

FORMULATION AND COMPARATIVE EVALUATION OF AN ECO-FRIENDLY POLYHERBAL TOOTHPASTE FOR ORAL HEALTH

Anju Verma¹, Shivansh Pathak¹, Ritu Mishra¹, Anshika Agrahari¹, Ankit Gupta¹, Pankaj Kumar Sonar*²

¹Department of Pharmaceutical Science and Technology, Madan Mohan Malaviya University of Technology Gorkhpur, Uttar Pradesh, India.

²Government Pharmacy College, B.R.D. Medical College Campus, Gorakhpur, Uttar Pradesh, India.

Article Received: 2 January 2026 | Article Revised: 23 January 2026 | Article Accepted: 12 February 2026

*Corresponding Author: Dr. Pankaj Kumar Sonar

Government Pharmacy College, B.R.D. Medical College Campus, Gorakhpur, Uttar Pradesh, India.

DOI: <https://doi.org/10.5281/zenodo.18640808>

How to cite this Article: Anju Verma, Shivansh Pathak, Ritu Mishra, Anshika Agrahari, Ankit Gupta, Pankaj Kumar Sonar (2026) FORMULATION AND COMPARATIVE EVALUATION OF AN ECO-FRIENDLY POLYHERBAL TOOTHPASTE FOR ORAL HEALTH. World Journal of Pharmaceutical Science and Research, 5(2), 644-651. <https://doi.org/10.5281/zenodo.18640808>



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ABSTRACT

Herbal toothpastes represent a natural and sustainable alternative to conventional synthetic dentifrices, offering both therapeutic and environmental benefits. The present study focused on the formulation, preparation, and evaluation of a herbal toothpaste containing extracts of *Azadirachta indica* (Neem), *Glycyrrhiza glabra* (Liquorice), and *Ocimum sanctum* (Tulsi), selected for their antimicrobial, antioxidant, and anti-inflammatory properties. Calcium carbonate and sodium bicarbonate were employed as abrasives, glycerol as a humectant, and acacia and tragacanth gums as binders and thickening agents, while peppermint and clove essential oils were incorporated to enhance freshness and antimicrobial activity. The prepared formulation was evaluated for organoleptic characteristics, moisture content, pH, foaming index, spreadability, and in vitro antimicrobial activity. The herbal toothpaste exhibited a smooth texture, pleasant odour, acceptable alkalinity (pH 8.51), foaming index of 1.33, moisture content of 4%, and spreadability of 17.33 g-cm/s, indicating satisfactory physicochemical performance. Furthermore, the formulation demonstrated appreciable antimicrobial activity, evidenced by effective zones of inhibition against oral pathogens. Overall, the developed herbal toothpaste displayed desirable organoleptic, physicochemical, and microbiological properties, supporting its potential as a safe, effective, and eco-friendly oral care product. Further clinical studies are recommended to substantiate long-term efficacy and therapeutic outcomes.

KEYWORDS: Herbal toothpaste, Neem, Tulsi, Liquorice, Foam index, MIC.

