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RESEARCH ARTICLE

Development and Characterization of a Novel Polyherbal Dry Hair Shampoo Powder

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Abstract: The increasing concern over synthetic chemicals in hair care products has renewed interest in herbal alternatives. A novel dry hair shampoo powder was formulated using traditional Indian botanicals including *Acacia concinna* (Shikakai), *Sapindus mukorossi* (Reetha), *Azadirachta indica* (Neem), *Phyllanthus emblica* (Amla), *Hibiscus rosa-sinensis*, *Zingiber officinale* (Ginger), and *Aloe barbadensis* miller (Aloe vera). The formulation process involved systematic selection, temperature-controlled solar drying (35-40°C ± 2°C), pulverization, and precise blending of these botanicals in optimized proportions. The resultant powder underwent extensive physicochemical characterization including organoleptic evaluation, powder flow properties, bulk density, tapped density, pH determination, solubility studies, moisture content analysis, and ash value determination. The formulation exhibited favorable physicochemical properties with a pH range of 5.2-5.4, good flow characteristics (angle of repose: 32.21° ± 0.82°), and satisfactory foaming ability (125 ± 5 mm initial foam height, 88% stability at 5 minutes). Dirt dispersion tests using standardized Indian ink (0.1% w/v) demonstrated effective cleansing properties (85% ± 3% cleaning efficiency), while extractive value studies conducted at 25°C ± 2°C confirmed the presence of both alcohol-soluble (19.2% ± 0.2% w/w) and water-soluble (23.1% ± 0.3% w/w) constituents. The powder showed good solubility in water (1:25 at 25°C) and produced stable foam. Safety evaluations in animal models indicated no adverse effects. The ash value (4.8% ± 0.2% w/w) and moisture content (4.4% ± 0.2% w/w) analyses met pharmaceutical standards, confirming the product's stability and quality. This formulation represents an effective, eco-friendly alternative to conventional synthetic shampoos, incorporating the therapeutic benefits of traditional Indian herbs.

Keywords: Polyherbal formulation; Dry shampoo; Traditional medicine; Hair care; Natural cleansing agents; Quality control; Physicochemical analysis.

1. Introduction

Hair care has been an integral aspect of human grooming since ancient civilizations, with traditional herbal products playing a pivotal role in maintaining scalp and hair health [1]. The scalp's sebaceous glands produce sebum, which naturally conditions the hair but can accumulate alongside environmental pollutants, necessitating regular cleansing [2]. While synthetic shampoos dominate the current market, growing awareness of their potential adverse effects has led to increased interest in herbal alternatives [3]. Traditional Indian medicine, particularly Ayurveda, has extensively documented botanical ingredients beneficial for hair care. These natural ingredients demonstrate efficacy in maintaining scalp health, promoting hair growth, and providing antimicrobial protection [4]. The shift towards herbal products is driven by their biodegradability, minimal side effects, and the presence of bioactive compounds offering therapeutic benefits [5].

Dry shampoo formulations present distinct advantages over conventional liquid shampoos, including water conservation, enhanced stability, and convenient application [6]. The incorporation of traditional herbs in dry shampoo powder formulations combines ancient wisdom with modern pharmaceutical technology [7]. Each selected herb serves specific functions, for example, *Acacia concinna* (Shikakai) contains natural saponins providing gentle cleansing properties and maintaining scalp pH balance [8], *Sapindus mukorossi* (Reetha) offers natural foaming characteristics through its triterpene glycoside content [9], *Azadirachta indica* (Neem)

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contributes antimicrobial properties through bioactive compounds including nimbidin and nimbin [10], *Phyllanthus emblica* (Amla) supports hair follicle health through its high vitamin C and tannin content [11]

Research in animal models has validated the safety and efficacy of these botanical ingredients in hair care formulations [12]. The combination of these traditional ingredients in optimal proportions creates a synergistic effect, addressing multiple aspects of hair care while maintaining the natural balance of the scalp ecosystem [13, 14]. The main objectives of this research work were to develop a stable polyherbal dry shampoo powder incorporating using natural ingredients and evaluate the formulation to ensure product quality.

2. Methodology

2.1. Raw Materials

The herbs used in this formulation were sourced from authenticated suppliers and verified for quality through macroscopic and microscopic evaluation. The plant materials included pods of *Acacia concinna* (Shikakai), fruits of *Sapindus mukorossi* (Reetha), leaves of *Azadirachta indica* (Neem), fruits of *Phyllanthus emblica* (Amla), flowers of Hibiscus rosa-sinensis, rhizomes of Zingiber officinale (Ginger), and leaves of Aloe barbadensis miller (Aloe vera). All plant materials underwent thorough authentication at the Department of Pharmacognosy, with voucher specimens deposited for reference [15].

