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THE EFFECT OF DIFFERENT BASES (CMC-Na AND PGA) IN TOOTHPASTE FORMULATED WITH BIDURI LEAF EXTRACT (*Calotropis gigantea* L.) ON PHYSICAL QUALITY AND ANTIBACTERIAL ACTIVITY AGAINST *Streptococcus mutans*

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ABSTRACT

Background: Toothpaste is a semi-solid preparation used to clean teeth and maintain oral health. Innovations in utilizing natural ingredients, such as Biduri leaf extract (*Calotropis gigantea* L.), in toothpaste formulation are based on its content of active compounds like flavonoids, tannins, and saponins, which have potential antibacterial properties and thus are beneficial for maintaining dental cleanliness and health. **Objective:** This study aims to determine the effect of different bases, CMC-Na and PGA, in Biduri leaf extract (*Calotropis gigantea* L.) toothpaste on its physical quality and antibacterial activity against *Streptococcus mutans*. **Methods:** Toothpaste was formulated into two preparations: Formulation 1 (3% CMC-Na base) and Formulation 2 (20% PGA base). Physical quality evaluations included organoleptic testing, pH, homogeneity, and foam height, while stability testing was conducted using the cycling test method. The data were analyzed using Independent T-Test and Paired T-Test. **Results:** There were significant differences in the physical quality of Biduri leaf extract toothpaste between the CMC-Na and PGA bases in terms of pH and foam height ($p<0.05$), but no differences in organoleptic properties and homogeneity. In the stability test, both bases were unstable in terms of pH and foam height. Antibacterial activity testing against *Streptococcus mutans* showed no significant difference between the two bases ($p>0.05$). **Conclusion:** The difference between CMC-Na and PGA bases in Biduri leaf extract (*Calotropis gigantea* L.) toothpaste affects its physical quality and stability, but does not influence its antibacterial activity against *Streptococcus mutans*.

ABSTRAK

Latar belakang: Pasta gigi merupakan sediaan semisolid untuk membersihkan gigi serta menjaga kesehatan rongga mulut. Inovasi pemanfaatan bahan alam, seperti ekstrak daun biduri *(Calotropis gigantea* L.*)*, dalam formulasi pasta gigi didasarkan pada senyawa aktif yang terkandung seperti flavonoid, saponin, serta tanin yang berpotensi sebagai antibakteri, sehingga bermanfaat dalam menjaga kebersihan dan kesehatan gigi. **Tujuan**: Tujuan penelitian ini yatu mengetahui pengaruh perbedaan basis CMC Na dan PGA pada pasta gigi ekstrak daun biduri (*Calotropis gigantea* L.) terhadap mutu fisik serta aktivitas antibakteri *Streptococcus mutans*. **Metode:** Pasta gigi diformulasikan ke dalam dua sediaan : Formulasi 1 (Basis CMC Na 3%), Formulasi 2 (Basis PGA 20%), Kontrol Positif yang digunakan yaitu Pasta Gigi merk "X" yang beredar, sedangkan Kontrol Negatif yang digunakan yaitu basis pasta tanpa ekstrak. Uji mutu fisik meliputi uji organoleptik, pH, homogenitas, dan tinggi busa, sedangkan pengujian penyimpanan suhu ekstrim menggunakan metode *cycling test*. Data hasil penelitian dianalisis dengan *Independent T Test* dan *Paired T Test*. **Hasil:** Adanya perbedaan mutu fisik pasta gigi ekstrak daun biduri *(Calotropis gigantea)* basis CMC Na dan PGA terhadap pH dan tinggi busa ($p<0,05$), tetapi tidak berpengaruh terhadap organoleptis dan homogenitas. Pada uji penyimpanan suhu ekstrim, kedua basis tidak stabil terhadap parameter pH dan tinggi busa. Pada uji aktivitas antibakteri *Streptococcus mutans* menunjukkan tidak adanya pengaruh perbedaan basis CMC-Na dan PGA terhadap aktivitas antibakteri pasta gigi ($p>0,05$). **Simpulan:** Perbedaan basis CMC-Na dan PGA pada pasta gigi ekstrak daun biduri *(Calotropis gigantea* L.*)* berpengaruh terhadap mutu fisik serta penyimpanan suhu ekstrim, namun tidak berpengaruh terhadap aktivitas antibakteri *Streptococcus mutans*.

