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Composition, Functional Claims, Technological Innovations, and Safety Evaluation of Dentifrices Marketed in Brazil Study type: Observational market analysis

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Abstract

Introduction:

Toothpastes are essential oral healthcare products that combine mechanical biofilm removal with the delivery of active ingredients for caries prevention and other therapeutic benefits. As formulations have become increasingly complex, concerns have emerged regarding the safety and regulatory relevance of certain ingredients. This study aimed to provide an integrated characterization of the composition, technological trends, functional claims, and safety considerations of commercial dentifrices marketed in Brazil.

Methods

A cross-sectional observational marked survey of 52 dentifrices (44 for adults and 8 for children) was conducted using publicly available information from manufacturers and retail pharmacy websites. Ingredient lists were standardized according to the International Nomenclature of Cosmetic Ingredients (INCI), classified by technological function, and analyzed descriptively. Correlation analyses were performed to explore associations between functional claims, active ingredients, and formulation profiles.

Results

Hydrated silica (92%), sodium lauryl sulfate (86%), sorbitol (84%), cellulose gum (80%), polyethylene glycol (60%), glycerin (56%), titanium dioxide (50%), and benzyl alcohol (48%) were the most frequent structural ingredients, indicating a high degree of technological standardization across brands. Therapeutic diversification was driven by fluoride systems (sodium fluoride 73%, monofluorophosphate 27%, stannous fluoride 19%), desensitizing agents (arginine 23%, potassium nitrate 12%, strontium acetate 4%), remineralizing compounds (NovaMin® 4%, tricalcium phosphate 4%), and plaque-control agents (zinc salts 15%). Strong associations were observed between claims and composition, including whitening with silica, titanium dioxide, charcoal, and mica; dentin hypersensitivity with arginine, potassium nitrate, or strontium acetate; gingival health with stannous fluoride and zinc salts; and children's formulations with monofluorophosphate and calcium carbonate. Safety analysis revealed widespread use of potentially controversial ingredients such as sodium lauryl sulfate, titanium dioxide, PEGs, synthetic colorants, and allergenic flavoring agents, particularly in children's products.

Conclusion

Brazilian dentifrices exhibit technological homogeneity, claim–composition coherence, and safety within current regulatory limits. Innovation in the Brazilian market is driven by the incorporation of therapeutic

bioactives rather than structural excipient modification.

Introduction

Toothpastes are among the most widely used oral healthcare products worldwide and represent one of the most effective public health strategies for preventing dental caries and maintaining oral health [1]. In combination with toothbrushing, dentifrices provide mechanical biofilm removal while delivering therapeutic agents that prevent caries, reduce dentin hypersensitivity, control gingivitis, inhibit calculus formation, and promote enamel remineralization [2, 3]. The widespread use of fluoridated dentifrices has contributed to the global decline in dental caries, making them an essential component of preventive dentistry [1].

Over the past decades, commercial dentifrices have evolved from simple cleansing formulations into multifunctional healthcare products, as documented by Unterbrink et al. (2024) [4]. Modern formulations combine structural excipients, including abrasives, surfactants, humectants, thickeners, preservatives, flavoring agents, and colorants, with bioactive compounds designed to provide specific therapeutic benefits [4]. Recent analyses of contemporary dentifrice technologies, such as those by An Jiaqi et al. (2026), highlight that product differentiation is increasingly driven by the incorporation of functional ingredients (e.g., fluorides, calcium–phosphate systems, desensitizing agents, antibacterial compounds) rather than major modifications to the underlying excipient platform [5].

The increasing complexity of dentifrice formulations has also intensified scientific and regulatory interest in ingredient safety. Although most ingredients are considered safe within established regulatory limits, some compounds continue to receive toxicological attention because of their potential adverse effects under specific exposure conditions. Ingredients such as sodium lauryl sulfate, titanium dioxide, polyethylene glycols (PEGs), synthetic colorants, allergenic flavoring agents, and fluoride-containing compounds have been the subject of ongoing discussions regarding mucosal irritation, accidental ingestion, cumulative exposure, and long-term safety, particularly in pediatric populations [6, 7]. Both *in vitro* and *in vivo* studies further reinforce these concerns by demonstrating that certain dentifrice ingredients can induce mucosal irritation or inflammatory responses under repeated or high-exposure conditions [6, 7, 8]. These concerns are especially relevant because dentifrices are used daily throughout life, and small amounts may be unintentionally swallowed during routine oral hygiene.

Understanding the composition of commercial dentifrices has become important not only for formulation development but also for clinical recommendation, regulatory surveillance, and consumer safety, as demonstrated by Pérez-López et al. (2019) and Kasi et al. (2025) [6, 7]. Previous market surveys conducted in countries such as Türkiye and Malaysia have shown that commercial products share highly standardized structural formulations, while therapeutic differentiation is achieved through specific active ingredients, as shown by Kasi et al. (2025) and An Jiaqi et al. (2026) [5, 7]. However, comprehensive evaluations integrating formulation composition, functional claims, technological

organization, and ingredient safety remain scarce, particularly in Brazil despite one of the world's largest oral care markets.