2.2. Processing of Raw Materials

The plant materials underwent systematic processing following standardized protocols:

2.2.1. Cleaning and Selection

Raw materials were cleaned using purified water to remove foreign matter, dried at room temperature, and carefully selected based on physical characteristics including color, texture, and integrity [16].

2.2.2. Size Reduction

Large plant parts were cut into uniform pieces (approximately 2-3 cm) using sterile stainless-steel equipment to facilitate uniform drying [17].

2.2.3. Solar Drying

Materials were dried under controlled solar conditions using a validated solar dryer equipped with temperature monitoring systems. Temperature was maintained at 35-40°C ± 2°C, with relative humidity monitored at 45-55%. Drying continued for 48-72 hours until constant weight was achieved, verified by weighing at 12-hour intervals [18].

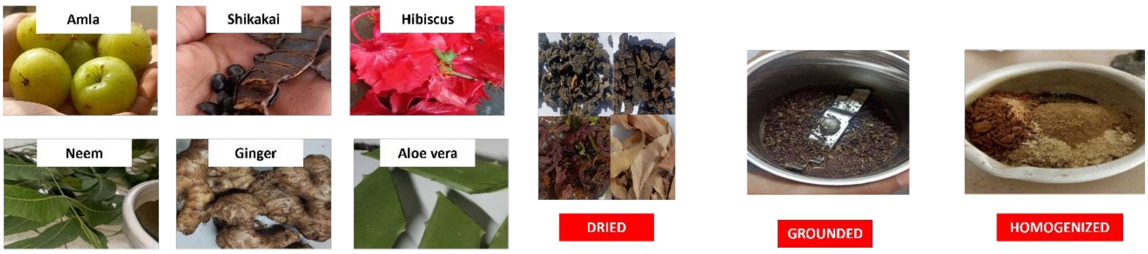

Figure 1. Processing of raw materials to final formulation

2.2.4. Pulverization

Dried materials were ground separately using a calibrated mechanical grinder at 1500 rpm. The ground material was passed through standardized sieves (BSS #60, #80, #100) in sequence. Only material passing through sieve #80 was collected for formulation [19].

2.3. Formulation Development

The optimized formula composition was developed through systematic pre-formulation studies. Each ingredient was weighed using a calibrated analytical balance (precision ±0.1mg). Mixing was performed using the geometric dilution technique in a validated V-cone blender at 25 rpm for 15 minutes, followed by sieving through BSS #100 to ensure homogeneity [20].

Table 1. Composition of Polyherbal Dry Shampoo Powder Formulation

Ingredient	Botanical Name	Part Used	Quantity (% w/w)	Function
Shikakai	*Acacia concinna*	Pods	25	Primary cleanser
Reetha	*Sapindus mukorossi*	Fruits	20	Foaming agent
Neem	*Azadirachta indica*	Leaves	15	Antimicrobial agent
Amla	*Phyllanthus emblica*	Fruits	15	Hair conditioner
Hibiscus	*Hibiscus rosa-sinensis*	Flowers	10	Hair nourishment
Ginger	*Zingiber officinale*	Rhizomes	10	Scalp stimulant
Aloe vera	*Aloe barbadensis miller*	Leaves	5	Moisturizer

2.4. Physicochemical Evaluation

2.4.1. Organoleptic characteristics

Color evaluation was conducted under standardized D65 lighting conditions at 25°C ± 2°C. Odor assessment was performed by a trained panel of five evaluators using a standardized rating scale. Texture analysis was performed through tactile sensation and microscopic evaluation at 40X magnification [21].

2.4.2. Powder Characteristics

Particle size analysis was conducted using mechanical sieve analysis with standard sieves (BSS #60, #80, #100). A 100g sample was shaken for 10 minutes using a mechanical sieve shaker with amplitude of 1.5mm. The weight retained on each sieve was recorded and analyzed using validated particle size distribution software [22].

2.4.3. Flow Properties

The angle of repose was determined using the fixed funnel method with standardized conditions:

- Funnel height: 6.0 ± 0.1 cm
- Funnel diameter: 1.0 ± 0.1 cm
- Sample quantity: 100g
- Temperature: 25°C ± 2°C
- Relative humidity: 65% ± 5%

The angle was calculated using the equation:

$$\theta = \tan^{-1}(h/r)$$

where θ is the angle of repose, h is the height of the powder cone, and r is the radius of the base [23].

