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Development and Optimization of Effervescent Toothpaste Tablets: A Novel Approach to Oral Hygiene

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A B S T R A C T :

Background: Effervescent formulations have gained significant attention in pharmaceutical and oral care applications due to their rapid dissolution and ease of use. This study focuses on the development and optimization of an effervescent toothpaste tablet, offering a convenient alternative to conventional toothpaste.

Methods: The formulation process involved the incorporation of effervescent agents (citric acid and sodium bicarbonate), active ingredients (potassium nitrate, sodium lauryl sulfate), and excipients (lactose, starch, magnesium stearate, and sucrose). Three formulation trials were conducted to achieve optimal effervescence, taste, and mechanical properties. The tablets were evaluated for weight variation, hardness, friability, and disintegration time.

Results: Trial 1 exhibited insufficient effervescence, while Trial 2 resulted in a bitter taste due to the active ingredients. Trial 3, incorporating sucrose for taste masking and optimized effervescent agent proportions, demonstrated optimal performance. The final formulation exhibited an average hardness of 1.08 kg/cm², friability of 1.4%, and a rapid disintegration time of 86 seconds, meeting the criteria for effervescent formulations.

Conclusion: The optimized effervescent toothpaste tablet successfully balanced mechanical stability, taste masking, and effervescence. This formulation offers a novel, convenient, and effective approach to oral hygiene, providing an alternative to traditional toothpaste.

Keywords: Effervescent toothpaste tablets, Formulation optimization, Taste Masking, Mechanical properties, Oral hygiene

1. Introduction

Oral hygiene plays a crucial role in maintaining overall health, with dental caries and periodontal diseases being among the most prevalent conditions affecting individuals worldwide (Petersen & Ogawa, 2012). Conventional toothpaste formulations, although effective, often contain water as a primary ingredient, making them susceptible to microbial contamination and reducing their shelf life (Vranić et al., 2004). In response to these limitations, solid toothpaste formulations such as toothpaste tablets have emerged as an innovative alternative, offering benefits such as enhanced portability, reduced plastic waste, and improved stability (Jones, 1997; Padmanabh et al., 2022). Effervescent toothpaste tablets, in particular, have gained attention due to their self-dissolving nature, which enhances dispersion and bioavailability of active ingredients, thereby improving oral health outcomes (Mirza & Gopinath, 2022).

Effervescence is a key physicochemical phenomenon utilized in various pharmaceutical and nutraceutical formulations to facilitate rapid disintegration and dissolution in aqueous environments (Jadhav & Gangurde, 2023). It is commonly achieved through acid-base reactions between citric acid or tartaric acid and a carbonate source such as sodium bicarbonate, generating carbon dioxide and leading to the breakdown of the tablet structure (Jacob et al., 2009). This mechanism not only aids in uniform distribution of active ingredients but also enhances sensory perception, making the formulation more acceptable to consumers (Adepu & Ramakrishna, 2021). Moreover, the absence of synthetic detergents such as sodium lauryl sulfate (SLS) in effervescent tablets can help reduce oral mucosal irritation, making them suitable for individuals with sensitive oral tissues (Herlofson & Barkvoll, 1994).

The incorporation of fluoride and other remineralizing agents, such as calcium phosphates or hydroxyapatite, in effervescent toothpaste tablets has shown potential in reinforcing enamel and preventing demineralization (Karlinsey et al., 2011). Additionally, plant-derived bioactives, including polyphenols and essential oils, have been investigated for their antimicrobial and anti-inflammatory properties, offering a multifunctional approach to oral care (Karygianni et al., 2015; Mandal & Domb, 2024). The growing emphasis on sustainability and eco-friendly personal care products has further fueled the demand for water-free, biodegradable formulations that minimize environmental impact (Couceiro et al., 2025).

Despite these advantages, research on the efficacy, safety, and consumer acceptability of effervescent toothpaste tablets remains limited. This study aims to explore the formulation, physicochemical properties, and potential clinical benefits of effervescent toothpaste tablets, contributing to the development of innovative and sustainable oral care solutions.

2. Materials and Methods

2.1. Materials

The materials used in the formulation of effervescent toothpaste tablets included various active and excipient ingredients, each playing a specific role in the composition. Potassium nitrate was utilized for its desensitizing properties, while sodium lauryl sulfate (SLS) functioned as a surfactant to enhance foaming. Citric acid and sodium bicarbonate were included to provide the effervescent effect necessary for rapid disintegration. Lactose acted as a filler, whereas starch potato served as a binder. Magnesium stearate was used as a lubricant to improve tablet formation. Additionally, menthol crystals were incorporated to impart a cooling sensation and freshening effect. In the final formulation, sucrose was added as a sweetening agent to mask any undesirable taste.

