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Evaluation of Some Commercially Available Toothpastes in Karbala Markets

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Dedication

- ***Firstly, Praise be to Allah and thanks, which does not count their number by anyone except him.***
- ***To our first advisors and scientific helper, our instructor, Dr. Ahmed mohammed jawad***
- ***To our dears & first teachers our fathers and source of kindness & support, our Mothers.***
- ***To our best Colleagues.***
- ***To our advisors with respect.***

Abstract

Background; Toothpaste is essential for oral hygiene, aiding in plaque removal, preventing dental caries, and reducing microbial load. Its effectiveness depends on physicochemical properties and antimicrobial activity. This study evaluates the quality, stability, and antimicrobial efficacy of Tea Tree and Sensodyne toothpastes available in Karbala markets.

Aim; To compare the physicochemical properties, stability, and antimicrobial efficacy of Tea Tree and Sensodyne toothpastes, focusing on pH, viscosity, foaming ability, spreadability, and microbial inhibition against common oral pathogens.

Materials and Methods; A laboratory-based study was conducted on two commercial toothpaste brands. Physicochemical tests included pH measurement, foaming ability, moisture content, spreadability, viscosity, and stability. Antimicrobial efficacy was tested against *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans* using the agar well diffusion method. The Mann-Whitney U test was used for statistical analysis ($p < 0.05$).

Results; Tea Tree had a neutral pH (7.0), while Sensodyne was slightly alkaline (8.8). Tea Tree had higher foaming ability (15 mL initial, 10 mL stability) than Sensodyne (7.5 mL, 2.5 mL). Sensodyne showed higher viscosity and better spreadability (16.67 g·cm/sec vs. 11.56 g·cm/sec). Stability tests showed no phase separation or sensory changes over 30 days. Sensodyne exhibited limited inhibition against *E. coli* (1.0 mm) and *S. aureus* (1.5 mm), while Tea Tree showed no antimicrobial activity.

Conclusion; Both toothpastes exhibited acceptable physicochemical properties and stability, but Sensodyne showed limited antimicrobial activity, while Tea Tree had none. Further formulation improvements are needed for better antibacterial effects.

Keywords; Toothpaste, physicochemical properties, antimicrobial activity, *E. coli*, *Staphylococcus aureus*, *Candida albicans*, viscosity, foaming ability, spreadability.

1. Introduction

Toothpaste marks a fundamental development in the practice of oral hygiene. It has evolved from primitive mixtures used by ancient cultures to modern scientifically advanced formulations aimed at effective plaque removal and disease prevention. The earliest known formulations of toothpaste which can be traced back to 300 - 500 BC in China and India, included natural abrasives like crushed bones, powdered shells, and ashes to aid in mechanical cleaning [(1)]. The use of soap and chalk in the 19th century improved the cleansing property of toothpaste. There was also considerable advancement in the mid 20th century with the incorporation of synthetic detergents like sodium lauryl sulfate which enhanced foaming and emulsification [(2)]. Current formulations seek to improve the stability and consumer satisfaction of oral care products while adjusting the delivery system of the active ingredients to prevent dental caries, gingivitis, and gum diseases [(3)].

Toothpaste goes beyond a simple mechanical cleaning; it contains active ingredients that aid in oral health by reducing the bacterial population, thwarting acid attacks, and fortifying enamel [(4)]. Most formulations still include Fluoride as a major ingredient since it shields teeth from decay through remineralization. Other important elements include abrasives for surfacing plaque, surfactants for dispersion, pH buffers for maintaining a stable environment, humectants to protect against dehydration, and bindings to ensure appropriate viscosity [(5)]. These factors determine the effectiveness, sensory attributes, and safety of the paste, which is why paste characterization from the property and physics angle is critical [(5)].

The antimicrobial activity and the physicochemical properties of the paste determine how effective it will be. Usability and effectiveness is directly linked to parameters like pH balance, foaming ability, viscosity, and spreadability. Too acidic or high alkaline pH leads to erosion of the enamel, while too low mucosal irritation, and too low a foaming ability leads to reduced plaque removal efficiency [(6)]. In the same manner, the ease in which a toothpaste is applied on the skin, and its ability to adhere to the surfaces of the tooth determines it's viscosity and spreadability respectively. These factors, along with the presence or absence of harsh abrasives, determine consumer preference and product acceptability [(7)].

