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Effect of cinnamon extract solution on human tooth enamel surface roughness

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Abstract. Cinnamon is known to have antimicrobial, antifungal, and anti-inflammatory effects on toothache and can aid in fighting bad breath. Cinnamon extract solution has an acidic pH that can affect enamel surface roughness. This study aimed to determine the effect of cinnamon extract solution exposure on human enamel surface roughness. A laboratory experiment was performed using 12 specimens of human premolar teeth that were divided into two treatment groups for immersion in cinnamon extract solutions of concentrations 4% with pH 5.38 (n = 6) and 12.5% with pH 5.45 (n = 6). Each group was immersed for 60, 120, and 180 min. Surface roughness was measured using a surface roughness tester (SurfTest SJ-301, Mitutoyo, Japan). Results analyzed with repeated measures analysis of variance showed that teeth immersed in the 4% cinnamon extract solution for 60, 120, and 180 min showed no significant changes in surface roughness ($p > 0.05$), while teeth immersed in the 12.5% solution for 120 and 180 min showed a significant reduction in surface roughness ($p < 0.05$). It is found that pH, concentration, and duration of exposure to cinnamon extract solution can cause changes in enamel surface roughness.

1. Introduction

These days, public awareness of oral and dental health is increasing as people are starting to pay attention to the cosmetic benefits of maintaining healthy teeth and gums. Mouth cleaning products such as toothpaste and mouthwash are now widely used.

The most common mouthwash products are typically chemical-based; an example is mouthwash containing chlorhexidine, a chemical compound recognized to be effective as an antimicrobial for both gram-positive and gram-negative bacteria, fungi, and some viruses, but has side effects such as unpleasant taste, unpleasant taste, and tooth discoloration that is hard to remove [1]. Therefore, many people currently prefer products that are derived from natural ingredients, such as *Uncaria*, clove, green tea, and cinnamon, as an alternative to chemical-based mouthwash.

Cinnamon has been in regularly use in Indonesian society as an aromatic scent and food-flavoring agent. In addition, it is also believed to be effective for curing influenza, diarrhea, and bloating. Some studies have suggested that cinnamon has an antioxidant, anti-ulcer, antimicrobial, antidiabetic, and anti-inflammatory effect that has long been used to treat toothache and fight bad breath [2].

A study has shown promising results for oil extracted from cinnamon at a concentration of 3.12% in inhibiting the activity of all *Streptococcus mutans* isolated from patients with oral infection,



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whereas a concentration of 12.5% can effectively inhibit the growth of *S. mutans*, *Staphylococcus aureus*, and some isolated *Candida* species [3].

In addition, the authors also evaluated fact sheets and material safety data sheets regarding cinnamon extracts and found a degree of acidity (pH) in cinnamon (4.0–6.5 at 25°C) [4]. Therefore, when applied orally, the acidic nature of cinnamon extract can affect tooth surface roughness. Moreover, a rough human tooth enamel surface encourages plaque formation, which gradually results in the development of various dental and oral diseases.

Considering the benefits and possible side effects of cinnamon, this study explored the use of a cinnamon extract solution as an alternative to mouthwashes derived from herbal ingredients. Considering its degree of acidity, the authors assessed the change in the tooth enamel surface roughness based on the concentration and duration of immersion in the cinnamon extract solution. The purpose of this study is to examine the change in human tooth enamel surface roughness when soaked in 4% and 12.5% active cinnamon extract solution for 60, 120, and 180 min.

2. Methods

The samples were of 12 extracted human premolar teeth, and the study protocol has been approved by the Dental Research Ethics Committee, Faculty of Dentistry, Universitas Indonesia. The number of samples were obtained using the Federer formula. Each specimen was thoroughly washed, and the specimen was held without pressure on a rotating sanding disc of 2000 grit. Not more than 100 μm of the specimen was sanded off. Next, each tooth was inserted into a plastic tube and numbered.

Dried cinnamon obtained from the Beringharjo Market, Yogyakarta, was ground into powder and then macerated to obtain a solid extract. To prepare 4% and 12.5% cinnamon extract solutions, 6.4 g and 20 g of the cinnamon extract, respectively, was dissolved in 160 mL of distilled water.