1. INTRODUCTION

One of the most important and indispensable parts of oral health care, toothpaste has been around since antiquity. Between 300 and 500 BC, toothpaste compositions were first created in China and India. Smashed bones, ground egg, and clam shells were used as abrasives to clean teeth during that time. The 19th century saw the development of contemporary toothpaste formulas. Eventually, soap and chalk were added to those mixtures. Sodium lauryl sulfate was employed as an emulsifying ingredient in several detergent formulation developments that started after 1945. The release of active ingredients during formulation development to prevent and/or treat oral illness has become the focus in recent years.^[1,2] Natural toothpaste manufactured from medicinal plants is frequently used for oral hygiene. In Asia, Neem (*Azadirachta indica*) twigs are frequently used. Herbal mouth and gum therapy has been shown to be very beneficial for the oral cavity, which is why natural dentists use it every day to maintain healthy gums. It contains a variety of naturally occurring anti-inflammatory and antibacterial substances.^[3] A dentifrice called toothpaste is used to clean, preserve, and enhance the condition of teeth. In addition to being primarily used to maintain oral hygiene, toothpaste also serves as an abrasive to help keep food particles and dental plaque off teeth, helps to remove and/or veil halitosis, and releases active ingredients like fluoride to help prevent gum disease and tooth disease. With the aid of toothpaste excipients, the toothbrush is mechanically employed to accomplish much of the cleaning.^[4] Herbal toothpaste uses ingredients derived from plants, such as essential oils, extracts, or powder, that provide therapeutic benefits. Studies have shown that formulations containing Neem, cloves, or basil extracts show antimicrobial activity corresponding to commercial synthetic products. Herbal toothpaste has gained popularity due to being fluorine-free, biodegradable, and gentle on tissue.^[5] Synthetic toothpaste acts faster but can have a strong effect on oral mucosa. Herbal toothpaste, on the other hand, offers a mild, biocompatible and sustainable alternative. They combine natural ingredients that prevent plaque build-up, fresh breathing and soothe the gums without side effects. In addition, herbal products attract people seeking holistic health care. Synthetic toothpaste can act faster but can be tough on oral mucosa and the environment.^[6,7] Modern synthetic toothpaste frequently carries chemical retailers along with fluorine, sodium lauryl sulfate (SLS), triclosan and synthetic sweeteners. Although effective, lengthy-time period use of such ingredients can cause unwanted results which include mucosal infection, enamel fluorosis and allergic reactions.^[8] In current years, customer's desire has shifted to herbal formulations due to their protection, environmental friendliness and multifunctional healing residences. Herbal toothpaste incorporates bioactive ingredients derived from medicinal vegetation known for their antimicrobial, anti-inflammatory, antioxidant and healing activities. Notably, liquorice (*Glycyrrhiza glabra*), Tulsi (*Ocimum sanctum*), and Neem (*Azadirachta indica*) have been widely reported in both traditional Ayurvedic medicine and modern scientific studies for their therapeutic potential in oral health management.^[9,10]

1.1 Importance of Selected Herbs

- **Liquorice (*Glycyrrhiza glabra*):** contains glycyrrhizin and glabridin, compounds which have antibacterial and anti-inflammatory activity effect against *Streptococcus mutans*, which is a major cariogenic bacterium.^[11]
- **Tulsi (*Ocimum sanctum*):** It contains eugenol, ursolic acid, and linalool. It shows antimicrobial and antioxidant properties, help in enhancement of gum health, and acts as a natural mouth freshener.^[12]
- **Neem (*Azadirachta indica*):** It contains the constituents such as nimbidin and azadirachtin, which have strong antibacterial and antifungal function. Neem twigs have been traditionally used in India for brushing teeth due to their natural antibacterial properties, helping maintain oral hygiene and prevent dental problems.^[13]

2. MATERIALS AND METHODS

2.1 Preparation of Plant Extracts

Fresh leaves of neem (*Azadirachta indica*) and tulsi (*Ocimum sanctum*), along with liquorice (*Glycyrrhiza glabra*) roots, were collected from the herbal garden of the Madan Mohan Malaviya University of Technology, Gorakhpur, thoroughly washed with distilled water, shade-dried, and finely powdered using laboratory grinder. About 100 grams of each powdered crude drug was extracted with 500 mL of distilled water by decoction method. The resulting extracts were filtered through Whatman No. 1 filter paper. The filtrates were dried to powder using a rotary evaporator and stored at 4 °C until further use.^[14]

2.2 Preparation of Herbal Toothpaste

Herbal toothpaste was prepared using the following formula.

| S. No. | Ingredient | Function | Quantity | Reference |
|--------|--------------------|--------------------------------|--------------|-----------|
| 1. | Calcium carbonate | Mild cleanser effect, abrasive | 40g | [15] |
| 2. | Sodium bicarbonate | Abrasive | 15g | [16] |
| 3. | Glycerol | Humectant | 15g | [17] |
| 4. | Gum acacia | Binder | 2g | [18] |
| 5. | Peppermint oil | Freshness and flavour | 1g | [19] |
| 6. | Clove oil | Antimicrobial and analgesic | 0.5g | [20] |
| 7. | Tragacanth powder | Thickener | 2g | [21] |
| 8. | Vanillin | Flavour | 0.5g | [15] |
| 9. | Neem extract | Antimicrobial | 2g | [22] |
| 10. | Tulsi extract | Antiseptic | 2g | [23] |
| 11. | Liquorice extract | Foaming, anti-inflammatory | 5g | [24] |
| 12. | Sodium benzoate | Preservative | 0.2g | [25] |
| 13. | Purified water | Vehicle | Q.S. to 100g | [26] |

