

Formulation and Evaluation of Herbal Toothpaste Using Natural Plant Extracts for Antimicrobial Oral Care: A Review

Abhinav P. Doifode, Aditya A. Deshmukh, Amol V. Raut, Aniket G. Magar,

Dr. Aijaz A. Sheikh, Dr. K. R. Biyani

Anuradha College of Pharmacy, Chikhli, Buldhana, Maharashtra, India

Sant Gadge Baba Amravati University

Abstract: *Tooth decay, gum disease and bad breath remain some of the most common health complaints worldwide, and nearly all of them trace back to the same cause: a dense, disease-promoting bacterial film on the teeth. Fluoride and chemical antiseptic toothpastes work well, but many people are looking for gentler, plant-based alternatives, a preference that sits comfortably with India's long tradition of using neem twigs, clove and similar herbs for oral care. This review brings together what has been published on herbal toothpaste: the plants most often used (neem, clove, tulsi, guava leaf, turmeric, aloe vera, pomegranate peel and others), the base ingredients that turn a plant extract into a usable paste, the common methods of preparation, and the tests used to judge quality, safety and antimicrobial action. We also look at clinical evidence, which is more mixed than the laboratory results suggest. Most studies report acceptable pH, foaming, spreadability and visible zones of inhibition against oral pathogens such as *Streptococcus mutans* and *Staphylococcus aureus*. Systematic reviews of human trials, however, describe the overall evidence as low in quality and inconsistent. We conclude that herbal toothpaste is a promising and affordable option, but that standardised extracts, fluoride-containing formulas, stability data and well-designed clinical trials are needed before strong claims can be made.*

Keywords: Herbal toothpaste, Antimicrobial activity, Oral care, Neem, Clove, Dental plaque, Formulation and evaluation.

I. INTRODUCTION

Most of us give our teeth about four minutes a day, and the humble toothpaste does a surprising amount of work in that time. It helps lift food debris and plaque, delivers an agent that protects enamel, freshens the breath, and leaves the mouth feeling clean. Yet the mouth is far from a sterile place. It is home to hundreds of bacterial species, a few fungi and some viruses, and when this community tips out of balance the result can be dental caries, gingivitis, periodontitis or oral candidiasis.

Modern toothpastes usually combine an abrasive, a humectant, a binder, a foaming agent, a flavour and a sweetener, together with fluoride and sometimes an antibacterial such as triclosan or chlorhexidine. These ingredients are effective, but they are not loved by everyone. Some users complain of mouth irritation, taste changes, staining or dryness, and there is steady consumer interest in products described as natural, chemical-free or ayurvedic. At the same time, resistance among oral bacteria to common antimicrobials is a growing concern, which has encouraged researchers to look again at plants as a source of antimicrobial compounds.

India has a head start here. Neem sticks (datun), clove, babool bark, mint and turmeric have been part of everyday oral hygiene for generations, and many Indian pharmacy colleges now run student and faculty projects on herbal dentifrices. The published literature is therefore large, but it is also scattered, and the quality of the reports varies widely. This



review tries to put it in one place. We describe the herbs most commonly used, the formulation approach, the evaluation tests, and the evidence for antimicrobial and clinical benefit, and we point out the gaps that still need filling.

Oral Microbes and the Case for Plant-Based Antimicrobials

Dental plaque is a structured biofilm in which bacteria stick to the tooth surface and to one another. *Streptococcus mutans* is the organism most often linked with caries, because it produces acid from dietary sugars and builds sticky glucans that anchor the biofilm. *Lactobacillus* species add to the acid load as decay advances. Gum disease involves a different crowd, including *Porphyromonas gingivalis* and other anaerobes, while *Candida albicans* is a frequent cause of oral thrush, especially in denture wearers and people with weakened immunity. *Staphylococcus aureus* and *Escherichia coli* are often used as convenient test organisms in student-level studies.

Plants fight microbes with an impressive chemical toolkit: phenolics, flavonoids, tannins, terpenoids, alkaloids and essential oils. Depending on the compound, these can damage the bacterial cell membrane, interfere with enzymes, block adhesion to the tooth surface, or disturb biofilm formation. Many of the same plants also reduce inflammation or pain, which is a useful bonus in an oral product. This combination of antimicrobial, anti-inflammatory and mild analgesic action is the main reason herbs have attracted so much interest in toothpaste development.

