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EFFECT OF ADDITION RAMIE AND COCONUT COIR FIBERS WITH DIFFERENT CONCENTRATIONS ON TENSILE STRENGTH OF ACRYLIC DENTURE BASE

Research Report
Penelitian

PENGARUH PENAMBAHAN SERAT RAMI DAN SABUT KELAPA DENGAN KONSENTRASI BERBEDA TERHADAP KEKUATAN TARIK BASIS GIGI TIRUAN AKRILIK

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ABSTRACT

Background: *Acrylic denture base material has advantages such as good aesthetics, ease of repair, and affordable price, but this denture has mechanical properties, one of which is low tensile strength so fractures often occur during use. Utilization of natural fibers such as ramie (Boehmeria Nivea) and coconut coir (Coco Nucifera L) can be used as an alternative reinforcement for acrylic denture bases.* ***Purpose:*** *To determine the effect of adding ramie fiber and coconut coir fiber at different concentrations on the tensile strength of the acrylic denture base.* ***Method:*** *This study used a laboratory experimental method with a flat dumbell-shaped specimen with a size of 75 × 10 × 3 mm based on ISO 527-1 (2019). The specimens consisted of 42 plates which were divided into 7 groups, namely 6 specimens each group without fiber addition (control), with the addition of ramie fiber 1%, 2%, 3%, and the addition of coconut coir fiber 1%, 2%, 3%. Tensile strength testing using Universal Testing Machine (UTM), data were analyzed by One-way ANOVA test and Post Hoc LSD test.* ***Result:*** *The 3% ramie fiber addition group had the highest tensile strength (76.47 MPa), the 1% coconut coir fiber addition group had the lowest tensile strength (58.91 MPa). There was a significant difference in the results of the control group's tensile strength test and the addition of 3% ramie fiber and 1% coconut coir fiber (p-value < 0.05).* ***Conclusion:*** *The greater the concentration of ramie and coconut fiber additions, the higher the tensile strength value, although the tensile strength value in the coconut fiber addition group was lower than the control group and ramie fiber addition.*

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ABSTRAK

Latar belakang: Bahan basis gigi tiruan akrilik mempunyai kelebihan dalam hal estetik, mudah direparasi dan harga relatif lebih murah, namun memiliki sifat mekanik (*tensile strength*) yang rendah sehingga sering terjadi fraktur saat penggunaan. Pemanfaatan serat alami seperti rami (*Boehmeria Nivea*) dan sabut kelapa (*Coco Nucifera L*) dapat dijadikan alternatif sebagai bahan penguat basis gigi tiruan tiruan Resin Akrilik Polimerisaasi Panas (RAPP). **Tujuan:** Untuk melihat pengaruh penambahan serat rami dan sabut kelapa dengan konsentrasi berbeda terhadap tensile strength basis gigi tiruan akrilik. **Metode:** Penelitian ini berupa eksperimental laboratorik dengan *specimen flat dumbell-shaped* dengan ukuran 75 × 10 × 3 mm berdasarkan ISO 527-1 (2019). Spesimen terdiri dari 42 plat yang dibagi menjadi 7 kelompok, yaitu masing-masing 6 spesimen kelompok tanpa serat (kontrol), penambahan serat rami 1%, 2%, 3% dan penambahan serat sabut kelapa 1%, 2%, 3%. Pengujian *tensile strength* menggunakan *Universal Testing Machine*, data dilakukan analisis dengan uji *One-way* ANOVA dan uji Post Hoc LSD. **Hasil:** Kelompok penambahan serat rami 3% memiliki *tensile strength* tertinggi (76,47 MPa), kelompok penambahan serat sabut kelapa 1% memiliki *tensile strength* terendah (58,91 MPa). Terdapat perbedaan yang bermakna pada hasil uji *tensile strength* kelompok kontrol dan penambahan serat rami 3% dan sabut kelapa 1% (*p-value* < 0,05). **Kesimpulan:** Semakin besar konsentrasi penambahan serat rami dan serat kelapa maka semakin meningkat pula nilai *tensile strength*, walaupun nilai *tensile strength* pada kelompok penambahan serat kelapa lebih rendah dari kelompok kontrol dan penambahan serat rami.

