Eco-design furniture and interior elements: aesthetics and innovation of splitting waste rattan weaving and production efficiency

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ABSTRACT

Rattan is a natural material with high fiber content. Rattan is cut into various sizes and types to be utilized. The process of cutting and slicing generally leaves waste in the form of elongated rattan hearts of irregular shapes and sizes. The amount is large, almost 30%, and is not utilized. However, waste from the splitting process in the rattan industry is usually disposed of through burning, leading to substantial waste. Therefore, this study aims to reduce rattan splitting waste through weaving techniques and then use it as a basis for innovation in furniture products and interior elements. The study was conducted using an experimental research method to produce woven sheets. Karen weaving has been applied to materials with similar characteristics, such as *lidi*, vetiver, and bamboo. Data were obtained through observation, interviews, and documentation. Data analysis, with inferential analysis, tests the hypothesis by generalizing. Following the weaving experiment, natural coloring and interior product design were conducted. The design process included sketching, creating shop drawings, modeling, and bringing the design to life through prototypes. The results consist of woven rattan fiber strip sheets with a striped pattern, light brown color, textured, somewhat rigid, yet flexible enough to be folded or rolled lengthwise. Various techniques can be applied to crafting products, such as gluing, bending, rolling, folding, and sewing. The most effective application of woven rattan fiber sheets is fixed attachment on a flat surface with a flat direction. The contribution of research results can add alternative materials for the creation of craft products, furniture, and interiors made from rattan waste woven sheets. These rattan fiber strip sheets can be applied in 2D and 3D homeware product designs, serving decorative and protective functions.

1. Introduction

The research aims to utilize woven rattan fiber strips to create sheets through the weaving technique. The second objective is to use these woven rattan fiber sheets as decorative elements in interior design and homeware products. Rattan material requires a processing process to be made into various products, and unfortunately, the processing process produces quite a lot of waste, around 50% [1]. On the other hand, the total number of businesses in the rattan industry in Indonesia amounts to around 3000. Thus, the total waste produced by the rattan industry is very large. Rattan material classification consists of large-diameter rattan of more than 20mm in size and small-diameter rattan below 20mm [2]. The small-diameter rattan utilized by the industry consists of rattan stems, skin, and rattan hearts. Splitting is one of the production processes used to create materials such as rattan flat core, rattan round core, and rattan peel. The waste generated from the splitting process typically consists of irregularly shaped and varied cross-sectional rattan pieces. Due to their irregular lengths, shapes, and sizes, rattan manufacturers categorize them as waste, often leading to burning as the disposal method.

Burning of leftover rattan impacts the environment because it causes air pollution, loss of resources, economic losses, and loss of opportunities, and recycling is an opportunity to reuse the material for better use. The latest developments in public awareness of environmentally friendly products are increasing. The global demand for environmentally friendly practices is driven by environmental crises and increasing awareness. This demand has opened up opportunities for the creation of eco-friendly products. Recycling is one of the eco-efficient technologies contributing to environmental sustainability [3], [4]. The trend of eco-friendly product creation has expanded into various fields, including interior design [5], [6]. Therefore, the urgency of research is the importance of natural resource efficiency based on the decreasing carrying capacity marked by environmental crises in various regions. The utilization of waste is an effort for efficiency and an economic opportunity for product innovation.

Efforts to maintain environmental sustainability through waste generated from the rattan furniture industry's splitting process have been carried out, including producing rattan fiber strips [7]. The waste undergoes a treatment process involving immersion in NaOH and subsequent pressing, creating a new material. NaOH is widely used for various purposes in the fiber processing industry to help clean, purify, and improve the quality of fibers that can separate the lignin and become more flexible. Its use is, therefore, widely used in the textile industry, such as silk fiber, pulp & paper, pineapple fiber, and so on. Rattan fiber waste soaked in NaOH results in highly flexible, pliable, pressed, and flat, making them suitable for various product creation techniques. One interesting technique worth exploring is weaving. Traditional weaving in Indonesia, using manual looms instead of machines, is still practiced in several regions [8], [9]. Materials used in traditional weaving include bamboo splints, coconut fronds, palm fronds, *mendong* (*Fimbristylis umbellaris*), water hyacinths, and more. Plant fibers are extracted and woven, including fibers from ramie, pineapple, banana stems, *agel* (*Corypha gebanga BL*), and other plants.