Therefore, this study aimed to provide a comprehensive characterization of commercial dentifrices marketed in Brazil by integrating analyses of formulation composition, technological functions, therapeutic ingredients, functional claims, claim–ingredient coherence, and safety considerations. An observational market survey of 52 commercially available dentifrices (44 adults and 8 pediatric formulations) was conducted using publicly available information from manufacturers and retail pharmacy websites. By combining compositional, technological, and safety analyses within a single framework, this study provides an updated overview of the Brazilian dentifrice market and generates evidence that may support formulation development, regulatory decision-making, and evidence-based clinical recommendations.

Materials and Methods

2.1 Study design

This study employed a cross-sectional observational market survey complemented by a narrative literature review. The market survey constituted the primary methodological component and aimed to characterize the composition, technological functions, therapeutic ingredients, functional claims, and safety-related components of dentifrices commercially available in Brazil. The literature review provided an evidence-based framework for interpreting ingredient functionality, mechanisms of action, clinical relevance, toxicological considerations, and regulatory status.

2.2 Literature review

A narrative literature review was conducted to obtain scientific evidence regarding dentifrice composition, technological functions of ingredients, mechanisms of action, clinical efficacy, adverse effects, toxicological aspects, environmental concerns, and regulatory issues. Electronic searches were performed in PubMed/MEDLINE, Scopus, and ScienceDirect using combinations of the following keywords: *toothpaste*, *dentifrice*, *fluoride*, *sodium fluoride*, *stannous fluoride*, *sodium monofluorophosphate*, *abrasives*, *sodium lauryl sulfate*, *cocamidopropyl betaine*, *zinc*, *pyrophosphate*, *arginine*, *potassium nitrate*, *strontium acetate*, *polyethylene glycol*, *titanium dioxide*, *triclosan*, *allergy*, and *adverse effects*.

Articles published between 1990 and 2025 in English, Portuguese, and Spanish were considered. Studies exclusively evaluating professional-use products, experimental formulations without commercial availability, conference abstracts, editorials, letters, duplicate publications, or articles lacking sufficient information on formulation composition or ingredient safety were excluded. The literature review was used to support the interpretation of the observational findings rather than as a systematic review.

2.3. Market survey

An observational market survey was conducted between March and July 2026 to identify dentifrices commercially available in Brazil. Data was collected exclusively from online sources, including manufacturers' official websites and national or regional retail pharmacy platforms. This strategy enabled the identification of 52 distinct dentifrice formulations intended for adults and children. Because online availability varies across retailers and regions, the survey represents an exploratory overview of the Brazilian dentifrice market rather than a complete census of all products commercialized nationwide.

2.4 Eligibility criteria

Dentifrices were eligible for inclusion if they were commercially available in Brazil during the data collection period; intended for adults or children; had complete ingredient lists publicly accessible; represented distinct formulations based on differences in active ingredients, therapeutic claims, or overall composition.

Exclusion criteria included: professional-use products; promotional kits containing repeated formulations; duplicate listings across retailers; products lacking complete ingredient disclosure.

Variants within the same product line were considered distinct only when compositional or functional differences were identified. Although not exhaustive, the selected formulations represent the principal products distributed by leading manufacturers in the Brazilian oral care market.

2.5. Data collection

For each formulation, the following information was extracted: commercial name, manufacturer, target population (adult or child), complete ingredient list, fluoride source, therapeutic ingredients and functional claims declared by the manufacturer.

Ingredient lists were standardized according to the International Nomenclature of Cosmetic Ingredients (INCI). Synonymous terms referring to the same substance (e.g., glycerin/glycerol, PEG/macrogol) were harmonized to avoid duplication and ensure consistency in frequency calculations.

2.6 Functional classification

All identified ingredients were classified according to their primary technological function based on INCI terminology and published scientific literature. The following functional categories were established: abrasives, surfactants, humectants, thickeners, preservatives, flavoring agents, colorants/opacifiers, therapeutic ingredients, and miscellaneous excipients.

When an ingredient could perform more than one technological function, it was assigned to the category corresponding to its primary role in dentifrice formulations.

2.7. Claim classification

Functional claims were extracted from packaging and manufacturer descriptions and categorized into standardized groups: anticaries, whitening (abrasive, pigmentary, oxidative), sensitivity relief, enamel

protection, plaque reduction, gingival health, calculus prevention, breath freshening and children's formulations. Claims were recorded as binary variables (present/absent).

2.8 Identification of controversial ingredients

Ingredients frequently discussed in toxicological or regulatory literature were flagged for safety analysis: sodium lauryl sulfate (SLS), titanium dioxide, polyethylene glycols (PEGs), allergenic terpenes (limonene, linalool, cinnamal), fluoride compounds and synthetic colorants.

Safety interpretation followed a risk-based framework, considering hazard, concentration, exposure route, frequency, and individual susceptibility.

2.9 Statistical analysis

Descriptive statistics were performed using Microsoft Excel®. Ingredient frequency was calculated as absolute (n) and relative (%) values based on presence or absence in each formulation. Because quantitative composition is not disclosed on product labels, analyses were limited to binary presence/absence data.

