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Characterization of ligno-cellulosic seed fibre from Wrightia Tinctoria plant for textile applications—an exploratory investigation

K. Subramanian *, P. Senthil Kumar, P. Jeyapal, N. Venkatesh

Department of Textile Technology, Bannari Amman Institute of Technology, Sathyamangalam 638401, Erode, Tamil Nadu, India

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Abstract

A hitherto uninvestigated ligno-cellulosic seed fibre from the plant Wrightia Tinctoria has been chosen for the current study to unravel its physical properties, and potentialities in textile applications. Both raw and partially delignified fibres were tested for their morphological and structural features by X-ray diffraction, optical microscope and FT-IR spectra, thermal properties by thermogravimetry and differential scanning calorimetry and fibre fineness properties. The non-spinnable brittle virgin fibre becomes spinnable after partial delignification due to the decreased fibre rigidity imparted by lignin. Knitted fabrics were made successfully with (20%) and without cotton blending.

Keywords: Lignocellulose; Seed fibre; Delignification; Tex; Tenacity; X-ray crystallinity; Fourier transform infrared (FT-IR); Spinning; Knitting; Fabric

1. Introduction

The dwindling petroleum resources and the mounting pollution problems globally with synthetic fibres and polymers have directed mankind to search for renewable alternate resources for ecofriendly raw materials such as natural vegetable fibres for diverse textile applications. Since, the majority of these natural fibres are ligno-cellulosic in nature, they are considered as low value industrial fibres. But the improvements in fibre and yarn production technologies through constant and indepth research over the years and ecological considerations have created a renewed research interest on the ligno-cellulosic fibres to explore their potentialities in textile and allied fields [1]. Since, the developments in composite material after meeting the challenges of aerospace sector have cascaded down for catering to the less demanding domestic and industrial applications, these renewable natural fibres can also be used as reinforcing materials [2,3] for these applications cost effectively. In this respect many well-known ligno-cellulosic fibres such as jute, ramie, sisal, hemp, coir etc. have been studied and well documented [1]. However, there are few vegetable fibres which still remain unutilized and are going as natural waste. One such hitherto uninvestigated ligno-cellulosic fibre is the seed fibre obtained from Wrightia Tinctoria (Latin) [Sweet Indrajao (English), Strikutaja (Sanskrit) and Hyamaraka (Indian)], a naturally growing drought and pest resistance tree of Indian origin [4], well known

* Corresponding author. Tel.: +91 4295 221289/3956; fax: +91 4295 223775.
E-mail addresses: drksubramanian@rediffmail.com, subramaniank@bitsathy.ac.in (K. Subramanian).

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for its medicinal values. It is a small, deciduous tree with a light gray and scaly smooth bark with a life cycle around 30 years, generally sighted in the uncultivated land areas. Its leaves are used to treat various skin disorders and possess anti-inflammatory and antidandruff activities. But there is no literature on its seed fibre properties. Hence, for the current study this seed fibre has been chosen to tap out its textile physical properties for exploiting its potential textile applications.

2. Experimental

2.1. Materials

Cotton fibre (commercial), sodium hydroxide pellet (analytical, Merck, India, purity >99.5%) for scouring, hydrogen peroxide (Pure, Merck, India, 50% w/v) for bleaching, sodium carbonate (analytical, Merck), sodium silicate (technical, Merck, India) a stabilizer for H_2O_2, benzene (guaranteed, Merck, India) and methanol (Excelar, Qualigens, India) for defatting and dewaxing of the fibre, distilled water, hydrochloric acid (Pure, 35% solution, Merck, India) for washing the scoured fibre to remove the last traces of alkali present in it, Turkey red oil (Sulphonated castor oil, anionic wetting agent, commercial, India), xylene (Sulphur free, Qualigens, India) an immersion medium for evaluation of apparent density of the fibre, sodium nitrite (analytical, Central Drug House Ltd., India) for humidity control inside a desiccator, anhydrous calcium chloride (>99.5% purity, Merck, India), a drying agent etc. were used as received except xylene. Xylene was dried over anhydrous calcium chloride for 24 h and then distilled under vacuum just before use. The seed fibre from Wrightia Tinctoria (Sweet Indrajao) plant was obtained from its fully matured wet bolls after drying under sunlight. The dry fibre yield of the plant is roughly around 1–3 kg per annum.

