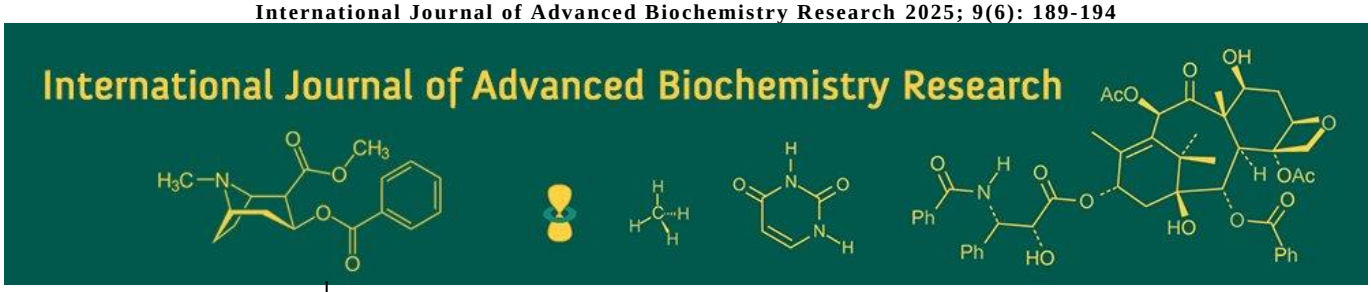

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Development and characterization of herbal colors for the Holi festival using natural ingredients

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Abstract
Background: Holi, the Indian festival of colors, holds immense cultural and spiritual significance, symbolizing the victory of good over evil and the arrival of spring. Traditionally celebrated with naturally derived colors, modern commercialization has led to widespread use of synthetic dyes, which pose health and environmental risks.
Introduction: Natural Holi colors, historically sourced from medicinal plants and kitchen ingredients, are safe, skin-friendly, and biodegradable. However, these have been largely replaced by synthetic variants that often contain toxic chemicals, heavy metals, and non-biodegradable substances, leading to dermatological issues and ecological harm. Renewed interest in herbal alternatives presents an opportunity to revive and validate traditional practices through scientific evaluation.
Aim and Objective: The aim of this study is to develop and evaluate herbal Holi color formulations using natural, plant-based ingredients that are safe for human use, environmentally friendly, and culturally significant. The objectives include formulating four herbal Holi colors-Red, Orange, Green, and Yellow-utilizing powdered and liquid extracts derived from medicinal and culinary plants. These formulations will be evaluated for their organoleptic (sensory), physical, and functional characteristics. Additionally, the study will assess the skin compatibility and stability of the colors under ambient storage conditions to ensure their safety and effectiveness for traditional festive use.
Materials and Methods: Natural ingredients including Neem, Tulsi, Spinach, Beetroot, Marigold, Turmeric, Arrowroot, and Corn flour were selected for color development. Essential oils like Rose, Mint, Cinnamon, and Lemongrass were added for fragrance and therapeutic benefits. Four formulations (F1-F4) were prepared using a standard base of Arrowroot, Corn flour, Multani mitti, and Gram flour. The powders were sieved, dried, and packed in airtight, eco-friendly containers. Evaluations included appearance, odor, flowability, solubility, skin irritation tests, and stability studies.
Results and Discussion: All four formulations displayed smooth textures, pleasant natural odors, and vibrant yet safe colors. The herbal powders showed good flowability and solubility in water and ethanol, but minimal solubility in non-polar solvents like glycerin. No adverse reactions were observed during patch tests, confirming skin compatibility. Stability tests over one month indicated no clumping, discoloration, or odor loss. The incorporation of essential oils enhanced not only the aesthetic appeal but also added antimicrobial and soothing benefits.
Conclusion: The study successfully developed safe, biodegradable, and skin-friendly herbal Holi colors that align with traditional practices and environmental sustainability. These formulations present a viable alternative to synthetic dyes and support a shift toward safer, culturally rooted celebrations. Future work may focus on optimizing color intensity, shelf-life extension, and scaling up for commercial production.

Keywords: Holi, herbal colors, natural dyes, synthetic color hazards, skin safety, eco-friendly, sustainability

Introduction
Holi, the festival of colors, is one of India's most loved and colorful celebrations. It marks the start of spring and represents the triumph of good over evil. Holi is a celebration that comes from Indian culture and mythology, such the story of Hiranyakashyap, Prahlad, and Holika. People celebrate it with joy, unity, and the fun flinging of colorful powders called Gulal. This festival breaks down social barriers, even if only for a short time. It brings people of all backgrounds together in a blaze of color and excitement. Traditionally, the colors used in Holi were derived from natural elements like flowers, leaves, and plant extracts.

