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Split Waste from Rattan Industry? Crafted Product and Furniture Industry Fiber Bar

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***Abstract*---**This research aims to reduce and use wastes of rattan industries, especially during the splitting stage. This stage refers to the process of making the rattan into rattan fiber strips. This Research & Development experimented with developing the previous study, using NaOH to produce the fibers. The research procedure included preparing, soaking, washing, pressing, drying, tensile, stretching, and workmanship-experimenting processes. The most effective and efficient process, with reliable rattan fiber strips for industrial purposes, was the 1kg soaking process of rattan. 1 Liter of H_2O: NaOH 98%, 100gram: 72 hours of the soaking process The result was light-brown, soft, and flexible rattan fiber strips. The widths of the strips were between 20mm and 35mm. The thicknesses of the strips were between 0.5 and 1mm. The length was adjusted based on the initial length of the material, 6000mm. The tensile strength of the rattan fiber was 3.747N while the stretching strength was 6.796%. The implementation of the fibers included crafted product designs and decorative or functional furniture. The applicable craftsmanship techniques included weaving, bundling, and winding. The rattan fiber strips of the research could be the innovation base or applied research result for product design and green interior. Unfortunately, the surface of the rattan fiber strips is not smooth. Moreover, the NaOH is sticked around the surface so it needs further attention.

***Keywords*---**rattan fiber, industrial waste of rattan, and NaOH.

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Introduction

Natural fibers are useful for many industrial purposes. A significant amount of natural fiber uses are observable in craftmanship and furniture industries (Kumar et al., 2019); (Suriani et al., 2021) & (Budhe et al., 2019). The natural fiber materials include fibers of pineapple, ramie, rattan, bamboo, mendong grass, reeds, etc. Rattan is a natural fiber and the non-wooden product of forest used by many industries (Ratnasingam et al., 2016); (Hartono & Sobari, 2016) & (Myers, 2015).

The rattan manufacturing industries exist even from the half-made material manufacturing industries and final-product manufacturing industries. The products manufactured by half-made material manufacturing industries are followed up by final-product manufacturing industries (Qi et al., 2019) & (Pratono, 2020). The product categories include the original-rattan trunk, furnished rattan, rounded core rattan, flat core rattan, peeled rattan or split rattan, and woven sheet rattan (Sunderland, 2004) & (Belcher, 1999). The final-product manufacturing industries manufactured the half-made products into crafted products or furniture. Rattan industries encounter various challenges dealing with efficient manufacturing processes (Adi Wicaksono & Ahmad Kadafi, 2020) & (Nasution et al., 2017). The inefficiency of rattan industries reached 50% (Zuraida et al., 2017). Efforts to reduce and use waste are important to keep sustainable natural resources and industries.

The splitting process of rattan industries leads to peeled rattan products (Gnanaharan, 1997); (C.H., 2004) & (Wahab et al., n.d.). Rattan peel is a product of splitting rattan peels with elliptic results(Sunderland, 2004). Rattan peel is the main commodity for industrial purposes with some standards, including color, size, and length (C.H., 2004). Thus, any rattan peel that does not meet the standard is considered waste. Splitting is a step that produces a lot of waste. The waste includes the parts of rattan, known as rattan squares.

Rattan squares usually have sizes ranging from 3mm - 5mm with widths of 6mm - 10mm. The largest rattan size is useful to make rattan strips. The strips of the natural fiber splitting process usually have a rectangular form. In the rattan industries, strong but soft rattan strips are the most preferable materials. The natural fiber strips include bamboo strips (Multazam & Saniyah, 2020) & (Ali et al., 2021), pandan leaf strips (Idawati et al., 2016) & (Ordas et al., 2020), and palm leaf strips (Lai et al., 2008); (Ferrão, 2021). The natural fiber strips are usually soft, for example, the banana trunk strips(Fawcett & Morris, 1914) and water hyacinth strips (Ajithram et al., 2021). The soft natural fiber strips include strand and strip fibers.

The waste of rattan strips have various sizes and forms. Some of them have irregular shapes. Thus, the efforts to make soft rattan strips are important. The process to keep the content of natural fiber materials is - soaking the materials with NaOH. Studies about natural fiber management with NaOH for rattan materials mostly include short fiber and trituration forms (Steven et al., n.d.); strands of rattan fibers (Sahoo et al., 2019). The use of NaOH is also useful to process natural fiber process of bamboo strip manufacturing process (Zakikhani et al., n.d.) and kenaf into fiber strands (Edeerozey et al., n.d.). This research explains how the waste management of rattan squares into soft rattan fibers.

