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Tensile mechanical properties and surface chemical sensitivity of technical fibres from date palm fruit branches (*Phoenix dactylifera* L.)

Salah Amroune [a,b], Abderrezak Bezazi [a], Ahmed Belaadi [a], Chenchen Zhu [c,d], Fabrizio Scarpa [c,d,*], Sameer Rahatekar [c,d], Abdellatif Imad [e]

[a] Laboratoire de Mécanique Appliquée des Nouveaux Matériaux (LMANM), Université 8 Mai 1945, Guelma, Algeria
[b] Université de M'sila, B.P 166 ICHBELIA, M'sila 28000, Algeria
[c] Advanced Composites Centre for Innovation and Science (ACCIS), University of Bristol, BS8 1TR Bristol, UK
[d] Bristol Centre for Nanoscience and Quantum Information (NSQI), University of Bristol, BS8 1FD Bristol, UK
[e] Laboratoirede Mécanique de Lille, Université Lille1, CitéScientifique, Avenue Paul Langevin, 59655 Villeneuve d'AscqCedex, France

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ABSTRACT

The paper describes the manufacturing process and the characterization of the tensile mechanical properties of treated and untreated palm dates long technical fibres. The fibres extracted from Fruit Bunch Branch of Palm Date (FBBPD) have been subjected to alkaline treatment with different NaOH concentrations at room temperature. The experimental results show that the chemical technical fibre treatments provide an increase of the mechanical properties (tensile strength and Young's modulus) under quasi-static tensile loading. A specific treatment leads a threefold increase of the failure stress. An analysis of stress at failure has been performed over a population of 630 samples using Weibull statistics with two and three-parameters, together with a one-way analysis of variance (ANOVA). FBBPD technical fibres show stiffness and strength performance comparable to the ones of agave Americana L fibres, and higher failure at strength than okra fibres.

1. Introduction

Natural fibres extracted from plants provide reinforcement to composites used in transport and constructions. A typical example is constituted by automotive components (interior trim doors, records of seats, carpet supports, bonnets) that are reinforced by plant fibres [1], like kenaf, jute, sisal, hemp and flax [2–10]. To obtain acceptable mechanical properties for the fibres it is necessary to use an adequate extraction method that allows the production reinforcements with minimal defects. There is abundant evidence in open literature that the production process has a significant impact on the chemical composition of the fibres, upon their lengths and general mechanical properties [11,12]. The most popular fibre extraction techniques consist in mechanical decortication, seawater retting, burial in earth and chemical methods using soda at low concentrations, to avoid the degradation of cellulose [13–16]. Physical properties like density, tensile strength and Young's modulus are linked to the internal structure and chemical composition, which vary from one fibre to another [17]. Belkhir et al. [18] investigated the effect of the harvest season and climate over the chemical composition of Alfa fibres. Alawar et al. have examined the effect given by a chemical treatment on the surface of the fibres surrounding the date palm leaves to improve the adhesion at the interface between fibre and matrix [19]. A study presented by Tahaet et al. [20] has identified the mechanical properties of fibres extracted from the stem spadix of palm date DPSS from the region of Ezbet El-Nakhl in Egypt. These rods have been cut into 50 cm long fibres and then chemically treated with hydroxide (NaOH) with a concentration ranging from 2% to 5% for periods varying between 2 and 24 h at a temperature of 23 °C. The most interesting results have been obtained from a solution of NaOH concentration of 2% for a treatment period of 2 h. The tensile strength of the chemically treated fibres was 600 MPa, which represents an increase of 50% compared to the case of the untreated reinforcements. Abdel-Rahmanet et al. [21] have investigated the mechanical properties of the fibres of the rods of Palms (rachis). The results of their study indicate that the tensile strength of the stem walls varies between 116 MPa and 208 MPa, while the heart of the rods provides 50% of those values. The Young's modulus of the stems ranges between 10 GPa and

* Corresponding author at: ACCIS, University of Bristol, BS8 1TR Bristol, UK.
E-mail addresses: amroune_salah@yahoo.fr (S. Amroune), ar_bezazi@yahoo.com (A. Bezazi), ahmedbelaadi1@yahoo.fr (A. Belaadi), f.scarpa@bristol.ac.uk (F. Scarpa), abdellatif.imad@polytech-lille.fr (A. Imad).

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30 GPa. An experimental study on the natural mat surrounding the date palm tree subjected to tensile loading has been performed by Al-Khanbashiet et al. [22]. Palm date fibres consist primarily of 46% mass of cellulose, 20% lignin and 18% of hemicelluloses. The diameter of these fibres varies between 100 and 1000 μm, which are values generally larger than the ones present in other natural fibres. Tensile strength varies from 170 to 275 MPa, and the modulus of elasticity ranges between 5 GPa and 12 GPa, with an elongation at break of 5–10%. Treatment with a concentration of 5% NaOH at 100 °C and a duration of 2 h showed evidence of the enhancement of the tensile failure stress (496 MPa) of 45% compared to untreated fibre configurations.

