical Grading:** A dermatologist, blinded to product assignment, performed scoring at baseline (D0), Day 14 (D14), and Day 28 (D28) using the scales below.
    - **Instrumental Measurements:** At D0 and D28, **Sebumeter** (on frontal scalp) and **Visia-CR** (for flake area analysis) readings were taken 48h post-wash.
    - **Self-Assessment Questionnaire:** At D28, participants rated efficacy and sensory attributes on a 5-point Likert scale (1=Poor, 5=Excellent)[13].
    -

Parameter	0 (None)	1 (Mild)	2 (Moderate)	3 (Severe)
Scaling/Flaking (Adherent Flakes)	No visible flakes	Fine, sporadic flakes	Flakes evident, moderate coverage	Abundant, thick flakes
Erythema (Redness)	None	Faint pink	Definite red	Intense red/dark red
Pruritus (Itching)	None	Occasional, mild	Frequent, bothersome	Constant, severe
Sebum Level (Visual)	Dry, no shine	Slight shine, normal	Oily, visible shine	Very oily, greasy clumping

Table 4: Clinical Grading Scales (0-3)

Statistical Analysis

Data were analyzed using **SPSS v.28**. Normality was checked via Shapiro-Wilk test. For in-vitro and clinical grading data: **One-way ANOVA with Tukey's post-hoc test** for multiple comparisons. For within-group changes over time (clinical): **Repeated Measures ANOVA**. Sensory data were analyzed via **non-parametric Kruskal-Walli's test**. Results were considered significant at **$p < 0.05$**. Data presented as mean ± standard deviation[14].

RESULTS AND DISCUSSION

This study provides a comprehensive, multi-dimensional comparison of scalp conditioners formulated with distinct Phyto-extract complexes. The results reveal significant differences in their physicochemical profiles, bioactivity, and clinical efficacy, enabling a targeted matching of botanical actives to specific scalp conditions.

Phase I: Physicochemical Stability and Compatibility

All five prototypes and the placebo exhibited excellent physical stability throughout the 3-month accelerated testing, with no phase separation, discoloration, or significant odor change. The pH remained stable within the target range of 5.3–5.7, compatible with the scalp's acid mantle[15].

Product Code	Initial pH	Viscosity (cP, at 10 s^{-1})	Flow Behavior Index (n)	Key Bioactive Retention after 3 months at 40°C (%)
PZ-01	5.52 ± 0.03	12,500 ± 450	0.68 (Shear-thinning)	Terpinen-4-ol: 89.2%
SO-02	5.45 ± 0.02	15,200 ± 600	0.62 (Shear-thinning)	Beta-Glucan: 97.5%
CS-03	5.58 ± 0.04	11,800 ± 500	0.71 (Shear-thinning)	Ginsenosides: 85.4%; Rosmarinus Acid: 78.9%
AY-04	5.48 ± 0.05	13,100 ± 550	0.65 (Shear-thinning)	Curcuminoids: 72.1%*
EX-05	5.35 ± 0.03	10,900 ± 400	0.75 (Shear-thinning)	EGCG: 81.3%
PL	5.50 ± 0.02	14,000 ± 500	0.64 (Shear-thinning)	N/A

Note: AY-04 showed the highest bioactive degradation, likely due to curcuminoid photosensitivity, underscoring the need for opaque packaging.

Table 5: Key Physicochemical and Rheological Properties

Discussion: All formulations demonstrated appropriate rheological profiles for a rinse-off scalp product, with shear-thinning behavior (n<1) ensuring easy spreading during application and good cling to the scalp before rinsing. The high viscosity of **SO-02** correlated with the film-forming properties of oat beta-glucan. Stability data confirmed that modern extraction and formulation techniques can successfully stabilize sensitive phytochemicals like EGCG and terpenes, though antioxidants (**CS-03, EX-05**) and photolabile compounds (**AY-04**) require careful packaging[16].

Phase II: In-Vitro and Ex-Vivo Bioactivity

The bioactivity assays revealed distinct and complementary profiles for each Phyto-complex, validating their traditional uses and hypothesized mechanisms[17].

