Utilization of *empon-empon* stem waste in the creation of eco-friendly homeware products

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ABSTRACT

Empon-empon stems, considered agricultural waste, present an untapped resource for crafting natural fiber products. While materials like banana stems, water hyacinth, and jute are commonly used for this purpose, *empon-empon* stems offer a novel alternative. This study explores the potential of *empon-empon* stems in creating ropes and other homeware products, aiming to not only reduce agricultural waste but also to provide additional income streams for farmers. The research methodology involves a comprehensive process of harvesting, separating, drying, and twisting *empon-empon* stems into rope. Additionally, a design-driven material (DDM) approach is employed to convert the rope into various products such as baskets, planter stands, and trays. The DDM approach includes analyzing material characteristics, visual exploration, creating shop drawings, and producing prototypes. The results demonstrate that *empon-empon* rope products are not only functional and aesthetically pleasing but also carry a unique aroma, adding to their appeal. These products have the potential to address the shortage of natural fibers in the craft industry and can serve as an alternative material for interior design applications. In conclusion, this research highlights the feasibility of utilizing *empon-empon* stems as a sustainable material for crafting innovative homeware products. By transforming agricultural waste into valuable goods, this approach contributes to both environmental sustainability and economic development in rural areas.

1. Introduction

The term "*empon-empon*" is derived from "*empon*," where "*empu*" in Javanese refers to the main rhizome or living root. It is known for its various benefits in human applications, including as cooking spices, beauty aids, medicines [1]–[3], and natural dyes [4]. *Empon-empon* is also known as "*temu-temuan*," denoting plants whose names begin with "*temu*" [5]. Fourteen types of *empon-empon* plants include *Temulawak* or Curcuma (*Curcuma heyneana Val*), galangal (*Alpinia galanga*), *lempuyang* (*Zingiber zerumbet*), turmeric (*Curcuma domestica*), aromatic ginger (*Kaempferia galanga*), ginger (*Zingiber officinale Rosc*), and bangle or purple ginger (*Zingiber perpereum Roxb*). The classification of *empon-empon* plant types does not refer to scientific classification but rather to their usefulness. [6]. *Empon-empon* plants can easily grow wild and be cultivated in tropical countries. The morphology of the *empon-empon* plant includes leaves, false stems, rhizomes, and roots. The stem is soft, round, upright, long, tenacious, and yellowish-green in color. It is composed of leaf midribs, fibrous, and has a distinctive aroma [5]. The *empon-empon* plant is being widely cultivated, with its rhizomes being the main commodity. Non-rhizome planting products, including flowers, leaves, stems, and roots, are categorized as waste. Utilizing *empon-empon* stem waste is important for maintaining environmental sustainability through raw material efficiency and providing benefits and economic value for *empon-empon* farmers. Empowering farmers is crucial because the majority are poor [7].

The research hypothesis posits that diverse types of fibrous plants have been transformed into ropes for the production of craft items. Examples of fibrous plants utilized for rope creation encompass banana stem fiber, hemp fiber, pineapple leaf fiber, purun fiber, kudzu stem fiber, *pandan*, *mendong*, seagrass, and additional varieties. *Empon-empon* stems possess attributes such as softness, elongation, tensile strength, and fibrous nature, similar to those of other fiber plants. Hence, it is plausible to fabricate *empon-empon* stems into ropes employing the twisting technique to generate rope. Previous research has explored the use of natural fiber materials for creating creative products. Straw is a cheap and abundant material used for making ropes, but it has a rough and somewhat brittle texture [8]. Research on utilizing rattan fiber waste left over from the Irat process has produced kaut rope, which, however, has a rough texture and expensive production costs [9], [10]. Banana fiber, when used to make rope, results in a strong rope with a soft texture that does not have a distinctive aroma like *empon-empon* [11], [12]. Ropes made from water hyacinth are produced in natural colors but break easily because the fibers are short [13], [14]. Other natural fiber materials, such as kudzu stems [15], bamboo fiber [16], nipah fiber [17], doyo fiber [18] face constraints regarding material availability and expensive production costs. The aim of the research is to utilize *empon-empon* stems, a harvest waste, to create rope as a semi-finished material for industrial purposes, particularly targeting the craft and furniture industry. Ropes made from natural fibers are widely used in these industries but are often in short supply. *Empon-empon* stem ropes can serve as an alternative material to replace ropes made from other natural fibers. The next research aims to utilize rope made from *empon-empon* stem waste to create aesthetic and eco-friendly homeware products with a distinctive *empon-empon* aroma.

