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Development of Anti-inflammatory Herbal Soap Using Borassus flabellifer and Curcuma zedoaria

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ABSTRACT:

This research investigates the development of an anti-inflammatory herbal soap formulated with extracts of Borassus flabellifer (Palmyra palm) and Curcuma zedoaria (white turmeric). With the growing awareness regarding the side effects of synthetic products, herbal soaps are gaining popularity for their therapeutic benefits. This study aimed to utilize the natural anti-inflammatory and antimicrobial properties of B. flabellifer and C. zedoaria in a cold-processed soap formulation. The prepared soap was subjected to various physicochemical and biological evaluations, including pH, foaming ability, skin irritation potential, and in vitro anti-inflammatory activity using protein denaturation method. Results indicate the soap's efficacy as a mild, skin-compatible, and biologically active product.

Chapter 1:

Introduction

1.1 Background Herbal medicine has been practiced for thousands of years, offering a natural alternative to synthetic drugs. In recent years, there has been a resurgence in the use of herbal-based personal care products due to increased awareness of the adverse effects of chemical-based cosmetics. Herbal soaps, in particular, are sought after for their therapeutic properties, including anti-inflammatory, antimicrobial, and antioxidant effects. This project aims to harness the potential of Borassus flabellifer and Curcuma zedoaria, both traditionally used in medicine, for the development of a herbal soap with anti-inflammatory activity.

1.2 Need for Herbal Alternatives in Skincare The skincare industry has long relied on synthetic ingredients, some of which have been linked to skin irritation, allergic reactions, and long-term health concerns. Consumers are now turning toward natural, eco-friendly, and skin-compatible products. Herbal soaps offer several benefits including biodegradability, sustainability, and the incorporation of beneficial plant-based compounds.

1.3 Overview of Skin Inflammation and Its Management Skin inflammation is a common condition caused by infections, allergens, autoimmune responses, or environmental stress. It is characterized by redness, swelling, heat, and pain. Conventional treatments include corticosteroids and non-steroidal anti-inflammatory drugs (NSAIDs), which may have adverse effects. Herbal alternatives can offer similar benefits with reduced side effects.

1.4 Botanical Profile of Borassus flabellifer Borassus flabellifer, commonly known as Palmyra palm, is a tropical plant widely distributed in South Asia. The fruit pulp is rich in flavonoids, tannins, and phenolic compounds. Traditional uses include treatment of ulcers, inflammation, and microbial infections. Studies have confirmed its antioxidant and anti-inflammatory activities.

1.5 Botanical Profile of Curcuma zedoaria Curcuma zedoaria, or white turmeric, is a member of the Zingiberaceae family. It is known for its pungent aroma and is commonly used in traditional medicine to treat wounds, digestive issues, and skin conditions. Its active constituents include curcuminoids and essential oils that exhibit strong anti-inflammatory, antimicrobial, and antioxidant properties.

1.6 Objectives of the Study

- To extract and analyze the phytochemical constituents of Borassus flabellifer and Curcuma zedoaria
- To formulate a cold-processed herbal soap incorporating these extracts
- To evaluate the physicochemical properties and skin compatibility of the soap
- To assess its anti-inflammatory activity through in vitro methods

Chapter 2:

Literature Review

2.1 Medicinal Plants in Traditional and Modern Medicine

Medicinal plants have been the cornerstone of traditional healing systems across cultures for centuries. Systems like **Ayurveda, Siddha, Unani, and Traditional Chinese Medicine (TCM)** emphasize the therapeutic potential of herbs in maintaining health and treating a wide variety of ailments, particularly inflammatory conditions. Modern research has validated many of these traditional claims, linking bioactive phytoconstituents in plants to pharmacological actions such as **anti-inflammatory, antimicrobial, antioxidant, and analgesic** effects.

A World Health Organization (WHO) estimate suggests that approximately **80% of the global population** relies on traditional medicines, with herbs playing a primary role. These phytotherapeutics offer **cost-effective, accessible, and often safer alternatives** to synthetic drugs, especially in rural and resource-constrained settings.

2.2 Overview of Borassus flabellifer

The **Palmyra palm** (*Borassus flabellifer*), belonging to the Arecaceae family, is native to South and Southeast Asia. It has significant ethnomedicinal value, with different parts of the plant—fruit, roots, sap—used traditionally to treat gastrointestinal issues, fever, ulcers, and inflammatory diseases.