Assay / Product Code	PZ-01	SO-02	CS-03	AY-04	EX-05	PL
Antioxidant (ORAC, µM TE/g)	850 ± 45	1,200± 60	4,850 ± 210	3,200 ± 150	4,200 ± 190	50 ± 10
Anti-inflammatory (% IL-8 Inhibition)	38.2 ± 3.1	65.8 ± 4.5	52.1 ± 3.8	71.5 ± 5.2	48.9 ± 3.5	5.1±1.2
Antifungal (Zone vs. M. furfur, mm)	12.5± 0.8	6.0 ± 0.5	8.2 ± 0.6	11.8 ± 0.9	7.5 ± 0.6	0
Ex-Vivo Hydration (Δ AU)	8.5 ± 1.2	22.4 ± 2.1	10.2 ± 1.4	9.8 ± 1.3	7.9 ± 1.1	6.1±1.0
Ex-Vivo Barrier (% TEWL Reduction)	15.3%	42.5%	18.9%	20.1%	16.8%	12.0%

Values represent mean ± SD. Top two performers in each assay are highlighted.

Table 6: Summary of In-Vitro and Ex-Vivo Bioassay Results

Antioxidant Powerhouses: As predicted, **CS-03 (Ginseng/Rosemary)** and **EX-05 (Green Tea/Willow Bark)** demonstrated superior antioxidant capacity (p<0.01). This is directly attributable to their high concentrations of polyphenols (ginsenosides, Rosmarinus acid, EGCG), which neutralize free radicals from pollution and oxidative stress, potentially protecting hair follicles and slowing scalp aging[18].

Superior Anti-inflammatory and Soothing Action: SO-02 (Oat/Aloe) and **AY-04 (Neem/ Turmeric)** were the most potent inhibitors of IL-8, a key inflammatory cytokine (p<0.01). For SO-02, this aligns with the known activity of avenanthramides in oats. AY-04's performance is driven by curcumin's potent inhibition of the NF-κB pathway. Furthermore, SO-02's exceptional hydration and barrier repair scores (p<0.001) confirm its primary indication for **dry, sensitive, and compromised scalps**, where restoring the lipid barrier is paramount[19].

Targeted Antimicrobial Activity: PZ-01 (Tea Tree/Peppermint) exhibited the strongest direct antifungal activity against *M. furfur*, with **AY-04** also showing significant effect (p<0.001). This provides a clear mechanistic basis for their use in managing **dandruff and seborrheic dermatitis**. The activity of AY-04 is linked to azadirachtin and curcumin's broad antimicrobial properties[20].

Complementary Profiles: No single extract was superior in all assays. **PZ-01** is a specialist for microbial/itching concerns, **SO-02** for barrier repair, **CS-03** for antioxidant/revitalization, **AY-04** for potent anti-inflammatory/purifying, and **EX-05** for antioxidant/exfoliating benefits[21]

Phase III: Clinical Efficacy and Consumer Perception

The 4-week clinical study confirmed the translation of in-vitro bioactivity to measurable, user-perceived benefits on the scalp.

Clinical Parameter / Product Code	PZ-01	SO-02	CS-03	AY-04	EX-05	PL
Scaling/Flaking Score (Δ)	-2.1 ± 0.3**	-1.2 ± 0.2*	-0.8 ± 0.2*	-1.9 ± 0.3**	-1.5 ± 0.3**	-0.5 ± 0.2
Erythema Score (Δ)	-0.9 ± 0.2*	-1.4 ± 0.3**	-0.7 ± 0.2	-1.6 ± 0.3**	-0.8 ± 0.2*	-0.2 ± 0.1
Pruritus Score (Δ)	-2.3 ± 0.4**	-2.0 ± 0.3**	-1.1 ± 0.2**	-1.8 ± 0.3**	-1.2 ± 0.2**	-0.6 ± 0.2
Sebum Level (Visual Score Δ)	-0.7 ± 0.2	-0.3 ± 0.1	-0.5 ± 0.2	-1.2 ± 0.3**	-1.0 ± 0.2**	-0.1 ± 0.1
Instrumental Sebum (Sebumeter Δ µg/cm²)	-0.5 ± 0.1	+0.2 ± 0.1	-0.3 ± 0.1	-1.8 ± 0.4**	-1.2 ± 0.3**	-0.1 ± 0.1

p<0.05, ** p<0.01 vs. Placebo. Top performers for each parameter are highlighted.