Green was derived from Neem (*Azadirachta indica*), yellow from Turmeric (*Curcuma longa*), and red from flowers such as *Butea monosperma* or *Rubia cordifolia*. Additional natural components comprised Indigo for blue, Henna for green, Marigold for yellow, and Charcoal for black, all utilized in the forms of powders, pastes, or water-based colors (Arya & Jaiswal, 2022) [3].

Natural Holi colors originate from plant-based sources like flowers, leaves, roots, and stems, making them safer and more environmentally friendly options compared to synthetic dyes. The colors commonly referred to as "herbal" or "organic"-the latter denoting plant sources grown through organic farming-are biodegradable, non-toxic, and can be advantageous for the skin, thanks to their anti-inflammatory and antibacterial properties (Pandey *et al.*, 2013) [14]. Conversely, synthetic Holi colors are produced via chemical methods and frequently include heavy metals and harmful substances. These may lead to skin irritation, respiratory problems, allergic reactions, and, with extended exposure, potentially result in organ damage or cancer. Furthermore, synthetic dyes lack biodegradability and play a significant role in environmental pollution (Kumbhar *et al.*, 2013) [14]. Natural colors such as Turmeric, Beetroot, Hibiscus, and Marigold present a skin-friendly and environmentally conscious choice; however, they may come with certain drawbacks, including reduced vibrancy, potential fabric staining, and increased production expenses. Furthermore, the absence of quality control in both synthetic and certain herbal colors available in markets presents a health risk, underscoring the necessity for regulation, increased awareness, and the availability of safe alternatives (Sharma *et al.*, 2013) [21]. The traditional herbal colors contributed not only to the festive atmosphere but also possessed beneficial medicinal and skin-friendly properties. Nonetheless, as modernization and commercialization have progressed, synthetic dyes have predominantly taken the place of these natural colors, primarily because of their cost-effectiveness and the convenience of mass production. The Gulal that is widely accessible today frequently contains industrial dyes and non-food grade chemicals, many of which are utilized in the textile, paper, and leather sectors. The presence of heavy metals and toxic compounds in these synthetic colors raises concerns regarding potential skin irritation, allergies, eye infections, respiratory issues, and in severe instances, even carcinogenic effects (Rawat *et al.*, 2008; Jain *et al.*, 2015) [19, 15]. Furthermore, the combination of synthetic powders with sand or soil has the potential to lead to physical abrasions and additional dermatological harm. Even with increasing recognition of the detrimental impacts, synthetic dye-based Holi powders remain prevalent in the market, primarily because of their affordability and accessibility. In recent years, there has been a notable increase in public interest in safer, eco-friendly, and skin-compatible alternatives. The market for herbal Holi powder is experiencing an annual growth rate of 10-15%, reflecting a change in consumer preferences towards organic and sustainable alternatives (Das *et al.*, 2015) [8]. Natural colors, sourced from plants and other organic materials, present a safe, eco-conscious, and culturally significant option. The colors in question are both biodegradable and non-toxic, while also being abundant in phytochemicals that could offer additional advantages for skin and hair health. Components such as Turmeric, Neem, Arrowroot, Haldi, and Bilva are recognized for their antimicrobial, anti-inflammatory, and soothing characteristics (Gardner & Lal, 2012; Khare *et al.*, 2023) [12, 16]. Preparing these colors is straightforward, economical, and can easily be accomplished at home with ingredients that are typically found in the kitchen or garden. Although certain institutions, like the National Botanical Research Institute (NBRI) in Lucknow, have effectively created herbal Gulal and facilitated the technology for commercial production, the broad accessibility and cost-effectiveness of these products continue to be constrained (Sharma *et al.*, 2013) [21]. A significant demand persists for organized investigation and innovation aimed at producing safe, affordable, and readily available natural colors for Holi. This study focuses on the development and characterization of herbal Holi colors made from natural ingredients, highlighting aspects of safety, cultural heritage, environmental sustainability, and accessibility. This initiative aims to restore traditional practices by employing contemporary scientific validation, seeking to reestablish a connection between individuals and nature while encouraging the adoption of organic alternatives during festive occasions.

