THE EFFECTS OF DIFFERENT ALKALI TREATMENTS WITH DIFFERENT TEMPERATURES ONTHE COLORIMETRIC PROPERTIES OF LIGNOCELLULOSICRAFFIA FIBERS

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Abstract - Raffia fiber is a lignocellulosic fiber which is peeled from palm tree leaves which are found in the tropical and subtropical zones. Raffia fiber has a potential to be used as a reinforcement fiber for composite structures instead of expensive, non-biodegradable and non-renewable synthetic fibers beside of its decorative and garments usages in textile market. In this study, the effects of different alkali treatments (sodium carbonate and sodium hydroxide) with various temperatures (40, 50, 60, 70, 80, 90, 100^{o}C) on the colorimetric properties (whiteness and yellowness indexes, K/S, L*, a*, b*, C*, h^{o}, ΔE*) of raffia fibers were examined. Color strength (K/S) of the raffia fibers increasedwith the increase on treatment temperature for all studied treatments. Also, pH increase resulted in darker, yellower and less white raffia fibers. Color properties of textile materials may be as important as their mechanical properties which depend on their end-usage type. For that reason, it should be noted thatalkalinity level of wet-processing treatments and treatment temperature increase will lead tosignificant color differences on the raffia fibers. Therefore, one should keep in mind that aforementioned appearance alterations may occuron raffia fibers depending on the severity of the wet processing treatment in respect of temperature and/or alkalinity.

Keywords - Raffia fiber, alkali treatment, sodium hydroxide, sodium carbonate, lignocellulosic fiber, reinforcement fiber, composites

I. INTRODUCTION

Limited oil resources, awareness of sustainability and eco-friendly conscious have generated interest in natural fibers due to their biodegradable, renewable and non-hazardous character[1, 2]. Especially, fiber resources which can be cultivated for industrial purposes by economically have become primary research field[3]. Pineapple, banana, abaca and raffia fibers are only few examples for trending natural fiber sources. These fibers are mostly lignocellulosic fibers which are popularly used for reinforcement of composite structures beside of their textile purposes.

Raffia fiber is one of the trending natural fiber sources which are used as both reinforcement fiber and textile material. It is peeled from leaves of raffia palm trees which are found in the tropical and subtropical zones of the world[2, 4].Raffia fibers can be used in clothes, shoes, handbags and composites in addition to their alternative usages as carpets, blankets, home decorations [2, 4-6].Raffia fibers havedifferent importance for some cultures according to their historical traditions and roots. Although it is not very common today, it was recorded in the past that raffia clothes were designed for ceremonials, special occasions and rituals. The structure and physical properties of raffia fibers variable depends on the growing conditions, harvesting time and soil type. Young's modulus and tensile strength of raffia fibers are 12.3-26±2 GPa and 500-527±84 MPa, respectively [5, 7]. Recent reportshave indicated that raffia fibers can be used as reinforcement in polymer composite structures replacing expensive, non-renewable and non-biodegradable synthetic fibers[1, 3, 7]. Raffia fibers are mostly encountered with different pre-treatment processes such as alkali treatment before and/or during manufacturing of composite structures[2, 7]. In this study, the effects of different alkali treatments with various application temperatures on the colorimetric properties of raffia fibers were examined.



Figure 1. Raffia Palm tree and Raffia fibers (photo source: http://www.ccapfairtrade.com/materials-detail.php?id=99)

II. MATERIAL AND METHOD

In this study, 100% raffia fiber plain woven fabric which was supplied from Philippines was utilized for alkali treatment study. Alkali treatment of raffia fibers was performed with sodium hydroxide and sodium carbonate at different temperatures to determine the effects of alkalinity and temperature of alkaline treatment on raffia fibers. Alkali treatmentswere carried out using sodium hydroxide (2% and 5%owf) and sodium carbonate (2%owf) in company with 1 g/l wetting agent for 30 minutes at 1:40 liquor ratio at different treatment temperatures (40, 50, 60, 70, 80, 90, 100 ^{o}C). Also, a control

process was performed with the absence of alkali agent due to the investigation of the effects of temperature on the raffia fibers. Alkali treatment and control treatment conditions were given in the Table 1.

