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Examining the Absorbency and Elasticity Properties of Modified Coconut Fibre: An Alternative Material for Diapers Filling

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ABSTRACT
Research on absorbent core and elastic-modified coconut fibre is motivated by the use of coconut fibre in terms of water absorption and elasticity. This study aims to: (1) determine the percentage of the absorbent core and elastic-modified coconut coir; (2) compare the percentage of the absorbent core and elastic-modified coconut fibre to the diapers X. The design used was experimental. The tools and materials consisted of modified coconut fibre, a Pasteur pipette, a specimen clamp, and a software system. Modified coconut coir was made from a mixture of Cinnamomum verum and Mutingia calabura L., with a sample mass ratio to diapers X, which was 1:40, circular shape with a diameter of 3 cm. The treatments for modified coconut coir were sun drying (Sample A) and a hair dryer (Sample B), which resulted in differences in the Absorbent core (Ab) and Elastic (E). The sample was forwarded for the E-test through the Tracker software system, which can detect the centre of mass of the object through the experimental video recording, and the other sample was measured Ab through the difference in the volume of water absorption. The results showed that Sample B could be used as an engineering material for Ab and E diapers X. It was concluded that: (1) %Ab-Sample B = 38.36%, %Ab-Sample A = 25.57%, %E-Sample B = 1.2%, %E-Sample A = 0.5%; (2) comparison of %E-Sample B to %E-Diapers X was 67%, and %E-Sample A to %E-Diapers X was 27%.

INTRODUCTION

The utilization of coconut fibre waste has been widely carried out with various functions according to the needs and thoughts of innovators in its development. This is because coconut fibre has multifunctional properties, including the strength of its fibre and is easily found in each region. Coconut fibre can absorb water, and coconut fibre from West Kalimantan has the highest absorption capacity compared to the absorption capacity of coconut fibre from Java and Papua, with a ratio of 7:5:4 (Kahar et al., 2019). Thus, the coconut fibre used in this study is coconut fibre from West Kalimantan.

There has been much research on the absorbent capacity of coconut fibre. Coconut fibre as an absorbent of CR(VI) in wastewater (Verma et al., 2021); Making absorbents from coconut fibre as an absorbent of heavy metal Pb(II) (Kardiman et al., 2020); Utilization of coconut fibre as a bio absorbent of heavy metal Pb(II) in industrial wastewater (Ifa et al., 2020); and others. The percentage of water absorption capacity with variations in coconut fibre has also been found with a value of 11.733 - 15.9%, but the absorption capacity of the coconut fibre is in the form of lightweight concrete boards (Jatmika & Mahyudin, 2017). Likewise, the elasticity of the material in coconut fibre was found to be 92462MPa, which was varied with a mixture of 20% rice husk at FAS 0.44 (Pujiana et al., 2020). Coconut fibre has the potential to have high absorption and elasticity. However, no research has been conducted on the engineering material of absorbent core and elastic from coconut fibre compared to popular baby diapers manufactured, which in this study are called Diapers X. Diapers X is made of 63.93% absorbent core and 1.80% elastic. The similarity of the properties of coconut fibre with Diapers X, which contains absorbent core and elastic values, can be tested by determining the percentage ratio of the two materials.

The coconut fibre in this study is a modified result in the form of a mixture of cherry leaves (*Muntingia calabura L.*) and cinnamon (*Cinnamomum verum*). Cherry leaves contain flavonoids, tannins, triterpenoids, saponins, and polyphenols, which show antioxidant activity. Flavonoids can function as antimicrobials, antiviruses, and antioxidants. Cinnamon contains essential oils with a distinctive aroma, so it can be used as aromatherapy. The main content of essential oils in cinnamon is cinnamaldehyde (60.72%), eugenol (17.62%), and coumarin (13.39%) (Widianti et al., 2021). Coconut fibre tends to be easily mouldy and contains microbes (Poongodi & Murthi, 2021). Modification of coconut fibre with the addition of cherry leaves (*Muntingia calabura L.*) is considered to be a natural preservative for coconut fibre from fungal and bacterial attacks, so it is expected to minimize microbial growth. This modified coconut fibre is used as a research variable through the STEAM-2C approach to test the percentage of absorbent core and elasticity, which are then compared with diapers X.