Approximately 12 mL of purified water was taken in a beaker; gum acacia and tragacanth powder were gradually dispersed under continuous stirring to prevent lump formation. The dispersion was further stirred for 5 min and allowed to hydrate for 25 min.^[27] Glycerol was then slowly added with continuous stirring to ensure uniform wetting and to prevent agglomeration.^[28] Calcium carbonate and sodium bicarbonate were subsequently incorporated in small portions at 5-min intervals with constant mixing, resulting in a total mixing time of approximately 15–20 min.^[29] Herbal extracts of tulsi, neem, and liquorice were then added and mixed until a homogeneous mixture was obtained.^[30,31] Clove oil and peppermint oil were incorporated as flavouring agents and mixed for an additional 2 min.^[32] Finally, the volume was adjusted with purified water q.s. to 100 g under continuous stirring and the formulation was allowed to stand to facilitate the removal of entrapped air bubbles.^[33]

2.3 Evaluation of Herbal Toothpaste

2.3.1 Organoleptic properties

The organoleptic properties (colour, taste, odour, texture) were analysed by the sensory organs and visual inspection.

Table 1: organoleptic properties evaluation of lab made toothpaste.

| S. No. | Organoleptic properties | Result |
|--------|-------------------------|-----------------------|
| 1. | Colour | Light Brown |
| 2. | Taste | Bitter |
| 3. | Odour | Pleasant (mint smell) |
| 4. | Texture | Smooth texture |

2.3.2 Moisture content

Ten grams of toothpaste was accurately weighed, dried in a hot air oven at 105 °C, and then cooled in a desiccator until a constant weight was obtained. The loss in weight was recorded as the percentage moisture content and calculated using the following formula.^[34]

$$\frac{\text{Weight loss}}{W_s} * 100\%$$

$$W_s$$

W_s (Weight of sample before drying) = 10g

W_f (Weight of sample after drying) = 9.8g

Weight loss = $W_s - W_f = 10 - 9.68 = 0.4g$

$$= 0.2/10 * 100$$

$$= 0.02 * 100 = 2.0 \%$$

2.3.3 Stability of storage

The formulated herbal toothpaste was subjected to storage stability studies for a period of three weeks at 25 ± 2 °C under controlled conditions. During the study period, the formulation was periodically evaluated for changes in physical appearance, colour, odour, pH, moisture content, foaming ability, and spreadability.^[18]

2.3.4 Homogeneity

Extrudability of the formulated toothpaste was evaluated at 27 ± 2 °C. Moderate and uniform pressure was applied to the collapsible tube, and the ease of extrusion and uniformity of the extruded mass were observed. The ability of the toothpaste to be expelled smoothly as a homogeneous mass, as well as the proportion of contents extruded prior to rolling from the crimped end, was recorded.^[35]

2.3.5 Determination of pH

Five grams of the formulated toothpaste was accurately weighed and dispersed in 45 mL of distilled water. The mixture was shaken vigorously to obtain a uniform suspension. The pH of the resulting suspension was then measured using a calibrated digital pH meter at room temperature, and the observed pH value was 8.51.

2.3.6 Antimicrobial evaluation

The *In vitro* antibacterial activity of the formulated herbal toothpaste was evaluated against the bacterial strain *Staphylococcus aureus* (MTCC 3160) using the disc diffusion method on Mueller–Hinton agar (MHA). The bacterial culture was evenly spread on MHA plates and allowed to establish. Sterile discs impregnated with the toothpaste formulation were placed on the inoculated agar surface, and the plates were incubated at 37 °C for 24 h. After incubation, the zones of inhibition (ZOI) were measured in millimetres (mm) figure 1. The minimum inhibitory concentration (MIC) was determined by preparing a standardized microbial suspension (colony-forming units per mL), followed by serial dilution and inoculation onto agar plates. The plates were incubated at 37 ± 1 °C, and the MIC was defined as the lowest concentration of the formulation showing no visible microbial growth. Each experiment was performed in triplicate, and the mean values were calculated. After 24 h of incubation, plates were examined for uniform circular and confluent growth, and the diameters of the inhibition zones were measured and statistically analysed.^[36]