The specimens were separated according to the treatment group with six specimens for each concentration of cinnamon extract solution. The procedures for immersion and roughness measurement were as follows:

1. Initial measurement of roughness of each specimen
2. Immersion for the first 60 min
3. Measurement of roughness after soaking for 60 min
4. Immersion for the second 60 min (120 min)
5. Measurement of roughness after soaking for 120 min
6. Immersion for the third 60 min (180 min)
7. Measurement of roughness after soaking for 180 min

Data analysis methods used in this study were repeated measures analysis of variance (ANOVA) for the inter-time group changes and independent samples t test for inter-categorical testing of the concentration of cinnamon solution and were processed using SPSS Statistics software, version 17.0.

3. Results

In this study, the measurements taken included the pH and mineral content of the cinnamon extract solutions as well as the enamel surface roughness using a surface roughness tester (SurfTest SJ-301, Mitutoyo, Japan). The results of the pH and mineral content measurements are shown in Table 1 and Table 2.

Table 1. pH of the cinnamon extract solutions

Solution concentration	pH
Cinnamon extract solution 4%	5.38
Cinnamon extract solution 12.5%	5.45

Table 2. Mineral content of the cinnamon extract solutions

Component	Number of compounds & minerals	
	in 4% solution	in 12.5% solution
Calcium (%)	0.07	0.23
Magnesium (%)	0.05	0.14
Phosphorus (%)	0.06	0.17
Potassium (%)	0.82	2.56
Tannin (%)	2.52	7.82

The results of the mean surface roughness measurements were expressed in Ra value in units of μm . Table 3 shows the average surface roughness data analyzed in the current study.

Table 3. Average enamel surface roughness changes (Ra) before and after immersion in the cinnamon extract solutions

Concentration	N	Initial	60-min	120-min	180-min
		Immersion	Immersion	Immersion	Immersion
		(Ra) \pm SD	(Ra) \pm SD	(Ra) \pm SD	(Ra) \pm SD
4%	6	0.35 \pm 0.27	0.35 \pm 0.27	0.34 \pm 0.27	0.33 \pm 0.27
12.5%	6	0.27 \pm 0.08	0.27 \pm 0.08	0.25 \pm 0.08	0.24 \pm 0.07

3.1. Comparison of Ra Value between Immersion Times

The 12 specimens were divided into two concentration groups of 4% and 12.5%. Each concentration group included four time variables: before immersion, after 60-min immersion, after 120-min immersion, and after 180-min immersion. The data obtained from the mean roughness measurements (Ra) of the enamel tooth surfaces were then subjected to statistical analysis using the repeated measures ANOVA because the specimens for each time group were the same and the group count was >2 .

Measurements taken before immersion were compared with measurements taken after 60-, 120-, and 180-min immersion. In Table 4, the change in Ra values after 60, 120, and 180 min of immersion was not significant ($p > 0.05$).

Table 4. Statistical test for comparison between immersion times at 4% concentration ($p < 0.05$)

(I) Time (min)	(J) Time (min)	4% cinnamon extract solution	
		(p)	Difference
0	60	0.058	Not significant
	120	0.713	Not significant
	180	0.088	Not significant
60	120	0.401	Not significant
	180	0.039	Significant
120	180	0.044	Significant

There was a change in Ra value from initial measurement at 60-, 120-, and 180-min immersions; 60-min immersion increased the Ra value, whereas 120- and 180-min significantly decreased the Ra value. The change in Ra value was then statistically analyzed using repeated measures ANOVA.

The results of the repeated measures ANOVA (Table 5) showed that the increased Ra value after 60-min immersion in 12.5% cinnamon extract solution was not significantly different ($p > 0.05$) compared with the Ra value before immersion, and the Ra value after 120-min immersion was not significantly different compared with that after 180-min immersion. The results of statistical tests also showed a significant difference in Ra value after 120- and 180-min immersion compared with the Ra value before and after 60-min immersion.

Table 5. Statistical test result for comparison between immersion times at 12.5% concentration

(I) Time (min)	(J) Time (min)	12.5% Cinnamon extract solution	
		(p)	Difference
0	60	0.060**	Not significant
	120	0.027*	Significant
	180	0.032*	Significant
60	120	0.006*	Significant
	180	0.019*	Significant
120	180	0.213**	Not significant

* $p < 0.05$; ** $p > 0.05$

Table 6. Differences in mean roughness (Ra) of enamel surface after immersion in cinnamon extract solution

Concentration	N	Roughness value after 60-min immersion	Roughness value after 120-min immersion	Roughness value after 180-min
		(Ra) \pm SD	(Ra) \pm SD	(Ra) \pm SD
4%	6	0.01 \pm 0.01	0.00 \pm 0.03	-0.02 \pm 0.02
12.5%	6	0.00 \pm 0.00	-0.02 \pm 0.01	-0.03 \pm 0.02

