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Dyeing of screw pine (*Pandanus tectorius*) leaves using natural dyes from local plants in Songkhla Province, Thailand

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Abstract

This study had investigated and discussed the dyeing of screw pine (*Pandanus tectorius*) leaves by using natural dyes from four local plants, namely, turmeric rhizomes, as well as teak, mango, and mangosteen leaves, found in Songkhla Province, Thailand. A sample of screw pine leaves were dyed using 2% aluminum potassium sulfate ($KAl(SO_4)_2$) for the dye mordanting process, which resulted in good color adhesion. Dyes obtained from turmeric rhizomes, as well as teak, mango, and mangosteen leaves produced yellow, reddish-purple, yellow-green, and orange colors, respectively. The color coordinate of the four dyes was investigated and reported. The tensile properties test showed that the dyed screw pine leaves exhibited good strength. Moreover, ozone treatment was found to decontaminate microbes and enhance the storage stability of the materials. The technology was then transferred to the Screw Pine Handicraft Community in Khlong U-Tapao River Basin, Songkhla Province, Thailand. This transfer of knowledge will enable the community to produce various different dyed screw pine leaf products that would generate a source of sustainable income.

Keyword: Basketry products, Community engagement, Natural dyes, Screw pine

1. Introduction

Thailand is a country blessed with an abundance of natural resources and the potential to utilize these natural resources to produce nature-based products. Thailand's basketry products are an example of a nature-based product. Some examples of plants used in basketry production are krachood (*Lepironia articalata*) [1], papyrus reed (*Cyperus involucratus* Roxb) [2], bamboo (*Bambusoideae*) [3], Yan lipao (*Lygodium flexuosm*), and screw pine (*Pandanus tectorius*). A variety of natural fibers are used, both in its original or modified form, in the production of basketry products. In ancient times, most of the color of these basketry products were the original color from the plants used in the production. However, products with colored patterns attract buyers and have become a trend these days because they are more distinct, fascinating, and fashionable, which is why this type of dyeing process is practiced by manufacturers nowadays. Since the discovery of aniline dyes from coal tar [4], synthetic dyes have been commonly used in numerous industries. There are over 10,000 different types of chemical dyes used in the dyeing industry. In addition, more than 700,000 tons of colored chemicals are used globally and approximately 200,000 tons of these synthetic dyes are released into the environment annually, which unfortunately causes environmental pollution. Many people have become interested in natural dyes from plants as it does not involve any chemical processing [5,6].

Screw pine (*Pandanus tectorius*) is a monocotyledon (genus: *pandanus,* family: *pandanaceae*). The plants in this family are perennials or ivy and are found at sea level, islands, beaches or wetlands. Screw pine is a plant species native to Thailand, Malaysia, Eastern Australia, and the Pacific Ocean islands. Its dominant feature is its ligulate leaves (sword-shaped with thorns in three positions on the edges of both sides and at the bottom middle surface of the leaves) (Figure 1(A)). The screw pine grows in saline soil and its leaves, hardwood, roots, and fruits are useful for a variety of purposes, such as handicraft, construction, medicine, fuel, etc. [7-9].

In Southern Thailand, the screw pine is utilized for making basketry products (Figure 1 (B)), which are products that have been inherited since ancient times and used as a household product. This plant can be used for making a variety of basketry products, including mats, handbags, wallets, basket, business card holders, and food containers [10]. The production of screw pine-based basketry product involves plant fibers that are used in their original form or sometimes colored with dyes to add a color pattern or design to the product to make it more distinct and attractive. Screw pine basketry entrepreneurs have used chemical dyes, such as fabric dyes, silk dyes, reed dyes etc., because of its advantages, such as color variety, durability (even when washing), UV resistance, heat resistance, and a range of usability for all kinds of fibers. However, some chemical dyes contain carcinogenic compounds; hence, exposure to these chemicals can be harmful during the dyeing process and in contaminated effluents, which causes residues in the environment and thereby affects the ecosystem [11,12].

Figure 1 Screw pine (*Pandanus tectorius*) (A) and a product (handbag) made from the screw pine leaf (B).

