Quality of Mud Fermented Natural Dyeing of Water Hyacinth Strands

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Abstract

The objectives of this study were 1) to test the mud fermented natural dyeing process of water hyacinth strands; 2) to examine the quality of colour adhesion of water hyacinth strands after fermented natural dyeing. The study method consists of 3 steps. Step 1: Preparing water hyacinth strands as raw material by taking 2 forms of water hyacinth strands including round strands and spiral strands from the same source of raw materials to be used as test sample materials. Step 2: Proceeding fermented natural dyeing of water hyacinth strands using 4 kinds of natural materials: mud, dried eucalyptus bark, fresh mango leaves, and fresh avocado leaves; applying cold dyeing process or fermented dyeing process for a period of 7 days at room temperature; randomly collecting samples every day, cleaning and drying them in a hot air oven at 40°C for 8 hours. Step 3: Measuring the colours of the samples with a Colourimeter (CIE lab) and recording their colours each day along with the use of systematic photographing techniques to compare colour differences after dyeing. The study results reported the quality of fermented natural dyeing of water hyacinth strands with the 4 natural materials using cold dyeing or fermentation dyeing for a period of 7 days that increased fermentation duration resulted in different colours. Fermented in mud, the round strands showed the values of (L*) in a range of 54.58 - 57.10, whereas the spiral strands showed the values of (L*) in a range of 48.10 - 42.60, with (+a*) indicating red, and (+b*) indicating yellow. Fermented with dye from dried eucalyptus bark, the round strands showed the values of (L*) in a range of 64.15 - 58.10, whereas the spiral strands showed the values of (L*) in a range of 59.51 -. 48.40, with (+a*) indicating red and (+b*) indicating yellow. Fermented with the dye of fresh mango leaves, the round strands showed the values of (L*) in a range of 64.82 - 49.28, whereas the spiral strands showed the values of (L*) in a range of 44.40 - 38.91, with (+a*) indicating red and (+b*) indicating yellow. Fermented with dye from fresh avocado leaves, the round strands showed the values of (L*) in a range of 64.28 - 64.20, whereas the spiral threads showed the value of (L*) in a range of 55.23 - 52.03, with (+a*) indicating red and (+b*) indicating yellow.

Keywords: Fermented natural dyeing, Mud fermentation, Round strands, Spiral strands

Introduction

Textile industry is now one among the largest scale industries in the world. As the production process becomes easier and moves along with rapidly changing trends, in many cases, used handicrafts were discarded as waste, thus causing more severe environmental problems. The industry emits more pollutions, uses larger amount of water than any other sector. It regularly releases toxic chemicals, and also consumes a huge volume of energy. Currently, most handicrafts are not biodegradable. This has led to the awareness of the need to develop products that take-into account the impact on people, society and the environment. This study explores techniques and methods make use of natural materials. Among them is the use of natural dyes as a potential substitute to synthetic dyes in industrial and handicraft processes. Today, in small and medium-sized enterprises, the production process still relies on chemical dyes for product dyeing. Synthetic dyes produced from chemical reactions that offer colour fastness are still used in fabric dyeing and silk dyeing. These dyes are easy to use and cost less that other dyes. Research results on synthetic dyeing processes using other materials were found to contain heavy metals which contaminate the environment are carcinogenic and toxic to consumers, whether in the form of pure elements, organic compounds, or inorganic compounds (Department of Science Service Journal, 2018). These elements are hazardous and have been linked to various diseases of the respiratory system, as well as a number of skin diseases. Accumulated chemicals used in the product dyeing process, may endanger the safety of workers involved in the dying processes (Rath Chompuphan and Chanakarn Ruangnarong, 2023). Residues of chemically contaminated wastewater in the environment may have negative effects on consumers if this water is fed into the local communal water supply.