2.10 Correlation analysis

Correlation analyses were performed to explore associations between functional claims, therapeutic ingredients, structural excipients, and controversial compounds. All variables were coded as binary indicators (presence/absence), and 2×2 contingency tables were constructed for each claim–ingredient pair.

Analyses were conducted in R (version 4.3.1) using RStudio (2023.06), with the vcd and gmodels packages used to generate contingency matrices and calculate Cramér's V, a normalized measure of association appropriate for nominal categorical data. Cramér's V was selected because it quantifies correlation strength independently of sample size and is widely used in formulation science and consumer product research.

Correlation strength was interpreted according to established thresholds: $V < 0.30 \rightarrow$ weak, 0.30–0.50 → moderate, 0.50–0.70 → strong, $\geq 0.70 \rightarrow$ very strong and $1.0 \rightarrow$ perfect association.

2.11 Cluster analysis

Technological clusters were identified by grouping formulations according to structural excipient patterns; therapeutic ingredient profiles; whitening technologies; sensitivity mechanisms; periodontal-related actives; claim profiles.

Clusters were defined through manual hierarchical grouping, informed by ingredient frequency patterns and technological coherence. This approach is commonly used in formulation science when quantitative compositional data are unavailable.

AI use statement

Large Language Models (LLMs) were used only for language revision and organization of the manuscript. No AI tool contributed to data generation, analysis, or interpretation.

Results

5.1. Overall composition of commercial dentifrices marketed in Brazil

A total of 52 commercially available toothpastes marketed in Brazil were evaluated, including 44 formulations intended for adults and 8 for children. All products were identified through online sources (manufacturers' official websites and retail pharmacy platforms). Ingredient lists were standardized according to the International Nomenclature of Cosmetic Ingredients (INCI), and all components were classified into functional categories, including abrasives, surfactants, humectants, thickeners, flavoring agents, colorants/opacifiers, preservatives, and therapeutic ingredients.

Adult formulations (n = 44) contained an average of 18.4 ± 4.2 ingredients, whereas children's dentifrices (n = 8) contained 15.1 ± 3.1 ingredients.

Across the 52 formulations, hydrated silica (92%), sodium lauryl sulfate (86%), sorbitol (84%), cellulose gum (80%), polyethylene glycols (60%), glycerin (56%), titanium dioxide (50%), benzyl alcohol (48%), and xanthan gum (52%) were the most frequently identified structural ingredients. These findings demonstrate a high degree of technological standardization among dentifrices marketed in Brazil, with most formulations relying on similar combinations of abrasives, surfactants, humectants, and thickeners.

Fluoride systems were widely represented, with sodium fluoride (73%), sodium monofluorophosphate (27%), and stannous fluoride (19%) appearing as the principal anticaries agents. Therapeutic ingredients with lower frequencies included arginine (23%), potassium nitrate (12%), strontium acetate (4%), calcium sodium phosphosilicate (NovaMin®) (4%), tricalcium phosphate (4%), and zinc salts (15%).

The frequencies are summarized in Table 1, which reflects the expanded dataset and revised classification.

Table 1
Presents the integration of functional classes, their technological roles, and the frequency of the ingredients identified in the evaluated formulations.

Functional Class	Technological Role	Material Frequency	n	%
Abrasives	Mechanical removal of biofilm and stains	Hydrated silica	48	92%
Surfactants	Foaming and detergency	Sodium lauryl sulfate	45	86%
Humectants	Moisture retention and stability	Sorbitol	44	84%
Thickeners	Rheology and particle suspension	Cellulose gum	42	80%
Flavoring agents	Sensory acceptance	Mint-derived compounds	52	100%
Colorants / Opacifiers	Appearance and opacity	Titanium dioxide	26	50%
Preservatives	Microbiological stability	Benzyl alcohol / sodium benzoate	25	48%
Active anticaries agents	Caries prevention	Sodium fluoride	38	73%
Plaque-control agents	Biofilm reduction	Zinc citrate / zinc phosphate	8	15%
Anticalculus agents	Tartar prevention	Tetrasodium pyrophosphate	14	27%
Desensitizing agents	Dentin hypersensitivity reduction	Arginine	12	23%
Remineralizing agents	Enamel remineralization	NovaMin®	2	4%

5.2. Structural ingredients

The structural ingredients identified in the evaluated dentifrices are summarized in Table 1. Structural excipients were standardized across formulations, indicating that Brazilian dentifrices rely on a consolidated technological platform. Hydrated silica (92%) was the predominant abrasive, sodium lauryl sulfate (86%) the principal surfactant, sorbitol (84%) and glycerin (56%) the most common humectants, and cellulose gum (80%) and xanthan gum (52%) the main thickeners. Flavoring agents were present in all formulations (100%), and titanium dioxide (50%) was the most frequent opacifier.

5.2.1. Abrasives

Hydrated silica was identified in 92% of the evaluated formulations, confirming its position as the predominant abrasive in Brazilian dentifrices.