Kata kunci:
Gigi tiruan akrilik, Serat sabut kelapa, Serat rami, Kekuatan tarik

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INTRODUCTION

One part of the denture is the base in the form of a base that covers the soft tissues in the oral cavity and the attachment of the denture teeth elements (Rahmadita and Putranti, 2018). In 1937, the first acrylic resin denture base material was introduced, namely polymethyl methacrylate (PMMA) or more commonly referred to as acrylic resin. Based on its polymerization, acrylic resin was divided into three types, self-polymerization, light polymerization, and heat polymerization. *Heat-Cured Acrylic Resin* (HCAR) began to be used widely for denture base materials in 1946 and since then this material has been frequently used because it meets the requirements as an ideal denture base material (Nandal *et al*., 2013; Felycia and Tarigan, 2021).

Acrylic resin has beneficial properties, namely, the color resembles the gingiva so that it looks better aesthetically, it is easy to manufacture, it is biologically safe, and the price is relatively cheaper (Alla *et al*., 2013; Anusavice, 2004; Mowade *et al*., 2012). In addition, the acrylic resin also has disadvantages, one of which is low tensile strength and resistance to fracture. This can occur during mastication at different temperatures so over time it can have an impact on damage to the denture base. Tensile strength is one of the mechanical properties of a material and this strength is related to the cracking or breaking of the denture base caused by the patient's habit of removing and installing dentures repeatedly (Rahmadita and Putranti, 2018).

The use of reinforcing materials can be done to improve the weaknesses of acrylic denture bases, including by using fiber. Fibers are pieces that form a complete network in a longitudinal direction and can be divided into two, namely synthetic fibers and natural fibers. The use of new materials in the form of natural fibers needs to be considered as an alternative, considering the price of synthetic fibers are relatively more expensive. Natural fibers can replace synthetic fibers so they are a good solution for denture reinforcement (Putri *et al*., 2016; Prawesthi *et al*., 2022a). Natural fibers are biomaterials that are environmentally friendly, biodegradable, and cheaper than synthetic reinforcements. This material has a high tensile strength and is still rarely used in dentistry (Kusumastuti, 2009; Hadianto *et al*., 2013; Prawesthi *et al*., 2022a)

The ramie plant (*Boehmeria Nivea*) is a producer of fiber derived from bark fiber. The advantages possessed by ramie plants are greater tensile strength, environmental friendliness, high water absorption, shine, and resistance to bacteria and fungi (Alfathoni and Wijanto, 2019). Coconut plant (*Coco Nucifera L*) which is a tropical plant and can be found in tropical countries such as Indonesia. All parts of the tree can be used in life and have high economic value, but coconut husk has not been used properly as a production material, causing environmental problems. Coconut coir fiber contains cellulose and lignin so the fiber has high rigidity. This fiber is starting to be widely used because it is easy to obtain, cheap, environmentally friendly, and does not harm health (Astika *et al*., 2013).

Several studies on strengthening the HCAR denture base with added fiber have been carried out, for example with fiberglass, steal wire, polyester fiber, and aluminum oxide. One of the studies on reinforced denture bases is what Sabda (2013) did about the tensile strength of HCAR denture base materials with added glass fiber. Another study by Astika *et al*., (2013) on the mechanical properties of coco fiber as a reinforced polyester composite. In addition, this fiber reinforcement is also used in engineering by Titani *et al*. (2018), namely the use of coconut fiber as a substitute for polyester composite fibers in aircraft structures. A similar study was also conducted by Prawesthi *et al*. (2022b) on the use of ramie fiber and banana stems based on heat cured acrylic resin on impact and flexural strength.