2.2. Methods

2.2.1. Preparation of Effervescent Toothpaste Tablets

The formulation process involved dry granulation, mixing, and compression steps to obtain the effervescent toothpaste tablets. Initially, the required quantities of citric acid, tartaric acid, and sodium bicarbonate were taken in a mortar and pestle and thoroughly mixed to ensure homogeneity. This dry granulation method facilitated uniform blending of the effervescent agents, which are crucial for the rapid disintegration of the tablet.

Following this, potassium nitrate and SLS were incorporated into the granulated mixture and blended uniformly. The addition of these ingredients ensured the desensitizing and foaming properties required for an effective toothpaste formulation. Subsequently, lactose (filler), starch (binder), and magnesium stearate (lubricant) were introduced into the mixture and mixed adequately to prevent aggregation and facilitate tablet compression.

Menthol crystals were then added to impart a cooling sensation and enhance breath-freshening properties. The final step in the formulation involved the addition of sucrose, which acted as a sweetening agent to mask any bitter or sour taste of the ingredients. The entire mixture was mixed thoroughly to ensure uniform distribution of all components and to maintain a dry consistency, as moisture could adversely affect the formulation by initiating premature effervescence.

The prepared powder blend was then transferred to a tablet punching machine, where tablets were punched as per the required specifications. Three different trials were conducted, adjusting the composition slightly to optimize tablet characteristics. The final formulation included all the essential components in their most effective proportions.

Trials and Formulation

Three different trials were conducted to optimize the formulation of the effervescent toothpaste tablet. The compositions of each trial are as follows:

Trial 1

Sr no.	Name of ingredients	Quantity to be taken
1	Potassium nitrate	1 gm
2	SLS (Sodium lauryl sulfate)	1 gm
3	Citric acid	10 gm
4	Sodium bicarbonate	10 gm
5	Lactose	3.5 gm
6	Starch potato	0.5 gm
7	Magnesium stearate	q.s
8	Menthol crystal	1 gm

Trial 2

Sr no.	Name of ingredients	Quantity to be taken
1	Potassium nitrate	1 gm
2	SLS (Sodium lauryl sulfate)	1 gm
3	Citric acid	10 gm
4	Sodium bicarbonate	15 gm
5	Lactose	3.5 gm
6	Starch potato	0.5 gm
7	Magnesium stearate	q.s
8	Menthol crystal	1 gm

Trial 3 (Final Formulation)

Sr no.	Name of ingredients	Quantity to be taken
1	Potassium nitrate	1 gm
2	SLS (Sodium lauryl sulfate)	1 gm
3	Citric acid	10 gm
4	Sodium bicarbonate	15 gm
5	Lactose	3.5 gm
6	Starch potato	0.5 gm
7	Magnesium stearate	q.s
8	Menthol crystal	1 gm
9	Sucrose	15 gm

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2.2.2. Evaluation Parameters

2.2.2.1. Weight Variation

To assess uniformity, twenty tablets from each formulation were randomly selected and weighed individually. The average weight was calculated, and the deviation of each tablet from the mean was determined. The standard average weight of the effervescent toothpaste tablet was found to be 250 mg.

2.2.2.2. Hardness Test

The mechanical strength of the tablets was assessed using a Monsanto Hardness Tester. In this test, the tablet was placed between a fixed and a movable jaw, and pressure was applied via a screw knob. The force required to break the tablet was recorded in kg/cm², ensuring that the tablets possessed adequate hardness for handling and storage while still being able to dissolve quickly upon use.

2.2.2.3. Friability

Friability testing was conducted using a Veego Friabilator to determine the tablet's resistance to abrasion and mechanical stress. Tablets were subjected to 100 revolutions at a speed of 25 rpm in a plastic chamber, where they were repeatedly dropped from a height of 6 inches. The tablets were pre-weighed before and after the test, and the percentage friability was calculated using the formula:
Friability (%) = (Initial weight – Final weight) / Initial weight × 100.

2.2.2.4. In vitro Disintegration Time

The disintegration time of the effervescent toothpaste tablets was determined using a tablet disintegration test apparatus. Six tablets from each formulation were placed in separate tubes of the apparatus, with a disc positioned over each tablet. The apparatus was maintained at a temperature of 37°±2°C, simulating the oral environment. The time required for the tablets to disintegrate completely was recorded, ensuring that the formulation met the required criteria for rapid disintegration.

3. Results

3.1. Formulation results

Trial 1 Result:
Effervescence was not properly produced. The reason for this failure was attributed to the quantity of the effervescent ingredients, such as citric acid and sodium bicarbonate, which may have influenced the reaction.

Trial 2 Result:
The tablets had a bitter or sour taste. This was due to the active ingredients, particularly sodium bicarbonate and citric acid. To counteract this, sucrose was added as a sweetening agent in the final formulation to mask the undesirable taste.