A literature review related to utilizing natural fiber materials woven without machines to produce ready-to-use materials that are quite familiar is cotton fabric production. The use of natural fiber materials to create sheets includes *mendong* (*Fimbristylis umbellaris*) [10] and water hyacinth as the main material, with a composition of 60% and 40% cotton thread [11]. Rattan stems are stripped, and their outer layers are taken as a commodity to be woven using looms with various patterns, produced in mass quantities to meet industrial needs. Traditional manual weaving techniques are used to create sheets of rattan combined with tree bark to produce mats for seating (*kasah*) [12]. Woven rattan peel using machines results in sheets combining rattan as the weft and thread as the warp to create mats [13]. The discovery of rattan fiber strips from leftover waste has led to the development of fiber strips [14]. This research serves as a follow-up and, simultaneously, a distinction from previous studies by utilizing rattan fiber strips through weaving to form sheets. Then, these woven sheets will be applied to various craft and furniture products for interior use.

2. Method

2.1. Material

The primary material in this research is waste from the rattan industry, which has been processed into rattan fiber strips. The specific type of rattan fiber strips to be investigated and utilized are those with a thickness ranging from 0.5 to 2 mm and a width of approximately 5 mm. The research material, obtained as waste from the production process, was sourced from a rattan furniture industrial center in Trangsan Village, Gatak Sub-district, Sukoharjo Regency, Central Java Province, Indonesia.

2.2. Use of the Development Experimental Method.

The research uses a developmental experiment. The developmental experiment continues the study to make the rattan fiber strips beneficial, explicitly using the weaving technique to produce sheets. The weaving technique is commonly employed with natural materials, whether in the form of poles or already in fiber form. Common materials woven using this technique include bamboo, coconut fronds, water hyacinth, *mendong*, and others. Following the weaving experiment, the research progresses to design homeware products based on woven rattan fiber strip sheets. The research stages are described as follows (see Fig.1):

- Prepare rattan fiber strip sheets, non-machine loom, and tool kits. A non-machine loom is chosen due to its simple technology and affordability, making it suitable for small-scale entrepreneurs.
- Weaving, considering the characteristics of rattan fiber as the primary material. The weaving process involves warping, setting the warp threads, threading them through the heddle, weaving, removing the woven material, and tidying up the final woven product.
- Efforts to produce woven sheets in various colors, followed by natural dyeing of the rattan fiber strip sheets.
- Designing interior design and homeware elements based on woven rattan fiber strip sheets. The design stages include sketching, technical drawings, modeling, and prototype creation [15]. The design for utilizing rattan fiber strip sheets in furniture products and interior fillings is by using a functional and aesthetic approach. Design limitations and considerations are based on the characteristics and properties of the woven rattan fiber sheets and the techniques used in their creation.
- Creating prototypes of decorative interior design elements and homeware products based on the rattan fiber strip sheets as the embodiment of the design.

