Material Exploration of Rice Straw Pulp

Zahra Syamsi Fadhila,[1*] Fajar Ciptandi,[1] Terbit Setya Pambudi[1]

[1]*Telkom University, Bandung, Indonesia*

*Corresponding email: zsyamsi@student.telkomuniversity.ac.id

Abstract

Rice straw is currently an agricultural waste that is often only handled by burning it in rice fields, while its chemical composition, comprising cellulose, hemicellulose, and lignin, is comparable to that of commonly used materials such as wood and bamboo. Rice straw is abundant and has been extensively researched as a base material for pulp-based products; however, research to date has primarily employed wood pulp manufacturing techniques to treat rice straw. An exploration of rice straw as a unique material may offer valuable insights into rice straw research. The research method used is the design thinking methods for research operation with the following stages: 1) Empathize to explore various insights on rice straw, 2) Define to identify problems by multiple experimentations of rice straw processing, 3) Ideate in the form of stage of analyzing experiment results, 4) Producing various prototype iterations, and 5) Testing the degradability of the prototype samples. This research can contribute by providing recommendations for utilizing rice straw agricultural waste as pulp products for home industries and farmers' union business units.

Keywords: rice straw pulp, design thinking method, material exploration, bioplastic composite

Introduction

Rice straw in Indonesia is currently an agricultural waste that is often only handled by burning on-site (International Rice Research Institute, 2019). A small portion of the total rice straw produced is used as animal feed and cage bedding (Van Hung et al., 2020). Its use as a craft material is also limited, due to the fact that most of the rice that is processed using the mechanical thresher often used by farmers produces straw that is cut into short, irregular, and mixed pieces that are not ideal for weaving (Sumarno et al., 2022), but may have uses in pulp-based products. The general mechanical characteristics of rice straw include having a strong structure, cushioning and insulating properties, and being easy to re-form.

Previous researches on rice straw utilization suggest further exploration is needed to combine different approaches in the development of more efficient and sustainable pulp processing processes (Purwandaru, 2013; Sisti et al., 2017). For generations, crafters and artists have done their own research on their materials by using their senses and repetitive attempts of material manipulation through various means (Groth & Mäkelä, 2016). Material familiarization using craft insights may offer a meaningful addition to the current state of rice straw material research.

Method

The research employs design thinking methods and incorporates additional insights from material-driven design. Each step of the method is carried out as described here:

1. Empathize: to explore various characteristics of rice straw by observing the material using the researcher's sense of sight, touch, and scent. The result of this process will be presented as a table of material benchmarks.
2. Define: to identify the most effective way to process rice straw into pulp by multiple experimentations of pre-processes (water retting, chemical retting, water boiling, and chemical boiling), and processing (dry milling, and wet pulping).
3. Ideate: to analyze results of experimentations through material benchmarking, choosing a viable binder most suitable for each composite, and creating formulas for each composite.
4. Prototyping: producing various prototype iterations.
5. Testing: testing the reaction of the degradability of the prototypes against water.

Result and Discussion

1. Empathize

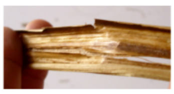
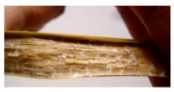
Characteristics	IR64	Ciherang Sub 1	Sri Median
			
Colour	Golden yellow	Light brown	Yellow and light brown
Brightness	High	Low	Medium
Shine	High shine	Dull	Slight shine
Texture	Smooth, brittle	Fuzzy and fibrous	Fuzzy
Flexibility	High	Low	Low
Stretch	Low	Low	Low
Scent	Hints of grass	Hints of wood	Hints of grass
Absorbency	Quick to absorb	Less absorbent	Less absorbent
Effects of characteristics to manipulation	Takes less time to ferment and boil	Takes more time to ferment and boil	In-between IR64 and Ciherang Sub 1

Figure 1. Material benchmarks of observed rice straw varieties

Based on the characteristics observed, *the Ciherang* variety requires more time to ferment, retting, and boil due to its physical characteristics. In cases where rice straw waste of mixed variety is used as a pulp material, the retting and boiling durations would need to be adjusted to the longest duration.