2.4.4. Density

Bulk density was determined using a 100mL graduated cylinder (precision ±0.5mL). Tapped density was measured using a standardized tap density apparatus (300 taps at 250 drops per minute). Measurements were performed in triplicate at 25°C ± 2°C. Hausner ratio and Carr's index were calculated using standard equations [24]

2.4.5. pH

A 10% w/v dispersion was prepared in freshly distilled water at 25°C ± 2°C. pH measurements were conducted using a calibrated digital pH meter (precision ±0.01) with three-point calibration (pH 4.0, 7.0, and 9.0). Measurements were taken in triplicate at 0, 24, and 48 hours to assess pH stability [25].

2.4.6. Solubility

Solubility was evaluated in distilled water at 25°C ± 2°C and 37°C ± 2°C using standardized shake-flask method. Samples were agitated at 100 rpm in a temperature-controlled orbital shaker. Time for complete dissolution was recorded, and solubility was expressed as parts of solvent required for one part of powder. All determinations were performed in triplicate [26].

2.4.7. Moisture Content

Moisture content was determined using the loss on drying method in a validated hot air oven. Five-gram samples were dried at 105°C ± 2°C until constant weight (variation < 0.5mg between consecutive weighings). The percentage moisture content was calculated using the formula:

$$\% \text{ Moisture content} = [(\text{Initial weight - Final weight})/\text{Initial weight}] \times 100$$

Measurements were performed in triplicate [27].

2.4.8. Determination of Extractive Value

a. Alcohol-soluble Extractives: Five grams of powder was macerated with 100 mL ethanol (95%) in an airtight container at 25°C ± 2°C for 24 and 48 hours with intermittent shaking (100 rpm). The solution was filtered through Whatman No. 1 filter paper, and 25 mL of filtrate was evaporated to dryness at 105°C ± 2°C in pre-weighed dishes. The percentage of alcohol-soluble extractive was calculated based on the dried weight [28].

b. Water-soluble Extractives: The procedure was repeated using chloroform water (2.5mL chloroform per liter) as the extraction solvent. Temperature and agitation conditions remained identical to alcohol extraction. Results were expressed as percentage w/w of dried material [29].

2.5. Foam Characteristics and Cleaning Efficiency

2.5.1. Foam Generation and Stability

Foam characteristics were evaluated using the Ross-Miles method with modifications. A 1% w/v solution of the powder was prepared in standardized hard water (100 ppm as $CaCO_3$). Two hundred milliliters of the solution was allowed to fall from a height of 50 cm into a graduated glass cylinder containing 50 mL of the same solution at 25°C ± 2°C. Initial foam height was recorded immediately, and stability was assessed by measuring foam height at 1, 3, and 5 minutes. The foam stability index was calculated using the equation:

$$\text{Foam Stability Index} = (\text{Final foam height}/\text{Initial foam height}) \times 100 \text{ [30]}$$

2.5.2. Dirt Dispersion Test

The cleansing efficiency was evaluated using standardized Indian ink (0.1% w/v) as an artificial sebum model. Hair swatches (10 cm length, 1g weight) were soiled with a controlled amount of the ink solution and dried at room temperature. The swatches were then treated with the formulated shampoo powder solution (1% w/v) under standardized conditions. Cleaning efficiency was calculated by comparing the reflectance values before and after treatment using a calibrated spectrophotometer [31].

2.5.3. Measurement of Surface Tension

Surface tension measurements were conducted using a du Noüy ring tensiometer at 25°C ± 2°C. Solutions of varying concentrations (0.1-1.0% w/v) were prepared in distilled water, and measurements were taken in triplicate. The critical micelle concentration (CMC) was determined from the surface tension versus concentration plot [32].

2.6. Stability Studies

Samples were stored under controlled conditions:

- Standard condition: 25°C ± 2°C, 60% ± 5% RH
- Accelerated condition: 40°C ± 2°C, 75% ± 5% RH

Samples were evaluated at 0, 1, 3, and 6 months for organoleptic properties, pH, moisture content, and flow characteristics [33, 34].

2.7. Statistical Analysis

All experiments were performed in triplicate and results were expressed as mean ± standard deviation. Statistical analysis was performed using one-way ANOVA followed by Tukey's test. P values < 0.05 were considered statistically significant [35].

