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Modification of Physical Properties of Coir by Grafting with Acrylonitrile

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ABSTRACT

Acrylonitrile was grafted onto coir in aqueous solution using tetravalent cerium as initiator. The physical properties of grafted fiber (9.07 to -31.6% graft) were studied using standard methods and compared with those of the ungrafted one. Some of the useful physical properties of the fiber, such as density, resilience, and electrical resistance, were found to increase with an increase in the percentage of grafting, whereas some other properties, such as moisture content, moisture regain, charring temperature, thermal insulating capacity, electrical conductivity, and tensile properties, decreased under similar conditions. Possible explanations for such changes have been advanced, and suitable end uses of the modified fiber identified.

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INTRODUCTION

In spite of the availability of various newer types of synthetic fibers as coir substitutes, the worldwide demand for natural coir fiber has been increasing every year. Coir, an excellent vegetable fiber of industrial importance, is produced in many parts of Asia. It offers immense possibility in industrial and nonindustrial utilization because of its natural resilience, durability, and resistance to dampness, coupled with its hard and tough exterior. Due to its gloss, dyeability, eye appeal, and high resilience, it is the fiber of choice for decorative and domestic use. Various authors have attempted modification of properties of natural fibers such as cotton [1-3], silk [4-6], and synthetic fibers such as polyethylene terephthalate [7, 8] and nylon 6 [9] by grafting. However, the grafting to coir fiber does not appear to have been investigated much. Hence, the present authors thought it worthwhile to investigate the modification of coir fibers by grafting it with acrylonitrile. This communication presents changes in observed properties of coir fiber after grafting. These properties include the following.

(A) Mechanical Properties, such as density, porosity, moisture content, and moisture regain.
(B) Thermal Properties, such as charring temperature and thermal insulating capacity.
(C) Tensile Properties, such as breaking load, tenacity, tensile strength, toughness, Young's modulus, rigidity modulus, elongation at break, and resilience.
(D) Electrical Properties, such as electrical resistance and electrical conductivity.

The observed increase in resilience of the modified coir fiber, which is related to the feel, handle, and loftiness of the fiber, suggests its end use in mattress, carpets, and soft cushion making after rubberization. Also, because of its enhanced resilience, grafted coir fiber can be utilized for the production of high stretch paper and for making resilient packaging materials to protect goods against shock in transport. The decrease of electrical conductivity of the fiber with grafting further suggests its end use in electrical insulators for specialized applications.

EXPERIMENTAL

Materials and Methods

Coir fibers from 10-month-old coconuts were obtained from Central Coir Marketing Cooperative Society, Bhubaneswar, India. These fibers were extracted from the nut in the usual manner after chemical retting and then made pectin- and wax-free following the methods of Baruah and Baruah [10]. The prepared fibers were grafted with acrylonitrile in an aqueous solution of Ce(IV) (0.005 to 0.015 M) at temperatures from 60 to 70°C while varying the reaction time between $\frac{1}{2}$ to 3 h using our previous method [11]. The grafted fibers were Soxhlet extracted with dimethylformamide until they were completely free from homopolymers and then they were oven dried at 60°C for 6 h and cooled to room temperature. The grafting percentages were calculated following the methods of Kojima et al. [12]. The modified fibers were then used for the investigation of the following physical properties.

A. Mechanical Properties

1. Density

The densities of ungrafted and grafted coir fibers were measured at 32 ± 1°C by the method of Fehlman [13]. The variation of density with percentage of grafting is shown in Fig. 1(a).

It is observed that the density of the grafted fiber is more than that of the ungrafted one, and the density increases with an increase in grafting percentage. This can be explained after Melikuziev et al. [1] by assuming that grafting increases the number of cross-links which in turn results in increased molecular packing and, therefore, increased density.

2. Porosity

The porosities of ungrafted and grafted coir fibers were determined using a Cambridge porosity meter after the method of Clayton [14]. The change in porosity with percentage of grafting is shown in Fig. 1(b).

It was found that the porosity of the grafted fiber is less than that of the ungrafted one, and the porosity decreases with an increase in the percentage of grafting. This can be ascribed to an decrease in the number of empty spaces per unit volume on the coir surface due to grafting.