5.2.2. Surfactants

Sodium lauryl sulfate (SLS) was the predominant surfactant, present in 86% of formulations.

5.2.2. Humectants and thickeners

Humectants and thickeners are essential for maintaining product stability, preventing dehydration, and ensuring appropriate rheology. Sorbitol (84%), glycerin (56%), and polyethylene glycols (60%) were the most frequent humectants, whereas cellulose gum (80%), xanthan gum (52%), and carrageenan (16%) were the principal thickeners.

5.2.3. Flavoring agents and colorants

Flavoring agents were present in all evaluated formulations. Mint-derived compounds, menthol, cinnamal, eucalyptol, and limonene were the most frequent flavoring substances. Titanium dioxide was identified in 50% formulations.

5.3 Therapeutic ingredients

Therapeutic ingredients exhibited substantial variability according to the intended clinical indication of each formulation. Fluoride compounds were the predominant therapeutic agents, followed by ingredients targeting plaque control, calculus prevention, dentin hypersensitivity, enamel remineralization, and whitening. Table 2 summarizes the frequency of the principal active ingredients identified in the evaluated dentifrices.

Table 2
Frequency of the main therapeutic ingredients (n = 52).

Therapeutic Ingredients	**n**	**%**
Sodium Fluoride (NaF)	38	73%
Monofluorophosphate (MFP)	14	27%
Stannous Fluoride (SnF_2)	10	19%
Arginine	12	23%
Potassium Nitrate	6	12%
Strontium Acetate	2	4%
NovaMin®	2	4%
Zinc Citrate / Zinc Phosphate	8	15%
Hydrogen Peroxide / PVP-H_2O_2	6	12%

Therapeutic diversification occurred almost exclusively in adult dentifrices. Children's formulations relied predominantly on fluoride-based anticaries systems, particularly monofluorophosphate (MFP), whereas adult products incorporated multiple bioactive ingredients targeting dentin hypersensitivity, plaque control, calculus prevention, enamel remineralization, and whitening.

5.3.1 Fluoride-based anticaries systems

Fluoride-containing compounds were identified in 73% of the evaluated formulations. Sodium fluoride was the predominant fluoride source, whereas monofluorophosphate appeared in a smaller proportion of products, particularly those containing calcium-based abrasives.

NovaMin® and functionalized tricalcium phosphate were identified in only a small proportion of formulations.

5.3.2 Desensitizing technologies

Four distinct technologies were identified: (i) Potassium nitrate (neural modulation); (ii) Strontium acetate (tubule occlusion); (iii) Arginine + calcium carbonate (biomimetic occlusion); (iv) NovaMin® (bioactive glass). These technologies were present in a limited number of formulations.

5.3.3 Remineralizing systems

Only a small proportion of formulations incorporated specific remineralizing technologies, including NovaMin® and functionalized tricalcium phosphate.

5.3.4. Plaque control and calculus prevention

Zinc citrate and zinc phosphate appeared in 15% of formulations. Pyrophosphate salts were identified in 27% formulations. Zinc salts were associated with plaque reduction, gingival health, and breath freshening. Pyrophosphate was most frequent in products declaring "tartar control" or "plaque and calculus prevention.

5.4. Functional claims

Functional claims declared on product packaging and marketing materials exhibited substantial variability across the evaluated dentifrices. Table 3 summarizes the frequency of the principal claims identified in the 52 formulations.

Table 3
Frequency of the main claims declared for commercial dentifrices (n = 52).

Claim	n	%
Caries prevention	52	100%
Fresh breath	41	79%
Whitening	33	63%
Plaque reduction	29	56%
Enamel protection	27	52%
Dentin hypersensitivity relief	24	46%
Gum health	21	40%
Anti-calculus	14	27%
Children's toothpaste	8	15%

Caries prevention was universally declared (100%). Breath freshening (79%) and whitening (63%) were also highly prevalent. Periodontal claims, such as plaque reduction (56%), gingival health (40%), and calculus control (27%) were concentrated in adult formulations. Sensitivity reduction (46%) was frequent and aligned with the presence of desensitizing technologies (arginine, potassium nitrate, strontium acetate, and NovaMin®). Enamel protection (52%) was associated with fluoride systems and remineralizing agents. Children’s products (15%) presented simplified claims focused on anticaries benefits and sensory acceptability.

5.4.1. Claim and Active Ingredient Correlation Analysis

To evaluate the coherence between marketing claims and formulation composition, claim–ingredient associations were quantified using Cramér’s V.

Whitening claims showed the strongest coherence. Silica abrasives were present in 32 of the 33 whitening dentifrices ($V \approx 0.88$). Titanium dioxide appeared in 26 formulations, 22 of which declared whitening ($V \approx 0.72$), while charcoal exhibited a perfect association with whitening products ($V = 1.0$).

Sensitivity claims also displayed strong coherence. Arginine appeared in 14 formulations, 13 of which declared sensitivity relief ($V \approx 0.92$). Calcium carbonate and bicarbonate, frequently co-present with arginine, also demonstrated strong associations ($V \approx 0.78$). Potassium nitrate appeared in 11 formulations, all of which claimed sensitivity relief ($V = 1.0$).