Trial 3 Result:
The final formulation produced optimum results with a balance of effervescence, taste, and mechanical properties.

3.2. General Appearance

- **Size:** Diameter (mm): 0.75, 0.76, 0.76; Thickness (mm): 0.85, 0.89, 0.88
- **Shape:** Round
- **Organoleptic properties:** Color: White.

3.3. Weight Variation Test

Sr. No.	Weight of Tablet (mg)	Deviation (mg)	Deviation (%)
1	710	0.5	0.29
2	690	20.5	2.88
3	730	19.5	2.74
4	730	19.5	2.74
5	710	0.5	0.29
6	690	20.5	2.88
7	730	19.5	2.74
8	730	19.5	2.74
9	690	20.5	2.88
10	720	9.5	1.33
11	720	9.5	1.33
12	710	0.5	0.29
13	700	10.5	1.47
14	710	0.5	0.29
15	690	20.5	2.88
16	690	20.5	2.88
17	720	9.5	1.33
18	700	10.5	1.47
19	710	0.5	0.29
20	730	19.5	2.74

The average weight deviation was calculated, with an overall deviation percentage of 1.82%, indicating that the test was passed.

3.4. Hardness Test

Sr.No.	Hardness (kg/cm²)
1	1.0
2	0.9
3	1.2
4	1.0
5	1.3
Average	1.08

Report: The hardness test was passed, with an average hardness of 1.08 kg/cm².

3.5. Friability Test

Weight of Tablets (gm)	Difference [W1 - W2] (gm)	% Friability
3.57	3.52	1.4%

Report: The friability test was passed, with an average friability of 1.4%.

3.6. Disintegration Test

Sr. No	Disintegration Time (Seconds)
1	80
2	90
3	70
4	90
5	100

Average Disintegration Time: 86 seconds.

4. Discussion

The formulation and optimization of an effervescent toothpaste tablet required careful consideration of ingredient selection and their interactions. The primary challenge encountered in the formulation was achieving an optimal balance between effervescence, taste masking, and mechanical properties.

The effervescence observed in the tablet formulation was attributed to the reaction between citric acid and sodium bicarbonate upon exposure to moisture. A well-balanced ratio of these ingredients is essential for effective effervescence (Patel & Siddaiah, 2018). In the first trial, insufficient effervescence was observed, which could be due to an imbalance in the quantities of citric acid and sodium bicarbonate. Similar findings have been reported in previous studies, where modifying the acid-base ratio improved the effervescence of pharmaceutical and oral hygiene formulations (Thluai et al., 2023).

Taste masking was another crucial parameter in the optimization of the formulation. Citric acid and sodium bicarbonate impart a characteristic sour and bitter taste, which can reduce consumer acceptability. The addition of sucrose in the final formulation significantly improved the palatability of the tablet. This approach aligns with research demonstrating the role of sweetening agents in masking undesirable tastes in effervescent formulations (Sharma et al., 2012).

Mechanical properties such as hardness, friability, and disintegration time were evaluated to ensure adequate tablet integrity and rapid dissolution. The hardness test results indicated an average hardness of 1.08 kg/cm², which is within the acceptable range for effervescent tablets. Studies suggest that maintaining tablet hardness within an optimal range is essential to prevent breakage while ensuring rapid disintegration upon administration (Dulla et al., 2018). Additionally, the friability test results (1.4%) confirmed the mechanical stability of the tablets, aligning with previous research that established friability limits of less than 1.5% for effervescent tablet formulations (Karalia et al., 2021).

The in-vitro disintegration study demonstrated an average disintegration time of 86 seconds, which is suitable for an effervescent formulation. Research has indicated that rapid disintegration (less than 2 minutes) enhances user experience and efficacy in oral hygiene applications (Markl & Zeitler, 2017). The optimized formulation achieved this requirement by carefully adjusting excipient proportions and employing lactose and starch as filler and binder, respectively. Studies have previously reported that using lactose and starch improves tablet disintegration and dispersion rates in effervescent formulations (van der Merwe et al., 2020).

Thus, the final formulation successfully balanced effervescence, taste masking, and mechanical integrity, making it an effective and consumer-friendly effervescent toothpaste tablet.

5. Conclusion

The study aimed to develop an optimized effervescent toothpaste tablet with improved mechanical properties, taste, and effervescence. The formulation was systematically refined through three trials, addressing key challenges such as insufficient effervescence, undesirable taste, and mechanical stability. The final formulation demonstrated effective effervescence, acceptable taste, and optimal hardness, friability, and disintegration properties. The study's findings align with existing literature on effervescent formulations, further validating the optimization strategies used. This effervescent toothpaste tablet formulation has the potential for commercial application, offering an innovative and convenient alternative to traditional toothpaste.

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