Table 1.Treatments conditions of raffia fibers

Alkali Treatment		pH	Time	Temperature (^oC)
Control	1g/l wetting agent	7.5	30 min.	40, 50, 60, 70, 80, 90, 100
Sodium Carbonate	1g/l wetting agent 2% owf Na_2CO_3	10.5	30 min.	40, 50, 60, 70, 80, 90, 100
Sodium Hydroxide	1g/l wetting agent 2% owfNaOH	12.5	30 min.	40, 50, 60, 70, 80, 90, 100
Sodium Hydroxide	1g/l wetting agent 5% owfNaOH	13.5	30 min.	40, 50, 60, 70, 80, 90, 100

Color measurementswere performed by using DataColorSpectraFlash 600 (DataColorSpectraFlash 600, Datacolor International, USA) spectrophotometer (D65 day light, 10° standard observer). The CIE L*, a*, b*, C* and h^o color coordinates were measured and the K/S (color strength) values, whiteness index (Stensby) and yellowness index (E313)were calculated for each raffia fabrics sample.The Lab color space describes mathematically all perceivable colors in the three dimensions L* axis for lightness, a* axis for greenness to redness (−a*:green, +a*:red) and b* axis for blueness to yellowness (−b* axis:blue, +b*axis:yellow) for the color components (Figure 2)[2, 8].

Color measurement equations are given as below[8]:

L*(Lightness/Darkness); Black = 0 and White = 100 1.1

a*; Red = Positive Value (+a*) and Green = Negative Value (−a*) 1.2

b*; Yellow = Positive Value (+b*) and Blue = Negative Value (−b*) 1.3

Kubelka-Munk equation, $K/S = (1 - R)^2/2R$ 1.4

$C^* (Chroma) = [(a^*)2 + (b^*)^2]^{1/2}$ 1.5

$h^o = \arctan (b^* / a^*)$ 1.6

$WIStensby = L^* + 3a^* - 3b^*$ 1.7

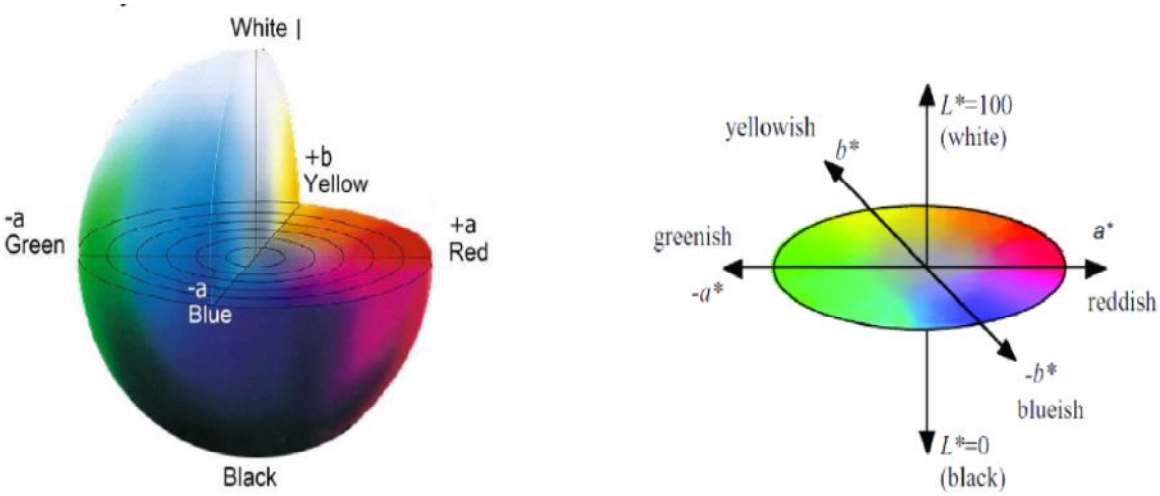


Figure 2. CIE 3D LAB color space [9, 10]

III. RESULTS AND DISCUSSIONS

Raffia fibers were treated with sodium hydroxide (2% and 5% owf) and sodium carbonate (2%owf) at seven different application temperatures (40, 50, 60, 70, 80, 90, 100 ^oC). Colorimetric measurements of alkali treated raffia fibers and control sample were given in the following tables (Table 2, Table 3, Table 4 and Table 5). For control treatment, only the wetting agent was included into the treatment bath without the involvement of sodium hydroxide and sodium carbonate. In here, the effects of only the different treatment temperatures on the color properties of raffia fibers were explored without any alkalinity presence at pH 7.5 (pH of control treatment). Table 2 displays this mentioned effect of control treatments. It was observed from Table 2that color strength (K/S) level of raffia fibers increased and the lightness (L*) level of the raffia fibers decreased with the treatment temperature increase leading to darker appearance. Amongst control process treatments, the highest K/S value which was 8.30was observed at 100 ^oC while the color strength (K/S) of the untreated raffia fiberwas 4.90. Color of the raffia fiber became darkerwith the application temperature increase. In parallel with the color strength results, whiteness index decreased, and yellowness index increased as a result of temperature increase.

