FORMULATION AND COMPARATIVE EVALUATION OF A POMEGRANATE PEEL-BASED HERBAL TOOTH POWDER AGAINST A MARKETED AYURVEDIC TOOTH POWDER

[1]Rakhshanda Bano Masood Ansari, [2] Dr. Allabaksha Mahboob Shaikh

[1]Final Year B. Pharm Student, [2]Professor, Department of Pharmacology

[1,2]Department of Pharmacy

M.C.E. Society's Allana College of Pharmacy, Azam Campus, Camp, Pune 411001, Maharashtra, India

Abstract: *Most dentifrices sold today rely on synthetic detergents, abrasives and preservatives, and while they clean teeth effectively, their prolonged use has been linked to enamel wear, gum irritation, altered taste perception and disruption of the resident oral flora. This has pushed formulators back towards plant-based alternatives that are gentler, cheaper to produce and easier on the environment. The present work reports the development of a herbal tooth powder built around dried pomegranate (Punica granatum L.) peel, a fruit by-product that is ordinarily discarded despite carrying a dense load of tannins, flavonoids, punicalagin and ellagic acid, compounds with well-documented antimicrobial and antioxidant characteristics. Peel powder was blended with Triphala churna, kaolin, sodium bicarbonate and clove oil to obtain a 20 g batch. The resulting powder was examined for its organoleptic profile, particle size distribution, bulk and tapped density, Hausner's ratio, angle of repose, pH, loss on drying, foaming behaviour and surface abrasiveness, and these results were set alongside the same parameters measured for the commercially available Vicco Vajradanti tooth powder. Antimicrobial performance of both samples was further compared using a resazurin-based microdilution assay against Escherichia coli and Bacillus spp., with streptomycin serving as the reference standard. The pomegranate peel formulation returned an alkaline pH of 9.0, a low moisture content of 0.2% w/w, an acceptable angle of repose of 34.22°, a non-abrasive surface response, and inhibitory activity against both test organisms that matched the marketed product, with minimum inhibitory concentrations exceeding 125 mg against E. coli and 250 mg against Bacillus spp. for either sample. Taken together, these results suggest that pomegranate peel can be turned into a safe, low-cost and ecologically sensible herbal dentifrice whose performance sits comfortably alongside an established Ayurvedic marketed product.*

Keywords *- Pomegranate peel, Punica granatum, herbal tooth powder, Vicco Vajradanti, oral hygiene, antimicrobial activity, agro-waste utilization*

1. INTRODUCTION

Keeping the mouth clean is one of the simplest yet most consequential habits a person can maintain, since neglecting it opens the door to dental caries, plaque build-up, gingivitis, periodontal disease and persistent bad breath. A large share of the blame for tooth decay and plaque formation falls on resident oral bacteria, particularly Streptococcus mutans and Lactobacillus species, and dentifrices such as tooth powders and toothpastes remain the frontline tools for keeping their numbers in check while supporting healthy gums and teeth [1,11,13].

The dentifrices that dominate store shelves typically lean on synthetic detergents, preservatives, artificial flavours and abrasive fillers. Used over months or years, these ingredients have been associated with enamel erosion, heightened tooth sensitivity, irritation of the oral mucosa, altered taste perception and disturbance of the natural oral microbial balance [11,14,17]. Such drawbacks have steadily pushed both formulators and consumers towards herbal oral-care alternatives, which are generally regarded as gentler, more affordable and more biocompatible [5,14].

Pomegranate (Punica granatum L.) peel was chosen as the active ingredient for this study on the strength of its phytochemical profile. The peel is a rich source of tannins, flavonoids, polyphenols, punicalagin and ellagic acid, constituents that have repeatedly demonstrated antimicrobial, antioxidant, anti-inflammatory and anticariogenic effects [4,15,22]. Its tannin fraction lends an astringent action that helps tighten gum tissue and calm inflammation, while its polyphenols interfere with bacterial cell walls and enzymes, curbing the growth of oral pathogens [1,3,10,23]. A further, more practical motivation was waste utilisation: pomegranate peel is generated in large quantities as a by-product of fruit consumption and processing and is usually thrown away, so channelling it into an oral-care formulation offers both a therapeutic and an environmental payoff [15,22].