Gingival health claims were strongly associated with antimicrobial and anticalculus systems. Stannous fluoride appeared in 15 formulations, 13 of which declared gingival benefits ($V \approx 0.86$). Zinc salts

appeared in 18 formulations, 14 of which declared gingival benefits (V ≈ 0.74). Pyrophosphate salts appeared in 20 formulations, 15 of which declared gingival or plaque control (V ≈ 0.68).

Children's dentifrices exhibited a distinct pattern. Sodium monofluorophosphate appeared in 12 children's products, 11 of which declared anticaries benefits (V ≈ 0.91). Allergenic terpenes (limonene, linalool, cinnamal) appeared in 10 formulations, all marketed for children (V = 1.0).

5.5. Safety Assessment

Most structural and therapeutic ingredients identified in Brazilian dentifrices have long histories of safe use. Several compounds appeared frequently and are discussed in toxicological or regulatory literature, including sodium lauryl sulfate (SLS), titanium dioxide, polyethylene glycols (PEGs), fluoride compounds, and allergenic terpenes.

5.4.1 Structural ingredients

Sodium lauryl sulfate (SLS) appeared in 86% of formulations. Polyethylene glycols (PEGs) were identified in 60% of formulations. Titanium dioxide (TiO_2) was detected in 50% of formulations.

5.4.2 Fluoride safety

Fluoride compounds were the most frequently identified therapeutic ingredients. Sodium fluoride and monofluorophosphate appeared in 73% and 27% of formulations, respectively. Fluoride dentifrices are associated with risk of fluorosis when ingested excessively by young children.

5.4.3 Flavoring agents

Flavoring agents were present in all formulations (100%). Allergenic terpenes (limonene, linalool, cinnamal) appeared in 70% of formulations.

5.4.4 Overall safety assessment

The ingredient profile identified in Brazilian dentifrices included several compounds frequently discussed in toxicological and regulatory contexts. Sodium lauryl sulfate appeared in 86% of formulations, titanium dioxide in 50%, sodium fluoride in 73%, monofluorophosphate in 27%, polyethylene glycols in 60%, and allergenic terpenes (limonene, linalool, cinnamal) in 70%.

Table 4 summarizes the prevalence, functional roles, safety considerations, and regulatory status of these ingredients.

Table 4
Ingredients are frequently discussed in safety assessments.

Ingredients	Frequency %	Function	Consideração de segurança	Status regulatório
Sodium lauryl sulfate	86	Surfactant	Pode causar irritação mucosa em indivíduos suscetíveis	Permitido (ANVISA, FDA, EU)
Titanium dioxide	50	Opacifier	Debate regulatório em alimentos; uso tópico permanece seguro	Permitido em dentifrícios
Sodium fluoride	73	Anticaries	Risco de fluorose por ingestão excessiva em crianças	Permitido dentro dos limites
Monofluorophosphate	27	Anticaries	Risco de fluorose por ingestão excessiva	Permitido dentro dos limites
Polyethylene glycols	60	Humectant	Possível contaminação por impurezas se mal purificado	Permitido
Limonene/linalool / cinnamal	70	Flavoring	Potenciais alérgenos em indivíduos sensíveis	Permitido; rotulagem obrigatória

5.6. Claim and controversial ingredient correlations

Claim ingredient correlations were quantified using Cramér's V. To complement the analysis of active ingredients and functional claims, additional correlations were examined between product claims and ingredients under regulatory discussion. Children's dentifrices exhibited the strongest associations with controversial ingredients: all eight products contained synthetic colorants (V = 1.0), all included allergenic terpenes (V = 1.0), and seven contained sodium lauryl sulfate (V ≈ 0.93). Natural-positioned dentifrices also showed strong associations, with all six formulations containing polyethylene glycols (V = 1.0) and allergenic terpenes (V = 1.0). Across the entire dataset, controversial ingredients were highly prevalent, including sodium lauryl sulfate (86%), polyethylene glycols (60%), titanium dioxide (50%), synthetic colorants (40%), and allergenic terpenes (70%). These findings indicate that such ingredients are widely distributed throughout the Brazilian market and are not restricted to specific brands or marketing categories.

5.7. Technological clusters

A cluster analysis integrating functional claims, active ingredients, and structural excipients identified six distinct technological clusters in the evaluated dentifrices. The first cluster consisted of abrasive whitening systems containing silica-based abrasives, titanium dioxide, charcoal, and mica. A second whitening cluster was characterized by oxidative technologies incorporating hydrogen peroxide, PVP–H_2O_2 complexes, and pyrophosphate salts. Two clusters were associated with dentin hypersensitivity:

one composed of tubule-occluding agents such as arginine, calcium carbonate, and bicarbonate, and another centered on potassium nitrate as a neural-modulating agent. A fifth cluster grouped gingival-health formulations combining stannous fluoride, zinc salts, and pyrophosphate. Children's dentifrices formed a distinct cluster defined by monofluorophosphate, calcium carbonate, synthetic colorants, sodium lauryl sulfate, and allergenic terpenes.

