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Cultivating brighter smiles: Harnessing the potential of Bulian wood activated charcoal toothpaste infused with varied concentrations of lime essential oil for effective at-home teeth whitening

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Abstract
The appearance of teeth plays a pivotal role in determining an attractive facial profile. Addressing tooth discoloration is contingent on the specific diagnosis, and various methods can be employed for treatment. Activated wood charcoal, owing to its remarkable stain absorption capabilities, emerges as a natural alternative to conventional home bleaching agents. Lime, derived from *Citrus aurantifolia*, is a citrus variety known for its citric acid content. This acid, characterized by an OH group, possesses teeth-whitening potential due to its oxidizing properties akin to ellagic acid and malic acid. Consequently, it is imperative to conduct research to evaluate the effectiveness of a toothpaste formulated with 10% Bulian wood activated charcoal and varying concentrations (7.5%, 10%, 12.5%) of lime essential oil as a tooth whitener for caries-free teeth. This study adopts an experimental research approach.
The subjects for this research were natural teeth displaying discoloration, enabling the assessment of the whitening effect on the tooth surface. The research commenced with the preparation of a toothpaste formulation comprising 10% Bulian activated charcoal powder and lime essential oil at concentrations of 7.5%, 10%, and 12.5%. Subsequently, the study examined the tooth surface whitening effect following the application of this toothpaste. Effectiveness was assessed by scoring the tooth surface whitening effect on control teeth and analyzed using the Mann-Whitney difference test. The research findings indicate differences in effectiveness when employing toothpaste containing 10% Bulian wood activated charcoal with 7.5%, 10%, and 12.5% lime essential oil for the control group with caries-free teeth. Specifically, no significant difference was observed for lime essential oil concentration at 7.5%. However, notable differences in effectiveness were identified between toothpaste containing 10% Bulian wood activated charcoal and formulations with 7.5%, 10%, and 12.5% lime essential oil for caries-free teeth ($p< 0.05$). In conclusion, this research underscores distinct variations in effectiveness among toothpaste formulations containing 10% Bulian wood activated charcoal and 7.5%, 10%, and 12.5% lime essential oil when employed as teeth whiteners for caries-free teeth ($p< 0.05$).

Keywords: Bulian wood activated charcoal, lime essential oil, teeth whitening effect

1. Introduction
The appearance of one's teeth significantly contributes to their overall facial aesthetics. Several factors influence the visual appeal of teeth, including their color, shape, position, and the quality of dental restorations. Among these factors, tooth color plays a pivotal role in determining an individual's satisfaction with their dental aesthetics [1, 2].
Teeth that exhibit cleanliness, health, and a whiter shade tend to enhance people's confidence in their overall appearance. Consequently, there has been a growing demand for dental services, particularly in the field of aesthetic dentistry [3, 4]. A 2011 study conducted at the University Sains Malaysia dental clinic revealed that out of 235 participants, 132 individuals (56.2%) expressed dissatisfaction with the color of their teeth. Discoloration is a common cause of such dissatisfaction, motivating many individuals to seek teeth-whitening procedures [1]. In the field of dentistry, various treatment options have emerged to address different types of tooth discoloration [5–7]. Tooth discoloration refers to alterations in the natural color of teeth, often resulting from various factors, including surface stains that damage the tooth enamel.

The natural color of teeth is inherently polychromatic, with variations in hue across different thirds of the tooth, influenced by the thickness and translucency of enamel and dentin, as well as the degree of calcification. Generally, primary teeth exhibit a bluish-white color, while permanent teeth can vary between grayish-yellow, grayish-white, or yellowish-white hues. Changes in natural tooth color can be categorized based on etiology and severity, typically as extrinsic or intrinsic discoloration [8–10].

Extrinsic discoloration attributed to coffee consumption is one of the most prevalent forms of tooth staining in modern society. The contemporary lifestyle, marked by a widespread consumption of coffee, has led to this type of discoloration. Given that approximately 10% of the Indonesian population is assumed to drink coffee, it's estimated that one billion cups of coffee are brewed daily [11]. Coffee is recognized as a more potent chromogen compared to tea or cola, and studies have indicated that coffee stains tend to be more enduring than those from tea [6].