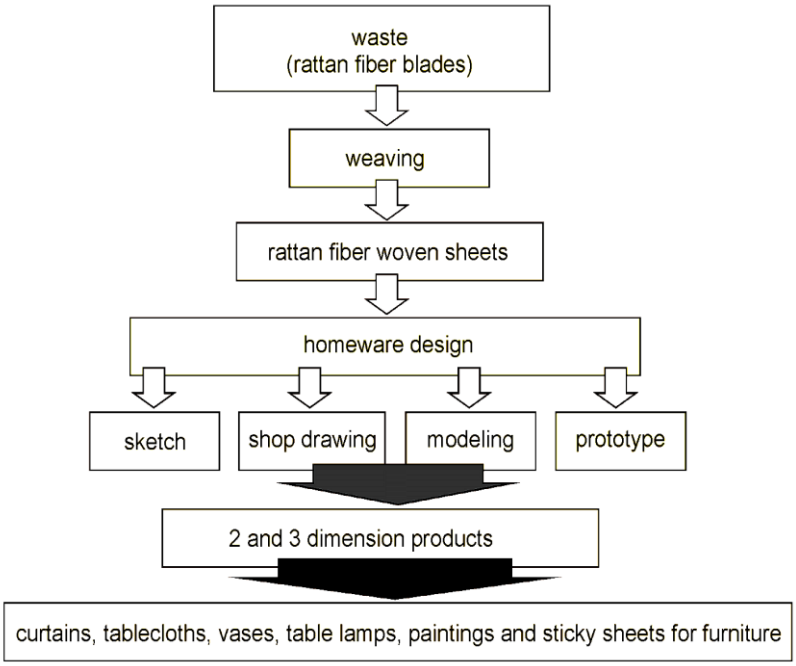

Fig. 1. The research flowchart

3. Result and discussion

3.1. Weaving Process

The weaving process is one of the techniques used in fabric-making, involving the crossing of threads lengthwise (warp) and widthwise (weft), see Fig. 2. Weaving with a non-machine loom (ATBM) begins with warping, arranging parallel threads on the loom beam. The next step is threading, where each thread is individually inserted into the heddle eyes. The warp threads are then threaded through the weaving comb, and their ends are tied to the cloth roller, preparing them for the weaving process. Cotton threads are used for the warp, while rattan fiber strips are used for the weft as waste from the splitting process. Rattan is a plant that grows vertically and has a high fiber content, but the type of rattan fiber used in this case is more brittle and shorter than fibers like sisal, pineapple, or banana stem fibers. Considering its physical and mechanical properties, rattan fiber strips cannot be used as warp threads for weaving with a non-machine loom. This is because the rattan fiber strips have a width of approximately 5 mm, a thickness of about 2 mm, and a rougher texture compared to regular threads. Using low-quality threads during weaving may lead to easy breakage due to friction

with the weft, which has a slightly harder and rougher surface. The best fiber yarns to use are hemp, pineapple, and bench yarns from synthetic fibers suitable for weaving rattan waste processing blades. The strongest synthetic fiber yarns are not recommended, based on the commitment to environmentally friendly products.

Fig. 2. From left to right: (a) Waste from rattan splitting process; (b) Waste processed into rattan fiber strips; (c) Weaving process; (d) Roll of woven rattan fiber strip sheets, 1 meter wide.

The complexity of the weaving process, based on the length of the weft, is as follows: 40 - 60 cm in length indicates an easy process, 80 - 100 cm suggests an effective process, and anything over 100 cm signifies a more complex process. The complexity arises due to the flexible and irregular nature of the material, which cannot be worked continuously, unlike weaving with full threads. This level of difficulty is compared to the material of the ribs, which is bamboo, which is stiff or even thread. The material is stiff, so when inserting the ribs as feed, they do not bend and stop in the middle of the road. The thread material used for feed is soft and small, so it can be assisted by using a bobbin. Weaving with rattan fiber strips requires inserting each strip one by one to form a sheet, similar to the techniques used in weaving with materials such as water hyacinth and vetiver roots. As a result, the rolling process, which is the final step of weaving, can only be done lengthwise.

The woven sheets are stiff, as the rattan fiber strips are thicker and wider than regular threads. Rattan woven sheets that have been widely produced and circulated in the market are rattan woven made of rattan skin. Rattan skin woven consists of rattan fibers with a certain width horizontally or forming a certain pattern. *Lampit*, or *kloso* is a rattan mat with a certain nayam pattern that has been produced for generations. Rattan skin sheets have been produced industrially in the form of rolls for various craft and furniture production purposes. The following is a comparison table with rattan skin woven with rattan waste blades from the remaining fibers (see Table 1). The comparison thickness of woven rattan fiber strips compared to woven fabric sheets, rattan woven from rattan waste is between 1 - 2 mm, while the maximum thickness of cotton, chiffon, satin, polyester, and linen fabrics is 0.75 mm.

The stiffness is higher than when using threads like pineapple, banana stem, or ramie fiber. The thickness and stiffness of the woven sheet are further considerations that influence its use in furniture design and as a decorative element in interior design. Despite the stiffness, the woven rattan fiber strip sheets are softer than those made from coconut fronds, water hyacinths, and vetiver roots. The warp threads are white, while the weft, consisting of rattan fiber strips, is brown. The rattan fiber strips dominate the woven sheets compared to the threads. Due to the wider size of the rattan fiber strips, the resulting woven sheets have a predominant natural light brown color. The waste processing to produce rattan fiber strips involves NaOH (Sumarno, Agung) and is not recommended for fashion design. Rattan fiber strip as a weft with a width of between 10 - 20mm and a thread diameter of 0.02 mm as a weave, resulting in a loose bond. This is compared to smaller sizes such as *lidi*, and dense. The density of rattan fiber strips as a woven material produces soft, warm, soundproof sheets. Therefore, the appropriate utilization is for decorative elements in interior design and homeware products.