Ideal Features of a Toothpaste

Whatever is put in the tube, a toothpaste has to meet some basic expectations. It should clean teeth effectively without scratching enamel or dentine, be safe if small amounts are swallowed, taste acceptable, and remain stable on the shelf. It should also have a pH that does not harm enamel or irritate the gums, form a smooth ribbon when squeezed from the tube, and stay uniform without separating or drying out. For herbal products, an additional requirement is that the plant actives are present at a dependable strength, so that the benefit seen in one batch can be expected in the next.

Composition of Herbal Toothpaste

A herbal toothpaste is essentially a conventional paste in which some or all of the synthetic actives have been replaced by plant material. The supporting ingredients still matter a great deal, because they decide how the product feels and how long it lasts. Table 1 summarises the usual building blocks.

TABLE I: Typical ingredients of a herbal toothpaste and their purpose

Category	Common examples	Purpose
Herbal actives	Neem, clove, tulsi, guava leaf, turmeric, aloe vera, pomegranate peel	Antimicrobial, anti-inflammatory, analgesic, antioxidant
Abrasive / cleaning agent	Calcium carbonate, dicalcium phosphate, baking soda	Removes plaque and stains
Binder / gelling agent	Acacia, tragacanth, xanthan gum, CMC	Holds the paste together, gives body
Humectant	Glycerin, sorbitol	Stops the paste from drying out
Foaming agent	Sodium lauryl sulphate (or milder natural saponins)	Spreads the paste and gives the foaming sensation
Sweetener	Saccharin sodium, honey	Improves taste
Flavour	Peppermint oil, clove oil, spearmint	Freshness, taste masking
Preservative	Methyl or propyl paraben, sodium benzoate	Prevents microbial spoilage
Vehicle	Purified water	Dissolves and carries ingredients

It is worth noticing how often reports use the same basic skeleton. For example, a *Cajanus cajan* (pigeon pea) leaf toothpaste was built on neem extract, clove oil, calcium carbonate, acacia, sodium lauryl sulphate, a paraben



preservative and saccharin. A polyherbal paste described in 2026 used neem, guava leaf, clove, cardamom and turmeric with honey, baking soda and coconut oil. Another recent formulation combined fenugreek, neem, clove oil, aloe vera gel, trikatu and pomegranate peel.

Medicinal Plants Used in Herbal Toothpaste

TABLE II: Plants commonly used and their reported oral benefits

Plant (botanical name)	Part used	Key constituents	Reported oral benefit
Neem (Azadirachta indica)	Leaf, bark, twig	Nimbin, azadirachtin, flavonoids	Antibacterial, antifungal, helps against plaque-forming bacteria
Clove (Syzygium aromaticum)	Bud, oil	Eugenol	Analgesic, antiseptic, breath freshening
Tulsi (Ocimum sanctum)	Leaf	Eugenol, ursolic acid, flavonoids	Antimicrobial, anti-inflammatory
Guava (Psidium guajava)	Leaf	Tannins, flavonoids	Antimicrobial, astringent
Turmeric (Curcuma longa)	Rhizome	Curcumin	Anti-inflammatory, antioxidant
Aloe vera	Gel	Polysaccharides, anthraquinones	Soothing, supports gum healing
Pomegranate (Punica granatum)	Peel	Ellagitannins, punicalagin	Antimicrobial, astringent
Cardamom (Elettaria cardamomum)	Seed	Terpenes (cineole)	Flavour, breath freshening
Fenugreek (Trigonella foenum-graecum)	Seed	Saponins, flavonoids	Anti-inflammatory

Neem and clove deserve special mention. Neem has been described as a strong antibacterial and antifungal that is effective against plaque-forming bacteria, while clove is valued for its eugenol, which provides pain relief and an antiseptic effect. Moringa leaf extract has also been proposed for its antioxidant and anti-cariogenic activity, and honey and coconut oil are often added for taste and soothing properties. Older work on herbal tooth powders shows the same pattern: clove, neem bark, acacia bark, mint and similar herbs were combined and then screened for activity against *Candida albicans*, *Staphylococcus aureus* and *E. coli*.

A quick caution is needed here. Plant potency depends on species, geography, harvest time, drying and extraction solvent. Two neem extracts bought from different suppliers are not necessarily equal. Many of the papers we looked at do not report any standardisation, such as marker compound content or a chromatographic fingerprint, and this makes comparison between studies difficult.

Methods of Preparation

The preparation process is fairly simple, which is part of why it is popular in college laboratories.