Fatigue and mechanical endurance are also key parameters to characterise the behaviour of natural fibres [4,23]. Recently, Belaadi et al. [4] have investigated the behaviour under quasi-static tensile and fatigue cyclic loading of sisal fibres. Single fibres used in that work has an approximate diameter of 250 μm and a length of 0.8–1 m. The samples have been subjected to tensile loading

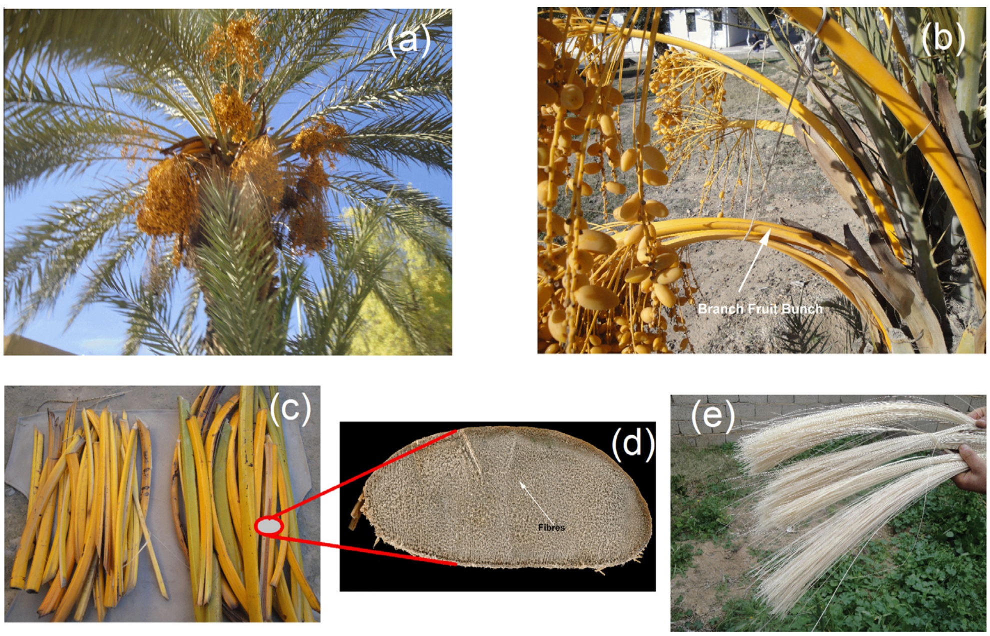

Fig. 1. Photographs of (a) date palm tree, (b) and (c) fruit bunch branch, (d) section transversal FBBPD (e) FBBPD technical fibres used in this work. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

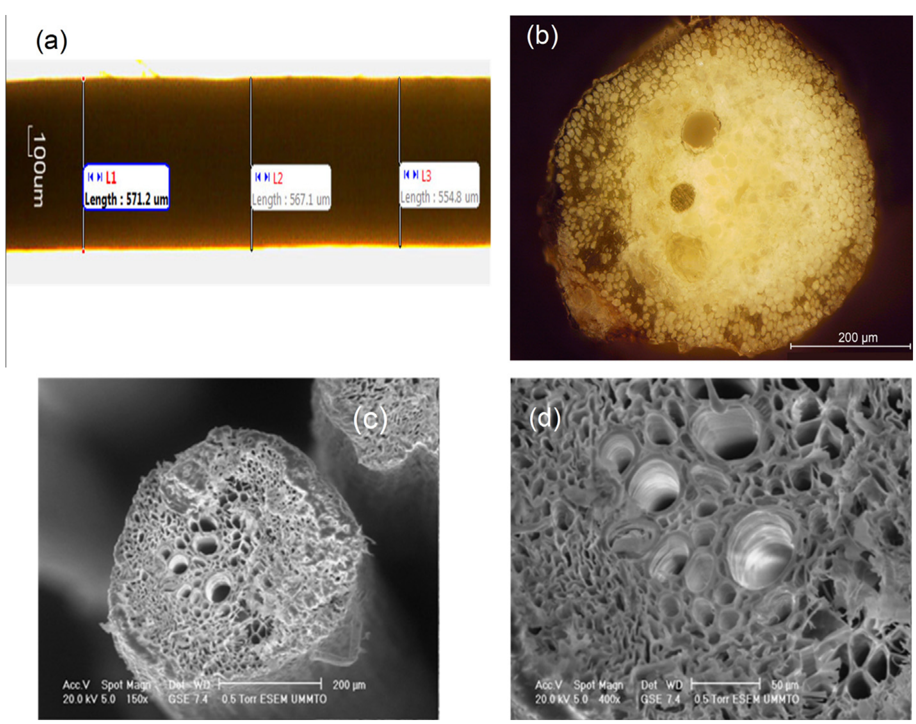

Fig. 2. (a, b) Optical microscopy image of a longitudinal and section cross. (c, d) SEM cross-sectional morphology and details of cell FBBDP technical fibre. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)