Our research is grounded in the principles of sustainable development, waste management, and product innovation. Sustainable development theory emphasizes the need to meet the needs of the present without compromising the ability of future generations to meet their own needs [19]. By utilizing *empon-empon* stems as a raw material for rope production, we contribute to sustainable agriculture and environmental conservation by reducing waste and promoting the efficient use of natural resources. Waste management theory guides our approach to utilizing empon-empon stems, a harvest waste, to create rope as a semi-finished material for industrial purposes. This theory emphasizes the importance of reducing, reusing, and recycling waste to minimize environmental impact and maximize resource efficiency [20]. By repurposing empon-empon stems into rope, we demonstrate a sustainable waste management practice that aligns with these principles. Innovation theory informs our research by highlighting the role of creativity and novelty in driving economic growth and development [21]. By exploring new ways to utilize agricultural waste for product development, we contribute to the innovation ecosystem and promote the creation of eco-friendly products with unique characteristics.

2. Material and method

The research material consists of the stems of the *empon-empon* plant, considered as harvest waste. Fourteen plant types, including curcuma (*Zingiber perpereum Roxb*), white curcuma (*Curcuma Zedoria*), mango curcuma (*Curcuma manga Val*), *temu kunci* (*Boesenberigia pandurata*), black curcuma (*Curcuma aeruginosa Roxb*), giring curcuma (*Curcuma heyneana Val*), galangal (*Alpinia galanga*), lempuyang (*Zingiber zerumbet*), turmeric (*Curcuma domestica*), galangal (*Kaempferia galanga*), ginger (*Zingiber officinale Rosc*), and bangle (*Zingiber perpereum Roxb*), are collectively referred to as *empon-empon*. Among these, six types are specifically used: *temulawak* (*Zingiber perpereum Roxb*), white ginger (*Curcuma Zedoria*), mango ginger (*Curcuma manga Val*), black ginger (*Curcuma aeruginosa Roxb*), giring ginger (*Curcuma heyneana Val*), and turmeric (*Curcuma domestica*). The stems of these *empon-empon* plants reach an average height of 1.5 m [3]. Rope is a material consisting of long strands made from various materials [22]. Longitudinal material is required for thread work in the context of making rope. Therefore, the height or length of the stem is a criterion for determining the type of *empon-empon* plant. Another criterion is the presence of soft material to produce a flexible rope. The processing efforts to produce material for rope involve experimental development. Developmental experiments are aimed at testing, checking, and proving a hypothesis about cause-and-effect relationships. The specific development experiment referred to in this research is the twisting technique for natural fiber materials, which are commonly used. Table 1 is a description of the type of empon, size, softness and selection.

Table 1. Information on the type of *empon*, its size, softness, and selection

Type of Empon-Empon	Stem Length	Hardness-Softness	Information
Curcuma	long	soft	utilized
White Ginger	long	soft	utilized
Mango Ginger,	long	soft	utilized
Temu kunci,	Medium	soft	not utilized
Black Ginger,	long	soft	utilized
Temu giring,	long	soft	utilized
Galangal,	long	hard	not utilized
Lempuyang,	Medium	soft	not utilized
Turmeric,	long	soft	utilized
Aromatic Ginger,	short	soft	not utilized
Ginger,	Medium	soft	not utilized
Bangle (Purple Ginger)	Medium	soft	not utilized