INTRODUCTION

Indonesia is recognized as a country with extraordinary biodiversity, with more than 40,000 types of plants identified as medicinal herbs (Marbun & Restuati, 2015). Herbal medicine uses natural substances as remedies, including in the field of ethnodentistry, with primary sources derived from medicinal plants and microbial endophytes that produce active metabolites (Ningsih et al., 2023). Herbal remedies have been traditionally used to treat various diseases, including oral and dental health problems, due to their proven antimicrobial, antibacterial, and antibiofilm properties (Ilic et al., 2017). The medicinal efficacy of herbal plants has been scientifically proven to possess therapeutic effects such as antimicrobial, antibacterial, and antibiofilm activity. One such medicinal plant known to help prevent dental caries is the giant milkweed plant (*Calotropis gigantea*) (Ningsih et al., 2023).

Calotropis gigantea contains antibacterial compounds such as flavonoids, saponins, and tannins (Alibasyah et al., 2020). Flavonoids work by disrupting the bacterial cell membrane, particularly the phospholipid layer, reducing membrane permeability and damaging bacterial structure. Meanwhile, saponins denature proteins, disrupting membrane permeability, damaging membranes, causing cell leakage, and ultimately lysing the bacteria (Kholidiya et al., 2024). Flavonoids such as quercetin are known to strengthen mineralized dental tissues and inhibit caries formation. Quercetin also inhibits caries-causing bacteria such as *Streptococcus* and *Lactobacillus*, with an inhibition zone of 16 mm at a concentration of 5.10 ± 0.60 mg/mg from *Calotropis gigantea* extract (Ningsih et al., 2023). In addition, a study by Ishnava et al. (2012) showed that crude latex extract of *Calotropis gigantea* at a concentration of 10%

produced an inhibition zone of 19 mm against *Lactobacillus acidophilus* (MIC 0.52 mg/ml) and *Streptococcus mutans* (MIC 0.032 mg/ml).

Dental caries, or tooth decay, is a multifactorial and chronic disease caused by tooth damage due to acids produced by bacteria (Ningsih et al., 2023). Several caries-causing bacteria commonly found in the oral cavity include *Streptococcus mutans*, *Lactobacillus acidophilus*, *Actinomyces meyeri*, *Enterococcus faecium*, *Aerococcus viridans*, and *Eubacterium limosum* (Hoceini et al., 2016). One way to prevent dental caries is by brushing teeth with toothpaste (Haryati, 2020). The choice of base in toothpaste formulation is crucial to obtain a good preparation. In this study, two types of bases are used: CMC-Na and PGA. CMC-Na is a neutral gelling agent with stable viscosity, resistance to microbial growth, and the ability to produce a clear gel (Hariningsih, 2019). Another additional base material that can be used is PGA (*Pulvis Gummi Arabicum*), which has good emulsifying properties, does not alter chemical structure, is natural, prevents sedimentation, and provides a homogeneous structure (Hariningsih, 2019). Therefore, the researcher is interested in conducting a study entitled: **"The Effect of Different Bases (CMC-Na and PGA) in Toothpaste Formulated with *Calotropis gigantea* Leaf Extract on Physical Quality and Antibacterial Activity Against *Streptococcus mutans*"**.