In the past, dyeing utilized natural dyes extracted from locally available plants to dye various products according to local knowledge that has been passed down from generation to generation. The raw materials are processed to extract the colour which would be used make natural dyes. The water used comes from many sources, for example, natural dyes may be processed from fermented mud. Natural dyes may also be extracted from plants such as dried eucalyptus bark, fresh mango leaves, fresh avocado leaves, etc. These materials give the naturally dyed products a unique colour appearance. Other than the colour properties that make these products stand out, natural dyes do no harm to users and leave no residues in the environment. The current trend of natural dye products shows increasing popularity and demand among consumers since they have turned to focus more on their personal health and the environment. Natural materials or natural dye products are thus able to satisfy consumer needs and reduce concerns about chemicals used in the production process.

Recognizing the importance of using environmentally-friendly processes of product development, the researcher therefore conducted this study to explore the use of natural raw materials to develop natural dyes so as to produce high value wickerwork products without using chemicals that may be harmful to the environment and consumers. A cold dyeing process or a natural fermented dyeing process were chosen as dyeing the method. It utilizes plants and natural materials without applying heat but relying on the natural properties of pigments from natural chemical reactions to help with the colour adhesion of water hyacinth strands. This could guide the improvement of distinctiveness of water hyacinth dyeing and maximize the use of local raw materials that provide uniqueness to water hyacinth wickerwork products.

Objectives

1. To test the natural dyeing process of mud-fermentation of water hyacinth strands.
2. To examine the quality of colour adhesion of water hyacinth stands after the process of fermented natural dyeing.

Methodology

The research method to study the relevant research objectives, employed an experimental approach aimed at examining the quality of mud fermented natural dyeing of water hyacinth strands, following the procedures described below.

Step 1: Preparing material of water hyacinth strands

Step 2: Proceeding fermented natural dyeing of water hyacinth strands

2.1 Mud-fermented natural dying

2.2 Fermented natural dyeing with dried eucalyptus bark, fresh mango leaves, and fresh avocado leaves.

Step 3: Testing the colour values of water hyacinth strands

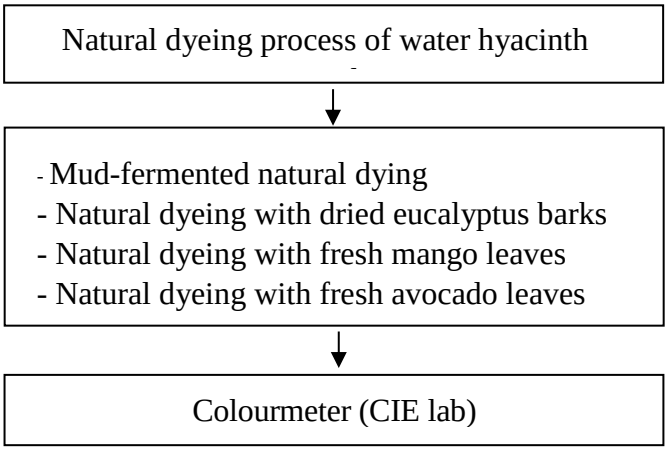

Figure 1 Conceptual framework of research method

Step 1 Preparing raw materials

Take water hyacinth stands in 2 forms of 1) round strands, and 2) spiral strands, from the same source of raw materials, and cut them into lengths of about 20 cm long to be used as material samples of water hyacinth strands in the experiment of fermented natural dyeing.

Figure 2 Preparing raw materials of water hyacinth in 2 forms:
1) Round strands, and 2) Spiral strands

Step 2: Fermented natural dyeing of water hyacinth strands

2.1 Mud-fermented natural dyeing

Prepare mud liquid for fermentation by bringing the mud to sun-dry, remove weeds from the mud, and finely grind the mud. Dissolve the finely ground mud in water at a ratio of 3 kg of ground mud to 3 liters of water and filter it with screen net to separate mud from unwanted organic particles.