Material and Method

Selection and Procurement of Materials

All raw plant materials utilized in the formulation of herbal Holi colours were sourced either from the herbal garden of the College of Pharmacy, Shivalik Campus, or from local markets in both dried and fresh forms. Dr. Ankit Kumar, Associate Professor in the Department of Pharmacognosy, carried out a thorough verification and authentication of all herbal materials. Freshly harvested plant materials including Neem (*Azadirachta indica*), Tulsi (*Ocimum* species), Vacha (*Acorus calamus*), Turmeric (*Curcuma longa*), Marigold (*Tagetes* species), Spinach (*Spinacia* species), and Mint (*Mentha arvensis*) were sourced from the herbal garden to guarantee quality and traceability. In the meantime, components such as Arrowroot (*Maranta arundinacea*), Corn flour (*Zea mays*), Multani mitti, Gram flour (*Cicer* species), Dalchini (*Cinnamomum verum*), and Rose oil (*Rosa* species) were obtained from nearby markets. Essential oils such as Lemon grass, Mint, Cinnamon, and Rose were sourced from certified organic suppliers to ensure their purity and safety for topical use.

Preparation of Plant Extracts and Essential Oils

In order to acquire juices or extracts from fresh plant materials like beetroot, spinach, and marigold, we crushed them and filtered them through muslin fabric. This was done in order to prepare essential oils and plant extracts. A little amount of essential oils, including rose, mint, lemon grass, and cinnamon, were added to the mixture in order to further improve the smell and therapeutic potential. In order to guarantee that the powders were distributed evenly, these were included into the powders during the final mixing stage.

Formulation of Herbal Holi Colours

Four herbal colour formulations-F1 (Red), F2 (Orange), F3 (Green), and F4 (Yellow)-were developed based on the composition provided in Table 1. Each formulation consisted of a blend of both powdered and liquid plant extracts. Arrowroot (*Maranta arundinacea*) and Corn flour (*Zea mays*) were used as base carriers due to their ability to provide bulk, absorb moisture, and enhance spreadability.

Multani mitti and Gram flour (*Cicer* species) were incorporated to improve the smoothness, texture, and adherence of the powders to the skin.

Natural colourants were added according to the targeted shade-Beetroot juice and Rose oil for red (F1), Marigold extract and Turmeric for orange (F2), Spinach juice and Neem for green (F3), and Turmeric and Cinnamon oil for yellow (F4). The herbal components were finely ground using a mortar and pestle, sieved through a 60-mesh filter to ensure uniformity, and then thoroughly mixed in their respective proportions.

Table 1: A detailed breakdown of the composition for each formulation, expressed per 100 grams.

S. No.	Common Name	Scientific Name	Part Used	Family	Composition of Color (per 100 gm)			
					F 1 (Red)	F2 (Orange)	F3 (Green)	F4 (Yellow)
1.	Arrowroot	*Maranta arundinacea*	Root	Marantaceae	40	40	40	40
2.	Corn Flour	*Zea mays*	Seed	Poaceae	16	16	16	16
3.	Multani Mitti	-		-	14	14	14	14
4.	Gram flour	Cicer species	Seed	Fabaceae	14	14	14	14
5.	Neem	*Azadirachta indica*	Leaves	Meliaceae	12	12	12	12
6.	Tulsi		Leaves		2.5	2.5	2.5	2.5
7.	Vacha	*Acorus calamus*	Rhizome	Acoraceae	1	1	1	1
8.	Turmeric	*Curcurma longa*.	Rhizome	Zingiberaceae	-	-	-	q. s
9.	Marigold	*Tagetes* species	Flower/ Juice	Asteraceae	-	q. s	-	-
10.	Beetroot	*Beta vulgaris*	Taproot/ Juice	Asteraceae.	q. s	-	-	-
11.	Spinach	*Spinacia* species	Leaves/ Juice	Amaranthaceae	-	-	q. s	-
12.	Lemon	*Cymbopogan flexuosus*	Leaves/ essential oil	Rutaceae	-	0.5	-	-
13.	Mint	*Mentha arvensis*	Leaves/ essential oil	Lamiaceae	-	-	0.5	-
14.	Dalchini	*Cinnamomum verum*	Bark/ essential oil	Lauraceae	-	-	-	0.5
15.	Rose oil	*Rosa* species	Flower/ essential oil		0.5	-	-	-

Addition of Essential Oils

To enhance the overall appeal and skin compatibility of the herbal colours, essential oils such as Rose (*Rosa* species), Mint (*Mentha arvensis*), Cinnamon (*Cinnamomum verum*), and Lemongrass (*Cymbopogon flexuosus*) were added at a concentration of 0.5% w/w during the final mixing stage. These oils contributed mild, pleasant fragrances and offered additional benefits such as antimicrobial, anti-inflammatory, and skin-soothing properties.