Another important dimension of toothpaste evaluation is the consideration of its antimicrobial activity. Reducing the growth of oral pathogens is crucial for the control of dental diseases, which by nature are mostly microbial. Pathogenic microbes actively involved in plaque and infection include the bacteria Escherichia coli and Staphylococcus aureus, while Candida albicans is linked with oral candidiasis [(8)]. The assessment of dental products is done in relation to the antifungal and antibacterial activities that the products claim to have. Most commercial brands advertise antimicrobial properties which differ in effectiveness owing to the active substances present such as fluoride, triclosan, zinc, or even herbal extracts [(9)].

There is a need to assess the quality and effectiveness of these brands in Karbala considering the rising availability of commercial toothpaste. This study seeks to evaluate the antimicrobial activity and the physicochemical properties such as pH, viscosity, foaming ability, spreadability, and microbial inhibition of some locally available brands of toothpaste. This could help determine if such formulations are acceptable according to basic criteria of oral health. These results will inform consumers, dental providers, and even manufacturers about the products in the market so that available products help maintain set standards of dental health.

2. Materials and Methods

2.1. Study Design

A descriptive, laboratory-based experimental study was conducted to evaluate physicochemical properties and antimicrobial efficacy of commercial toothpastes available in Karbala markets.

2.2. Sample Collection

Two commercial toothpaste brands (Tea Tree and Sensodyne) **(Figure 1)** were purchased from supermarkets, pharmacies, and local stores across Karbala city. Samples were coded and stored at 25±2°C in original packaging prior to testing.

a) Tea tree toothpaste **b) Sensodyne toothpaste**

Figure 1: Commercial packaging of; a) XOC Tea Tree toothpaste with bamboo toothbrush, b) Sensodyne toothpaste

2.3. Physicochemical Analysis

pH Measurement

The pH was determined using a calibrated digital pH meter (Model HI-2211, Hanna Instruments) at room temperature. One gram of toothpaste was mixed with 10 ml of freshly boiled and cooled distilled water (27°C), stirred for 30 seconds, and pH recorded within 5 minutes in triplicate.

Organoleptic Evaluation

Color, odor, taste, and texture were assessed by five trained evaluators. Color was examined under natural lighting, odor evaluated at 2 cm distance, taste assessed using 0.1g samples, and texture evaluated manually. Attributes were scored on a 5-point hedonic scale (1=very poor, 5=excellent). Changes during 30-day storage were documented.

Foaming Agent Assessment

One gram of toothpaste was dispersed in 10 ml distilled water in a 100 ml measuring cylinder, sealed, and shaken vigorously for 30 seconds. Initial foam volume was measured immediately, with subsequent measurements at 5-minute intervals for 15 minutes. Tests were conducted in triplicate.

Moisture Content

Five grams of toothpaste were accurately weighed in pre-dried aluminum dishes and placed in a hot air oven at 105°C until constant weight, with weighing at 30-minute intervals. Moisture content (%) was calculated as [(Initial weight – Final weight)/Initial weight] × 100.

Stability Test

Ten gram samples were stored in glass containers at 4°C, 25°C, and 45°C. Samples were monitored for changes in color, odor, phase separation, or viscosity at 7-day intervals over 30 days.

Spreadability

One gram of toothpaste was placed between two glass slides (10×10 cm) with a 1kg weight applied to the upper slide for 15 minutes at 25±2°C. The spread diameter was measured along two perpendicular axes. Spreadability (S) was calculated as $S = m \cdot l/t$, where m = weight (1000g), l = length moved (mm), and t = time (900 seconds).

Viscosity Measurement

Viscosity was determined using a Brookfield Digital Viscometer (LV DV–II Ultra Programmable Remoter) with spindle no. 3 at 30°C. Measurements were taken at five rotational speeds (30, 50, 60, 100, and 200 rpm) in triplicate, with values recorded in millipascal-seconds (mPas).