Ropes are made from elongated fibrous material; some types of *empon-empon* stems are soft, tenacious, and long. Therefore, several types of *empon-empon* stems can be used to make rope. The technique for making fiber into rope is the twisting technique, which has been widely developed using natural fiber materials. The research process is generally divided into two stages. The first stage focuses on researching rope as a semi-finished product for creative products. The second stage involves homeware design using rope made from *empon-empon* stems. The processing steps to produce rope include picking, separating the *empon-empon* stems from the leaves, drying, and twisting; (1) Collecting *empon-empon* stems from the garden as harvest waste, then cleaning them from debris such as soil and gravel, and transporting the *empon-empon* rhizomes; (2) Separating the *empon-empon* stem bones from the leaves is necessary because the leaves become hard when dry and are therefore unsuitable for making rope. This separation process is performed manually using a knife; (3) Drying is conducted to prevent the resulting rope from shrinking and to avoid mold growth; (4) Twisting is the process of combining natural fiber materials to make rope, which can be done manually or with machinery. After twisting and producing the rope, the next step is the creative process of designing the product. The design for crafting products relies on the DDM (*Design Driven Material*) principle. This principle is adopted because the design process starts with considering the properties of the material before conceptualizing the product. Material considerations, as the foundation for product creation, include analyzing material characteristics and craftsmanship techniques, followed by considering product function and the required material combinations [13], [23], [24]. The creative process involves visual exploration, design analysis, alternative selection, creating shop drawings, and realizing the design through a prototype, see Fig. 1.

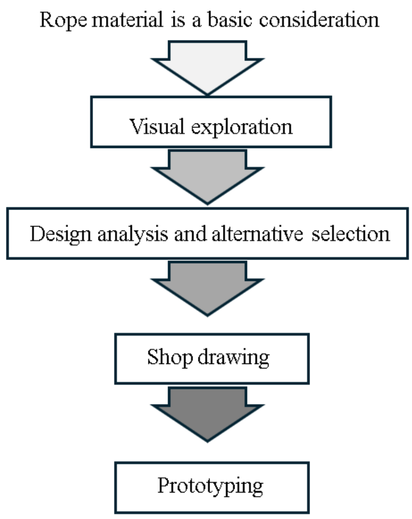

Fig. 1. Diagram of the material processing stages and the design process

3. Results and Discussion

Indonesian people have been using natural fiber materials to make ropes and products since ancient times [25], [26]. This practice continues today, with the craft and furniture industries being the largest consumers. The demand for natural fiber in the creative industry is increasing, leading to supply shortages [19]. Natural fiber materials needed for the creative industry include kenaf (*Hibiscus cannabinus*), hemp (*Boehmeria nivea*), mendong (*Fimbristylis globulosa*), purun (*Lepironia articulata*), pineapple fiber (*Ananas comosus L. Merr*), water hyacinth (*Eichhornia crassipes*), sisal, banana stems, and others. The potential for utilizing *empon-empon* stem fiber to meet industrial needs is substantial in 2022, reaching 229,651,026.00 kg, consisting of *temu lawak* or Curcuma (*Zingiber perpereum Roxb*), *temu ireng* (*Curcuma aeruginosa Roxb*), and turmeric (*Curcuma domestica*). Data was only collected on *temu lawak*, *temu ireng*, and turmeric because, besides the three types of *empon-empon* with tall stems, the selling price is low. It is assumed that if 1 kg of dried *empon-empon* stems is equivalent to 0.25 kg, then each year it will produce 57,412,756.50 kg/year. In Table 2 is the volume of empon-empon produced from 2020 to 2022.The potential of *empon-empon* stems can be used as an alternative to provide fiber materials for industry.

Table 2. The volume of *empon-empon* produced between 2020 and 2022

Name	Year 2020	Year 2021	Year 2022
Temulawak (*Zingiber perpereum Roxb*)	26.742.721	32.282.031	28.099.702
Temu hitam (*Curcuma aeruginosa Roxb*)	7.201.988	6.519.135	5.051.749
Turmeric (*Curcuma domestica*)	193.582.819	184.825.890	196.499.570

Utilizing *empon-empon* stem waste for products requires a processing process to turn it into a semi-finished material first. The processing of materials into semi-finished products includes picking, separating stems from leaves, drying, and twisting to form rope.