Natural dyes are made from natural products, such as barks, berries, and leaf extracts, to create a variety of colors and have been used for dyeing purposes for centuries [10]. Several types of plants are also used, including sappan bark (red dye), turmeric (yellow) and indigo (blue). The current trend of using natural colors is more popular and of great demand. When compared to chemical dyes, natural dyes are more environment-friendly and provide more appealing colors [13-16]. This study reports on the dyeing of screw pine using plant extracts, namely four plant extracts (turmeric, teak, mango, and mangosteen) that are found in abundance in Songkhla province, Thailand. This participatory action research (PAR) was performed with the help of members of the Screw Pine Handicraft Community in Khlong U-Tapao River Basin, Songkhla Province, Thailand.

2. Materials and methods

2.1 Preparation of screw pine leaves

The fresh screw pine leaves were collected from Khlong U-Tapao River Basin in Songkhla Province, Thailand. The leaves were dried under the sunlight for 1 hour, cut into strips measuring 1 cm x 100 cm and sun-dried again for 1 day. Finally, the dried screw pine leaves were boiled in hot water for 30 minutes to remove contaminants and to activate the surface. The leaves were then ready for the dyeing process.

2.2 Preparation of natural dyes

Turmeric rhizomes as well as teak, mango, and mangosteen leaves (Figures 2 (A-D)) were collected from Songkhla Province, Southern Thailand. As for the turmeric, its rhizomes were used to extract the natural dye by first washing it thoroughly with tap water, cutting it into small pieces of approximately 1 cm, blending it in a blender (Otto, BE-127A), and lastly, storing it in a plastic bottle at room temperature until needed. As for the teak, mango, and mangosteen, the leaves were washed with tap water to remove residue, cut into small pieces of approximately 1 cm, and stored in a plastic bottle at room temperature until needed.

2.3 Dyeing the screw pine leaves

The sun-dried screw pine leaves were dyed with dyes extracted from turmeric, teak, mango, and mangosteen. 100 g of prepared screw pine leaves were placed in a 20 L steel pot for the dyeing process with turmeric extract. The turmeric powder (1 kg) was poured into the pot followed by water (10 L). The ratio of screw pine leaves to turmeric extracted dye to water was 1:10:10 % w/w. All the materials were boiled for 12 hours and then 100 g of sodium chloride (NaCl) was added as an electrolyte to enhance migration, adsorption and fixation of the dyestuff to the screw pine leaves. The mixture was boiled continuously for 4 hours while being stirred every 15 minutes. The dye solution (50 mL) was collected and analyzed for color property using a colorimeter (Hunter Lab, Konica; Japan). The dyed screw pine leaves were then washed 3 times with water to remove excess dye until no color effluent was observed. They were then processed for the dye mordanting process by immersing 100 g of dyed screw pine leaves into 500 mL of 2.0% $KAl(SO_4)_2$ for 30 minutes and then left to dry in the shade for 24 hours.

Characteristics of the screw pine leaves dyed with colors extracted from turmeric rhizome and the teak, mango, and mangosteen leaves were then investigated for their color coordinates (L, a* and b*) by using a colorimeter (Hunter Lab, Konica; Japan).

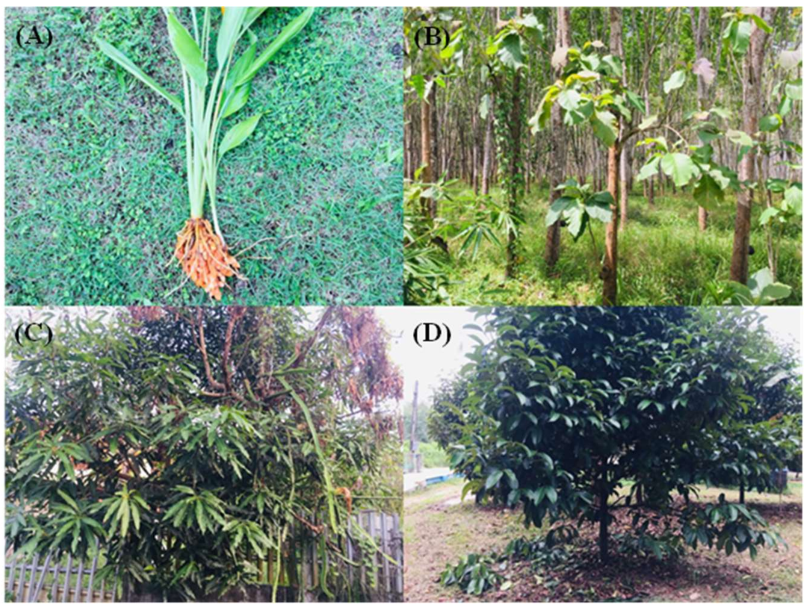

Figure 2 Local plants used for the preparation of dyes are (A) turmeric rhizome, (B) teak, (C) mango and (D) mangosteen.

