FORMULATION, PHYSICOCHEMICAL EVALUATION AND ANTIMICROBIAL ACTIVITY OF TOOTHPASTE TABLETS CONTAINING MAGNOLIA BARK EXTRACT

SAOWALAK PHONSRI

A Thesis Submitted to the Graduate School of Naresuan University

in Partial Fulfillment of the Requirements

for the Master of Science in Cosmetics Sciences

2024

FORMULATION, PHYSICOCHEMICAL EVALUATION AND ANTIMICROBIAL ACTIVITY OF TOOTHPASTE TABLETS CONTAINING MAGNOLIA BARK EXTRACT

SAOWALAK PHONSRI

A Thesis Submitted to the Graduate School of Naresuan University

in Partial Fulfillment of the Requirements

for the Master of Science in Cosmetics Sciences

2024

Thesis entitled “Formulation, physicochemical evaluation and antimicrobial activity of toothpaste tablets containing magnolia bark extract”

By Miss Saowalak Phonsri

has been approved by the Graduate School as partial fulfillment of the requirements

for the Master of Science Program in Cosmetic Sciences of Naresuan University

Oral Defense Committee

..... Chair/ Enternal Examiner
(Dr. Somkamol Intawong)

..... Advisor
(Assistant Professor Worawut Kriangkrai, Ph.D.)

..... Co – Advisor
(Associated Professor Tasana Pitaksuteepong, Ph.D.)

..... Internal Examiner
(Assistant Professor Sasiprapa Limsirilak, Ph.D.)

Approved

……

(Associate Professor Krongkarn Chootip, Ph.D.)

Dean of the Graduate School

Title	FORMULATION, PHYSICOCHEMICAL EVALUATION AND ANTIMICROBIAL ACTIVITY OF TOOTHPASTE TABLETS CONTAINING MAGNOLIA BARK EXTRACT
Author	Saowalak Phonsri
Advisor	Assistant Professor Worawut Kriangkrai, Ph.D.
Co - Advisor	Associated Professor Tasana Pitaksuteepong, Ph.D.
Academic Paper	M.S. Thesis in Cosmetic Sciences, Naresuan University, 2024
Keywords	Toothpaste tablets, Magnolia bark extract, Cleaning efficacy, Hydrated silica, Antimicrobial activity

ABSTRACT

This study investigated the formulation and performance characteristics of compressed toothpaste tablets incorporating magnolia bark extract and varying concentrations of hydrated silica. The tablets were prepared by direct compression method. The effects of hydrated silica content on key performance parameters, including physicochemical properties, cleaning efficacy, antimicrobial activity, and stability, were investigated. The findings revealed that increased silica content led to reduced tablet hardness without significantly affecting friability or foaming properties. The formulation containing 15% w/w hydrated silica achieved a cleaning efficacy of 50.31%, closely rivaling conventional paste-based toothpaste (54.99%). All formulations complied with pharmacopoeial standards for weight variation, hardness, and friability; however, accelerated stability testing indicated minor concerns that necessitate further optimization. The optimized F6 formulation exhibited a Relative Dentin Abrasivity (RDA) of 84.15, well within safe limits for enamel preservation. Furthermore, antimicrobial assessments showed that tablets with magnolia bark extract produced inhibition zones against *Streptococcus mutans* comparable to those containing chlorhexidine. These results provide critical insights into the development of environmentally sustainable oral care products that maintain therapeutic efficacy while utilizing natural antimicrobial agents.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who have supported me throughout the course of this research and the completion of this thesis.

First and foremost, I would like to extend my heartfelt thanks to my advisor, Assistant Professor Worawut Kriangkrai, Ph.D., for their invaluable guidance, continuous support, and insightful suggestions throughout this research. Their expertise and constructive feedback have been crucial in shaping this work.

I am also deeply grateful to my co-advisors, Associated Professor Tasana Pitaksuteepong, Ph.D., and Associated Professor Rungarun Kriangkrai, Ph.D., for their encouragement, expertise, and invaluable assistance. Their guidance has been vital in every phase of this research, and their input has enhanced the quality of my work.

A special thanks to the Chair of my Oral Defense Committee, Dr. Somkamol Intawong, for their leadership and support during the defense process.

I would also like to acknowledge Assistant Professor Sasiprapa Limsirilak, Ph.D., the Internal Examiner, for their time and effort in reviewing my thesis and offering helpful suggestions for improvement.

I am also grateful to the Faculty of Pharmaceutical Sciences, Naresuan University, for providing the resources and laboratory facilities that made this research possible.

I would like to acknowledge the support of my family and friends, who have been a constant source of encouragement and motivation throughout my studies. Their understanding, patience, and love have helped me stay focused and driven.

Finally, I would like to thank all the researchers, authors, and individuals whose work I have referenced in this thesis. Their contributions to the field have been fundamental to the advancement of knowledge, and this work is a testament to their research.

This thesis would not have been possible without the collective support and contributions of all these individuals, and I am truly thankful for each one of them.

Saowalak Phonsri

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

CHAPTER I

INTRODUCTION

Statement of the study

The amount of garbage being produced worldwide is a significant environmental issue. Increasing awareness of these problems, which are having profoundly negative effects on our natural surroundings, highlights the complexity of solving this challenge. Every year, approximately 13 million tons of waste are dumped into the ocean, with around 8 million tons of this being single-use plastics (Chen et al., 2021). Among this total, 1.5 million tons come from discarded toothpaste tubes (Sharif et al., 2021). These empty toothpaste tubes are difficult to reuse and recycle due to their composition of various materials, which would take over 500 years to break down (Kumar et al., 2023). The growing concern over environmental and health issues is influencing the production and sale of cosmetic products, leading to a new trend in the industry: the use of organic and natural materials and the adoption of environmentally friendly packaging.

Several forms of toothpaste products are available in the market, including pastes, creams, gels, and powders, with toothpaste in tablet form recently introduced to consumers. Toothpaste in chewable tablet form is an emerging trend in cosmetic development and has gained popularity due to its various advantages, such as ease of use, low manufacturing costs, being preservative-free, relatively stable, and convenient for packaging, shipping, and storage (Kumar et al., 2023). However, there are currently no standards in place to monitor the quality and specifications of toothpaste in tablet form. To ensure product quality, manufacturers must adhere to standard guidelines for pharmaceutical products in chewable tablet form, as established by the Drug Pharmacopeia.

Various chemical ingredients have been identified as beneficial for use in oral care products. However, some chemical ingredients can cause adverse reactions, such as resistance to antibiotics, dentine corrosion, or staining of the teeth (Dumitrel et al., 2024). Given these issues and the contemporary shift towards natural products to reduce environmental problems, there is increasing consumer awareness of the potential benefits of natural products in medicinal products.

Specifically of interest in this research project is the use of natural ingredients in teeth hygiene products. There are now several oral care products manufactured with herbal ingredients available in the marketplace, that offer various benefits for oral hygiene, such

as being antimicrobial, antiplaque, or antiquaries. Herbal ingredients offer significant advantages over chemical ingredients and are claimed to be both effective and with fewer side effects.

In this study, magnolia bark extract, derived from *Magnolia officinalis*, was selected for its richness in phenolic compounds such as magnolol and honokiol. These compounds exhibit strong antimicrobial, antioxidant, and anti-inflammatory properties (Chang et al., 1998; Ogata et al., 1997). Notably, these substances demonstrated inhibitory effects on *Streptococcus mutans*, the primary bacterium responsible for dental caries, by disrupting biofilm formation and bacterial adhesion (Sakaue et al., 2016). Furthermore, magnolia compounds have shown potential for therapeutic applications in dentistry with relatively low cytotoxicity (Lee et al., 2011).

Based on this prior positive information regarding natural ingredients in oral hygiene products, the objectives of this research were, first, to develop a new format of toothpaste in chewable tablet form, termed toothpaste tablets. As product aesthetics are important to consumers, the tablets were designed to have an attractive appearance, be convenient to use, and easy to carry, while retaining the suitable and beneficial properties of toothpaste typically available in plastic tubes. The research work also focused on the formulation and physicochemical evaluation of the toothpaste tablets, which were prepared using a direct compression process. Magnolia bark extract was incorporated into the formulation for its antibacterial properties.

This work provided a useful model for product development and offered valuable information to guide the cosmetics industry in the production of toothpaste tablets.

Objectives of the study

1. To develop toothpaste tablets containing magnolia bark extract by direct compression manufacturing procedures.

2. To investigate the abrasivity, cleaning, and antimicrobial properties of the toothpaste tablets containing the magnolia bark extract.

3. To investigate the relationship between the physicochemical properties of powder blends and the tablet properties.

CHAPTER II

LITERATURE REVIEW

Oral care market - growth, trends, and forecast (2020 - 2025).

The Toothpaste Market - Growth, Trends, and Forecast (2020 - 2025) from Munson and Vujicic (2021) shows that the global toothpaste market is anticipated to grow at a Compound Annual Growth Rate (CAGR) of 6.1% during the forecast period from 2020 to 2025. This growth is attributed to the increasing dental problems among both children and adults. Additionally, the rising popularity of herbal oral care products is another significant factor driving the growth of the toothpaste market (El Enshasy et al., 2024).

Oral care products are designed for a wide range of treatments to improve oral hygiene and provide dental care. The rising awareness of oral hygiene is motivating a shift from traditional products to innovative appliances and formulations. The cosmetic aspects of maintaining an aesthetically pleasing smile and a fresh breath are also relevant factors in the development of oral hygiene products.

Over the past few years, the market has witnessed technological breakthroughs in dental health and oral hygiene products, with several new and innovative high-performance products being launched. This trend is likely to continue (Hartshorn & Nair, 2023).

Introduction of toothpaste

Toothpaste is a semi-solid oral hygiene product used to clean teeth, maintain oral health, and promote fresh breath. It consists of abrasives, detergents, binders, humectants, flavoring agents, preservatives, and active ingredients such as fluoride (Vranić et al., 2004). The primary function of toothpaste is to remove food debris and plaque, a biofilm that forms on the teeth and can lead to cavities and gum disease if not regularly removed (Addy, 1986).

The benefits of toothpaste extend beyond basic cleaning. Fluoride-containing toothpaste helps strengthen enamel and prevent dental caries by enhancing remineralization and inhibiting demineralization (Haider et al., 2021). Antimicrobial agents, such as triclosan or herbal extracts, contribute to gum health by reducing bacterial growth and inflammation (Rossi et al., 2014). Additionally, specialized formulations offer benefits such as whitening, sensitivity reduction, and tartar control, catering to specific oral health needs (Prete et al., 2022).

As oral health awareness increases, consumers are becoming more interested in natural and herbal toothpaste alternatives. This shift has led to the inclusion of plant-derived ingredients such as Magnolia bark extract, which has been recognized for its antimicrobial and anti-inflammatory properties, offering a natural approach to oral care (Lee et al., 2011).

General components of toothpaste

Toothpaste formulations typically consist of several key components that contribute to their efficacy, texture, and stability. These components include abrasives, humectants, binders, surfactants, flavoring agents, sweeteners, preservatives, and active ingredients (Maldupa et al., 2012).

1. Abrasives: These remove plaque and stains from teeth. Common abrasives include calcium carbonate, hydrated silica, and dicalcium phosphate (Ali et al., 2020).
2. Humectants: Ingredients such as glycerin and sorbitol prevent toothpaste from drying out and help maintain consistency (Pader, 2018).
3. Binders: These helps maintain toothpaste structure and prevent separation. Common binders include xanthan gum and cellulose derivatives (Imam et al., 2013).
4. Surfactants: Agents like sodium lauryl sulfate (SLS) or alternative mild surfactants create foam and aid in the dispersion of active ingredients (Vranić et al., 2004).
5. Flavoring agents and sweeteners: Menthol, peppermint oil, and saccharin improve taste and consumer acceptability (Bankova et al., 2018).
6. Preservatives: These prevent microbial contamination, with parabens and sodium benzoate being commonly used (Nowak et al., 2021).
7. Active Ingredients: Fluoride, antimicrobial agents, and herbal extracts contribute to the therapeutic effects of toothpaste.

As consumers seek alternatives to synthetic active ingredients, natural compounds such as herbal extracts are gaining popularity in toothpaste formulations. One such ingredient is magnolia bark extract, which offers a natural antimicrobial and anti-inflammatory alternative to conventional chemicals.

Magnolia bark extract: composition and medicinal properties

Magnolia bark extract has been extensively studied for its bioactive components, primarily magnolol and honokiol, which exhibit potent antimicrobial, anti-inflammatory, and antioxidant properties. These compounds have been shown to inhibit the growth of oral pathogens such as *Streptococcus mutans* and *Porphyromonas gingivalis*, both of which are responsible for dental caries and periodontal disease (Lee et al., 2011).

Research by Sakaue et al. (2016) demonstrated that magnolol and honokiol possess broad-spectrum antimicrobial activity, effectively reducing bacterial viability and biofilm formation. Another study by Walker et al. (2013) highlighted the anti-inflammatory effects of magnolia bark extract, showing that it can reduce gingival inflammation and oxidative stress, which are key factors in periodontal disease progression.

In addition to its antimicrobial properties, magnolia bark extract has been reported to have anti-halitosis effects. A study conducted by Tangerman and Winkel (2013) indicated that magnolol can suppress the production of volatile sulfur compounds (VSCs), which contribute to bad breath. This property makes it a valuable ingredient in oral care products aimed at improving overall oral hygiene.

Furthermore, the antioxidant activity of Magnolia bark extract has been found to protect oral tissues from oxidative damage. Zhao and Liu (2011) reported that honokiol exhibits strong free-radical scavenging abilities, which can contribute to the prevention of oral diseases linked to oxidative stress, such as oral cancer and periodontitis.

Despite the promising therapeutic properties of magnolia bark extract, challenges related to its stability and solubility in oral care formulations remain. Ongoing research is focused on improving its bioavailability through encapsulation techniques and novel formulation approaches (Komarov et al., 2017).