This study aims to see how far the influence of ramie fiber and coconut coir added to the HCAR base plate in providing tensile strength and to determine the concentration of ramie fiber and coconut coir fiber produces the best tensile strength. In the end, it is hoped that the results of this study can be useful for providing additional reinforcement on the HCAR denture base and at the same time increasing the cultivation of natural fibers for the use of reinforcement materials. This research was conducted in April-May 2022 at the Dental Technology Laboratory of Health Polytechnic Jakarta 2 for the fabrication of specimens and tensile strength tests were carried out at the Static laboratory, B2TKS BRIN, PUSPITEK Gd.220, South Tangerang.

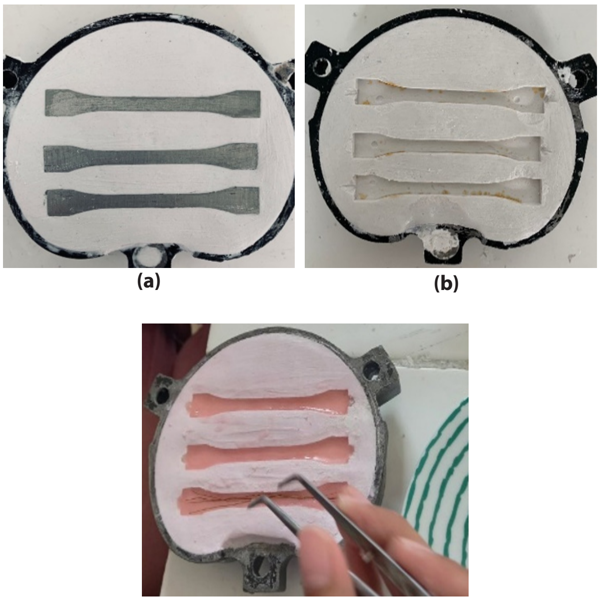
MATERIAL AND METHOD

This research method is an experimental laboratory with a post-test only design with a control group design. The total number of specimens was 42 acrylic plates, divided into 7 groups, namely 6 control samples each (no fiber added), added ramie fiber 1%, 2%, 3%, coconut coir fiber 1%, 2%, and 3%. The use of fiber concentration 1%, 2% and 3% as a reinforcement in HCAR is based on previous research conducted by Mowade *et al*. (2012), Riyadi *et al*. (2019), and Fransisca and Nasution (2015).

The natural fibers used are ramie and coconut coir fibers. For ramie fiber (*Boehmeria Nivea*) it is taken from a very hard and glossy white bark. The coconut coir fiber used is taken from the dried coconut (*Cocos Nucifera L*) and the inside is taken. The use of this natural fiber previously required an alkalization process with 5% NaOH solution which aims to increase the roughness of the fiber surface layer, the adhesion between the polymer matrix to the fiber, and reduce water absorption in the fiber (Ku *et al*., 2011).

The volume of fiber in this study was 1%, 2%, and 3% of the weight of the acrylic plate with the formula fiber volume (%) = fiber weight (gr)/sample weight (gr) x 100% (Hadianto *et al*., 2013). In this study, the sample weight before adding fiber was 1.7 gr, so after being put into the formula. It was found that a 1% concentration required 0.017 gr fiber, a 2% concentration required 0.034 gr fiber, and a 3% concentration required 0.051

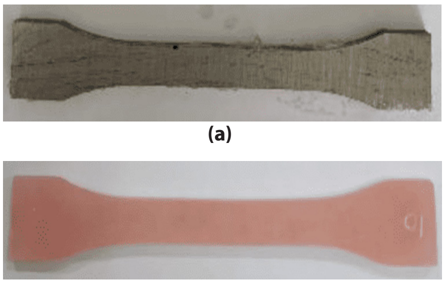
gr fiber. All the fibers added were placed lengthwise according to the length and width of the sample and placed in the middle 1/3 of the mold between the acrylic dough (Figure 1).


(a) (b)

(c)

Figure 1. (a) Metal master in cuvette; (b) Mold space; (c) Laying of fiber in acrylic dough

The specimen is a dumbbell-shaped acrylic plate from a metal master mold, with a size according to ISO 527-1 (2019) 75 x 10 x 3 mm for tensile strength test (Figure 2) (Standard, 2019).