Tooth discoloration can be addressed through various treatment approaches based on the specific diagnosis. One common method involves chemical bleaching techniques designed to eliminate oxidizing materials responsible for the discoloration. Bleaching is a process aimed at whitening teeth by utilizing chemicals like hydrogen peroxide and carbamide peroxide [11–13]. However, it's important to note that the use of these chemicals can result in side effects, including hypersensitivity, as well as cervical and external root resorption of the teeth [14]. Moreover, hydrogen peroxide is known to be unstable, and at very high concentrations, it can exhibit mutagenic properties. Furthermore, it has the potential to inhibit pulp enzyme activity, leading to permanent changes in the pulp [15].

In contrast, carbamide peroxide is more frequently employed in at-home teeth whitening procedures compared to hydrogen peroxide due to its superior safety profile and fewer associated side effects [16]. Carbamide peroxide is a compound formed from hydrogen peroxide and urea. For at-home whitening, a 100% concentration of carbamide peroxide is commonly used, and this concentration has received approval from the American Dental Association (ADA) for outdoor use as a safe and effective dental treatment. However, the effectiveness of carbamide peroxide as a home whitening agent remains a topic of ongoing discussion, largely due to its potential effects on the oral cavity, including gingival irritation and tooth sensitivity [17].

Considering the drawbacks of carbamide peroxide and hydrogen peroxide, researchers have actively sought alternative natural teeth-whitening ingredients that are safer and more cost-effective. Activated wood charcoal is one such natural ingredient that can serve as an alternative to home bleaching chemicals, owing to its remarkable stain-absorbing properties. Activated charcoal, a carbon-based material, can be derived from various carbon-containing raw materials, including wood charcoal. Its exceptional absorption capabilities have led to its widespread use in gas purification, water purification, and oil purification [18].

Many individuals are unaware of simple methods and ingredients for teeth whitening. Activated charcoal, readily available in communities, presents itself as an accessible and straightforward alternative for teeth whitening. This natural remedy offers a convenient means of brightening discolored teeth. Wardani's research [19] highlights the significance of activated charcoal, particularly for its carbon component, in its capacity to enhance tooth color and remove plaque [6].

The primary objective of this study is to assess the varying effectiveness of Bulian wood activated charcoal toothpaste when combined with lime essential oil concentrations of 7.5%, 10%, and 12.5%, respectively, as tooth whiteners for teeth free from caries in an *in vitro* setting.

Materials and Methods

Design and Samples

This research employed an experimental approach, specifically utilizing a Pre and Post Test Group with a control design. The study included 40 samples and was conducted in two laboratories: the Pharmacy Laboratory of the Pharmacy Department at the Health Polytechnic, Ministry of Health, Jambi, and the laboratory of the Faculty of Science and Technology at Jambi University.

Variables

In this research, the independent variables consist of 10% Bulian wood activated charcoal powder and lime essential oil at concentrations of 7.5%, 10%, and 12.5%. The dependent variable is the whitening effect observed on the tooth surface, which was assessed by measuring the color change before and after treatment involving Bulian wood activated charcoal and lime essential oil at these concentrations.

Sample preparation

The samples utilized were maxillary anterior teeth that had been previously extracted. These teeth were meticulously cleaned using a scaler, bur brush, and micromotor. Subsequently, a clear nail polish was applied to the tooth's root to shield it from any solution penetration through the dentin tubules and the apical part of the tooth. Initial color measurements of the tooth samples were recorded using the Vita Classic Shade Guide.

Coffee Solution Preparation and Soaking

To create the coffee solution, 200 grams of coffee powder were placed in a plastic glass container, and 400 ml of hot water was added. The mixture was stirred until achieving a consistent and thick coffee solution, ensuring the thorough blending of the powder and water. A total of 400 ml of coffee solution was prepared for the tooth sample container, with 15 ml of this solution poured into each plastic container. Over the course of 10 days, the coffee solution was replaced daily, following the methodology of prior research. After the 10-day soaking period, the teeth were removed, rinsed with saline, dried with a tissue, and subsequently subjected to a second enamel color measurement using the Vita Classic shade guide.