A powder, rather than a paste, gel, mouthwash or tablet, was selected as the dosage form because tooth powders are among the oldest and most uncomplicated dentifrice preparations used in Ayurvedic practice. They need no synthetic binders, surfactants, humectants or preservatives, which keeps the formulation simple and shelf-stable [9,17]; the near-absence of moisture also limits the chances of microbial contamination during storage, and direct powder-to-tooth contact is thought to improve cleansing and antimicrobial action [6,8].

Vicco Vajradanti Tooth Powder was used as the benchmark for comparison because it is among the best-known and most widely sold Ayurvedic dentifrices in the Indian market, built from herbal ingredients such as babul, vajradanti, clove, cinnamon, bakul and licorice that are traditionally credited with strengthening gums and slowing tooth decay [18]. Being an established, commercially successful product, it offered a realistic yardstick against which the physicochemical behaviour and antimicrobial activity of the experimental pomegranate peel powder could be judged [11,17].

Against this background, the present study set out to formulate a pomegranate peel-based herbal tooth powder, characterise its physicochemical properties and antimicrobial activity against representative Gram-positive and Gram-negative oral bacteria, and compare these outcomes with those of the marketed Vicco Vajradanti tooth powder, with a view to assessing the peel's potential as a safe, economical and eco-friendly dentifrice ingredient.

2. MATERIALS AND METHODS

2.1 Plant material and drug profile

Fresh pomegranate fruits were procured locally and their peels were separated, washed and used as the source material for the active ingredient. Botanically, Punica granatum L. belongs to the family Lythraceae, and its dried pericarp is known to carry tannins, flavonoids, polyphenols, anthocyanins, punicalagin, ellagic acid and gallic acid, the peel alone accounting for roughly 30–40% of total fruit weight [4,6,7,15,22,24]. Punicalagin, the principal hydrolysable ellagitannin of the peel (molecular formula $C_{48}H_{28}O_{30}$, molecular weight 1084.7 g/mol, melting range 238–240 °C), is considered a major contributor to the peel's antioxidant, antimicrobial, anti-inflammatory, anticariogenic and wound-healing activity, largely through free-radical scavenging and disruption of microbial cell walls and enzymes [1,4,10,19,23,24].

2.2 Preliminary phytochemical screening

Before formulation, the dried and powdered pomegranate peel was screened for its major phytochemical classes using standard wet-chemistry colour tests: ferric chloride for tannins, lead acetate solution for phenolic compounds, dilute ammonia with concentrated sulphuric acid for flavonoids, Mayer's and Wagner's reagents after acid hydrolysis for alkaloids, and concentrated sulphuric acid in chloroform for steroids [6,7,8]. The colour changes recorded for each test are summarised in the Results section (Table 2 and Fig. 1).

2.3 Formulation of the pomegranate peel tooth powder

Freshly collected pomegranate peels were rinsed thoroughly to remove surface debris and shade-dried for seven days until no residual moisture remained (Fig. 2), after which they were reduced to a fine powder using a mixer grinder (Fig. 3 and Fig. 4) to increase surface area and aid uniform blending (Fig. 5). The peel powder was then passed through a suitable sieve, as were the remaining excipients, to remove coarse particles and impurities (Fig. 6) [6,8].

