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The effect of adding pineapple leaf fiber (*Ananas comosus* (*L.*) *Merr*) to heat-cured type acrylic resin on impact strength tests

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Abstract

Background: Heat-cured acrylic resin is a type of acrylic resin whose polymerization process is done by heating. Several methods have been used to improve the properties of acrylic resin materials, one of which is by adding natural fiber andusing pineapple leaf fiber as a natural fiber to strengthen heat-cured acrylic resin in impact strength tests.

Objective: Todetermine the impact strength of acrylic resin, with the addition of Pineapple leaf fiber and without the addition of Pineapple leaf fiber.

Research Method: This research uses laboratory experimental research. The sampling method used 16 samples per group, consisting of 2 groups, namely the control group (acrylic resin without the addition of Pineapple leaf fiber) and the treatment group (acrylic resin with the addition of Pineapple leaf fiber). Test the impact strength using the Universal impact tester machine (joule). The test result data was analyzed using the independent T-test (Sig < 0.05).

Results: The highest mean impact test value was in the treatment group (acrylic resin with the addition of Pineapple leaf fiber) at 4.22 Joules, while the lowest mean value was in the control group (acrylic resin without the addition of Pineapple leaf fiber) at 1.45 Joules. Based on data analysis, sig = 0.000 (< 0.05), which means there is a difference in the impact strength value of acrylic resin with the addition of Pineapple leaf fiber and without the addition of Pineapple leaf fiber.

Conclusion: There is an effect of adding pineapple leaf fiber to heat-cured acrylic resin.

Keywords: Heat-Cured Acrylic Resin; Pineapple Leaf Fiber (*Ananas comosus* (*L.*) *Merr*); Impact Strength

1. Introduction

The ideal denture base material should have suitable physical properties, including biocompatibility, good esthetics, radiopacity and ease of repair. The denture base must be strong enough to withstand maximum chewing loads. Even though it has excellent properties, acrylic resin (polymethyl methacrylate) has poor weaknesses in several mechanical and physical properties, such as impact resistance, flexural strength, and easy fracture (8). Impact strength is the ability of a material to withstand impact loads until the material breaks. In everyday life, impact force when using dentures refers to sudden pressure, which causes the denture to fall and hit a hard surface (4). Several methods have been used to improve the properties of acrylic resin materials, one of which is the addition of fiber. Various fibers have been incorporated and characterized extensively, such as synthetic fibers used to incorporate acrylic resin as a base for dentures. namely by adding fibers in the form of glass fiber, carbon fiber, polyethylene fiber, aramid, and metal wire (8). Pineapple leaf fiber has excellent strength, compared to other natural materials, because it contains a lot of alpha-cellulose, which can improve

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the mechanical properties of acrylic resin. The mechanical properties of Pineapple leaf fiber are very high, and can be used to strengthen acrylic resin (14). Pineapple leaf fiber also has the advantage of good mechanical strength, non-cytotoxic and non-inflammatory, however, the weakness of Pineapple leaf fiber is that it contains two slightly cytotoxic compounds, namely lignin and silica (10).

1.1. Acrylic resin

Acrylic resin is a polymer widely used in Dentistry. One of the most commonly used prosthesis base materials is polymethyl methacrylate, or hot polymerization type acrylic resin. Hot polymerization type acrylic resin has excellent aesthetic advantages, the surface texture is similar to rubber, the water absorption is relatively low and the dimensional change is small. This acrylic resin also has a weakness in the form of microporosity (3). The type of acrylic resin is differentiated from the setting process, acrylic resin is divided into several types, such as cold cured, heat cured and light cured. One type of acrylic resin that is often used is heat cured acrylic resin. In general, acrylic resin with a heating process has a disadvantage, namely that it is prone to breaking, so it needs to be added with natural fibers (8).

Acrylic resin consists of liquid and powder components. Powders made from prepolymerized polymethyl methacrylate (PMMA) fields, with “0.5-1%” benzoyl peroxide added to the initial particles are what start the polymerization process, and are called initiators along with pigments, dyes and opacifiers. The liquid is unpolymerized methyl-methacrylate, with a small amount of hydroquinone added as an inhibitor, to reduce the liquid from polymerizing or hardening during storage. The liquid can be cross-linked using a cross-linking agent, such as ethylene glycol dimethacrylate (TEGDMA) (1).