Activated Charcoal Production from Bulian Wood Charcoal

The raw material for activated charcoal was sourced from Jambi City, totaling 2 kg in quantity. The wood charcoal was then ground into a fine powder using a charcoal grinding machine, a process conducted for 2 hours in a ball mill within a grinding machine. The resulting powder was further filtered through a 200-mesh Retsch tool. Subsequently, sieving was performed to obtain a precise particle size, involving sieves one size above and one size below the desired dimensions. The filtered wood charcoal was transferred into an acrylic pot and subjected to heating in a furnace at 800°C for a duration of 3 hours to activate it. The resulting activated wood charcoal was left in a desiccator for 15 minutes to stabilize its temperature. For each sample, 100 grams of activated wood

charcoal was weighed, resulting in a total of 9000 grams (9 kg) for the entire sample group, considering 6 samples over 15 days.

Treatment of Samples

Begin by preparing 10 healthy permanent maxillary anterior teeth (teeth 43, 42, 41, 31, 32, 33) that have been extracted and are free from calculus. To protect the tooth roots, apply a coat of clear nail polish and immerse the teeth in Arabica coffee for 6 hours over the course of 10 days, with daily coffee changes. Next, prepare the electronic toothbrush, ensuring that it exerts a pressure measuring between 300 to 400 n/m2. This pressure range has been determined as optimal since brushing teeth with a force ranging from 300 to 400 n/m2 has been shown to increase plaque removal efficiency on the tooth surface.

Next, formulate the toothpaste containing 10% Bulian wood activated charcoal and 7.5%, 10%, and 12.5% lime essential oil. Apply a pea-sized amount of toothpaste onto the electric toothbrush, spreading it evenly over the bristle surface. Proceed by brushing the teeth's surfaces with minimal pressure, employing small circular movements for a duration of 2 minutes. After brushing, allow the toothpaste to remain on the teeth for 10 minutes. Each specimen that has undergone this paste application should be labeled to distinguish those that had contact with the toothpaste for the specified 10-minute period over 10 days. Seal each container and start a timer for 10 minutes. Subsequently, using tweezers, retrieve the specimens one by one from the containers, rinse them with saline water, and then allow them to dry. Finally, measure the color changes that occurred after toothpaste exposure using the Vita Classic Shade Guide. Repeat the same procedure for toothpaste containing 10% activated charcoal with 7.5%, 10%, and 12.5% lime essential oil.

Data Analysis

To analyze the teeth whitening effect of Bulian wood activated charcoal at concentrations of 7.5%, 10%, and 12.5% on healthy teeth, the paired t-test was employed. If the normality test indicates non-normal data distribution, a non-parametric test, namely the Wilcoxon Sign Rank test, was used to analyze the effect of tooth whitening using Bulian wood activated charcoal on both healthy teeth and teeth filled with composite resin. All data analyses were performed using SPSS version 16.00 software, with statistical significance set at $p < 0.05$.

Results

A summary of the mean values before and after brushing with toothpaste containing 10% Bulian wood activated charcoal, along with different concentrations of lime essential oil (7.5%, 10%, and 12.5%), and the control group, as a teeth whitening agent for caries-free teeth, is presented in Table 1.

Table 1: Description of the mean value of teeth whitening pre-post intervention with 10% bulian wood + orange on days 1 to 10

Day	Mean ± SD (Bulian10% + lime 7,5%	Mean ± SD Bulian 10%+lime 10%	Mean ± SD Bulian 10%+ lime 12,5%	Mean ± SD Control Group
Pre	15.90±0.21	15.95±0.16	15.70±0.48	14.85±1.11
1	15.80±15.10	15.10±	14.85±0.85	14.85±1.11
2	15.55±14.45	14.45±1.54	13.25±1.25	14.65±1.27
3	14.25±13.00	13.00±2.69	11.25±2.00	14.60±1.29
4	13.75±10.75	10.75±2.02	9.55±2.24	14.05±1.48
5	11.80±9.00	9.00±1.86	8.35±2.38	12.95±1.59
6	10.90±7.85	7.85±1.84	7.00±2.52	12.35±1.68
7	10.00±6.60	6.55±1.88	5.55±2.15	11.95±1.72
8	8.85±2.19	6.00±1.67	4.40±1.81	11.70±1.62
9	7.55±2.23	5.20±1.62	3.50±1.51	11.35±1.52
10	6.05±2.39	3.95±1.54	2.65±1.70	11.20±1.48