(a)

(b)

Figure 2. (A) Metal master mold; (B) Specimen

Figure 5 shows a diagram of how research works in general. The specimens were made from HCAR material (BasiQ20, Vertex, Netherland) and the fibers used were cut according to the length and width of the specimen plate shape, then weighed so that the fiber weight criteria were met, then the fibers were dipped in monomer until all were wetted. The polymer and monomer in a ratio of 2.4 gr : 1 ml were stirred in a mixing jar. The dough is then put into the mold space to a height of 1/3 of the way before the dough reaches the dough phase, impregnated with the fibers, and placed in the middle 1/3 of the mold. After the dough phase is added to 2/3 of the dough and the cuvette is closed, the plastic cellophane is previously layered on top of the dough and the cuvette is pressed by hand. The cuvette was opened again, the remaining acrylic was cleaned then the cuvette was closed again and pressed with a table press using a pressure of 2200 psi (50 kg/cm^2). The next stage is curing, which is putting the cuvette for 20 minutes into boiling water (100°C), then the cuvette is removed and cooled (according to the manufacturer's rules). After that, the specimen was removed from the cuvette and the surface of the specimen was smoothed with abrasive paper numbers 360, 600, and 1000. Then, the specimen was cleaned with water spray.

Immersion in distilled water and storage in an incubator at 37°C for 24 hours was carried out after the specimen-making process was completed. After drying, each specimen at both ends is numbered and a line is marked in the middle of the specimen, then it is ready for testing and data analysis. The *Universal Testing Machine* (UTM) (Shimadzu, Japan) was used for testing Tensile strength, with a load of 10 kN, a grip distance of 50 mm, and a crosshead speed of 5 mm/min. The test method is that the specimen is placed vertically/perpendicularly and both ends are clamped and then pulled until they break (Figure 3). Specimens before and after testing with UTM are shown in Figure 4. The tensile strength value is calculated by the formula (Setiawan and Ardianto, 2018) $\sigma = F_{max}/A_o$; σ = Tensile strength (MPa); F= Pulling force (N); A= Surface area (mm^2).

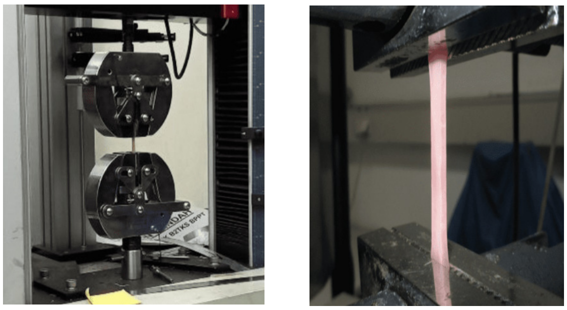
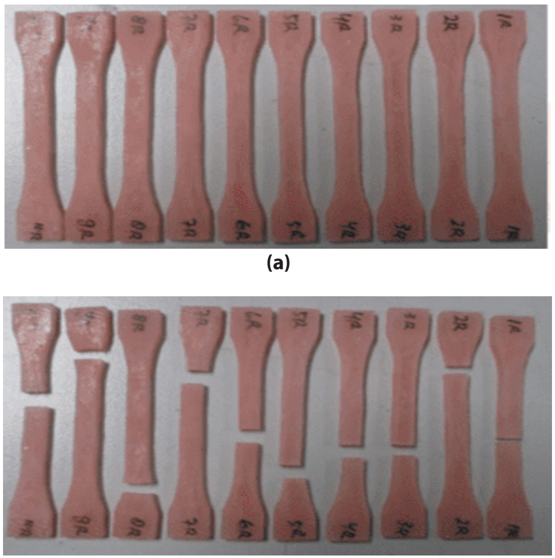

(a) (b)

Figure 3. (a) Universal testing machine; (b) Specimen when pulled


(a)

(b)