3. Moisture Content and Moisture Regain

Moisture content and moisture regain of ungrafted and grafted coir fibers were determined by using the method of Smith and Matthews [15] at 35°C and 65% relative humidity in a special humidity chamber. The results of moisture content and regain studies are presented in Figs. 2(a) and 2(b), respectively. It is seen that the moisture content of the grafted fiber is lower than that of the ungrafted one and it also decreases with an increase in grafting percentage. The moisture regain values follow the same trend. Decrease in moisture content and regain of the fiber may be explained by supposing a decrease in the number of empty spaces per unit volume on the coir surface as explained above.

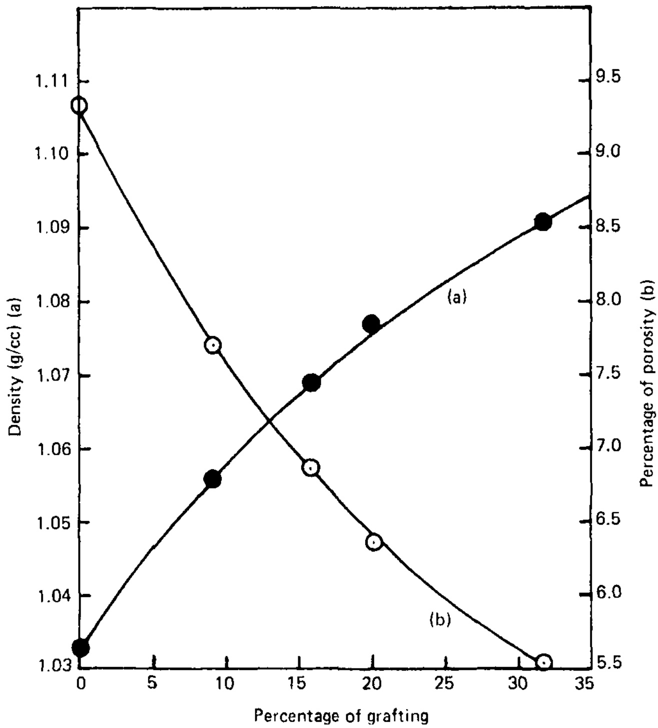

FIG. 1. (a): Variation of density with percentage of grafting. (b): Variation of porosity percentage with percentage of grafting.

B. Thermal Properties

4. Charring Temperature

The charring temperatures of ungrafted and grafted coir fibers were determined by the method of Preston [16]. The variation of charring temperature with grafting percentage is shown in Fig. 3(a).

It is seen that the charring temperature of grafted fiber is less than that of the ungrafted one, and also the linearity decreases with an increase in the percentage of grafting. This may be explained by assuming a loss in the degree of crystallinity of the fiber due to grafting.

5. Thermal Insulating Capacity

The thermal insulating capacities (k^{-1}) of grafted coir fibers were determined by using the disk method [17, 18] and compared with that of the ungrafted one.

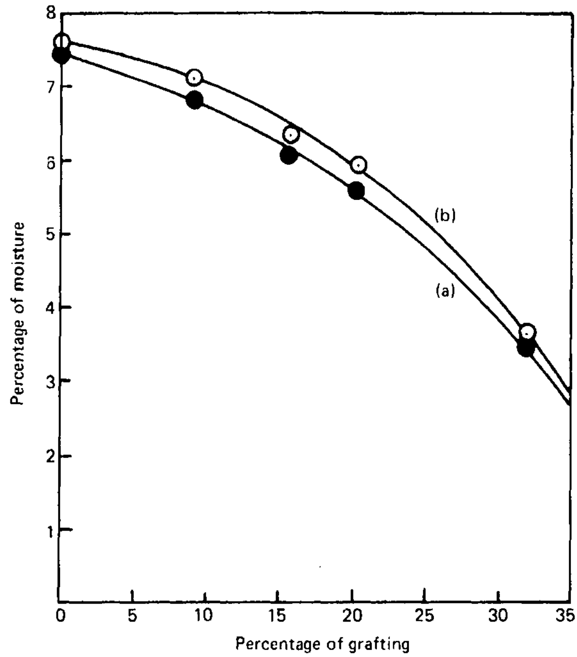

FIG. 2. (a): Variation of moisture content percentage with percentage of grafting. (b): Variation of moisture regain percentage with percentage of grafting.