Materials

The investigated materials were the waste of rattan production process with small diameters into peeled rattan. The small-sized rattans have diameters between 5 and 19mm(Dransfield & Manokaran, 1993); (C.H., 2004) & (Mathew & Bhat, 1997). The common types of rattan used by Indonesian industries are *Sega* rattan (*C. Caesius*) and *Kobo* rattan (*Preycinetia javanensis BL*). The peeled rattans from Industries were considered wastes. The waste of small diametric rattan in rattan processing industries included the sliced rattan and rattan squares. Sliced rattan refers to leftovers with a width of 5mm and a thickness of 3mm. Sliced rattan is considered waste because the size is small and the shape is irregular. The rattan square refers to peeled rattan parts. The size is thicker than 3mm with widths between 6 and 10 mm. Small diametric rattan leftovers only produce rattan square waste. Rattan square is still processable into rounded-core rattan (fitrit). However, it can be only produced in 1 or 2 units. Thus, the process still has a high amount of waste with unequal product cost and output. In this research, the wastes of rattan leftovers were from rattan furniture industries in Sukoharjo, Central Java, Indonesia. The other material was NaOH obtained from a local chemistry shop. Then, the researchers used H_2O from the groundwater. The tools used by the researchers were a soaking tube and a rolling press machine to produce longwise fiber strips.

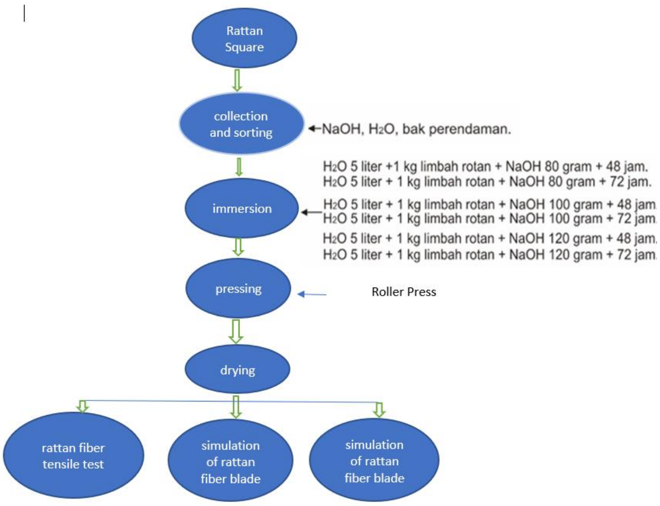
Method

This research is a Research & Development with an experimental approach (Eden & Ackermann, 2018). The experimental development was observable in the use of NaOH by the previous researchers (Edeerozey et al., n.d.); (Sahoo et al., 2019) to soften and keep the fiber materials. The research procedures included these stages:

1. Procuring the rattan square, NaOH, and H_2O; Procuring some research tools, such as soaking tubs, a rolling press machine, and a micrometer;
2. Soaking the rattan waste with HO_2 and NaOH. The ratio of the compounds and the applied time were varied. Here are the ratios of the compositions and the applied time.
   a) NaOH 80gram + 1kg rattan cleavage + 5 liter of HO2 5 + 48 hour soaking time.
   b) NaOH 80gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.
   c) NaOH 100gram + 1kg rattan cleavage + 5 liter of 2 5 + 48 hour soaking time.
   d) NaOH 100gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.
   e) NaOH 120gram + 1kg rattan cleavage + 5 liter of 2 5 + 48 hour soaking time.
   f) NaOH 120gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.

The best selections and compositions were based on the effectiveness and efficiency criteria with the same weights. The applied efficiency criterion with the best result was the ratio with minimum cost. The effectiveness criterion was based on the process in the shortest time.