Figure 3 Preparing mud liquid for fermentation

The process of mud-fermented natural dyeing was carried out by bringing the 2 forms of water hyacinth strands, 1) round strands and 2) spiral strands to ferment in 6 litres of mud liquid for 7 days at room temperature. Randomly collect the samples every day, wash and clean them and bring them to oven-dry using a hot air oven at the temperature of 40°C for 8 hours. After that, measure the colour values using a Colourmetre (CIE lab), and record the results each day along with using the systematic photographing technique to compare colour differences after dyeing.

2.2 Fermented natural dyeing with dried eucalyptus bark, fresh mango leaves, and fresh avocado leaves.

Figure 4 Dried Eucalyptus Bark

Bring both forms of water hyacinth strands i.e. 1) round strands and 2) spiral strands to dye in natural dye water made from 1) dried eucalyptus bark, 2) fresh mango leaves, and 3) fresh avocado leaves. Roughly cut or chop the materials until you have 300 g and soak them in 3 litres of water and leave for 2 hours. After that, bring them to a boil at 100°C for 1 hour, and filter the natural dye water with a white linen cloth. Add 50 g of alum and 50 g of salt into the dye water. Dye water hyacinth strands by a cold dyeing process or using the fermentation dyeing process for a period of 7 days at room temperature. Randomly collect the samples every day, wash and clean them and oven-dry using a hot air oven at 40°C for 8 hours. After that, measure the colour values using a Colourmetre (CIE lab), record the results each day along with using a systematic photographing technique to compare colour differences after dyeing.

Figure 5 Fermented natural dyeing with dried eucalyptus barks

Figure 6 Fermented natural dying with fresh mango leaves

Figure 7 Fermented natural dyeing with fresh avocado leaves

Step 3: Testing the colour values of water hyacinth strands

Measuring colour values with a Colourmetre (CIE lab) is to use the system to measure colours or characterize colours instead of relying on using human vision because colour perception is based on individual experience with different interpretations. It has often been found that each person describes the colour of the same thing differently. Therefore, colour measurements have been developed to provide numeric values consistently identifying colour differences without relying on human experience or thought to measure colours. Colour values are characterized as follows:

Colourmetre CIE L* a* b*)	Interpretation
L* Axis indicates lightness	L* = 0 means blackness L* = 100 means whiteness
a* Axis represents redness – greenness	(-a*) means greenness (+a*) means redness
b* Axis represents yellowness – blueness	(-b*) means blueness (+b*) means yellowness

Results

The result reported the quality of fermented natural dyeing of water hyacinth strands using different kinds of natural raw materials including 1) mud, 2) dried eucalyptus barks, 3) fresh mango leaves, and 4) fresh avocado leaves, through a natural dyeing process of cold dyeing or fermentation dyeing for a period of 7 days. The test with colourmeter (CIE L* a* b*) provided colour values of different types of natural materials and the quality of colour adhesion on 2 forms of water hyacinth strands: 1) round strands and 2) spiral strands as shown in Table 1.

Table 1 Colour values of round and spiral strands of water hyacinth using mud-fermented natural dyeing

