Industrial Crops and Products 77 (2015) 66–73

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Accelerated retting cum softening of coconut fibre

Gautam Basu [a], Leena Mishra [a,*], Seiko Jose [a], Ashis Kumar Samanta [b]

[a] ICAR—National Institute of Research on Jute and Allied Fibre Technology, Kolkata 700040, India
[b] Department of Jute and Fibre Technology, University of Calcutta, Kolkata 700019, India

ARTICLE INFO

Article history:
Received 16 April 2015
Received in revised form 31 July 2015
Accepted 7 August 2015
Available online 3 September 2015

Keywords:
Coconut fiber
Chemical retting/softening
Physico-mechanical properties
XRD
Component analysis
Effluent treatment

ABSTRACT

Accelerated chemical retting of raw coconut fibre was attempted. The treatment of raw coconut fibre with a combination of sodium sulphide, sodium hydroxide, sodium carbonate, reduce retting time from 6 to 12 months to 2 h. Chemical treatment decreases the linear density (about 36%), diameter (about 35%), and flexural rigidity (about 72%), ultimately resulting in much softer fibre. The treatment showed positive result towards mechanical proprieties. Fine structure analysis of the treated fibres through FTIR, XRD, TGA, SEM and component analysis validates the beneficial modification with improved properties. The chemical constituent, FTIR and TG analyses revealed enhancement of cellulose content and reduction in lignin, hemicelluloses etc. Resultant crystallinity index of the treated coconut fibre is enhanced by 36% compared to the raw fibres. SEM showed that chemical retting is most efficient in removal of impurities. The effluent obtained from chemical retting was suitably treated to make it safe for discharge.

1. Introduction

Coconut fibre, extracted from the husk (the fibre containing part) of coconut (*Cocos nucifera* L.) is one of the stiffest and most durable ligno-cellulosic natural fibrous materials. The stiffness, which may be due to its high lignin content (up to 40%) (Mohanty et al., 2005), and large diameter, makes the fibre unsuitable for finer textile applications. India is the highest producer of coconut fibre (43,1500 t) (FAO, 2013), a part of which is extracted by the conventional back water retting process which completes in about 6–12 months. The literature (Manilal et al., 2010) claims that during this retting, extensive chemical reactions and microbial intervention happens, which facilitates partial removal of the gummy matter and lignin from the fibre matrix. Backwater retting particularly enhances softness, colour parameters and spinning quality for making of export quality ropes/cordages that are used in mats and carpets.

The practice of backwater retting is now slowing down due to associated health hazards and pollution to the air and seawater, near coconut growing area. Retting results in release of large quantities of organic substance and chemicals including pectin, pentosan, tannins, polyphenols, sulphide, phosphate, nitrate, hydrogen sulphide, ammonia and thereby results in increased biological oxygen demand levels (Remani et al., 1989; Bijoy Nandan, 1997). This renders the backwater unsuitable for fishing and normal flora and fauna. Hence, there is an urgent need for a suitable process for softening of coconut fibres for making finer yarn or ropes, without polluting the backwaters and also to reduce the longer time needed in the traditional retting process.

Some reports (Varma et al., 1984; Mahato et al., 1993, 1995, 2009; Sreenivasan et al., 1996; Anto et al., 1998; Gu, 2009; Brígida et al., 2010; Manilal et al., 2010) are available on effects of chemical treatments (viz., sodium hydroxide, hydrochloric acid, acetic acid, nitric acid, hydrogen peroxides) on coconut fibres. Limited work (Anto et al., 1998; Sarma, 2001; van Dam, 2002) is reported on softening of coconut fibre with an aim to study the subsequent spinnability. Efforts made by Anto et al. (1998) using castor oil and urea, silicon softeners, sodium hydroxide for softening of coconut fibre results in little success. Chemical treatment of coconut fibre using cationic softener based on quaternary ammonium salts was reported to provide temporary softness due to its poor rubbing fastness (Sarma, 2001). The use of epoxy based softeners and (amino) silicon-derivatives had also been tried for this, but the results were not found satisfactory as the yarn had a slippery feel (van Dam, 2002). Some work are reported on conventional and non-conventional retting including chemical retting of other lingocellulosic fibres like hemp (Liu et al., 2015), ramie (Angelini et al., 2015) and flax (Nair et al., 2014).

So there is ample scope for undertaking an integrated study on treatment/modifications of coconut fibre. The aim of the present work is to provide a captive method for chemical retting/softening of coconut fibre in controlled conditions with much less water

* Corresponding author. Tel.: +91 9748046445; fax: +91 3324712583.
E-mail address: leena2010mishra@gmail.com (L. Mishra).

http://dx.doi.org/10.1016/j.indcrop.2015.08.012
0926-6690/

Table 1
Effect of treatments on physical properties and mechanical properties of coconut fibre.

