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COLOR STRENGTH ESTIMATION OF COIR FIBERS BLEACHED WITH PERACETIC ACID

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Abstract: *The production rates of textile materials increase day by day due to the increasing population of the world. This rapid increase in production boosts the demand of raw materials to be used in textile manufacturing. The insufficiency of necessary natural fiber supply leads to new investigations of other natural fiber alternatives since the use of sustainable and inexpensive natural fibers presents an opportunity to protect the environment. Coir fiber obtained from the husk of ripe/matured coconut has various fields of use such as door mats, floor mats, brushes, matresses, upholstery padding, sacking and horticulture. In this study, in order to determine the optimum bleaching conditions for coir fiber, a wide variety of peracetic acid concentrations are applied at different bleaching processing times. Color strength values of bleached coir fiber fabrics vary under different conditions. This study aims to obtain the estimation of color strength values on the samples of coir fibers bleached with peracetic acid. In order to solve the problem, various mathematical function models are utilized. Then, an artificial bee colony algorithm is used to optimize the weights of the functions. Sample data of the fiber is used to verify the correctness of the color strength estimation model. The estimated results are compared with the results of experimental studies. Results show that the prediction model can fit the experimental results with a high precision. The model based on artificial bee colony is a good candidate to estimate the color strength of bleached coir fiber fabric.*

Key words: *Coconut fruit, Coir fibers, color strength estimation, swarm intelligence, artificial bee colony*

1. INTRODUCTION

Rapid growth of world population and the insufficiency of necessary fiber supply lead to new investigations of other fiber alternatives. The use of sustainable and inexpensive natural fibers presents a promising opportunity to protect the environment. Coir fiber obtained from the husk of ripe/matured coconut has a constrained field of use such as door mats, floor mats, brushes, matresses, upholstery padding, sacking and horticulture. Botanical name of Coir, a common name of coconut, is Cocos Nucifera and its plant belongs to Arecaceae family which is also known as palm [1]. Coconut trees grow up in the tropical zones of the world, but the main production is in the wet tropical area of Asia, including countries Indonesia, Phillipines, India, Sri Lanka, Malaysia and Thailand, covering about 86.7% of the total world coir fiber production [1].

Bleaching may be necessary for coir fibers in order to meet the demands of the end use application types since coir yarns and fabrics can be dyed with natural dyes and reactive dyes. In order to achieve repeatable colorometric results and pale shades during dyeing, bleaching, prior to dyeing, can be applied to coir fiber products. Morevoer, bleaching process may be necessary for special applications of coir fiber in composite materials. A review of the color measurements in the textile industry is presented in [2].

The degradation products of peracetic acid are oxygen and acetic acid and it is an environmentally safe bleaching agent since peracetic acid enables an ecofriendly bleaching with low water, energy and chemical consumption [3]. Therefore, in this study, firstly, bleaching of coir fiber fabric with peracetic acid at various conditions are performed and the color properties of bleached coir fabrics were measured.

Secondly, the color strength (K/S) values of coir fiber fabrics bleached with peracetic acid is estimated using an artificial bee colony algorithm, a swarm intelligence methodology since the treatment conditions require many experiments and thus, the use of such a technique would prevent the extensive amount of experiments which are costly and time consuming. The main purpose of using the artificial bee colony algorithm is to investigate and confirm its fitting capability to estimate the color strength values of bleached coir fiber fabrics. The performance of the artificial algorithm is demonstrated in detail against various approaches in the literature [4-6].