Table 1. Comparison of the characteristics of woven and rattan woven sheets.

	Mats or *lampit*, namely manually woven sheets, are traditionally made from rattan skin processed into mats with various woven patterns.
	Rattan woven sheets are produced mechanically. Its nature is manual, so the weaving pattern tends to be geometric, namely squares, triangles, hexagons, stars, etc.
	The rattan bark sheets are larger in size and woven horizontally, rattan as the weft.
	Rattan heart woven sheet, the remaining rattan fibers after the skin is removed. Rattan material functions as a weft in the weaving process.

3.2. Weaving Patterns

The difference in color, size, and type of materials used for the warp and weft creates a visual impression of forming striped patterns. Weaving patterns generally consist of plain and striped patterns [19]. Striped patterns include horizontal, vertical, random, diagonal, square, or a combination. Weaving rattan fiber strips can be used to create various patterns. For example, the difference in size and color between the weft and warp will result in a square pattern on the woven sheet.

3.3. Natural dye

The base color of woven rattan fiber strips is light brown with a plain pattern [16]. The threads and rattan fiber strips allow for coloring due to their porous surfaces [17]. Efforts to achieve various colors can be made through natural dyeing to promote environmentally friendly production. The materials used for coloring and fixing the colors are sourced from the surrounding natural environment, eliminating the need to import materials from other regions [18], [19]; see Fig. 3.

Fig. 3. The results of natural dyeing on woven rattan fiber strip sheets using *secang*, turmeric, pandan leaves, indigo, and teak leaves with the fixatives alum, chalk, and teak fixing

The production technology and equipment are relatively simple, following the processes and tools developed by weaving artisans. Common natural materials used for dyeing and readily available in the surrounding environment include *secang*, turmeric, pandan leaves, indigo, and teak leaves. Dyeing is performed by boiling the coloring materials until they reach a boiling point and then immersing the woven rattan fiber strips. The dyeing process is repeated 3 - 4 times, followed by drying. Fixing agents such as chalk, alum, teak, and vinegar are used to ensure color fastness. The fixing process involves immersing the dyed material in water containing one of the fixing agents without boiling. The immersion is carried out for 5 minutes, and the material is dried. Strong colors are achieved with dyeing using *secang*, turmeric, and teak leaves. Alum fixing results in relatively minimal color changes. Chalk fixing produces medium color density between alum and teak fixing. Teak fixing produces the most intense color, and both turmeric and teak leaves with teak fixing produce similar colors. Exploring natural dyeing can be expanded using various natural materials that produce various color variations. Naturally dyed colors may not be as vibrant and long-lasting as synthetic dyes.

3.4. Homeware Designs

Three important aspects of product design are related to material, working techniques, and product function [20]. A material's mechanical and physical properties and working techniques are important considerations in a design process that aligns with the principle of "form follows material." Weaving with rattan fiber strips allows for various techniques such as folding, bending, sewing, gluing, and rolling. As the woven results are in sheet form, the most applicable technique for creating products is the gluing technique using adhesive. The proper selection of materials significantly impacts the success of a design; an attractive design with the wrong material choice may lead to a failed outcome. Thus, the accuracy of material selection should be accompanied by precise working techniques. A community's social and cultural conditions influence the technology and techniques used in product development [21]. The application of woven rattan fiber strip sheets in homeware can be 2D or 3D, serving decorative and functional purposes with fixed or non-fixed properties. The most applicable utilization with a fixed feature is through adhesive techniques on vertical surfaces. The textured surface of the woven sheets reduces dust retention compared to horizontal surfaces.