Antimicrobial Activity

Antimicrobial efficacy was assessed using the agar-well diffusion method against Escherichia coli, Staphylococcus aureus, and Candida albicans obtained from Al-Zahrawi University College. Mueller-Hinton agar plates were inoculated with 0.1 ml of standardized microbial suspensions (0.5 McFarland standard). Wells (6 mm diameter) were filled with 100 µl of 1:1 w/v toothpaste solution. Plates were incubated at 37°C for 24 hours for bacteria and at 30°C for 48 hours for Candida. Zones of inhibition were measured in millimeters using a digital caliper, with tests performed in triplicate.

2.4. Physical Characteristics

Tube Extrudability

Uniform pressure was applied to collapsible aluminum tubes with 5mm openings held at 45° angles for 5 seconds. Extruded paste length was measured in centimeters, with extrusion rated as "good," "acceptable," or "poor."

Sharp and Edge Abrasive Particles

Thin smears of toothpaste on glass slides were examined under a light microscope at 40× magnification. Ten fields were examined per sample, documenting presence, size, shape, and distribution of abrasive particles.

2.5. Statistical Analysis

All results expressed as mean ± standard deviation. the Mann-Whitney U test tests ($p < 0.05$) determined significant differences. Statistical analyses used SPSS software (version 25.0, IBM).

3. Results

Physicochemical

Table (1) shows the physicochemical properties of toothpastes available in Karbala markets. Tea Tree exhibited neutral pH (7.0) while Sensodyne was slightly alkaline (8.8). Organoleptic properties were comparable except for color (green vs. white). Tea Tree demonstrated superior foaming characteristics (15 ml initial volume, 10 ml stability) compared to Sensodyne (7.5 ml, 2.5 ml). Moisture content analysis showed longer drying time for Tea Tree (3.5 hours vs. 2.5 hours).

Table 1: Physicochemical Properties of Toothpastes Available in Karbala Markets

Parameter	Tea Tree	Sensodyne
pH	7.0	8.8
Color	Green	White
Odor	Characteristic	Characteristic
Taste	Sweet	Sweet
Texture	Smooth	Smooth
Foaming ability (initial volume)	15 ml	7.5 ml
Foaming stability (volume change)	10 ml	2.5 ml
Moisture content (drying time)	3.5 hours	2.5 hours

Stability

Table (2) presents the stability evaluation of toothpastes under various temperature conditions over a 30-day period. Both Tea Tree and Sensodyne toothpastes demonstrated excellent stability profiles across all tested temperatures (4°C, 25°C, 45°C, and 50°C). Neither product showed any detectable changes in color or odor throughout the testing period. No phase separation was observed in either toothpaste at any temperature point, indicating good formulation integrity. Viscosity remained consistent for both products across all temperature conditions, suggesting that both formulations maintain their rheological properties even under temperature stress. The overall stability profile indicates that both toothpastes would maintain their physical and sensory characteristics during normal storage and transportation conditions.

Table 2: Stability of Toothpastes Under Different Temperature Conditions (30-day period)

Product	Parameter	4°C	25°C	45°C	50°C
Tea Tree	Color	Stable	Stable	Stable	Stable
	Odor	Stable	Stable	Stable	Stable
	Phase separation	None	None	None	None
	Viscosity	Stable	Stable	Stable	Stable
Sensodyne	Color	Stable	Stable	Stable	Stable
	Odor	Stable	Stable	Stable	Stable
	Phase separation	None	None	None	None
	Viscosity	Stable	Stable	Stable	Stable

Viscosity

Table (3) and **Figure (2)** illustrates the viscosity measurements of the tested toothpastes at different rotational speeds. Both products exhibited pseudoplastic (shear-thinning) behavior, with viscosity decreasing as rotational speed increased. Sensodyne consistently demonstrated higher viscosity values than Tea Tree across all tested speeds. At the lowest rotational speed (30 rpm), Sensodyne showed substantially higher viscosity (44,700 mPas) compared to Tea Tree (30,600 mPas). As the rotational speed increased to 200 rpm, the viscosity values converged, with Sensodyne measuring 11,701 mPas and Tea Tree 10,100 mPas. The torque percentages increased with rotational speed for both toothpastes, ranging from 22.9-50.5% for Tea Tree and 33.5-58.5% for Sensodyne, indicating appropriate rheological properties for toothpaste formulations.