Figure 4. (a) Specimens before testing; (b) After testing

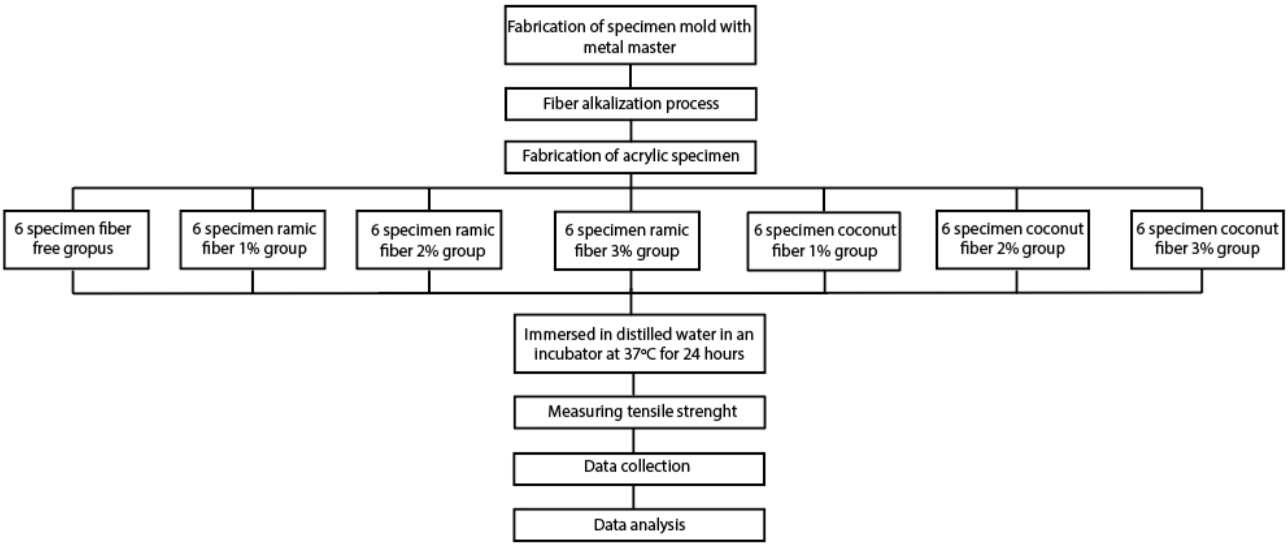


Figure 5. Workflow diagram

RESULT

The data generated from this study were previously tested for normality using the *Shapiro-Wilk* test and the results obtained were normal data distribution because all groups had a *p-value* > 0.05, then continued with the Lavene homogeneity test, the data obtained in all groups were homogeneous because the *p-value* > 0.05. In Figure 6, it can be seen that the mean tensile strength value in each group shows a different value. The mean tensile strength value for the addition of 3% ramie fiber group had the highest mean value of 76.47 MPa, followed by the addition of 2% ramie fiber group, which was 71.08 MPa, then the addition of 1% ramie fiber group, which was 68.51 MPa. The smallest mean tensile strength was found in the group free fiber (control) which was 66.11 MPa. Meanwhile, for the addition of coconut fiber, the largest mean value is the group free fiber (control) which is 66.1167 MPa, then followed by the addition of 3% coconut fiber, which is 63.0767 MPa, and the addition of 2% coconut fiber, which is 60.6583 MPa, and the group that has the smallest mean value is the 1% addition of coconut fiber, which is 58.9133 MPa.