Expt. no.	Treatment	Physical property				Mechanical property			
		Weight loss (%)*	Diameter (μn)	Linear density (tex)**	*L*/*D* ratio	Flexural rigidity (cN mm^2)	Breaking tenacity (cN/tex)	Breaking elongation (%)	Specific work of rupture (mJ/tex m)
1	Control	–	345 (57)	53 (58)	695 (61)	1273 (49)	11.3 (67)	21.5 (33)	12.1 (42)
2	Backwater retted	–	282 (37)	44 (49)	748 (58)	613 (57)	14.0 (53)	27.1 (39)	12.0 (58)
3	Water at boil for 2 h	2.60 (10)	381 (55)	52 (46)	689 (48)	1235 (64)	12.1 (46)	18.8 (27)	13.9 (43)
4	Steaming at 121 °C for 2 h	7.20 (7)	347 (56)	48 (58)	712 (62)	1177 (67)	12.2 (56)	19.2 (41)	14.5 (42)
5	20% NaOH at boil for 2 h	12.2 (13)	341 (53)	45 (67)	789 (73)	1034 (49)	13.8 (39)	24.7 (36)	19.3 (48)
6	40% Na_2S at boil for 2 h	17.6 (8)	227 (57)	41 (47)	917 (54)	731 (76)	13.4 (41)	27.8 (29)	18.1 (41)
7	15% Na_2CO_3 at boil for 2 h	11.5 (9)	359 (54)	49 (57)	742 (63)	1084 (49)	11.9 (46)	22.4 (42)	12.5 (56)
8	40% Na_2S, 20% NaOH at boil for 2 h	21.7 (9)	249 (52)	43 (59)	898 (72)	893 (56)	11.8 (87)	21.5 (37)	18.2 (56)
9	40% Na_2S, 15% Na_2CO_3 at boil for 2 h	20.1 (11)	255 (57)	48 (47)	915 (59)	921 (64)	12.1(65)	21.2 (35)	17.4 (47)
10	40% Na_2S,15% Na_2CO_3, 20% NaOH at boil for 2 h	28.4 (13)	225 (41)	34 (52)	991 (63)	361 (55)	14.2 (59)	21.3 (33)	21.6 (43)
11	3% H_2O_2 for 2 h at 80 °C (pH-11)	13.6 (9)	251 (59)	39 (39)	891 (48)	890 (53)	11.7 (57)	19.9 (36)	17.5 (39)
12	2% $NaIO_4$ at boil for 2 h	6.40 (7)	276 (63)	52 (46)	734 (49)	1062 (48)	8.4 (51)	14.3 (45)	9.5 (47)
13	HCl (35%) at 30 °C for 1 h	37.4 (23)	250 (64)	35 (57)	1073(64)	745 (67)	2.9 (167)	3.90 (98)	0.5 (99)
14	H_2SO_4 at 30 °C for 1 h	Immediate surface charcoaling at and above 30% concentration and fibre became brittle during storage even after alkaline neutralization							

The figures in the parenthesis indicates CV% of the corresponding value.
* Results shows the mean value of ten repeat tests.
** Tex is the weight of 1000 m long fibre in gram.

and time, to produce softer and relatively finer grade coconut fibre, without deteriorating the tensile and physical properties. The paper reports the effects of selected treatments on the physical and mechanical properties, crystallinity index and morphological changes using scanning electron microscopy of coconut fibres. FTIR, TGA and composition analysis of the fibres were done for qualitative and quantitative evaluation of fine structure. Waste black liquor obtained from chemical retting of coconut fibres has been processed using different methods of effluent treatment. The physico-chemical characteristics after each treatment were determined for developing a suitable effluent treatment method to be used industrially.

2. Materials and methods

2.1. Materials

Raw brown coconut fibre and conventionally backwater retted coconut fibres (retting period of 10 months) of a specific variety was collected from a single plot of cultivable land at Thiruvanantapuram, Kerala, India. Sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), sodium sulphide (Na_2S), sodium periodate ($NaIO_4$), hydrogen peroxide (H_2O_2) (50% w/v), sodium metasilicate ($Na_2SiO_3{\cdot}5H_2O$), sulphuric acid (H_2SO_4), hydrochloric acid (HCl) (assay, 35%), and glacial acetic acid (CH_3COOH), activated charcoal were procured from E Merc, India.

2.2. Treatment of coconut fibre with water, steam, acids and alkalis

Raw coconut fibres were subjected to selected treatments with water, steam, alkalis (NaOH, Na_2CO_3), reducing agent (Na_2S), oxidative agents ($NaIO_4$, H_2O_2), and acids, (H_2SO_4, HCl at different concentrations viz.,100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, 5%). Detail conditions of the treatments are given in Table 1. The material to liquor ratio for all the above said chemical treatments were maintained to 1:20. The treated coconut fibres (other than acid treated) were then successively washed with warm water, and 5% (w/w) acetic acid solution until it is free from alkali. The alkali-free fibres were then further washed with plain water, and dried in air. Acid treated coconut fibres were also washed with warm water, and then with 5% (w/w) sodium carbonate solution to neutralize the residual acid and then further washed with plain water, and dried in air.

2.3. Measurement of weight loss

The weight loss of coconut fibre due to specific treatments was measured from the weight of fibre sample before and after a treatment using the following relationship:

$$\text{Weight loss } (\%) = \left(\frac{(W_1 - W_2)}{W_1}\right) \times 100$$

where W_1 and W_2 are the dry weights of untreated and treated fibre samples respectively.