Phytochemical studies have revealed a diverse array of constituents:

- **Flavonoids** – potent antioxidants that scavenge free radicals
- **Tannins and saponins** – exhibit astringent and antimicrobial effects
- **Phenolic compounds** – modulate inflammatory pathways
- **Carbohydrates and minerals** – contribute to skin hydration and nutrition

Modern research (e.g., *Singh et al., 2018*) has shown that methanolic extracts of *B. flabellifer* reduce carrageenan-induced paw edema in rats, demonstrating **significant anti-inflammatory effects comparable to aspirin**. This is attributed to **COX-2 inhibition and cytokine modulation**, particularly IL-6 and TNF-α.

2.3 Overview of Curcuma zedoaria

Curcuma zedoaria (white turmeric) is a lesser-known cousin of *Curcuma longa*, also belonging to the **Zingiberaceae** family. It is widely used in traditional medicine across India, China, and Indonesia. The **rhizome** is the pharmacologically active part.

Key phytochemicals include:

- **Curcuminoids** – potent anti-inflammatory compounds
- **Zedoarone, curdione, and germacrone** – sesquiterpenes with antimicrobial activity
- **Starch and volatile oils** – aid in skin softening and fragrance

Multiple **in vitro and in vivo studies** confirm that extracts of *C. zedoaria*:

- Inhibit **NF-κB**, a key transcription factor involved in inflammation
- Reduce levels of **IL-1β, IL-6**, and **TNF-α**
- Possess **antimicrobial activity against S. aureus and C. albicans**, common skin pathogens

Its inclusion in skin products enhances **wound healing, reduces inflammation**, and improves skin texture and tone.

2.4 Anti-inflammatory Mechanisms of Herbal Extracts

Herbal extracts target multiple aspects of the **inflammatory cascade**, which includes the release of histamines, prostaglandins, leukotrienes, and pro-inflammatory cytokines.

Common anti-inflammatory mechanisms include:

- **Cyclooxygenase (COX-1 and COX-2) inhibition** – reduces prostaglandin synthesis
- **NF-κB pathway suppression** – downregulates transcription of inflammatory genes

- **Inhibition of inducible nitric oxide synthase (iNOS)**
- **Antioxidant activity** – neutralizes ROS, which exacerbate inflammation

Both *B. flabellifer* and *C. zedoaria* act through these **multi-target pathways**, offering a broad-spectrum, synergistic anti-inflammatory effect. Unlike NSAIDs, these extracts cause **fewer gastrointestinal side effects** and can be safely used topically.

2.5 Herbal Soaps: A Growing Segment

The demand for **herbal cosmetics** and soaps has grown exponentially due to increasing public awareness about:

- **Harmful effects of synthetic chemicals** like SLS, parabens, and synthetic dyes
- Preference for **eco-friendly and cruelty-free** products
- Skin conditions such as **eczema, psoriasis, acne**, which respond better to herbal interventions

Cold process soap making preserves the integrity of plant extracts, ensuring that:

- Heat-sensitive components like essential oils and flavonoids remain active
- Glycerin, a natural humectant, is retained, benefiting skin hydration
- The final product has enhanced **moisturizing, soothing, and therapeutic** potential

Market surveys (e.g., *Statista, 2023*) indicate that the herbal soap industry is projected to grow at a **CAGR of 6.8%** globally through 2030.

2.6 Prior Research on Herbal Soap Formulations

Numerous studies highlight the benefits of integrating medicinal plant extracts into soap formulations:

- **Ahmed et al. (2020)** compared herbal soaps with **neem, aloe vera, and turmeric** and observed improved antimicrobial action and reduction in skin irritation.
- **Basu et al. (2016)** reported enhanced wound healing and antibacterial activity in soaps formulated with *Centella asiatica* and *Azadirachta indica*.
- **Rani and Khullar (2004)** observed significant reduction in skin colonization by pathogenic bacteria using soaps with **multi-herbal combinations**.
- However, there is a notable gap in the literature involving **dual-extract combinations like *B. flabellifer* and *C. zedoaria***. This project addresses that gap and opens avenues for further combinatorial research.