2. *Define*

Retting	Fastest retting method is using chemical retting (1% soda ash solution) for 2 days
	Water retting method takes at most 6 days, but results in the best visual outcome
Boiling	Chemically retted straw need the least boiling time (45 minutes)
	Water retted straw needs 60 minutes boiling time, but results in best visual outcome
Pulping	Chemically retted straw need the least wet pulping time of 4 minutes and 4 minutes of dry milling
	Water retted straw need need wet pulping of 8 minutes, and 4 minutes of dry milling

Figure 2. Results of pre-processing experiments

Based on the result of the retting, boiling, and pulping experimentation, retting the rice straw in 1% soda ash solution is favorable due to its short duration. The chemically retted rice straw also requires the least time to boil in a 1% soda ash solution, and pulping the chemically retted rice straw requires the shortest duration. A rough pulp can also be created by shortening the pulping duration. Therefore, chemical retting is the ideal pre-process for producing rice straw pulp.

3. *Ideate*

Characteristics	Dry Milled Pulp	Wet Pulp	Rough pulp
			
Colour	Light brown	Dark brown	Yellow and light brown
Brightness	High	Low	Medium
Texture	Powdery and soft	Porridge-like and slightly fibrous	Fibrous and rough
Flexibility	High	High	Low
Stretch	Low	Low	Low
Scent	Hints of grass	Hints of grass	Hints of grass
Absorbency	Quick to absorb	Quick to absorb	Quick to absorb
Storage	Can be stored for a long period of time in room temperature	Can be stored two days in room temperature, and up to a month in 5 degree celsius	Can be stored for a long period of time in room temperature after dried

Figure 3. Material benchmarks of the resulting rice straw pulp

Based on the material benchmark analysis of the resulting pulp, dry pulp is favorable due to its absorption qualities, color, brightness, and shelf life. At the same time, wet pulp is applicable for direct processing without storage. Rough pulp may offer more material strength due to its longer fibers, but may lack absorption qualities in specific settings because it has less surface.

Product	Composite Board	Flexure Composite	Paper
Ingredients (grams)	• Modified tapioca (15) • Water (80) • 6% Vinegar (13) • Vegetable oil (5) • Gum rosin (5) • Dry pulp (12)	• Modified tapioca (10) • Water (80) • 6% Vinegar (13) • Dry pulp (6)	• Modified tapioca (12) • Water (60) • Dry pulp (50)
Steps	1. Dissolve gum rosin in vegetable oil, and heat over a double boiler until evenly melted. 2. Mix all ingredients without pulp and heat over medium for 6 minutes. 3. Mix pulp into the binder evenly. Fit into mold. 4. Dry and cure for 24 hours or 90 minutes in an 80 degree celsius oven.	1. Mix all ingredients without pulp and heat over medium for 3 minutes. 2. Mix pulp into the binder evenly. Spread over a flat surface. 3. Dry and cure for 24 hours or 40 minutes in an 80 degree celsius oven.	1. Soak dry pulp in water for 30 minutes. 2. Cook with starch over low heat for 2 minutes. 3. Mix into a vat of water, and shape with mold and deckle. 4. Dry for 8 hours, or 10 minutes in an 80 degree celsius oven.

Figure 4. Composite product recipes

To achieve solid and flexural composite properties, we developed recipes inspired by bioplastic explorations by Dunne (2018). The starch chosen for the binders is modified tapioca starch, as it is produced locally and widely available. Steps were chosen to minimize the use of tools and ingredients.