Drying and Packaging

The formulated herbal colour powders were spread on clean trays and air-dried under ambient conditions (25-30 °C) in a dust-free environment to retain their natural properties. Once completely dry, the powders were packed in eco-friendly, airtight pouches to prevent moisture absorption and microbial contamination. All samples were labeled and stored in cool, dry conditions until further evaluation (Figure 1).

Fig-1: Formulated herbal colours

Preliminary Tests of Herbal Holi Colors

Preliminary evaluations were conducted to assurance the safety, skin compatibility, and environmental friendliness of the formulated herbal Holi colors. These assessments ensure that the product is devoid of harmful effects and appropriate for topical application during festivities. Colors for Holi that are made from herbal sources, including plant roots, leaves, flowers, and essential oils, are regarded as safer and more environmentally friendly options compared to synthetic dyes (Yadav *et al.*, 2011) [24].

The following preliminary parameters were assessed

- **Appearance:** The physical appearance of each formulation was visually examined for uniformity, texture, and particle distribution.
- **Odor:** Each sample was evaluated for its characteristic herbal or essential oil-based aroma, indicating the presence of natural components.
- **Skin Irritation Test:** A patch test was conducted by applying a small quantity of the formulation on the forearm of healthy volunteers. Observations for any redness, itching, or irritation were recorded over 24 hours.
- **Flowing Property:** The texture and flowability of the powders were observed manually to evaluate ease of application.
- **Stability Test:** Samples were stored in airtight pouches at room temperature and observed over one month to check for changes in color, texture, odor, or clumping.

Evaluation of Herbal Holi Colors

Further quality assessments were carried out to analyze functional properties of the herbal formulations:

1. Solubility Test

A fixed quantity of each formulation was added to various solvents (water, ethanol, glycerin) in test tubes. The mixtures were shaken thoroughly and observed visually to assess solubility behavior, indicating the dispersibility of colorants in different mediums.

2. Angle of Repose
The angle of repose (AoR) is an important indicator of powder flow properties. It was calculated using the formula:

$$\tan \alpha = \frac{H}{R}$$

Where-α = Angle of repose; H = Height of the powder cone; R = Radius of the base.

Approximately 10 grams of powder was poured through a funnel placed at a fixed height onto a graph paper. The radius and height of the formed cone were measured, and the angle was calculated. This method is widely accepted for evaluating flow behavior in powdered formulations (Müller *et al.*, 2021) [17].

3. Skin Sensitivity Test
To assess dermal sensitivity, a small amount of the color was applied to the forehead or inner forearm of healthy volunteers. Any signs of irritation, redness, or inflammation were monitored over 24 hours.

4. Color Stability
The stability of the natural color was monitored by storing the samples at room temperature and observing for any discoloration or fading over a period of 7 days.

5. Water Washability
A small quantity of the formulated herbal color was applied to the skin and left for 5 minutes. The area was then washed with water to evaluate the ease of removal and staining potential.

6. pH Measurement
A 10% (w/v) aqueous dispersion of each formulation was prepared, and pH was measured using pH paper to ensure compatibility with skin, which typically has a pH between 4.5 and 6.5.

Results and Discussion
The formulated herbal Holi colors (F1 to F4) were evaluated for several physicochemical and dermatological parameters to assess their suitability, safety, and appeal for festive use. The summarized results are presented in Table 3 and further analyzed below.

1. Appearance and Texture
The visual appearance of the herbal colors was vibrant and aesthetically pleasing-F1 (Red), F2 (Orange), F3 (Green), and F4 (Yellow). Each hue reflected the effectiveness of natural pigments such as beetroot (red), turmeric (yellow), spinach (green), and marigold (orange). The texture of all formulations was smooth, facilitating easy spreadability over the skin, which enhances user satisfaction during application (Table 2).
These findings are consistent with the sensory expectations from traditional Holi colors and align with consumer preferences, as supported by Agarwal *et al.* (1992) [1], who found that brightness and color vibrancy significantly influence acceptance.