Number of Dyeing day	Appeared Colour	Colour Value Water Hyacinth Strands (Round)			Appeared Colour	Colour Value Water Hyacinth Strands (Spiral)		
		L*	a*	b*		L*	a*	b*
Control		$88.20^{a}\pm 2.51$	$9.04^{a}\pm 2.13$	$30.50^{a}\pm 0.63$		$66.26^{a}\pm 1.84$	$9.20^{a}\pm 0.93$	$24.13^{a}\pm 3.06$
Day1		$54.58^{bc}\pm 2.51$	$1.10^{c}\pm 0.78$	$14.44^{d}\pm 0.79$		$48.10^{bc}\pm 0.92$	$2.23^{e}\pm 0.38$	$11.70^{d}\pm 0.61$
Day2		$53.82^{bc}\pm 2.30$	$2.10^{b}\pm 0.81$	$15.20^{d}\pm 2.43$		$46.20^{cd}\pm 1.12$	$2.70^{de}\pm 0.29$	$12.50^{cd}\pm 1.00$
Day3		$50.51^{c}\pm 1.45$	$2.20^{b}\pm 0.33$	$13.71^{d}\pm 1.83$		$46.60^{cd}\pm 1.82$	$4.10^{b}\pm 0.23$	$16.20^{b}\pm 1.39$
Day4		$51.74^{c}\pm 2.74$	$2.64^{b}\pm 0.44$	$15.60^{d}\pm 0.17$		$44.70^{de}\pm 1.85$	$3.70^{bc}\pm 0.38$	$14.70^{bcd}\pm 0.90$
Day5		$54.10^{bc}\pm 1.86$	$2.98^{b}\pm 0.56$	$16.10^{cd}\pm 1.08$		$50.20^{b}\pm 1.11$	$2.90^{cde}\pm 0.34$	$15.10^{bc}\pm 0.95$
Day6		$56.20^{b}\pm 2.85$	$2.90^{b}\pm 0.87$	$18.23^{bc}\pm 1.78$		$48.62^{bc}\pm 1.25$	$3.20^{cd}\pm 0.51$	$15.60^{bc}\pm 1.05$
Day7		$57.10^{b}\pm 1.10$	$2.62^{b}\pm 0.52$	$18.70^{b}\pm 0.33$		$42.60^{e}\pm 1.72$	$3.22^{cd}\pm 0.27$	$12.64^{cd}\pm 2.40$

Remark: Different letters shown vertically indicate statistically significant difference at a confidence level of 95%

Table 1 reports the round and spiral water hyacinth strands in mud-fermented natural dyeing for 7 days, suggesting that increased time of mud-fermentation of the strands resulted in significant reduction of lightness (L*) with day 4 and day 5 showing the lowest (L*) as 50.51 and 51.74, respectively. As for the value of redness or greenness (a*), the increased time had no significant effect on (a*). The value of yellowness or blueness (b*) was found to be highest as 18.70 on day 7, whereas (b*) were lowest but not statistically different during day 1 to day 4, equaling 14.44, 15.20, 13.71 and 15.60, respectively.

The spiral strands fermented in mud for an increased period of time resulted in a statistically significant decrease in brightness (L*), with the lowest (L*) of 42.60 on day 7. The value of redness or greenness (a*) was found to be lowest as 2.23 on day 1. As for the value of yellowness or blueness (b*), increased fermentation time had no statistically significant effect on (b*).

Table 2 Colour values of round and spiral water hyacinth strands using fermented natural dying with dried eucalyptus barks

Number of Fermentation Day	Appeared Colour	Colour Value – Water Hyacinth Strands (Round)			Appeared Colour	Colour Value – Water Hyacinth Strands (Spiral)		
		L*	a*	b*		L*	a*	b*
Control		$88.20^{a}\pm 2.51$	$9.04^{a}\pm 2.13$	$30.50^{a}\pm 0.63$		$66.26^{a}\pm 1.84$	$9.20^{a}\pm 0.93$	$24.13^{a}\pm 3.06$
Day1		$64.15^{cd}\pm 0.97$	$9.64^{bc}\pm 0.14$	$28.63^{abc}\pm 0.09$		$59.51^{b}\pm 1.45$	$11.42^{c}\pm 0.33$	$27.91^{cd}\pm 0.51$
Day2		$68.73^{b}\pm 1.17$	$7.19^{d}\pm 1.21$	$28.08^{bc}\pm 1.55$		$59.48^{b}\pm 0.30$	$10.88^{c}\pm 1.06$	$27.94^{cd}\pm 1.89$
Day3		$62.65^{d}\pm 0.51$	$10.94^{bc}\pm 1.52$	$28.16^{bc}\pm 1.73$		$59.27^{b}\pm 0.94$	$12.01^{bc}\pm 0.23$	$29.75^{ab}\pm 0.69$
Day4		$64.96^{c}\pm 0.12$	$11.22^{ab}\pm 0.49$	$29.89^{ab}\pm 1.01$		$58.31^{b}\pm 0.48$	$11.14^{c}\pm 0.08$	$28.69^{bc}\pm 0.30$
Day5		$62.72^{d}\pm 1.21$	$9.33^{bc}\pm 0.95$	$26.75^{c}\pm 1.40$		$45.32^{d}\pm 0.44$	$14.62^{a}\pm 0.58$	$25.43^{e}\pm 0.82$
Day6		$53.40^{f}\pm 0.57$	$13.15^{a}\pm 0.14$	$27.48^{c}\pm 0.22$		$46.48^{cd}\pm 0.26$	$13.47^{ab}\pm 0.47$	$25.75^{e}\pm 0.46$
Day7		$58.10^{e}\pm 0.25$	$11.12^{bc}\pm 0.60$	$29.73^{ab}\pm 1.23$		$48.40^{c}\pm 0.52$	$13.93^{a}\pm 0.41$	$26.93^{e}\pm 0.75$