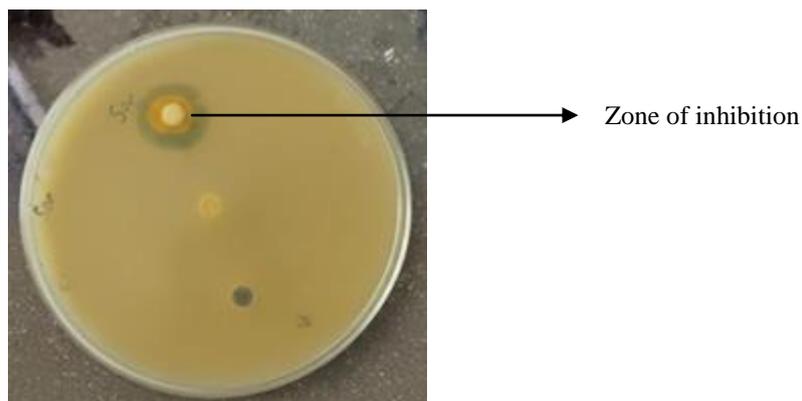


Figure 1: Anti- bacterial evaluation.

2.3.7 Foaming test

Foaming ability of the toothpaste formulation was evaluated by dispersing 1 g of the sample in 6 mL of distilled water in a test tube. The tube was tightly closed with a stopper and shaken vigorously for 10 s to generate foam. The height of the foam formed was measured, and the foaming index was calculated as the ratio of the total height of the dispersion (including foam) to the height of the liquid column. The foaming index reflects the foaming capacity of the toothpaste, where moderate and stable values indicate effective cleaning and surfactant performance, while excessively high or low values suggest poor formulation characteristics.^[37] The foaming index was calculated using the following equation:

$$\text{Foam ratio} = \frac{\text{Foam height} + \text{Liquid height}}{\text{Liquid height}}$$

Liquid height = 6 ml

Foam height = 1.7 cm

$$\text{Foam ratio} = \frac{1.7 + 6}{6} = 1.28$$

Foam index = 1.28

2.3.8 Spreadability

The spreadability test was performed to evaluate the ease of spreading of the toothpaste formulation. Approximately 0.1 g of the formulated toothpaste was placed between two glass microscope slides and compressed for 15 s by applying a 100 g weight on the upper slide [38]. The spreadability was calculated using the following formula:

$$\text{Spreadability} = \frac{M \times L}{T}$$

M=Weight tied to the upper slide (g)

L= Length of spread (cm)

T= Time (sec) taken to spread to that length

$$\text{Spreadability} = \frac{100 \times 2.6}{15}$$

Spreadability = 17.33 g·cm/sec

3. RESULTS AND DISCUSSION

Evaluation experiments were conducted to compare the physicochemical and functional properties of formulated herbal toothpaste with those of commercially available marketed herbal toothpaste. The comparative results of all tested parameters are summarized in Table 2. Overall, the laboratory-formulated toothpaste exhibited performance comparable to, and in some parameters superior to, the commercial formulation. Both preparations demonstrated almost similar foaming capacity, indicating equivalent cleansing potential. Notably, the laboratory-made toothpaste showed enhanced spreadability, suggesting improved ease of application and surface coverage during brushing. In addition, abrasiveness was higher in the laboratory formulation compared to the marketed toothpaste. While moderate abrasiveness can contribute to effective plaque and stain removal, excessive abrasiveness may increase the risk of enamel wear; therefore, this parameter requires careful optimization. These findings indicate that the laboratory-developed formulation is capable of achieving comparable functional performance to commercial toothpaste, with improved spreadability and cleaning potential. However, further refinement of the abrasive content is recommended to ensure safety and long-term dental health.

Table 2: Evaluation tests for the formulated toothpaste and marketed herbal toothpaste.

| S. No. | Properties | Formulated toothpaste | Marketed toothpaste |
|--------|---|-----------------------|---------------------|
| 1. | Abrasiveness | 4 | 3 |
| 2. | Hard and sharp edged abrasive particle. | Absent | Absent |
| 3. | Spreadability (g·cm/sec) | 17.33 | 13.3 |
| 4. | pH | 8.51 | 8.0 |
| 5. | Foaming ability (index) | 1.28 | 1.3 |
| 6. | Stability (37 °C for 21 days) | Good | Good |
| 7. | Moisture content and volatile content determination (% by mass) | 2 | 1.9 |

4. CONCLUSION

The laboratory-formulated herbal toothpaste demonstrated physicochemical and functional performance comparable to a commercial herbal formulation, with favourable spreadability, abrasiveness, and overall acceptability. In vitro findings suggest that the developed formulation is effective and potentially safer for routine oral care, supporting its promise as an alternative to synthetic dentifrices. Nevertheless, comprehensive clinical validation is warranted to confirm long-term efficacy and to elucidate the individual contributions of herbal constituents.

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