3. After the soaking process, the researchers took the rattans. Then, the researchers washed the rattans with flowing water to remove the NaOH.
4. The pressing process with a roller presser aimed to produce longwise rattan strips.
5. The drying process
6. The tensile and stretching tests of rattan fibers
7. The application test of rattan fiber strips with weaving techniques and twisting techniques. The scheme of the research (see the first scheme)



Scheme 1: The research scheme

Result

The process of splitting the small diametric rattan led to waste productions, such as rattan square. The surface of the rattan squares includes trapezoid, triangular, flat, and irregular shapes. After selecting the rattan square, the leftover wastes were to soak in a tub filled with water and NaOH. The researchers experimented with some soaking tubes with different ratios of composition and time.

The comparing variable was constant. They were the soaking period and H_2O. The non-constant variables were NaOH and the soaking period. The amount variances of NaOH were 80gram, 100gram, and 120grams to determine the results and the efficiency. The variances of soaking periods were 48 hours, 72 hours, and 100 hours. The large amounts of experiments required more formulations by multiplying the comparison proportionally. The researchers used the multiplication of the rattan waste amounts, NaOH, and H_2O with a constant soaking period.

After the soaking process, the researchers took the rattans. Then, the researchers washed the rattans with flowing water to remove the NaOH. The next stage was pressing the rattan squares, with some shapes including triangles, rectangles, squares, and irregular shapes, into think and longwise shapes. The researchers promoted the process with a rolling press machine. The machine rotated and pressed the rattan squares to produce longwise rattan strips. The pressing process also removed the water and dissolved non-celluloid compounds contained in the water.

The researchers adjusted the distances of the machines because they influenced the thickness of the strips. The thickness or the distance between the pressing tubes was arranged into 0.6 mm. The results of the rattan strips after being dried were 0.7 until 0.8 mm long with a width of 2.0 - 2.3 cm. A wider slit of the roller for more than 0.65 would result in thicker rattan fiber strips. Thus, the strips would not be wider and would be stiff. The thinner roller resulted in wider strips but the strips might be broken while being pressed. The weathered rattan tended to be breakable while being pressed. Figure 1 shows the broken strips while being pressed.

Figure 1: (a) The broken rattan fiber strip while being pressed

The pressing machine pressed, squeezed, and dissolved the water content. The results showed the rattan fiber strips in a dried condition. Rattan fiber strips that were half-dried only needed to be aerated. The researchers dried the rattan fiber strips for 6 - 8 hours after the materials were ready at room temperature. The room temperature was between 20 and 30°C (Maurer-Spurej et al., 2001). The researchers put the rattan fiber strips under warm temperatures between 30 and 40°C under the sun. This process made the rattan fiber strips wavy and the tissues were broken. See figure 2.

Figure 2: The rattan fiber strips were broken and wavy due to extreme heat during the drying process

The excellent rattan fiber sheets should be merged and flexible. The merged rattan fiber sheets would lead to wider and relatively constant rattan fiber strips. The width of the strip was between 15 and 30mm. The changes of the rattan square width into rattan fiber strips were average from 4 until 10 mm. The average differences in the rattan fiber strip width were significant because of the different shapes and sizes. Table 1 shows the experimental results of the various compositions.

Compositions and Durations	Visual	Remarks
NaOH 80gram + 1kg rattan cleavage + 5 liter of 2 5 + 48 hour soaking time.		Hard, stiff, and broken while being pressed
NaOH 80gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.		Hard, stiff, and broken while being pressed
NaOH 100gram + 1kg rattan cleavage + + 5 liter of 2 5 + 48 hour soaking time.		Fairly soft, hard, partially broken
NaOH 100gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.		Soft, flexible, and tidy
NaOH 120gram + 1kg rattan cleavage + 5 liter of 2 5 + 48 hour soaking time.		Soft, flexible, and tidy
NaOH 120gram + 1kg rattan cleavage + 5 liter of 2 5 + 72 hour soaking time.		Soft, flexible, and tidy

Table 1 The ratios of the compositions, duration, visual result, and remark The experimented rattan fiber strip results

The most effective and efficient result was the rattan squares with 72 soaking hours, NaOH 100gram, 1kg cleavage, and 5 liters of water. The rattan squares became soft and flexible with brown-yellowish color. The soaking treatment with NaOH 80gram resulted in hard and stiff rattan fiber strips with brown color. The excellent qualities of the strips were thin, wide, flat, flexible, and strong. Each rattan fiber strip contained 50 - 80 fiber sheets. The rattan fiber sheets had different diameters and lengths. The diameter measurement of the sheet showed an average diameter of 0.024mm (see table 2).