The STEAM-2C approach (Science, Technology, Engineering, Art, Mathematics, Culture, Communication) contains components that support the treatment of research variables, starting from the ideas that arise, the testing process, data processing, to the representation of the findings. The complex combination of various scientific perspectives is expected to provide a more meaningful description in exploring the results of research findings. This makes the research variables tested more structured and measurable, and clarified based on the field of study in various dimensions of knowledge. This STEAM-2C approach can interpret each entity in the research activities carried out so that it can be described more clearly to support the research method used. The STEAM-2C approach in this study is shown in Table 1.

Table 1. STEAM-2C Method in Research

Components of the STEAM-2C	Method Activities in this Study
Science (S)	Conducting tests to determine the absorbent core and elastic properties of coconut fibre as indicated by the value and percentage comparison to diapers X.
Technology (T)	1. Using technology in making samples. 2. Using the Tracker Application in elastic tests.
Engineering (E)	1. Processing of making coconut fibre samples 2. Absorbent core and elastic test treatment
Art (Art)	Carrying out variations in the independent variables on coconut fibre samples in terms of the drying process.
Mathematics (M)	1. Determining the elastic value, elastic percentage, and elastic ratio. 2. Determining the absorbent core value, absorbent core percentage, and absorbent core ratio.
Culture (C)	1. Using natural materials that come from nature/the environment. 2. Using materials that are also developed/utilized by cultural communities.
Communication (C)	The results of the study are reported/disseminated in the form of scientific articles.

Based on the description, this study aims to test the percentage of absorbent core and elastic engineering materials in modified coconut fibre with the STEAM-2C method; and compare the percentage of absorbent core and elastic in modified coconut fibre with the STEAM-2C method against diapers X. This study is expected to be an initial step that can describe the opportunity to use modified coconut fibre as an alternative material to replace absorbent core and elastic in baby diapers (diapers X). This is an effort to minimize environmental pollution from the large amount of baby diaper waste that is difficult to decompose. The results of this study are expected to be reviewed further through other studies.

RESEARCH METHOD

This research is a quantitative research with a research design in the form of a true experimental design. This research began by collecting old coconut fibres and separating the coarse dusty fibres from the fine fibres without coconut fibre dust with two separation processes until clean coconut fibres with fine fibres were obtained. Based on the measurement results, the initial coconut fibre was 15 grams, the first separation obtained 3 grams, and the second separation obtained a mass of fine fibres (m) of 0.5 grams, which was then converted into $m = 5 \times 10^{-4}$ kg. Two repetitions were carried out to produce two variations of the independent variables reviewed from the drying process. The control variable in the form of the type of coconut fibre used for the two samples was the same, while diapers X functioned as a comparison of the percentage of Absorbent core (Ab) and Elastic (E) tested in this study.

Furthermore, a sample of coconut fibre was boiled for 30 minutes in boiling water that had been given 6 grams of cinnamon and 6 grams of cherry leaves at a temperature of around 50°C on an infrared stove. Repeats were carried out for another sample. After the *process* of water shrinkage and absorption of substances by coconut fibre ends, which is indicated by the physical properties of coconut fibre, which was initially yellow to dark brown, and the boiling water has dried, the coconut fibre is drained. Sample A is coconut fibre that is dried with a hair dryer, which is then called Sample B, and Sample B is coconut fibre that is dried with sunlight, which is called Sample A. The drying process is carried out until the coconut fibre sample is very dry. It takes 7 minutes at a temperature of 40-50°C in the Sample B drying process, while Sample A drying at a temperature of 34°C requires a drying time of 3 days, in 5 hours from 10.00-15.00 Western Indonesia Time (WIB), so that the total is 15 hours. The dried sample was then decomposed so that the coconut fibre was easier to compress to be formed in a circular container with a diameter (d) = 3 cm = 3×10^{-2}m, so the cross-sectional area (A) of the modified coconut fibre sample in the form of a circle is 7.07×10^{-4} m.

The resulting samples in the form of modified coconut fibre dried with a Hair Dryer (Sample B) and modified coconut fibre dried with sunlight (Sample A) can be seen in Fig. 1.

(a) (b)

Fig 1. *Modified Coconut Fibre Samples. (a) Sample B, (b) Sample A*

Both samples were then given the same treatment and the same test. In this study, the first elastic test was carried out, and the second absorbent core test was carried out. This is because the absorbent core test uses water as its treatment, so that it can cause a wet effect on the coconut fibre, while the elastic test sample used must be dry. This conditioning is an effort to make time effective so that it does not require re-treatment in the drying process.