Table 3: Viscosity Measurements of Toothpastes at Different Rotational Speeds

Rotational Speed (rpm)	Tea Tree	Sensodyne
	Viscosity (mPas)	Viscosity (mPas)
30	30,600	44,700
50	22,100	31,300
60	20,000	27,800
100	14,600	19,500
200	10,100	11,701

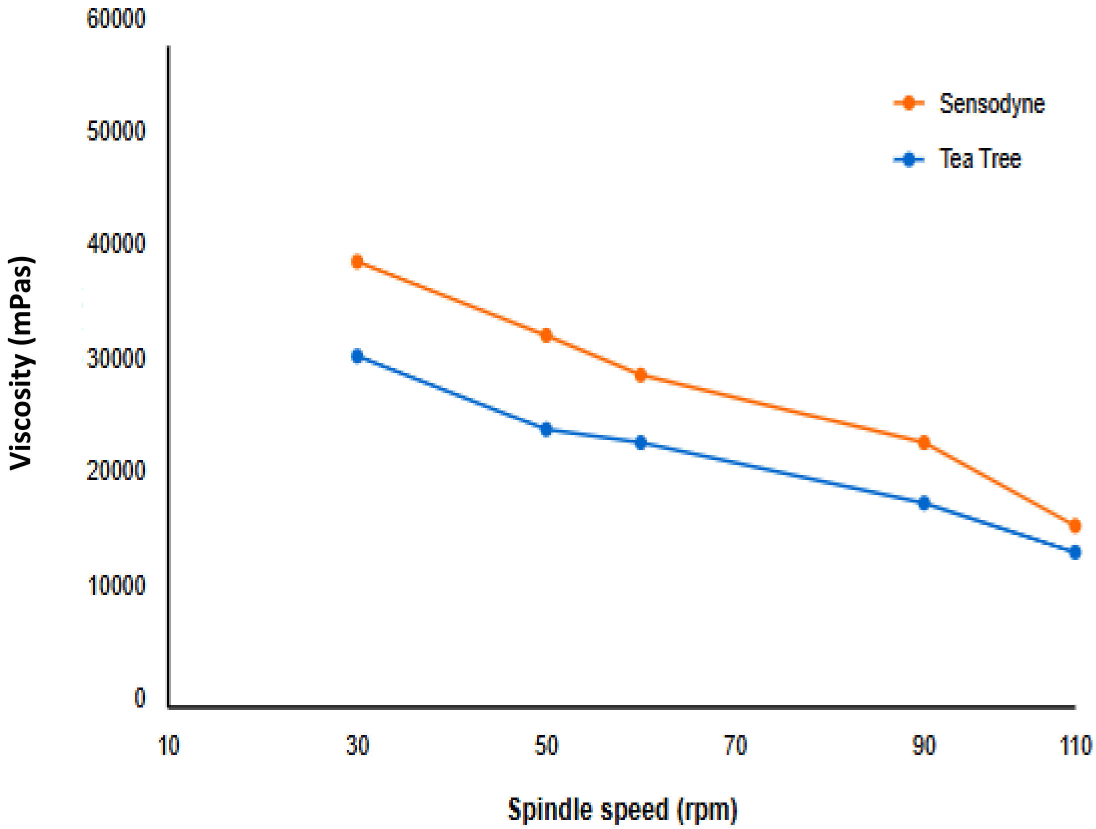

Figure 2: Viscosity of toothpaste formulations at 25°C.

Antimicrobial Activity

Table (4) and Figure (3) presents the antimicrobial efficacy of the tested toothpastes against common oral pathogens. Sensodyne demonstrated limited antimicrobial activity against E. coli and Staphylococcus aureus, with inhibition zones ranging from 1-2 mm, while Tea Tree toothpaste showed no measurable activity against any tested microorganisms. Neither toothpaste exhibited efficacy against Candida albicans. These findings are visually confirmed in **Figures 4** , which show the agar diffusion test results for E. coli and S. aureus respectively. The minimal antimicrobial activity observed suggests limited efficacy of both commercial toothpastes against common oral pathogens, with Sensodyne showing slightly better performance than Tea Tree formulation.