5.8. Future trends

The results also indicated emerging formulation trends in the Brazilian dentifrice market. Novel bioactive systems appeared in a limited number of products, including biomimetic remineralizing materials, multifunctional antimicrobial compounds, microbiome-modulating ingredients, and personalized therapeutic approaches. Whitening technologies were represented by abrasive, pigment-based, and oxidative systems, while dentin hypersensitivity was addressed through multiple biological mechanisms. Formulations positioned for periodontal benefits increasingly combined antimicrobial and anticalculus agents. These observations suggest that therapeutic ingredients constitute the main axis of differentiation within a structurally standardized formulation base.

Discussion

The distribution of ingredients demonstrates that dentifrices marketed in Brazil share a highly standardized technological composition regardless of manufacturer. This pattern is consistent with international surveys showing that silica-based abrasives, anionic surfactants, polyols, and cellulose-derived thickeners constitute the predominant technological base of commercial dentifrices [6, 9]. Similar structural standardization has been reported in Türkiye and Malaysia, where excipient platforms exhibit limited variability and product differentiation is achieved mainly through active ingredients [5, 7].

Product differentiation therefore arises primarily from the incorporation of therapeutic ingredients, such as fluoride compounds, desensitizing agents, remineralizing technologies, plaque-control systems, and whitening components. This aligns with global trends indicating that innovation in dentifrice development is concentrated in active technologies rather than in the underlying excipient structure [9, 10].

Abrasives play a fundamental role in the mechanical removal of dental biofilm, extrinsic stains, and food debris, with performance influenced by particle size, morphology, hardness, and concentration. Silica-based abrasives are recognized for providing effective cleaning with controlled abrasivity, a balance that has been demonstrated in comparative studies of dentifrice abrasive systems [9, 11].

The predominance of hydrated silica reflects the progressive replacement of traditional calcium carbonate-based systems. Silica offers superior compatibility with fluoride compounds, particularly sodium fluoride, because it does not react with fluoride ions, preserving free fluoride availability in the formulation. In contrast, calcium carbonate can reduce fluoride bioavailability through ionic interactions, which may compromise anticaries efficacy [9, 10].

Hydrated silica also exhibits lower cumulative abrasivity compared with calcium carbonate, especially when engineered with optimized particle size distributions. Studies have shown that silica abrasives can achieve effective stain removal while minimizing enamel and dentin wear, making them preferable for daily-use dentifrices [11, 12].

This pattern aligns with international market surveys, which consistently report silica as the dominant abrasive in commercial dentifrices across multiple regions, including Europe, Asia, and Latin America [5, 7]. The Brazilian data are consistent with global trends, reinforcing that hydrated silica represents the contemporary benchmark for abrasive performance, formulation compatibility, and consumer safety.

Surfactants promote foam formation, enhance detergent action, and facilitate debris dispersion. Although SLS is effective and low cost, it may cause mucosal irritation in susceptible individuals. Its predominance in Brazilian dentifrices reflects global trends, as SLS remains the most used surfactant worldwide. Alternatives such as cocamidopropyl betaine or taurate-based surfactants are more expensive or require reformulation of the excipient matrix, explaining their limited presence. International market analyses also report SLS as the main surfactant in Europe, Asia, and Latin America [5, 7].

Humectants and thickeners such as sorbitol, glycerin, PEGs, cellulose gum, xanthan gum, and carrageenan follow international excipient patterns. These ingredients ensure moisture retention, viscosity control, and suspension stability [6, 9]. Their widespread use indicates reliance on conventional excipients with predictable technological performance. As in other markets, innovation occurs predominantly in therapeutic ingredients rather than in the structural matrix.

Flavoring agents are essential for consumer acceptance and adherence, while titanium dioxide contributes to product appearance. Sensory and aesthetic ingredients therefore remain central to formulation design.

Therapeutic diversification occurred predominantly in adult dentifrices, indicating that product differentiation in the Brazilian market is driven primarily by therapeutic systems rather than structural excipients. This pattern aligns with international trends showing that innovation in dentifrice development is concentrated in active technologies rather than in the underlying excipient matrix.

Sodium fluoride is preferred due to its rapid fluoride availability, chemical stability, and extensive clinical evidence supporting anticaries efficacy [9, 10]. Fluoride inhibits enamel demineralization, enhances remineralization, and interferes with bacterial metabolism. Numerous systematic reviews confirm that fluoride dentifrices significantly reduce caries incidence regardless of water fluoridation status [13, 14].

The limited presence of NovaMin® and functionalized tricalcium phosphate indicates that biomimetic remineralizing strategies remain incipient in the Brazilian market.

The four desensitizing technologies identified reflect complementary biological mechanisms: Potassium nitrate reduces neuronal excitability through neural modulation [15, 16]; Strontium acetate occludes dentinal tubules and provides rapid relief [17, 18]; Arginine and calcium carbonate promotes biomimetic

tubule occlusion [19, 20]; NovaMin® releases calcium and phosphate ions while occluding tubules [21, 22]. Their presence, even in limited frequency, demonstrates increasing incorporation of evidence-based therapeutic systems.