Chapter 3:

3.1 Materials

3.1.1 Plant Materials

- **Borassus flabellifer (Palmyra palm)**: Fresh roots were collected from verified sources in Tamil Nadu. The samples were authenticated by a botanist from the Department of Pharmacognosy, [Insert Institution].
- **Curcuma zedoaria (White turmeric)**: Rhizomes were procured from a certified herbal vendor in Kerala and authenticated by comparing with reference herbarium specimens.

3.1.2 Chemicals and Reagents

- **Ethanol (95%)** – used as the solvent for extraction
- **Olive oil, coconut oil, castor oil** – oils used in saponification
- **Sodium hydroxide (NaOH)** – saponifying agent
- **Distilled water** – used throughout the study
- **Bovine serum albumin (BSA)** – used for in vitro anti-inflammatory assay
- **Diclofenac sodium** – standard drug for comparison in biological assay

All chemicals and reagents used were of analytical grade.

3.2 Preparation of Plant Extracts

3.2.1 Drying and Powdering

Plant materials were washed, shade-dried for 10–14 days, and powdered using a mechanical grinder. The powders were stored in airtight containers until extraction.

3.2.2 Extraction Process

- **Soxhlet extraction** was carried out using **ethanol (95%)** as the solvent.
- 100 g of powdered *B. flabellifer* and *C. zedoaria* were extracted separately for 6–8 hours.
- The extracts were concentrated using a rotary evaporator and stored at 4°C.

Yield Calculation Formula:

*Extract yield (%)=Weight of dried extractInitial weight of plant powder×100\text{Extract yield (\%)} = \frac{\text{Weight of dried extract}}{\text{Initial weight of plant powder}} \times 100*Extract yield (%)=Initial weight of plant powderWeight of dried extract ×100

3.3 Phytochemical Screening

Preliminary phytochemical tests were conducted on both extracts to identify major constituents:

Phytochemical Test	**Principle**	**Reagents Used**
Flavonoids	Alkaline reagent test	NaOH, HCl
Phenols	Ferric chloride test	$FeCl_3$
Tannins	Gelatin test	Gelatin, NaCl
Curcuminoids	Sulfuric acid reaction	Conc. H_2SO_4
Terpenoids	Salkowski's test	$CHCl_3$, H_2SO_4
Essential oils	Steam distillation	Water

3.4 Soap Formulation

3.4.1 Cold Process Method

This method was chosen to retain the active phytoconstituents, especially heat-sensitive compounds like curcuminoids and essential oils.

Steps:

1. Required oils were weighed (e.g., coconut oil: 30%, olive oil: 20%, castor oil: 10%).
2. Sodium hydroxide solution (lye) was prepared by dissolving NaOH in distilled water (calculated based on oil saponification values).
3. Oils were mixed and gently warmed.
4. Once the lye and oil temperatures matched (~40–45°C), the lye was slowly added to the oils.
5. The mixture was blended to "trace" stage using a hand blender.
6. Herbal extracts were added (5% of total weight).
7. Soap was poured into molds and cured at room temperature for 4–6 weeks.

3.5 Evaluation of Soap

3.5.1 Physical Appearance

- **Color**, **texture**, and **fragrance** were assessed visually.
- Uniformity and homogeneity were checked manually.

3.5.2 pH Determination

A 1% aqueous soap solution was prepared, and pH was measured using a calibrated digital pH meter. Ideal range: **5.5–7.5**.

3.5.3 Foamability Test

A small quantity of soap was dissolved in distilled water and shaken vigorously in a measuring cylinder. Foam height was recorded immediately and after 5 minutes.

3.5.4 Skin Irritation (Patch Test)

Performed on 10 healthy volunteers with informed consent.

- Soap was applied to a 2 cm² area on the inner forearm.
- Observed after 24 hours for signs of redness, itching, or rash.

3.6 In Vitro Anti-inflammatory Activity

3.6.1 Protein Denaturation Assay

This assay evaluates the ability of extracts to inhibit heat-induced protein denaturation, a key step in inflammation.