Acrylic resin has various mechanical properties, including impact strength and flexural strength. There are deficiencies in the resin in its mechanical properties, one of which is the case of fractures in dentures. Denture fractures are often caused by impact pressure, such as when the denture falls on the floor, when sneezing or coughing. Flexural pressure is the application of a bending load to the denture base repeatedly. Fracture of replacement teeth is usually caused by swaying, which occurs when dentures accidentally fall against hard objects, and bending stress (6)(12).

1.2. Pineapple leaf fiber

Pineapple leaf fiber is a type of fiber that comes from plants which comes from the leaves of the pineapple plant (vegetable fiber). The part of the pineapple plant that is often used as waste is the leaves, even though pineapple leaves contain a lot of pineapple leaf fiber, which can be reused (13).

The contents of pineapple leaf fiber include lignin, pectin, wax, ash, fat, cellulose, and other substances such as protein and other organic acids). Pineapple leaf fiber has a multitude of contents. The cellulose content in pineapple leaf fibers can increase bond strength (13).

Pineapple fiber consists of cellulose and non-cellulose, obtained by mechanically removing the outer layer of the leaves. The outermost layer of the leaf is the midrib which consists of cambium cells, namely the pigments chlorophyll, xanthophyll and carotene which are complex components of tannin and lignin found in the middle of the leaf (7).

Alkalization is a surface treatment on natural fibers using an alkaline solution (NaOH), aimed at removing non-cellulosic substances in natural fibers, thereby increasing the mechanical properties and reducing the fiber's water absorption capacity (2).

Figure 1 Pineapple leaf fiber [13]

2. Material and methods

This research method is true experimental laboratory, with a post-test only control group design. The material used to make pineapple leaf fiber is pineapple leaves that are 1-1.5 years old or after the pineapple plant has harvested its fruit. Then the pineapple leaf fiber is taken using a decorticator machine. Grind the pineapple leaf fibers using a blender and then dry them in the oven, at a temperature of 115°C, for 1 hour. The material for making the sample uses Hirodent brand heat cured acrylic resin with a rectangular sample shape, size $65\times10\times8$ mm^3.

2.1. Making pineapple leaf fiber

In this research, a mechanical method was used to separate pineapple leaf fibers, which can be done by sorting pineapple leaves with the best quality, without defects, not dry, and cutting the pineapple leaves into one length, washing them with water to remove dirt. From the Pineapple leaves, then put them in a decorticator tool to separate the fibers from the Pineapple leaves, after the fibers are separated from the leaves, wash the Pineapple leaf fibers with water, until the fibers are clean from any adhering substances, after the washing process is complete and the Pineapple leaf fibers are dried in the sun, drying takes approximately 2 days.

2.2. Alkalization

The alkalization process involves boiling with ethanol for 30 minutes, then drying by placing it in an oven at 80°C for 10 minutes. Next, it was boiled again with 6% Naoh solution, for 1 hour, at 100°C, in a glass beaker, and cooled to room temperature. Pineapple leaf fibers are washed by soaking all the fibers in distilled water, for 10 minutes, then neutralized (boiled) again, with a 6% CH3COOH solution, for 1 hour, at a temperature of 100ºC, and dried by putting them in the oven, for 10 minutes, at a temperature of 80°.

2.3. Pineapple Leaf Fiber Refining

Pineapple leaf fibers that have been alkalized, cut into small pieces with scissors, are dried in an oven at 100ºC to reduce the water content. Next, it is crushed with an electric blender until it becomes fine fiber. Before application, 50 ml of Pineapple leaf fiber is soaked using silane coupling agent liquid, in a glass beaker, then left to dry for 40 minutes. Next put the pineapple leaf fibers in the oven, at a temperature of 115°C, for 1 hour. Pineapple leaf fiber is stored in an incubator at 37ºC for 24 hours, after which it can be used as natural fiber.

2.4. Calculation Of Total Fiber Concentration

The way to calculate the percentage of fiber is by comparing the weight of the fiber and the weight of the sample. The size of the acrylic resin plate is $65 \times 10 \times 8$ mm^3, calculated by weight. The formula used is:

Vf = Vfiber % x VprintMf = pf x vf

Fiber volume:

Vƒ = Vfiber % x Vprint
Vƒ = 15% x (65 x10 x8) cmVƒ = 15% x 5,200 cm^3
Vƒ = 780 cm^3

Fiber mass:
Mƒ = pƒ x vƒ
Mƒ = 1,5 $\frac{gr}{cm^3}$ x 780 cm^3
Mƒ = 1.17 gr $\sim$ 1 gr

2.5. Making Molds for Acrylic Resin Plates

White gypsum with a ratio of 100 grams of gypsum to 24 ml of water (according to the manufacturer's instructions), mixed using a spatula, then put into the prepared cuvette and placed on top of the vibrator. The wax model measuring $65\times 10 \times 8$ mm^3 is placed in the middle of the cuvette and left to set, after hardening the plaster surface is smeared with vaseline, the antagonist cuvette is installed, filled with plaster mixture on top of the vibrator and pressed, left until the plaster hardens. After the cast hardens, the antagonist cuvette is removed and wax is removed, by dousing it with hot water, until the wax is gone, then a mold is obtained. The mold model is then smeared with Could Mold Seal (CMS).