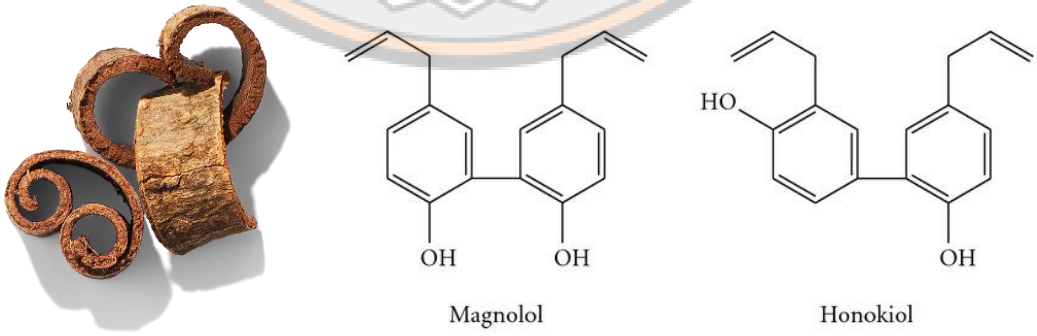

Figure 1 Magnolia bark (Left), Magnolol and Honokiol (Right)

Fluoride in toothpaste

Fluoride is a naturally occurring element widely utilized in dental care to enhance oral health and prevent cavities through three key mechanisms (Sharma et al., 2020). The primary function of fluoride in oral care is to promote the remineralization of tooth enamel by binding to areas of decay and attracting essential minerals to repair the damaged site. Additionally, fluoride helps prevent further decay by stimulating the formation of fluorapatite, a highly acid- and bacteria-resistant form of tooth enamel. Furthermore, fluoride exhibits antibacterial properties, inhibiting bacterial growth and preventing microbial adhesion to the tooth surface.

A systematic review conducted in March 2019 examined the efficacy of various fluoride concentrations in toothpaste for preventing dental caries (Walsh et al., 2019). This study analyzed 96 research articles published between 1955 and 2014, encompassing data from both children and adults who used fluoride-containing toothpaste as part of their oral hygiene routine. The fluoride concentration in the examined toothpaste formulations ranged from 0 to 2400 ppm. The findings revealed that fluoride toothpaste significantly reduces the risk of dental decay, decreasing the incidence of new caries by approximately 24% compared to non-fluoride toothpaste in both children and adults. Furthermore, toothpaste containing 1450 to 1500 ppm fluoride demonstrated superior efficacy in reducing new carious lesions compared to formulations containing 1000 to 1250 ppm, highlighting the enhanced protective effect of higher fluoride concentrations. However, when fluoride levels exceeded 1700 to 2200 ppm or 2400 to 2800 ppm, the reduction in new cavities was comparable to that observed with 1450 to 1500 ppm, suggesting a threshold beyond which additional fluoride does not provide further benefits.

At the lower end of the concentration spectrum, research by Ammari et al. (2003) indicated that children using toothpaste with fluoride concentrations below 550 ppm did not experience a significant reduction in dental decay. Instead, the efficacy of low-fluoride toothpaste was comparable to that of non-fluoride formulations. Additionally, excessive fluoride intake has been linked to dental fluorosis, a condition characterized by enamel pitting and staining, which primarily affects children under the age of six, whose teeth are still in the developmental stage (Saeed et al., 2020).

Chewable tablets

Chewable tablets are an oral dosage form designed to be chewed before ingestion (Renu et al., 2015). Upon mastication, the tablet breaks down into smaller particles, facilitating dissolution and subsequent absorption to achieve the desired pharmacological effect. These tablets should disintegrate smoothly, have a pleasant taste, and leave no bitter or unpleasant aftertaste.

Chewable tablets are primarily formulated for individuals who experience difficulty swallowing conventional tablets. Key factors in their formulation include flow properties,

lubrication, disintegration, organoleptic characteristics, compressibility, compatibility, and stability (Sengar et al., 2024). Additionally, chewable tablets offer a convenient alternative for maintaining oral hygiene in situations where traditional toothbrushing is impractical or inaccessible.

Excipients used in tablet preparation

Excipients are substances incorporated into tablet formulations to enhance the physical and chemical properties of drugs. These properties include bulkiness, disintegration, dissolution rate, and bioavailability, all of which contribute to the overall effectiveness and stability of the formulation. The pharmaceutical industry categorizes excipients into various types, including diluents or fillers, binders or adhesives, disintegrants, glidants, lubricants, flavors, colors, and sweeteners. Additionally, excipients must satisfy specific criteria to ensure compatibility, safety, and efficacy in pharmaceutical formulations (Abrantes et al., 2016).

1. Physiologically inert.
2. Acceptable to regulatory agencies.
3. Physically and chemically stable.
4. Free from bacterial contamination.
5. Should not interfere with the bioavailability of the drug.
6. Commercially available in forms and purity that meet pharmaceutical standards.
7. Cost-effective and inexpensive.
8. Compliant with regulatory standards.

List of Excipients (Rowe et al., 2009):

1. Diluents are also known as fillers, are substances used to adjust the volume of a tablet to the required or desired size. They serve an important role as disintegrants in dispersible and orally disintegrating tablets.
2. Binders are employed in tablet formulations as binding agents to impart cohesive strength to the powdered materials, ensuring the tablet maintains its structural integrity.
3. Lubricants are incorporated into tablet formulations to minimize friction between the die and the tablet, preventing adhesion to the die and punches. Additionally, lubricants facilitate the smooth ejection of the tablet from the die cavity.
4. Glidants help in the free flowing of powdered materials from hopper to die cavity and decrease friction between particles.
5. Anti- adherents are added to prevent the adhesion of powdered materials to punches and dies.

6. Superdisintegrants are used to enhance the rapid breakdown of tablets into smaller particles upon contact with water in the oral cavity, facilitating faster disintegration.

Tablet manufacture

The common pharmaceutical tablet manufacturing processes include direct compression, dry granulation, and wet granulation. Among these, the direct compression process is the simplest, requiring fewer unit operations, which in turn reduces manufacturing costs (Armstrong, 2007). In this method, tablet production involves blending excipients with active ingredients, followed by compression into tablet form. The direct compression process for tablet manufacturing can be divided into three key steps, as illustrated in Figure 2 (Aulton & Taylor, 2013).

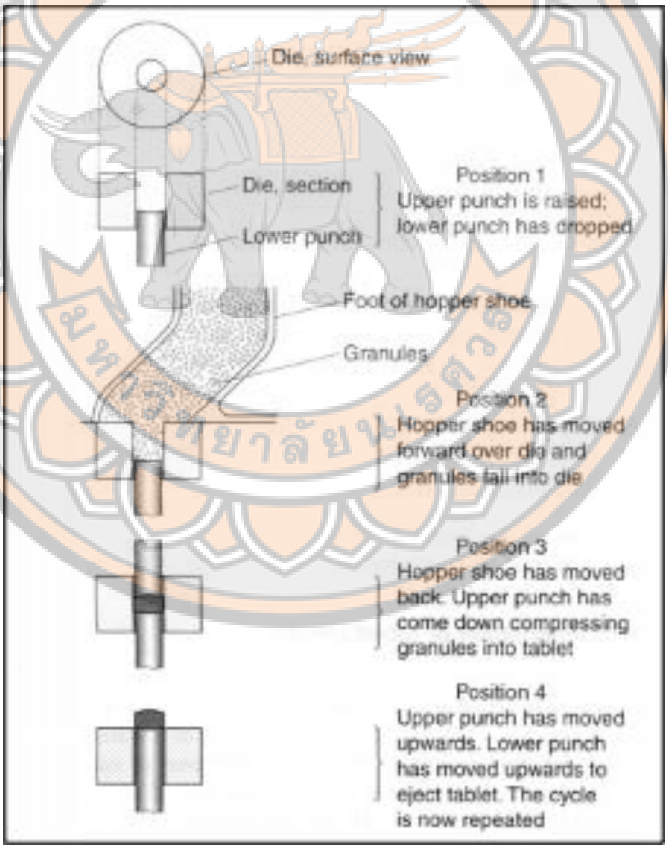

Figure 2 Tablets Compression Process (Aulton ME, Pharmaceutics,2nd ed., 2002, p.399)

Step 1. Filling

Position 1: The upper punch is raised, and the lower punch drops to create a cavity in the die.

Position 2: The feed shoe moves over the die cavity and the feed material

falls from the hopper to the die cavity.

Step 2. Compression

Position 3: The feed shoe is displaced, and the upper punch descends to compress the feed material into tablets.

Step 3. Ejection

Position 4: The upper and lower punches move upward to eject the compressed tablet. This process continues repeatedly until the feed material is exhausted.

Reviews on evaluation of toothpaste

Maintaining good oral hygiene is essential for overall health and an aesthetically pleasing smile. Regular tooth brushing helps prevent cavities, tooth decay, and gum disease, which, if left untreated, can lead to serious health complications. However, oral hygiene practices also have certain drawbacks. Toothpaste formulations contain abrasive particles that, when used in combination with a toothbrush, may contribute to enamel wear over time.

Baig et al. (2021) conducted an investigation into the tribology of tooth brushing, focusing on the friction and wear characteristics of enamel resulting from brushing with abrasive toothpaste slurries. A tribometer, modified with a toothbrush head, was employed to replicate the toothbrushing motion. Three abrasives were examined in this study: angular silica, spherical silica, and alumina, with an abrasive-free toothpaste slurry serving as the control. The study examined the changes in friction over time during the brushing simulation and evaluated the alterations in enamel surface roughness. The results revealed that the alumina slurry caused higher friction, greater wear depth, and more pronounced roughening of the enamel surface compared to the silica slurries. Among the abrasives tested, spherical silica exhibited the lowest friction and material loss. The abrasive-free slurry, although not inducing wear or surface roughening, resulted in the highest friction during brushing.

Ogboji et al. (2018) conducted a physicochemical evaluation to assess the antimicrobial properties of a green toothpaste formulated using natural ingredients, including turmeric, aloe vera, guava, mint, neem, and lemon. This formulation was compared to three commercial toothpastes—Close-Up, Oral-B, and Dabur-Herbal. The

physicochemical properties analyzed in both the formulated and commercial toothpastes included color, taste, odor, texture, abrasiveness, spreadability, cleansing ability, foaming ability, stability, homogeneity, moisture content, gritty matter, and pH. Notably, antimicrobial testing was performed on Streptococcus mutans, a key pathogen responsible for dental caries. The results revealed significant differences in the zones of inhibition between the various toothpastes, with the formulated green toothpaste exhibiting more favorable results in terms of spreadability, pH, foam, gritty matter, and homogeneity compared to the commercial products. The findings suggested that the green toothpaste, containing phytochemicals with antimicrobial properties, may offer a safer alternative to conventional toothpastes that contain synthetic chemicals.

Reviews on evaluation of tablets dosage form for oral care

Tablet dosage forms, including those for oral care, require extensive evaluation to ensure their effectiveness, stability, and patient acceptability. Various quality control tests are employed to assess the physicochemical properties of these formulations.

A study by Alderborn and Frenning (2008) emphasized that hardness and friability tests are crucial in determining the mechanical strength of tablets, ensuring they can withstand handling without breaking. Disintegration time is another key parameter; research by Fouad et al. (2020) demonstrated that optimal disintegration ensures active ingredient release within an appropriate timeframe for effective action in the oral cavity.

pH measurement is critical for oral care tablets, as an inappropriate pH may lead to enamel erosion or irritation. According to a study by CLE (2008), toothpaste tablets should maintain a neutral to slightly alkaline pH to support enamel integrity while effectively controlling bacterial growth.

Foaming ability is an essential property in oral care tablets as it enhances the distribution of active ingredients. A comparative study conducted by Maher et al. (2023) found that formulations incorporating mild surfactants, such as sodium lauryl sulfate alternatives, provided effective foaming while minimizing mucosal irritation.

Finally, moisture content analysis is performed to ensure tablet stability and prevent microbial contamination. Research by Yee et al. (2024) suggested that excessive moisture can lead to tablet degradation and reduced shelf life. Proper packaging and inclusion of moisture-absorbing agents have been recommended to maintain stability.

CHAPTER III

RESEARCH METHODOLOGY

The research approach was divided into 8 parts following:

1. Materials and methods.
2. Preparation of the powder blends
3. Powder characterization.
4. Preparation of toothpaste tablets.
5. Evaluation of tablets.
6. Physicochemical characterization of toothpaste tablets.
7. Antimicrobial test.
8. Stability test.

Materials and methods

The formulation of the toothpaste tablets developed in this study was based on conventional oral toothpaste. The selection of ingredients was carefully considered to ensure their suitability for the direct compression method used in manufacturing the tablets. The antimicrobial active ingredient, magnolia bark extract (LEMA-14A), was sourced from Forecus Co., Ltd, Thailand. Hydrated silica (Zeodent 113, Evonik, Germany), Dicalcium phosphate dihydrate (Calcium phosphate from Merck, Germany) and Sodium bicarbonate (Bicar® pharma, Solvay, Belgium) were used as abrasive. Xylitol (Xylisorb®, Roquette, France) was used as tablet diluent. It also improved the taste and texture of toothpaste formulations (Agiba & Eldin, 2019) and provided dental health benefits such as reducing the risk of dental caries (Nayak et al., 2014). Sorbitol powder (Neosorb®, Roquette, France) was used as a sweetener and provides a pleasant mouthfeel. All other chemicals were pharmaceutical grade. The complete list of ingredients used in the formulation is presented in Table 1.

Table 1 Toothpaste tablet ingredients and functions

Part		Ingredients	Functions	Grade, Manufacture/ Country
A	1	Xylitol	Sweetener	Pharmaceutical Grade, Roquette/France
	2	Sorbitol powder	Sweetener	Pharmaceutical Grade, Roquette/France
	3	Poloxamer 407	Cleansing agent	Pharmaceutical Grade, BASF/Germany
	4	Sodium coco sulfate	Cleansing agent	Pharmaceutical Grade, BASF/Germany
B	5	Hydrated silica	Abrasive	Pharmaceutical Grade, Evonik/Germany
	6	Sodium fluoride	Anticaries agent	Pharmaceutical Grade, Sigma-Aldrich/USA
	7	PVP K-30	Binder	Pharmaceutical Grade, BASF/Germany
C	8	Calcium carbonate	Abrasive	Pharmaceutical Grade, Merck/Germany
	9	CI 16035	Coloring agent	Food Grade, Givaudan/Switzerland
D	10	Magnolia bark extract	Antibacterial agent	Herbal Extract, Forecus Co., Ltd/Thailand
	11	Peppermint flavor	Flavoring agent	Food Grade, MANE/France
	12	Menthol crystals	Cooling agent	Pharmaceutical Grade, Sigma-Aldrich/US
	13	Methyl diisopropyl propionamide	Cooling agent	Pharmaceutical Grade, Symrise/Germany
E	14	Dicalcium phosphate dihydrate	Abrasive	Pharmaceutical Grade, Merck/Germany
	15	Sodium bicarbonate	Abrasive	Pharmaceutical Grade, Solvay/Belgium
	16	Magnesium stearate	Anticaking	Pharmaceutical Grade, Purac/Netherlands

Preparation of the powder blends

The preparation of the powder blends prior to compression was carried out in sequential steps to ensure uniformity and consistency in the final formulation. Table 2 presents seven toothpaste tablet formulations (F0-F6) designed to evaluate the effects of magnolia bark extract and hydrated silica. F0 serves as the negative control, containing 0% magnolia bark extract. To study the effect of varying concentrations of hydrated silica, F1-F6 were designed.