A 20 g batch of tooth powder was prepared by combining pomegranate peel powder [19,17] with Triphala churna [25,26], kaolin, sodium bicarbonate and clove oil [30] in the proportions listed in Table 1, with kaolin functioning as the principal abrasive, sodium bicarbonate as a mild abrasive and buffering agent, and clove oil supplying flavour together with mild analgesic and antiseptic action. All sieved ingredients were combined by geometric dilution until a visually homogeneous blend was obtained, and the finished powder was packed into a clean, dry, airtight container, labelled and stored at room temperature (Fig. 7) [6,8].

table 1: composition of the formulated pomegranate peel tooth powder (batch size: 20 g)

Ingredient	Quantity	Functional category
Pomegranate peel powder	5 g	Antimicrobial agent / antioxidant
Triphala churna	5 g	Herbal therapeutic agent
Kaolin	6.5 g	Abrasive agent
Sodium bicarbonate	3.5 g	Mild abrasive / buffering agent
Clove oil	q.s.	Flavouring agent / analgesic / antiseptic

fig. 2: shade-dried pomegranate peels prior to size reduction

fig. 3: peel fragments undergoing particle size reduction in a mixer grinder

fig. 4: mixer grinder (model: classic 333) used for powdering

fig. 5: pomegranate peel powder obtained after grinding

fig. 6: sieving of the powdered ingredient blend

fig. 7: packaged formulated pomegranate peel tooth powder

2.4 Evaluation of the tooth powders

Identical evaluation procedures were applied to both the formulated pomegranate peel tooth powder and the marketed Vicco Vajradanti tooth powder so that the two could be compared on equal footing.

Organoleptic properties such as colour, odour, taste and texture were assessed by direct sensory observation. Particle size distribution was studied by sieve analysis using sieve numbers 60 and 80 (Fig. 8): a known quantity of powder was placed on the nested sieves, shaken mechanically for a fixed interval, and the amount retained on each sieve was weighed [8,27].

Bulk density was determined by gently introducing a weighed quantity of powder into a graduated cylinder without compaction and recording the volume occupied, while tapped density was obtained by mechanically tapping the same cylinder until the volume stabilised (Fig. 9). Hausner's ratio was then calculated as the tapped-to-bulk density ratio, and the angle of repose was measured by the fixed funnel method, in which powder was allowed to flow through a funnel onto a flat surface to build a conical heap whose height and base radius were used to compute the angle ($\theta = \tan^{-1}(h/r)$) [8,27,29].

For pH determination, one gram of powder was dispersed in 10 mL of distilled water, allowed to stand for 30 minutes, and the pH of the resulting suspension was read on a calibrated digital pH meter [9,17]. Loss on drying was measured by drying a known mass of powder in a hot air oven to constant weight and applying the relation Loss on Drying = [(Initial Weight − Final Weight) / Initial Weight] × 100 [6,8].

Foaming index was assessed by shaking 0.5 g of powder with 5 mL of distilled water in a measuring cylinder and recording the volume of foam generated after a brief rest period [9,17]. Finally, an abrasion test was carried out by rubbing a small quantity of powder against a clean china dish under finger pressure for a fixed time, after which the dish surface was visually inspected for scratching, since enamel-equivalent abrasion testing apparatus was not available [17,28].

fig. 8: sieve analysis set-up used for particle size determination

fig. 9: bulk and tapped density apparatus

2.5 Antimicrobial susceptibility testing

Antimicrobial activity of both tooth powders was evaluated by a resazurin-based microdilution assay for minimum inhibitory concentration (MIC), carried out at the Advanced Scientific Research Laboratory, Department of Chemistry, Abeda Inamdar Senior College, Pune. The test organisms were Bacillus spp. (ATCC 11778), representing Gram-positive bacteria, and Escherichia coli (ATCC 8739), representing Gram-negative bacteria, with streptomycin used as the reference antibiotic [1,10,17,23].

Fresh broth cultures of both organisms were grown in sterile Muller Hinton broth at 37 °C for 24 hours and adjusted to a turbidity of 0.5 McFarland standard (approximately 1×10^8 CFU/mL), then diluted to a working inoculum of 1×10^5 CFU/mL. In sterile 96-

well microtitre plates, 100 µL of microbial suspension was dispensed into each well, 100 µL of the test sample (pomegranate peel tooth powder or Vicco Vajradanti tooth powder) was added to the first well of each row and serially diluted across the remaining wells, and growth and sterility controls were included on every plate [3,10,23].