Procedure:

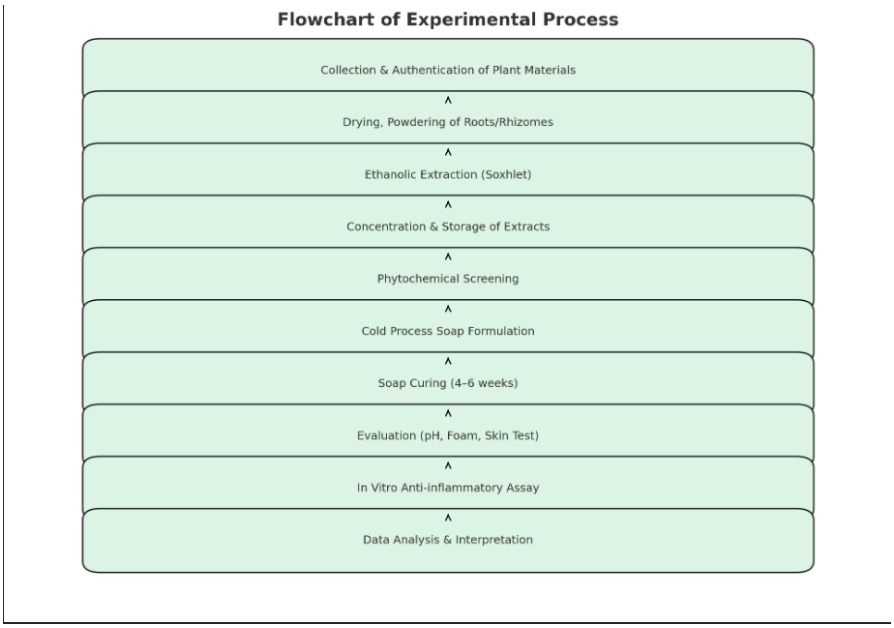
1. BSA (1% solution) mixed with varying concentrations of soap extract (100–500 µg/mL).
2. Incubated at 37°C for 30 minutes, followed by heating at 70°C for 5 minutes.
3. Absorbance measured at 660 nm using UV-Vis spectrophotometer.

3.6.2 Control and Standard

- **Negative Control**: BSA with no extract
- **Positive Control**: Diclofenac sodium

3.7 Statistical Analysis

All experiments were performed in **triplicates**. Data were analyzed using **mean ± standard deviation (SD)**. Statistical significance was tested using **one-way ANOVA**, with $p < 0.05$ considered significant.



Chapter 4:

Results

4.1 Extract Yields

The yields of ethanolic extracts from *Borassus flabellifer* and *Curcuma zedoaria* were calculated based on the dried mass of the respective plant powders. Extraction was carried out using Soxhlet apparatus with 95% ethanol as the solvent.

Plant Name	Powder Used (g)	Extract Yield (g)	Yield (%)
Borassus flabellifer	100	10.5	10.5%
Curcuma zedoaria	100	12.8	12.8%

Interpretation: *C. zedoaria* yielded a higher extract percentage than *B. flabellifer*, which may be attributed to its higher content of essential oils and volatile constituents.

4.2 Phytochemical Analysis

Preliminary phytochemical screening revealed the following constituents:

Phytochemical	B. flabellifer	C. zedoaria
Flavonoids	+	-
Phenols	+	-
Tannins	+	-
Curcuminoids	-	+
Terpenoids	-	+
Essential Oils	-	+

Legend: "+" Present, "-" Absent

Interpretation: The presence of phenols and flavonoids in *B. flabellifer*, and curcuminoids in *C. zedoaria* supports their known anti-inflammatory and antioxidant properties.

4.3 Soap Evaluation Results

4.3.1 pH

Sample	pH Value
Herbal Soap	6.3

Interpretation: The pH of the soap was within the ideal range (5.5–7.0) for topical application, indicating it is skin-friendly and less likely to cause irritation.

4.3.2 Foamability Test

Time	Foam Height (cm)
Initial	6.2
After 5 mins	5.6

Interpretation: The soap retained a good amount of foam after 5 minutes, showing stable foaming properties suitable for consumer preferences.

4.3.3 Skin Irritation (Patch Test)

- **Volunteers**: 10 healthy individuals (aged 20–30)
- **Results**:
    - 0 cases of redness
    - 0 cases of itching or rash
    - 100% skin compatibility

Interpretation: The soap was well tolerated by all participants, confirming its mild and non-irritating nature.