The first stage was base sweeteners followed by adding a mixture of xylitol and sorbitol powder combined with abrasives ingredients (hydrated silica, dicalcium phosphate dihydrate). The colorant was pre-blended with calcium carbonate using geometric dilution until a uniform mixture was achieved and then incorporated into the formulation. The liquid phase containing magnolia bark extract, flavoring agents, menthol crystals, and methyl diisopropyl was mixed and stirred until a clear solution was obtained, then added into the powder mixture using appropriate mixing equipment. The liquid was gradually absorbed by the powder components, resulting in a uniform and cohesive blend. Functional agents (poloxamer 407, sodium coco sulfate, sodium fluoride, PVP K-30, sodium bicarbonate, and magnesium stearate were added. All ingredients were passed through a 60-mesh sieve to ensure uniform particle size distribution. Finally, the powder blend was collected in a plastic bag, and magnesium stearate was added and mixed thoroughly for 5 minutes before proceeding with the compression process.

Table 2 Composition of toothpaste tablets formulations

Ingredients (% w/w)	Formulations						
	F0	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Xylitol	51.96	51.46	50.46	48.46	46.46	43.46	38.46
Sorbitol Powder	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Poloxamer 407	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Sodium Coco Sulfate	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Hydrated Silica	2.00	2.00	3.00	5.00	7.00	10.00	15.00
Sodium Fluoride	0.22	0.22	0.22	0.22	0.22	0.22	0.22
PVP K-30	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Calcium Carbonate	6.00	6.00	6.00	6.00	6.00	6.00	6.00
CI 16035	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Magnolia Bark Extract	0.00	0.50	0.50	0.50	0.50	0.50	0.50
Peppermint flavor	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Menthol Crystals	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Methyl Diisopropyl Propionamide	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Dicalcium Phosphate Dihydrate	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Sodium Bicarbonate	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Magnesium Stearate	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

As seen from the table 2, xylitol content gradually decreased from 51.96% (F0) to 38.46% (F6), while the concentration of hydrated silica increased from 2% in F0 to 15% in F6. This variation in ingredient composition was intended to evaluate the impact of hydrated silica concentration on the tablet's physical properties and performance.

Xylitol, as the main sugar alcohol, has been shown to improve the taste and texture of toothpaste formulations (Vranić et al., 2004). Additionally, it provides dental health benefits such as reducing the risk of dental caries (RP et al., 2024). Sorbitol powder, which was included at a constant concentration of 15%, serves as a humectant to maintain moisture content and prevent the tablets from becoming brittle (Jamieson et al., 2012).

Poloxamer 407, incorporated at a constant 3% level across all formulations, functions primarily as a cleansing agent in the toothpaste tablets. It enhances the dispersion of active ingredients and contributes to the overall mouthfeel of the formulation (Dumortier et al., 2006). Sodium coco sulfate, another detergent component included at 1.5%, aids in the foaming properties of the toothpaste (Yi & Xu, 2022).

The incorporation of hydrated silica increased progressively in formulations F2 to F6. Hydrated silica acts as an abrasive property of the toothpaste, which is essential for removing plaque from the teeth (Ali et al., 2020). The increase in hydrated silica concentration is expected to enhance the cleaning efficacy of the toothpaste, which will be evaluated in the later sections of this study.

The concentration of 0.22% sodium fluoride was selected based on established guidelines and scientific evidence supporting its efficacy in preventing dental caries. This concentration provides approximately 1,000 ppm of fluoride ions, which is the level commonly recommended by dental health authorities for daily use toothpaste (Gupta et al., 2021). Other ingredients, such as PVP K-30 and calcium carbonate, were included at constant levels for their roles as binder and abrasive agents, respectively, with calcium carbonate providing additional polishing action.

In terms of flavor and sensory properties, all formulations (F0 to F6) contained a constant level of peppermint flavor (1.5%) and menthol crystals (0.5%) to provide a refreshing taste and cooling sensation. Magnolia bark extract was included in formulations F1 to F6 to assess its potential antimicrobial and antioxidant benefits, while F0 served as a control and did not contain magnolia bark extract.

These varying formulations were carefully prepared and are expected to yield valuable insights into the optimal balance of ingredients that provide effective cleaning and sensory characteristics while ensuring acceptable tablet integrity.

Powder characterization

The quality of the toothpaste tablets is significantly influenced by the physicochemical properties of the powder blends used in their formulation. Therefore, the final powder blend for each formulation was evaluated for key parameters to ensure consistency and manufacturability. Initially, the appearance of the powder was examined to assess its uniformity in color and texture. The pH of the blend was measured to ensure compatibility with oral formulations, while the moisture content was analyzed to prevent stability and compressibility issues during tablet production.

In addition to these fundamental assessments, the powder blend was further characterized for its flowability and compressibility properties, which play a crucial role in the tablet manufacturing process. These included the angle of repose, bulk density, tapped density, compressibility index, Hausner's ratio, and fineness. Evaluating these properties ensures that the powder exhibits adequate flow and compaction behavior, which are essential for achieving uniform tablet weight and strength (Stanley-Wood, 2008).

1. **Appearance of powder**

The appearance of the powder is a critical parameter in evaluating the quality and consistency of the powder blend used in tablet formulation. This assessment ensures uniformity in color, texture, and overall physical characteristics, which can impact the manufacturability and performance of the final product. To evaluate the appearance, the powder blend was visually inspected under

standardized lighting conditions. The color was examined for uniformity, as variations could indicate improper mixing or ingredient incompatibility. The texture was assessed by touch and visual inspection to detect irregularities such as clumping, which may suggest moisture absorption or inadequate blending. Additionally, the presence of any foreign particles or agglomerates was carefully noted, as these could compromise the final product's quality and stability.

2. pH measurement

The pH measurement of the powder blend is an essential quality control parameter to ensure compatibility with oral formulations. The pH of the final product can influence the stability of active ingredients, user safety, and overall effectiveness. To determine the pH, 10 grams of the final powder blend were dissolved in 10 mL of deionized water in a 100 mL beaker. The mixture was stirred thoroughly to form a homogeneous suspension. Once the suspension was well-mixed, the pH was measured using a calibrated pH meter. The recorded pH values were evaluated to confirm compliance with acceptable ranges for oral care products, typically between pH 6 and 8 (Pharmacopeia, 2022).

3. **Moisture content measurement**

The moisture content of the final powder blend is an important parameter that influences the stability, flowability, and compressibility of the formulation. Excess moisture can cause clumping, microbial growth, and reduced tablet integrity, while insufficient moisture may impact compaction properties during tablet formation. To determine the moisture content, a moisture analyzer (HE53, Mettler Toledo, Switzerland) was used. The loss on drying (LOD) method was applied, in which a precise 3 g sample of the final powder blend was evenly spread on the sample pan of the analyzer. The instrument was set to a drying temperature of 105°C, and the sample was heated until a constant weight was achieved. The moisture content (%) was automatically calculated based on the weight loss during drying. Each measurement was performed in triplicate to ensure accuracy and reproducibility (Pharmacopeia, 2022). The obtained moisture content values were compared to standard acceptance criteria for oral solid dosage forms, typically not exceeding 5% to ensure optimal storage stability and tablet manufacturability (Pharmacopeia, 2022).

Figure 3 Moisture Analyzer, Model HE53, Mettler Toledo, Switzerland

4. Flowability of powder

The flowability of the final powder blend is a critical parameter that influences the manufacturing process, particularly the uniformity of tablet weight and content. Poor flowability can lead to inconsistent filling of tablet dies, affecting the final product's quality and performance. Flowability is commonly evaluated using three key parameters: angle of repose, bulk density, and tapped density.

Angle of repose

The angle of repose is a fundamental measure of powder flow properties. It is defined as the maximum angle at which a powder can be piled without collapsing. A lower angle of repose indicates better flowability, whereas a higher angle suggests increased interparticle friction and poor flow behavior. To determine the angle of repose, the fixed cone method was used. A specified amount of powder was allowed to flow freely through a funnel onto a flat surface, forming a conical heap. The height (h) and radius (r) of the heap were measured, and the angle of repose (θ) was calculated using the equation:

$$\tan\theta = \frac{h}{r}$$

Where:
θ = angle of repose
h = height in cm.
r = radius in cm.

According to Pharmacopeia (2022) standards, the angle of repose can be classified into different flow properties, as summarized in Table 3. a value below 25° indicates excellent flow, while an angle greater than 40° suggests very poor flow, leading to potential

challenges in tablet manufacturing, such as inconsistent die filling and poor weight uniformity.

Table 3 Pharmacopoeia Specifications for the Angle of Repose

Angle of repose (°)	Type of flow
< 25	Excellent
25 - 30	Good
30 - 40	Passable
> 40	Very poor

Bulk density

Density is defined as the weight per unit volume. Bulk density (ρ_{bulk}) refers to the mass of the powder divided by its bulk volume and is expressed in g/cm³. The bulk density of a powder is primarily influenced by factors such as particle size and distribution, particle shape, and the tendency of particles to adhere to one another. To measure bulk density, the powder blend is carefully introduced into a dry 10 ml cylinder without any compaction. The powder is leveled off without applying any force, and the unsettled apparent volume (V_0) is recorded. The bulk density is then calculated using the following formula:

$$\rho_{bulk} = \frac{M}{V_0}$$

Where:
ρ_{bulk} = Apparent bulk density
M = Mass of powder blend
V_0 = apparent volume of powder blend

Tapped density

Tapped density is the ratio of the total mass of the powder to its tapped volume. The volume is determined by subjecting the powder to 500 taps. The powder is then tapped an additional 750 times, and the volume is recorded. If the difference between the two volumes exceeds 2%, the powder is tapped an additional 1250 times. Tapping continues until the difference between the two volumes is less than 2%, at which point the final tapped volume (V_f) is measured to the nearest graduated unit. The tapped density is then calculated in g/ml using the following formula:

$$\rho_{tapped} = \frac{M}{V_f}$$

Where:
ρ_{tapped} = Tapped density
M = Weight of powder blend
V_f = Tapped volume of powder blend

5. Compressibility of powder

The compressibility of the final powder blend is a parameter that determines the powder's ability to flow and compact during tablet compression. It directly influences tablet uniformity, mechanical strength, and manufacturing efficiency. Two key parameters used to assess powder compressibility are the Compressibility Index (Carr's Index) and Hausner's Ratio.

Compressibility Index (Carr's Index)

The Compressibility Index is calculated based on the difference between the bulk density and tapped density of the powder. It indicates the powder's ability to pack and its potential for flow issues. A lower compressibility index signifies better flow properties, while a higher value suggests poor flow and higher cohesiveness.

The Compressibility Index (%) is determined using the equation:

$$\text{Compressibility index} = \frac{\rho_{tapped} - \rho_{bulk}}{\rho_{tapped}} \times 100$$

According to Pharmacopeia (2022) guidelines, a Compressibility Index below 15% indicates good flow properties, while values above 25% suggest poor flowability.

Hausner's Ratio

The Hausner's Ratio is another measure of powder flowability and is calculated as the ratio of tapped density to bulk density. A lower Hausner's Ratio (≤1.25) indicates good flow, whereas a higher ratio (>1.25) suggests poor flowability and a tendency for powder aggregation.

Hausner's Ratio is calculated using the equation:

$$\text{Hausner ratio} = \frac{\rho_{tapped}}{\rho_{bulk}}$$

The relationship between compressibility index and hausner's ratio is summarized in Table 4, where powders with a Hausner's Ratio between 1.00 and 1.11 are classified as having excellent flow, while values exceeding 1.60 indicate very, very poor flow. The evaluation of these parameters was performed using a tapped density tester following Pharmacopeia (2022) guidelines. These results provided critical insights into the powder's suitability for compression and manufacturability, ensuring consistency in tablet production.

Table 4 Pharmacopoeia Specifications for Compressibility Index and Hausner's Ratio

Compressibility index	Flow property	Hausner ratio
≤ 10	Excellent	1.00 – 1.11
11 – 15	Good	1.12 – 1.18
16 – 20	Fair	1.19 – 1.25
21 – 25	Passable	1.26 – 1.34
26 – 31	Poor	1.35 – 1.45
32 – 37	Very poor	1.46 – 1.59
> 38	Very, very poor	> 1.60

6. Fineness of powder

The fineness of the final powder blend plays a key role in evaluating particle size distribution, which affects the flowability, compressibility, and uniformity of the tablet formulation. Proper particle size ensures consistent blending, reduces segregation, and enhances tablet quality. To assess fineness, sieve analysis was performed using a standard sieve. All final powder blends were passed through a 60-mesh sieve (250 microns) to ensure uniformity. The sieving process was conducted under controlled conditions to prevent moisture absorption and external contamination. The percentage of powder retained on the sieve was recorded to confirm compliance with the required particle size specifications for oral solid dosage formulations (Pharmacopeia, 2022).

Preparation of toothpaste tablets

The toothpaste tablets were prepared using the direct compression method, a widely used technique for tablet manufacturing due to its simplicity and efficiency (Armstrong, 2007). Accurately weighed quantities of the prepared powder blends were compressed into tablets using a Single Punch Tablet Press (Model: TDP-1.5, Zhejiang Capsulcn Machinery Co., Ltd., China), equipped with a 10 mm round flat punch (diameter: 10 mm; biconvex; average tablet weight: 500 mg). The target thickness of the tablets was set at 5.5 mm. This method ensures uniform tablet weight, hardness, and content uniformity, which are essential for product quality and performance (Shangraw, 1989).