3.1. Processing Materials into Rope

Picking *empon-empon* stems occurs during harvesting after the rhizomes of the plant have been removed. The *empon-empon* stem consists of leaf stalks that cover each other regularly, closing to form a circle. The stalk extends upward into a leaf consisting of a lamina and a leaf spine [24]. Its tenacious and elongated nature is the basis for the use of *empon-empon* stems. *Empon-empon* plants that are 7-9 months old, with some leaves turning yellow or drying out, are signs that the plant is ready to be harvested [5]. Harvesting is done by cutting the stem to separate the rhizome. The stems are usually discarded, burned, or left to rot. Collecting and cleaning the tips of the rhizomes that are still attached to the stem and removing other dirt. The second method of collection is for empons that grow wild and are not harvested. Empons that are not harvested generally dry out in place. Picking is done before they become hard, porous, and brittle. The *empon-empon* stem consists of layers of lamina that form a leaf stalk, covering each other regularly to form a circle of stem. After the stems have been picked, the bark needs to be peeled to speed up the drying process and facilitate the twisting process. The next step is to separate the *empon-empon* stem from the leaves using a knife or cutter. This separation is necessary because *empon-empon* leaves become very brittle in dry conditions, making them unsuitable for use as rope.

Drying can be done in the oven or by sun-drying. It should be carried out until the moisture content reaches around 13-15%. Drying above 13% will cause the material to become hard and brittle, making it unsuitable for twisting into rope. To maintain stability, storage in a warehouse is necessary, while ensuring the humidity level is controlled. Excessive space can lead to mold growth, resulting in rot and making the fibers brittle. Conversely, in a hot environment, the *empon-empon* stem will become hard and brittle. The six types of *empon-empon* stems used as research materials include *temulawak* (*Zingiber perpereum Roxb*), white ginger (*Curcuma Zedoria*), mango ginger (*Curcuma manga Val*), black ginger (*Curcuma aeruginosa Roxb*), *temu giring* (*Curcuma heyneana Val*), and turmeric (*Curcuma domestica*). Their color and aroma tend to be similar. In dry conditions, the aroma of the stems is very difficult to differentiate and tends to be the same as the rhizomes. Only a small number of farmers can differentiate the aroma of the stems. The physical characteristics of the six types of *empon-empon* stems in dry conditions are relatively similar, with the most notable difference being that the turmeric stems have the smallest diameter and are the most resilient. Therefore, twisting does not require differentiation or separation between the types of *empon-empon* stems. Spinning can be done manually or by machine. However, manual spinning has very low productivity and is insufficient to meet industrial needs. The hardness level of the rope is similar to *mendong*, softer than rope made from seagrass, and harder than water hyacinth rope and banana stem rope. The color of the rope is brownish-yellow with a distinctive *empon-empon* aroma and a diameter of 10-15 mm.

3.2. Analysis of Product Function

The existence of products can be assessed based on their practical and decorative functions. Practical functions are closely related to human needs and daily life, serving as objects of utility. These functions are further divided into primary functions and secondary or supporting functions [26]. For example, a basket, which is designed to store items, requires an analysis of the items' sizes—whether they are large or small, long or short, round or square, geometric or organic, or abstract—depending on the basket's size. *Empon-empon* rope, the main material for making baskets, creates hollow spaces, necessitating additional coatings like plastic or paper to prevent leakage for fine-grained items such as flour, sand, or beads. The density, hardness, softness, or breakability of the stored items also need to be considered in the design. Characteristics such as whether the items are solid, liquid, or wet are crucial. *Empon-empon* rope, being soft, is not suitable for storing liquid, wet, or damp items. Additionally, it is not recommended for items with sharp or pointed edges, such as knives, saws, drills, *etc*., as they can damage the basket. Baskets are used to store various items, including books, toys, kids' tools, and shopping items. They can also store small, elongated items such as umbrellas and sticks. For example, the average folding/rolling umbrella container has a practical function with dimensions of approximately 10 cm in diameter and between 15-75 cm in length. The decorative function serves to enhance the beauty of a product and the interior environment. Products can function either independently or as complements, improving overall performance. These principles are crucial in considering craft/creative product design [27].