2. MATERIALS AND EXPERIMENTS

100% coir fiber plain woven fabric was utilized for this study. Prior to peracetic acid bleaching process, hydrophilization process was carried out to coir fiber fabrics at 1:20 liqour ratio and 95°C for 60 minutes with 10 g/l sodium hydroxide, 5 g/l sodium carbonate and 2 g/l wetting agent (DyStar, Germany). Afterwards, coir fiber fabrics were rinsed in hot water for 10 minutes and then, cold neutralization process was carried out at 1:20 liqour ratio with 1 ml/l acetic acid for 15 minutes. Finally, coir fiber fabrics were cold rinsed for 10 minutes and left to dry out at ambient conditions. Peracetic acid bleaching process was carried out at 70°C with 1:30 liquor ratio at about pH 5 (with sodium carbonate). 1g/l wetting agent (DyStar, Germany) was also added to the bleaching bath. In order to determine the optimum bleaching conditions for coir fiber, ther wide variety of peracetic acid concentrations (5, 10, 20 and 30 g/l) were applied at different bleaching processing times (30, 60, 90 minutes). Following the bleaching treatments, bleached coir fiber fabrics were rinsed for 15 minutes cold rinse, 5 minutes hot rinse and 5 minutes cold rinse, respectively. Afterwards, color strength values of the coir fiber samples were determined using a DataColor 600 spectrophotometer. Each sample was measured from four different areas, and the average values were calculated. The color strength (K/S) values of bleached coir fiber fabrics are shown in Table 1. In general, as the peracetic acid concentration increases and bleaching duration prolongs, the K/S (color strength) degrees of the bleached samples gradually decreases. For example, 30 g/l peracetic acid bleaching for 90 minutes resulted in relatively low K/S value of 7.25. Peracetic acid bleaching using 5 g/l peracetic acid for 60 and 90 minutes did not result in any reduction in color strength leading to comparable similar K/S results with the scoured coir fabric (Table 1). On the other hand, peracetic acid bleaching using 5 g/l peracetic acid for 30 minutes led to slight colour strength increase. This means that peracetic acid bleaching using 5 g/l peracetic acid for all studied durations (30 60 and 90 minutes) did not cause an expected bleaching effect. It was earlier reported that some lignocellulosic fibers such as raffia, jute and pineapple fibers may become yellower and less white after alkali treatments and significant color strength increase for treatments with increased alkali concentrations could be probably linked to chlorophyll degradation since chlorophylls are easily deteriorated with alkaline agents [7-9].

***Table 1**: Color strength performance of coir fibers bleached with peracetic acid at pH=5*

Bleaching duration (minutes)	Peracetic acid concentration (g/l)	*L**	*a**	*b**	K/S
Scoured	-	48.1	9.11	27.12	12.15
30	5	48.4	7.87	28.91	13.32
30	10	52	7.09	28.56	10.54
30	20	53.6	5.05	28.57	10.55
30	30	55.6	7.58	32.42	9.97
60	5	50	8.46	29.92	12.25
60	10	55.6	9.08	33.44	10.70
60	20	62.3	6.65	34.69	7.82
60	30	64	4.21	30.72	6.37
90	5	51.1	9.46	31.67	12.14
90	10	57.1	7.06	32.13	9.28
90	20	63.5	6.02	36.74	8.97
90	30	65.8	6.36	36.23	7.25

3. ESTIMATION METHODOLOGY

The artificial bee colony algorithm, firstly proposed by Karaboga [10] is based on collective flock intelligence of swarms and is inspired by the social behavior of honey bees looking for food sources. The bee colony consists of three kinds of bees: employed bees, onlooker bee and scout bees. In this study, artificial bee colony algorithm [5, 6, 11]is utilized for color strength estimation according to the micro structure of coir fibers bleached with peracetic acid. The main steps of the algorithm are presented in Figure 1.

1	Randomly initialize a random bee population for the available food locations
2	Repeat
3	Employed bee phase: investigate the food sources in which the amount of nectar is high.
4	Onlooker bee phase: follow the nectar information shared by the employed bees to further exploit the food sources with high content
5	Scout bee phase: randomly discover new food locations once the nectar amount is fully consumed in an already discovered food source
6	Until stop conditions are met

***Fig. 1**. The main steps of the artificial bee colony algorithm*

The algorithm is initiated via by Equation (1) where i represents a bee in the population, j represents the problem dimension and x_j^{max} and x_j^{min} represents the upper and lower limits of the problem search space, respectively (Step 1 of Figure 1).

$$x_{ij} = x_j^{min} + rand\ (0,1)\left(x_j^{max} - x_j^{min}\right) \quad \textbf{(1)}$$

Onlooker bees receiving the information about the food source from employed bees, probabilistically select the food source and using Equation (2), further exploit the food sources in the search where v_i represents a new solution in the neighborhood of the current solution, x_i represents the current solution, x_k represents a random neighbor of the current solution, ϕ_{ij} represents a random value selected in the range $[-1,1]$ and D represents the problem dimension. If the newly obtained solution value is better than the previous solution value, the new information about is stored, otherwise discarded (Step 3-4 of Figure 1).