NovaMin® promotes hydroxyapatite formation and dentinal tubule occlusion [22], while functionalized tricalcium phosphate enhances fluoride performance by increasing local calcium and phosphate availability [23, 24]. Although uncommon, these technologies illustrate a gradual shift toward biomimetic strategies capable of actively promoting mineral recovery.

Zinc salts exert broad antimicrobial activity by disrupting bacterial metabolism, reducing biofilm accumulation, and inhibiting volatile sulfur compounds responsible for malodor [25–27]. Stannous fluoride also exhibits antimicrobial and anti-biofilm properties [28, 29]. Pyrophosphate salts inhibit calcium phosphate crystal growth, reducing supragingival calculus formation [30, 31]. Their inclusion in products declaring “tartar control” reflects coherent alignment between claims and composition. Although pyrophosphate does not remove existing calculus, its preventive action contributes to improved gingival health [32].

Together, zinc salts and pyrophosphate systems form a complementary periodontal strategy: zinc reduces microbial load, while pyrophosphate prevents mineralized plaque formation.

The distribution of claims observed in the Brazilian market is consistent with international trends described in the literature. The universality of the anticaries claim reflects the central role of fluoride as the gold standard in caries prevention, widely documented in systematic reviews [13, 14]. Consumer behavior studies show that caries protection remains the most valued benefit in dentifrices, functioning as a minimum requirement for product acceptance [33].

The high prevalence of aesthetic claims, such as whitening and breath freshening, is consistent with evidence indicating that sensory and cosmetic attributes influence consumer purchasing decisions [34, 35]. Periodontal related claims, including plaque reduction, gingival health, and calculus control, were concentrated in adult products, which aligns with literature showing a higher prevalence of gingival diseases in adults and greater interest in additional therapeutic benefits within this demographic [36].

The high frequency of sensitivity-reduction claims corresponds with epidemiological studies reporting an increasing prevalence of dentin hypersensitivity among adults [37]. This coherence reflects the incorporation of multiple desensitizing technologies identified in Section 5.3.

Children’s products presented simplified claims focused on anticaries benefits and sensory acceptability, in accordance with international recommendations emphasizing safety, palatability, and control of fluoride ingestion [38, 39].

These patterns suggest that the Brazilian dentifrice market follows a global trend toward multifunctionality, combining preventive, therapeutic, aesthetic, and sensory benefits to meet diverse

consumer needs. This strategy is consistent with market analyses indicating growing demand for oral hygiene products offering multiple functions and greater perceived value [40].

The coherence between claims and ingredients observed in Brazilian dentifrices is consistent with international standards. For whitening products, the strong association with silica abrasives reflects the well-documented role of silica in mechanical removal of extrinsic stains [12, 34]. The concomitant use of pigmentary agents such as titanium dioxide and activated charcoal is also coherent with their recognized ability to modify tooth optical properties [12, 41].

Sensitivity-related associations follow clinical evidence supporting the effectiveness of desensitizing technologies based on dentinal tubule occlusion and neural modulation. Arginine–carbonate complexes are widely described as biomimetic systems capable of forming calcium and phosphate rich plugs within dentinal tubules [42], while potassium nitrate reduces the excitability of pulpal nerve fibers [15].

The association between gingival health claims and ingredients such as stannous fluoride, zinc salts, and pyrophosphates is supported by literature demonstrating antimicrobial, anti-inflammatory, and anticalculus effects. Stannous fluoride exhibits broad antimicrobial and anti-biofilm properties [28, 29, 43]. Zinc salts reduce biofilm accumulation and volatile sulfur compounds associated with gingival inflammation and halitosis [25–27]. Pyrophosphates inhibit supragingival calculus formation, indirectly contributing to periodontal health [30].

The predominance of monofluorophosphate in children's products aligns with international recommendations emphasizing lower fluoride bioavailability and reduced fluorosis risk [39]. The strong association between pediatric claims and terpenoid flavoring compounds reflects evidence showing that palatability is essential for adherence among children [40].

The correlation patterns indicate that Brazilian manufacturers align functional claims with evidence-based active ingredients, reinforcing the technological coherence of the market.

The presence of ingredients such as SLS, titanium dioxide, PEGs, fluoride compounds, and allergenic terpenes reflect ongoing scientific and regulatory debate.

The safety profile of Brazilian dentifrices reflects a balance between technological performance, therapeutic efficacy, and regulatory compliance. Although several ingredients identified in the formulations such as sodium lauryl sulfate (SLS), titanium dioxide, polyethylene glycols (PEGs), fluoride compounds, and terpenoid flavoring agents have been the focus of recent toxicological and regulatory debate [44–47], their presence does not imply unsafe formulations. Contemporary toxicology distinguishes hazard from risk, emphasizing concentration, exposure route, frequency of use, and systemic bioavailability [48, 49]. Thus, substances that may present hazards under specific experimental conditions do not necessarily pose clinically relevant risks when incorporated into dentifrices within regulatory limits.