Remark: Different letters shown vertically indicate statistically significant difference at a confidence level of 95%

Table 2 reports the round and spiral water hyacinth strands in fermented natural dyeing with dried eucalyptus barks for a period of 7 days, suggesting that increased time had a significant effect on decreased brightness (L*) on day 6 and day 7, with the lowest (L*) of 53.40 and 58.10, respectively. The value of redness or greenness (a*) on day 6 was highest as 13.15. The values of yellowness or blueness (b*) on day 5 and day 6 were lowest but not statistically different, with (b*) of 26.75 and 27.48, respectively.

The spiral strands in fermented natural dyeing with dried eucalyptus barks for increased time resulted in a statistically significant decrease in brightness (L*). On day 5, (L*) value was lowest as 45.32, and during day 1 to day 4, (L*) values were not significantly different, equaling 59.51, 59.48, 59.27, and 58.31, respectively on day 1, day 2, day 3, and day 4. The value of redness or greenness (a*) on day 5 was highest as 14.62, and during day 1 to day 4, (a*) values were not significantly different, equaling 11.42, 10.88, 12.01, and 11.14, respectively on day 1, day 2, day 3, and day 4. As for the value of yellowness or blueness (b*), increased time had a statistically significant effect on (b*) value. On days 5, day 6, and day 7, (b*) values were found lowest as 25.43., 25.75, and 26.93 respectively.

Table 3 Colour values of round and spiral water hyacinth strands using fermented natural dying with fresh mangoes leaves

Number of Fermentation Day	Appeared colour	Colour Value Water Hyacinth Strands (Round)			Appeared Colour	Colour Value Water Hyacinth Strands (Spiral)		
		L*	a*	b*		L*	a*	b*
Control		$88.20^{a}\pm 2.51$	$9.04^{a}\pm 2.13$	$30.50^{a}\pm 0.63$		$66.26^{a}\pm 1.84$	$9.20^{a}\pm 0.93$	$24.13^{a}\pm 3.06$
Day1		$64.82^{b}\pm 1.87$	$12.28^{c}\pm 1.50$	$32.95^{b}\pm 0.38$		$44.40^{b}\pm 1.66$	$8.59^{d}\pm 0.08$	$20.81^{de}\pm 0.27$
Day2		$60.48^{c}\pm 1.44$	$14.27^{bc}\pm 1.18$	$33.63^{ab}\pm 0.44$		$42.80^{bc}\pm 0.46$	$11.43^{ab}\pm 0.63$	$23.01^{bcd}\pm 1.96$
Day3		$53.34^{d}\pm 0.68$	$16.17^{ab}\pm 0.83$	$29.83^{c}\pm 1.55$		$40.89^{cd}\pm 0.49$	$12.75^{a}\pm 0.13$	$24.58^{bc}\pm 0.59$
Day4		$65.47^{b}\pm 0.78$	$12.97^{c}\pm 0.92$	$35.04^{a}\pm 1.03$		$40.78^{cd}\pm 2.55$	$12.99^{a}\pm 0.91$	$25.24^{b}\pm 2.05$
Day5		$51.89^{de}\pm 1.02$	$17.66^{a}\pm 1.29$	$33.04^{b}\pm 0.91$		$39.78^{d}\pm 0.41$	$11.51^{ab}\pm 0.74$	$22.15^{cd}\pm 1.71$
Day6		$50.48^{e}\pm 1.41$	$16.34^{ab}\pm 0.22$	$30.50^{c}\pm 1.58$		$36.22^{e}\pm 1.07$	$10.49^{bc}\pm 0.35$	$19.08^{e}\pm 1.35$
Day7		$49.28^{e}\pm 0.99$	$15.52^{ab}\pm 1.84$	$29.57^{c}\pm 0.65$		$38.91^{d}\pm 1.46$	$11.67^{ab}\pm 0.48$	$21.68^{d}\pm 0.97$