2.4 Tensile properties of dyed screw pine leaves

The dyed screw pine leaf sample was investigated for tensile properties. The experimental set up and testing procedure had adhered to the ASTM D 2556-02 standard [17]. A tensile tester (Universal Testing Machine, UTM-H50KS, HOUNSFEILD) was used for investigating the breaking force and % elongation.

2.5 Preservation of dyed screw pine leaves with ozone

One persistent challenge in the storage of basketry products is the contamination of microorganisms, like bacteria, yeast, and mold. The dyed screw pine leaves in this study were treated with ozone, as suggested by Podkumnerd *et al*. (2023). The leaves were placed in an ozone treatment cabinet for 5 hours with an ozone concentration of 750 mg/h. Then, they were stored in a sealed bag and kept for 1 month, after which they were tested for fungal contamination using the Rose Bengal Chloramphenicol Agar (RBCA) (AOAC, 2005) and compared to the control sample.

3. Results and discussion

3.1 Physical characteristics of dyes obtained from local plants

Based on the investigation of the physical characteristics of dyes extracted from the four plants, it was found that the turmeric rhizome dye was yellow, as shown in Figure 3(A). The turmeric's yellow color is due to the curcumin pigment, which occurs in three analogues of curcumin and belongs to the diferuloylmethane class, namely, curcumin I (60%), curcumin II (24 %) and curcumin III (14 %) [15]. Meanwhile, the teak leaves gave of a reddish-purple color (Figure 3(B)) due to the high anthocyanin content present in the leaves [18,19]. The dye from mango leaves gave of a yellow-green color (Figure 3(C)) due to a large concentration of flavonoids [5,20,21] while the dye from the mangosteen gave of an orange color (Figure 3(D)) as the main component in mangosteen leaves is tannin [13]. The color coordinates of the four dyes were investigated and the lightness (L), green-red (a*) and blue-yellow (b*) values are reported in Table 1.

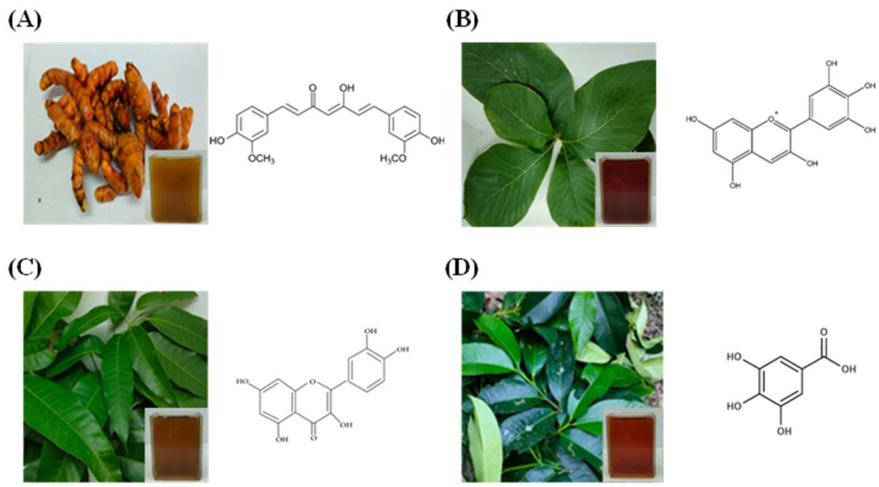

Figure 3 Color of the dyes and their main chemical structure in (A) turmeric rhizomes, (B) teak leaves, (C) mango leaves and (D) mangosteen leaves.

Turmeric dye imparted the highest lightness (L = 30.83±0.31) since the dye's color was yellow and the color tone was lighter than the other dyes extracted from teak, mango, and mangosteen. Turmeric extract is known for its brilliant color component (curcumin) as it imparts a fluorescent effect [15].

Table 1 Color coordinates of dyes extracted from turmeric rhizomes as well as teak, mango and mangosteen leaves.

