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COMPRESSIVE STRENGTH OF $Ca(OH)_2$ COMBINED WITH *MUSA ACUMINATA* AS A PULP CAPPING MATERIAL

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ABSTRACT
Background*: The weakness of $Ca(OH)_2$ is its low compressive strength and mechanical properties which can affect the stability of the material to the liquid in the tooth root canal so that it can dissolve the root canal medicament material. Due to the various weaknesses of $Ca(OH)_2$, the researchers are interested in combining $Ca(OH)_2$ with natural ingredients extracted from Musa acuminata (Mauli Banana) stem. Musa acuminata stem extract (MaSE) contains bioactive compounds such as tannins, saponins, alkaloids, flavonoids and lycopene which have antioxidant, anti-inflammatory, antibacterial and anti-viral properties. One of the requirements for pulp capping material is to have sufficient compressive strength, therefore, it is necessary to conduct research to test the value of the compressive strength of the combination of Ca(OH)2 with Musa acuminata stem extract.* ***Purpose:*** *To analyze the compressive strength of the pulp capping material from the combination of calcium hydroxide and Musa acuminata stem extract, with a ratio of 1:1; 1:1.5 ; and 1.5:1.* ***Method:*** *This research is a pure experimental study with a posttest-only design with a control group design, consisting of 4 treatment groups, including: group 1 the combination of $Ca(OH)_2$ with Musa acuminata stem extract at 1:1, group 2 1:1.5, group 3 1.5:1, and group 4 as a positive control.* ***Results:*** *One Way Anova test ($p<0.05$) which means there is a significant difference. Data analysis was continued with the LSD Post Hoc test ($p<0.05$) which showed that there were significant differences between groups, between each treatment group.* ***Conclusion:*** *The combination of $Ca(OH)_2$ with 50% MaSE and PG ratio of 1.5 : 1 : 0.375, has the highest compressive strength (1.40 MPa), so it can be concluded that the more Musa acuminata stem extract in the combination, the lower the compressive strength.*

Keywords : *Calcium hydroxide, Compressive strength, Musa acuminata stem extract*
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INTRODUCTION

Dental caries is a disease that affects the hard tissues of the teeth (enamel, dentin, and cementum) which is caused by various factors including foods that include carbohydrates, such as sucrose and sugar or sweet foods that easily stick to the teeth (cariogenic foods). This happens because cariogenic foods can be fermented by bacteria and produce acids that can damage the tooth structure if left unchecked for a long time.[1,2] The severity of caries according to depth is divided into superficial, media and profunda caries. The prevalence of profunda caries is calculated to be higher, which is 59.76%.[3,4]

Profunda caries is a cavity in the tooth, from enamel, dentin and even reaching into the pulp, causing pain.[5] If dental caries is not treated, it will eventually reach the pulp and cause pulp inflammation or pulpitis. Reversible pulpitis is a condition of mild to moderate pulp inflammation caused by stimulation, if the stimulus is removed then the pain will disappear.[6] The best treatment for this condition is endodontic treatment in the form of pulp capping which aims to protect pulp tissue from chemical, electrical, thermal and mechanical irritants that harm the pulp.[7]

Pulp capping treatment is an alternative to root canal treatment provided that the damage is reversible, asymptomatic and there are no signs of inflammation in the pulp tissue.[8] Pulp capping materials have requirements, one of which is to have sufficient compressive strength so that the pulp capping material can accept the force of mastication, therefore it is important for this material to have good mechanical properties to withstand forces that can cause fracture during the mastication process, restoration placement and during the recovery period.[9,10] The main requirements of this material are non-toxic, biocompatible, and bioactivity to cover the exposed pulp area well. A commonly used material today is calcium hydroxide as the gold standard material.[8,10]

Calcium hydroxide is able to induce mineralization, has low cytotoxicity, has biocompatibility to tissues, overcomes periapex tissue inflammation, and can stimulate hard tissue formation.[9,11] Calcium hydroxide has low mechanical properties. [10] The disadvantage of calcium hydroxide is its low compressive strength, which can affect the stability of calcium hydroxide material to the fluid in the root canal, which can dissolve the root canal medicament material.[12]