Collection and processing of plant material

Leaves, buds or bark are collected, authenticated by a botanist or pharmacognosist, washed, shade-dried and powdered. Sieving gives a uniform particle size, which affects both smoothness and abrasiveness.

Preparation of extracts

Depending on the plant, the active material may be used as a fine powder, or extracted by maceration, decoction or Soxhlet extraction with water or ethanol. Essential oils such as clove oil are usually added as supplied. Concentrated extracts are generally easier to mix into a paste than raw powder.

Preparation of the base

The binder (for example acacia) is first hydrated in a portion of water or glycerin to form a smooth mucilage. The abrasive and other dry powders are then blended in geometrically, meaning small amounts at a time, to avoid lumps.



Incorporation of actives

The herbal extract or powder, foaming agent, sweetener and preservative are added gradually while mixing. Flavour oils go in last, since volatile oils can be lost if added early or with heat.

Final adjustment and packing

The paste is brought to a uniform consistency with the required quantity of purified water or humectant, checked for pH, and packed into clean, well-closed collapsible tubes or jars. Batches are usually made as 100 g units in laboratory studies.

One practical point is that herbs and water together are an invitation for microbes. Because of this, preservative choice and good hygiene during preparation deserve more attention than they sometimes receive.

Evaluation Parameters

TABLE III: Common evaluation tests for herbal toothpaste

Test	Brief method	What it tells us
Organoleptic evaluation	Look, smell and taste	Colour, odour, taste, overall acceptability
pH	10% aqueous suspension measured with a pH meter	Safety for enamel and gums; most commercial pastes are roughly 5.5 to 10.5
Spreadability	Paste placed between two slides under a known weight; time or spread diameter noted	Ease of spreading in the mouth
Extrudability	Force or weight needed to expel paste from the tube	Ease of squeezing
Foaming ability	Paste shaken in water in a measuring cylinder; foam height recorded	Cleaning feel and consumer acceptance
Homogeneity	Visual and finger-feel inspection	Uniform mixing, no gritty lumps
Moisture and volatile matter	Known weight heated in an oven (for example 105 °C) until constant weight	Drying tendency and shelf life
Cleaning (abrasive) ability	Stain removal on an extracted tooth or eggshell	Plaque and stain removal
Relative density	Density bottle method	Consistency between batches
Abrasiveness	Gritty particles checked on a glass slide	Possible scratching of tooth surface
Irritancy test	Applied to skin or mucosa of volunteers or animal models	Safety
Stability studies	Storage at different temperatures and humidity for weeks to months	Shelf life, separation, microbial growth
Antimicrobial activity	Agar well or disc diffusion, MIC	Ability to inhibit oral pathogens

Typical reports describe the paste as having an acceptable appearance, a pleasant smell, and a near-neutral pH. A polyherbal paste of neem, guava, clove, cardamom and turmeric, for instance, had a pH of 7.5 and an olive-green colour with a slightly bitter taste. Moisture and volatile matter, cleaning ability, spreadability and foaming were similarly tested on the *Cajanus cajan* paste and compared with a marketed product. Several recent studies deliberately compare their laboratory formula with branded herbal pastes such as Patanjali Dant Kanti and Dabur Babool.

Some points often get overlooked. Many herbal pastes are coloured, so a change in shade on storage should be noted as a stability sign. Abrasiveness is usually judged only roughly, even though it is critical for tooth safety. And very few student studies measure fluoride, microbial limits or heavy metals, all of which matter if a product were ever meant for sale.



Evaluation of Antimicrobial Activity

The most common laboratory approach is the agar diffusion method. A sterile plate is seeded with the test organism, wells are cut or discs placed, the toothpaste (or its extract) is applied, and the plate is incubated, usually at 37 °C for 24 hours. A clear zone around the well indicates inhibition, and its diameter in millimetres is measured. Test organisms generally include *Staphylococcus aureus*, *Streptococcus mutans*, *Lactobacillus acidophilus*, *Escherichia coli* and *Candida albicans*. Standard antibiotics or marketed pastes act as positive controls.

Results are usually encouraging. A polyherbal formula containing clove, mango leaf, tulsi, ivy gourd leaf and guava leaf was assessed for physical, chemical and antimicrobial properties using disc diffusion against *Staphylococcus aureus*. A neem and clove dental gel with honey and vitamin E was reported in a recent preprint to have antimicrobial action, though it has not been peer reviewed. Earlier work screened tooth powders against *Candida*, *Staph. aureus* and *E. coli* by the diffusion method.