The sheets can be removed and cleaned for non-fixed applications on horizontal surfaces. Common uses include placemats, coasters, and table covers. However, woven rattan fiber sheets have water-absorbing properties, making them unsuitable for designs in direct contact with water. The scope of interior design work generally includes walls, ceilings, floors, and their respective elements [22]. Decorative aspects of interior design include curtains, wall decorations, paintings, photographs, and more. Interior elements encompass chairs, tables, cabinets, vases, waste bins, storage baskets, *etc*. The absorption of rattan materials for the industry is for furniture and craft products. Therefore, the absorption and market efforts that have been built using rattan fiber waste woven sheets are for furniture and crafts, especially decorative ones. Various types of decorative and interior elements require soft finishing as upholstery. Soft finishing protects and enhances products; the fabric is the most commonly used material [23], [24]. Woven rattan fiber strip sheets can be an alternative to fabric or similar materials in upholstery. Design is a creative process to produce products involving sketching, technical drawings, modeling, and prototyping [15]. The results and descriptions of each step are as follows.

1) Design Sketch

Sketching is a rough drawing that serves as a stimulus for ideas and thoughts [25], [26]. Ideas are explored and developed, then expressed visually through sketching [27]. Besides being a medium for exploring ideas, sketches also serve as a means of communication [25]. The fundamental consideration for sketching ideas is based on the nature and characteristics of the material, working techniques, and the function of the design product. Considering the nature and character of woven rattan fiber strip sheets, they can be utilized as curtains. The function of curtains is to regulate incoming light through windows, restrict views from the outside or inside, control air circulation through windows, and provide insulation for the room [28], [29]. Woven rattan fiber strip sheets are suitable for curtains as they reduce incoming light, obstruct views, and minimize airflow. This is due to the composition of the woven rattan fiber strip sheets, consisting of woven strips of rattan fibers with relatively wide gaps between them. It creates a difference in density and openness compared to fully-threaded woven fabrics. The application of woven rattan fiber strip sheets for interior design settings includes functional and decorative products. As decorative elements in interior settings, curtains stand out due to their distinctive colors (light brown, natural), material (rattan fibers), and

weaving patterns. The natural color and material properties make it suitable for tropical-style interior design. The technical application of woven rattan fiber strip sheets refers to the characteristics of the material, allowing them to be used as curtains with panel models or in roll form, see Fig. 4. The textured surface of the woven rattan fiber strips even allows for applying painting techniques to create paintings as wall decor.

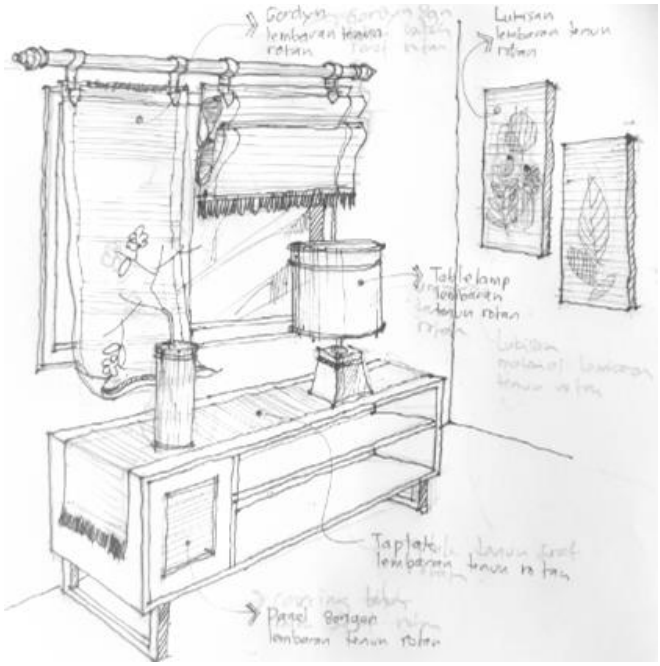

Fig. 4. Sketches of decorative elements for interior design and homeware based on woven rattan fiber strips.

Interior accessories include both 2-dimensional and 3-dimensional items that serve decorative, functional, and incidental purposes [22]. They can be hung, attached, placed, or arranged in various ways. Utilizing woven rattan fiber strip sheets for interior decorative accessories is done through adhesive techniques. The unique characteristic of the woven rattan fiber strip sheets lies in the part that needs to be exposed. These sheets can be applied to panels or surfaces of furniture products. Furniture pieces with wide panels, such as wardrobes, tables, consoles, nightstands, pantries, and cabinets, can benefit from applying woven rattan fiber strip sheets. Using woven rattan fiber strip sheets with adhesive techniques for furniture products serves decorative and protective functions. The protective function involves safeguarding materials with soft wood quality, low-cost materials, or plain and soft-textured wood. A product's utility and economic value can be enhanced by incorporating woven rattan fiber strip sheets. The uniqueness lies in the decorative aspect, specifically in the color and strip pattern resulting from rattan fiber strip sheets weaving. The colors, textures, patterns, and weaving techniques contribute to the material's distinctiveness, increasing the product's decorative and economic value. The application of woven rattan fiber strip sheets in this activity is limited to pantry furniture, consoles, and nightstands.