Test I (Elastic)
In determining the Elastic value (*E*) is done using the Elastic Modulus or Young's Modulus formula is shown in formula (1).

$$E = \frac{\sigma}{\epsilon} \tag{1}$$

E = Young's modulus, units of pressure (N/m^2)
σ = uniaxial stress, for uniaxial force per unit surface area, units of pressure (N/m^2)
ε = strain, or proportional deformation (change in length divided by original length), dimensionless

The Young's Modulus formula used by substituting *F* as (*m.a*) is shown in formula (2).

$$E = \frac{\frac{F}{A}}{\frac{\Delta L}{l_0}} = \frac{F.l_0}{A.\Delta L} = \frac{(m.a).l_0}{A.\Delta L} \tag{2}$$

F = force (N)
m = mass (kg)
a = acceleration (m/s^2)
l_0 = initial length (m)
ΔL = change in length (m)
A = cross-sectional area (m^2)

To determine the acceleration value (a) and the change in length (ΔL), the Tracker application is used. This Tracker application can automatically detect vibrations or movements presented in the video recording to be analyzed (Trocaru et al., 2020) because this application contains a motion sensor (Amaliah et al., 2020), one of which is a mass point sensor of an object, as shown in Fig. 2.

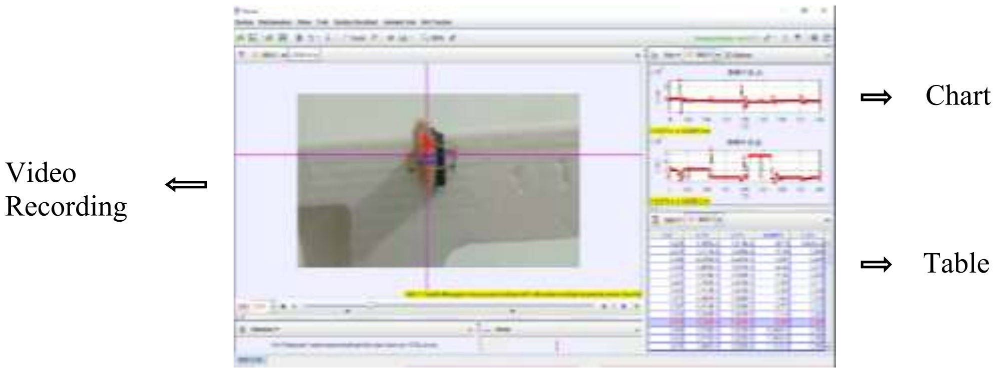


Fig 2. *Example of Elastic Data Analysis on Video Recording with Tracker Application*

The results of this analysis are presented automatically in the form of a graph of the X and Y axis coordinates against time (*t*), and can automatically analyze the values of a and L required in this study. The treatment of a sample is in the form of placing a stagnant position vertically by clamping it thinly on one part of the sample. Furthermore, a disturbance in the form of a thrust force (*F*) is given quickly and constantly horizontally, which causes the sample to move harmonically/vibrate as many as five vibrations. This treatment is recorded in the form of a video and repeated three times until three videos are obtained for each sample. The data results are automatically analyzed in the Tracker application in the form of graphs and quantitative data. The large number of quantitative data presented requires several considerations to select one quantitative data point based on the graph, with the following stages as shown in Fig. 3.