2.6. Making Acrylic Resin with the Addition of Pineapple Leaf Fiber Powder

Acrylic resin powder and liquid are mixed in a ratio of 3:1, then put it in a porcelain cup and stir. After 3 minutes, the dough reaches the dough phase which is characterized by the acrylic resin not sticking to hands and equipment, so it can be shaped. The addition of Pineapple leaf fiber powder to acrylic resin is done by adding 1 gram of Pineapple leaf fiber powder manipulated resin to each acrylic resin sample, according to the fiber weight calculation. The process of manipulating acrylic resin is made by mixing polymer with monomer, in a ratio of 4.5:1.5 gr. After the dough reaches thedough stage, the dough is put into a mold, covered with chellopane plastic, then use a 100psi hydraulic press or bagel press, to remove the remaining dough, then the cuvette is opened and the remaining acrylic resin is removed with a cement shoe, then the cuvette is closed again and boiled in boiling water for 45 minutes**.**

2.7. Acrylic Resin Impact Strength Testing

In this study, the test specimens were in the form of rectangular plates, using the Charpy method, measuring 65mm x 10mm x 8mm, with a total of 16 samples from the treatment group and 16 samples from the control group. The principle of this test is that when a test object is subjected to an impact load, the test object experiences an energy absorption process, which results in plastic deformation, resulting in fracture. The Charpy impact method is used to determine the fracture resistance of test specimens. The stages of testing the Charpy impact method are as follows:

Measure the dimensions of the test object, length, height, cross-sectional area, notch angle and notch radius.

- The test object is placed on the test equipment support.
- Reset the pendulum needle of the test equipment.
- Pendulum locking.
- Release the pendulum until it breaks the test object.

This tool works with the pendulum swing principle, namely moving the test object which is swung in the opposite direction to the notch, the pendulum hits the test object, moves the pointer according to the impact force of the pendulum, and the results of the process of destroying the test object are obtained.

3. Results and discussion

3.1. The effect of pineapple leaf fiber on acrylic resin

The results of the impact strength test that have been measured for group I acrylic resin samples (with the addition of Pineapple leaf fiber), have a high average value of impact strength, namely 4.22 joules, compared to group II (without the addition of Pineapple leaf fiber) which only has an average value The impact force is 1.45 joules. Based on a series of research that has been carried out and the results of the Independent T-test statistical test which shows a significance value of 0.000, which means there is a significant difference between the 2 groups of heat-cured type acrylic resin samples, there is an effect of adding Pineapple leaf fiber to the heat-cured type acrylic resin on increase in impact strength. The cellulose content in Pineapple leaf fibers increases the bond strength, so that the heat-cured acrylic resin reinforced by Pineapple leaf fibers, when subjected to loads from the pendulum in the impact testing machine, does not break easily. The main function of Pineapple leaf fiber is to transfer the stress received by the acrylic resin, which is transferred to the fiber. The fibers also help distribute stress on the acrylic resin sheet. The fibers added to acrylic resin must be stronger than acrylic resin, because the fibers can withstand maximum pressure. Soaking the fiber in NaOH solution was proven to be more effective in increasing the mechanical strength value compared to without alkalization, because the adhesion between the resin and fiber without alkalization was less than perfect because it was limited by a wax-like layer on the fiber surface.

There is an effect of adding Pineapple leaf fiber on the impact strength of heat-cured type acrylic resin, so that there is a significant increase in the impact strength of heat-cured type acrylic resin with the addition of Pineapple leaf fiber.

3.2. Alkalization of pineapple leaf fiber

In this research, pineapple leaf fiber was subjected to an alkalization process first, to optimize the cellulose content in pineapple leaf fiber. To obtain a good bond between the matrix and fiber, fiber surface modification is carried out. Surface modification is carried out to increase compatibility between natural fibers and the matrix. The alkalization process aims to remove components that make up the fiber, which are less effective, or which are not needed, such as non-cellulose content, in determining interfacial strength, namely hemicellulose, lignin, or pectin. By reducing hemicellulose, lignin or pectin, the wettability of the fiber by the matrix will be better, so that the interfacial strength will increase. In addition, reducing hemicellulose, lignin or pectin will increase surface roughness which results in better mechanical interlocking between fiber and matrix (9).