METHOD

Preparation of *Calotropis gigantea* Leaf Extract

The preparation of the *Calotropis gigantea* (biduri) leaf extract began by weighing 200 grams of dried simplicia. The powdered simplicia was then placed into a maceration container, followed by the addition of 1.5 liters of chloroform solvent, or just enough to fully submerge the powder. The mixture was stirred until homogeneous. The maceration process was carried out in a dark container or a place protected from direct sunlight for five days. During this period, the mixture was stirred for 15 minutes each day. After maceration, the filtrate was evaporated using a water bath at 50°C until a thick extract of *Calotropis gigantea* leaves was obtained (Hidayah et al., 2020).

Formulation of Toothpaste with *Calotropis gigantea* Leaf Extract

Table 1 Toothpaste Formulation Design

Ingredient	Usage Range	Function	Formulation (%)	
			F1	F2
***Calotropis gigantea* Leaf Extract**	-	Active Ingredient	15	15
Calsium carbonate	30-40%	Abrasive	30	30
CMC Sodium	3-6%	Pasta base	3	-
PGA	10-20%	Pasta base	-	20
Sodium benzoate	0,1-0,5%	Preservative	0,5	0,5
Sodium lauryl sulphate	1-2%	Foaming agent	2	2
Sorbitol	20-60%	Humectant	20	20

Ingredient	Usage Range	Function	Formulation (%)	
			F1	F2
Sodium sakarin	0,12-0,3%	Sweetener	0,12	0,12
Menthol	0,4%	Corrigen (Odoris and saporis).	0,14	0,14
Aquadest ad	-	Solvent	100 (60 g)	100 (60 g)

Preparation of Toothpaste Formulated with *Calotropis gigantea* Leaf Extract Using CMC-Na Base

The toothpaste preparation process begins by preparing all necessary tools and materials, followed by weighing each ingredient according to the required quantities. In the first mortar, menthol, sodium lauryl sulfate, and calcium carbonate are mixed and ground until homogeneous (mixture 1). Meanwhile, another mortar and pestle are preheated with hot water, after which the water is discarded and the tools are dried. CMC-Na is then sprinkled into hot water and allowed to swell, then stirred until it forms a thick gel (mixture 2). *Calotropis gigantea* leaf extract is added gradually into mixture 2 while continuously stirring until homogeneous (mixture 3). Mixture 1 is then added into mixture 3 and stirred again until all components are evenly mixed (mixture 4). Sorbitol is combined with sodium benzoate, then added to mixture 4 and stirred until a uniform paste is formed. Once the mixture is fully homogeneous, the toothpaste formulation is transferred into prepared containers.

Preparation of Toothpaste Formulated with *Calotropis gigantea* Leaf Extract Using PGA Base

The toothpaste preparation process begins by preparing all the necessary tools and materials, then weighing each ingredient according to the required amount. In the first mortar, menthol, sodium lauryl sulfate, and calcium carbonate are mixed and ground until homogeneous (mixture 1). Meanwhile, another mortar and pestle are heated with hot water, after which the water is discarded and the tools are dried. PGA is then added into the mortar along with hot water and stirred until thickened (mixture 2). *Calotropis gigantea* leaf extract is gradually added into mixture 2 while continuously stirring until homogeneous (mixture 3). Mixture 1 is then added into mixture 3 and stirred again until all ingredients are evenly mixed (mixture 4).

Physical Quality Testing

Physical quality testing includes organoleptic evaluation, homogeneity, pH measurement, and foam height test. The foam height test is performed by weighing 1 gram of toothpaste, mixing it with distilled water, and placing the mixture into a 100 mL measuring cylinder. The cylinder is shaken by inverting it regularly for 20 seconds, then left to stand for 5 minutes. Afterward, the height of the foam formed is observed and measured using a ruler (Hidayati et al., 2022). The preparation is then subjected to extreme temperature storage testing to evaluate the stability under extreme temperature conditions during storage. This accelerated test is conducted using a cycling method with 3 cycles between cold (4°C) and hot (40°C) temperatures.