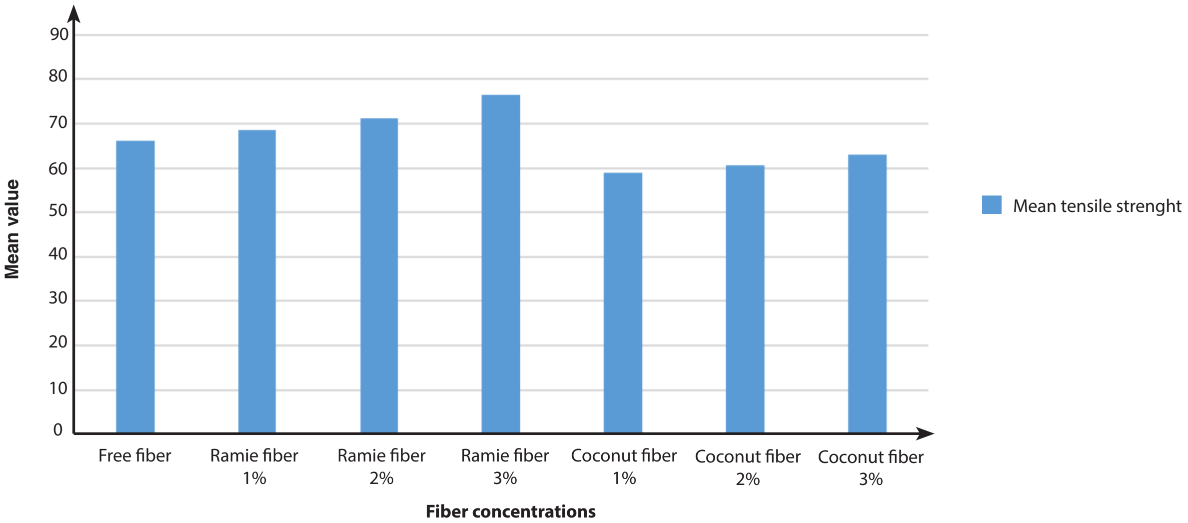


Figure 6. The mean tensile strength of all groups

Table 1 shows the difference in the mean value of the *Tensile Strength Test* (MPa) in the free fiber group (control), the group with 1%, 2%, 3% ramie fiber addition, and 1%, 2%, and 3% coconut fiber addition. The analysis was carried out using *One-way* ANOVA with *p-value* < 0.05, and because *p-value* = 0.00 (Ho was rejected) it was continued with the Post-Hoc *Least Significant Different* (LSD) test to see the differences between the groups. In Table 1, it can be seen that the data obtained showed significant differences (*p-value* < 0.05), namely between the control group and the 3% ramie fiber and 1% coconut fiber group, between the 1% ramie fiber group and the 3% ramie fiber group, 1% coconut fiber. and 2%, between the 2% ramie fiber group and the 1%, 2%, and 3% coconut fiber group, and between the 3% ramie fiber group and the 1%, 2%, and 3% coconut fiber group. Meanwhile, between other groups, there was no significant difference because *p-value* > 0.05.

Table 1. LSD test *One-way* ANOVA, differences between groups of HCAR plates free fiber (control), with the addition of ramie fiber 1%, 2%, 3% and coconut coir fiber 1%, 2%, 3% (N= 42)

Group		Mean difference	Sig.
Free fiber (Control)	Ramie fiber 1%	-2.397	0.420
	Ramie fiber 2%	-4.970	0.099
	Ramie fiber 3%	-8.377	0.005*
	Coconut coir fiber 1%	7.945	0.014*
	Coconut coir fiber 2%	5.458	0.072
	Coconut coir fiber 3%	3.040	0.308
Ramie fiber 1%	Ramie fiber 2%	-2.573	0.387
	Ramie fiber 3%	-5.981	0.042*
	Coconut coir fiber 1%	10.341	0.002*
	Coconut coir fiber 2%	7.855	0.011*
	Coconut coir fiber 3%	5.437	0.073
Ramie fiber 2%	Ramie fiber 3%	-3.408	0.237
	Coconut coir fiber 1%	12.914	0.000*
	Coconut coir fiber 2%	10.428	0.001*
	Coconut coir fiber 3%	8.010	0.010*
Ramie fiber 3%	Coconut coir fiber 1%	16.322	0.000*
	Coconut coir fiber 2%	13.835	0.000*
	Coconut coir fiber 3%	11.418	0.000*
Coconut coir fiber 1%	Coconut coir fiber 2%	-2.486	0.425
	Coconut coir fiber 3%	-4.905	0.120
Coconut coir fiber 2%	Coconut coir fiber 3%	-2.418	0.416