Soaking the fiber in NaOH solution was proven to be more effective in increasing mechanical strength values than without alkalization, because the adhesion between the resin and fiber without alkalization was less than perfect because it was limited by a wax-like layer on the fiber surface. NaOH is the main alkalizing ingredient which will break the hydrogen bonds in cellulose. Cellulose will bond with the Na- group, while the –H group in cellulose will bond with the –OH group to form a hydroxyl group which will then dissolve. This situation can increase the adhesion of Pineapple leaf fibers with the hot polymerized acrylic resin matrix because it will form good interfacial adhesion between the fiber surface and thematrix surface so that it can increase the mechanical strength of the acrylic resin (5).

Cellulose is a polysaccharide that has a general formula, such as starch $(C6H10O5)n$. Cellulose is a substance that does not dissolve in water, which is found in plant cell walls, especially in stems, stalks and all parts that contain wood. Cellulose is a homopolysaccharide which have linear shaped molecules. The linear structure causes cellulose to be crystalline and not easily dissolved. Cellulose is not easily degraded chemically or mechanically. In nature, cellulose is usually associated with other polysaccharides, such as hemicellulose or lignin, to form the main framework of plant cell walls. Cellulose plays a role in providing strength to the fiber itself, and is not easily degraded chemically or mechanically. Apart from that, cellulose is also a material that can be used for thermal insulation and sound absorption applications (11).

Table 1 Impact Strength Measurement Results

Impact Strength Results (*Joule*)		
No	Control	Treatment
1	0,98	2,47
2	0,51	4,27
3	2,06	3,50
4	1,95	5,45
5	2,78	4,01
6	1,75	4,48
7	0,98	2,47
8	2,11	5,09
9	0,87	4,37
10	1,34	5,81
11	1,85	3,19
12	0,87	4,27
13	1,95	5,35
14	1,23	5,09
15	0,51	4,27
16	1,49	3,55
Average	1,45	4,22
Standard Deviation	0,646	1,004

Based on table 1, it can be seen that the average impact strength was greater in the treatment group (with the addition ofPineapple leaf fiber), the average impact strength was 4.22 joules. Meanwhile, the impact strength was small, which occurred in the control group (without the addition of pineapple leaf fiber), which had an impact strength of 1.45 joules.

Table 2 Shapiro-wilk Normality Test

Shapiro-wilk			
Group Control	Statistic	df	Sig.
	0,954	16	0,549
Treatment	0,954	16	0,551

Based on the data from the normality testing results that have been carried out, it is known that the significance value of test material I (heat-cured type acrylic resin with the addition of Pineapple leaf fiber) and test material II (heat-cured typeacrylic resin without the addition of Pineapple leaf fiber), respectively has a significance value of 0.551 and 0.549. In accordance with the provisions, if the significance value is > 0.05, then the data obtained is normally distributed.

Table 3 Levene-Test Homogeneity**.**

Levene Statistic	**df1**	**df2**	**Sig.**
1.786	1	30	0.191

Based on the data homogeneity test given in Table 3, the significance value obtained is 0.191. Based on the provisions, if the significance value is > 0.05, it can be interpreted as the two groups coming from a homogeneous data population.

Because the assumptions of data normality and homogeneity of variance are met, the Independent T-test can be used with the results shown in table 4 below.

Table 4 Independent T Test Statistical**.**

T-test Independent			
	Average	Standard Deviation	Sig. (2-tailed)
Control	1,451	0,646	0,000
Treatment	4,227	1,004	0,000

Based on the results of the independent T-test parametric test, the sig value was obtained. (2-tailed) is 0.000. Based on the provisions of the independent T test, if the significance value (2-tailed) is <0.05 then there is a significant difference inthe impact strength between acrylic resin with the addition of Pineapple leaf fiber and acrylic resin without the addition of Pineapple leaf fiber.

4. Conclusion

This research aims to determine the impact strength of heat cured acrylic resin with the addition of pineapple leaf fiber. From the research that has been carried out and statistical tests, it can be concluded that there is an influence of the addition of Pineapple leaf fiber on the impact strength of heat-cured type acrylic resin, so that there is a significant increase in the impact strength of heat-cured type acrylic resin with the addition of Pineapple leaf fiber.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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