Antibacterial Activity Testing

The antibacterial activity of *Calotropis gigantea* leaf extract toothpaste against *S. mutans* bacteria was tested using the well diffusion method. A sample of 0.1 grams, including formulations F1, F2, a positive control (commercial toothpaste brand "X"), and a negative control (toothpaste base without extract), was placed into each well.

Data Analysis

Data analysis was conducted using an Independent T-Test to compare the test results of the two formulations. The results indicate no significant difference if the significance value (sig.) is > 0.05, and a significant difference if the significance value (sig.) is < 0.05.

RESULT

A. Determination Results

The plant determination carried out at UPT Materia Medica Kota Batu showed that the plant used in this study is *Calotropis gigantea* L.

B. Extract Yield

The results of the extract yield calculation are shown in the following table:

Table 2. Results of the *Calotropis gigantea* L. Extract Yield

Simplicia Weight (g)	Extract Weight (g)	% Extract Yield
200	138,18	69,09

C. Phytochemical Screening Results of *Calotropis gigantea* Leaf Extract

The results of chemical constituent identification in the extract are shown in the table below:

Table 3. Results of Chemical Constituent Identification in *Calotropis gigantea* L. Extract

Chemical Constituent	Result
Flavonoid	+
Saponin	+
Tanin	+

Description: + = The results indicate the presence of active compounds
- = The results indicate not presence of active compounds

D. Physical Quality Testing and Extreme Temperature Storage of Calotropis gigantea Leaf Extract Toothpaste Preparation

1. Organoleptic Test

The organoleptic test of *Calotropis gigantea* leaf extract toothpaste produced characteristics as shown in the table below:

Table 1 The Organoleptic Test of *Calotropis gigantea* Leaf Extract Toothpaste

Formulation	Replication	Organoleptic	Observation Results	
			Before Extreme Temperature Storage Test	**After 3 Cycles of Extreme Temperature Storage Test**
F1	I	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea* leaf and menthol	Characteristic of *Calotropis gigantea* leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol
	II	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea* leaf and menthol	Characteristic of *Calotropis gigantea* leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol
	III	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea* leaf and menthol	Characteristic of *Calotropis gigantea* leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol
F2	I	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea* leaf and menthol	Characteristic of *Calotropis gigantea* leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol
	II	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea* leaf and menthol	Characteristic of *Calotropis gigantea* leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol
	III	Color	Green	Green
		Odor	Characteristic of *Calotropis gigantea*	Characteristic of *Calotropis gigantea*

Formulation	Replication	Organoleptic	Observation Results	
			Before Extreme Temperature Storage Test	After 3 Cycles of Extreme Temperature Storage Test
			leaf and menthol	leaf and menthol
		Form	Semi solid	Semi solid
		Taste	Fresh menthol	Fresh menthol

Description :

F1 : Toothpaste formulation from *Calotropis gigantea* leaf extract using 3% CMC-Na base.

F2 : Toothpaste formulation from *Calotropis gigantea* leaf extract using 20% PGA base

2. Homogenity Test

The homogenity test results of *Calotropis gigantea* leaf extract toothpaste is shown in the following table:

Table 2 Homogenity Test Results of *Calotropis gigantea* Leaf Extract Toothpaste

Formulation	Replication	Homogeneity Observation Results	
		Before Extreme Temperature Storage Test	After 3 Cycles of Extreme Temperature Storage Test
I	I	Homogeneous	Homogeneous
	II	Homogeneous	Homogeneous
	III	Homogeneous	Homogeneous
II	I	Homogeneous	Homogeneous
	II	Homogeneous	Homogeneous
	III	Homogeneous	Homogeneous

3. pH Test

The pH test results of the *Calotropis gigantea* leaf extract toothpaste preparation can be seen in the table below:

Tabel 3 pH Test Results of the *Calotropis gigantea* Leaf Extract Toothpaste

Formulation	Replication	pH Observation Results	
		Before Extreme Temperature Storage Test	After 3 Cycles of Extreme Temperature Storage Test
I	I	9,34	7,29
	II	9,33	7,25
	III	9,32	7,24
Average ± SD		**9,33 ± 0,01**	**7,26 ± 0,02**
II	I	8,85	7,28
	II	8,96	7,32

Formulation	Replication	pH Observation Results	
		Before Extreme Temperature Storage Test	After 3 Cycles of Extreme Temperature Storage Test
	III	9,04	7,35
Average ± SD		**8,95 ± 0,09**	**7,31 ± 0,03**

4. Foam Height Test

The results of the foam height test on *Calotropis gigantea* leaf extract toothpaste are shown in the table below:

Tabel 4 Results of the Foam Height Test on *Calotropis gigantea* Leaf Extract Toothpaste

Formulation	Replication	Height Foam Observation Results (cm)	
		Before Extreme Temperature Storage Test	After 3 Cycles of Extreme Temperature Storage Test
I	I	1,3	0,4
	II	1,1	0,2
	III	0,8	0,3
Average ± SD		**1,06 ± 0,25**	**0,3 ± 0,1**
II	I	0,8	0,4
	II	0,7	0,3
	III	0,5	0,2
Average ± SD		**0,66 ± 0,15**	**0,3 ± 0,1**

5. Antibacterial Activity Results Against *Streptococcus mutans*

The results of the antibacterial activity test of *Calotropis gigantea* leaf extract toothpaste against *Streptococcus mutans* bacteria are shown in the table below:

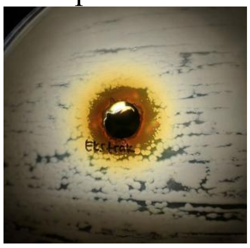
Tabel 8 Results of the Antibacterial Activity Test of *Calotropis gigantea* Leaf Extract Toothpaste

Test Group	Average Inhibition Zone (mm) ± SD	Classification
Control (+)	11,92 ± 0,1	Strong
Control (-)	16,67 ± 0,82	Strong
F1(CMC-Na)	15,28 ± 0,56	Strong
F2 (PGA)	15,64 ± 1,21	Strong


Replication 1


Replication 2


Replication 3



Leaf Extract of Biduri

Picture 1 Antibacterial Activity Results Against *Streptococcus mutans*

DISCUSSION

This study used *Calotropis gigantea* leaf extract as the active ingredient at a concentration of 15%, formulated into toothpaste preparations with different bases: formulation I used 3% CMC-Na as the base, while formulation II used 20% PGA. Both formulations were then subjected to physical quality tests, including organoleptic test, pH test, and foam height test. The testing continued with antibacterial activity testing against *Streptococcus mutans* using the well diffusion method. The bacteria used were obtained from the Surabaya Public Health Laboratory Center and cultured at the Microbiology Laboratory of IIK Bhakti Wiyata.

The organoleptic test results showed that the toothpaste remained organoleptically stable after undergoing extreme temperature storage testing for 3 cycles. The results consistently showed the preparation maintained a green color, characteristic odor of *Calotropis gigantea* leaf and menthol, semi-solid form, and fresh menthol taste before and after the extreme temperature storage test. Based on these results, no reactions occurred between ingredients in the formula that could damage the toothpaste preparation during extreme temperature storage (Wahyuddin et al., 2018).

The homogeneity test results indicated that formulation I (3% CMC-Na base) and formulation II (20% PGA base) produced homogeneous toothpaste preparations. Homogeneity testing on both preparations showed they remained uniform, with no coarse or fine clumps, separated particles, or air bubbles. These results indicate that both formulas meet the homogeneity requirements for toothpaste, according to SNI No. 12-3524-1995, which states that toothpaste must be homogeneous, free of air bubbles, lumps, and separated particles (Gratia et al., 2021).