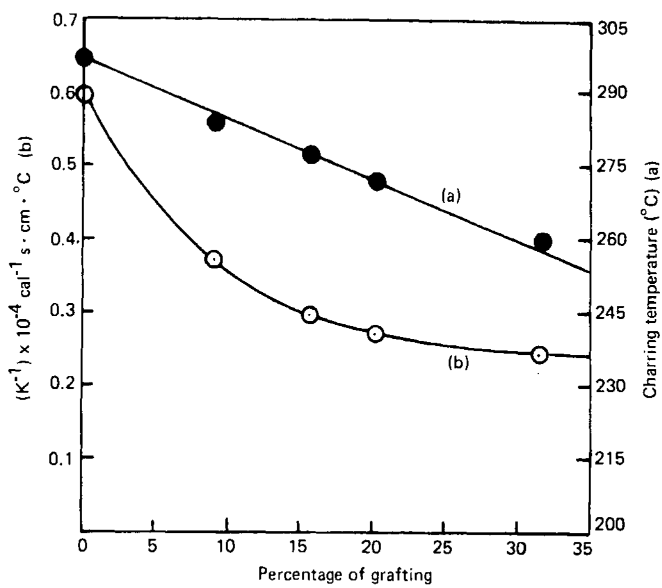

FIG. 3. (a): Variation of charring temperature with percentage of grafting. (b): Variation of thermal insulating capacity (k^{-1}) with percentage of grafting.

The changes in thermal insulating capacity with percentage of grafting are shown in Fig. 3(b). It is seen that k^{-1} decreases with an increase in grafting percentage. This might be due to an increase in the number of pendant groups on the coir backbone which conducts more and more thermal energy by the process of molecular vibration.

C. Tensile Properties

The miscellaneous tensile properties [19, 20] of grafted coir fibers were investigated and compared with those of the ungrafted ones by using the Instron Tensile Tester [21] at 35°C and constant relative humidity (65%).

6. Breaking Load

The results of breaking load measurements are shown in Fig. 4(a). It is seen that there is a gradual decrease in the breaking load of the fiber with grafting.

7. Tenacity

The results of tenacity measurements are shown in Fig. 4(b). It is noted that the tenacity of the fiber decreases as the graft-on percentage increases.

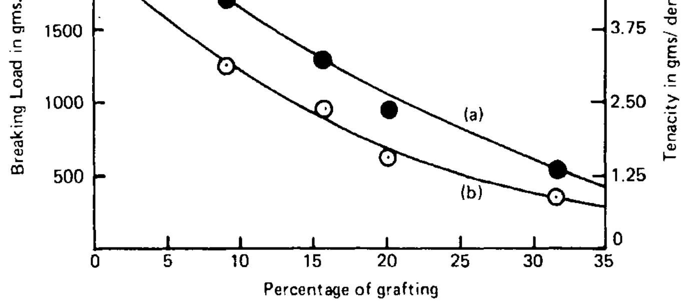

FIG. 4. (a): Variation of breaking load with percentage of grafting. (b): Variation of tenacity with percentage of grafting.

