Fecha de recepción: abril 2023
Fecha de aceptación: mayo 2023
Versión final: junio 2023

Biomateriales alternativos para la producción sostenible de estructuras textiles

Cristina Pires(*), Catarina Guise(**)
Carla Silva(***) y Lígia Rodrigues(****)

Abstract: The textile industry is one of the most pollutant industries in the world. Synthetic fibres represent more than 60% of fibres in this industry, which, together with the high-energy consumption of the sector, increases the ecological footprint of textile production. Therefore, it is important to promote a circular economy in the textiles life cycle to decrease the consumption of fossil fuel raw materials and increase the use of natural fibres. In this work, the potential of *Cordyline australis* leaves for use in textile production was investigated. The process involved extracting the fibres from the leaves through a water-retting pre-treatment, followed by an enzymatic treatment using cellulases. The resulting fibres were blended with virgin cotton fibres to produce a ring-spun yarn and a knitted structure, which were then dyed and analysed to compare their properties with those of a 100% virgin cotton structure. The leaf fibres from *Cordyline australis* showed promising results as an alternative natural textile fibre, although these fibres applied in the textile sector are still in an initial stage of development.

Keywords: sustainable textile fibres - alternative biomaterials - Cordyline australis fibres, cotton fibres, degumming, yarn spinning, knitting, dyeing

[Resúmenes en inglés y portugués en la página 133]

(*) Grado en Biología Aplicada (UM 2020) y Máster en Biotecnología (UM 2022). Es investigadora del Departamento de Química y Biotecnología de CITEVE. Su trabajo se basa en el reciclaje textil y el estudio de fibras naturales de fuentes alternativas. Algunos de sus intereses incluyen la sostenibilidad, la biotecnología ambiental y la economía circular.

(**) Máster y Doctorado en Ingeniería Biomédica (UM 2016). En CITEVE es investigadora del Departamento de Química y Biotecnología. Trabaja en diversos proyectos de investigación relacionados con la sostenibilidad y la economía circular. También asesora a estudiantes de maestría.

(***) Grado en Ingeniería Biológica (UM 1996), Máster en Biotecnología Industrial (USP-Brazil 1999) y Doctorado en Química Textil (UM 2005). En CITEVE es directora del Departamento de Química y Biotecnología, y tiene más de 20 años de experiencia en investigación aplicada a la industria, con más de 50 artículos y 10 patentes publicadas.

(****) Máster en Ingeniería de Bioprocesos (UM 2001), Doctor en Ingeniería Química y Biológica (UM 2005) y Calificaciones de la Universidad de Minho (2017). Actualmente, es Profesora Asociada con Calificaciones en la Universidad de Minho (UM, Portugal), Subdirectora de la Escuela de Ingeniería, Presidente del Consejo Pedagógico de la Escuela de Ingeniería y Directora Asociada del Centro e Ingeniería Biológica (CEB).

Introduction

The textile and apparel sector is one of the most significant industries in the world. In 2020, the global clothing market reached 1,5 trillion euros and it is anticipated to increase to 2,25 trillion by 2025 (Ihzaturrahma & Kusumawati, 2021). However, textile production requires a great quantity of resources like water, fossil fuels, chemicals and raw materials that result in a great amount of waste, liquid and solid toxic effluents, and greenhouse gases (Koszewska, 2018; Yacout & Hassouna, 2016). Moreover, synthetic fibres represent 64% of the global market of fibres, increasing this impact on the environment, due to their origin in fossil fuels (Textile Exchange, 2022). There has been increased focus on using renewable and natural resources, as well as repurposing waste from other industries in the textile industry. This is aimed at reducing the adverse effects that the industry has on the environment.

Natural fibres are capable of undergoing biodegradation. (Kozłowski et al., 2020). Within the category of natural fibres, there are vegetable fibres that come from various parts of plants such as seeds (e.g., cotton), stalks (e.g., linen, jute, hemp), leaves (e.g., sisal, corn), or fruit (e.g., coconut). However, leaf fibres are typically rougher and harder, which limits their commercial value. These fibres are normally extracted through mechanical scrapping of the non-fibrous material (Smole et al., 2013).