Figure 4 Singe Punch Tablet Press, Model: TDP-1.5, Zhejiang Capsulcn Machinery, China

Evaluation of toothpaste tablets

Following the compression of the final powder blends, the toothpaste tablets were subjected to a series of evaluations to assess their physical and mechanical properties. These quality control tests are essential to ensure the uniformity, stability, and overall performance of the formulated tablets (Aulton & Taylor, 2013). The evaluation parameters included:

1. **Organoleptic parameters**

The tablets were examined for their appearance, color, odor, and overall aesthetic characteristics, which play a crucial role in consumer acceptance (Shangraw, 1989).

2. **Weight variation**

To assess the uniformity of the toothpaste tablets, a weight variation test was conducted following Pharmacopeia (2022) guidelines. Twenty tablets were randomly selected, and their individual and collective weights were measured using a digital weighing balance. The average weight of the tablets was then calculated based on the total weight of all selected tablets.

The weight variation test serves as an essential method for evaluating content uniformity in tablet formulations. The percentage deviation of each tablet was determined using the following formula:

$$\%\text{deviation} = \frac{\text{Individual weight} - \text{Average weight}}{\text{Average weight}} \times 100$$

The obtained values were then compared against pharmacopoeia standards, as outlined in Table 5, to ensure compliance with acceptable limits for weight variation.

Table 5 Pharmacopoeia Specifications for Tablet Weight Variation

Maximum % of weight difference allowed	Average weight of tablets (mg)
10%	Less than 130 mg
7.5%	130 – 324 mg
5%	More than 324 mg

The results from this test help ensure that the toothpaste tablets maintain consistent content distribution, which is critical for dosage accuracy and product stability.

3. Tablet thickness measurement

Tablet thickness is a critical physical characteristic that influences not only the appearance but also the packaging, handling, and consumer perception of the product (Pharmacopeia, 2022). Variations in tablet thickness may indicate inconsistencies in formulation or compression force during manufacturing. To assess the uniformity of tablet thickness, ten tablets were randomly selected. Their thickness (in mm) was measured using a digital vernier caliper (Model: 0.01 mm resolution metric, RS PRO, China), which provides precise readings with minimal measurement errors. The mean thickness and standard deviation were then calculated to determine the consistency of the tablets.

Figure 5 Digital Caliper Caliper, Model: 0.01 mm resolution metric, RS PRO, China

4. **Tablet hardness measurement**

Tablet hardness is defined as the force required to break a tablet when applied across its diameter (Pharmacopeia, 2022). It is an important quality attribute that determines a tablet's mechanical strength, influencing its resistance to chipping, abrasion, and breakage during manufacturing, transportation, storage, and handling (Sinka et al., 2009). Maintaining an optimal hardness level ensures that the tablet remains intact while still allowing for proper disintegration and dissolution.

For each formulation, the hardness (kg/cm^2) was measured using an analog push-pull gauge (Model: NK-500, Wenzhou Weidu Electronics Co., Ltd., China). Ten tablets were randomly selected, and their hardness values were recorded. The mean hardness and standard deviation were then calculated and reported to evaluate the uniformity of tablet strength.

Figure 6 Hardness test on tablet (left), and Analog Push Pull Gauge, Model: NK-500, Wenzhou Weidu Electronics Co., Ltd., China (right)

5. Tablet friability measurement

Friability is a key parameter that reflects the mechanical strength of tablets and their ability to withstand handling, packaging, and transportation without breaking or crumbling (Osei-Yeboah & Sun, 2015). A friability test is essential for evaluating the durability of tablets under simulated conditions of mechanical stress.

The Roche friabilator (Model: FTA-20N, Campbell, USA) was employed to assess friability following the standardized procedure described in Pharmacopeia (2022) guidelines. Twelve pre-weighed tablets were placed in the friabilator, which consists of a rotating plastic drum that operates at 25 revolutions per minute (rpm) for 4 minutes, completing 100 rotations in total. During each rotation, the tablets were allowed to fall from a height of 6 inches, simulating real-world mechanical stress.

After the test, the tablets were removed, dusted to eliminate any loose particles, and reweighed. The weight loss, expressed as a percentage, was used to determine the friability of the tablets using the following formula:

$$\% \text{ Friability} = [W_1\text{-}W_2/W_1] \times 100$$

Where:

W_1 is the weight of the tablets before the test, and
W_2 is the weight of the tablets after the test.

According to Pharmacopeia (2022) standards, a friability value below 1.0% is considered acceptable for conventional compressed tablets, indicating adequate mechanical strength.

Figure 7 Roche friabilator, Model: FTA-20N, Campbell, USA

Physicochemical Characterization of Toothpaste Tablets

The physicochemical properties of toothpaste tablets were evaluated to determine their effectiveness, stability, and overall performance. The assessment included foamability, cleaning ability, and abrasiveness tests, adapted from previous studies.

1. Foam test

The foaming ability of toothpaste aids in the dispersion of active ingredients and enhances the mechanical cleaning process. The foam test was conducted following the methodology described by Annisa et al. (2023). A 10 mL aliquot of a 1% w/v toothpaste tablet slurry was placed into a graduated cylinder (250 mL, Pyrex®, Germany) containing 50 mL of distilled water. The solution was vigorously shaken for 30 seconds, and the foam height was recorded immediately. The stability of the foam was further assessed by measuring the foam height after 5 minutes. The results provided an indication of the surfactant efficiency and foaming capability of the toothpaste formulation.

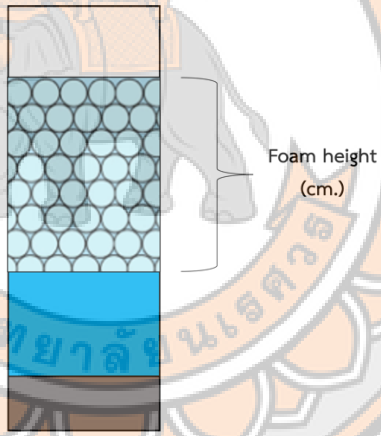

Figure 8 Diagram showing foam height measurement

2. Cleaning ability

The cleaning ability of the toothpaste tablets was assessed using a method adapted from Ogboji et al. (2018). Eggshells, which contain a high concentration of calcium and closely resemble tooth enamel, were used as a model surface. One hard-boiled egg was used for each toothpaste sample tested.

The procedure involved boiling 200 mL of water in a beaker, followed by the addition of 15 mL of vinegar and 1 mL of red food coloring. A hard-boiled egg was immersed in this solution for 5 minutes to allow the shell to absorb the dye. A permanent marker was used to draw a line along the length of the eggshell, dividing it into two equal halves.

Brushing was performed using an Oral-B® Pro-Health Precision Clean electric toothbrush. The toothbrush was pre-moistened with distilled water, and excess water was removed before brushing one half of the eggshell using back-and-forth motions for 3 minutes without toothpaste. The toothbrush was then rinsed, and a slurry of the toothpaste sample was applied before brushing the other half of the eggshell using the same technique.

Afterward, the egg was rinsed and examined for color removal on each side. The stain removal efficacy was quantitatively assessed using a colorimetric spectrophotometer (Model: Mini scan EZ 4500S, HunterLab, USA), following the equation:

$$\%Removal = \frac{L^*(Brushed) - L^*(Stained)}{L^*(Initial) - L^*(Stained)} \times 100$$

Where:

L*(Initial) is the brightness before staining
L*(Stained) is the brightness after stain application
L*(Brushed) is the brightness after toothbrushing

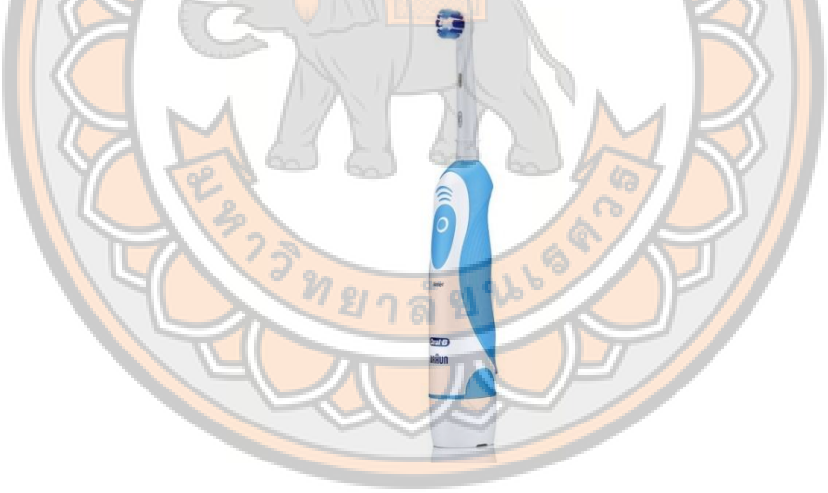

Figure 9 Oral-B® Pro-Health Precision Clean Electric Toothbrush

Figure 10 Colorimetric spectrophotometer, Model: Mini scan EZ 4500S, HunterLab, USA

3. Abrasivity Test

The abrasivity of the toothpaste tablet was assessed following the guidelines outlined in ISO 11609:2007 – *Dentistry: Toothpastes – Requirements and Test Methods*. This test is essential in evaluating the potential wear caused by the toothpaste during brushing, as excessive abrasiveness may lead to enamel damage. The procedure outlined in ISO 11609 provides standardized conditions for testing and ensures reproducibility across different laboratories. The abrasivity test was conducted by the Oral Biology Research Center (OBRC) to ensure adherence to recognized standards and provide an objective evaluation of the toothpaste's performance.

The primary objective of this test is to determine the relative abrasivity of the toothpaste tablet by measuring the rate of abrasion of an enamel surface under controlled conditions.

A standardized toothbrush simulator, typically comprising a motorized system capable of simulating brushing motions. A brushing simulator (Model: V-8 cross brushing machine, SABRI Dental Enterprise, Inc., Villa park, IL, USA), was employed. Additionally, human tooth enamel specimens were used as a substrate for abrasion. These enamel specimens were pre-treated and cleaned before use, in accordance with ISO 11609 recommendations.

The toothpaste tablet sample was prepared by grinding the tablets into a fine powder to obtain a uniform mixture. A specified weight of the powdered toothpaste was then mixed with a controlled volume of distilled water to create a slurry with a consistent consistency that mirrors the actual use conditions of the toothpaste.

The abrasion test was carried out using a mechanical brushing simulator. The test involved the application of the toothpaste slurry to a standardized enamel specimen under a constant brushing force. The enamel specimen was subjected to a set number of brushing cycles, typically 1500 cycles, simulating normal use by an average consumer. The brushing was performed using a load of 200 grams and at a speed of approximately 60 strokes per minute, as per the guidelines outlined in ISO 11609:2007.

Each cycle was followed by washing the specimen to remove any toothpaste residues, and the abrasion was measured by comparing the weight loss of the enamel specimen before and after the brushing cycles. The weight loss was quantified using an analytical balance, and the data were used to calculate the abrasivity value of the toothpaste tablet.

To quantify the abrasivity, the Relative Enamel Abrasivity (REA) and Relative Dentin Abrasivity (RDA) values were calculated.

$$\text{Dentifrice abrasivity} = \frac{\text{10 x test dentifrice net CPM per gram}}{\text{Mean reference net CPM per gram}}$$

$$\text{Dentifrice abrasivity} = \frac{\text{100 x test dentifrice net CPM per gram}}{\text{Mean reference net CPM per gram}}$$

The results were expressed in terms of the mean weight loss of the enamel and dentin specimens per cycle, which serves as an indicator of the abrasivity. According to ISO 11609, acceptable abrasivity values are those that fall within a predefined threshold, ensuring that the toothpaste does not cause excessive wear on tooth enamel or dentin.

The abrasivity results of the toothpaste tablet were evaluated based on the Relative Dentin Abrasivity (RDA) value, which is an internationally recognized measure of toothpaste abrasivity on dentin. According to ISO 11609:2007, the RDA value is classified into four categories to assess the potential impact of toothpaste on dentin wear (Table 6).

Table 6 The RDA (Relative Dentin Abrasion) value

RDA value	Abrasivity level
0-70	Low Abrasive
71-100	Medium Abrasive
101-150	Highly Abrasive
151-250	Regarded as Harmful Limit

Figure 11 Brushing simulator, Model: V-8 cross brushing machine, SABRI Dental Enterprise, Inc., Villa park, IL, USA

Antimicrobial test

The antimicrobial efficacy of the toothpaste tablets was evaluated using the agar well diffusion method against *Streptococcus mutans* ATCC 25175, which was obtained from the Cosmetics and Natural Products Research Center, Faculty of Pharmaceutical Sciences, Naresuan University. Wells on Mueller-Hinton agar were filled with toothpaste slurry, and a commercial toothpaste served as a control to compare the antimicrobial performance of the formulated toothpaste tablets. The tested samples included: toothpaste tablets containing 0.5% magnolia bark extract, toothpaste tablets with 0.15% chlorhexidine (CHX), a commercial toothpaste, a placebo toothpaste tablet (without active ingredients), a 0.5% magnolia bark extract solution, and a 0.15% CHX solution.

The toothpaste dilutions were prepared by dispersing 10 mg of each sample in 500 µL of double-distilled water. The antimicrobial activity was evaluated using the agar well diffusion method. Agar plates were inoculated with *Streptococcus mutans*, and wells (6 mm in diameter) were created using a sterile cork borer. Each well was filled with the prepared dilution, and the plates were incubated at 37 °C for 24 h. Zones of inhibition were measured to assess antibacterial efficacy. After 24 h of incubation at 37°C, inhibition zones were measured to assess antimicrobial activity. All plates were made in triplicates.

This study was approved by the Institutional Biosafety Committee of Naresuan University (Approval No. NUIBC MI 64-11-46).

Stability test

The stability of the toothpaste tablets was evaluated to ensure their physical integrity and performance over time. The study was conducted following the ASEAN Guideline on Stability Study of Drug Product (R1) (Guideline, 2005), which outlines standard storage conditions and testing intervals for pharmaceutical and cosmetic products.