Remark: Different letters shown vertically indicate statistically significant difference at a confidence level of 95%

Table 3 shows that the round and spiral water hyacinth threads in fermented natural dyeing with fresh mango leaves for a period of 7 days, suggesting that fermentation for an increased period of time resulted in a significant decrease in brightness (L*), with lowest (L*) of 50.48 and 49.28 on day 6 and day 7, respectively. For the redness or greenness value (a*), increased time had no statistically significant effect on (a*). For the value of yellowness or blueness (b*), increased time had no statistically significant effect on (b*), with (b*) was lowest as 30.50 and 29.57 on day 6 and day 7, respectively.

Spiral water hyacinth strands in fermented natural dyeing with fresh mango leaves for increased time resulted in a statistical significant decrease in brightness (L*), with the lowest (L*) of 36.22 on day 6. For the value of redness or greenness (a*), day 3 and day 4 were reported with the highest (a*) but not statistically different, equaling 12.75 and 12.99, respectively. For the value of yellowness or blueness (b*), it was lowest as 19.08 on day 6

Table 4 Colour values of round and spiral water hyacinth strands using fermented natural dying with fresh avocado leaves

Number of Fermentation Day	Appeared Colour	Colour Value – Water Hyacinth Strands (Round)			Appeared Colour	Colour Value – Water Hyacinth Strands (Spiral)		
		L*	a*	b*		L*	a*	b*
Control		$88.20^{a}\pm 2.51$	$9.04^{a}\pm 2.13$	$30.50^{a}\pm 0.63$		$66.26^{a}\pm 1.84$	$9.20^{a}\pm 0.93$	$24.13^{a}\pm 3.06$
Day1		$64.28^{d}\pm 1.00$	$13.77^{a}\pm 1.32$	$34.55^{b}\pm 1.18$		$55.23^{b}\pm 1.76$	$8.02^{c}\pm 0.52$	$27.13^{bc}\pm 3.59$
Day2		$72.32^{b}\pm 1.89$	$8.85^{bcd}\pm 0.36$	$33.69^{bc}\pm 0.95$		$50.15^{cd}\pm 0.18$	$8.79^{c}\pm 0.03$	$24.19^{c}\pm 0.06$
Day3		$68.11^{c}\pm 0.71$	$6.72^{d}\pm 0.63$	$33.75^{bc}\pm 1.39$		$49.97^{cd}\pm 0.09$	$11.64^{a}\pm 0.11$	$32.46^{a}\pm 0.11$
Day4		$67.41^{c}\pm 0.46$	$8.09^{cd}\pm 0.58$	$31.01^{cd}\pm 0.43$		$51.16^{bcd}\pm 0.81$	$9.77^{bc}\pm 0.54$	$27.20^{bc}\pm 0.10$
Day5		$66.12^{cd}\pm 1.57$	$7.51^{cd}\pm 1.16$	$34.53^{b}\pm 1.67$		$51.42^{bc}\pm 1.12$	$9.77^{bc}\pm 0.61$	$30.15^{ab}\pm 1.01$
Day6		$66.33^{cd}\pm 1.15$	$10.24^{bc}\pm 1.82$	$33.63^{bc}\pm 0.82$		$47.86^{cd}\pm 1.10$	$10.92^{ab}\pm 1.14$	$27.42^{bc}\pm 3.61$
Day7		$64.20^{d}\pm 0.97$	$11.36^{ab}\pm 2.36$	$39.63^{a}\pm 3.14$		$52.03^{bc}\pm 0.12$	$10.94^{ab}\pm 0.14$	$33.29^{a}\pm 0.08$