Plates were incubated at 37 °C for 18–24 hours to allow microbial growth, after which 10 µL of 0.01% w/v resazurin solution was added to each well and the plates were incubated for a further 2–4 hours. Reduction of resazurin by metabolically active organisms turns the dye from blue to pink, so the MIC was read as the lowest test concentration at which a well remained blue, indicating that growth had been suppressed.

3. RESULTS AND DISCUSSION

3.1 Preliminary phytochemical screening

The colour reactions obtained for pomegranate peel powder (Table 2 and Fig. 1) confirmed the presence of tannins, phenolic compounds, flavonoids, alkaloids and steroids. The clear positive responses for tannins, phenols and flavonoids are consistent with literature reports on pomegranate peel and support its selection as the active ingredient, since these very classes of compounds are widely credited with the antioxidant and antimicrobial behaviour expected of the formulation.

table 2: Preliminary phytochemical screening of pomegranate peel powder

Test	Observation	Inference
Tannins	Dark green colour	Positive
Phenols	White precipitate	Positive
Flavonoids	Yellow colour	Positive
Alkaloids	Cream-coloured precipitate	Positive
Steroids	Greenish colour	Positive

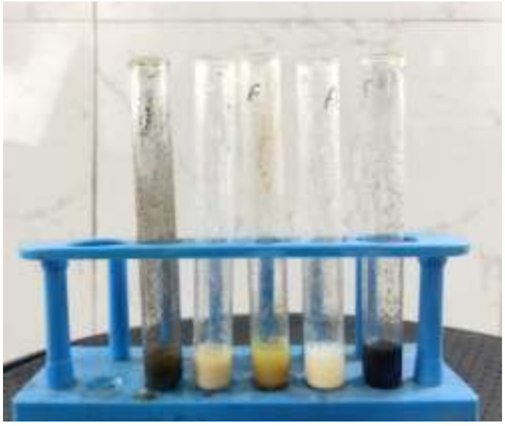

fig. 1: colour changes observed during preliminary phytochemical screening of pomegranate peel powder

3.2 Particle size, packing and flow behaviour

Sieve analysis (Fig. 8 for apparatus, Fig. 13 for the Vicco sample) showed that the bulk of both powders was retained on sieve no. 80, confirming a fine and reasonably uniform particle size in each case; the formulated powder retained 0.10 g on sieve no. 60 and 1.19 g on sieve no. 80, against 0.04 g and 0.12 g, respectively, for Vicco Vajradanti, indicating that the experimental batch carried a somewhat coarser overall fraction.

Bulk and tapped density measurements (Fig. 9) gave values of 0.57 g/mL and 1.0101 g/mL for the formulated powder, compared with 0.45 g/mL and 0.66 g/mL for the marketed product, so the pomegranate peel formulation packed more densely on tapping. The corresponding Hausner's ratios of 1.77 and 1.46 both point to comparatively poor flow by that measure, yet the angle of repose told a more favourable story for the experimental powder: 34.22° (Fig. 14) against 38.66° for Vicco Vajradanti, placing the formulated powder in the 'good' flow category and the marketed product in the 'fair' category. The mismatch between Hausner's ratio and angle of repose is not unusual for fine herbal powders, where inter-particulate cohesion can inflate the tapped-to-bulk density ratio even as the powder still flows acceptably under gravity.