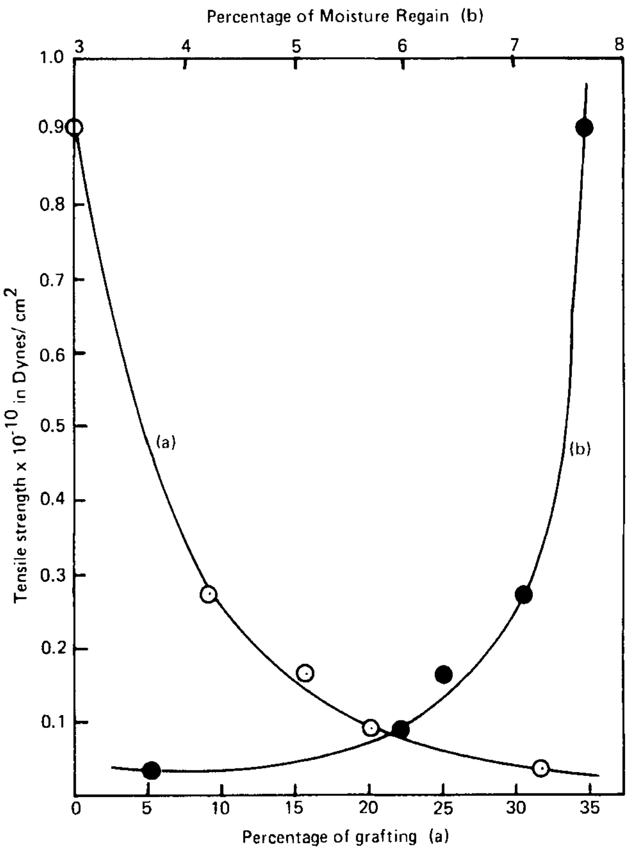

FIG. 5. (a): Variation of tensile strength with percentage of grafting. (b): Variation of tensile strength with moisture regain.

8. Tensile Strength

The results of tensile strength measurements of coir fiber versus grafting percentage and versus moisture regain are shown in Fig. 5(a) and 5(b), respectively. It is observed that the tensile strength of the fiber falls with a rise in the percentage of grafting and increases with a rise in moisture regain. It has already been observed above (cf. 3) that moisture regain is intimately connected with the rise in graft-on percentage (Fig. 2b). Hence, the decrease of tensile strength with an increase in percentage of grafting or with a decrease in percentage of moisture regain is reconciled.

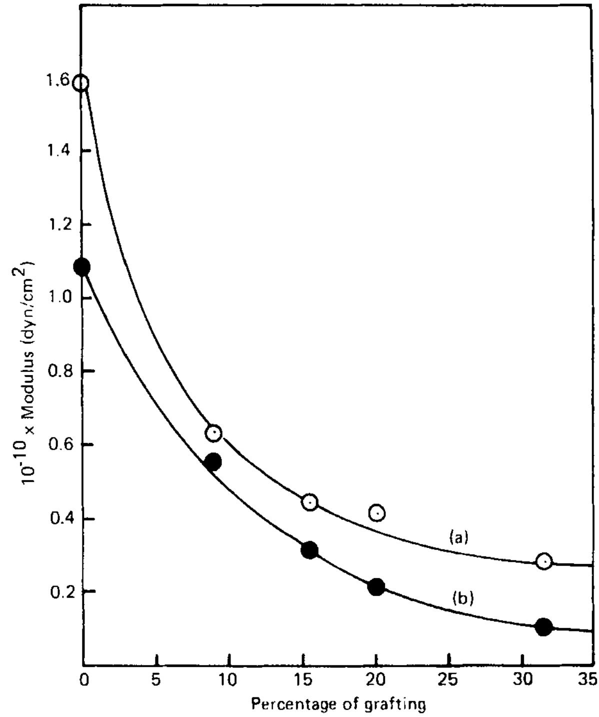

FIG. 6. (a): Variation of Young's modulus with percentage of grafting. (b): Variation of rigidity modulus with percentage of grafting.

9. Young's Modulus

The variations of Young's modulus (Y) with grafting percentage are shown in Fig. 6(a). Yield point, total stretch, elasticity elastic limit, and toughness were calculated from load elongation plots (Fig. 7). The results are presented in Table 1.

In general, it is noticed that all these properties show a decreasing trend with a rise in grafting percentage.

10. Rigidity Modulus

The rigidity modulus of the grafted fibers was measured and compared with that of the ungrafted one by the torsion pendulum method [22].

The variation of rigidity modulus with grafting percentage is presented in Fig. 6(b). The same is found to decrease with a rise in grafting percentage.