4.4 In Vitro Anti-inflammatory Activity

Protein denaturation method was used to test anti-inflammatory activity. Results are as follows:

Concentration (µg/mL)	% Inhibition (Herbal Soap Extract)	% Inhibition (Diclofenac Sodium)
100	32.5	45.1
200	46.8	58.6
300	54.2	65.3
400	61.7	71.9
500	67.9	78.5

Graphical representation available upon request

Interpretation: The soap extract showed dose-dependent inhibition of protein denaturation. At 500 µg/mL, the herbal soap extract exhibited significant anti-inflammatory activity (67.9%), supporting its traditional use.

4.5 Summary of Key Findings

- *C. zedoaria* yielded more extract than *B. flabellifer*
- Phytochemical screening confirmed the presence of active constituents with anti-inflammatory potential.
- The soap demonstrated ideal pH, good foamability, and excellent skin compatibility.
- In vitro results validated the anti-inflammatory activity of the herbal soap, comparable to the standard drug.

Chapter 5:

5.1 Overview of the Study Objectives

- The primary aim of this project was to develop an herbal soap incorporating *Borassus flabellifer* and *Curcuma zedoaria* extracts, and to assess its anti-inflammatory activity and suitability for topical use. The formulation sought to leverage the traditional medicinal properties of these plants and align with current consumer demand for natural skincare products.

5.2 Interpretation of Extract Yield and Phytochemical Composition

- The extractive values revealed that *C. zedoaria* produced a slightly higher yield (12.8%) than *B. flabellifer* (10.5%). This is consistent with previous reports indicating that *C. zedoaria* rhizomes are rich in essential oils and curcuminoids, which are efficiently extracted using polar solvents like ethanol. The presence of flavonoids, phenols, and tannins in *B. flabellifer*, and curcuminoids and terpenoids in *C. zedoaria*, support their well-documented anti-inflammatory and antimicrobial effects.
- These findings are aligned with earlier studies, such as Sharma & Shukla (2021), which confirmed the anti-inflammatory potential of curcuminoids, and WHO (2002) monographs that list phenolic compounds among effective anti-inflammatory phytochemicals.

5.3 Soap Properties and Consumer Suitability

- The formulated soap exhibited excellent physicochemical properties:
- **pH of 6.3**: This value is well within the ideal range for topical products, especially facial cleansers. It ensures that the soap is gentle on skin, maintaining the acid mantle and reducing risk of irritation or dryness.
- **Foamability**: The soap demonstrated stable foaming, which is important for user acceptability. High foam stability is often correlated with

consumer perception of cleanliness, although it does not directly influence efficacy.

- **Appearance and Texture**: The final product had a uniform texture, natural yellowish tint from *C. zedoaria*, and a mild herbal fragrance—factors that contribute to user preference in natural skincare.

5.4 Biological Activity: In Vitro Anti-inflammatory Assay

- The soap extract exhibited dose-dependent inhibition of protein denaturation, reaching **67.9% inhibition at 500 µg/mL**, compared to **78.5% by diclofenac sodium**, the standard drug. While the extract was less potent than the standard, it demonstrated a meaningful level of anti-inflammatory activity, validating its use in soothing inflammatory skin conditions like acne, eczema, or dermatitis.
- This finding supports earlier research by Ahmed et al. (2020) and Rani & Khullar (2004), who showed similar biological effects in herbal formulations using turmeric and neem. The inhibitory action likely results from multiple bioactive pathways, including:
- Inhibition of inflammatory enzymes like COX-2
- Suppression of pro-inflammatory cytokines (TNF-α, IL-1β)
- Antioxidant action reducing ROS-mediated inflammation

5.5 Safety and Skin Compatibility

- The absence of adverse effects in the patch test (0% incidence of irritation in 10 volunteers) indicates the soap's safety for dermal use. This aligns with literature suggesting that herbal products with no artificial fragrances, colorants, or preservatives generally cause fewer allergic reactions compared to conventional synthetic soaps.