Sample Codes	**The X^{th} experiment**	**The diameter of the rattan fiber (mm)**	**The photographs of the fibers**
Rattan fibers	1	0.02369	
	2	0.02423	
	3	0.02406	
Average		**0.02406**	

Table 2 The measurement of rattan fiber sheet diameters

The tensile test of the rattan fiber sheet is 3.747N while the stretching or straining test shows a value of 6.96%. The fiber sheet refers to rattan fiber strip constructions. Here are the results of the tensile test (see table 3).

Sample Codes	**The X^{th} experiment**	**The tensile and stretching tests of rattan fibers**	
		The tensile test result (N)	**The stretching or straining test result (%)**
Rattan fibers	1	3,924	8.02
	2	3,825	4.78
	3	3,531	7.42
	4	3,825	8.50
	5	3,629	5.26
Average		**3,747**	**6,796**

Table 3 The tensile test of rattan fibers

Rattan fiber strips had some features, such as soft, flexible, strong, flat, wide, and long. The color of the strips was natural light-brown. The existence of rattan fiber strips is important to meet the industrial needs and supplies. The fiber is flat so that it can easily be woven into 2 dimensional sheets with various patterns or motifs. See figure 3:

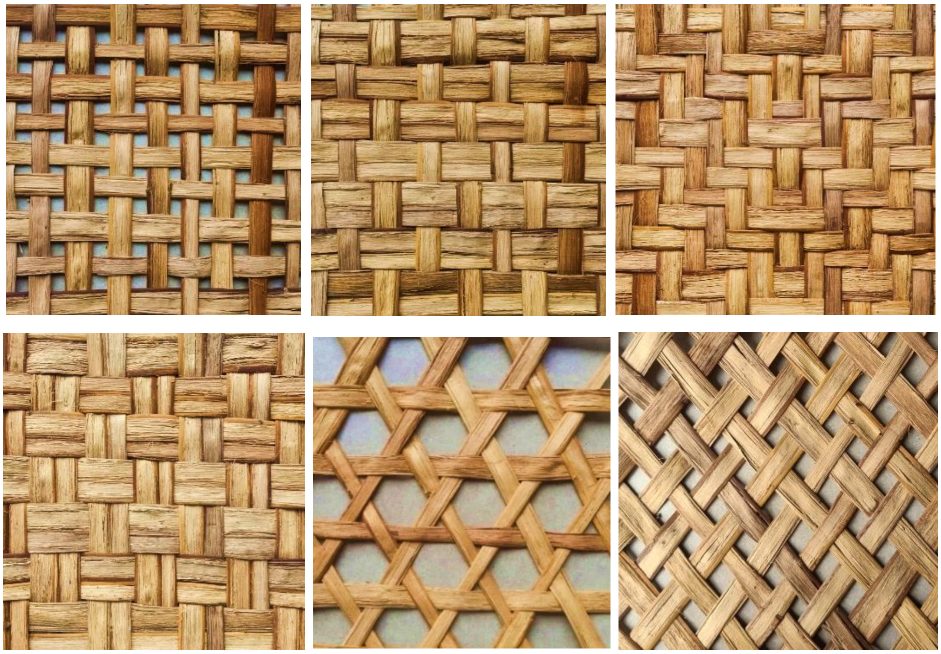


Figure 3: The implementation of woven rattan fiber strips into 2-dimensional sheets

The rattan fiber strips are flat and flexible for various crafted products and furniture with 3-dimensional weaving technique. The simulation of 3-dimensional weaving technique with the produced rattan fiber strips. See figure 4.

Figure 4: The rattan fiber strips are flat and flexible so they are easy to be applied with 3-dimensional weaving technique.

The flexible rattan fiber strips are useful for designing crafted products and furniture. The rattan fibers are also applicable for winding or twisting technique. This technique can be applied by crafted product and furniture industries to wrap some materials. The technique is also useful as finishing touch of a woven object. The implementation of winding technique on the strips. See figure 5.