Based on the results shown in Table 5, the pH of both formulations remained within the acceptable pH range for toothpaste according to SNI 8861-2020, which is between 6 and 10 (Egam et al., 2023). The Independent T-Test results for the pH test showed a significance value of 0.002 ($p < 0.05$), indicating a significant difference between the pH values of formulation 1 and formulation 2. After extreme temperature storage testing, a decrease in pH was observed in both formulations, but still within the established standard limits. The paired T-Test on the extreme temperature storage test for pH parameter showed a significant difference in pH values for both formulation 1 and formulation 2 ($p < 0.05$). These results suggest that the difference in bases between CMC-Na and PGA affects the pH during extreme temperature storage of the preparation. Previous research showed that pH stability changes could be caused by non-airtight storage containers. This study indicated that ambient air entering the preparation could lower the pH value during extreme temperature storage testing (Febrianti et al., 2021). Other studies showed that decomposition of a preparation during production and storage could alter the pH value due to increased temperature of the preparation (Azizah et al., 2022).

Based on the foam height measurements shown in Table 6, the foam height remains within the allowable limit, which is not more than 1.5 cm (Marlina et al., 2017). Data analysis using the Independent T-Test yielded a significance value of 0.041 ($p < 0.05$), indicating a significant difference in foam height between formulation 1 and formulation 2. The extreme temperature storage test showed a decrease, with a significant difference in foam height before and after the extreme temperature storage test using 3 cycles ($p > 0.05$). This indicates instability of the saponins contained in the *Calotropis gigantea* leaf extract as well as the SLS in the toothpaste formulation during storage (Suyit et al., 2022).

Preliminary testing of the *Calotropis gigantea* leaf extract showed an inhibition zone of 10.55 mm against *Streptococcus mutans* bacteria. This value is classified as "Strong" antibacterial activity. The flavonoid, tannin, and saponin content in the leaf extract is known to inhibit the growth of *Streptococcus mutans* bacteria (Alibasyah et al., 2020). The antibacterial activity test results presented in Table 8 and Figure 1 show that the positive control group (K+) using herbal toothpaste brand X had an inhibition zone of 11.92 mm. Conversely, the negative control group (K–), which was the formulation without extract, showed a higher average inhibition zone of 16.67 mm. The strong inhibition zone in the negative control may indicate other factors contributing to the inhibition of *Streptococcus mutans* growth, such as the alkaline pH of the formulation. The negative control formulation with alkaline pH can inhibit the growth of *Streptococcus mutans* (Edon et al., 2023). It is possible that components in the negative control, such as preservatives, inhibit bacterial growth. Sodium benzoate is an effective preservative that inhibits microbial growth (Ulya et al., 2020). Formulation 1 (CMC-Na) toothpaste with *Calotropis gigantea* leaf extract showed an average inhibition zone of 15.28 mm, while formulation 2 (PGA) showed an average inhibition zone of 15.63 mm. Data analysis using the Independent T-Test indicated no significant difference in antibacterial activity between the *Calotropis gigantea* leaf extract toothpaste formulations with CMC-Na and PGA bases. The limitations of this study include insufficient in-depth literature review regarding the additional ingredients used, such as the activity of sorbitol and sodium benzoate against *Streptococcus mutans*. Furthermore, pH testing was not performed on the positive and negative controls.

CONCLUSION

The difference in bases, CMC Na and PGA, in toothpaste formulations containing *Calotropis gigantea* leaf extract affects the physical quality of the toothpaste, such as pH and foam height. The accelerated extreme temperature storage test through 3 cycles showed that the difference in bases influences the stability of the toothpaste under extreme temperature storage conditions. However, the antibacterial activity test of the toothpaste containing *Calotropis gigantea* leaf extract against *Streptococcus mutans* showed no effect of the type of base used on its antibacterial activity.

SUGGESTION

Further evaluation of the formulation bases is necessary, such as viscosity testing. In addition, formula optimization should be conducted, especially regarding the humectant and preservative materials used in the toothpaste formulation containing *Calotropis gigantea* leaf extract.

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