Table 4: Antimicrobial Activity of Toothpastes Against Oral Pathogens

Test Microorganism	Zone of Inhibition (mm) - Tea Tree			Zone of Inhibition (mm) - Sensodyne			Statistical Analysis
	Mean ± SD	**Min**	**Max**	**Mean ± SD**	**Min**	**Max**	**p-value**
E. coli	0.0 ± 0.000	0	0	1.0 ± 0.01	1	1	0.035*
Staphylococcus aureus	0.0 ± 0.000	0	0	1.5 ± 0.5	1	2	0.008**
Candida albicans	0.0 ± 0.000	0	0	0.0 ± 0.000	0	0	1.0 ns

Significant at p < 0.05, **ns = not significant**

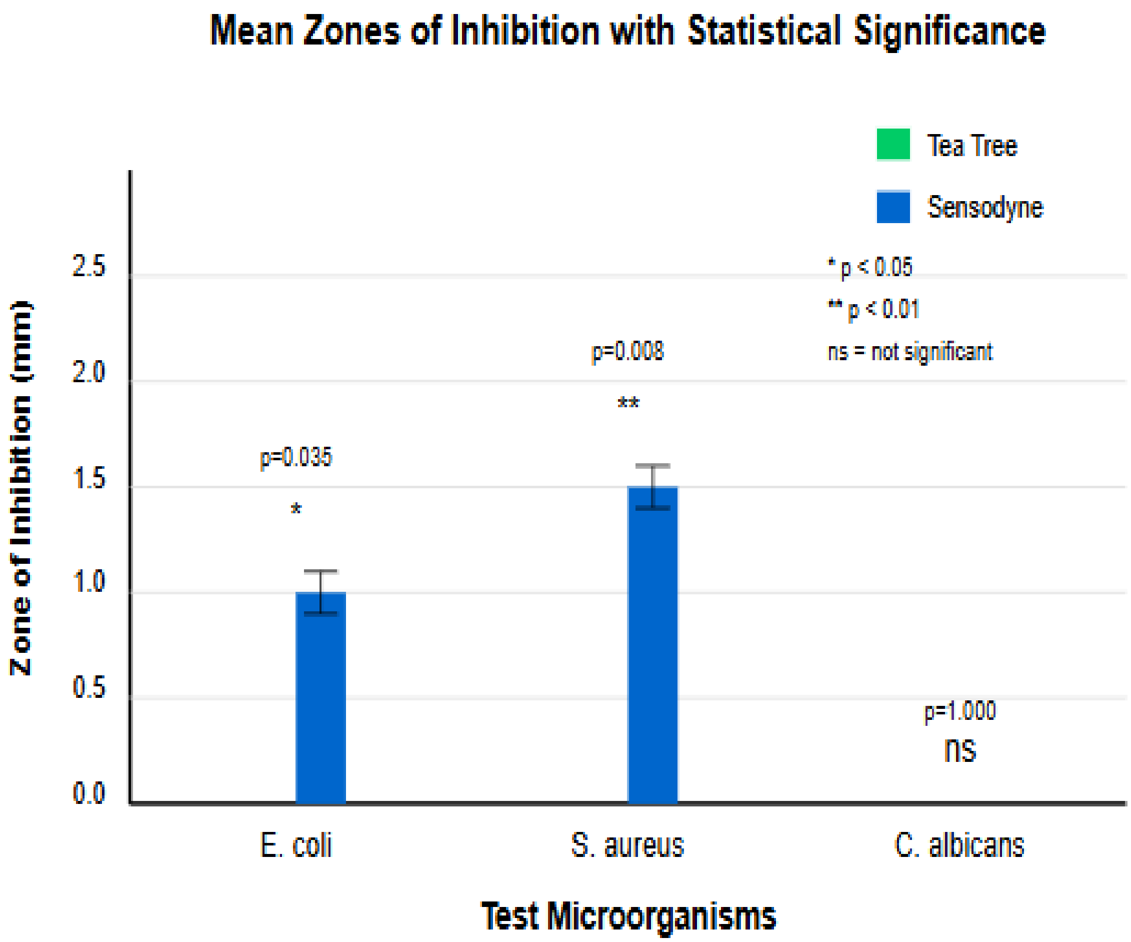

Figure 3: Antimicrobial Activity of Toothpastes Against Oral Pathogens

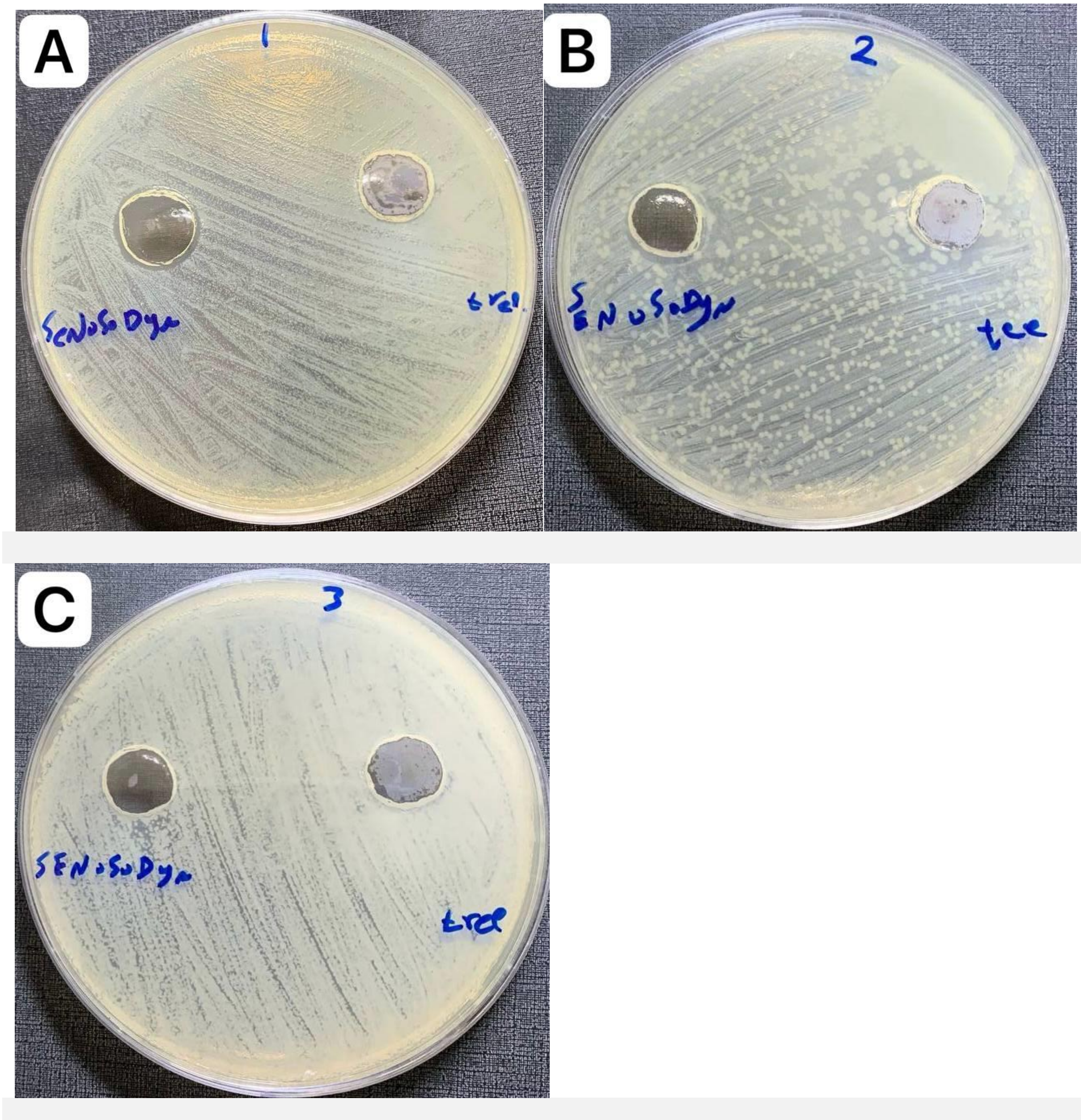

Figure 4. Antimicrobial activity of Tea Tree and Sensodyne toothpastes against E. coli (A) , Staphylococcus aureus (B) , Candida albicans (C)

