UTILIZATION OF SUGAR PALM FRUIT SHELL WASTE FOR THE PRODUCTION OF SUSTAINABLE PACKAGING

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Abstract

This study aimed to produce paper from waste sugar palm fruit shells as an alternative source of cellulose fiber for sustainable packaging applications. The paper process involved alkali pulping with 1 M sodium hydroxide, bleaching with hydrogen peroxide, and fiber blending. The resulting paper sheets exhibited a light-yellow color and suitable physical characteristics for packaging use. The bleaching process effectively reduced lignin content, producing lighter and more uniform paper surfaces. Color measurement results showed values of L* = 81.99 ± 0.30, a* = 2.32 ± 0.05, and b* = 16.16 ± 0.26, indicating a light and slightly warm tone. These characteristics are desirable for eco-friendly packaging, as the natural tone enhances aesthetic appeal and supports sustainability. A satisfaction survey of 120 participants revealed high satisfaction with the bleached sugar palm fruit shell paper, particularly in terms of appearance (mean = 4.29), suitability for product development, and color. Although uniformity of thickness received the lowest rating (mean = 3.87), overall satisfaction remained high. A packaging prototype for sugar palm cubes was developed based on the Design for Environment (DfE) concept. The use of natural paper color, black printing, and sustainable materials achieved both aesthetic value and environmental responsibility. The study demonstrates the potential of sugar palm fruit shell paper as a sustainable packaging material that supports community-based resource utilization and local economic development.

Keywords: Sugar palm fruit, sustainable Packaging, agricultural waste

Introduction

The growing global concern over environmental pollution and the overuse of non-biodegradable materials has driven the search for sustainable and renewable alternatives in packaging industries. Paper made from agricultural residues is recognized as an eco-friendly

material that can replace conventional wood-based paper, thereby reducing deforestation and waste accumulation (Belyamani et al., 2026).

Pak Nam Sub-district, Bang Khla District, Chachoengsao Province, is an old community located along the Bang Pakong River Basin, where the local population traditionally engages in subsistence farming such as fruit orchards, vegetable cultivation, rice farming, fisheries, and the production of palm juice from sugar palm trees (*Borassus flabellifer*). However, due to changing economic conditions and low agricultural profitability, many local farmers have abandoned traditional sugar palm production. In response, a group of dedicated villagers formed the Palm Juice Village community enterprise to preserve local wisdom and cultural identity. With support from government agencies, the community continues to produce palm juice, palm sugar, and palm jelly-combining traditional practices with modern techniques to create cultural and economic value while promoting community-based tourism (Tossawut, T. et al., 2022). Sugar palm fruit shells and fibres are by-products of sugar palm processing, often discarded after extracting the edible parts and sap. According to Ilyas et al. (2019), sugar palm fibres and stems, although often treated as agricultural waste, are rich in cellulose and possess great potential as alternative raw materials for value-added applications, including biodegradable composites and paper production (Ilyas, R. A. et al., 2019). Previous research has demonstrated that paper can be produced from various types of agricultural residues, including date palm, reed leaves, coconut husks, and pineapple leaves (Belyamani et al., 2026; Ohama, P. et al., 2024; Nkeudem, A. G. et al., 2023; Bussaban, K., & Chumee, J., 2019). These findings suggest that waste sugar palm fruit shells could serve as a renewable fiber source for sustainable material development.

Therefore, this study aimed to utilize waste sugar palm fruit shells as an alternative cellulose fiber for paper production and to evaluate their potential application in sustainable packaging. Furthermore, the research included the design of a sugar palm cube packaging prototype using the Design for Environment (DfE) concept, integrating environmental consciousness with functional and aesthetic product design.

Research Objectives

This study aims to produce paper from waste sugar palm fruit shells for sustainable packaging application.

Scope of the Research

1. Waste sugar palm fruit shells were collected from Bang Khla district, Chachoengsao province, Thailand.
2. Paper was produced from sugar palm bark pulp mixed with other natural fibers.
3. a total of 120 participants were surveyed to evaluate their satisfaction with the sugar palm fruit shell paper.

Research Methodology

1. Preparation of sugar palm fruit shell

Sugar palm fruit shells were cleaned to remove dust, sun-dried until completely dry, and then cut into small pieces. The prepared sugar palm fruit shells were stored in plastic bags at room temperature.

2. Paper preparation

The prepared sugar palm fruit shells were boiled with 1 M sodium hydroxide (NaOH) solution at 100°C for 2 hours. The pulp was washed with tap water until the pH reached

neutrality. The pulp was bleached with 12% hydrogen peroxide (H_2O_2) at 100 °C for 1 hour until a light-yellow color was obtained. The bleached pulp was then rinsed thoroughly with tap water before being mixed with bleached coconut husk pulp and mulberry pulp until homogeneously. The resulting pulp was formed into sheets by handmade paper mold and sun-dried until completely dry.