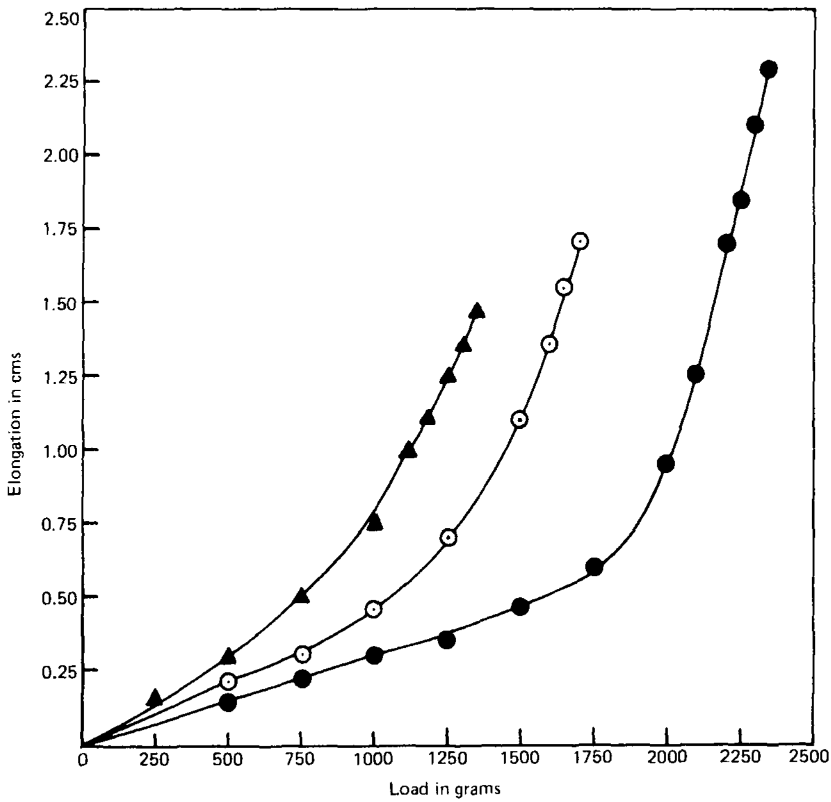

FIG. 7. Variation of elongation with load. (●) Ungrafted. (⊙) 9.07% grafted. (▲) 15.71% grafted.

11. Elongation at Break

The results of this study are presented in Fig. 8(a). It is noted that elongation at break of the grafted fibers linearly decreases with a rise in percentage of grafting.

In general, the decreasing trend of tensile properties may be explained as being due to a loss in orientation of the coir cellulose structure due to cross-links [23] developed during grafting. The same result can also be explained by assuming a loss in the degree of crystallinity of the fiber during the grafting process.

Another explanation for the trend is that there is considerable loss of hydrogen bonding between hydroxyl groups of adjacent chains of the coir cellulose skeleton after grafting.

TABLE 1

Tensile properties	Ungrafted	Grafted 9.07%	Grafted 15.71%
I. Yield point (g)	1787.5	1075	637.5
II. Total stretch (cm)	2.28	1.70	1.47
III. Elasticity (cm)	0.625	0.50	0.40
IV. Elastic limit (g)	1775	1050	625
V. Toughness (ergs/g)	2.5×10^9	1.18×10^9	0.77×10^9

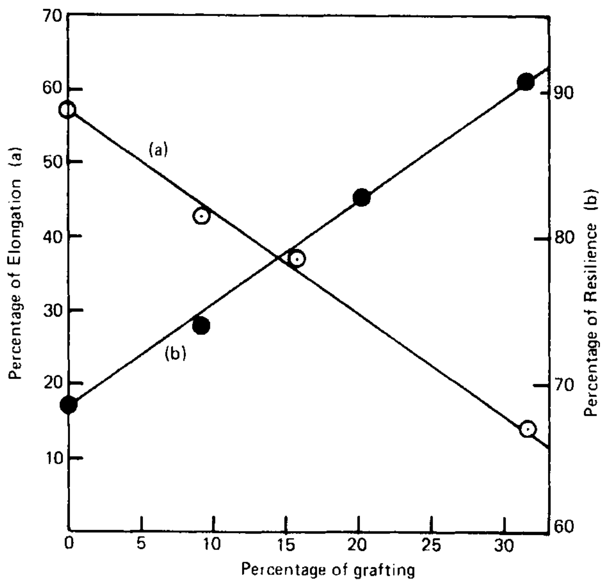

FIG. 8. (a): Variation of percentage of elongation at break with percentage of grafting. (b): Variation of resilience percentage with percentage of grafting.