3.3. Visual Exploration

Considerations in the design process include various stages, including exploration and sketching. The exploration of ideas is a crucial part of successful design regarding product form and function. Sketches are a commonly used visual exploration medium to explore ideas. They are rough drawings, serving as a temporary medium for exploring ideas and communication [28]–[32]. Sketch drawings are an outpouring of imagination onto paper in rough form, as shown in Fig. 2. They provide opportunities for spontaneity, speed, form exploration, and efficiency in the design process. Sketch drawing combines expressive and technical aspects, especially in product design. However, the spontaneity of the design form still considers the characteristics of the materials, craftsmanship techniques, and product function.

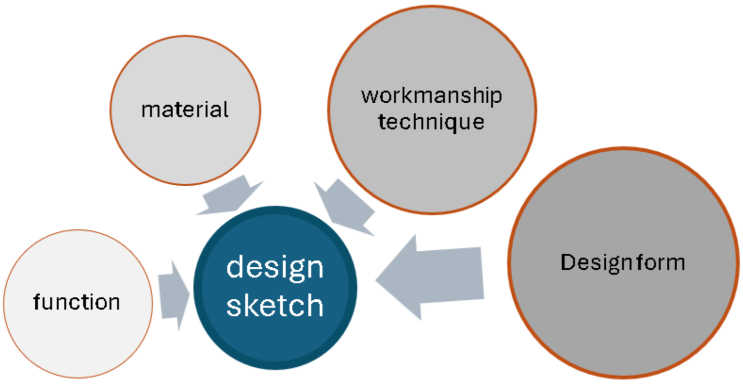

Fig. 2. Design Sketch Consideration Scheme

. Design is a part of a broader and more complex economic activity. The three pillars of economic activity include production, distribution, and consumption. Design, as part of the production process, plays a crucial role in distribution and product mobility. Distribution occurs after production, and considering the effectiveness and efficiency of product mobility can help minimize waste from the design process. In the product creation process, adopting a product operational system can enhance efficient product mobility. Systems that may be adopted include the knock-down system, stacking system, folding system, and nesting system. Nesting, for example, involves inserting one product into another to save on packaging and transportation costs. The products inserted can be similar or smaller products. Transportation considerations include how products can be arranged from the smallest to the largest size. Fig. 3 illustrates an exploration of ideas through several sketches, adjusting the size of the products to be accommodated.

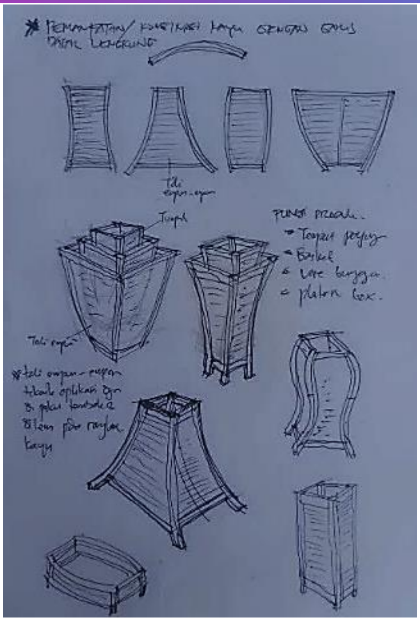

Fig. 3. Manual Visual Exploration with Sketches

Visual exploration through sketch drawings involves rough drawings with the opportunity to refine shapes. Subsequently, computer design drawings are used to focus and simulate the designs, as shown in Fig. 4. This process allows for more accurate colors, shape proportions, and dimensions. Measurable dimensions and proportions enable the simulation of stacking and nesting systems [33]. Product size, component size, and even curvature can be simulated for suitability.