Table 1 illustrates the variations in tooth surface color change, with an approximate mean value of 6.00 after 10 uses of toothpaste containing 10% Bulian and 7.5% Lime, around 4.00 after 10 uses of the combination of 10% Bulian and 10% Orange Lime, and approximately 3.00 after 10 uses of the combination of 10% Bulian and 12.5% Lime. In contrast, the control group exhibited an average value of nearly 11 after 10 uses.

Table 2: Results of the Difference Test (Wilcoxon Signed Rank Test) pre-post intervention

	N	Bulian wood 10%+lime 7,5%	Bulian wood 10%+lime 10%	Bulian 10%+lime 12,5%	Control Group
Pre – Post 1	10	0,157	0,014	0,017	1,000
Pre – Post 2	10	0,066	0,011	0,005	0,046
Pre – Post 3	10	0,005	0,011	0,005	0,059
Pre – Post 4	10	0,005	0,005	0,005	0,006
Pre – Post 5	10	0,005	0,005	0,005	0,005
Pre – Post 6	10	0,005	0,005	0,005	0,004
Pre – Post 7	10	0,005	0,005	0,005	0,005
Pre – Post 8	10	0,005	0,005	0,005	0,005
Pre – Post 9	10	0,005	0,005	0,005	0,005
Pre – Post 10	10	0,005	0,005	0,005	0,005

Table 2 displays the results of the Wilcoxon Signed Rank Test, which measures the difference before (pre) and after (post 1 to post 10) brushing with toothpaste containing 10% Bulian wood activated charcoal with varying concentrations of lime essential oil (7.5%, 10%, and 12.5%), as well as the control group. The results indicate significant differences ($p < 0.05$) for most cases, except for pre - post values 1 and 2 when using 10% Bulian wood activated charcoal with 7.5% lime essential oil, and in the control group for pre – post 1 and 3, where no significant difference was observed ($p > 0.05$).

Table 3: Different Test Results (Mann-Whitney Test) Effectiveness of Toothpaste Containing Bulian Wood Activated Charcoal on Control as a Whitener for Caries-Free Teeth

	N	p									
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Bulian 10%+lime 7,5% >< Control	10	0.146	0.728	0.000	0.002	0.012	0.005	0.002	0.000	0.000	0.000
Bulian wood 10%+lime 10% >< Control	10	0.002	0.007	0.005	.000	0.000	0.000	0.000	0.000	.000	0.000
Bulian wood 10%+lime 12,5% >< Control	10	0.002	0.000	0.000	.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3 presents the results of the Mann-Whitney Test, indicating differences in the effectiveness of toothpaste containing 10% Bulian wood activated charcoal with varying concentrations of lime essential oil (7.5%, 10%, and 12.5%) compared to the control group as a tooth whitener for caries-free teeth. The results show significant differences ($p< 0.05$), except for the 1st and 2nd pre-post differences in toothpaste containing 10% Bulian wood activated charcoal with 7.5% lime essential oil. In toothpaste containing 10% Bulian wood activated charcoal with 10% and 12.5% lime essential oil, significant differences in effectiveness were observed from the first repetition (post 1) through post 10 ($p< 0.05$).

Table 4: Results of the Kruskal-Wallis Test: Differences in Effectiveness Between Toothpaste Containing 10% Bulian Wood Activated Charcoal and Various Lime Essential Oil Concentrations (7.5%, 10%, and 12.5%) as Teeth Whitening Agents for Cavity-Free Teeth

	N	Mann-Whitney differentiation Test (Sig.)									
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Bulian 10%+lime 7,5% >< Bulian 10%+lime 10% >< Bulian 10%+lime 12,5%	10	0.013	0.001	0.009	0.001	0.006	0.003	0.001	0.001	0.001	0.008

Table 4 reveals significant differences in the effectiveness of toothpaste containing 10% Bulian wood activated charcoal when combined with different concentrations of lime essential oil (7.5%, 10%, and 12.5%) as a tooth whitening agent for cavity-free teeth, as indicated by the results of the Kruskal-Wallis Test ($p< 0.05$).

