NATURAL DYEING OF HEMP YARNS

Monthon Nakpathom[1], Buppha Somboon[1], Nootsara Narumol[1] & Sarita Pinmanee[2]
[1] *National Metal and Materials Technology Center, National Science and Technology Development Agency, Pathumthani, Thailand*
[2] *Highland Research and Development Institute (Public Organization), Chiang Mai, Thailand*
monthonn@mtec.or.th[1]

Abstract: With its exceptional physical properties, high comfort, excellent durability as well as relatively eco-friendly manufacturing process, hemp is regarded as one of the highest quality fibers and is in high demand. Recently, there has been a national strategic plan which supports cultivation of hemp as a new economic plant in Thailand, especially for the hill tribe people located in the northern area. Meanwhile, increasing worldwide environmental awareness of the manufacture and application of synthetic dyes in textile industry, there has been growing interest in natural dyes. This research was carried out to investigate dyeing of 720 and 1908 denier industrial and 2295 denier hill tribe hemp yarns with four natural dyes; lac (*Laccifer lacca* Kerr.), marigold flower (*Tagetes erecta* L.), garcinia bark (*Garcinia Dulcis (Roxb.)* Kurz) and annatto seed (*Bixa orellana* L.). The color yield, color coordinates and color fastness to washing and light of the resultant dyed yarns were also determined.

1. Introduction

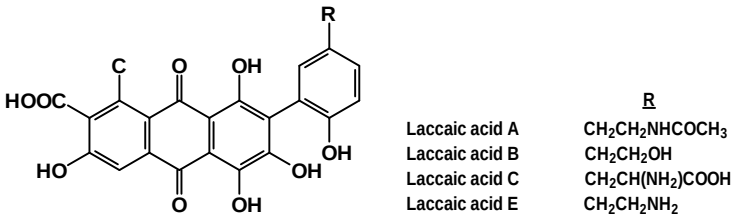
Hemp (*Cannabis sativa*) is regarded as one of the oldest plants grown for its fibers used for the manufacture of rope, canvas and clothing [1]. Hemp not only possesses several excellent properties such as strength, warmth, comfort and durability, it is considered as environmentally friendly plant because less pesticides and herbicides are needed during growing [2]. Although hemp farming is allowed in many countries, it must be legally permitted in Thailand, resulting in inadequate supply and high cost. Until recently, cultivation of hemp as a new economic plant has been assigned as one of the national strategic plan in order to assist the hill tribes to stop growing opium, leading to a more sustainable living. This strategic plan includes hemp growing, its fiber and fabric production and other applications.

Nowadays, natural dyes are becoming more of interest due to environmental concerns over synthetic dyes despite their inferior characteristics such as limited availability, low color yield, poor reproducibility and inferior fastness properties [3,4]. Most of natural dyes generally require metallic mordants, for example, alum, iron sulfate and copper sulfate to increase the affinity between fiber and dye molecule, resulting in higher color yield, different shades and better fastness properties. However, the majority of these metallic mordants are rather toxic and their excess usage can lead to consumer harm and environmental risk. These drawbacks prevent them from being commercially employed.

Several researches have focused on the improvement of dyeing quality of hemps. For examples, pretreatment of hemp yarns with a commercial product of acrylic copolymer before dyeing with 2:1 pre-metallised acid dyes significantly improved the uptake of the dyes [5]. The use of low-temperature air plasma on hemp fabrics before dyeing with some acid and direct dyes enhanced the dyeing rate, final dye exhaustion and colour yield of dyed samples [6]. In addition to fabric and construction, hemp fabrics dyed with natural dyes from woad, weld and madder with the presence of alum and potassium bitartrate mordants showed a good ultraviolet protection with the UPF (Ultravilolet Protection Factor) above 15 [7]. Hemp fabrics dyed with turmeric provided with the UPF of 15-30 with the use of citric acid and ferrous sulfate mordants [8].

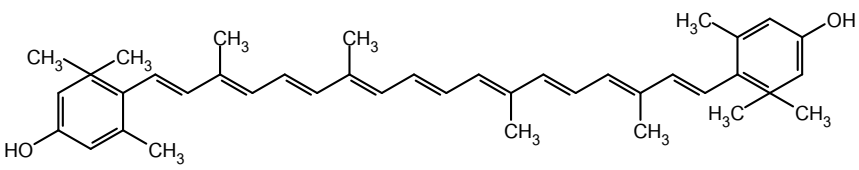
In this research, 720 and 1908 denier industrial and 2295 denier hill tribe hemp yarns were dyed with four natural dyes from lac (*Laccifer lacca* Kerr.), marigold flower (*Tagetes erecta* L.), garcinia bark (*Garcinia Dulcis (Roxb.)* Kurz) and annatto seed (*Bixa orellana* L.). The major coloring components of these natural dyes are shown in Figure 1. The color yield, color coordinates and color fastness to washing and light of the dyed yarns were measured to evaluate the effect of yarn size on the dyeing results.