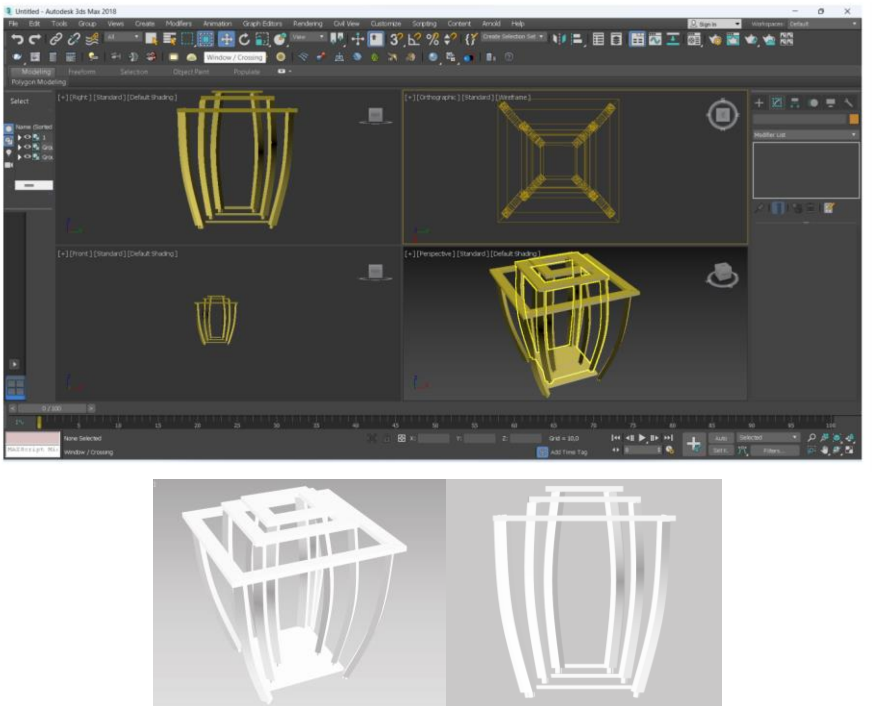

Fig. 4. Visual Exploration with Computers

3.4. Shop Drawings

Communicating understanding and ideas is an integral part of the design process [34]. Therefore, sketches are generally followed up with shop drawings or CAD drawings [35]. Shop drawings, also known as technical drawings or working drawings, are standardized, scaled, measurable, proportional, and detailed. In cases of low complexity, a sketch may be sufficient or even clearer. Designer workshops are involved and can directly experience the design's weaknesses before mass production.

Below are several technical drawings of craft products and furniture based on *empon-empon* ropes with various processing techniques.

3.5. Prototype

The creative process begins with ideas, images, and prototypes as manifestations of those ideas. Besides being a manifestation, the prototype is also a part of design exploration [27]. Prototypes are essential in exploring ideas to evaluate, simulate, and open up possibilities for design improvements. These improvements can include construction details, performance aspects, or product colors. Prototypes serve as a design language to represent and realize design thinking [33]. Fig. 5 shows prototypes of crafts made from *empon-empon* rope with various craftsmanship techniques.

Fig. 5. Prototype of Craft Products Made from *Empon-Empon* Rope

4. Conclusion

The research findings demonstrate that utilizing *empon-empon* stems to make rope can effectively reduce harvest waste and significantly increase benefits and economic value for *empon-empon* farmers. The unique characteristics of *empon-empon* stem rope, including its strength, texture, color, and distinctive aroma, make it a valuable resource that can address the scarcity of natural fiber rope in the creative industry. While the study successfully showcases the potential of *empon-empon* stem rope, there are certain weaknesses that should be acknowledged. The range of products currently produced from *empon-empon* stem rope is limited, indicating a need for further research and development to explore its full potential. Additionally, more comprehensive studies could be conducted to evaluate the environmental impact and sustainability of utilizing *empon-empon* stems for rope production. Despite these limitations, the research makes several significant contributions to the field. It highlights the practical benefits of utilizing *empon-empon* stems, not only in reducing waste but also in creating high-quality, environmentally friendly products. Furthermore, the study provides insights into the potential applications of *empon-empon* stem rope in various industries, which could lead to new opportunities for economic growth and sustainable development. In terms of future research potential, there are several avenues that could be explored. Firstly, further studies could focus on expanding the range of products made from *empon-empon* stem rope, particularly in the field of interior design and decoration. Secondly, the research could be conducted to optimize the production process of *empon-empon* stem rope, including exploring new techniques for weaving and treating the fibers. Finally, future research could also investigate the potential of combining *empon-empon* rope with other materials to create innovative and sustainable composite materials.

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