Apart from these, the role played by moisture in modifying tensile properties of a vegetable fiber [24] cannot be overemphasized. Moisture is supposed to be taken up by the coir fiber by the process of adsorption and capillary condensation [25]. However, the process of adsorption might be adversely affected due to clogging of capillary pores on the fiber surface because of grafting. This may explain the parallel fall of tensile properties with the loss of moisture regain due to grafting as noticed above (cf. 3).

The lower value of elongation at break of the grafted fiber can be explained as being due to a decrease in chain flexibility [26] as well as an increase in packing density of the fiber after grafting.

12. Resilience

The resilience of ungrafted and grafted coir fibers was measured by a compressional resilience tester [27]. The variation of resilience with the percentage of grafting is shown in Fig. 8(b). The resilience of grafted coir fiber is more than that of the ungrafted one and increases linearly with an increase in the percentage of grafting.

This may be explained as being due to low molecular interaction between adjacent chains of the coir cellulose structure after grafting. Again, loss of stretchability of the fiber due to cross-linking after grafting might be another contributory factor to this trend.

D. Electrical Properties

The electrical resistance of grafted coir fibers was measured using a Million Megohmmeter (BPL, Model RM, 160 MK IIIA) and compared with the theoretical values calculated from the formula [28]

$$R = aM^{-n}$$

where R is the resistance in megohms of a 4-cm length fiber, M is the moisture content percentage, and a and n are constants.

For coir, a cellulosic fiber,

$$\log a = 12.6$$
$$n = 9.3$$

(Table 2). The experimental values show a close resemblance with the theoretically calculated values. It is observed that electrical resistance increases with a rise in grafting percentage.

14. Electrical Conductivity

The variation of electrical conductivity with grafting percentage is shown in Fig. 9. It is seen that electrical conductivity decreases with an increase in percentage of grafting.

Loss of moisture content of the fiber with a rise in grafting percentage, as noted earlier (cf. 3), may also explain the changes observed in electrical resistance and electrical conductivity. This is because the moisture content of the fiber greatly affects the electrical conductivity [29].

TABLE 2

Nature of the fibers	Resistance calculated theoretically (MΩ)	Resistance measured experimentally (MΩ)
Ungrafted	0.93×10^5	0.78×10^5
9.07% graft	2.13×10^5	2.05×10^5
15.71% graft	6.49×10^5	5.6×10^5
20.07% graft	14.25×10^5	13×10^5

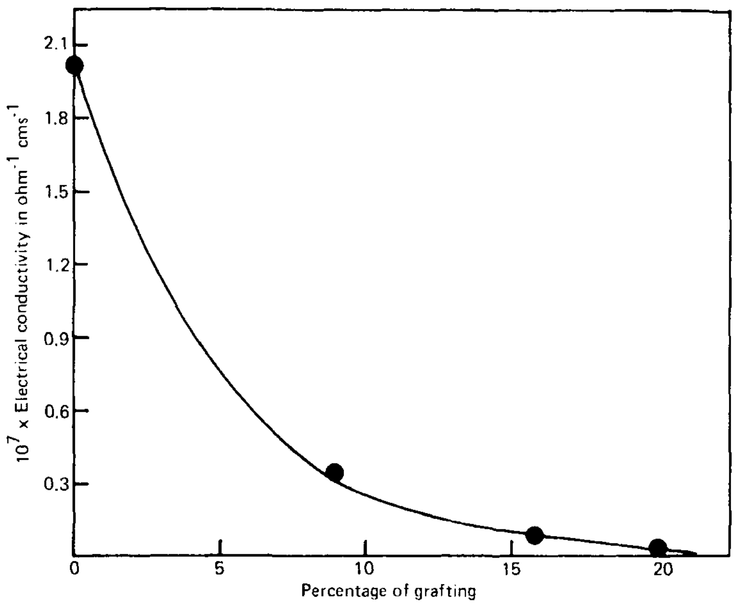

FIG. 9. Variation of electrical conductivity with percentage of grafting.