Based on some of the disadvantages of calcium hydroxide, researchers are interested in experimenting with combining calcium hydroxide with natural products to obtain better quality pulp capping materials.[9] One such natural product is *Musa acuminata* stem extract (*Mauli* banana). *Musa acuminata* stem extract contains saponins, alkaloids, vitamin C, beta-carotene, lycopene and maximum tannins. Various studies have shown that *Musa acuminata* stem extract contains antibacterial, antifungal and antioxidant properties.[13,14] Banana stem extract, including *Musa acuminata*, contains several types of phytochemicals, namely saponins with the highest content, flavonoids and tannins. Flavonoids are the largest group of phenolic compounds. Flavonoids are one of the polyphenolic compounds that have various effects including antioxidant, anti-tumor, anti-inflammatory, antibacterial and antiviral effects.[15,16]

The combination of calcium hydroxide with *Musa acuminata* stem extract is expected to improve the deficiency of calcium hydroxide as a pulp capping material, and can accelerate recovery and protect the pulp from irritation so that tooth vitality can be maintained.[16] Based on the description above, it is necessary to conduct research to find out how the compressive strength of pulp capping material from the combination of calcium hydroxide with *Musa acuminata* stem extract (*Mauli* banana).

MATERIAL AND METHODS

This research is a true experimental laboratory with a posttest-only design with control group design to test the compressive strength of the combination of $Ca(OH)_2$ with *Musa acuminata* stem extract as a pulp capping material. This research has received an ethical eligibility permit issued by the ethical Committee of Medical Research Ethics Dentistry Faculty, University of Lambung Mangkurat with register number: 032/KEPKG-FKGULM/EC/II/2023.

The production of *Musa acuminata* stem extract was conducted at the Biochemistry and Biomolecular Laboratory, Faculty of Medicine, Universitas Lambung Mangkurat, Banjarbaru, while the compressive strength test was conducted at the Engineering Materials Laboratory, Department of Mechanical and Industrial Engineering, Faculty of Engineering, Gajah Mada University, Yogyakarta.

Musa acuminata stems (*Mauli* banana) were obtained from the Banjarbaru Development Agricultural Vocational School. The *Musa acuminata* stems were washed, cut into 10 cm lengths, and oven dried at 40-50o C for 5 days. The dried *Musa acuminata* stem was pulverized using a blender until it became a 600g simplisia powder. The *Musa acuminata* stem simplisia powder was soaked with 70% ethanol in a closed container for 3x24 hours. The macerate was stirred and filtered occasionally; the macerate was then soaked for 4 days to precipitate the solute. The extraction results were then evaporated with a vacuum rotary evaporator at 40ºC and evaporated again using a water bath until 41.75 g of thick extract of *Musa acuminata* stem was collected. The next step is to conduct an ethanol-free test using potassium dichromate ($K_2Cr_2O_7$). The extract is declared ethanol-free if there is no color change. Finally, the *Musa acuminata* stem extract is ready.

The sample in this study used a combination of two materials, namely $Ca(OH)_2$ with *Musa acuminata* stem extract. The sampling technique used in this study was non-probability sampling methods in the form of purposive sampling. The study was conducted using 4 groups with each group consisting of 3 repetitions. Group 1 is a combination of $Ca(OH)_2$ with *Musa acuminata* stem extract in a ratio of 1:1, group 2 is 1:1.5, group 3 is 1.5:1, and group 4 is a positive control group. Each group was added with 40% propylene glycol as much as 0.375 ml. The addition of propylene glycol 40% as much as 0.375 ml aims to increase the hydration reaction that leads to the formation of hydrates, makes the particles in the combination of ingredients smaller, and also functions as an accelerator.