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}), j = 1, \dots, D \tag{2}$$

Once the nectar amount is consumed, i.e., the current solution cannot be further improved, the food source is abandoned, and scout bees are released to discover new food sources by using equation (1) (Step 5 of Figure 1). All these steps form one cycle of the algorithm and continue until the stopping criteria are met.

The mathematical functions used in the model are given in Equations (3-8). The aim is to optimize the weights ($w_1 - w_{10}$) of these equations in order to minimize the total error and reveal the most accurate estimation values since the values of the weights may greatly influence the estimation results. Here, six different functions; linear (Equation 3), quadratic (Equation 4), cubic (Equation 5), exponential (Equation 6), sigmoid (Equation 7) and exponential-trigonometric (Equation 8) are utilized for parameter optimization to estimate the color strength of coir fibers bleached with peracetic acid.

$$F_{linear} = w_1 + w_2X_1 + w_3X_2 \tag{3}$$

$$F_{quadratic} = w_1 + w_2X_1 + w_3X_2 + w_4X_1X_2 + w_5X_1^2 + w_6X_2^2 \tag{4}$$

$$F_{cubic} = w_1 + w_2X_1 + w_3X_2 + w_4X_1X_2 + w_5X_1^2 + w_6X_2^2 + w_7X_1^2X_2 + w_8X_2^2X_1 + w_9X_1^3 + w_{10}X_2^3 \tag{5}$$

$$F_{exponential} = w_1 + w_2{X_1}^{w_3} + w_4{X_2}^{w_5} \tag{6}$$

$$F_{sigmoid} = w_1 + w_2/(1 + e^{w_3X_1}) + w_4/(1 + e^{w_5X_2}) \tag{7}$$

$$F_{exponential-trigonometric} = w_1 + w_2e^{w_3X_1 + w_4X_2 + w_5}\tanh(w_6X_1 + w_7X_2 + w_8) \tag{8}$$

x_1: Bleaching duration (First input), x_2: peracetic acid concentration (g/l) (Second input)

Fig.2 presents the estimation results of various functions corresponding to the original experiments while detailed results are presented in Table 2. The cubic form has achieved the best results while exponential-trigonometric form has been the runner-up. As a result, in the worst case, average percentage gap was 9.34% between the estimation results and the original experiment results and in the best case, the cubic form achieved 2.78% gap between the estimation results and the original experiment results.

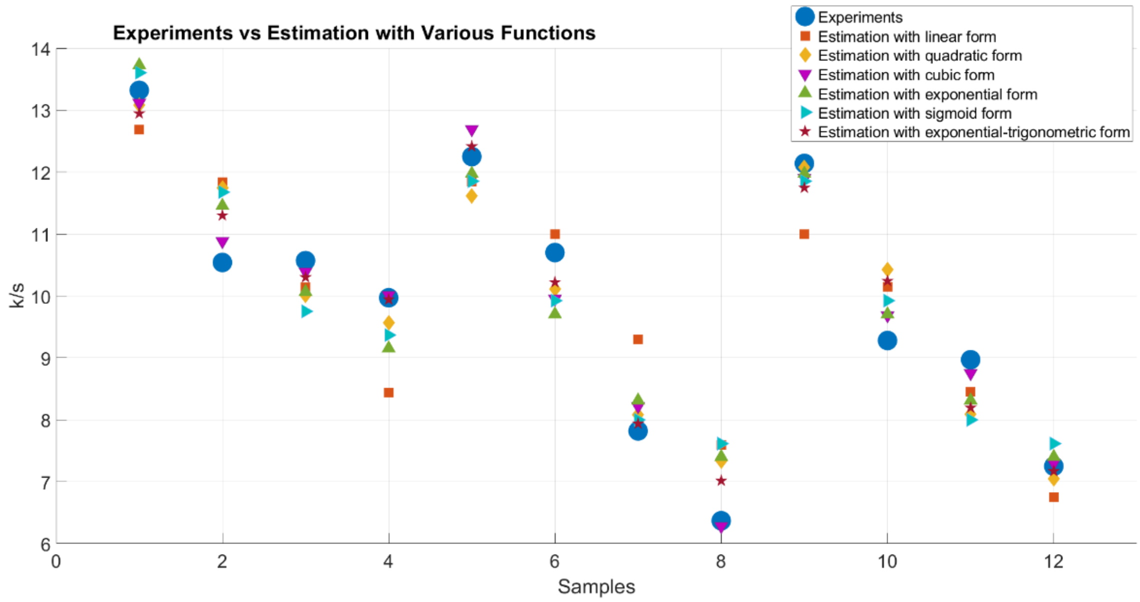

Fig. 2*: Experiments vs. estimation with various functions*

Table 2: *Estimation of color strength and error percentages of various functions*