a)

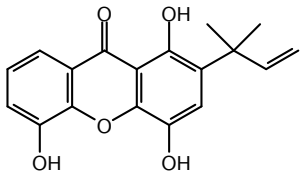


	R
Laccaic acid A	$CH_2CH_2NHCOCH_3$
Laccaic acid B	CH_2CH_2OH
Laccaic acid C	$CH_2CH(NH_2)COOH$
Laccaic acid E	$CH_2CH_2NH_2$

b)



c)



d)

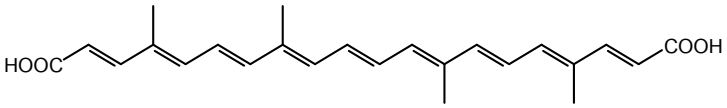


Figure 1: *Coloring components of natural dyes: a) lac, b) marigold flower, c) garcinia bark, d) annatto seed*

2. Materials and Methods

2.1. Materials

Three types of hemp yarns were used in this research, i.e., 720 and 1,908 denier industrial yarn from a local store at Chiang Mai province, Thailand and 2,295 denier hill tribe yarn from

Highland Research and Development Institute. Stick lac, marigold flower, garcinia bark and annatto seed were obtained from the northern and north-eastern part of Thailand. A soaping agent, Lavenol PA, was supplied from Boothawee Chemephan Co., Ltd., Thailand. Alum ($AlK(SO_4)_2.12H_2O$) was purchased from Asia Pacific Specialty Chemicals Ltd., Thailand.

2.2. Scouring

Hemp yarns were initially scoured in a solution of 10 g/L Lavenol PA soap and 1.5 g/L sodium carbonate at the boil for 1 hour. Then they were rinsed thoroughly with water and air-dried.

2.3. Natural dye extraction

Natural dye solutions from lac, marigold flower, garcinia bark and annatto seed were prepared by boiling corresponding natural dye material for 1 h with the weight ratio of yarn to natural dye material (1:3) with the exception of marigold flower (1:0.5). A small amount of tamarind paste and sodium carbonate were also added during dye extraction of lac and annatto seed, respectively. The resulting natural dye extracts were later filtered to remove remaining residues.

2.4. Mordanting and Dyeing

Alum was used as a meta-mordant at 5%owf in dyeing with lac and garcinia bark, whereas alum pre-mordanting was carried out for dyeing with marigold flower by soaking yarn in 10 g/L of alum solution at room temperature for 30 min. Dyeing was performed in an open bath with the liquor ratio (LR) of 1:30. Hemp yarns were placed in the dyeing solutions at room temperature. The temperature was then raised to the boil and dyeing continued at the boil for 1 h. The dyed yarns were later rinsed thoroughly with water and air-dried.

2.5. Testing and Measurements

Color strength of the dyed fabrics were calculated in terms of K/S values by the Kubelka-Munk equation ($K/S = (1-R)^2/2R$, where R is the reflectance). The reflectance of the dyed samples was measured on Datacolor 650 spectrophotometer. Color fastness tests to washing and light were tested according to ISO 105-C01 (1989) and ISO 105-B02, respectively. The color change and color staining on the adjacent fabrics (silk and cotton) of the dyed samples was assessed using grey scale ratings, ranging from 1 (very poor), 2 (poor), 3 (fair), 4 (good) to 5 (very good).

3. Results and Discussion

As shown in Table 1, it was found that dyeing of hemp yarns with these natural dyes produced different color shades, i.e., red form lac, brownish yellow from marigold flower, greenish yellow from garcinia bark and orange from annatto seed. The color strength, K/S value, was measured at λ_{max} values of 520-530 nm for lac, 400-410 nm for marigold flower and garcinia bark and 470 nm for annatto seed. Exceptional high K/S values of 20-26 were obtained for marigold flower dye compared to the others. It was also evident that K/S increased with increasing yarn size. The 2295 denier hill tribe yarn gave highest K/S values in each type of natural dye, whereas the 720 denier industrial yarn gave the lowest. This was attributed to the relatively larger surface area of the 720 denier yarn compared to the others.

Table 1: *K/S values and CIELAB L*a*b* values of natural dyed hemp yarns*

Dye	Hemp yarn (denier)	K/S	CIELAB			Samples
			L*	a*	b*	
Lac	720	2.85	48.46	19.75	-1.21	
	1908	4.02	44.70	24.50	1.27	
	2295	4.82	40.77	18.71	3.25	
Marigold flower	720	20.22	62.69	7.42	59.08	
	1908	20.99	61.26	7.92	58.91	
	2295	26.78	45.94	15.18	46.61	
Garcinia Bark	720	2.73	79.82	-0.64	40.72	
	1908	4.89	71.92	-0.86	41.32	
	2295	8.00	66.57	1.62	45.49	
Annatto Seed	720	5.37	59.74	31.8	42.80	
	1908	7.96	55.58	30.71	44.78	
	2295	9.40	42.87	28.14	37.44	