fig. 13: sieve analysis of vicco vajradanti tooth powder

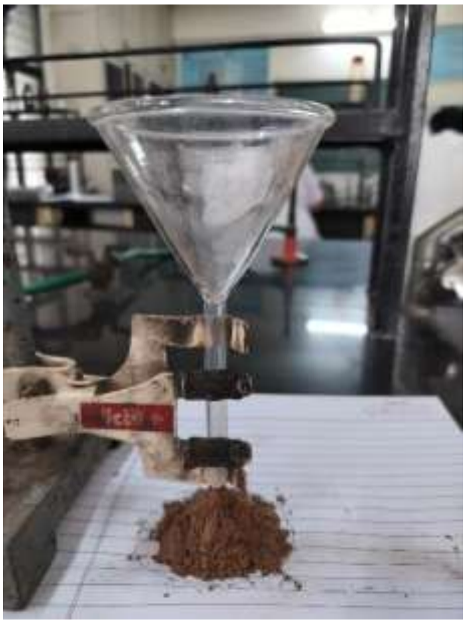

fig. 14: angle of repose determination by the fixed funnel method

3.3 pH, moisture content and foaming behaviour

The formulated tooth powder showed an alkaline pH of 9.0, whereas Vicco Vajradanti measured 6.23, essentially neutral to mildly acidic (Fig. 15). An alkaline reaction is generally seen as desirable in a dentifrice because it can help neutralise the organic acids produced by cariogenic bacteria, so the pomegranate peel formulation may offer an added buffering benefit that the marketed comparator does not.

Loss on drying came to 0.2% for the formulated powder and 0.33% for Vicco Vajradanti (Fig. 10), both comfortably low and indicative of good storage stability with little risk of moisture-driven microbial spoilage. Foaming index, recorded as the volume of foam generated from 0.5 g of powder in 5 mL of water, was 0.7 mL for the formulated powder against 0.4 mL for the marketed product (Fig. 11); both fall in the mild-foaming range expected of a powder rather than a surfactant-rich paste, with the experimental formulation showing a slightly stronger cleansing-foam response.

fig. 10: petri dishes in the hot air oven during loss-on-drying determination

fig. 11: foaming index test: formulated tooth powder (right) and vicco vajradanti tooth powder (left)

3.4 Organoleptic character and abrasiveness

On sensory evaluation, the formulated powder was light brown with a faint clove/astringent odour and a bitter, astringent aftertaste, while Vicco Vajradanti was darker brown with a characteristic menthol aroma and a cooling, slightly bitter-sour taste; both powders shared a smooth texture. In the abrasion test, neither powder produced any visible scratching on the china dish surface (Fig. 12), suggesting that both are non-abrasive enough for routine oral use, although this bench-top substitute test cannot fully reproduce the wear behaviour of natural enamel and should be read as an indicative result only.

fig. 12: abrasion test on china dish: formulated tooth powder (left) and vicco vajradanti tooth powder (right)

3.5 Comparative physicochemical summary

table 3: comparative physicochemical evaluation of the formulated pomegranate peel tooth powder and marketed vicco vajradanti tooth powder

Parameter	Formulated tooth powder	Vicco Vajradanti tooth powder
Colour	Light brown	Dark brown
Odour	Mild clove / astringent	Menthol-like
Taste	Bitter, astringent aftertaste	Slightly bitter-sour, cooling menthol note
Texture	Smooth	Smooth
Wt. retained on sieve no. 60 (g)	0.10	0.04
Wt. retained on sieve no. 80 (g)	1.19	0.12
Bulk density (g/mL)	0.57	0.45
Tapped density (g/mL)	1.0101	0.66
Hausner's ratio	1.77	1.46

Angle of repose	34.22°	38.66°
Flow property	Good	Fair
pH (aqueous dispersion)	9.0	6.23
Loss on drying (%)	0.2	0.33
Foaming index (mL)	0.7	0.4
Abrasion on china dish	Not detected	Not detected

3.6 Antimicrobial susceptibility (MIC)

Both tooth powders inhibited the growth of the test organisms in the resazurin microdilution assay, evidenced by wells that remained blue rather than turning pink at the concentrations tested (Fig. 16 and Fig. 17). The MIC of the formulated pomegranate peel tooth powder against Escherichia coli was above 125 mg, identical to that recorded for Vicco Vajradanti, while against Bacillus spp. both powders returned an MIC of 250 mg.