Laboratory results should be interpreted carefully, though. Diffusion tests are semi-quantitative. A large zone of inhibition does not always mean a strong antimicrobial, since it also depends on how well the active compound diffuses through the agar. Minimum inhibitory concentration (MIC), minimum bactericidal concentration and biofilm assays give more meaningful information, but are used less often. Testing whole toothpaste is also tricky, because the surfactant and preservative can inhibit growth on their own, which can make the herbal part look better than it is. The proper control is a placebo paste made with the same base but without the herbal actives.

Clinical Evidence

A good lab result is only half the story, and this is where the literature becomes more cautious. Two systematic reviews have summarised randomised trials of herbal toothpaste in adults, and they do not entirely agree.

The first, covering ten trials, found that conventional toothpaste performed better than herbal toothpaste for plaque and gingival inflammation overall. But when the studies were split into short-term and longer-term use, the difference disappeared. The authors concluded that there is currently no high-quality evidence either to support or to reject the anti-plaque and anti-gingivitis effects of herbal dentifrice.

The second and larger review pooled 24 trials, 15 on herbal toothpaste with 899 participants and nine on herbal mouth rinse with 698 participants. It found herbal toothpaste to be comparable to non-herbal toothpaste for short-term plaque reduction, and it was not superior to fluoride toothpaste, though it did beat non-fluoride toothpaste. Importantly, the authors noted that the evidence came from low-quality studies. A third review focused on *Streptococcus mutans* and found that natural products were effective, but did not provide concrete evidence that they were more antibacterial than conventional products.

Put simply, herbal pastes seem to work reasonably well and may match ordinary pastes in the short term, but the trials are small, vary in design and often fall short on quality. Anyone claiming that herbal toothpaste is better than a fluoride product is going beyond what the evidence supports.

Advantages and Limitations

Advantages. Herbal pastes are generally well accepted by users who prefer natural products, draw on familiar traditional ingredients, are relatively cheap to make from locally available plants, and often combine antimicrobial, anti-inflammatory and soothing actions in a single product. Several authors also describe fewer irritant effects than some synthetic pastes, although this is rarely tested directly.

Limitations. Variation between batches of plant material, lack of standardisation, short shelf life from microbial spoilage or oxidation of volatile oils, bitter or earthy taste, staining of teeth or the tube, and uncertain fluoride content are all real challenges. Fluoride is the best-proven agent for caries prevention, and a herbal paste without it may not give equivalent protection against cavities. Natural also does not automatically mean safe: clove oil can irritate mucosa at high concentrations, and allergic reactions to plant ingredients do occur.



Future Prospects

Several directions look worthwhile. First, extracts should be standardised against marker compounds so that two batches really are comparable. Second, herbal actives could be combined with fluoride to get the best of both worlds, and their interaction tested. Third, studies should include MIC values, biofilm models and placebo-base controls instead of relying only on zone diameters. Fourth, stability studies under accelerated conditions should be routine. Fifth, newer technologies, such as nanoparticle delivery of plant actives, may improve penetration into plaque and sustain release, though they bring their own safety questions. Finally, well-designed, adequately powered, blinded clinical trials with standard plaque and gingival indices are needed to move herbal toothpaste from promising to proven.

II. CONCLUSION

Herbal toothpaste is an appealing meeting point between traditional knowledge and modern pharmaceuticals. The ingredients are familiar, the preparation is simple, and laboratory studies repeatedly show activity against common oral microbes, along with acceptable physical properties. The clinical picture is more modest: current systematic reviews suggest short-term performance similar to conventional pastes, but with low-quality evidence and no proof of superiority over fluoride. The most useful next steps are not new recipes but better science, meaning standardised extracts, proper controls, stability and safety data, and robust human trials. With that groundwork, herbal toothpaste could become a trustworthy complement to established oral care rather than just an attractive alternative.

ACKNOWLEDGMENT

The authors express their deepest gratitude to Prof. (Dr.) Faisal Shaikh, their project guide, for his valuable guidance throughout the practical work. Without his support, completing this project would have been very difficult. His motivation, constructive suggestions and generous time during the dissertation work, together with his encouragement, helped the authors greatly, and they consider it their fortune and honour to have worked under his guidance.

The authors also sincerely thank their Principal, Dr. R. H. Kale, for his suggestions, guidance and encouragement, and for providing the infrastructure and facilities required for the practical work.

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