The toothpaste tablets were packaged in glass containers with caps and stored under two distinct conditions:

Storage Condition	Testing Frequency
Long-term stability 30°C ± 2°C/75% RH ± 5% RH	0, 3, 6, 9, 12, 18, 24 months and annually through the proposed shelf-life
Accelerated stability 40°C ± 2°C/75% RH ± 5% RH	0, 3, 6 months

At each designated time point, toothpaste tablets were withdrawn from storage and assessed for physical characterization, including visual defects, hardness, friability, and weight variation. The evaluation of visual defects was based on a scoring system to quantify the extent of physical changes observed in the tablets:

Score	Description
0	no change
1	very slightly changed
2	slightly changed
3	moderately changed
4	very changed
5	extremely changed (unacceptable)

This stability testing protocol provided insight into the long-term durability of the toothpaste tablets under real-time and accelerated conditions. The results aided in determining the optimal packaging, shelf-life, and storage recommendations to maintain product quality and efficacy (Kashinath et al., 2024).

CHAPTER IV

RESULTS AND DISCUSSION

Preparation of toothpaste tablets

The formulation of toothpaste tablets in this study was based on the careful selection and optimization of excipients commonly used in traditional toothpaste preparations. A range of formulations (F0 to F6) was designed to explore the effects of varying concentrations of hydrated silica, on the physical properties and performance of the tablets. The results from this study demonstrate that the reduction of xylitol content, from 51.96% in F0 to 38.46% in F6, and the progressive increase of hydrated silica concentration, from 2% in F0 to 15% in F6, contributed to variations in the tablet's structural integrity, cleaning efficacy, and sensory characteristics.

In conclusion, the varying formulations prepared in this study are expected to provide valuable insights into the optimal combination of ingredients that can deliver effective cleaning, desirable sensory characteristics, and robust tablet integrity. The findings from this study will contribute to the development of toothpaste tablets that not only meet consumer preferences but also address the growing demand for effective, environmentally friendly oral care products.

Evaluation of powder mixture

The prepared toothpaste tablet formulations (F0–F6) were evaluated for their physicochemical properties, including pH, moisture content, tapped density, bulk density, compressibility index, Hausner's ratio, and angle of repose (Table 7). These parameters provide insights into the flowability, compressibility, and overall suitability of the powder for direct compression into tablets.

All formulations appeared as fine powders with a light pink color and were successfully passed through a 60-mesh sieve, indicating a uniform particle size distribution suitable for tablet compression. The moisture content varied between 3.98% and 4.34%, ensuring that the powders remained free-flowing and stable (Pharmacopeia, 2022).

The tapped and bulk densities of the formulations were recorded, with the compressibility index ranging from 13.04% to 38.74%. A lower compressibility index (<15%) suggests excellent flow properties, whereas higher values indicate reduced flowability (Carr, 1965). Correspondingly, Hausner's ratios ranged between 1.15 and 1.63, where values closer to 1.2 indicate good flow properties, while values above 1.6 suggest poor flowability (Pharmacopeia, 2022).

The angle of repose, a key factor in assessing powder flow, varied between 29.90° and 45.24°. Formulations with an angle of repose below 40° exhibited better flow characteristics, whereas higher values suggested increased inter-particle friction, which might affect tablet uniformity (Aulton & Taylor, 2013). The pH values ranged from 6.88 to 7.26, which is within the acceptable range for oral formulations (Pharmacopeia, 2022).

These results confirm that the powder blends exhibited adequate flow and compressibility properties to ensure uniform filling during tablet compression, minimizing weight and content variability.

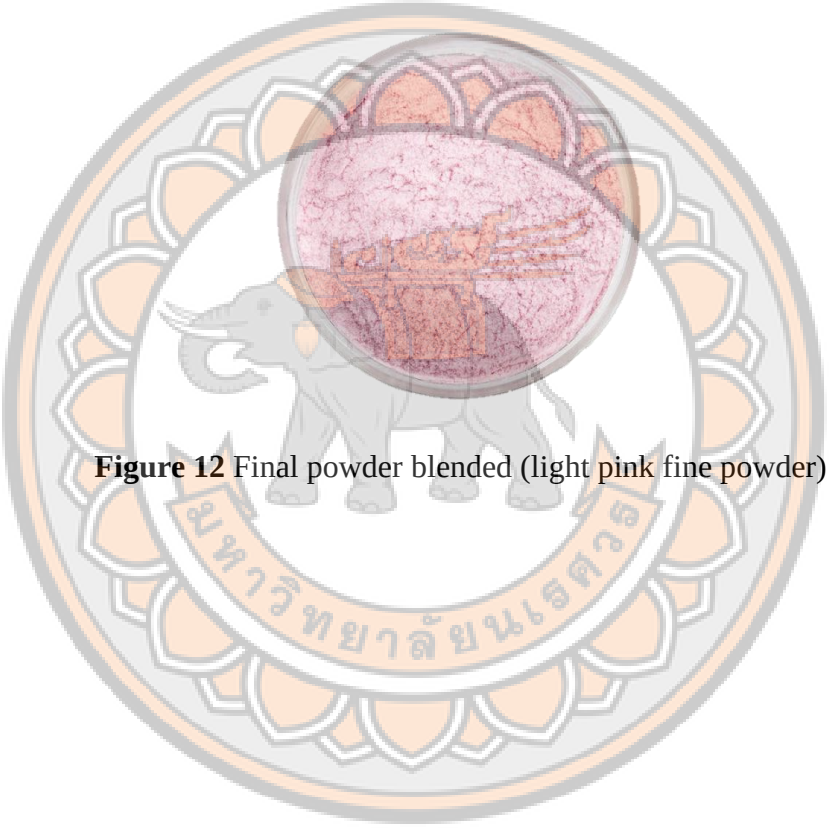

Figure 12 Final powder blended (light pink fine powder)

Table 7 Physical characteristics evaluation of powder blended

Formulations	Physicochemical properties (mean ± SD)						
	Moisture content (%)	**Tapped density (g/ml)**	**Bulk density (g/ml)**	**Compressibility index (%)**	**Hausner's ratio**	**Angle of repose (θ)**	**pH (1% w/v)**
F0	4.02 ± 0.20	0.84 ± 0.01	0.73 ± 0.01	13.50 ± 0.16	1.16 ± 0.01	30.20 ± 0.60	6.88 ± 0.02
F1	3.98 ± 0.18	0.86 ± 0.01	0.75 ± 0.01	13.04 ± 0.14	1.15 ± 0.00	29.90 ± 0.66	6.92 ± 0.01
F2	4.02 ± 0.21	0.92 ± 0.01	0.75 ± 0.01	18.63 ± 0.20	1.23 ± 0.00	38.87 ± 0.40	6.88 ± 0.01
F3	4.21 ± 0.40	0.92 ± 0.01	0.71 ± 0.01	23.53 ± 0.92	1.31 ± 0.02	43.83 ± 0.38	6.90 ± 0.00
F4	4.16 ± 0.34	0.92 ± 0.01	0.64 ± 0.01	30.84 ± 1.57	1.45 ± 0.03	41.68 ± 1.68	7.29 ± 0.01
F5	4.22 ± 0.11	0.85 ± 0.00	0.57 ± 0.00	33.17 ± 0.55	1.50 ± 0.01	45.24 ± 0.41	7.11 ± 0.00
F6	4.34 ± 0.55	0.72 ± 0.01	0.44 ± 0.00	38.74 ± 0.90	1.63 ± 0.02	41.95 ± 0.32	7.26 ± 0.01

Impact of hydrated silica on powder characteristics

Hydrated silica significantly influences the physical and flow properties of the toothpaste tablet formulations. As shown in the formulation compositions (Table 6), hydrated silica concentration increases progressively from 2% (F1) to 15% (F6). The relationship between hydrated silica content and key physicochemical parameters is discussed below:

1. pH variation

The pH of the formulations increased slightly with higher hydrated silica content, ranging from 6.88 (F0) to 7.26 (F6). This increase can be attributed to the alkaline nature of silica-based excipients, which may contribute to a minor elevation in pH (Gao et al., 2022). However, all formulations remained within the acceptable pH range for oral care products (Pharmacopeia, 2022).

2. Moisture content stability

Moisture content remained relatively stable across formulations, ranging from 3.98% to 4.34%. Hydrated silica has high porosity and moisture-retention capacity, which might explain the slight increase in moisture content at higher hydrated silica levels (Zornoza-Indart & Lopez-Arce, 2016). Despite this, the moisture levels remained within acceptable limits to prevent powder agglomeration and maintain flowability.

3. Bulk and tapped density trends

Bulk density decreased progressively from 0.73 g/ml (F0) to 0.44 g/ml (F6). Tapped density also showed a decreasing trend from 0.84 g/ml (F0) to 0.72 g/ml (F6). This reduction is expected, as hydrated silica is a highly porous and low-density material, leading to a decrease in both bulk and tapped density (Sarawade et al., 2010). The lower density values at higher hydrated silica concentrations indicate increased air entrapment within the powder bed, which may affect tablet compaction.

4. Compressibility index and hausner's ratio

Compressibility index values increased with hydrated silica content, from 13.04% (F1) to 38.74% (F6), while hausner's ratio also increased from 1.15 (F1) to 1.63 (F6). These trends suggest that higher levels of hydrated silica led to poorer flowability and increased inter-particle friction. The high surface area of hydrated silica particles contributes to stronger inter-particulate forces, increasing compressibility (Sun, 2011).

5. Angle of Repose and Flowability

The angle of repose increased from 29.90° (F1) to 45.24° (F5), indicating a decrease in powder flowability with higher hydrated silica levels. This behavior aligns with the increased compressibility index and Hausner's ratio, as hydrated silica's fine particles promote cohesion, leading to higher resistance to flow (Carr, 1965). However, formulations containing up to 5% hydrated silica (F3) exhibited acceptable flow properties, whereas higher concentrations (≥7% in F4–F6) showed poor flow characteristics, which may require the addition of glidants to improve processability.

Increasing hydrated silica content significantly influences powder properties, particularly reducing density, increasing compressibility, and decreasing flowability. While moderate amounts of hydrated silica improve tablet functionality by enhancing abrasiveness and binding capacity, excessive levels negatively impact flow properties, which could pose challenges in tablet manufacturing. Optimizing the concentration is essential to balance functionality and processability.

Evaluation of toothpaste tablets

The formulation of toothpaste tablets in this study was based on the careful selection and optimization of excipients commonly used in traditional toothpaste preparations. A range of formulations (F0 to F6) was designed to explore the effects of varying concentrations of hydrated silica, on the physical properties and performance of the tablets.

The physicochemical properties of the toothpaste tablet formulations were evaluated to ensure they met the necessary standards for effective performance and consumer acceptance. Table 8 presents the results for weight variation, thickness, hardness, and friability of the various formulations. These properties were assessed to determine the consistency, robustness, and ease of use of the tablets.

Table 8 Physicochemical evaluation of toothpaste tablets

Formulations	Physicochemical properties (mean ± SD)			
	Weight variation (mg)	Thickness (mm)	Hardness (kg/cm^2)	Friability (%)
F0	502.30 ± 6.50	5.60 ± 0.05	5.75 ± 0.48	0.22 ± 0.02
F1	500.90 ± 6.65	5.57 ± 0.04	5.62 ± 0.53	0.21 ± 0.03
F2	501.56 ± 3.31	5.59 ± 0.08	5.28 ± 0.49	0.35 ± 0.04
F3	498.62 ± 4.22	5.61 ± 0.03	5.11 ± 0.45	0.32 ± 0.06
F4	499.59 ± 2.48	5.56 ± 0.09	5.20 ± 0.35	0.42 ± 0.08
F5	498.53 ± 6.52	5.57 ± 0.04	4.95 ± 0.42	0.41 ± 0.05
F6	497.51 ± 8.14	5.62 ± 0.06	4.90 ± 0.55	0.38 ± 0.11

SD = Standard deviation

The weight variation of the toothpaste tablets in all formulations remained consistent, with only slight deviations from the target weight. The values ranged from 497.51 mg to 502.30 mg, which are within acceptable limits (±5%) for solid dosage forms. There was no significant trend observed in relation to the increasing amount of hydrated silica. This indicates that the inclusion of hydrated silica did not significantly affect the overall weight of the tablets, suggesting that its incorporation did not interfere with the tablet's basic composition.

The thickness of the toothpaste tablets ranged from 5.56 mm to 5.62 mm, with only minor variations across the formulations. The slight changes in thickness can be attributed to the varying levels of hydrated silica. In particular, the formulations with higher concentrations of hydrated silica (F4–F6) exhibited marginally thicker tablets (5.56–5.62 mm), which could be a result of the increased volume contributed by the added hydrated silica. However, these differences were minimal and did not lead to any significant impact on the tablet’s appearance or ease of handling.

Hardness is a critical parameter for evaluating the tablet's mechanical strength and ability to withstand handling during transportation and storage. The hardness of the tablets decreased as the concentration of hydrated silica increased, from 5.75 kg/cm² in F0 to 4.90 kg/cm² in F6. This decrease in hardness could be attributed to the increasing proportion of hydrated silica, which may have affected the bonding between the ingredients, making the tablets slightly softer. The reduction in hardness, especially noticeable from F4 onwards, suggests that higher levels of hydrated silica might reduce the compressibility of the tablets, resulting in lower mechanical strength (Van Veen et al., 2005).

Friability is an important measure of tablet durability and resistance to breakage. The friability values for the formulations ranged from 0.21% (F1) to 0.42% (F4). Interestingly, an increase in the concentration of hydrated silica did not lead to a proportional increase in friability. In fact, the formulations with higher concentrations of hydrated silica (F4–F6) showed slightly higher friability values, indicating that the increased silica content made the tablets more susceptible to surface abrasion. This could be due to the increased hardness and more brittle texture of the tablets, which may be linked to the abrasive properties of hydrated silica. As the concentration of hydrated silica increased, the tablets likely became more prone to breaking during handling, leading to an increase in friability (Gao et al., 2022).

The results suggest that the increasing concentration of hydrated silica in the formulations had a noticeable impact on certain physicochemical properties, especially hardness and friability. The addition of hydrated silica, which acts as a mild abrasive, improved the mechanical properties related to the texture of the tablets, but also increased their brittleness, leading to a rise in friability.

In conclusion, while hydrated silica plays a crucial role in improving the cleaning efficacy of the toothpaste tablets, its increasing concentration can negatively affect the tablet's hardness and friability. This trade-off must be carefully balanced to maintain the optimal performance of the tablets while ensuring they remain robust enough for handling and use.