Experiment	Linear Form	Quadratic Form	Cubic Form	Exponential Form	Sigmoid Form	Exponential-Trigonometric Form
13.32	12.69	13.09	13.12	13.73	13.60	12.95
10.54	11.84	11.74	10.88	11.46	11.68	11.30
10.57	10.14	10.01	10.39	10.06	9.75	10.30
9.97	8.44	9.56	10.01	9.15	9.37	9.94
12.25	11.84	11.61	12.69	11.97	11.85	12.41
10.7	10.99	10.11	9.95	9.70	9.92	10.22
7.82	9.29	8.08	8.22	8.31	8.00	7.94
6.37	7.59	7.33	6.28	7.40	7.62	7.02
12.14	11.00	12.07	11.90	11.97	11.85	11.75
9.28	10.15	10.43	9.68	9.70	9.92	10.24
8.97	8.45	8.09	8.75	8.31	8.00	8.20
7.25	6.75	7.04	7.30	7.40	7.62	7.17
Average Gap (%)	9.34	6.43	2.78	6.18	7.02	4.47

4. CONCLUSIONS

In this study, firstly, color strength of coir fibers was investigated after different peracetic acid bleaching processes. Peracetic acid bleaching on coir fiber resulted in lower color strength values. Peracetic acid bleaching process with varying application times result in different color strengths. In general, as the peracetic acid concentration increases and bleaching duration prolongs, the K/S (color strength) degrees of the bleached samples gradually decreases. Secondly, it was aimed to estimate the color strength of coir fibers bleached with peracetic acid by means of an artificial bee colony algorithm using various mathematical functions. The model achieved a successful fit on the samples. The results confirmed that the artificial bee colony algorithm provided high estimation accuracy to estimate the color strength of the fiber.

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REFERENCES

[1] Dam J. "*Coir Processing Technologies*". Common Fund for Commodities, Amsterdam, Netherlands. 2002.

[2] Raluca B. "*A review of color measurements in the textile industry*". Annals of the Oradea University, Fascicle of Textiles, Leatherwork. Oredea, Romania2016. p. 19-24.

[3] Gedik G, Avinc O. "*Bleaching of Hemp (Cannabis Sativa L.) Fibers with Peracetic Acid for Textiles Industry Purposes*". Fibers and Polymers. 2018;19(1):82-93.

[4] Karaboga D, Basturk B. "*On the performance of artificial bee colony (ABC) algorithm*". Applied Soft Computing. 2008;8(1):687-97.

[5] Kalayci CB, Gupta SM. "*Artificial bee colony algorithm for solving sequence-dependent disassembly line balancing problem*". Expert Systems with Applications. 2013;40(18):7231-41.

[6] Kalayci CB, Ertenlice O, Akyer H, Aygoren H. "*An artificial bee colony algorithm with feasibility enforcement and infeasibility toleration procedures for cardinality constrained portfolio optimization*". Expert Systems With Applications. 2017;85:61-75.

[7] Mínguez-Mosquera MI, Gandul-Rojas B. "*High-performance liquid chromatographic study of alkaline treatment of chlorophyll*". Journal of Chromatography A. 1995;690(2):161-76.

[8] Khan F, Ahmad SR. "*Chemical modification and spectroscopic analysis of jute fibre*". Polymer Degradation and Stability. 1996;52(3):335-40.

[9] Elenga RG, Djemia P, Tingaud D, Chauveau T, Maniongui JG, Dirras GF. "*Effects of alkali treatment on the microstructure, composition, and properties of the Raffia textilis fiber*". BioResources. 2013;8(2):2934-49.

[10] Karaboga. "*An idea based on honey bee swarm for numerical optimization*". Technical report-tr06, Erciyes university, engineering faculty, computer engineering department; 2005.

[11] Kalayci CB, Hancilar A, Gungor A, Gupta SM. "*Multi-objective fuzzy disassembly line balancing using a hybrid discrete artificial bee colony algorithm*". Journal of Manufacturing Systems. 2015;37(0):672-82.