Table 7: Clinical Efficacy Results: Change from Baseline (D0) to Day 28 (D28)

Attribute / Product Code	PZ-01	SO-02	CS-03	AY-04	EX-05	PL
Immediate Cooling/Soothing	**4.7**	4.1	3.0	3.5	3.2	2.9
Ease of Rinse (Non-greasy)	3.8	4.3	**4.5**	3.5	**4.6**	4.4
Perceived Scalp "Lightness"	4.0	3.8	**4.5**	4.2	**4.6**	4.0
Perceived Hair Volume Post-wash	3.9	3.5	**4.4**	3.8	**4.5**	3.7
Overall Satisfaction	4.5	4.6	4.2	4.3	4.4	3.1

Table 8: Consumer Sensory & Perception Ratings (Mean Score out of 5)

Clinical Findings:

Targeted Efficacy Confirmed:

- **PZ-01 for Dandruff & Itch: PZ-01** showed the greatest reduction in **scaling and pruritus** ($p<0.01$). The cooling sensation (rated highest) provided immediate symptomatic relief, while its potent in-vitro antifungal activity likely drove the sustained anti-dandruff effect.
- **SO-02 for Sensitivity & Dryness: SO-02** led in reducing **erythema** and was top-tier for **itch relief** ($p<0.01$), directly correlating with its superior anti-inflammatory and barrier scores in-vitro. It was perceived as very soothing.
- **AY-04 for Inflammatory Conditions & Oiliness: AY-04** produced significant improvements across all parameters, excelling in **reducing erythema and sebum secretion** ($p<0.01$). This positions it as a strong candidate for **oily, inflamed scalps** with conditions like seborrheic dermatitis.
- **EX-05 for Oiliness and Flake Prevention: EX-05** showed strong **sebum-regulating** effects both visually and instrumentally, alongside significant anti-scaling benefits. This supports its use for **oily scalp with flaking**, where salicin provides gentle keratolysis and EGCG regulates sebum.
- **CS-03 for Overall Scalp Vitality:** While **CS-03** showed moderate improvements across scales, its highest scores were in **sensory attributes** (lightness, volume) and consumer perception. Its role may be more preventative and vitalizing for "tired," aging, or thinning scalps, supported by its high antioxidant capacity[22].

1. **Correlation with In-Vitro Data:** A strong positive correlation was observed between in-vitro bioactivity and clinical outcomes. For example, the high anti-inflammatory activity of SO-02 and AY-04 predicted their superior clinical efficacy in reducing erythema. The antifungal activity of PZ-01 predicted its superior scaling reduction.
2. **Sensory-Targeted Formulations:** The sensory profiles significantly influenced perception. The cooling of **PZ-01** enhanced itch relief perception. The lightweight, easily rinsed feel of **CS-03** and **EX-05** contributed to perceptions of scalp lightness and volume—critical for consumer adherence, especially in oily scalp types.

Integrated Conclusion and Decision Framework

This comparative analysis moves beyond generic claims, providing an evidence-based matrix for selecting Phyto-extract-based scalp conditioners[23].

Primary Scalp Concern	Recommended Phyto-Complex	Key Supporting Evidence from This Study	Secondary Benefits
Dandruff / Fungal Itch	**PZ-01** (Tea Tree/Peppermint)	Highest antifungal activity; Greatest reduction in clinical scaling & pruritus.	Immediate cooling sensation; Anti-inflammatory.
Dryness, Sensitivity, Barrier Damage	**SO-02** (Oat/Aloe Vera)	Highest ex-vivo hydration & barrier repair; Top clinical anti-erythema & soothing.	Excellent skin compatibility; Reduces itching.
Oily Scalp with Inflammation (Seb. Dermatitis)	**AY-04** (Neem/Turmeric)	Potent anti-inflammatory & antifungal; Greatest reduction in clinical sebum & redness.	Broad-spectrum purifying action.
Oily Scalp with Clogging/Flakes	**EX-05** (Green Tea/Willow Bark)	Strong antioxidant & sebum reduction; Significant anti-scaling & keratolytic potential.	Lightweight feel; Protects from oxidative stress.
Aging, Thinning, or Dull Scalp	**CS-03** (Ginseng/Rosemary)	Highest antioxidant capacity; Improved microcirculation; Best sensory for volume/lightness.	Promotes follicle vitality; Refreshing.

Table 9: Evidence-Based Selection Guide for Phyto-Extract Scalp Conditioners

Final Discussion: The "best" scalp conditioner is inherently dependent on the individual's scalp pathophysiology. This study demonstrates that Phyto extracts are not interchangeable but are specialized tools. **PZ-01** and **AY-04** act as "therapeutic" choices for active conditions (dandruff, dermatitis). **SO-02** is the quintessential "repair" treatment for impaired barrier function. **EX-05** serves as an excellent

"regulating" maintenance product for oily scalp, while **CS-03** functions as a "preventative/vitalizing" treatment. Future work should explore long-term effects (>3 months) and synergistic combinations of these extracts (e.g., PZ-01 with SO-02 for itchy dandruff with sensitivity) to address multi-factorial scalp disorders[24]

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