Description: *Significan

DISCUSSION

In this study the mean tensile strength of HCAR in the fiber-free group was 66.1167 MPa, this value was greater than previous research conducted by Rahmadita and Putranti (2018) which was 50.867 MPa and Zuriah Sitorus *et al*. (2014), namely 53.010 MPa. But, the mean tensile strength value in this study both in the free fiber group and with the addition of ramie fiber and coconut coir fiber was still within the recommended limits according to ISO 527 specifications, which ranged from 36-77 MPa and was greater than the tensile strength value based on ASTM D 638 is 55 Mpa (Zuriah Sitorus *et al*. 2014). The tensile strength of HCAR dentures can be influenced by several factors, including the presence of residual monomers and invisible porosity, wasted acrylic material during pressing so that the fiber concentration in the sample is not evenly distributed and manual polishing with abrasive paper causes roughness on the sample surface not to be equally (Rahmadita and Putranti, 2018).

The difference in tensile strength values in the free fiber group between this study and the research Zuriah Sitorus *et al*. (2014); Rahmadita and Putranti (2018) may be due to differences in the HCAR denture base material used and the size of the specimen. In this study the HCAR materials used were Vertex with the shape of specimen according to ISO 527-1 2019. While in a previous study conducted by Rahmadita and Putranti (2018), the HCAR material used was GC, America with a size of 60 x 12 x 3.9 mm, while Zuriah Sitorus *et al*. (2014) used GC, America with a size of 80 x 10 x 4 mm. This difference in acrylic resin brands allows for differences in the ratio of polymer and HCAR monomer, polymerization process, water absorption, and invisible internal porosity (Manappallil, 2010; Prawesthi *et al*., 2022b).

The use of acrylic based ramie fiber in this study gave a higher value than the free fiber group, possibly due to load transfer between the fiber and the polymer matrix and the adhesion between the two. When under load, the interatomic bonding of the HCAR polymer has the lowest Young's modulus. Cracks in the denture base are caused by long-term deformation because Young's modulus of the HCAR denture base exceeds the stress point threshold. The added fiber increases the HCAR stress point threshold. This is because the fibers absorb some of the load on the denture base, which increases tensile strength and makes the denture base less likely to fracture (Anusavice, 2004; Mowade *et al*., 2012).

In addition, in this study the orientation of the fiber direction is in the same direction, as well as the length and width are the same as the acrylic plate. The orientation and direction of the fibers on the acrylic plate affect the flexural strength. The direction of the fiber is placed perpendicular to the direction of the force, at which point the force is evenly distributed throughout the fiber section. This situation is by the *Fiber Reinforced Composite* (FRC) efficiency (Krenchel Factor) theory, which explains that if the position of the fiber is unidirectional to the tensile strength, then the value is 1 and if the position of the fiber is perpendicular to the tensile strength, then the value is 0 (Cullen *et al*., 2013).

Another study was also conducted by Lokantara and Suardana (2007) on orientation analysis and processing of filter fiber, which stated that 0º fiber orientation has a strong bond because the fiber direction is mostly in the same direction as the load strength. Another possibility that can increase the tensile strength value in this study, is besides ramie fiber has a fairly high cellulose content, also because it is given an alkalizing treatment with 5% NaOH. The purpose of alkalization using NaOH serves to reduce the water content of the fiber, increase the adhesion between the matrix and the ramie and increase the surface roughness of the ramie fiber (Putri *et al*., 2016) . This is in accordance with research Maryanti *et al*. (2011) on the effect of alkalization of coconut polyester composites, noting that the addition of NaOH percentage in fiber alkalization can increase the value of tensile strength. Another possibility, the highest mean in the group with the addition of ramie fiber compared to the group free fiber and the addition of coconut coir fiber because the cellulose composition of ramie fiber (65%) is higher than that of coconut coir fiber (26.6%), cellulose plays an important role in the strength of the fiber itself and does not easily degraded chemically or mechanically, so that the tensile strength of ramie fiber is the highest (915 MPa) compared to coconut coir fiber (175%) (Habibie *et al*., 2021; Pradana *et al*., 2017). The increase in tensile strength values in the 1%, 2%, and 3% ramie fiber addition groups could be due to the addition of increasing fiber volume fraction which will provide greater tensile strength. This is in accordance with a study conducted by Riyadi *et al*. (2020) regarding the addition of rice husk nano cellulose with concentrations of 1%, 2%, 3%, 4%, and 5% to the flexural strength of the HCAR resin denture base which was seen to increase compared to the control group.