2.2. Methods

2.2.1. Dewaxing and defatting

The fatty and waxy materials present in the bone dry seed fibre of known weight (2 g) were removed by Soxhlet extraction, continuously for 10 h using a mixture of benzene and methanol (1:1 v/v). The resulting fibre was dried under vacuum (10^{-2} mm of Hg) at 45 °C for about 3 h. Then it was kept over anhydrous $CaCl_2$ in a desiccator for about 5 days and weighed. From the difference in the weights of the bone dried fibres before and after extraction, the percentage of fatty and waxy materials was calculated.

2.2.2. Estimation of lignin

Lignin content in the defatted fibre was estimated by determining the dry mass remained after treating with 72% sulphuric acid [5–7]. About 2 g of chopped and powdered original fibre (defatted) was taken in a 100 ml flask. To this 25 ml of 72% (w/w) H_2SO_4, was added and steeped for 75 min at 35 °C with frequent stirring. Then it was transferred to a one litre flask and diluted to 600 ml with distilled water, refluxed for 3 h. It is cooled and filtered through a weighed Gooch crucible (G4). The residue in the crucible is then washed repeatedly with water to free it from traces of acid, dried at 105 °C, cooled and weighed.

2.2.3. Chemical treatment of the fibres

Wrightia Tinctoria is a ligno-cellulosic seed fibre and hence possesses the inherent attributes of these fibres [1]. The fibre is highly brittle and is easily hand-crushable due to the high lignin content. Hence, this fibre requires chemical treatment to improve its properties for textile and allied applications [8–12]. This was done by delignification by caustic treatment and oxidative bleaching as reported for other lingo-cellulosic fibres [8–14].

2.2.3.1. Delignification by alkali treatment. The experimental fibre was subjected to partial delignification [8–13] by boiling with 1.5% (w/v) NaOH for 1 h. The material:liquor (*m*:*l*) ratio was 1:40. A wetting agent (Turkey red oil, 1.0 g/l) was used to facilitate wetting and hence, massive delignification.

The solution attains dark brown colour [13] after the reaction, due to the leaching out of the lignin from the fibre. This was decanted and the resultant fibre was digested for 30 min at 75 °C, washed thoroughly and repeatedly with copious volume of distilled water to remove the traces of alkali. Final traces of alkali present in the fibre were removed by washing with 1% (v/v) solution of 35% (w/v) HCl at room temperature (28 °C) and then with distilled water until the washings are neutral to litmus paper, squeezed to remove the excess water, dried under ambient conditions and then under vacuum at 45 °C.

2.2.3.2. Delignification by bleaching. Bleaching of the alkali treated fibre was carried out using alkaline hydrogen peroxide at 70 °C for 20 min. The fibre weight based weight percentages of additives used in the bleaching experiment were, water: 96–97, sodium hydroxide: 0.05, sodium carbonate: 0.1, Turkey red oil: 0.02, sodium silicate: 2.0 and hydrogen peroxide (50%): 1.0. The material to liquor ratio (*m*:*l*) employed was 1:20. The stabilizer, sodium silicate was added to slow the rate of peroxide decomposition under alkaline conditions and combine with or neutralize metal impurities that may catalyze the decomposition of H_2O_2 and induce fibre damage. It also buffers the peroxide solution by increasing the pH. Sodium hydroxide/sodium carbonate is an activator for H_2O_2. In H_2O_2 bleaching of the fibre, oxidative delignification [11,15–17] also occurs.