Remark: Different letters shown vertically indicate statistically significant difference at a confidence level of 95%

Table 4 reports the round and spiral water hyacinth strands in fermented natural dyeing with fresh avocado leaves for a period of 7 days, suggesting that increased time had no statistically significant effect on (L*). The value of redness or greenness (a*) was highest as 13.77 on day 1, and the value of yellowness or blueness (b*), was highest as 39.63 on day 7.

Spiral water hyacinth strands in fermented natural dyeing with fresh avocado leaves for increased time had no statistically significant effect on brightness (L*). The value of redness or greenness (a*) was found to be highest on day 6 and day 7, equaling 10.92 and 10.94, respectively. The value of yellowness or blueness (b*) was found to be lowest on day 2, equaling 24.19.

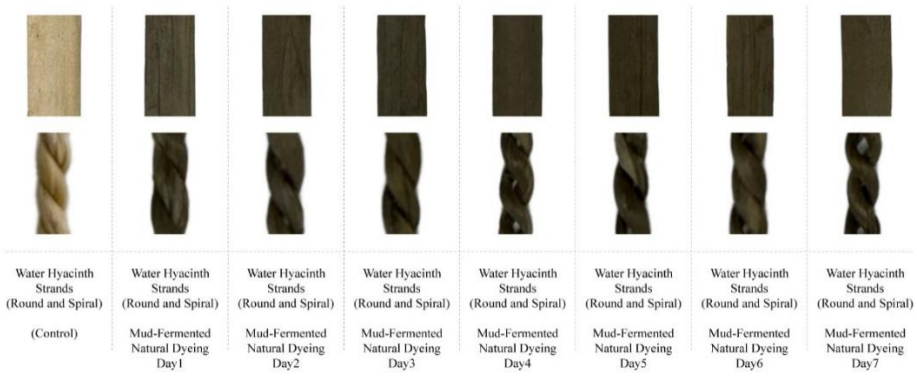

Figure 8 Colours of round and spiral water hyacinth strands in mud-fermented natural dyeing

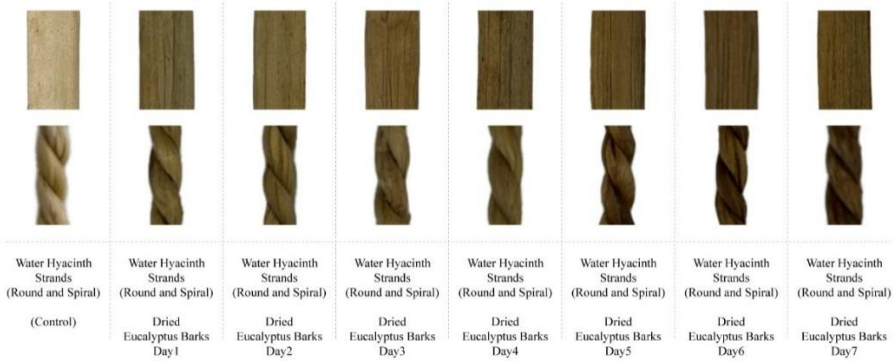

Figure 9 Colours of round and spiral water hyacinth strands in fermented natural dyeing with dried eucalyptus barks

Figure 10 Colours of round and spiral water hyacinth strands in fermented natural dyeing with fresh mango leaves