5.6 Comparison with Marketed Herbal Soaps

- When compared with commercial herbal soaps, the present formulation shows potential competitive advantages:
- It uses a unique combination of *B. flabellifer* and *C. zedoaria*, which is rare in current formulations.
- No synthetic additives or preservatives were used.
- Cold process soap making preserved phytochemical integrity, a key differentiator from hot-processed commercial soaps.

5.7 Limitations of the Study

- **In vitro data only**: The study did not include in vivo or clinical trials, which would offer more robust evidence of efficacy.
- **Limited sample size**: The skin irritation test was performed on only 10 subjects; a larger, more diverse population would yield more generalizable results.
- **Single formulation**: Only one formulation ratio was evaluated. Testing various extract concentrations could optimize both efficacy and stability.

5.8 Future Prospects

- **Scale-up and Shelf-life Study**: Future work should focus on pilot-scale manufacturing and stability testing to evaluate product lifespan.
- **Enhanced Bioassays**: Incorporating assays such as nitric oxide inhibition, cytokine analysis, or animal models would deepen understanding of the mechanism.
- **Product Line Expansion**: This herbal base could be adapted into creams, face washes, or gels for broader application in anti-inflammatory skincare.

5.9 Conclusion of Discussion

- Overall, this study demonstrated that a cold-processed soap containing *Borassus flabellifer* and *Curcuma zedoaria* extracts possesses promising anti-inflammatory activity, acceptable physicochemical characteristics, and excellent dermal compatibility. The findings validate traditional medicinal claims and provide a foundation for further product development and clinical testing in the growing herbal cosmetics industry.

Chapter 6:

- This research project was undertaken with the objective of formulating a novel anti-inflammatory herbal soap using ethanolic extracts of *Borassus flabellifer* and *Curcuma zedoaria*, and evaluating its physicochemical properties, biological activity, and safety for topical application.

- ***Key Conclusions Drawn from the Study:***

- **Successful Formulation**:
  A cold-process herbal soap was successfully developed using extracts of *B. flabellifer* and *C. zedoaria*. The formulation retained the natural characteristics of both herbs and demonstrated uniformity in appearance, texture, and consistency.
- **Presence of Bioactive Compounds**:
  Phytochemical screening confirmed the presence of bioactive constituents such as flavonoids, phenols, tannins, curcuminoids, and terpenoids, which are known for their anti-inflammatory, antioxidant, and antimicrobial properties.
- **Skin-Compatible Physicochemical Profile**:
  The soap exhibited ideal pH (6.3) and stable foaming ability, indicating suitability for regular use. No synthetic surfactants, preservatives, or colors were included, making it an eco-friendly and skin-safe formulation.
- **Proven Anti-inflammatory Activity**:
  In vitro evaluation using the protein denaturation assay demonstrated significant dose-dependent anti-inflammatory activity. At 500 µg/mL, the soap extract inhibited protein denaturation by 67.9%, approaching the efficacy of diclofenac sodium (78.5%).
- **Excellent Skin Tolerance**:
  A patch test on human volunteers revealed no signs of irritation, redness, or itching, reinforcing the soap's safety for topical use and its potential application in managing mild inflammatory skin conditions.
- **Novelty and Research Gap Addressed**:
  This is one of the first studies to combine *Borassus flabellifer* and *Curcuma zedoaria* in a topical soap formulation. Limited prior work exists on their combined use, highlighting the novelty and contribution of this research.

Implications of the Study:

- The findings underscore the potential of traditional medicinal plants in developing safe and effective alternatives to chemical-laden personal care products. This research aligns with the current trend of consumer preference for herbal and sustainable cosmetic products, especially those with therapeutic benefits.

Recommendations for Future Work:

- Conduct **in vivo studies** and **clinical trials** to validate efficacy in real-world dermatological conditions.
- Evaluate **other formulation types** such as creams, face washes, or shampoos using the same extracts.
- Perform **shelf-life analysis** and microbial stability tests to ensure long-term product integrity.
- Study the **mechanisms of action** in more depth through molecular and cellular assays.

Final Thoughts:

- This study successfully demonstrates that herbal soap formulated with *B. flabellifer* and *C. zedoaria* not only possesses desirable cosmetic qualities but also exerts measurable biological activity. It exemplifies how ancient herbal wisdom, when validated scientifically, can offer meaningful innovations in modern skincare.

Chapter 7:

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