4. Prototype

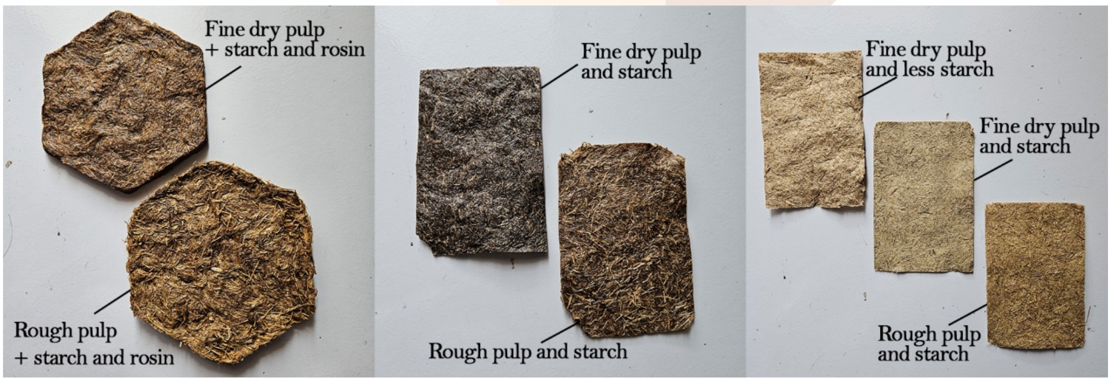


Figure 4. Composite prototypes resulted from rice straw pulp and starch-based binder

From left to right, the prototypes created were composite board, flexure composite, and paper. Composite board prototypes were made using fine dry pulp and rough dry pulp. Flexure composites were made using fine dry pulp and rough dry pulp. Meanwhile, the paper prototypes were made using fine dry pulp and half of the recipe's starch, followed by fine dry pulp and starch, and then rough pulp and starch.

5. Testing

The testing is conducted to determine the degradability of each composite. The test was conducted by soaking each prototype in water and observing the time it took for each composite to break down into pulp, with the binders dissolved into the water. We have found that the paper prototype with fine dry pulp and half the recipe starch broke down into pulp the fastest, within 20 seconds. The paper prototype using rough pulp dissolved within 47 seconds, and the fine dry pulp dissolved within approximately 1 minute. Both flexure composites dissolved within 6 minutes, and the composite boards dissolved within 10 hours. The addition of gum rosin and the thickness of the composite boards contribute to its longer durability against water.

Conclusion

Findings show that rice straw is a viable material for producing non-load-bearing composite boards, flexure composite, and paper. The favorable processes for rice straw were chemical retting, alkali boiling, and dry pulping. Starch-based bio-plastic binders are viable for all three composites. This research focused on multiple experimentations and explorations using craft-based methods, therefore benefiting from the flexibility of art-based exploration. The results from this research will require further development to enhance the durability and implementation of biodegradable waterproof coatings.

References

Dunne, M. (2018). Bioplastic cook book. *Retrieved December*, *12*, 2020.

Groth, C., & Mäkelä, M. (2016). The knowing body in material exploration. *Studies in Material Thinking*, *14*(2), 1–11.

International Rice Research Institute. (2019, May 31). *Rice Straw Management*. https://www.irri.org/rice-straw-management

Purwandaru, P. (2013). Pemanfaatan Jerami Untuk Produk Ramah Lingkungan UKM Melalui Proses Kempa= Utilization of Straw as Sme Environmental Friendly Products Via Felts Process. *Jurnal Teknologi Lingkungan BPPT*, *14*(2), 83–88.

Sisti, L., Totaro, G., Vannini, M., & Celli, A. (2017). Retting process as a pretreatment of natural fibers for the development of polymer composites. In *Lignocellulosic composite materials* (pp. 97–135). Springer.

Sumarno, Dharsono, & Chandra, N. R. A. (2022). *Jerami Bahan Alternatif Desain Mebel & Kerajinan*. Deepublish Digital.

Van Hung, N., Maguyon-Detras, M. C., Migo, M. V., Quilloy, R., Balingbing, C., Chivenge, P., & Gummert, M. (2020). Rice straw overview: availability, properties, and management practices. *Sustainable Rice Straw Management*, *1*.