Samples were made using a 4 mm diameter by 6 mm high mold according to ISO 9917-1:2007 standard. Calcium hydroxide powder with 50% concentration of *Musa acuminata* stem extract was stirred on a glass slab using a cement spatula until homogeneous. Preparation of a mixture of $Ca(OH)_2$ and *Musa acuminata* stem extract in the ratio of 1:1; 1:1.5; 1.5:1 and positive control. Comparison of 1:1 was done by mixing 1 g of $Ca(OH)_2$, 1 ml of *Musa acuminata* stem extract and 0.375 ml of propylene glycol 40% stirred until homogeneous with a paste-like consistency. Comparison of 1:1.5 was done by mixing 1 g of $Ca(OH)_2$, 1.5 ml of *Musa acuminata* stem extract and 0.375 ml of 40% propylene glycol stirred until homogeneous with a paste-like consistency. The ratio of 1.5:1 is done by mixing 1 ml of *Musa acuminata* stem extract, 1.5 g of $Ca(OH)_2$ and 0.375 ml of 40%

propylene glycol stirred until homogeneous with a paste-like consistency, for the positive control in this study using $Ca(OH)_2$ with distilled water, after the ingredients are combined then inserted into the mold as shown in Figure 1.

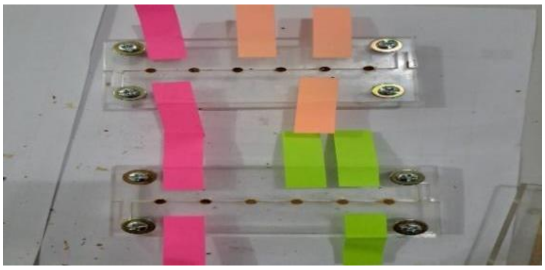

Figure 1. Mould for sample making

After 24 hours until the sample hardens, the sample is removed from the mold. then the sample is allowed to stand again for 48 hours at 37ºC until the sample hardens properly. Test the compressive strength of the sample using a Universal Testing Machine (UTM). The sample is placed in the center of the pressure device by positioning the vertical axis of the sample perpendicular to the flat plane, Then the tool is turned on and the pressing part moves slowly until the material is destroyed. The monitor on the tool will show the compressive value, the number listed is Newton (N) then divided by the cross-sectional area so that the compressive strength is obtained in units of Mega Pascal (MPa), the results are recorded and then processed.

The data obtained were processed and data analysis was carried out with a normality test using the Shapiro-Wilk test. Furthermore, the data were tested for homogeneity using Levene's Test, then parametric analysis was carried out with One Way Anova for the difference test, followed by the LSD Post Hoc test to determine significant differences between groups.

RESULTS

The results of data analysis showed $p>0.05$ which indicated that the data were normally distributed and homogeneous. In the One Way Anova test, it was found that $p = 0.036$ ($p < 0.05$), so there was a significant difference in the data, and continued with the Post Hoc LSD test, the results were found to be $p < 0.05$, so there was a significant difference between groups. Mean and Standard Deviation of compressive strength values of the combination of $Ca(OH)_2$ with *Musa acuminata* stem extract (MaSE) and propylene glycol are shown in Table 1.

Tabel 1. Mean and Standard Deviation Values of Compressive Strenght

Groups	Mean ± SD Value of Compressive Strenght (MPa)
Group 1	0,95 ± 0,172
Group 2	0,89 ± 0,141
Group 3	1,40 ± 0,310
Group 4	1,32 ± 0,160

Note:
Group 1 = $Ca(OH)_2$ (1) + (1) MaSE + (0,375) PG
Group 2 = $Ca(OH)_2$ (1) + (1,5) MaSE + (0,375) PG
Group 3 = $Ca(OH)_2$ (1,5) + (1) MaSE + (0,375) PG
Group 4 = $Ca(OH)_2$ as control (+) group

Based on the results of the study the average value of compressive strength in group 1 is (0.95 MPa), group 2 (0.89 MPa), group 3 (1.40 MPa), positive control group (1.32 MPa). The highest compressive strength value is in group 3 with a combination of $Ca(OH)_2$ with *Musa acuminata* stem extract and propylene glycol in a ratio of 1.5 : 1 : 0.375, while the lowest compressive strength value is in group 2 with a combination of $Ca(OH)_2$ with *Musa acuminata* stem extract and propylene glycol ratio of 1 : 1.5 : 0.375.