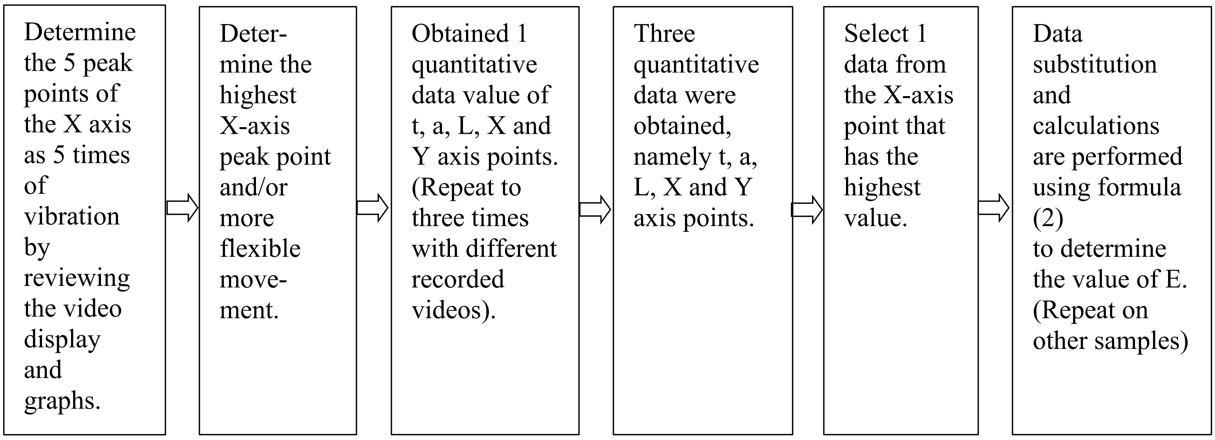


Fig 3. *Flowchart of Data Analysis Method*

After the stages are carried out according to Fig. 3, the large elastic value of the two samples is found, which is then expressed as a percentage. The results of the percentage of elastic values from the two samples (Sample B and Sample A) are each multiplied by 40 because the mass of each coconut fibre sample is (0.5 g) and the mass of diapers X (20 g), so the ratio is 1: 40. The results obtained are compared with the ratio followed by number simplification. Then, the difference in the percentage of elasticity between each modified coconut fibre sample and the percentage of elastic diapers X is also sought. The smaller the difference in the percentage of the modified coconut fibre sample to diapers X, the more elastic the modified coconut fibre sample has in the form of approaching, equal to or exceeding the percentage of elasticity in diapers X. Furthermore, the percentage of each coconut fibre sample is compared with the percentage of elastic diapers X so that the comparison of the percentage of elasticity is shown in formula (3).

$$\text{Comparison } E_{\text{sample-diapers}} (\%) = \frac{\%E_{sample}}{\%E_{diapers\ X}} \times 100 \quad (3)$$

If the percentage of elasticity of the modified coconut fibre sample compared to the percentage of elasticity of Diapers X reaches more than 50%, then the sample can be considered as a substitute elastic material in Diapers X.

Test II (Absorbent Core)

A coconut fibre sample with a mass (*m*) of 5 x 10^{-4} kg that has been compressed into a circle is placed in a container. Then, water with a volume (V_1) of 20 ml is poured, and the time is measured for up to 1 second and then drained. The volume of the residual water is calculated (V_0), so that the amount of water volume absorbed is found ($\Delta V = V_1 - V_0$). Repetition is carried out three times on each coconut fibre sample, and then the results are averaged. The average data on the volume of water absorbed (ΔV) by the modified coconut fibre sample is processed by making a comparison equation between the water absorption volume and the percentage of absorbent core between the modified coconut fibre sample and Diapers X as shown in formulas (4) and (5).

$$\Delta V_{\text{sample B}} : \Delta V_{\text{diapers X}} = \%Ab_{\text{sample B}} : \%Ab_{\text{diapers X}} \quad (4)$$

$$\%Ab_{\text{ sample B}} = \frac{(\Delta V_{SHD}).(\%Ab_{diapers\ X})}{\Delta V_{diapers\ X}} \quad (5)$$

The results of the calculation of the percentage of the absorbent core of the two samples are compared with the percentage of the absorbent core in diapers X, so that the numerator can be simplified to form the ratio of the three variables. Furthermore, the difference in the percentage of the absorbent core between the sample and diapers X is calculated. Modified coconut fibre samples that have high absorption capacity (absorbent core) can be reviewed from the percentage that is close to, the same as, or exceeds the percentage of the absorbent core in Diapers X. The percentage of each sample is then compared to Diapers X as shown in formula (6).

$$\text{Comparison } \%\ Ab_{sample-diapers\ X} = \frac{\%Ab_{sample}}{\%Ab_{diapers\ X}} \text{ x } 100 \qquad (6)$$