Lac dyed yarn had a pinkish red color with very poor (1) wash fastness and very poor-poor to fair (1-2 to 3) light fastness. Marigold flower dyed yarn gave a brownish yellow color with very poor-poor to fair (1-2 to 3) wash fastness and poor-fair to fair (2-3 to 3) light fastness. Garcinia bark dyed yarn yielded a yellow color with poor to fair-good (2 to 3-4) wash fastness and poor to poor-fair (2 to 2-3) light fastness. Annatto seed dyed yarn had an orange color with very poor-poor to poor-fair (1-2 to 2-3) wash fastness and very poor-poor to poor (1-2 to 2) light fastness. Hemp yarns dyed with natural dyes from lac, marigold flower, garcinia bark gave low color staining on adjacent cotton and silk fabrics with the grey scale rating of 4-5. On the other hand, cross staining on both cotton and silk fabrics with the grey scale rating of 1-2 occurred in case of those dyed with annatto seed.

Table 2: *Color fastness to washing and light of natural dyed hemp yarns*

Dye	Hemp yarn (denier)	Wash fastness			Light fastness
		Color change	Color staining		
			Cotton	Silk	
Lac	720	1	4-5	4-5	1-2
	1908	1	4-5	4-5	2
	2295	1	4-5	4-5	3
Marigold flower	720	1-2	4-5	4-5	2-3
	1908	2	4-5	4-5	2-3
	2295	3	4-5	4-5	3
Garcinia bark	720	2	4-5	4-5	2
	1908	3	4-5	4-5	2
	2295	3-4	4-5	4-5	2-3
Annatto seed	720	2-3	1-2	1-2	1-2
	1908	2	1-2	1-2	1-2
	2295	1-2	3-4	3-4	2

Based on this research results, on-site training of dyeing process of hemp yarns with natural dyes was set up for the hill tribe people at the Royal Project Pang Dang Nai Extension Station, Amphoe Chiang Dao, Chiang Mai Province and the Royal Project Tham Wiang Gae Extension Station, Amphoe Song Khwae, Nan Province as illustrated in Figure 2.

Figure 2: *Natural dyeing of hemp yarn training*

4. Conclusion

Dyeing of hemp yarns with natural dyes from lac, marigold flower, garcinia bark and annatto seed yielded red, yellow and orange color shades, respectively. Color strength of the dyed samples was influenced by the size of hemp yarns. As the yarn denier became finer, lower

color strength was observed due to its higher surface area. Color fastness to washing and light of these natural dyed hemp yarns were mostly below fair, thus further improvement is necessary.

Acknowledgement

This research is under the project of Research and Development on Dye Technology in Hemp Fiber and financially supported by Highland Research and Development Institute (Public Organization).

References

[1] Liberalato, D. Prospect of hemp utilization in the European textile industry, *Agroindustria*, 2/3 (2003), pp. 147-148.
[2] Hemp, *Available from* http://en.wikipedia.org/wiki/Hemp *Accessed:* 2112-05-01.
[3] Deo, H. T. & Desai, B. K.: Dyeing of cotton and jute with tea as a natural dye, *Coloration Technology*, Vol. 115 (1999) No. 7-8, pp. 224-227, ISSN 1478-4408.
[4] Lokhande, H. T. & Dorugade, V. A.: Dyeing nylon with natural dyes, *American Dyestuff Reporter*, Vol. 88 (1999) No. 2, pp. 29-34, ISSN 1526-2847.
[5] Cai, Y.; David, S. K. & Pailthorpe, M. T. Dyeing of jute and jute/cotton blend fabrics with 2:1 pre-metallised dyes, *Dyes and Pigments*, Vol. 45 (2000) No. 2, pp. 161-168, ISSN 0143-7208.
[6] Radetic, M.; Jovancic, P.; Jocic, D.; Topalovic, T.; Puac, N. & Petrovic, Z. L. J. The influence of low-temperature plasma and enzymatic treatment on hemp fabric dyeability, *FIBRES & TEXTILES in Eastern Europe*, Vol. 63 (2007) No. 4, pp. 93-96, ISSN 1230-3666.
[7] Grifoni, D.; Bacci, L.; Zipoli, G.; Carreras, G.; Baronti, S. & Sabatini, F. Laboratory and outdoor assessment of UV protection offered by flax and hemp fabrics dyed with natural dyes, *Photochemistry and Photobiology*, Vol. 85 (2009) No. 1, pp. 313-320, ISSN 1751-1097.
[8] Schmidt-Przewozna, K. & Kowalinski, J. Light fastness properties and UV protection factor of naturally dyed linen, hemp and silk. *2008 International Conference on Flax and Other Bast Plants*, pp. 364-374, ISBN 978-0-9809664-0-4.