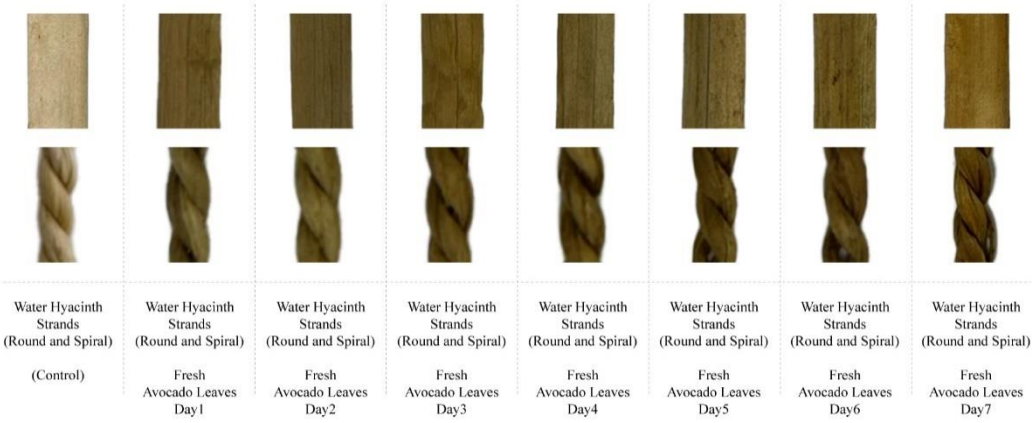

Figure 11 Colours of round and spiral water hyacinth strands in fermented natural dyeing with fresh avocado leaves

Conclusion

The quality of natural dyeing of water hyacinth strands with different natural materials and plants including mud, dried eucalyptus bark, fresh mango leaves, and fresh avocado leaves through the cold dyeing or fermentation dyeing process for a period of 7 days is reported with increased time resulting in differences in the colours. Using mud-fermented natural dying, the round strands had (L*) in a range of 54.58 - 57.10, whereas the spiral strands had (L*) in a range of 48.10 - 42.60, with (+a*) indicating red and (+b*) indicating yellow. Using fermented natural dyeing with dried eucalyptus bark, the round strands had (L*) in a range of 64.15 - 58.10, whereas the spiral strands had (L*) in a range of 59.51 -. 48.40, with (+a*) indicating red and (+b*) indicating yellow. Using fermented natural dyeing with fresh mango leaves, the round strands (L*) fell within the range of between 64.82 - 49.28, whereas the spiral strands had (L*) in a range of 44.40 - 38.91, with (+a*) indicating red and (+b*) indicating yellow. Using fermented natural dyeing with fresh avocado leaves, the round strands (L*) fell within a range of 64.28 - 64.20, and the spiral strands had (L*) in a range of 55.23 - 52.03, with (+a*) indicating red and (+b*) indicating yellow.

Recommendations

1. Recommendations from research

1.1 Research results suggested physical characteristics of water hyacinth that composes of interior large angular pores and cellulose fibers. The exterior surface of water hyacinth being conditioned for wickerwork was not smooth with uneven light and dark brown colours, naturally coated with wax, making it difficult for the adhesion of natural colour.

1.2 Natural dyeing of water hyacinth strands with natural raw material and different kinds of plant including mud fermentation, fermented dyeing with dried eucalyptus barks, fresh mango leaves, and fresh avocado leaves using the cold dyeing process or fermentation dyeing for a period of 7 days resulted in good colour adhesion but uneven due to different physical characteristics of water hyacinth strands.

1.3 Mud fermented natural dyeing other than being natural mordant, it affects the increased intensity of colour by the duration of fermentation as a result of chemical reaction between the mud and the material. The results showed that increased duration had a statistically significant effect on the decrease in brightness (L*).

2. Recommendations for further research

2.1 In the production, it is recommended to select raw materials of water hyacinth strands with a similar outer surface so as to increase the efficiency of colour adhesion as well as an even and consistent appearance.

2.2 Other types of mordant, natural raw materials, and plants should be examined to compare different colour values and the efficiency of colour adhesion.

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