2. Odour and Sensory Appeal
Each formulation emitted a distinct and pleasant aroma due to the inclusion of essential oils (Table 2).
F1: Rose
F2: Lemon
F3: Mint
F4: Spices (cinnamon)

This aromatic feature added to the cosmetic appeal and user comfort, reflecting the Holistic approach of using herbal ingredients for sensory enrichment.

3. Solubility and Water Washability
All formulations were found to be insoluble in both water and ethanol, making them suitable as dry, non-dripping powders. Importantly, the washability of all four formulations was rated as good-they could be easily rinsed off with plain water without staining or requiring soap, thus validating their practical application and user convenience (Table 2).

4. Skin Sensitivity and pH
Patch tests confirmed that all four formulations were non-irritant and safe for topical use. The pH values of the colors ranged from 6.0 to 7.2, which is close to the natural pH of human skin (4.5-7), ensuring dermatological compatibility. F4 showed a slightly alkaline pH of 7.2, which still lies within the acceptable skin-tolerant range (Table 2).

5. Color Stability
All herbal formulations maintained their color, odour, texture, and non-sensitizing properties over a 60-day observation period, stored in airtight containers at room temperature in a dry environment. This demonstrates the formulations' stability and shelf-life, making them commercially viable and safe for storage (Table 2).

6. Flow ability (Angle of Repose)
The angle of repose was calculated using the formula:

$$\tan \alpha = \frac{H}{R} = \frac{6.8}{10.225} = 0.6653 \Rightarrow \alpha = \tan^{-1}(0.6653) \approx 33.6^{\circ}$$

An angle of repose around 33.6° indicates that the powders have some cohesiveness, but are still within acceptable limits for flowability (Carr, 1965; Raymus, 1985) [6, 18]. As per D. Geldart *et al.* (2006) [9], angles between 30-45° suggest moderate cohesion and manageable flow properties, suitable for handling and packaging in powder form.

7. Consumer Preference and Acceptance
A study by Dipangka Saikia *et al.* (2021) [20] demonstrated that 70% of Group A and 62% of Group B preferred Holi colors made from tapioca or rice flour with natural dyes over commercial colors, which are often associated with harmful side effects. These results resonate with the positive sensory and safety data from this study, indicating a growing consumer shift towards safe, eco-friendly, and skin-friendly Holi colors.

Table 2: Evaluation of Herbal Holi color

S. No	Evaluation parameter	F1	F2	F3	F4
					
1	Appearance	Red	Orange	Green	yellow
2	Texture	Smooth	Smooth	Smooth	smooth
3	Odour	Rose	Lemon	Mint	Spices
4	Solubility Water, Ethanol	Insoluble	Insoluble	Insoluble	Insoluble
5	Sensitivity of Skin	Sensivity	Sensivity	Sensivity	Sensivity
6	Color Stability	Stable	Stable	Stable	Stable
7	Water washability	Good	Good	Good	Good
8	pH	6	7	7	7.2

Conclusion

The increasing recognition of the health and environmental risks linked to synthetic Holi colors has ignited a resurgence in the exploration and advocacy for natural, plant-derived alternatives. This study emphasizes the significance of employing sustainable materials like herbal extracts, food-grade fillers, and biodegradable components in the formulation of safe Holi powders. Studies show that natural dyes sourced from traditional and herbal origins not only minimize the likelihood of skin allergies, respiratory problems, and eye injuries but also provide sustainable and non-toxic alternatives that meet consumer preferences for eco-friendly products.

The study highlights the significance of powder flow properties-specifically bulk density and angle of repose-as essential factors in maintaining the quality, safety, and usability of natural Holi powders. The integration of methodologies from the pharmaceutical and powder technology domains provides a foundational approach for enhancing product formulation. Studies on consumer behavior indicate a gradual transition towards eco-friendly practices during festivals; however, there is a necessity for increased awareness and policy backing to maintain this momentum.

In summary, embracing natural Holi colors that are backed by scientific formulation, thorough safety assessments, and community education can enhance the safety of celebrations and promote environmental sustainability. Additional interdisciplinary studies and public health initiatives are crucial for encouraging the broad acceptance and regulation of environmentally friendly colorants in traditional festivals.

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