Color	Plants			
coordinate	Turmeric rhizomes	Teak leaves	Mango leaves	Mangosteen leaves
L	30.83±0.31	25.07±0.70	23.47±0.45	24.30±0.50
a*	5.53±0.50	4.43±0.40	6.47±0.45	4.70±0.46
b*	13.77±0.71	4.53±0.31	6.13±0.45	4.37±0.35

3.2 Dyeing of screw pine leaves

The dyeing of screw pine leaves with dyes extracted from four plants using 2% $KAl(SO_4)_2$ as mordant is shown in Figure 4 (A-D). As compared with other dyes, the screw pine leaves show good dyeing effects as well as the production of color similar to that of the dyes. Screw pine leaves dyed with turmeric rhizomes, as well as teak, mango, and mangosteen leaves exhibited dark yellow, pinkish red, light yellow and brown colors, respectively.

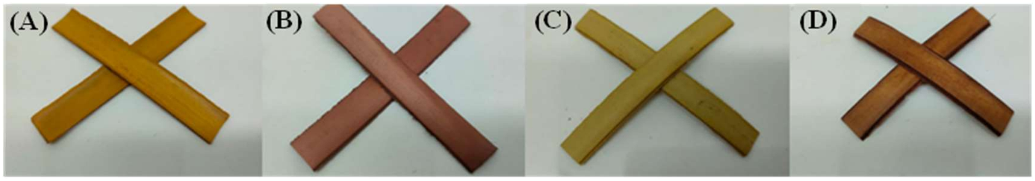

Figure 4 Characteristics of screw pine leaves dyed using local plants, such as (A) turmeric rhizomes, (B) teak leaves, (C) mango leaves and (D) mangosteen leaves.

Table 2 shows the color measurement of screw pine leaves dyed with dyes extracted from the four plants. The color coordinate of dyes from turmeric were 58.40 (L), 19.80 (a*) and 54.47 (b*), respectively. This shows that the color from turmeric rhizomes can be used to dye the surfaces of screw pine leaves. The color coordinates of dyes from teak, mango, and mangosteen leaves are summarized in Table 2. The four dyes extracted from four different plants do provide a variety of colors.

Table 2 Color coordinates of screw pine leaves dyed with dyes extracted from turmeric rhizomes as well as teak, mango, and mangosteen leaves.

Color coordinates	Plants			
	Turmeric	Teak	Mango	Mangosteen
L	58.40±0.40	49.60±0.36	62.47±0.45	44.53±0.31
a*	19.80±0.20	25.43±0.31	11.43±0.40	25.43±0.40
b*	54.47±0.45	23.33±0.31	36.37±0.40	33.43±0.45

3.3 Tensile properties of dyed screw pine leaves

The tensile properties of screw pine leaves before and after dyeing were investigated. Figure 5 shows the breaking force (N) and % of elongation of the tested samples. In Figure 5 (A), the breaking force of screw pine leaves dyed with dyes extracted from turmeric rhizome as well as teak, mango, and mangosteen leaves and the control sample were 185.67±29.26, 195.33±25.38, 111.33±17.03, 157.00±47.03, and 191.33±59.10 N, respectively. These breaking forces were not significantly different at a 95% confidence level based on the One-way ANOVA test. Figure 5 (B) depicts the dyed screw pine samples' % of elongation, with the control sample exhibiting an elongation of 3.94±0.95. A slight decrease in elongation was observed in the dyed screw pine samples; however, this decrease was not statistically significant. Overall, the investigation into the tensile properties indicated that dyeing screw pine leaves with natural substances through boiling can be an effective method that does not adversely affect the strength properties of the screw pine leaves.

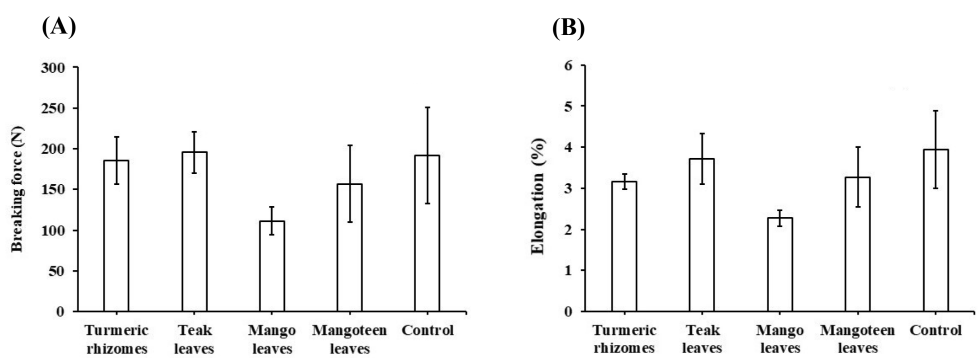

Figure 5 Tensile properties - (A) breaking force (N) and (B) % of elongation of screw pine leaves dyed with extracts from turmeric rhizome, as well as teak, mango, and mangosteen leaves and the control sample were investigated based on the ASTM D 2256-02 standard.