3. Color analysis

The color of the sugar palm fruit shell paper was measured using the light reflectance technique with a Hunter Lab Spectrophotometer ColorQuest XE. The CIELab system (L*, a*, b*) was employed to evaluate the paper color, where L*, a*, and b* represent lightness, redness–greenness, and yellowness–blueness, respectively.

4. Consumer survey

A total of 120 participants were recruited to evaluate the developed sugar palm fruit shell paper. The evaluation was conducted using a structured questionnaire based on the following criteria: surface texture, color, visual appeal, tensile strength, uniformity of thickness, sheet formation, suitability for product development, and overall characteristics. Participants were asked to rate each attribute on a 5-point Likert scale, where 1 = very poor, 2 = poor, 3 = fair, 4 = good, and 5 = excellent. The responses were collected and analyzed to assess the overall acceptability and suitability of the paper for potential product applications.

Research Results

Bang Khla District, Chachoengsao Province, is one of the local communities that produces palm sugar from sugar palm trees (Borassus flabellifer). Sugar palms grow abundantly throughout the area, and local people continue to utilize various parts of the trees. The ripe fruits are used to make traditional palm desserts and peeled for sale, leaving behind the shells and fibrous residues as agricultural waste. As shown in Figure 1, these sugar palm fibers and shells contain cellulose, which provides potential for utilization in paper production.

Figure 1: Residues of sugar palm fruit shells as agricultural waste from Bang Khla District, Chachoengsao Province, Thailand

The sugar palm fruit shell paper was formed into sheets measuring 80 × 60 cm. The front side exhibited a rough and uneven surface, whereas the back side was relatively smooth with clearly visible fibers. The paper showed distinct surface texture and a light-yellow color, as shown in Figure 2. After the bleaching process, the color became lighter due to the reaction between hydrogen peroxide (H_2O_2) and sodium hydroxide (NaOH), which generated perhydroxyl ions (HOO^-). These ions oxidized the carboxylic functional groups (–COOH) in the fiber structure, resulting in color fading.

Table 1 shows the color measurement values of the sugar palm fruit shell paper. From the color measurement, the lightness value (L*) was 81.99 ± 0.30, the redness–greenness value (a*) was 2.32 ± 0.05, and the yellowness–blueness value (b*) was 16.16 ± 0.26. These results indicate that the paper had a light-yellow color.

Figure 2: Sugar palm fruit shell paper: front side (left) and back side (right).

Table 1: The color of sugar palm fruit shell paper

Sample	Color coordinates		
	L*	a*	b*
sugar palm fruit shell paper	81.99±0.30	2.32±0.05	16.16±0.26

Table 2: Satisfaction level of sugar palm fruit shell paper

Satisfaction level of sugar palm fruit shell paper	Mean	Standard deviation	Level
Surface texture	4.02	0.72	Good
Color	4.23	0.76	Good
Visual appeal	4.29	0.67	Good
Tensile strength	3.90	0.89	Good
Uniformity of thickness	3.87	0.88	Good
Sheet formation	4.02	0.73	Good
Suitability for product development	4.24	0.76	Good
Overall characteristics of the paper	4.22	0.68	Good
Total	**4.10**	**0.58**	**Good**

The majority of respondents were female (68.3%), while males accounted for 31.7%. In terms of age, most respondents were between 20–29 years old (41.7%), followed by those under 20 years old (20.8%). Respondents aged 30–39 years accounted for 17.5%, those aged

40–49 years for 11.7%, and respondents aged 50–59 years and 60 years or older accounted for only 5% and 3.3%, respectively.

Table 2 shows the satisfaction levels of the sugar palm fruit shell paper. The results indicated that the highest satisfaction was in terms of appearance (mean = 4.29), followed by suitability for product development, paper color, overall characteristics, sheet formation, strength, and surface texture, respectively. The uniformity of thickness was rated lowest (mean = 3.87), but still within a high level of satisfaction.

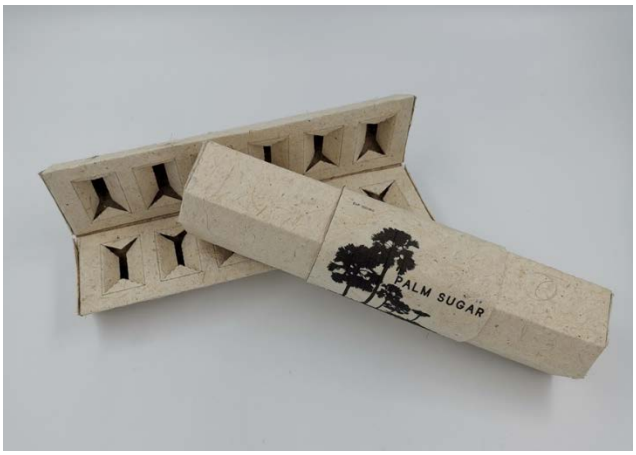

Figure 3: A prototype packaging for palm sugar cubes made from sugar palm fiber paper

The products derived from sugar palm processing in the "Nam Tan Sod" Village, Pak Nam Subdistrict, Bang Khla District, Chachoengsao Province, include sugar palm cubes. The packaging design was developed based on the Design for the Environment (DfE) concept, which aims to promote environmental awareness among both producers and consumers. This concept emphasizes environmental preservation, health and safety, sustainable use of resources, and product life cycle considerations.