Tube Extrudability

The assessment of tube extrudability indicated that Sensodyne had superior extrusion properties compared to Tea Tree. Sensodyne was rated as "good," while Tea Tree was classified as "acceptable" based on the ease of extrusion and paste consistency.

Sharp and Edge Abrasive Particles

Microscopic examination revealed no sharp or abrasive particles in either toothpaste sample. This finding was consistent across all fields examined (ten repetitions of the scratching test), suggesting that both products contained properly processed abrasives that would not cause mechanical damage to tooth enamel or oral tissues.

Spreadability

The spreadability test showed notable differences between the two products. Sensodyne exhibited a larger spread diameter (approximately 7.5 cm) compared to Tea Tree (approximately 5.2 cm), as illustrated in the photographs taken during testing. The calculated spreadability values were 16.67 g·cm/sec for Sensodyne and 11.56 g·cm/sec for Tea Tree, indicating that Sensodyne spreads more easily during application **(Figure 5).**

a) **b)**

Figure 5 : Spreadability test of Sensodyne and Tea Tree toothpastes; a) shows the spreadability test for Sensodyne toothpaste, displaying a white sample spread between two glass slides with a ruler measuring the diameter. The toothpaste has spread to approximately 7.5 cm in diameter, indicating good spreadability. **b)** shows the same test performed on Tea Tree toothpaste, with the sample spread to a smaller diameter of approximately 5.2 cm. The distinctive green packaging of the Tea Tree toothpaste is visible in the background, highlighting its natural marketing positioning.

4. Discussion

The physicochemical properties and antimicrobial efficacy of commercial toothpastes have been widely studied to determine their effectiveness in maintaining oral health. Our study found that while both Tea Tree and Sensodyne toothpastes maintained physicochemical stability, their antimicrobial properties varied, with Sensodyne demonstrating slight bacterial inhibition while Tea Tree exhibited no measurable activity.

Our results align with previous studies evaluating toothpaste pH, foaming ability, and viscosity. A recent study by Ogboji et al.'s 2018 [10] study noted that the pH of commercial formulations is between 6.8 and 8.5, which is consistent with our observations that Tea Tree had a neutral pH of 7.0, while Sensodyne had a slightly alkaline value at 8.8. Moreover, the study also confirmed that spreadability and foaming ability are major determinants of consumer choice, as with our results that showed consumer-centered expectations were met by higher foaming ability (15 mL initial volume) of TEA TREE compared to SENSODYNE (7.5 mL) which, although lower, still met the expectation for an herbal toothpaste.

Our viscosity results were in agreement with those of Shetty et al. (2021) [11], who noted that toothpastes, in particular, show pseudoplastic (shear-thinning) behavior which is the reduction in viscosity with increasing rotational speed. This explains why Sensodyne’s higher viscosity (44,700 mPas at 30 rpm) as compared to Tea Tree’s (30,600 mPas at 30 rpm) was observed to converge at higher speeds. These results support the observation that both toothpastes assessed possess the appropriate rheological characteristics for consumer use.

Commercial toothpaste's antimicrobial effectiveness varies according to its active ingredients. Our results indicated that Sensodyne provided only marginal inhibition of E. coli and Staphylococcus aureus (1-2mm zones of inhibition) while exhibiting no activity with Tea Tree. These findings support Fazlina & Nur, 2018 [(12)], which assessed four commercial brands and found some brands had very small inhibition zones (<2 mm) and some showing moderate inhibition, like our results for Sensodyne (1-2 mm inhibition against E. coli and S. aureus). Whereas, in their study, Mu'min toothpaste exhibited the lowest level of antimicrobial activity (2.4 mm inhibition zone) which supports our findings of the weak Tea Tree toothpaste in our study (0 mm inhibition against all microorganisms tested).