The mean value of the group free fiber addition (control) was relatively higher than the group with 1%, 2%, and 3% coconut coir fiber addition. This is probably because the lignin composition in coconut coir fiber (29.4%) is quite high compared to ramie fiber (0-1%), so although an alkalization process has been carried out to remove these substances and the possibility of the alkalization process carried out in this study is not perfect so that lignin is still high in the surface of the coconut coir fiber so that the interlocking process between the fiber and polymer is also reduced (Habibie *et al*., 2021). In addition, due to the decomposition process (decay) that may occur in coconut coir soaked in distilled water solution for 24 hours in an incubator which is the research stage.

This is in accordance with research Lokantara and Suardana (2007) which states that the longer the immersion, the more easily the fiber expands. The expanding fiber will fill the space between the polymer matrix and the fiber, and the water will chemically bind to the cellulose molecules until they reach their saturation point. When water molecules are absorbed by the coconut coir fiber and exceed its saturation point, it will cause the decomposition of the coconut fiber, namely decay. In immersion in fresh water, the coconut coir fibers experience more pull-out, the water that enters the matrix and is absorbed by the coconut coir fibers causes debonding or the release of bonds on the surface of the fibers with the matrix, resulting in a decrease in the strength value of the material (Lokantara and Suardana 2007). Another possibility is due to the uneven distribution of coconut coir fibers, which causes the accumulation of fibers at a certain point so that the fibers cannot withstand the applied force (Sari *et al*., 2011).

In the 1%, 2%, and 3% coconut coir fiber addition groups, the mean value was relatively not too high but there was an increase, although the value was not too large. The increase in tensile strength in the additional group of coconut coir fiber is due to the addition of fiber volume in each group and causes these fibers to be more able to transmit energy evenly and be able to accept greater tensile loads (Titani *et al*., 2018; Astika *et al*., 2013). This condition is in accordance with research Bale et al. (2018) which states that the volume fraction of the fiber increases, indicating an increase in the load received by the fiber and the tensile strength.

Another possibility is that the increased fiber volume fraction due to the alkalizing treatment of coconut coir fiber with 5% NaOH also increases so it affects the increase in tensile strength. Another possibility is that the increase in fiber volume fraction due to the alkalizing treatment of coconut coir fiber with 5% NaOH also increases so it affects the increase in tensile strength. This can be explained by the alkalizing treatment of the fiber which aims to remove hemicellulose, lignin, and other ineffective materials from the fiber, thereby increasing the roughness of the fiber surface with a large volume fraction of coconut coir fiber, the rougher surface of the fiber increases and provides a good mechanical interlocking effect on the matrix (Maryanti *et al*., 2011; Lokantara and Suardana, 2007).

CONCLUSION

The addition of ramie fiber can increase the tensile strength of the HCAR denture base because ramie fiber has high cellulose content and low lignin so the tensile strength becomes greater. The greater the concentration of ramie fiber, the higher the tensile strength value. The coconut coir fiber group had a lower tensile strength value than the control and ramie fiber groups, so the addition of coconut coir fiber is less beneficial in increasing the tensile strength of denture acrylic base. The low tensile strength of the addition of coconut coir fiber is due to the high content of hemicellulose and lignin and the possibility of an imperfect alkalization process.

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