2) 3D Designs

The development of science and technology in the design field also helps the design process be effective and efficient. The existence of technology in helping the design process is through the existence of 3D design software. Three-dimensional design and modeling are now developing rapidly, so much software can be used. Modeling in this activity is done using SketchUp software. 3D design modeling includes three dimensions: the design object's length, width, and height. 3D design drawings are necessary because they provide a simulated, proportional, and scaled representation that closely approximates the design's real visual and textural aspects. Modeling serves as an effective and efficient means of communication to various parties. Communicating through 3D models greatly aids craftsmen, as most have a non-academic and self-taught background in their business [2]; see Fig. 5.

Fig. 5. Implementing design ideas with 3D models.

3) Prototype

Prototypes are a crucial aspect of the design process because they serve as explorations and manifestations of the design in a simulated form [30], [31]. Prototyping is an experimental stage that utilizes woven rattan fiber strip sheets to assess the product's performance. Prototypes are created with the actual materials and dimensions. Additionally, prototypes also serve as a measuring tool [32]. For artisans in the rattan furniture industry, prototypes double as sample products for production reference and production capability assessment, see Fig. 6. The production capability is reflected in the quality of the sample products, as production in this context is predominantly handcrafted.

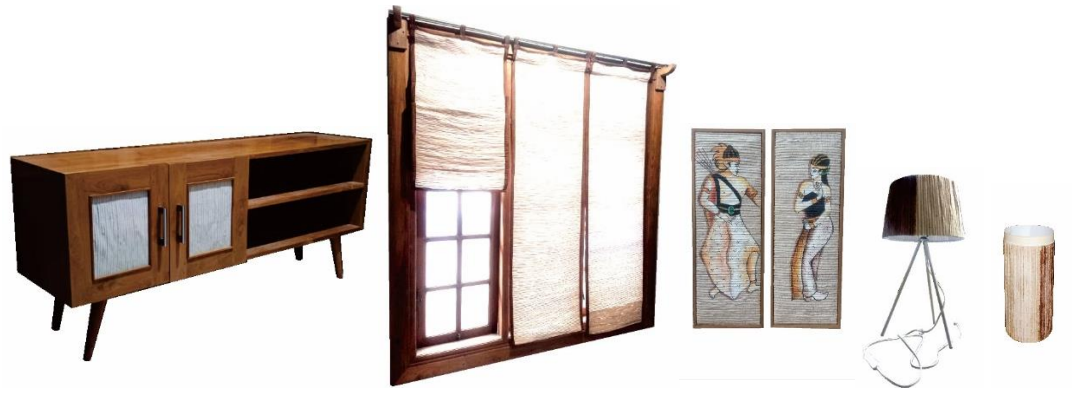

Fig. 6. Application of woven rattan fiber strip sheets for curtains with panel and roll systems.

Woven rattan fiber strip sheets for craft designs and interior decorative elements are the main material and supporting material. Its use as the main material is reviewed from the percentage of the most dominant material used, reaching more than 60% compared to other materials. Tablecloths, curtains, and even raw materials are all made of woven rattan fiber strip sheets. The main material can also be reviewed based on the role of the material, as the material with the most functions and roles as a product, its application is on the bedside lamp shade. Woven rattan fiber strip sheets are supporting materials, and the existence of the material is not too dominant, acting as a complement or as a decorative element of a product. It is used as a decorative element in the design of a console table, where the main material is teak wood while the woven rattan sheets are used as attachments to the panel board door (see Fig. 7). utilization of woven rattan fiber strip sheets, as interior elements include aesthetic and functional aspects that are useful for protecting and beautifying interior design. Decorative elements for interior design, such as sheets, are used for tablecloths, pillow covers, chair upholstery, and paintings. Woven sheets for decorative three-dimensional interiors are used for furniture panels and flower vase covers. The natural light brown color, with lines and textures typical of rattan, is in harmony with the interior design, with a natural theme and a warm atmosphere. The use of woven rattan fiber strip sheets as a functional product is to utilize loose and loose weaves as curtains and lampshades. The result is that lamp covers and curtains can reduce the penetration of light and sunlight through window glass (see Fig. 6).