Discussion

Activated wood charcoal serves as a natural alternative to home bleaching chemicals due to its strong stain absorption properties. It is a form of carbon material that can be derived from various carbon-containing raw materials, with wood charcoal being one of the suitable sources [20]. For those unfamiliar with simple teeth-whitening methods, activated charcoal presents an accessible and straightforward option [14]. Lime, scientifically known as *Citrus aurantifolia*, belongs to the citrus family and contains citric acid. This citric acid possesses a similar level of acidity to ellagic acid found in strawberries, which is known for its teeth-whitening potential [21]. Lime fruit is notably rich in citric acid, characterized by an OH group, making it an effective oxidizer akin to ellagic acid and malic acid. This compound can disrupt dye molecules within conjugation bonds, neutralizing their color and delivering a whitening effect.

An analysis of the Mann-Whitney Test, designed to assess the efficacy of toothpaste containing 10% Bulian wood activated charcoal and 7.5%, 10%, and 12.5% lime essential oil against the control group as a tooth-whitening agent for healthy teeth, revealed a significant difference ($p<0.05$). This difference was observed in all cases except for the 1st and 2nd pre-post comparisons in toothpaste containing 10% Bulian wood activated charcoal with varying concentrations of 7.5% lime essential oil.

This outcome signifies that a change in tooth surface whitening occurred after the 1st repetition (post 1) and continued until the 10th repetition (post 10) when brushing with toothpaste containing Bulian activated charcoal combined with either 10% or 12.5% lime essential oil. However, for toothpaste containing 10% activated charcoal and 7.5% lime essential oil, the color change only became noticeable starting from the 3rd repetition (post 3). This observation is further supported by the data in Table 5.1.1, which illustrates alterations in tooth surface coloration, indicating an average value of 15.95 at post 1 and 3.95 at post 10 for the combination of Bulian 10% + Lime 10%. Conversely, for the combination of Bulian 10% + Lime 12.5%, the color values were 15.75 at post 1 and 2.60 at post 10.

Table 5.1.1 also reveals that brushing with 10% Bulian activated wood charcoal paste, combined with variations of 7.5%, 10%, or 12.5% lime essential oil, led to noticeable changes in tooth surface color. These changes are evident from the average tooth surface color scores. It is evident that as the paste is used repeatedly each day, the tooth surface becomes brighter. Activated wood charcoal stands out as one of the most effective ingredients for cleaning and whitening teeth. This effectiveness arises from the negative ionic charge of substances that attract positively charged ionic substances on the tooth's surface, including chromogen deposits.

These deposits may result from various sources, such as nicotine, pigments in food or beverages (coffee, tea, wine), tar, or staining from Chlorhexidine, an antiseptic that binds to the tooth's anion surface. Activated charcoal forms binding bonds and subsequently expels these substances from the mouth and body. Therefore, when activated charcoal is applied to the tooth surface, its exceptional absorption power helps absorb chromogen deposits and other factors within the enamel that alter tooth color [1, 21]

The significance of using toothpaste containing lime is highlighted in the results of another study conducted by Nurhaeni [22] which demonstrated that lime fruit at a concentration of 2.5% produced the most significant average difference in tooth color, specifically 6.20. Furthermore, research by Rochmah *et al*. [23] indicates that lime (*Citrus aurantifolia*) has the potential to whiten discolored tooth enamel and identifies an optimal timeframe for achieving this effect.

In Table 5.1.4, the Mann-Whitney Test yielded significant differences ($p<0.05$) in the effectiveness of toothpaste containing 10% Bulian wood activated charcoal when combined with varying concentrations of 7.5%, 10%, and 12.5% lime essential oil as a tooth whitener for caries-free teeth. This suggests that toothpaste containing 10% Bulian wood activated charcoal, combined with lime essential oil at each concentration, is effective in changing the tooth surface color. Notably, with 7.5% lime essential oil, color changes

begin as early as the 3rd repetition (post 3), as shown in Table 5.1.3, indicating that toothpaste containing 10% Bulian wood activated charcoal and 10% or 12.5% lime essential oil brings about more rapid whitening of the tooth surface.