Table 2. Color properties of raffia woven fabrics after control treatmentsvarying different temperatures (at pH 7.5)

	K/S	L^*	a^*	b^*	C^*	h^o	ΔE^*	Whiteness Index (Stensby)	Yellowness Index (E313)
Untreated	4.90	73.1	5.76	25.3	25.9	77.1		27.1	57.0
40°C	5.19	71.1	5.58	25.2	25.8	77.5	2.02	25.2	57.8
50°C	6.49	69.2	6.58	26.2	27.0	75.9	4.11	24.6	61.7
60°C	6.47	70.7	5.94	27.1	27.7	77.7	3.07	22.4	61.7
70°C	6.72	70.1	5.60	26.4	26.9	78.0	3.21	22.3	63.5
80°C	8.31	64.3	6.91	26.2	27.0	75.2	8.97	22.0	65.1
90°C	8.23	63.2	7.70	25.7	26.8	73.3	10.2	24.0	65.9
100°C	8.30	62.9	7.77	27.2	28.3	74.1	10.6	21.7	68.8

Sodium carbonate and sodium hydroxide were used as alkali agents with varying amounts leading to different pH conditions. Sodium carbonate treatment was applied at 2% concentration by weight andthe application pH was 10.5. Colorimetric measurements of raffia fibers after sodium carbonate (2%owf Na_2CO_3) treatment were given in Table 3. Color strength of sodium carbonate treated raffia fibers exhibitedascending trend (Table 2) similar tothe aforementioned control treatments (Table 2).However, it is vital to point out that the highest K/S value was 12.4 for sodium carbonate treated raffia fiber at 100°C meanwhile the highest K/S value was 8.30withoutthe alkali agent presence at 100°C after control process. Therefore, in other way of saying, higher alkalinity of the treatment resulted in higher color strength values leading to darker appearance.

Table 3. Color properties of raffia woven fabrics after 2% Sodium Carbonate treatment at different application temperatures (at pH 10.5)

	K/S	L^*	a^*	b^*	C^*	h^o	ΔE^*	Whiteness Index (Stensby)	Yellowness Index (E313)
Untreated	4.90	73.1	5.76	25.3	25.9	77.1		27.1	57.0
40°C	7.61	65.1	6.66	29.9	30.6	77.5	9.33	15.9	70.6
50°C	7.58	64.7	7.49	31.2	32.1	76.5	10.5	15.9	74.0
60°C	8.17	62.3	8.11	31.3	32.3	75.5	12.7	15.9	76.6
70°C	8.47	61.9	8.08	32.7	33.7	76.1	13.7	13.6	79.1
80°C	11.4	60.2	8.86	33.5	34.7	75.2	15.6	13.6	83.0
90°C	12.3	59.1	9.11	32.9	34.2	74,6	16.3	14.4	83.0
100°C	12.4	59.0	9.29	32.7	34.0	74.2	16.3	15.2	82.9

Two different sodium hydroxide concentrations (2%, 5% by weight) were prepared leading to different pH conditions. Color properties of raffia fabrics after 2%NaOH treatment (pH 12.5) at different temperatures were given in the Table 3. When the application temperature increased, color strength also increasedin line with the previous treatments. However, it is important to state that the color strength levels of 2% NaOH treated raffia fibers were significantly higher than those of control process treated and sodium carbonate treated raffia fibers (Table 4 versus Tables 2 and 3).In parallel, yellowness index increased up to 94.5 E313 and whiteness index decreaseddown to 5.39 Stensbywhile yellowness and whiteness indexes of untreated raffia fibers was measured as 57.0 and 27.1, respectively.

Table 4. Color properties of raffia woven fabrics after %2 NaOH treatment at different temperatures (at pH 12.5)

	K/S	L^*	a^*	b^*	C^*	h^o	ΔE^*	Whiteness Index (Stensby)	Yellowness Index (E313)
Untreated	4.90	73.1	5.76	25.3	25.9	77.1		27.1	57.0
40°C	8.60	60.8	7.87	34.2	35.1	77.0	15.4	10.4	82,0
50°C	9.60	60.8	8.54	36.0	37.0	76.7	16.5	9.81	85.5
60°C	14.0	58.8	8.68	38.2	39.2	77.2	19.5	6.52	90.5
70°C	14.4	54.5	9.40	37.7	38.9	76.0	22.7	7.12	94.2
80°C	14.7	52.1	8.98	35.4	36.5	75.8	23.6	7.62	93.1
90°C	19.7	48.1	8.28	34.4	35.4	76.5	26.8	5.39	94.5
100°C	21.3	46.9	8.22	32.9	33.9	76.0	27.4	6.42	93.2

Afterwards, sodium hydroxide treatment with 5%NaOH concentration by weight (at pH 13.5)was applied to raffia fibersat different temperatures. Color measurements of sodium hydroxide (5% by weight) treated raffia fibers were given in Table 5. In this whole study, the lowest whiteness index (1.50) and the highest index (99.0) values weremeasuredon the 5% NaOH treated raffia fibers. This treatment (5% NaOH) caused a drastic change for color properties such as color strength (K/S), lightness (L*), yellowness (E313) and whiteness (Stensby) indexes.