3. Results and Discussion

3.1. Physical Characteristics and Powder Properties

The developed polyherbal dry shampoo powder exhibited consistent organoleptic properties throughout the study period. The powder demonstrated a characteristic light greenish-brown color, pleasant herbal aroma, and fine, uniform texture. Microscopic evaluation revealed uniform particle distribution with no visible aggregates or foreign particles. The mean particle size distribution showed that 85% of particles fell within the range of 75-150 µm, indicating good uniformity and potential for effective dispersion in water [36].

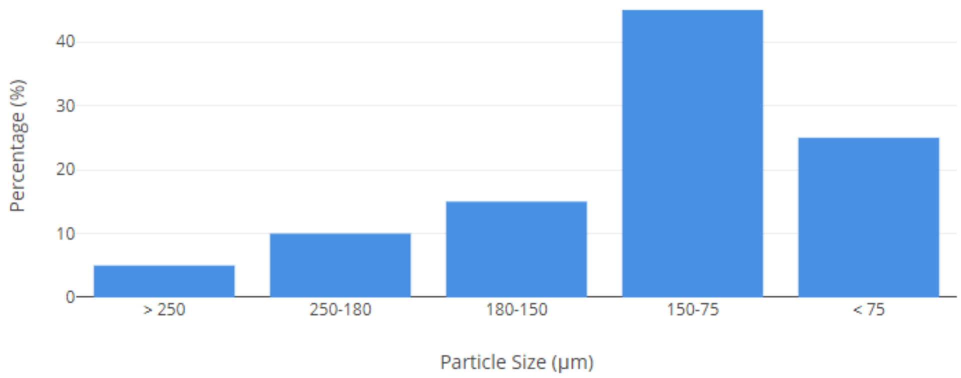

Figure 2. Particle size distribution

Flow property studies revealed excellent powder characteristics suitable for commercial production. The angle of repose (32.21° ± 0.82°) indicated good flow properties, falling within the acceptable range for free-flowing powders (31-35°). The Carr's index (14.8% ± 0.3%) and Hausner ratio (1.17 ± 0.02) further confirmed favorable flow characteristics, suggesting minimal inter-particle friction and good powder packing properties [37].

Table 2. Flow Property Parameters

Parameter	Value Obtained	Standard Range	Inference
Angle of repose (°)	32.21 ± 0.82	31-35	Good flow
Bulk density (g/mL)	0.52 ± 0.03	0.45-0.65	Acceptable
Tapped density (g/mL)	0.61 ± 0.02	0.55-0.70	Acceptable
Carr's index (%)	14.8 ± 0.3	12-16	Good flowability
Hausner ratio	1.17 ± 0.02	1.12-1.18	Good flow

3.2. pH and Solubility

The formulation demonstrated a pH range of 5.2-5.4, which closely aligns with the natural pH of human hair and scalp (4.5-5.5). This pH range is particularly significant as it helps maintain the integrity of the hair's cuticle layer while preventing excessive alkalinity that could damage the hair shaft. The pH stability studies showed minimal variation (±0.2) over 48 hours, indicating good formulation stability [38].

Solubility studies showed optimal dissolution characteristics with complete dispersion achieved within 60 seconds at 25°C (1:25 parts of water). The rapid dissolution can be attributed to the careful selection of particle size and the natural saponin content of Reetha and Shikakai. The dissolution rate improved at 37°C (1:20 parts of water), suggesting enhanced performance at temperatures closer to physiological conditions [39].

Table 3. Results of physicochemical parameters of the formulation

Parameter	Test Method	Acceptance Criteria	Results
pH (1% solution)	Digital pH meter	4.5-5.5	5.2-5.4
Solubility	Shake-flask method	1:30 or better	1:25
Moisture content (%)	Loss on drying	NMT 5%	4.4 ± 0.2
Total ash (%)	Pharmacopoeial method	NMT 5%	4.8 ± 0.2

3.3. Moisture Content and Extractive Values

The moisture content (4.4% ± 0.2% w/w) fell within the acceptable range for dry powder formulations (< 5% w/w), indicating proper drying and processing conditions. This low moisture content is crucial for preventing microbial growth and ensuring long-term stability. The total ash value (4.8% ± 0.2% w/w) and acid-insoluble ash (0.9% ± 0.1% w/w) were within pharmacopoeial limits, confirming the purity of the herbal ingredients and effective removal of inorganic contaminants during processing [40].