Both formulations were therefore more active, in relative terms, against the Gram-positive Bacillus spp. than against the Gram-negative E. coli, a pattern commonly attributed to the additional outer membrane that Gram-negative cells possess, which restricts the entry of many plant-derived antimicrobials [12]. The fact that the experimental pomegranate peel powder matched the marketed product at every tested concentration is an encouraging sign for its antimicrobial credentials, although the MIC values obtained here are comparatively high next to those of purified antibiotics, which is expected for a crude, multi-component herbal powder rather than an isolated active compound; testing at higher concentrations and with more refined extracts would help establish a tighter MIC range.

table 4: minimum inhibitory concentration (mic) of the formulated and marketed tooth powders (standard: streptomycin)

Test organism	MIC of formulated tooth powder	MIC of vicco vajradanti tooth powder
Escherichia coli (Gram-negative)	Above 125 mg	Above 125 mg
Bacillus spp. (Gram-positive)	250 mg	250 mg

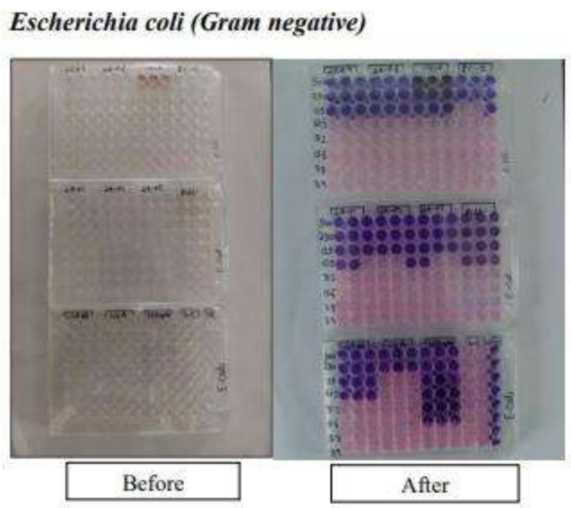

fig. 16: resazurin mic assay plates for Escherichia coli before (left) and after (right) incubation

Bacillus spp.(Gram positive)

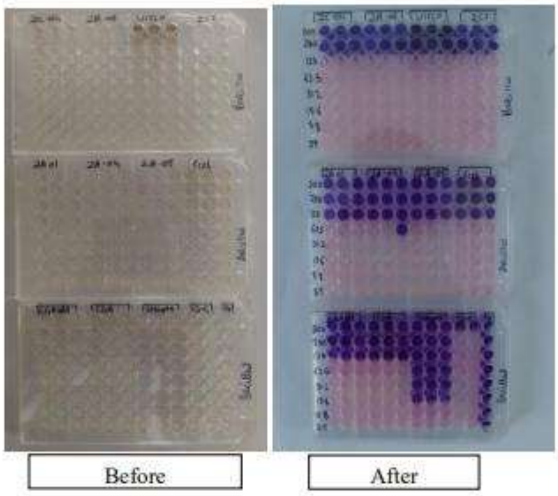

fig. 17: resazurin mic assay plates for bacillus spp. before (left) and after (right) incubation

3.7 Overall Comparative Discussion

Taken together, the data indicate that the pomegranate peel-based tooth powder performs at least as well as the established Vicco Vajradanti product on most of the parameters tested. It packed more densely, showed a better angle of repose, carried a beneficial alkaline pH, retained slightly less moisture on drying, foamed a little more strongly, and matched the marketed powder's antimicrobial activity against both test organisms, while remaining equally non-abrasive. Its main disadvantage relative to the marketed product was a somewhat coarser particle size fraction and a higher Hausner's ratio, both of which point to scope for refining the milling and sieving steps in any future scale-up of the formulation.

4. CONCLUSION

A herbal tooth powder built around pomegranate peel, Triphala churna, kaolin, sodium bicarbonate and clove oil was successfully formulated and benchmarked against the marketed Vicco Vajradanti tooth powder. The experimental formulation displayed acceptable organoleptic properties, a favourable alkaline pH, low moisture content, a mild but adequate foaming response, a non-abrasive surface profile, and antimicrobial activity against Escherichia coli and Bacillus spp. that was comparable to the marketed product. These outcomes support the view that pomegranate peel, a fruit-processing by-product that is ordinarily discarded, can be converted into a safe, economical and environmentally sensible ingredient for herbal oral-care products, and that the resulting tooth powder is a reasonable candidate dentifrice for further development and larger-scale evaluation.

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