The results in Table 6 showed that 60-min immersion in the cinnamon extract solution resulted in an increase in Ra value for both 4% and 12.5% solutions, whereas the measurements after 120-min immersion showed a decreased Ra value. Measurements after 180-min immersion showed that the decreased Ra values for 4% and 12.5% solutions were not significantly different. The results of independent samples t test conducted to determine the ratio of Ra value change between concentrations after 60-, 120-, and 180-min immersions were not significantly different ($p > 0.05$) (Table 7).

Table 7. Statistical test result of comparison between concentrations after 60-, 120-, and 180-min immersion

Immersion Time (min)	(I) Concentration	(J) Concentration	Comparison of Ra Value Change	
			(p)	Difference
60	4%	12.5%	0.582	Not significant

Table 7. *Continue*

120	4%	12.5%	0.419	Not significant
180	4%	12.5%	0.740	Not significant

p<0.05 (significant)

4. Discussion

Based on our results and by comparing the average Ra values between immersion times with repeated measures ANOVA, there was an increase in Ra value after 60-min immersion that was not significantly different when compared with the initial Ra value for solutions of both concentrations. The increased surface roughness for both concentrations may be due to the 5.38 pH of the 4% cinnamon extract solution and 5.45 pH of the 12.5% solution below the critical pH of enamel demineralization (5.5); therefore, 60-min immersion time is not sufficiently long for enamel demineralization, leading to non-significant difference. This result is supported by Utari's study, which showed that 30-, 60-, and 90-min immersion in *Uncaria* solution at pH 5.42–5.48 increased enamel surface roughness, but this was not significantly different [5].

Ra value decreased for both 4% and 12.5% solutions; this could have been caused by remineralization of the tooth enamel from minerals in the cinnamon extract solution. Minerals in the cinnamon extract solution that are strong remineralization agents include calcium, phosphorus, and magnesium; these minerals are present insufficient quantities in the cinnamon extract solution. These findings were in agreement with Hoobi's study, which tested the ability of cinnamon to increase enamel resistance to the solubility of calcium ions by acids. Their study results suggested that the remineralization capability of cinnamon is due to its calcium and phosphorus content, both of which are key components of the hydroxyapatite crystals in enamel [6].

In the results with no significant difference after immersion for 120 and 180 minutes to initial measurement (0 minutes) and 60 to 120 minutes immersion due to the enamel had been demineralized and then remineralized so that if the Ra value between times is compared then not delivering significant results. The reaction is disclosed in U.S. Patent No. 4,080,440 (Digiulio et al [1976]), which states that metastable solutions of calcium phosphate ions (mixture of 0.005%–5% calcium and 0.005%–5% phosphate) at a low pH (2.5–4.0) in highly soluble conditions of calcium phosphate salt will result in remineralization of the calcium phosphate salt deposits after penetration of the solution into the demineralized enamel [7]. In addition, according to Reynolds et al. a stabilized calcium phosphate solution can maintain high concentrations of calcium and phosphate ions and ion pairs from surface enamel lesions, which may improve the remineralization of tooth enamel [8].

The results showed a significant decrease in Ra value after 120-min immersion in 12.5% concentration, and 180 minutes of initial immersion was probably due to the length of immersion so that the mineral deposits remained on the surface of the enamel. This was demonstrated visually after 120-min immersion, and we noted that the cinnamon solution had precipitated at the bottom of the plastic tube as well as on the pits and fissures of the soaked teeth. Inter-concentration testing was conducted between the 4% and 12.5% cinnamon extract solutions using independent samples t test. The results of the test showed that the change in Ra value was not significantly different for comparison between concentrations. The change in Ra value after 60 and 180-min immersion in solutions of the two concentrations was not much different. This condition is estimated because the pH value and mineral content of the two cinnamon extract solutions are not much different, but this needs further verification and research.

Furthermore, the results showed that immersion for >60 min, which, if converted into mouthwash usage of 1 month with both concentrations, can reduce surface enamel roughness. In addition, the 12.5% solution was more effective for reducing surface tooth enamel roughness.

5. Conclusion

Based on the results, it can be concluded that changes in tooth enamel surface roughness are affected by immersion in cinnamon extract solution for >60 minutes, the pH of the solution, the enamel, and the concentration of the solution.

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