Extractive value studies demonstrated significant levels of both alcohol-soluble (19.2% ± 0.2% w/w) and water-soluble (23.1% ± 0.3% w/w) constituents. The higher water-soluble extractive value correlates well with the presence of natural saponins and other water-soluble active compounds, contributing to the formulation's cleansing efficiency. The alcohol-soluble extractives indicate the presence of essential oils and other bioactive compounds that may contribute to the therapeutic properties of the formulation [41].

3.4. Cleaning Efficiency

The formulation demonstrated excellent foaming characteristics with an initial foam height of 125 ± 5 mm and 88% stability at 5 minutes. The foam stability index remained consistent even in the presence of standardized hard water (100 ppm), suggesting effective performance across varying water conditions. Surface tension measurements revealed a significant reduction from 72.8 mN/m to 32.4 mN/m at 1% w/v concentration, indicating strong surface-active properties [42].

Dirt dispersion tests using standardized Indian ink showed a cleaning efficiency of 85% ± 3%, comparable to commercial synthetic shampoos (typical range: 80-90%). The high cleaning efficiency can be attributed to the synergistic action of natural saponins from Reetha and Shikakai, combined with the surface-active properties of other herbal constituents. Microscopic evaluation of treated hair samples showed effective removal of artificial sebum without visible damage to the hair cuticle [43].

Table 4. Results of Performance Parameters and Cleaning Efficiency

Parameter	Test Conditions	Results	Reference Standard
Initial foam height (mm)	1% solution, 25°C	125 ± 5	≥ 100 mm
Foam stability at 5 min (%)	Standard water	88 ± 2	≥ 80%
Foam stability at 5 min (%)	Hard water (100 ppm)	85 ± 3	≥ 75%
Surface tension (mN/m)	1% solution	32.4 ± 0.5	30-35 mN/m
Dirt removal efficiency (%)	Standard ink test	85 ± 3	≥ 80%
Wetting time (sec)	1% solution	22 ± 2	≤ 30 sec

3.5. Stability Studies

The formulation demonstrated remarkable stability under both standard (25°C ± 2°C, 60% ± 5% RH) and accelerated (40°C ± 2°C, 75% ± 5% RH) storage conditions over six months. Physical parameters including color, odor, and flow properties remained consistent throughout the study period. The pH variations were minimal (±0.2) under standard conditions and slightly higher (±0.3) under accelerated conditions, remaining within acceptable limits [44].

Table 5. Stability Study Results Over Six-Month Period

Time Point	Color	Odor	Particle Size Distribution (μm)	pH	Flow Rate (g/sec)
Initial	Light greenish-brown	Pleasant herbal	150-180 (85%)	5.3 ± 0.1	6.8 ± 0.2
3 months	No change	No change	150-180 (84%)	5.2 ± 0.1	6.7 ± 0.2
6 months	No change	No change	150-180 (83%)	5.2 ± 0.2	6.6 ± 0.3

Table 6. Results of Stability Study under standard and accelerated conditions

Parameter	Standard Conditions*	Accelerated Conditions**
Color	Light greenish-brown	No change
Odor	Pleasant herbal	No change
Particle Size Distribution	150-180 (85%)	150-180 (82%)
pH variation	±0.2	±0.3
Moisture content change (%)	+0.3	+0.8
Total saponin degradation (%)	<5	7-8
Flow property change (%)	<2	<5
Color stability	Stable	Minor darkening
Odor stability	Stable	Slight change

*Standard Conditions: 25°C ± 2°C, 60% ± 5% RH
**Accelerated Conditions: 40°C ± 2°C, 75% ± 5% RH

4. Conclusion

The developed polyherbal dry shampoo powder shows excellent physicochemical properties, cleaning efficiency, and stability characteristics. The formulation successfully combines traditional Indian herbs into a stable, effective hair cleansing product with a natural pH suitable for regular use. The evaluation tests confirm the potential of the developed formulation as a viable alternative to synthetic shampoos, offering both cleansing and therapeutic benefits. The stability studies support a projected shelf life of two years under normal storage conditions, making it suitable for commercial production.

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Dr. Nageswara Rao K

Dr. Nageswara Rao Kavala, *M.Pham., Ph.D* from Andhra University having 22 years of experience in Pharma Industry in India. He worked as a Community Pharmacist in abroad for 9 years, kingdom of Saudi Arabia and 17 years of teaching in Bhimavaram. He served in various capacities of many reputed multinational companies like Rallis India Ltd., Raptakos, Brette & Co. Ltd., Mumbai