Figure 5: The rattan fiber strips are flexible and applicable to produce products with winding technique

Discussion

Waste refers to leftovers of a business or an activity. Every individual, industry, and community perceives the definition and category of waste differently (Sumarno et al., 2015). Eco-efficiency is a technology to keep a sustainable environment (Munir et al., 2013); (Gertsakis & Lewis, 2003); (Korhonen & Seager, 2008) & (Caiado et al., 2017). Indonesia is a country with the highest production of rattan in the world(Myers, 2015); (Sastry, 2001) & (Subchiandi & Suharno, 2013). Thus, the activities of using rattan should gain awareness and efficient efforts.

Rattan plants only require a short-harvesting period (Sunderland et al., 2008); (Siebert, 2004) & (Rachchh et al., 2014). The balance product life cycle between the consumption period and the harvesting period of rattan makes rattan a green environment material (Straka & Layton, 2010) & (Finnveden & Östlund, 1997). Thus, any exaggerating exploitation should be prevented to keep nature from any damage and to preserve nature (Miloševic, 2020) & (Yang & Jia, 2015).

The rattan manufacturing industries exist even from the half-made material manufacturing industries and final-product manufacturing industries. Inefficient productions of these industries lead to waste production. Essentially, these wastes can be used by applying eco-efficiency technology. This technology is important to keep the balance of rattan as a green plant. The volume and the types of the produced waste from the half-material industries can be reused. Wastes can be used as industrial materials or for any other purposes.

The efficiency occurs via the recycling process of rattan square to meet the industrial needs for producing rattan plaited sheets. The industries include crafted products and furniture industries. The research effort led to a significant efficiency of the waste management process, the rattan squares, into rattan fiber strips. It happened because the process did not produce any solid waste, *zero waste*. Efficient and green behaviors become the global demands to preserve nature (I. K. Hong et al., 2021); (Nilashi et al., 2021) & (Ch'ng et al., 2021). The green environment and harmonious lifestyles become the global trend to design products (Khor & Udin, 2013); (Z. Hong et al., 2019), interior designs (Wu et al., 2019); (Ning et al., 2017), and architecture (Yuan et al., 2017) & (Ragheb et al., 2016). Recycling rattan wastes into rattan fiber strips is an effort to preserve the environment, design, and industry.

The researchers observed the soaked rattan waste samples with NaOH + H_2O with different solution concentrations and periods. The first variable, the concentrations of NaOH were the masses of 80gram, 100gram, and 120gram. The second variable, the soaking periods were 48 hours and 72 hours. The examination was observable in different results. The test or examination with 80gram of NaOH and 72 hour soaking period resulted in stiff, hard, and dirty rattan fiber strips. The test with 100gram of NaOH and 72 hour soaking period resulted in flexible, soft, and a bit dirty rattan fiber strips. The test with 120gram NaOH and 72 hour soaking period resulted in more flexible, softer, and cleaner rattan fiber strips than the other ratios. From the variables, the effectiveness of 100gram of NaOH and 72 hour soaking period could meet the standards and needs of industrial rattan fiber strips. The experiment with 120gram of NaOH and 72 soaking periods resulted in more flexible and more soft rattan fiber strips. however, the needed time was not efficient.

The sodium hydroxide, NaOH, is a caustic soda for industrial needs. The physical appearance of NaOH is a white crystal. The crystal does not smell if it is put a room temperature. NaOH is a base compound with a pH level of 14. Thus, the compound is hygroscopic, corrosive, and reactive with acid. The management with NaOH was - soaking the rattan carefully. Water can dissolve NaOH and produces an exothermic reaction that leads to heat. Thus, if the compound touches skins, it makes the people feel itchy, hot, irritated, and bitter. Washing rattan after the soaking process is important to remove the side effects of NaOH solvent. The product finishing step of the production stage has decorative and protective functions (Csanády et al., 2019); (Anwar et al., 2016) & (Sumarno et al., 2019). It could also reduce the effects of skin and rattan fiber strip contact.

The properties and the characteristics of rattan fiber strips are wide, long, thin, ductile, flexible, soft, uneven surface, and naturally brown-colored. The unique and natural brown color of the strips appears because the attached alkali solutions react with the lignin of the rattan fibers during the soaking process (Steven et al., n.d.). Weather, the age of the rattan, and the treatment influenced any wooden materials or moldy rattan (Sanusi, 2012) & (Humar et al., 2008). The moldy materials after undergoing all processes had color turned into darker brown and blackish. These colors were also observable on the other parts of the rattan, except the inner parts of rattans. The colors did not change into light brown because of the silica layer of the rattan peels.