Efficacy of toothpaste tablets

Foamability test

The foam test is a critical evaluation of the foaming capacity of toothpaste formulations, which directly influences the sensory experience during use. The foam height, measured in centimeters (cm), provides insight into the ability of the toothpaste tablets to produce foam when mixed with water. The results of the foam test for the various formulations (F1 to F6) and commercial toothpaste brands are presented in Table 9.

Table 9 Foam height of toothpaste tablets formulations

Formulations	Foam height (cm)
F0	7.20 ± 0.15
F1	7.22 ± 0.35
F2	7.02 ± 0.15
F3	6.98 ± 0.05
F4	7.15 ± 0.12
F5	6.52 ± 0.05
F6	6.82 ± 0.30
Commercial toothpaste tablet brand A	4.33 ± 0.51
Commercial toothpaste tablet brand B	1.20 ± 0.30
Conventional toothpaste brand C	10.2 ± 0.52

The foam height results indicate that the toothpaste tablet formulations (F1 to F6) produced significantly higher foam than the commercial toothpaste tablet brands A and B. Among the formulations, F1 exhibited the highest foam height at 7.22 ± 0.35 cm, followed closely by F4 (7.15 ± 0.12 cm) and F2 (7.02 ± 0.15 cm). These formulations showed a robust foaming ability, indicating that they have the potential to provide a satisfactory sensory experience during use.

Formulation F5, with a foam height of 6.52 ± 0.05 cm, exhibited the lowest foam production among the tested formulations, which could be attributed to the decreased xylitol

content and the increased concentration of hydrated silica that may reduce foam formation. Similarly, formulation F6 produced a moderate foam height of 6.82 ± 0.30 cm, reflecting a balance between the silica and xylitol contents.

In comparison to conventional toothpaste, F1 demonstrated a significantly higher foam height than both brand A (4.33 ± 0.51 cm) and brand B (1.20 ± 0.30 cm). The lower foam height observed in brand B may be due to a lower foaming agent concentration or the presence of ingredients that reduce foamability. Notably, brand C, a common toothpaste produced the highest foam height (10.2 ± 0.52 cm) as expected, due to the traditional formulation of conventional toothpaste, which typically includes a higher concentration of surfactants and foaming agents (Shanebrook, 2004).

These foam test results suggest that the toothpaste tablet formulations, particularly F1, F2, and F4, exhibit good foaming properties, which are essential for user satisfaction. The foam height is a critical factor in evaluating the performance of toothpaste tablets, as it influences the perception of cleanliness and freshness (Lavoie et al., 2007).

Cleaning test

The cleaning test is a key parameter in evaluating the effectiveness of toothpaste formulations in removing stains or debris. The percentage of removal was measured by using a spectrophotometer to assess the reduction in the stain intensity after treatment with the toothpaste tablets. The results of the cleaning test for the various formulations and commercial samples are presented in Table 10.

Table 10 Cleaning test of toothpaste samples

Sample	%Removal (Mean ± SD)
DI Water	16.61 ± 1.01
F0	35.47 ± 1.13
F1	36.64 ± 0.81
F2	45.52 ± 0.78
F3	45.86 ± 0.65
F4	44.66 ± 0.57
F5	55.67 ± 0.08
F6	56.31 ± 0.62
Commercial toothpaste tablet brand A	33.71 ± 1.20
Commercial toothpaste tablet brand B	20.55 ± 0.61
Conventional toothpaste brand C	57.27 ± 0.66

The cleaning test results show a clear distinction between the performance of the toothpaste tablet formulations and the commercial toothpaste samples in terms of their stain removal capabilities. Among the formulations, F6 achieved the highest stain removal percentage at 50.31 ± 0.50%, which was significantly higher than the other formulations. This suggests that F6, with its higher hydrated silica concentration, may offer enhanced cleaning efficacy due to the increased abrasiveness of the formulation (Pilecco et al., 2024).

F5 also demonstrated good cleaning performance, with a stain removal percentage of 45.01 ± 0.38%. This indicates that a higher concentration of hydrated silica in the tablet formulation positively impacts the cleaning ability, as silica is a known abrasive agent (Hubbs et al., 2005). Similarly, F1, F2, and F3 displayed moderate cleaning capabilities, with removal percentages ranging from 34.15% to 34.85%. These formulations, while effective, did not perform as well as F5 and F6 in terms of stain removal.

In comparison to the commercial toothpaste samples, the toothpaste tablet formulations demonstrated competitive cleaning performance. commercial toothpaste tablet brands A showed a stain removal percentage of 49.40 ± 2.35%, which is similar to F6 but slightly lower. commercial toothpaste tablet brands B had a modest removal percentage of 32.35 ± 0.81%. The common toothpaste brand C exhibited the highest stain removal (54.99 ± 1.12%), which aligns with its traditional formulation designed for optimal stain removal and cleaning.

These results underscore the potential of toothpaste tablet formulations, particularly F5 and F6, in offering effective cleaning performance comparable to that of conventional toothpaste products.

Abrasivity test

The abrasivity of toothpaste formulations is an important parameter in determining their potential to cause wear on both dentine and enamel during brushing. The Relative Dentine Abrasivity (RDA) and Relative Enamel Abrasivity (REA) values were measured to assess the abrasive potential of the different toothpaste tablet formulations, as well as commercial samples. Table 11 presents the results of the abrasivity test for the selected formulations.

Table 11 Abrasivity values of toothpaste samples

Formulation	**Type of toothpaste samples**	**RDA Mean±SEM**	**REA Mean±SEM**
F1	Tablet	51.05±1.64	2.04±0.15
F6	Tablet	84.15±2.01	8.23±0.82
Commercial toothpaste tablet brand A	Tablet	24.02±1.06	1.03±0.54
Conventional toothpaste brand C	Paste	123.08±4.05	13.03±2.00

The Relative Dentine Abrasivity (RDA) and Relative Enamel Abrasivity (REA) values were used to evaluate the potential for wear on the teeth. These values are critical in determining the safety and effectiveness of toothpaste formulations.

F6 exhibited the highest abrasivity among the tested formulations, with an RDA of 84.15 ± 2.01 and an REA of 8.23 ± 0.82. The higher abrasivity in F6 can likely be attributed to the increased concentration of hydrated silica, which is a known abrasive agent (Johannsen et al., 2013). Despite the higher abrasivity, these values remain below the standard RDA value of 100, indicating that F6 is within the acceptable range for dentine and enamel wear. F1, with an RDA of 51.05 ± 1.64 and an REA of 2.04 ± 0.15, demonstrated lower abrasivity compared to F6. This could be due to its lower concentration of silica and a more balanced composition of ingredients designed for gentle abrasion.

The commercial toothpaste tablet brand A showed the lowest abrasivity among the tablet formulations, with an RDA of 24.02 ± 1.06 and an REA of 1.03 ± 0.54. This formulation appears to be designed for less abrasive cleaning, making it suitable for users with sensitive teeth or those seeking a gentler formulation.

In contrast, conventional toothpaste (brand C), a standard toothpaste, exhibited the highest RDA of 123.08 ± 4.05 and REA of 13.03 ± 2.00. This is consistent with conventional toothpaste formulations, which often contain higher concentrations of abrasives to provide superior cleaning and stain removal, although they can be more aggressive on the enamel and dentine (Schemehorn et al., 2011).

The decision to test only four formulations was based on the need to compare the abrasivity of the most representative formulations, particularly those with significant variations in silica content. Since abrasivity is closely related to the composition of the toothpaste (e.g., the concentration of silica and calcium carbonate), it was essential to test a range of formulations that would reflect different levels of abrasivity and performance. This approach allowed for a focused analysis of how ingredient variations influence the abrasivity profile, while avoiding the inclusion of too many formulations that might have yielded similar results.

These abrasivity values are within the acceptable range for safe tooth cleaning. All tested formulations, including F6, which exhibited the highest abrasivity, are considered safe for use, as they are well below the standard RDA value of 100.

Antimicrobial test

The antimicrobial activity of the toothpaste tablet formulations was evaluated by measuring the average diameter of the inhibition zone around each sample. The results are summarized in Table 12 and presented graphically below.

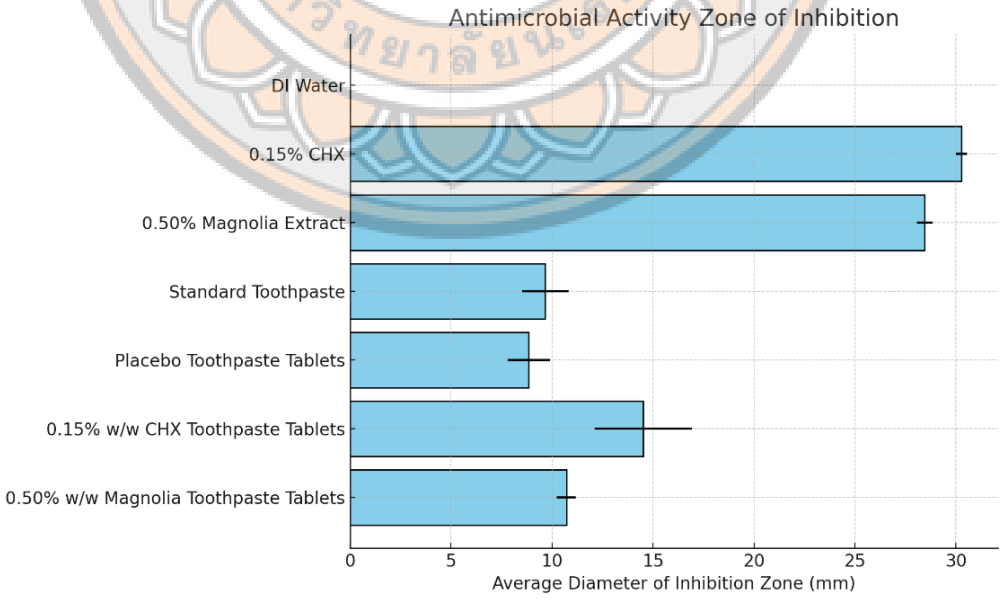

Figure 13 Antimicrobial activity zone of inhibition (mm)

Table 12 Antimicrobial activity zone of inhibition (mm)

Sample	Avg. diameter of inhibition zone (mm)
0.50% w/w magnolia toothpaste tablets	10.71 ± 0.47
0.15% w/w CHX toothpaste tablets	14.52 ± 2.41
Placebo toothpaste tablets	8.85 ± 1.04
Standard toothpaste	9.66 ± 1.15
0.50% magnolia bark extract	28.45 ± 0.39
0.15% CHX	30.27 ± 0.27
DI water	0.00

The antimicrobial activity of the toothpaste tablets was assessed by measuring the average diameter of inhibition zones. As shown in Table 7, formulations with 0.50% magnolia bark extract and 0.15% CHX exhibited the highest efficacy, with inhibition zones of 28.45 ± 0.39 mm and 30.27 ± 0.27 mm, respectively, indicating very strong antimicrobial activity. Toothpaste tablets containing 0.50% magnolia bark extract and 0.15% CHX also showed moderate to strong activity, with inhibition zones of 10.71 ± 0.47 mm and 14.52 ± 2.41 mm. In contrast, placebo and standard toothpaste demonstrated low antimicrobial activity (8.85 ± 1.04 mm and 9.66 ± 1.15 mm), while DI water showed no activity. These results support the efficacy of magnolia bark extract as a promising natural antimicrobial agent for oral care applications (Komarov et al., 2017).

Figure 14 Development of zone of inhibitions of toothpaste formula in culture media against microbes; (1) magnolia toothpaste tablets, (2) placebo toothpaste tablets, (3) CHX toothpaste tablets, and (4) Std. toothpaste

Figure 15 Development of zone of inhibitions of extract in culture media against microbes; (5) 0.50% magnolia bark extract, (6) DI water, and (7) 0.15% Chlorhexidine

Stability test

Stability studies were conducted to assess the physical properties of formulation F6 under accelerated conditions, specifically at 40°C and 75% relative humidity (RH) for 6 months. The parameters evaluated included the general appearance, color, taste, weight variation, thickness, hardness, and friability of the tablets over time. The results from the stability tests are summarized in the Table 13.

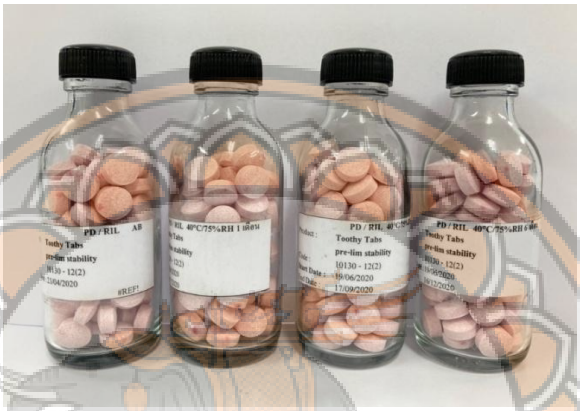

Figure 16 The stability test sample of F6 formula

Table 13 The general appearance of F6 after stability studies

Times/ Conditions	Initial	1 month		3 months		6 months	
	AB*	AB*	40°C/75% RH	AB*	40°C/75% RH	AB*	40°C/75% RH
Appearance							
	1	1	1	1	1	1	2
Color	1	1	2	1	2	1	3
Taste	1	1	2	1	2	1	3
Weight variation	498.48 ± 7.29	500.48 ± 6.05	491.85 ± 4.45	501.10 ± 4.71	495.43 ± 5.88	500.16 ± 6.65	488.12 ± 5.35
Thickness	5.19 ± 0.05	5.26 ± 0.02	5.13 ± 0.02	5.19 ± 0.03	5.19 ± 0.04	5.51 ± 0.05	5.51 ± 0.05
Hardness	5.51 ± 0.60	5.45 ± 0.44	5.52 ± 0.89	5.57 ± 0.60	4.90 ± 0.60	5.48 ± 0.55	4.22 ± 0.45
Friability	0.32 ± 0.82	0.51 ± 0.50	0.45 ± 0.03	0.48 ± 0.03	0.63 ± 0.05	0.55 ± 0.12	0.58 ± 0.08

*Note: Ambient temperature: AB

The general appearance, color, and taste of F6 showed minimal changes over the first 3 months of storage. However, after 6 months of accelerated stability testing at 40°C and 75% RH, slight degradation was observed in these characteristics. The appearance score increased from 1 (no change) at the initial and 1-month time points to 2 (slightly changed) at 6 months. A similar trend was observed for both color and taste, where a slight change (score of 2) was noted at 3 months, progressing to a moderately noticeable change (score of 3) at 6 months. This suggests that while the formulation maintained good organoleptic properties for several months, prolonged exposure to accelerated conditions led to some degradation in sensory attributes.