Bulian wood activated charcoal proves to be effective in addressing staining on caries-free tooth surfaces. When applied to the tooth surface, activated charcoal demonstrates a remarkable capacity for absorption. Its primary function is to absorb chromogen deposits and other factors present in discolored tooth enamel. This action impacts the chemical bonds within the teeth, resulting in discoloration. Consequently, brushing with activated charcoal leads to a change in tooth enamel color through direct contact with the tooth surface [20].

In a study conducted by Nurhaeni *et al*. [22], it was determined that strawberries (*Fragaria* x *ananassa*) with a concentration of 100% were more effective in whitening teeth compared to limes (*Citrus aurantifolia*) with a concentration of 2.5%. However, there was no significant difference in their whitening effects. This suggests that using lime at a concentration of 2.5% has a relatively lesser impact on surface teeth whitening.

Among all the toothpaste variants containing 10% Bulian activated wood charcoal, combined with 7.5%, 10%, or 12.5% lime essential oil, significant color changes (whitening) occurred in various tests. However, among the three lime essential oil concentration types, the ones demonstrating the most pronounced color changes were the variants containing 10% and 12.5% lime essential oil. This observation aligns with the average score values before and after brushing (Table 5.1.1), illustrating changes in tooth surface coloration. Specifically, the pre-brushing average score was 15.90, and post-10 was 6.05 for toothpaste containing Bulian 10% + Lime 7.5%. For the combination of Bulian 10% + Lime 10%, the pre-brushing value was 15.95, and post-10 was 3.95, while for Bulian 10% + Lime 12.5%, the pre-brushing value was 15.70, and post-10 was 2.65.

Conclusion

There was a significant difference in effectiveness observed among toothpaste formulations containing 10% Bulian wood activated charcoal and 7.5%, 10%, and 12.5% lime essential oil as teeth whiteners for caries-free teeth ($p<0.05$).