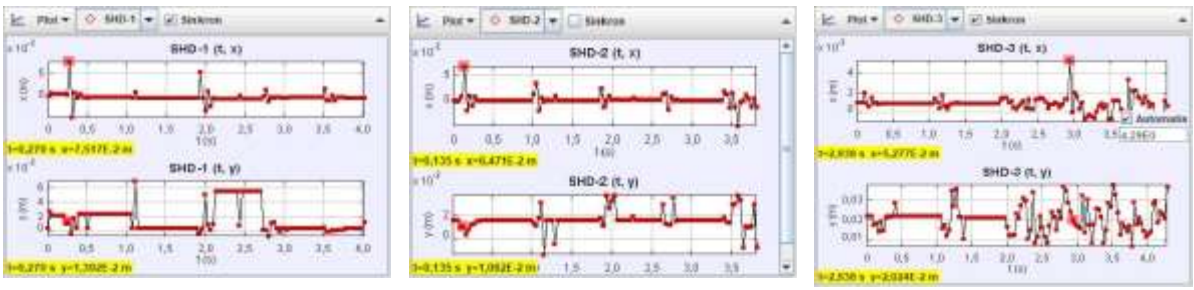
If the modified coconut fibre sample has a large percentage ratio of absorbent core more than 50% of Diapers X, then the coconut fibre sample can be considered as an alternative material to replace the absorbent core material in Diapers X. For test I and test II: If the coconut fibre sample with the same variation (reviewed from the drying process) has a large percentage of absorbent core and elastic more than 50% of the percentage of absorbent core and elastic in Diapers X, then the coconut fibre can be used as an alternative material to replace the absorbent core and elastic in Diapers X.

RESULTS AND DISCUSSION

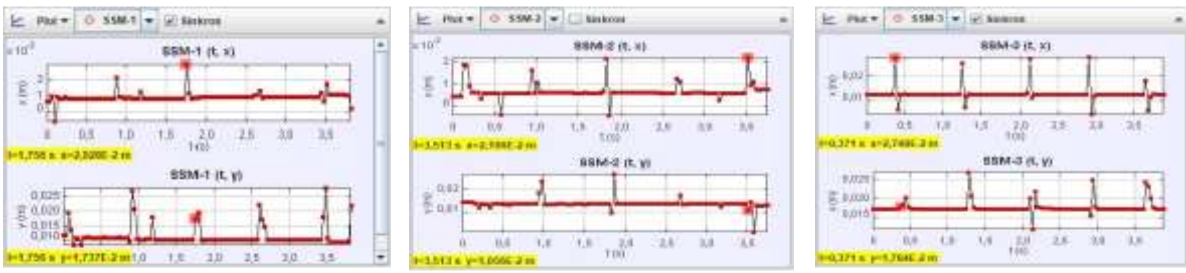
The results of this study show the elasticity and absorption of coconut fibre. Analysis using the Tracker application shows the results of the elasticity of coconut fibre, while the absorption is analyzed by calculating the absorption formula.

Elastic Test (E)

Through the video recording of the elastic experiment conducted, the data results are automatically represented in the form of a graph in the Tracker application. Following the flowchart of the research method (Fig. 3), one peak point is obtained at three repetitions of Sample B and Sample A, which is shown by the red circle in Fig. 4.



(a)



(b)

Fig 4. *Graph of Data Analysis Results Assisted by the Tracker Application: (a) Sample B, (b) Sample A*

Each peak point of the graph selected in Fig. 4 can be automatically represented by the Tracker application in the form of a data table. Furthermore, the data is clarified for further analysis in determining the data used by selecting one of the three repetitions in each sample. The results of the data selection are shown in the bold section in Table 2.

Table 2. Data Analysis with the Tracker Application for Elastic Tests

Sample	t (s)	x (m)	y (m)	a (m/s^2)	L (m)
Sample B-1	**0,270**	**7,517 x 10^{-2}**	**1,392 x 10^{-2}**	**11,58**	**0,109**
Sample B-2	0,135	6,471 x 10^{-2}	1,062 x 10^{-2}	11,77	0,06209
Sample B-3	2,938	5,277 x 10^{-2}	2,024 x 10^{-2}	6,519	0,449
Sample A-1	**1,756**	**2,928 x 10^{-2}**	**1,737 x 10^{-2}**	**6,534**	**0,140**
Sample A-2	3,513	2,196 x 10^{-2}	1,056 x 10^{-2}	3,904	0,197
Sample A-3	0,371	2,748 x 10^{-2}	1,784 x 10^{-2}	2,991	0,01507

Based on the data in Table 2, the samples used were Sample B-1 and Sample A-1 because each had the highest x value during the three repetitions. It was found that the acceleration of $a_{sample\ B}$ = 11.58 m/s^2 and $a_{sample\ A}$ = 6.534 m/s^2; the final length of LSample B = 0.109 = 0.11 m and LSample A = 0.14 m. The acceleration data was used to calculate the force (F), and the final length data was used to calculate the change in length (ΔL). Thus, the value of FSample B = 57.9 x 10^{-4} N, and the value of FSample A = 32.67 x 10^{-4} N; ΔLSample B = 8 x 10^{-2} m, and ΔLSample A = 11 x 10^{-2} m. The data obtained were expressed as a percentage, and then the E and %E values were obtained for the samples shown in Table 3.