3.5. Prototype testing in interior settings.

The design is incorporated into a prototype to individually determine the product's performance [33]. Interior design includes elements of the floor, walls, and ceiling. Furniture such as room fillers, picture frames, bedside lamps, paintings, and so on complete a room. The existence of furniture in a room is to support the designation of a room as a whole. Product testing in the actual environment is therefore needed to determine the performance and evaluation of the product as a whole. The product's performance in question can be related to economic aspects concerning effectiveness and efficiency, mechanical aspects, and aesthetics [34]. Product testing in the actual environment concerns the aesthetic performance of the product in the interior design setting, including the suitability of the theme and atmosphere of the room, which is related to the harmonization of one product with another. The materials and colors that need to be harmonized are the wall colors for neutral colors. Neutral colors are colors with strong intensity, soft, and not dominating; white, cream, and gray are examples of neutral colors.

Frames, windows, and doors made of wood with a natural brownish-yellow color, with glass openings or windows. This condition is so that external factors affect the atmosphere of the room's interior. During the day in tropical areas, lighting is sufficient from sunlight. However, excessive light entering the room results in heat, glare, and discomfort [35]. Curtains made of woven rattan fiber strip sheets function to hold back and reduce sunlight so that it is not dazzling and hot. The same condition also occurs in woven rattan fiber strip sheets as a cover for night lights. Its existence can block light rays at night, requiring only a little light. The sky with a neutral color will give the impression that the room is more expansive brighter, looks higher, and has no visual interference. The existence of furniture products and decorative elements of the room so that they are in harmony, not too prominent but not too dominant. The dominance of color is intended to be compared to plastic products with very strong colors. Product testing as a unity between the floor, walls, ceiling, room filling and decorative elements, light reflection, bright room, warm atmosphere so that the atmosphere of the room can be felt.

Fig. 7. Utilization of woven rattan fiber strip on the door panel, nightstand, and pantry.

Eco-design is an approach that focuses on minimizing negative impacts on the environment and maximizing resource efficiency [36], [37]. The recent environmental crisis and natural disasters have forced all humanity to return to being environmentally friendly [38]. The environment is not only the natural environment but the environment, of course, broadly, including the social and cultural environment. Commonly applied eco-efficiency technologies are recycle, reuse, and reduce, also called 3R [39]. In terms of material use, materials from renewable sources can be recycled, and the product life cycle must be paid attention to. The use of residual waste in the rattan industry to become furniture products and interior elements is an effort to implement it. Environmental awareness has spread to various sectors, one of which is in the fields of architecture, art, and design.

4. Conclusion

The research findings are woven sheets utilizing waste from the rattan industry, especially from the weaving process. In woven sheets, waste from the weaving process functions as weft, while the warp uses yarn. The result is a light brown woven sheet that is striped, textured, water-absorbent, soundproof, transparent, and can be rolled up. It can be used as a decorative element such as curtains, tablecloths, paintings, furniture panels, tissue boxes, and flower vases. Fold, bending, sewing, and gluing Techniques can be applied as design considerations for product creation. Practical recommendations from the results of research that the existence of rattan weaving waste can thus be a new alternative material for the creation of furniture and interior design products as other decorative elements with a natural theme. Efforts are needed to utilize production waste to increase efficiency and create environmentally friendly products. The weakness of the research results is that waste woven sheets made from rattan weaving waste produce sheets that are not flexible like fabrics made from yarn. The basic materials, textures, and sizes are different; the results of the combination and bonding between rattan and yarn are not as tight as woven sheets of yarn, ribs, pineapple fibers, banana fibers, and hemp fibers. Cleaning or washing needs to be done carefully and thoroughly. Recommendations, referring to the innovation of waste rattan woven sheets and material weaknesses, therefore further research to produce better-woven sheets aesthetically include physical, mechanical, and economical through collaborative research between complementary fields of science. Use, and in large quantities, therefore, it is necessary to carry out sustainable design development to create more varied products.

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