Conflict of Interest

Not available

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Not available

References

1. Tin-Oo MM, Saddki N, Hassan N. Factors influencing patient satisfaction with dental appearance and treatments they desire to improve aesthetics. BMC oral health. 2011;11(1):1–8.
2. Sari H, Sembiring BM. Efektivitas Pasta Gigi Pemutih Ekstrak daun alang-alang (*Imperata Cylindrica* L. Beauv). BEST Journal (Biology Education, Sains and Technology). 2021;4(2):262–7.
3. Solovyov LA, Shmakov AN, Zaikovskii VI, Joo SH, Ryoo R. Detailed structure of the hexagonally packed mesostructured carbon material CMK-3. Carbon. 2002;40(13):2477–81.
4. Souza GDM de, Santos LM, Fernandes CA, Dantas EDV, Galvão MR, Assunção IV de, *et al*. Sensitivity in dental bleaching and the use of anti-inflammatory agents; c2014.
5. Yunita TG, Haryani W, Sutrisno S. Efektivitas Antara Buah Stroberi Dengan Buah Jeruk Lemon Sebagai Bahan Alami Pemutih Gigi (Secara *in vitro*). Journal of Oral Health Care, 2017, 5(1).
6. Yazici AR, Celik C, Dayangaç B, Özgünaltay G. The effect of curing units and staining solutions on the color stability of resin composites. Operative dentistry. 2007;32(6):616–622.
7. Siregar. Efektivitas Penggunaan Pasta Gigi Arang Aktif (Activated Charcoal) Terhadap Perubahan Warna Gigi Pada Masyarakat Kampung Belawan Bahagia Kecamatan Medan Belawan Tahun; c2020.
8. Fauziah C, Fitriyani S, Diansari V. Colour change of enamel after application of *Averrhoa bilimbi*. Journal of Dentistry Indonesia. 2013;19(3):53–56.
9. Ariani D, Mahatidana D. Dental and Oral Health Promotion Program for People with Mental Illness. Journal Multidisiplin Madani. 2022;2(11):3893–905.
10. Adusumilli H, Avula JSS, Kakarla P, Bandi S, Mallela GMK, Vallabhaneni K. Color stability of esthetic restorative materials used in pediatric dentistry: An: *in vitro*: study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2016;34(3):233–237.
11. Prehanto A, Haryono H, Raharjo TJ. The Existence of Coffee Barista Education in Kota Lumpia (Semarang). Innovative Journal of Curriculum and Educational Technology. 2019;8(1):17–23.
12. Maesaroh I, Silviani S. Formulasi Sediaan Pasta Gigi Karbon Aktif dengan Basis Virgin Coconut Oil (VCO). Jurnal Ilmiah Manuntung; c2019.
13. Price RBT, Sedarous M, Hiltz GS. The pH of tooth-whitening products. Journal-Canadian dental association. 2000;66(8):421–6.
14. Puspitasari MT. Efektifitas pasta gigi yang mengandung zat aktif charcoal terhadap pemutihan warna gigi dan tinjauannya menurut Islam; c2018.
15. Reksodiputro S. Efek Jus Buah Stroberi Terhadap Pemutihan Kembali Permukaan Email Gigi Yang Berubah Warna Karena Kopi. Tidak Diterbitkan Karya Ilmiah Jakarta: Universitas Indonesia; c2004.
16. Riani MD, Oenzil F, Kasuma N. Pengaruh aplikasi bahan pemutih gigi karbamid peroksida 10% dan hidrogen peroksida 6% secara home bleaching terhadap kekerasan permukaan email Gigi. Journal Kesehatan Andalas, 2015, 4(2).
17. Cardoso PC, Reis A, Loguercio A, Vieira LCC, Baratieri LN. Clinical effectiveness and tooth sensitivity associated with different bleaching times for a 10 percent carbamide peroxide gel. The Journal of the American Dental Association. 2010;141(10):1213-20.
18. Simaremare RT, Rosma M. Penyuluhan Tentang Manfaat Penggunaan Pasta Gigi Berbahan Arang Aktif Charcoal Dan Sikat Gigi Pada Anak Remaja Di Panti Asuhan Simpang Tiga JL. Danau Toba No 14 SEI AGUL. In: Prosiding Seminar Nasional Pengabdian Kepada Masyarakat" Penguatan Peran Perguruan Tinggi Dalam Meningkatkan Kualitas Hidup Di Era New Normal Melalui Hasil Pengabdian Kepada Masyarakat". Lembaga Penelitian dan Pengabdian Kepada Masyarakat (LPPM) Universita; c2021. p. 32–37.
19. Wardani AK, Prabowo YB, Fortuna G. Pengaruh Pemberian Ekstrak Alpukat (*Persea americana* mill) Berbagai Konsentrasi Terhadap Pemutihan Gigi

Ekstrakoronal. Universitas Diponegoro; c2021.
20. Febrianti L, Nawangsari D. Array Formulasi Sediaan Pasta Gigi Dengan Arang Aktif Tempurung Kelapa (*Cocos nucifera* L) Sebagai Pemutih Gigi. Jurnal Farmasi & Sains Indonesia. 2021;4(2):50–7.
21. Thomas ANS. Tanaman obat tradisional. (No Title). 1992;
22. Nurhaeni N, Symond D, Ristiono B. Perbandingan Efektivitas Buah Stroberi (*Fragaria* X *Ananassa*) Dengan Buah Jeruk Nipis (*Citrus aurantifolia*) Sebagai Bahan Alami Pemutih Gigi Secara *In vitro*. Andalas Dental Journal. 2017;5(2):112–8.
23. Rochmah N, Lestari S. Potensi Jeruk Nipis (*Citrus aurantifolia*) dalam Memutihkan Email Gigi yang Mengalami Diskolorasi Lime (*Citrus aurantifolia*) Potential to The Whiten Discoloration Tooth Enamel. Insisiva Dental Journal: Majalah Kedokteran Gigi Insisiva. 2014;3(1):78–83.

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