The weight of the toothpaste tablets remained stable during the study, with only minor fluctuations observed. The initial weight variation was 498.48 ± 7.29 mg, and after 6 months, it was 488.12 ± 5.35 mg, which is within an acceptable range according to pharmaceutical standards (USP, 2022). Similarly, the thickness of the tablets showed minor variations, from an initial 5.19 ± 0.05 mm to 5.51 ± 0.05 mm at 6 months. The slight increase in thickness over time may be attributed to the hygroscopic nature of some ingredients, particularly sorbitol and xylitol, which can absorb moisture from the environment and expand slightly in response to humidity (Juvonen et al., 2021).

The hardness of F6 decreased slightly over the 6 months, from an initial value of 5.51 ± 0.60 kg to 4.22 ± 0.45 kg. This decline in hardness could indicate a loss of tablet integrity due to the prolonged storage under elevated temperature and humidity conditions (Nokhodchi & Javadzadeh, 2007).

In terms of friability, the tablets exhibited an increase in friability over time, from 0.32 ± 0.82% at the initial stage to 0.58 ± 0.08% after 6 months. While the friability values remained low, indicating that the tablets maintained reasonable mechanical strength, the slight increase in friability suggests a weakening in tablet cohesion as a result of stability testing (Zhao et al., 2022).

The results from the stability study indicate that F6 remains relatively stable under accelerated conditions for the first 3 months, with slight changes in appearance, color, and taste. However, by 6 months, moderate changes in these attributes, along with a decrease in hardness and a slight increase in friability, were observed. These findings highlight the need for further optimization of the formulation, especially in terms of moisture stability, to ensure long-term preservation of physical characteristics. The acceptable weight variation and minor changes in thickness indicate that the formulation remains robust in terms of size and mass consistency, which is crucial for consumer acceptance and dosing accuracy.

Relationship between weight variation, thickness, hardness, and friability over time

The physical characteristics of F6, including weight variation, thickness, hardness, and friability, demonstrated a dynamic relationship over the 6-month stability study. These parameters are interdependent, with changes in one often influencing the others.

1. Weight variation and thickness relationship

Weight variation remained relatively stable, with only minor fluctuations over time. Initially, the tablet weight was 498.48 ± 7.29 mg, and after 6 months, it decreased slightly to 488.12 ± 5.35 mg. This minor reduction could be attributed to slight moisture loss or structural modifications due to prolonged exposure to elevated temperature and humidity.

Thickness followed a similar trend, initially measuring 5.19 ± 0.05 mm and increasing slightly to 5.51 ± 0.05 mm by the end of the study. The increase in thickness without a proportional increase in weight suggests that the tablets may have absorbed moisture, leading to slight swelling. This phenomenon is common in formulations containing hygroscopic excipients like sorbitol and xylitol, which can absorb atmospheric moisture and cause expansion (Juvonen et al., 2021).

2. Hardness and friability relationship

Tablet hardness showed a gradual decline over time, starting from 5.51 ± 0.60 kg at the initial stage and decreasing to 4.22 ± 0.45 kg after 6 months. The reduction in hardness is likely due to moisture absorption weakening the internal bonding forces between tablet components, making the structure less compact and more prone to breaking under pressure (Patel et al., 2006). This reduction in hardness is also correlated with the increase in thickness, as moisture-induced expansion may disrupt the tablet's internal matrix.

As hardness decreased, friability values increased. Initially, friability was 0.32 ± 0.82%, which increased to 0.58 ± 0.08% at the 6-month mark. Higher friability indicates that the tablets became more fragile over time, likely due to the reduction in hardness and the softening of the tablet structure (Seitz & Flessland, 1965). The relationship between hardness and friability is well-established, where a decrease in hardness typically results in an increase in friability, making the tablets more susceptible to mechanical stress during handling and transportation.

3. Overall interpretation

The observed trends suggest that moisture absorption played a significant role in influencing the physical characteristics of the toothpaste tablets over time. The minor weight reduction and thickness increase indicate moisture interactions with excipients, leading to changes in tablet integrity. As hardness declined, friability increased, further confirming the weakening of tablet structure over time. These findings highlight the

importance of selecting moisture-resistant excipients and optimizing packaging conditions to ensure long-term stability.

CHAPTER V

CONCLUSIONS

This study successfully developed toothpaste tablets incorporating magnolia bark extract, demonstrating their potential as an effective and eco-friendly oral care product. The formulations exhibited acceptable physical properties, including uniform weight, thickness, and hardness, with friability tests confirming mechanical stability. The pH values were within the neutral to weakly acidic range, making the tablets safe for oral use. Foamability and cleaning ability tests showed promising results, with the F6 containing 15% hydrated silica providing the highest cleaning efficacy. The relative dentin abrasion (RDA) tests confirmed that all formulations remained within safe limits. Antimicrobial testing revealed that toothpaste tablets with 0.50% magnolia bark extract effectively inhibited *Streptococcus mutans*, though its activity was slightly lower than that of chlorhexidine. Stability tests indicated minimal changes in appearance and taste over six months, with a slight decrease in hardness, highlighting the importance of moisture control in packaging.

The results of this study highlight the effectiveness of the formulated toothpaste tablets in maintaining oral hygiene while offering an environmentally friendly alternative to traditional toothpaste. The F6 with a higher concentration of hydrated silica demonstrated superior cleaning ability, while all tested formulations maintained acceptable physical stability. The antimicrobial properties of magnolia bark extract further supported its role as a natural antibacterial agent, making it a viable option for oral care applications. Stability studies indicated that proper packaging is crucial to maintain the integrity of the product over time. Overall, these findings provide strong evidence for the potential of toothpaste tablets as a sustainable and effective alternative for oral hygiene. However, further improvements are recommended to ensure long-term consumer acceptance and to enhance their overall efficacy.

REFERENCES

REFERENCES

Abrantes, C. G., Duarte, D., & Reis, C. P. (2016). An overview of pharmaceutical excipients: safe or not safe? *Journal of pharmaceutical sciences*, *105*(7), 2019-2026.

Addy, M. (1986). Plaque control as a scientific basis for the prevention of dental caries. *Journal of the Royal Society of Medicine*, *79*(Suppl 14), 6.

Agiba, A. M., & Eldin, A. B. (2019). Insights into formulation technologies and novel strategies for the design of orally disintegrating dosage forms: a comprehensive industrial review. *International Journal of Pharmacy and Pharmaceutical Sciences*.

Alderborn, G., & Frenning, G. (2008). Mechanical strength of tablets. *Pharmaceutical dosage forms: Tablets*, *3*.

Ali, S., Farooq, I., Shahid, F., Hassan, U., & Zafar, M. S. (2020). Common toothpastes abrasives and methods of evaluating their abrasivity. *Journal of Oral Research*, 9-15.

Ammari, A., Bloch-Zupan, A., & Ashley, P. (2003). Systematic review of studies comparing the anti-caries efficacy of children's toothpaste containing 600 ppm of fluoride or less with high fluoride toothpastes of 1,000 ppm or above. *Caries research*, *37*(2), 85-92.

Annisa, M., Harsini, H., & Murti, Y. B. (2023). Evaluation of herbal gel toothpaste formulated using bay leaf essential oil on physicochemical characteristics and extrinsic stain removal. *J Herbmed Pharmacol*, *12*(3), 425-431. https://doi.org/10.34172/jhp.2023.47

Armstrong, N. A. (2007). Tablet manufacture by direct compression. *Encyclopedia Pharmaceut Technol*, *6*, 3673-3683.

Aulton, M. E., & Taylor, K. (2013). *Aulton's pharmaceutics: the design and manufacture of medicines*. Elsevier Health Sciences.

Baig, M., Cook, R., Pratten, J., & Wood, R. (2021). Evolution of wear on enamel caused by tooth brushing with abrasive toothpaste slurries. *Wear*, *476*, 203580.

Bankova, M., Vogt, R., Sun, S., Saphow, J. W., Yeung, V., Barieca, T., Semeghini, V., Tipnis, T., & Lee, C. (2018). The science of developing appealing flavors to drive compliance. *J Clin Dent*, *29*, A20-24.

Carr, R. L. (1965). Evaluating flow properties of solids. *Chemical engineering*, *72*, 163-168.

Chang, B., Lee, Y., Ku, Y., Bae, K., & Chung, C. (1998). Antimicrobial activity of magnolol and honokiol against periodontopathic microorganisms. *Planta Med*, *64*(4), 367-369. https://doi.org/10.1055/s-2006-957453

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: Production, usage, disposal, and adverse impacts. *Science of the total environment*, *752*, 141772.

CLE, T. (2008). Maintaining the integrity of the enamel surface. *J Am Dent Assoc*, *139*, 25S-34S.

Dumitrel, S.-I., Matichescu, A., Dinu, S., Buzatu, R., Popovici, R., Dinu, D. C., & Bratu, D. C. (2024). New Insights Regarding the Use of Relevant Synthetic Compounds in Dentistry. *Molecules*, *29*(16), 3802. https://www.mdpi.com/1420-3049/29/16/3802

Dumortier, G., Grossiord, J. L., Agnely, F., & Chaumeil, J. C. (2006). A review of poloxamer 407 pharmaceutical and pharmacological characteristics. *Pharmaceutical research*, *23*, 2709-2728.

El Enshasy, H. A., Niazy, M. A., Kamh, R., Heng, L. H., & Salaie, R. N. (2024). Recent Development in Oral Hygiene Products: From Product Development to Market. In *Natural Conservative Dentistry: An Alternative Approach to Solve Restorative Problems* (pp. 239-253). Bentham Science Publishers.

Fouad, S. A., Malaak, F. A., El-Nabarawi, M. A., & Abu Zeid, K. (2020). Development of orally disintegrating tablets containing solid dispersion of a poorly soluble drug for enhanced dissolution: in-vitro optimization/in-vivo evaluation. *PLOS ONE*, *15*(12), e0244646.

Gao, Y., Zhang, Y., Hong, Y., Wu, F., Shen, L., Wang, Y., & Lin, X. (2022). Multifunctional role of silica in pharmaceutical formulations. *AAPS PharmSciTech*, *23*(4), 90.

Guideline, A. (2005). ASEAN guideline on stability study of drug product. *ASEAN Consultative Committee for Standard and Quality, Philiphines*.

Gupta, A., Gallagher, J. E., Chestnutt, I. G., & Godson, J. (2021). Formulation and fluoride content of dentifrices: a review of current patterns. *British dental journal*, 1-6.

Haider, A., Khadatkar, P., Suresh, S., Arisutha, S., & Verma, S. (2021). Fluorides-foundation for healthy teeth: a dental perspectives. *Journal of sol-gel science and technology*, *100*, 375-387.

Hartshorn, J. E., & Nair, R. U. (2023). Dental innovations which will influence the oral health care of baby boomers. *Special Care in Dentistry*, *43*(3), 359-369. https://doi.org/https://doi.org/10.1111/scd.12835

Hubbs, A., Greskevitch, M., Kuempel, E., Suarez, F., & Toraason, M. (2005). Abrasive blasting agents: designing studies to evaluate relative risk. *Journal of Toxicology and Environmental Health, Part A*, *68*(11-12), 999-1016.

Imam, S. H., Bilbao-Sainz, C., Chiou, B.-S., Glenn, G. M., & Orts, W. J. (2013). Biobased adhesives, gums, emulsions, and binders: current trends and future prospects. *Journal of Adhesion Science and Technology*, *27*(18-19), 1972-1997.

Jamieson, P. R., Le, A., & Mulderrig, K. B. (2012). Sorbitol and mannitol. *Alternative sweeteners. CRC Press, Taylor & Francis Group, Boca Racton*.

Johannsen, G., Georg, T., Annsofi, J., & and Liljeborg, A. (2013). The importance of measuring toothpaste abrasivity in both a quantitative and qualitative way. *Acta Odontologica Scandinavica*, *71*(3-4), 508-517. https://doi.org/10.3109/00016357.2012.696693

Juvonen, H., Antikainen, O., Lemmens, M., Ehlers, H., & Juppo, A. (2021). The effect of relative humidity and formulation variables on chewable xylitol-sorbitol tablets. *International journal of pharmaceutics*, *601*, 120573.

Kashinath, K. P., Sardar, M. S., Sah, S. K., & Kaity, S. (2024). Stability and accelerated stability studies of dosage forms. In *Physico-Chemical Aspects of Dosage Forms and Biopharmaceutics* (pp. 19-42). Elsevier.

Komarov, G. N., Hope, C. K., Wang, Q., Adejemi, A. A., Smith, P. W., Burnside, G., Inui, T., & Higham, S. M. (2017). Dental plaque regrowth studies to evaluate chewing

gum formulations incorporating magnolia bark extract. *Journal of Functional Foods*, *37*, 612-617. https://doi.org/https://doi.org/10.1016/j.jff.2017.08.016

Kumar, A., Sivakumar, G., & Baskaran, A. (2023). AN ALTERNATIVE TO TOOTHPASTE WITH CHEWABLE TOOTHPASTE TABLETS -A REVIEW. *PARIPEX INDIAN JOURNAL OF RESEARCH*, 130-132. https://doi.org/10.36106/paripex/8710446

Lavoie, F., Feeney, N., Mc Callum, L., Paquet, M.-J., Fortin, Y., Nadeau, D., Duhamel, A., Lefebvre, D., Roy, M., & Boudreau, S. (2007). Evaluation of toothpastes and of the variables associated with the choice of a product. *Canadian Journal of Dental Hygiene*, *41*(1), 42-57.

Lee, Y.-J., Lee, Y. M., Lee, C.-K., Jung, J. K., Han, S. B., & Hong, J. T. (2011). Therapeutic applications of compounds in the Magnolia family. *Pharmacology & Therapeutics*, *130*(2), 157-176. https://doi.org/https://doi.org/10.1016/j.pharmthera.2011.01.010

Maher, S., Geoghegan, C., & Brayden, D. J. (2023). Safety of surfactant excipients in oral drug formulations. *Advanced Drug Delivery Reviews*, *202*, 115086.

Maldupa, I., Brinkmane, A., Rendeniece, I., & Mihailova, A. (2012). Evidence based toothpaste classification, according to certain characteristics of their chemical composition.