3.4 Microbial contamination of screw pine leaves preserved by ozone.

The effect of ozone treatment on microbial decontamination was investigated. The dyed screw pine leaf samples were treated with ozone at a 750 mg concentration for 5 hours and kept in a sealed plastic bag for 1 month. At the beginning of the investigation, all samples showed microbial contamination. Microbial contamination increased in the untreated samples, which indicates that microbes can grow during storage. However, when treated with ozone, no microbes were detected, which suggests that ozone treatment is an efficient technique for arresting microbial contamination. The results are shown in Table 3.

Table 3 Effect of ozone treatment on microbial decontamination

Source of dyes	Started (log cfu/g)	Untreated (log cfu/g)	Ozone Treated (log cfu/g)
Turmeric	1.55 ± 0.13^{c}	1.93 ± 0.08^{b}	N.D.
Teak	1.46 ± 0.15^{bc}	2.14 ± 0.15^{ba}	N.D.
Mango	1.34 ± 0.12^{bc}	$2.10\pm0.15b^{a}$	N.D.
Mangosteen	1.22 ± 0.24^{b}	2.09 ± 0.09^{ba}	N.D.
control	1.92 ± 0.08^{a}	2.34 ± 0.12^{a}	1.1 ± 0.17^{a}

* The different letters in each column represent the comparison of mean by method. Duncan's multiple range test (DMRT) indicated a 95% confidence interval

3.5 Technology transfer

As there are several products that can be created out of the dyed screw pined leaves, hence, knowledge pertaining to the dyeing technology was transferred to the Screw Pine Handicraft Community in Khlong U-Tapao River Basin, Songkhla Province, Thailand, as shown in Figure 6 (A-C).

Figure 6 Technology and knowledge transfer pertaining to dyeing screw pine leaves using dyes extracted from plants found in the community: (A) preparation of the dye; (B) dyeing of screw pine leaves; and (C) production of products made from dyed screw pine leaves.

The community can create new products such as place mat, bow and tissue box (Figure 7 (A-C)) out of dyed screw pine leaves. The use of dyed screw pine leaves with different colors provides an option for designing these products. This can generate a sustainable income and further strengthen the practice of using natural resources in a sustainable manner in the community.

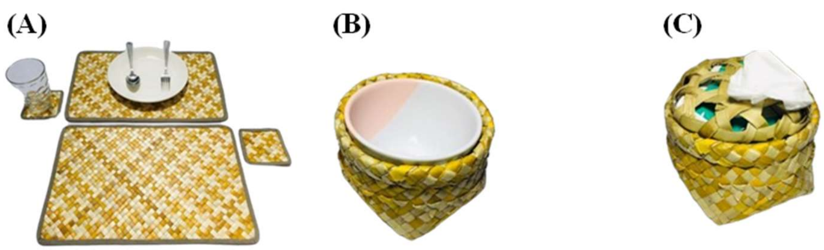

Figure 7 Examples of products made from dyed screw pine leaves, such as (A) place mat, (B) bowl jacket and (C) tissue box.

4. Conclusion

This study presented the use of dyed screw pine leaves in basketry production. This type of leaf is abundantly found in Songkhla province, Thailand, but its utilization is limited. This study focused to the development of a dyeing technique for screw pine leaves using four local plants, namely, turmeric, teak, mango and mangosteen. The preparation of the dyes from these plants was easy, fast and suitable to be implemented in the community.

Results show that the dyes produce a variety of colors with promising physical properties, and this opens up the possibility for designing attractive basketry products. Ozone treatment can reduce microbial contamination, which then increases storage time and consumer safety. This current study focused on using various types of plants to create a variety of colors to produce innovative products that can generate a form of sustainable income for the community. Moreover, this study will certainly contribute to the preservation of knowledge pertaining to screw pine weaving amongst the Screw Pine Handicraft Community in Khlong U-Tapao River Basin, Songkhla Province and, hopefully, pass that knowledge on to the next generation.

5. Acknowledgement

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