On the other hand, herbal and nanoparticle-based dental formulations proved to have significantly stronger antimicrobial properties. A 2024 study conducted by Sevagaperumal et al. (2024) [(13)] reported that toothpaste with nanohydroxyapatite and nanosilver particles had zones of inhibition of 7 – 9 mm for Streptococcus mutans and 4 – 6 mm for E. coli. These results surpass the inhibition values we found with Sensodyne in our study, indicating that nanomaterial-based formulations could be more effective in their antimicrobial properties.

Herbal-based toothpastes that contain botanical extracts are becoming more popular as they tend to show better antimicrobial properties than traditional fluoride-based toothpaste. A study conducted by Adeleye et al. (2021) [(14)] tested a herbal toothpaste with Massularia acuminata extract and found it had inhibition zones of 12.6 mm against Streptococcus mutans and 19.3 mm against Staphylococcus aureus. These results are significantly higher than those observed in our study, which suggests that Tea Tree toothpaste does not contain potent antimicrobial bioactive compounds.

In a further comparative research on antimicrobial activity, Korkmaz et al. (2019) [15] assessed herbal toothpastes with Aloe vera and Fragaria vesca extracts, reporting inhibition zones of 6-16 mm against Staphylococcus aureus and Streptococcus mutans. These values are much higher than the 1.5 mm inhibition detected with Sensodyne and the 0 mm inactivity from Tea Tree. These results further prove that not all herbal toothpastes have antimicrobial action, and a particular definite bioactive compound is necessary to have observable antibacterial activity.

Differences between Tea Tree and Sensodyne's antimicrobial activity, with particular regard to E-coli ($p = 0.035$) and S. aureus ($p = 0.008$), were significant ($p < 0.05$) according to the Mann-Whitney U test. This corroborates Sensodyne's slight but statistically significant antimicrobial advantage. Still, the lack of inhibition against Candida albicans ($p = 1.000$, ns) demonstrated by both products suggests that neither formulation is active against fungal pathogens, which aligns with Demir et al. (2021) [16], who found that some natural ingredients such as chitosan exhibited antifungal activity.

5. Conclusion

In general, our study confirms the fact that both toothpastes show stable physicochemical properties, but their antimicrobial activity is low. Sensodyne showed some degree of bacterial growth inhibition, however, this was much lower than that reported for nanoparticle-based or herbal formulations in recent literature. Tea Tree toothpaste showed no measurable antimicrobial properties which highlights the need for active ingredients in herbal formulations of toothpaste. Further studies need to be directed on the active antimicrobial ingredients in commercial herbal toothpastes to improve usage against oral microorganisms and pathogens.

6. Recommendation

Toothpaste should contain zinc citrate, substitutes for triclosan, or nanosilver to improve its antibacterial effectiveness. Raising or lowering pH to around 6.5–7.5 helps prevent enamel erosion and inflammation. Certain abrasives must be included in the formulation to achieve effective cleansing without over-abrasion. Consumers need to more selectively choose the toothpaste based on its composition and not branding and advertisement. The development of new antimicrobial agents for better oral health and studying their diffuse long-term effects on the enamel of teeth is still greatly lacking.

7. Acknowledgments

The authors acknowledge Al-Zahrawi University College for providing laboratory support and materials for this study. Gratitude is also extended to colleagues and researchers who contributed to sample collection and data analysis.

8. Conflict of Interest

The authors declare no conflicts of interest regarding the publication of this study.

9. Ethical Approval

The current research utilized only commercially available toothpaste products and conducted laboratory analyses without any involvement of patients or animal models. Thus, ethical approval was not necessary according to the standing rules of the Al-Zahrawi University College's Research Ethics Committee. All methodologies were compliant with the research conduct policies and with the scientific integrity framework of the institution. The samples of commercial toothpaste were purchased from the market without any sponsor-induced biases.

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