The widths of the strips were wider than the rattan peels. The thickness sizes of rattan peel rattan peels were about 2mm with a width of 10 mm (C.H., 2004). Rattan fiber strips of this research had widths of 12 - 30 mm. The superiority of rattan fiber strips includes wider width. Thus, the strips were effective to weave and making larger woven fields. The weaving technique was the most obvious technique for rattan-based products (Jasper & Pirngadie, 1912). The crafted product and furniture industry development encountered hindrances due to limited labor (Abdullah et al., 2015) & (Irjayanti & Azis, 2012). Wider rattan strips became the solution for limited labor. Thus, the weaving jobs would be accurate and effective. Various rattan squares could be processed into various rattan strips. The width of the strip was between 15 and 30 mm. The sizes were different from other natural fiber strips. The width of the strip was smaller than a banana, pineapple, ramie, and kenaf fiber strips. The rattan fiber strips are wider than the mendong plant, water hyacinth, and rice straw fiber strips. Classifying the rattan fiber strips based on the width is important to do. The width of the rattan fiber strips was categorized into smaller, moderate, and wider categories. The smaller fiber strips were between 15 and 20 mm. The moderate fiber strips were between 20 and 25 mm. The wider fiber strips were between 25 and 30 mm.

The other characteristics of the rattan fiber strips were soft and flexible. The reaction between NaOH and H_2O within a certain period made the rattan fiber strips soft. The flexibility of rattan fiber strips existed due to the content of inter-fiber adhesive substances. These substances dissolved during the pressing process. The separated inter-fiber tissues from the fiber strip surface could break easily. However, the strips remained flexible. The flat rattan fiber strips were soft and flexible. These strips are suitable to produce crafted products and furniture with weaving techniques into sheets and three-dimensional products. The rattan fiber strips for three-dimensional product purposes could be folded and were unbreakable. The weakness of the soft fiber strip was - susceptibility toward pressures, weights, and pulls. The soft and flexible rattan fiber strips could be woven with winding and bundling techniques. The rattan fiber strips could be processed into rattan fiber lines (Sumarno, 2022). The soft and flexible rattan fiber strips had some shortcomings for tight-weaving technique applications.

The new material invention is suitable for product-innovation bases and the implementation of the product (Konietzko et al., 2020) & (Ramakrishna et al., 2019). The use of rattan fiber strips was targeted for the crafted product and furniture industries. The underlying reason is - that rattan is the raw material for crafted products and furniture industries (Kumar et al., 2019). The implementation for crafted products and furniture products includes baskets, boxes, lampshades, wall decoration, frames, pots, planter boxes, etc. The implementation for furniture includes tables, chairs, partitions, cupboards, cabinets, display racks, etc. The implementation could be also for seat backs and decorative and functional furniture panels. The implementations of natural materials and recycled materials are important to support a sustainable environment.

Conclusion

The half-made material invention for crafted product and furniture industries includes half-made rattan fibers. If the rattan fiber strips could be alternative materials to develop product designs. The mechanical properties of flat and longwise fibers are light, strong, ductile, and cheap. The process of the fiber also does not lead to solid wastes. The raw material invention for developing crafted products and furniture was based on rattan fiber strips.

Suggestions

The efficiency efforts of rattan industries in this research focused on leftover wastes in the form of rattan squares. The wastes were short rattan wastes from the original parts of rattan, rattan poles, rounded core rattan (fitrit), flat core rattan, peeled rattan, split rattan, and woven rattan sheets. These wastes should be investigated to create better process efficiency. The rattan industrial wastes were processed to be flexible, strong, long, wide, and thin, made from peeled rattans. Therefore, this research is important to be followed up and to create a better process of the current research shortcomings, especially about the characteristics of rattan fiber strips and the implementation of innovative crafted products and furniture designs. NaOH is a base compound with a pH level of 14. Thus, the compound is hygroscopic, corrosive, and reactive with acid. The reaction of a compound is an exothermic reaction that can make itchy, inflamed, irritated, and bitter senses. The limitation of this research was observable on the rattan fiber strip surface. The surface could make people feel itchy, especially those with sensitive skin. The side effects of NaOH implementation should gain further investigation.

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