Munson, B., & Vujicic, M. (2021). Projected supply of dentists in the United States, 2020–2040. *Health Policy Institute Research Brief. American Dental Association. May*.

Nayak, P. A., Anand, N. U., & and Khandelwal, V. (2014). The effect of xylitol on dental caries and oral flora. *Clinical, Cosmetic and Investigational Dentistry*, *6*(null), 89-94. https://doi.org/10.2147/CCIDE.S55761

Nokhodchi, A., & Javadzadeh, Y. (2007). The effect of storage conditions on the physical stability of tablets.

Nowak, K., Jabłońska, E., & Ratajczak-Wrona, W. (2021). Controversy around parabens: Alternative strategies for preservative use in cosmetics and personal care products. *Environmental research*, *198*, 110488.

Ogata, M., Hoshi, M., Shimotohno, K., Urano, S., & Endo, T. (1997). Antioxidant activity of Magnolol, honokiol, and related phenolic compounds. *Journal of the American Oil Chemists' Society*, *74*, 557-562. https://doi.org/10.1007/s11746-997-0180-3

Ogboji, J., Chindo, I., Jauro, A., Boryo, D. E. A., & M, L. (2018). Formulation, physicochemical evaluation and antimicrobial activity of green toothpaste on streptococcus mutans. *International Journal of Advanced Chemistry*, *6*, 108. https://doi.org/10.14419/ijac.v6i1.10808

Osei-Yeboah, F., & Sun, C. C. (2015). Validation and applications of an expedited tablet friability method. *International journal of pharmaceutics*, *484*(1-2), 146-155.

Pader, M. (2018). Glycerine in oral care products. In *Glycerine* (pp. 381-393). CRC Press.

Patel, S., Kaushal, A. M., & Bansal, A. K. (2006). Compression physics in the formulation development of tablets. *Critical Reviews™ in therapeutic drug carrier systems*, *23*(1).

Pharmacopeia, U. S. (2022). *The United States Pharmacopeia and National Formulary (USP 44-NF 39)*.

Pilecco, R. O., da Rosa, L., Tribst, J., Kleverlaan, C., Özcan, M., & Feilzer, A. (2024). Relative abrasive potential of silica-based conventional and tablet dentifrices on enamel and dentin. *PLOS ONE*, *19*. https://doi.org/10.1371/journal.pone.0313637

Prete, B., Barsoum, F., & Ouanounou, A. (2022). Toothpaste in Dentistry: A Review. *Oral Health Group*.

Renu, J. D., Jalwal, P., & Singh, B. (2015). Chewable tablets: a comprehensive review. *The Pharma Innovation Journal*, *4*(5), 100-105.

Rossi, A. D., Ferreira, D. C. A., Silva, R. A. B. d., Queiroz, A. M. d., Silva, L. A. B. d., & Nelson-Filho, P. (2014). Antimicrobial activity of toothpastes containing natural extracts, chlorhexidine or triclosan. *Brazilian dental journal*, *25*(3), 186-190.

Rowe, R. C., Sheskey, P., & Quinn, M. (2009). *Handbook of pharmaceutical excipients*. Libros Digitales-Pharmaceutical Press.

RP, R., Aswathy, B., Nabeela, P., Rekha, M., Ravindran, R., & Paduvanpadath, L. (2024). FORMULATION AND EVALUATION OF RICE BRAN OIL INCORPORATED TOOTHPASTE FOR ORAL HYGIENE.

Saeed, M., Malik, R. N., & Kamal, A. (2020). Fluorosis and cognitive development among children (6–14 years of age) in the endemic areas of the world: A review and critical analysis. *Environmental Science and Pollution Research*, *27*, 2566-2579.

Sakaue, Y., Domon, H., Oda, M., Takenaka, S., Kubo, M., Fukuyama, Y., Okiji, T., & Terao, Y. (2016). Anti-biofilm and bactericidal effects of magnolia bark-derived magnolol and honokiol on Streptococcus mutans. *Microbiol Immunol*, *60*(1), 10-16. https://doi.org/10.1111/1348-0421.12343

Sarawade, P. B., Kim, J.-K., Hilonga, A., & Kim, H. T. (2010). Production of low-density sodium silicate-based hydrophobic silica aerogel beads by a novel fast gelation process and ambient pressure drying process. *Solid State Sciences*, *12*(5), 911-918.

Schemehorn, B. R., Moore, M. H., & Putt, M. S. (2011). Abrasion, polishing, and stain removal characteristics of various commercial dentifrices in vitro. *Journal of Clinical Dentistry*, *22*(1), 11.

Seitz, J. A., & Flessland, G. M. (1965). Evaluation of the physical properties of compressed tablets I: Tablet hardness and friability. *Journal of pharmaceutical sciences*, *54*(9), 1353-1357.

Sengar, A., Vashisth, H., Chatekar, V. K., Gupta, B., Thange, A. R., & Jillella, M. (2024). From concept to consumption: A comprehensive review of chewable tablets. *World Journal of Pharmaceutical Research*, *13*(16), 176-189.

Shanebrook, A. C. (2004). Formulation and use of surfactants in toothpastes. *Citeseer: colloid and surface phenomenon*.

Shangraw, R. F. (1989). Compressed tablets by direct compression. *Pharmaceutical dosage forms: Tablets*, *1*, 195-246.

Sharif, R. B., Tusher, M. S. R., & Zawad, M. (2021). *A Study Based on the Elimination of the Packaging Materials with Low Utile Value and Sustainable Packaging in the Oral Care Industry of Bangladesh* Department of Civil and Environmental Engineering (CEE), Islamic University …].

Sinka, I., Motazedian, F., Cocks, A., & Pitt, K. (2009). The effect of processing parameters on pharmaceutical tablet properties. *Powder Technology*, *189*(2), 276-284.

Stanley-Wood, N. (2008). Bulk powder properties: instrumentation and techniques. *Bulk Solids Handling: Equipment Selection and Operation*, 1-67.

Sun, C. C. (2011). Decoding powder tabletability: roles of particle adhesion and plasticity. *Journal of Adhesion Science and Technology*, *25*(4-5), 483-499.

Tangerman, A., & Winkel, E. G. (2013). Volatile sulfur compounds as the cause of bad breath: a review. *Phosphorus, Sulfur, and Silicon and the Related Elements*, *188*(4), 396-402.

Van Veen, B., Bolhuis, G., Wu, Y., Zuurman, K., & Frijlink, H. (2005). Compaction mechanism and tablet strength of unlubricated and lubricated (silicified) microcrystalline cellulose. *European Journal of Pharmaceutics and Biopharmaceutics*, *59*(1), 133-138.

Vranić, E., Lacević, A., Mehmedagić, A., & Uzunović, A. (2004). Formulation ingredients for toothpastes and mouthwashes. *Bosn J Basic Med Sci*, *4*(4), 51-58. https://doi.org/10.17305/bjbms.2004.3362

Walker, J. M., Maitra, A., Walker, J., Ehrnhoefer-Ressler, M. M., Inui, T., & Somoza, V. (2013). Identification of Magnolia officinalis L. bark extract as the most potent anti-inflammatory of four plant extracts. *The American journal of Chinese medicine*, *41*(03), 531-544.

Walsh, T., Worthington, H. V., Glenny, A. M., Marinho, V. C., & Jeroncic, A. (2019). Fluoride toothpastes of different concentrations for preventing dental caries. *Cochrane database of systematic reviews*(3).

Yee, K. M., Mohamad, N., Kee, P. E., Chew, Y.-L., Lee, S.-K., Lakshminarayanan, V., Tan, C. S., & Liew, K. B. (2024). Recent Advances in Orally Disintegrating Tablet: Properties, Formulation and Production. *Drug Delivery Letters*, *14*(3), 211-225.

Yi, R., & Xu, C. (2022). Experimental study on dense foam toothpaste. *China Surfactant Detergent & Cosmetics*, *52*(11).

Zhao, C., & Liu, Z.-Q. (2011). Comparison of antioxidant abilities of magnolol and honokiol to scavenge radicals and to protect DNA. *Biochimie*, *93*(10), 1755-1760.

Zhao, H., Yu, Y., Ni, N., Zhao, L., Lin, X., Wang, Y., Du, R., & Shen, L. (2022). A new parameter for characterization of tablet friability based on a systematical study of five excipients. *International journal of pharmaceutics*, *611*, 121339.

Zornoza-Indart, A., & Lopez-Arce, P. (2016). Silica nanoparticles (SiO2): Influence of relative humidity in stone consolidation. *Journal of Cultural Heritage*, *18*, 258-270.

APPENDIXS

APPENDIXS

Table 14 Commercial toothpastes composition as listed on packages

Products	Compositions
Commercial toothpaste tablet brand A	Sorbitol, Mannitol, Sodium Cocoyl Glutamate, PVP, Sodium Chloride, Sodium Bicarbonate, Menthol, Talc, Magnesium Stearate, Spearmint Oil
Commercial toothpaste tablet brand B	Sodium Bicarbonate, Xylitol, Spearmint Flavor Powder, Maltitol, Hydrated Silica, Peppermint Powder, Kaolin, Microcrystalline Celluloses, Sodium Cocoyl Glycinate, Sodium Fluoride, Menthol. Contain Sodium Fluoride 0.22% w/w (1000 ppm Fluoride)
Commercial toothpaste (common toothpaste) brand C	Sorbitol, Hydrated Silica, Water (Aqua), Glycerin, PVP, Hydroxyapatite, Sodium Coco-Sulfate, Flavor, Cellulose Gum, Sodium Benzoate, Xanthan Gum, Triclosan, Sodium Saccharin, Xylitol, Cyclodextrin, Carrageenan, Menthol, Mannitol, Microcrystalline, Cellulose, Sucrose, Zea Mays (Corn) Starch, Hydroxypropyl Methylcellulose, CI 77891, CI 77007

APPENDIXS

Color Detection Before and After Brushing

Figure 17 (a) The color detected before brushing, showing the initial stain intensity on the test surface.

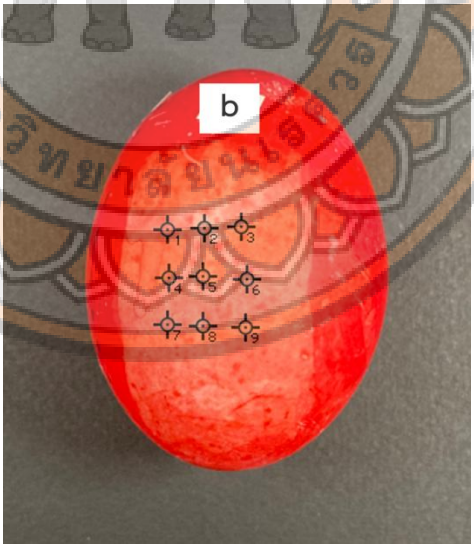

Figure 18 (b) The color detected after brushing, illustrating the effectiveness of the toothpaste formulations in removing the stain.

APPENDIXS

Biosafety approval no. NUIBC MI 64-11-46

ใบรับรองด้านความปลอดภัยทางชีวภาพ

ชื่อโครงการ (ภาษาไทย)	การตั้งตำรับ ประเมินคุณสมบัติทางเคมีกายภาพและประสิทธิภาพในการยับยั้งแบคทีเรียของผลิตภัณฑ์ยาสีฟันรูปแบบเม็ดที่มีส่วนผสมของสารสกัดจากเปลือกแมกโนเลีย
ชื่อโครงการ (ภาษาอังกฤษ)	Formulation physicochemical evaluation and antimicrobial activity of toothpaste tablets containing magnolia bark extract
ชื่อผู้วิจัย	นางสาวเสาวลักษณ์ พลศรี
ชื่ออาจารย์ที่ปรึกษา	ผู้ช่วยศาสตราจารย์ ดร.วรรณี เกรียงไกร
สังกัดหน่วยงาน/คณะ	คณะเภสัชศาสตร์
เลขสำคัญโครงการ	NUIBC MI 64-11-46
เลขที่รับรองโครงการ	64-73
ประเภทการรับรอง	งานประเภทที่ 2
การรับรองครั้งที่ 1	ข้อเสนอการวิจัยนี้ได้ผ่านการพิจารณาและรับรองจากคณะกรรมการเพื่อความปลอดภัยทางชีวภาพ มหาวิทยาลัยนเรศวร ครั้งที่ 3/2565 เมื่อวันที่ 7 ธันวาคม 2564 เห็นว่ามีความสอดคล้องกับแนวทางปฏิบัติเพื่อความปลอดภัยทางชีวภาพ จึงเห็นควรให้ดำเนินการวิจัยด้านความปลอดภัยทางชีวภาพ ตามข้อเสนอการวิจัยนี้ได้
วันหมดอายุครั้งที่ 1	7 ธันวาคม 2565

ลงนาม

(ดร.วิสาข์ สิงหรณ์ไพบูลย์)
ประธานคณะกรรมการเพื่อความปลอดภัยทางชีวภาพ
มหาวิทยาลัยนเรศวร

BIOGRAPHY

BIOGRAPHY

Name –Surname Saowalak Phonsee

Date of Birth April 22, 1995

Address 99 M.6 Banna, Palian District, Trang, 92140, Thailand

Work Place Maison Royal Company Limited, Raintree Office Garden Building A2 Floor 3, 270 Rama IX Soi 17, Khwaeng Bang Kapi, Khet Huai Khwang, Bangkok 10310

Position NPD Supervisor

Work Experiences

2018 Rubia Industries Limited, 70 Phuchao Saming Phray, Bang Ya Phraek, Phra Pradaeng District, Samut Prakan 10130

2022 Do Day Dream Company Limited, 32 Thanon Kheha Rom Klao, Rat Phatthana, Saphan Sung, Bangkok 10240,

2022 Maison Royal Company Limited, Raintree Office Garden Building A2 Floor 3, 270 Rama IX Soi 17, Khwaeng Bang Kapi, Khet Huai Khwang, Bangkok 10310

Education Background

2017 Faculty of Pharmaceutical Sciences, Naresuan University, Bachelor of Sciences (B.S.) Cosmetics Sciences

Publication

Kriangkrai, W., Woravut, N., Pitaksuteepong, T., & Phonsee, S. (2018). Performances of fixative polymers for the virgin Thai hair. *Science, Engineering and Health Studies*, *12*(2), 103–110. https://doi.org/10.14456/sehs.2018.7