Table 5. Color Properties of raffia woven fabrics after 5%NaOH treatment at different temperatures (at pH 13.5)

	K/S	L^*	a^*	b^*	C^*	h^o	ΔE^*	Whiteness Index (Stensby)	Yellowness Index (E313)
Untreated	4.90	73.1	5.76	25.3	25.9	77.1		27.1	57.0
40°C	12.9	57.5	9.83	39.9	41.1	76.2	21.8	6.97	95.5
50°C	15.0	55.0	9.94	40.2	41.4	76.1	23.9	5.95	98.5
60°C	16.1	54.4	9.68	40.8	42.0	76.7	24.7	4.49	99.5
70°C	15.0	53.5	9.22	40.4	41.5	77.2	25.1	3.37	99.2
80°C	17.8	50.8	8.80	38.1	39.1	77.0	25.9	3.81	98.0
90°C	21.5	49.5	7.87	37.7	38.5	78.0	26.8	1.50	97.5
100°C	23.0	48.2	8.07	37.6	38.5	77.9	27.9	1.66	99.0

Finally, color stength (K/S) and lightness (L*) values of raffia fibers were compared according to temperature and pH differences (Figure 3). Three different temperatures (40, 70 and 100°C) were selected for comparison. Also, measured pH values of treatment applications were used for evaluation (Figure 3; pH 7.5: control treatment, pH 10.5: 2% sodium carbonate treatment, pH 12.5: 2% sodium hydroxide treatment, pH 13.5: 5% sodium hydroxide treatment). It can be clearly seen from the Figure 3 thatapplication pH and temparature led to drastic changes on color strength and lightnessvalues of raffia fibers. These results were in line with the earlier studies where were reported that some lignocellulosic fibers such as raffia, jute and pineapple fibers may become yellower and less white after alkali treatments [2, 7, 11, 12].The significant color strength increase and lightness level decrease for treatments with increased alkali concentrations (ascending pH levels) can be probably linked to chlorophyll degradation since chlorophylls are easily deteriorated in alkali agents [11, 13].

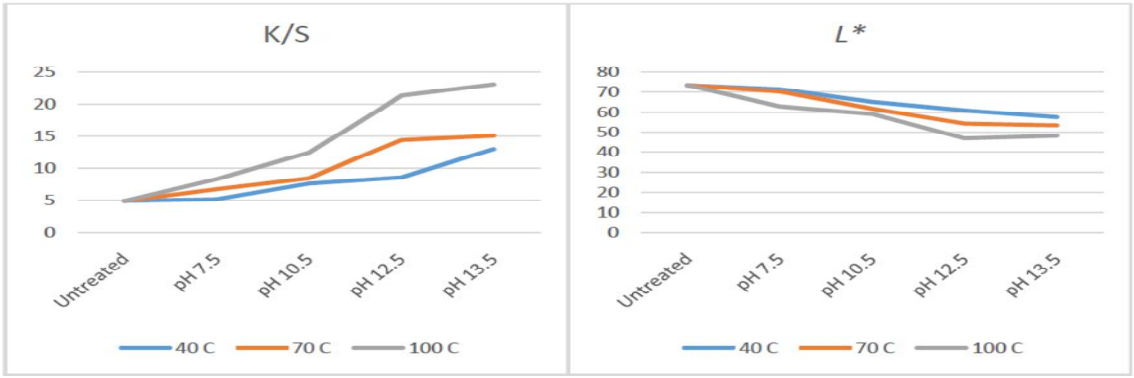


Figure 3. Comparison of color stength (K/S) and Lightness (L*) levels of raffia fibers depending on the treatment temperature and pH

CONCLUSIONS

Alkali treatments are generally used for scouring process for cellulosic textile materials. As a result, these alkali treatments generally resultin slightly whither and slightly less yellow appearance. Color properties of textile materials may be as important as their mechanical properties which depend on their end-usage type. In this study, the effects of different alkali treatments with various application temperatures on the colorimetric properties of raffia fibers were explored. Treatment pH and temparature led to drastic changes on color strength and lightnessvalues of raffia fibers. The higher treatment temparature led to higher color strength values leading to darker, yellower and less white appearance. Similarly, higher alkalinity with higher pH levels resulted in higher color strength values leading to again darker, yellower and less white appearance. Theseobserved significant color strength increases and lightness level decreases for treatments with increased alkali concentrations (at ascending pH levels) can be possibly linked to chlorophyll degradation as chlorophylls can be easily deteriorated

in alkali agents. It should be noted that alkalinity level of wet-processing treatments and treatment temperature increase will lead tosignificant color differences on the raffia fibers.

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