The design concept was inspired by the natural characteristics of the sugar palm tree and incorporated paper made from sugar palm fruit shells. The natural color of the paper was maintained and combined with black printing to enhance visual contrast while preserving an eco-friendly appearance. The packaging prototype was designed to conveniently contain sugar palm cubes and to present an attractive, environmentally responsible appearance that appeals to consumers as shown in Figure 3.

Discussion

The findings of this study demonstrate that sugar palm fruit shells can serve as a viable alternative source of cellulose fiber for sustainable paper production. The alkali pulping and hydrogen peroxide bleaching processes were effective in breaking down lignin and producing a light-colored, uniform fiber structure, comparable to other agricultural residue-based papers such as pineapple fiber paper reported by Ohama et al. (2024). The high L*, a*, and b* values confirmed that the paper possessed natural brightness and warmth, which are desirable characteristics for eco-friendly and aesthetically pleasing packaging applications.

The positive satisfaction results from 120 respondents indicate that consumers recognized the quality and visual appeal of the sugar palm fruit shell paper. High satisfaction in appearance and product suitability suggests that this material aligns well with sustainable

design expectations. Although the uniformity of thickness received the lowest score, it remained within an acceptable range, implying that further process optimization could enhance the paper's consistency and quality.

Moreover, the successful application of the Design for Environment (DfE) concept in developing sugar palm cube packaging highlights the potential for integrating sustainability with local craftsmanship. This approach not only reduces agricultural waste but also adds economic value to the community through environmentally responsible product innovation. Future research should focus on improving the mechanical properties, durability, and scalability of the production process to strengthen its commercial potential and expand its applicability in sustainable packaging industries.

Conclusion

This study successfully produced paper from waste sugar palm fruit shells as an alternative cellulose source for sustainable packaging. The pulping and bleaching processes yielded light-yellow paper with uniform texture and suitable characteristics for packaging applications. Color analysis and satisfaction results from 120 respondents confirmed its desirable appearance and product potential. The packaging prototype for sugar palm cubes, developed under the Design for Environment (DfE) concept, effectively integrated environmental awareness with functional and aesthetic design. Overall, sugar palm fruit shell paper demonstrates strong potential as an eco-friendly material that supports sustainable resource utilization and community-based product development.

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References

Belyamani, I., Alameri, A., & Soghman, J. (2026). Sustainable paper production from date palm and reed leaves through the valorization of agricultural waste products. *Next Materials*, *10*, Article 101392.

Bussaban, K., & Chumee, J. (2019). From coconut husk waste to community business. In W. Karwowski & T. Ahram (Eds.), *Advances in human factors, business management and society* (pp. 229–238). Springer.

Ilyas, R. A., Sapuan, S. M., Ibrahim, R., Abral, H., Ishak, M. R., Zainudin, E. S., Atikah, M. S. N., Mohd Nurazzi, N., Atiqah, A., Ansari, M. N. M., Syafri, E., Asrofi, M., Herlina Sari, N., & Jumaidin, R. (2019). Effect of sugar palm nanofibrillated cellulose concentrations on morphological, mechanical, and physical properties of biodegradable films based on agro-waste sugar palm (*Arenga pinnata* (Wurmb.) Merr) starch. *Journal of Materials Research and Technology*, *8*(5), 4819–4830.

Inkuer, A. (2024, February). Creating an image with diversity from native plants in nutrition in Phraek Nam Daeng Subdistrict, Amphawa District, Samut Songkhram Province. In *Proceedings of the International Academic Multidisciplinary Research Conference in Venice 2024* (pp. 45–49). IRTC.

Nkeudem, A. G., Metuge, S., Mabel, K. F., Ning, T. R., & Ngole, S. I. U. (2023). Hand-made paper produced from pineapple leaves (*Ananas comosus*) as a potential material for food packaging. *Journal of Tertiary and Industrial Sciences*, *3*(1), 65–79.

Ohama, P., Kumpun, S., Pattanayaiying, R., & Chumee, J. (2024). Product development of pineapple paper from pineapple (*Ananas comosus*) waste materials for sustainability of pineapple farmer community. In *Proceedings of the International Conference on Technology, Education, Management, and Sustainability (ICTEMS)* (pp. 39–45). ICTEMS.

Tossawut, T., Rojpitakkul, L., & Lobdhom, P. (2022). Local wisdom on palm sugar production and adaptation of the Palm Juice Village, Pak Nam Sub-district, Chachoengsao, Thailand. *PSAKU International Journal of Interdisciplinary Research*, *11*(2), 101–115.