Cordyline australis is a plant characterized by long and slender leaves (Figure 1). Despite its limited use in the textile industry, a recent research has shown its potential for textile applications, as it exhibits similar properties to some fibres that are presently used commercially (Sumihartati et al. 2021). Moreover, this plant requires low water consumption during cultivation, and it does not require the use of pesticides or herbicides. Furthermore, it is highly resilient to climate change. Therefore, *C. australis* is a promising alternative fibre for the textile industry.

Figure 1. Example of *Cordyline australis*. Botanical garden of the University of Trás-os-Montes e Alto Douro (UTAD, 2022).

Materials and methods

The following section describes the materials and methods utilized for this study.

Enzymatic treatment

For the extraction of the fibres of the *Cordyline australis* leaves (Figure 2), a pre-treatment method using water retting was employed. This involved soaking the leaves in water for 21 days to eliminate some material present on the superficial layer.

Figure 2. *Cordyline australis* leaves used in this work.

Figure 3. *Cordyline australis* leaves after 21 days in the water retting pre-treatment.

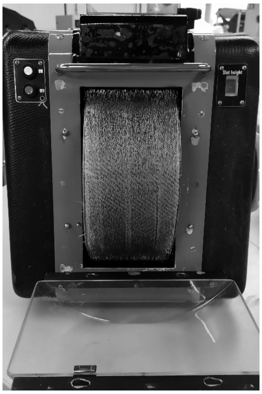

Figure 4. Manual card.

After 21 days (Figure 3), the non-cellulosic material of the leaves was scrapped off and the fibres were manually individualized. They were then left to dry naturally before undergoing an enzymatic treatment using cellulase. This treatment was performed on one-half of the fibres, allowing a comparison to be made with the untreated raw material.
To achieve better fibre separation and remove any remaining debris, both the enzymatically treated and non-enzymatically treated fibres were carded using a small carding machine (Figure 4).

Characterization of the Cordyline australis fibres
To evaluate the properties of the fibres, various tests were performed, including measurement of linear density (fineness) and tenacity (breaking force per the linear density). The chemical composition was analysed using - *Fourier transform infrared* (FTIR) *spectroscopy*, while whiteness was assessed using Berger's scale (Ly et al., 2020; Zarubica et al., 2005). Additionally, colour difference was measured using colour coordinates based on the CIELAB system (Atodiresei et al., 2013) through a spectrophotometer -*Datacolor Spectraflash sf450*.

Spinning and knitting
Following the characterization process, the fibres were prepared for spinning (Figure 5), which began with a 100% virgin cotton yarn. The following steps were taken: carding, drawing/roving (Figure 6), spinning (Figure 7) and winding.

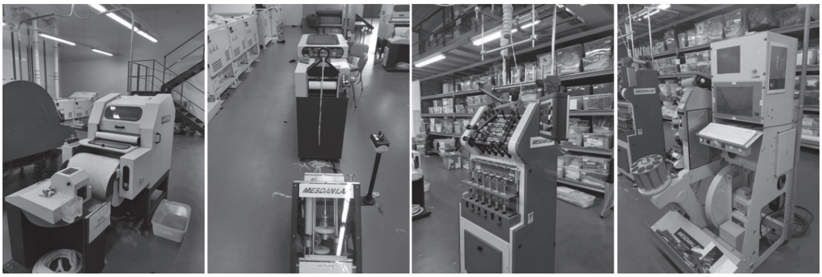

Figure 5. Spinning system in CITEVE. (A) card, (B) drawing/roving frame, (C) ring-spinning, (D) winder.

Figure 6. On the left, the sliver from the card, and on the right the sliver from the drawer.

Figure 7. Detail of the ring spinning process – from the roving to the yarn.
To produce yarn using fibres from *Cordyline australis* leaves, a blend was created with cotton, consisting of 10% *Cordyline australis* fibres and 90% cotton (Figure 8).