There is also a significant difference in compressive strength value between group 1 $Ca(OH)_2$: MaSE: PG (1: 1: 0.375) with group 3 $Ca(OH)_2$: MaSE: PG (1.5: 1: 0.375), then group 2 Ca(OH)2: MaSE: PG (1: 1.5: 0.375) with group 3 $Ca(OH)_2$: MaSE: PG (1.5: 1: 0.375), and group 2 $Ca(OH)_2$: MaSE: PG (1: 1.5: 0.375) with group 4 as positive control.

DISCUSSION

This study shows that increasing the ratio of *Musa acuminata* stem extract to calcium hydroxide can cause the compressive strength value to decrease significantly, because this study uses *Musa acuminata* stem extract in the form of a solution, where materials with higher water content will certainly produce materials with lower viscosity which can affect the structure of the sample material and ultimately reduce its compressive strength. Lower viscosity will decrease the powder ratio, make the liquid saturated and a lot of excess liquid cannot react with calcium hydroxide powder, resulting in a less strong material structure, and making the compressive strength of the material decrease.[9]

The increase in compressive strength value occurs because the ratio of calcium hydroxide is more than the ratio of *Musa acuminata* stem extract, so that the content of aromatic compounds in *Musa acuminata* stem extract decreases, plus 40% propylene glycol material which makes the sample have a stronger compressive strength, namely (1.40 MPa). Based on research conducted by Rukmo M, et al (2022) the results of the study prove that Propylene glycol 40% can increase compressive strength in combination, because

Propylene glycol can increase denser consistency when mixing. Propylene glycol is also known to be hygroscopic and can reduce the amount of water available in the hydration process so that it can produce a material structure that is harder and has good mechanical properties.[17]

In the combination of calcium hydroxide with *Musa acuminata* stem extract, a molecular bond occurs, between the hydrogen atoms of aromatic compounds from *Musa acuminata* stem extract with oxygen atoms of water contained in *Musa acuminata* stem extract, both bonds between these molecules, are weak hydrogen bonds. In this study, the lowest compressive strength value was obtained in the combination group of $Ca(OH)_2$ with 50% MaSE and PG in the ratio of 1: 1.5: 0.375 (0.89 MPa), because the ratio of *Musa acuminata* stem extract increased from 1:1 to 1:1.5, the concentration of aromatic compounds will increase. Therefore, the weaker bonds will be more and more so that the material structure has a lower compressive strength.[9,18] The aromatic compounds in banana leaf are derived from flavonoids.[19]

In addition to hydrogen bonds, hydroxyl (OH-) groups derived from calcium hydroxide have van der Waals bonds with aromatic compounds and active ingredients in *Musa acuminata* stem extract. Van der Waals bonds are weak bonds and can make the molecules of the two materials bind tightly together, resulting in a weaker material structure and lower compressive strength.[9,18]

In this study, the combination of $Ca(OH)_2$ with MaSE and PG has a high pH (11.9), while $Ca(OH)_2$ with pH (12.5), and MaSE with pH (5). According to research by Widjiastuti et al (2019), the pH of the mixture of the two materials can affect the compressive strength of the sample material. At higher pH, the material structure has stronger surface strength and lower porosity. At a lower pH, there is a change in the microstructure of the material due to increased porosity and will ultimately result in a decrease in compressive strength. This occurs because in an acidic atmosphere, hydroxyl ions from calcium hydroxide that play a role in early stage hardening are disrupted.[9,20,21] Based on this, it is possible that the pH of *Musa acuminata* stem extract can affect the compressive strength of the two combinations, but from several studies on the effect of pH on compressive strength, pH was found to have no significant effect.[9] Based on the results of the study, it shows that adding *Musa acuminata* stem extract (MaSE) in the combination will reduce the compressive strength value. The highest value is in group 3 with a compressive strength of 1.40 MPa, with a ratio of 1.5 $Ca(OH)_2$: 1 MaSE: 0.375 PG, and the lowest value in group 2 with a compressive strength of 0.89 MPa, with a ratio of 1.5 MaSE: 1 $Ca(OH)_2$: 0.375 PG. There are also significant differences between group 1 with group 3, group 2 with group 3, and group 2 with group 4. The results of the study also showed that group 3 is equivalent in compressive strength value to group 4 as a positive control, which is indicated by the results of the Post Hoc LSD test $p>0.05$.

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