CONCLUSION

Finally, it is concluded that the physical properties of coir fiber largely depend on the hydrophillic nature of the hydroxyl groups present in its cellulose backbone, and any chemical treatments which modify this backbone affect the moisture uptake capacity of the fiber and therefore modify the electrical, mechanical, thermal, and tensile properties of the fiber.

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REFERENCES

[1] Sh. Melikuziev and Yu. T. Tashpulatov, Deposited Doc. VINITI, 18, 398 (1979).
[2] V. N. Sharma and E. H. Daruwalla, Cellul. Chem. Technol., 13(14), 433 (1979).
[3] G. S. Buck, Jr., Am. Assoc. Text. Technol., 9, 9 (1953).
[4] A. Kitamaru, A. Shibanato, and K. Nito, Nippon Sanshigaku Zasshi, 48(6), 477 (1979).
[5] H. Morimoto, Kiito Kensasho Kenkyu Hokoku, 34, 75 (1980).
[6] K. Harabayashi, Sen'i Gakkaishi, 36(10), 391 (1980).
[7] I. F. Osipenko, L. I. Mishkina, T. M. Prokopchuk, and A. V. Tuchkov, Skaya, Ser. Khim. Nauk, 3, 105 (1980).
[8] D. V. Lopatick, Qm, Bondareva, N. R. Prokopchuk, A. V. Tuchkovskya, I. F. Osipenko, V. I. Kovalev, V. F. Patsei, and N. I. Prokopchik, Ser. Khim. Nauk, 5, 88 (1981).
[9] A. K. Mukherjee, R. Duraiswamy, and A. K. Sengupta, Man-Made Text. India, 24(6), 301, 318, 320, 322 (1981).
[10] P. Baruah and H. K. Baruah, Sci. Cult., 10, 201 (1944-45); 11, 369 (1945-46).
[11] N. Mohanty, B. Pradhan, M. C. Mohanta, and H. K. Das, J. Macromol. Sci.–Chem., A19(8&9), 1189 (1983).
[12] K. Kojima, S. Iwabuchi, and K. Kojima, J. Polym. Sci., Part B, 9, 25 (1971).
[13] P. Fehlman, Schweiz. Arch. Angew. Wiss., p. 109 (1943).
[14] F. H. Clayton, J. Text. Inst., 26, T171 (1935).
[15] S. Smith and J. A. Matthews, Ibid., 27, T219 (1936).
[16] J. M. Preston, Ibid., 40, T767 (1949); 41, 681 (1950).
[17] J. B. Speakman and H. N. Chamberlan, Ibid., 21, T29 (1930).
[18] N. Mohanty, S. N. Torasia, M. C. Mohanta, D. K. Rout, and H. K. Das, J. Macromol. Sci.–Chem., A20(3), 409 (1983).
[19] M. M. Haque and M. Habibuddoula, Bangladesh J. Sci. Ind. Res., 15(1-4) (1980).
[20] A. O. Mathai, N. S. Varier, and K. L. Moudgill, J. Sci. Ind. Res., 7B, 119 (1948).
[21] H. Hindiman and G. S. Burr, Trans. ASME, p. 789 (1949).
[22] G. N. Prabhu, Coir, 3(4), 29 (1959).
[23] I. F. Osipenko, L. I. Mishikina, T. M. Prokopchuk, E. N. Pilipenko, N. R. Prokopchuk, and L. A. Belokurskaya, Vestn. Akad. Nauk BSSR, Ser. Khim. Nauk, 2, 75 (1980).

[24] R. Meredith, J. Text. Inst., 36, T107 (1945); 47, T499 (1956); 48, T163 (1957).
[25] A. Silver, Am. Dyest. Rep., 43, 697 (1954).
[26] I. Hiroshi, Zoku Kenshi no Kozo, p. 209 (1980).
[27] E. C. Derby, Am. Dyest. Rep., 33, 199 (1944).
[28] Walker, Bell Lab. Rec., (April 1929).
[29] J. W. S. Hearle and G. E. Cusick, J. Text. Inst., 46, T699 (1955).

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