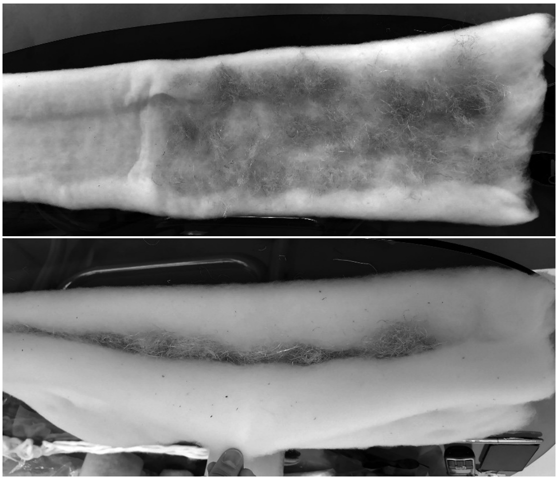

Figure 8. Blend of the *Cordyline australis* fibres with cotton before carding.

Two yarns were created using this blend, one with treated fibres and one with non-treated fibres, in order to compare their properties. Both were characterized for linear density and tenacity before being knit into textile structures using a laboratory-knitting machine called Tricolab (Figure 9). The resulting structures were then dyed (Figure 10) and characterized in terms of their colour properties. The knitted structures made with the treated and non-treated fibres were compared to a knitted structure made from 100% cotton.

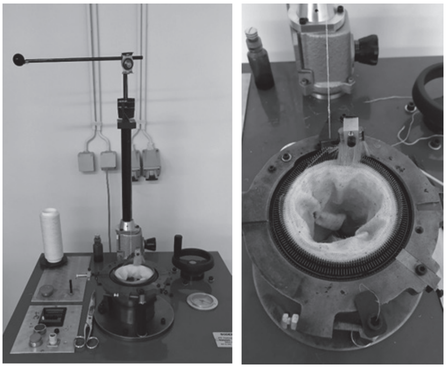

Figure 9. Knitting machine.

Figure 10. Bleached (on the left) and dyed (on the right) knitted structures.

Results and discussion

In the subsequent section, the results obtained in the extraction of the fibres, spinning, knitting and the tests performed on the fibres and yarn are described and discussed.

Enzymatic treatment

The water-retting pre-treatment performed on the leaves resulted in different degrees of degradation (Figure 11).

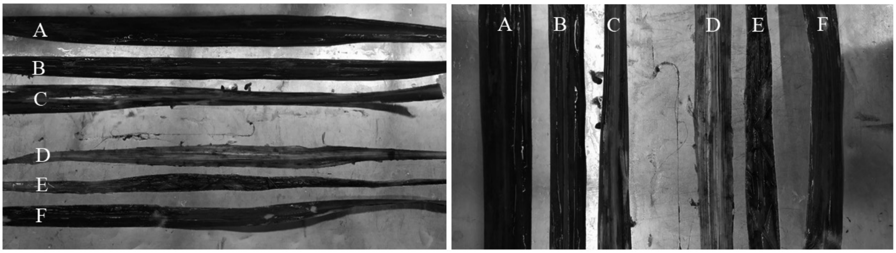

Figure 11. Leaves from the water retting pre-treatment. Leaves (A), (B) and (C) present a low level of degradation compared to leaves (D), (E), and (F).

The discrepancies in degradation observed in Figure 11 can be attributed to the water temperature and the maturity level of the leaves. Fluctuations in temperature or low temperatures could have hindered the action of the microorganisms that caused the degradation of the outer layer of the leaves (Hossain et al., 2021). Similarly, it was proposed that leaves with a lower level of maturity might need higher temperatures or more time in water for efficient degradation (Mafaesa et al., 2019). The extraction process for leaves with low levels of degradation was significantly more challenging. Additionally, the fibres with higher levels of degradation exhibited less debris, which, in turn, decreased their greenish appearance, as seen in Figure 12.

Figure 12. Dry fibres from the water retting pre-treatment. The fibres on the left resulted from leaves with a higher degree of degradation, and the ones on the right from leaves with a lower degree of degradation.

Manual carding proved to be an effective method for separating and cleaning fibre bundles, particularly for fibres that were not treated with enzymes. Through the movement and abrasion of the card, the non-cellulosic material was eliminated, which could have been degraded if enzymes were used. This resulted in a uniform appearance for both treated and untreated fibres, as seen in Figure 13.