Table 3. Elastic Values and Elastic Percentages of Sample B and Sample A

Sample	**Sample Mass for $\frac{1}{40}$ Mass of Diaper X (5 x 10^{-4} kg)**		**Sample Mass (x40) = Mass of Diapers (20 x 10^{-4} kg)**	
	E (N/m^2)	%E	E (N/m^2)	%E
Sample B	3,07	0,0307	122,9	1,2
Sample A	1,26	0,0126	50,4	0,5

The amount of %ESample B and %ESample A is compared with %EDiapers X = 1.8%. The difference between %EDiapers X and %ESample B is 0.6%, and the difference between %EDiapers X and %ESample A is 1.3% The comparison of the percentage of %ESample B to %EDiapers X is 67%, and the comparison of the percentage of %ESample A to %EDiapers X is 27%. This shows that Sample B is more appropriate as a substitute elastic material in Diapers X compared to Sample A because the difference in the percentage of elastic is smaller, and the comparison of the percentage of elastic in Sample B to Diapers X reaches more than 50%. Thus, Sample B can be considered as a substitute elastic material in Diapers X.

In this study, coconut fibre exhibited high elasticity when mixed with certain substances or compounds. The coconut fibre in this study was modified by mixing cherry leaves (*Muntingia calabura* L.) and cinnamon (*Cinnamomum verum*). Coconut fibre has fibres that can become more elastic with the addition of certain compounds or substances (Farrel, 2021). Coconut fibre has elastic properties and can be mixed with other compounds or substances to demonstrate its elastic properties (Putra & Yovial, 2022). This is because coconut fibre has the characteristics of fibre permeability, and the tensile strength of coconut fibre, or elasticity, is tested through an evaporation process at a certain temperature (Wahyudi et al., 2020). This indicates that coconut fibre can change its fibre quality, which in this study was the level of elasticity due to the influence of the temperature difference treatment given to the coconut fibre.

Absorbent Core Test

The data found through the average results of three repetitions in determining the volume of water that can be absorbed by the sample (in 1 second at 20mL of water, namely: ΔVSample B = 0.3mL, and ΔVSample A = 0.2 mL. The results of the ΔV sample obtained were converted from milliliters (mL) to liters (L), and the results were multiplied by 40 as a comparison of the equivalence with the mass of diapers X. The results obtained were that ΔVSample B = 0.012 L, and ΔVSample A = 0.008 L. Through equation (5), it is known that the % absorbent core of Diapers X = 63.93%, and the amount of water volume absorbed by Diapers X (ΔVDiapers X) for 1 second = 20mL = 0.02 L, then obtained %AbSample B = 38.36%, and %AbSample A = 25.57%.

In the calculation of the comparison of the percentage of absorbent core between Sample B and Diapers X according to equation (6), it was found to be 60%, and the comparison of the percentage of absorbent core between Sample A and Diapers was 40%. This shows that the percentage of absorbent core in Sample B is greater than that of Sample A. It was found that the Sample B has a large comparison of the percentage of absorbent core of more than 50% from Diapers X, so the Sample B can be considered as an alternative material to replace the absorbent core material in Diapers X. So, Sample B have a large percentage of absorbent core and elastic of more than 50% of the percentage of absorbent core and elastic diapers X. Sample B can be used as alternative materials to replace absorbent core and elastic materials in Diapers X.

Based on data and data processing results, it was found that Sample B samples have the potential as engineering materials for absorbent core and elastic in Diapers X, meaning that Sample B samples can be used as alternative materials to replace absorbent core and elastic materials in Diapers X. This is because the findings obtained that the percentage of Sample B in the absorbent core test and elastic test showed a higher percentage compared to the percentage of Sample A. The absorbent core test, which focuses on testing the ability of a material to absorb a certain volume of water (Ndapeu et al., 2016), in this study, the material is in the form of modified coconut fibre samples whose variables are varied in terms of drying. Coconut fibre samples dried with a hair dryer, Sample B; and coconut fibre samples dried with sunlight, Sample A.