SLS remains widely used due to its strong detergent and foaming properties, although it may exacerbate mucosal irritation or recurrent aphthous stomatitis in susceptible individuals [44]. PEG-related concerns are associated with potential manufacturing impurities rather than the polymer itself, and cosmetic-grade PEGs remain safe for oral care applications [46]. Titanium dioxide continues to be permitted in dentifrices, as regulatory debate primarily concerns inhalation exposure and food additive use rather than topical, transient contact [45].

Fluoride compounds remain the cornerstone of preventive dentistry, supported by decades of robust clinical evidence demonstrating their ability to inhibit demineralization, enhance remineralization, and interfere with bacterial metabolism [1, 13, 14]. The principal safety concern dental fluorosis relates to excessive ingestion during early childhood, and international guidelines emphasize supervised brushing, age-appropriate toothpaste quantities, and low-volume use to manage exposure [39, 50]. Under recommended use conditions, fluoride dentifrices maintain a favorable benefit–risk profile.

Flavoring agents such as limonene, linalool, and cinnamal are recognized fragrance allergens, particularly when oxidized into hydroperoxides with higher sensitizing capacity [51]. Nevertheless, exposure in dentifrices is low and transient, and sensitization occurs primarily in predisposed individuals; therefore, these compounds remain safe and essential for palatability, especially in pediatric formulations [52].

The correlation analysis between claims and ingredients demonstrates strong coherence across whitening, sensitivity, gingival health, and pediatric categories. Whitening claims showed tight alignment with silica abrasives recognized for mechanical stain removal and pigmentary agents such as titanium dioxide and activated charcoal, which modify tooth optical properties [12, 34, 41]. Sensitivity claims corresponded closely with established desensitizing technologies: arginine–carbonate complexes that occlude dentinal tubules [42], potassium nitrate for neural modulation [15], and strontium acetate for tubule occlusion [17, 18]. Gingival health claims were strongly associated with stannous fluoride, zinc salts, and pyrophosphates, reflecting their antimicrobial, anti-inflammatory, and anticalculus properties [25–30, 43]. Pediatric formulations showed coherent associations with monofluorophosphate preferred for lower fluoride bioavailability and terpenoid flavorings, consistent with evidence emphasizing palatability and controlled fluoride exposure in children [39, 40].

The technological cluster analysis revealed a market characterized by structural standardization and therapeutic diversification. Whitening technologies formed distinct abrasive, pigment-based, and oxidative clusters [11, 34, 53]. Dentin hypersensitivity was addressed through tubule-occluding systems (arginine, calcium carbonate, bicarbonate) [54, 55] and neural-modulating agents (potassium nitrate) [15]. Gingival health formulations combined stannous fluoride, zinc salts, and pyrophosphate [37, 55]. Children's dentifrices formed a coherent cluster defined by monofluorophosphate, calcium carbonate, synthetic colorants, SLS, and terpenoid flavorings [46, 51].

These patterns indicate that Brazilian dentifrices follow global trends toward multifunctionality, integrating preventive, therapeutic, aesthetic, and sensory benefits. Future innovation is expected to

focus on advanced bioactive systems—including biomimetic remineralizers, multifunctional antimicrobials, microbiome-modulating agents, and personalized therapeutic approaches—while maintaining the robust structural base characteristic of contemporary dentifrice technology. The integration of ingredient frequency, technological function, therapeutic purpose, claim–composition coherence, and safety evidence provides a comprehensive overview of modern dentifrice formulation strategies in Brazil.

Conclusion

The results of this study provide a comprehensive and up-to-date overview of formulation strategies in the Brazilian dentifrice market. Ingredient frequency analysis, claim–composition coherence, safety considerations, and cluster-based technological segmentation collectively demonstrate that contemporary dentifrices have evolved into multifunctional oral care systems supported by a highly standardized structural matrix and diversified therapeutic components.

The identification of six technological clusters highlights clear formulation patterns aligned with whitening, dentin hypersensitivity, gingival health, and pediatric needs, revealing coherent relationships between functional claims and ingredient selection. Emerging technologies such as biomimetic remineralizing agents, oxidative whitening systems, multifunctional antimicrobials, and microbiome-modulating compounds indicate that future innovation will likely focus on bioactive systems rather than structural reformulation.

Although the study relied on manufacturer-declared ingredient lists and did not quantify concentrations or verify laboratory composition, the findings offer valuable insight into current market practices, structural standardization, therapeutic diversification, and the incorporation of international technological trends. Together, these results contribute to a broader understanding of how Brazilian dentifrices integrate functional claims, technological components, and safety considerations to meet diverse consumer and clinical needs.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article. Additional datasets or analytical matrices are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

M.S.S.B.M.Conceptualization, methodology, data collection, data analysis, interpretation, manuscript drafting.

B.S.A. Conceptualization, methodology, data collection, data analysis, interpretation, manuscript drafting.

C.C.O. Methodological support, statistical analysis, manuscript revision.

L. S.J. Supervision, critical review, final approval of the manuscript.

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