In terms of the drying process, Sample B requires a faster time to dry compared to Sample A. This is because the amount of heat given to Sample B is higher than Sample A and is more stable (Andezai et al., 2020). The drying process with the help of sunlight on Sample A is influenced by wind factors, cloud conditions that sometimes cover the sun's rays, etc. In addition, the temperature experienced by Sample A is lower than Sample B. This can affect the speed and time interval needed for drying. Sample A, Sample B takes 7 minutes while Sample B takes 15 hours to dry.

Drying with a hair dryer is considered more effective in terms of drying time, temperature stability, and the amount of heat given compared to drying with sunlight. Perfect drying by a hair dryer affects the ability of modified coconut fibre samples to absorb water. This is clarified that perfect drying affects the absorbent core of the material (Yasaroh & Kuswanto, 2021). This is because Sample B experiences perfect drying with constant temperature and minimal humidity due to external air factors that affect it, while Sample A, although dried for a relatively longer time compared to Sample B, has an impact factor in the form of environmental temperature that can re-moisten the sample after being given heat from sunlight so that there is a possibility that Sample A cannot experience a perfect drying process as Sample B. This drying has an effect on water absorption; the drier the sample, the greater its ability to absorb water (Ristiawan, 2018). The Sample B sample has a higher percentage of absorbent core compared to the percentage of Sample A absorbent core.

Comparison of the percentage of absorbent core to Diapers X shows that the percentage produced by the Sample B is more than 50% of Diapers X, which shows the potential of the Sample B as a substitute for the absorbent core in Diapers X. The large percentage shows the ability of the Sample B to absorb water against 20ml of water within 1 second can produce water absorption that is close to the absorbent core of Diapers X. The determination of the absorbent core test with a water volume of 20mL in 1 second is because Diapers X has such a test so that the results of the Sample B percentage can be compared with diapers X because the control variables are equivalent.

In addition, this study also tested the elasticity of Sample B and Sample A. The percentage of Sample B elastic is higher than the percentage of Sample A. This was obtained through data analysis assisted by the Tracker application. This application is very helpful in sensors or movement analysis that relies on the centre of mass and the results of real video recording. The arrangement is made with the sample position placed in a stagnant and wind-free position to minimize external factors that affect the large elastic value of the coconut fibre sample. The force is given using one right index finger while maintaining a constant rhythm and magnitude of force.

The elastic properties are physically visible by observing the texture of the elastic material of the two samples. Sample A tends to have physical properties that tend to be rougher, dark brown, difficult to shape and compress in a circular container. Sample B, on the other hand, has a softer texture, is light brown, easy to shape and compress. Through the tracker application, the elastic properties can be measured in their entirety, so that Sample B is more elastic than Sample A. The movement of the elastic properties of the sample is very fast so that the naked eye cannot predict the acceleration components and the final length obtained, but with the help of this tracker application, the movement can be done in slow motion so that the mass points can be detected so that the acceleration and final length are found from the results of the video recording obtained.

The properties of the absorbent core and elastic in the Sample B tend to be better than the Sample A, indicating that the Sample B sample has the potential to be considered as an engineering material for absorbent core and elastic in the sense of being an alternative material for absorbent core and elastic to replace Diapers X. The results of the comparison of the percentage of absorbent core and elastic in the Sample B and Diapers X samples show that the Sample B has a percentage that is close to the percentage of Diapers X, with a comparison percentage of more than 50%. Thus, it can be concluded that Sample B can be used as an alternative material to replace the absorbent core and elastic in Diapers X.

CONCLUSION

Absorbent core and elastic on coconut fibre modified with the STEAM-2C method, namely: %Ab-Sample B of 38.36% and % Ab-Sample A of 25.57%, and %E-Sample B of 1.2% and %E-Sample A of 0.5%. The percentage of absorbent core and elastic of the coconut fibre sample to Diaper X, namely: the percentage comparison of absorbent core and elastic of the coconut fibre sample to Diaper X, respectively, Ab-Sample B of 67%, and Ab-Sample B of 27%. E-Sample B of 67%, and Ab-Sample B of 28%. So, diapers have the best absorbency and elasticity are in Sample B.

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