STUDY OF TEXTILE POTENTIAL OF FIBRES EXTRACTED FROM TUNISIAN AGAVE AMERICANA L.

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Abstract

Agave Americana L. *fibres have quite important textile potential. In this paper, we demonstrate this potential by studying the extraction of these fibres from leaves, their physical properties such as fineness, density and their mechanical behaviour in tensile tests. The intrinsic variability of all these properties is also studied, showing natural maturity and ageing of fibres.*

Key words

Agave Americana L.*, fibres, intrinsic variability, textile potential*

Introduction

Agave fibres are extracted from the leaves of certain agave plants. These fibres occur, after their extraction, in bundles constituted of several ultimate fibres held together by waxy and sticky substances. Ultimate fibres have an average equivalent diameter of 24 µm and a length of 1 to 7.5 mm [4, 5]. These long technical fibres are generally hard, stiff, and coarse in texture, and for these reasons, they are considered as 'hard' fibres included in the long vegetable fibres class.

Figure 1. The agave *Americana L.* plant

In Tunisia, the agave *Americana L.* is the most abundant variety of agave [1]. This variety is characterised by the fact that it is a very voluminous plant with long, fleshy, rigid, hard-surfigured and lanceolate leaves, which grow directly out from the central stalk to form a dense rosette (Figure 1). Its floral stalk, sometimes termed the trunk, can reach 10 to 20 m in length (Figure 2). This agave plant is native to Mexico and other parts of the Caribbean area. These plants were brought from there to Europe, Africa and the Far East by the Spanish and Portuguese, where they naturalised rapidly, especially in the high, arid regions around the shores of the Mediterranean [3, 5].

Figure 2. Floral stalk of the agave *Americana L.* plant

The agave *Americana L.* was much used by Tunisians for its fibres until the 1960s, when fibres extracted by simple immersion in seawater were used to make ropes and twines for agricultural and marine purposes. Now, these plants are no longer used.

Since 1998, a research program has been undertaken in order to evaluate the potential of the agave *Americana L.* as a new source for textile fibres. This paper presents the physical and mechanical properties and their intrinsic variability of agave *Americana L.* fibres as appropriated from several leaves of different agave plants growing in the region of Monastir (Tunisia).

Materials and methods

Agave fibres can be extracted from their leaves either mechanically, by a combined action of crushing and beating using machines called 'raspadors', or by retting the leaves' vegetable parenchyma in seawater and cleaning either by hand or with a decorticator [5]. Crushing and beating actions risk decreasing the resistance of the fibres. Furthermore, ecological problems caused by rejects and the long period of time for extraction in seawater do not incline us to recommend the use of these two methods. For these reasons, some tests for extracting chemically the fibres were devised.

To study their physical and mechanical properties, the fibre samples were extracted by retting in seawater. The tensile tests of these fibres were carried out using a Shirley dynamometer, Micron 250, with a constant strain rate according to ASTM standard D3217-79. The tests were conducted under standard conditions: 20°C ± 2°C and 65% ± 2% R.H. according to ASTM standard D1776-85.

Because of the high variability found in tests for physical and mechanical properties, we chose to study the effect of biological factors of influence on the properties measured. This was achieved at the intra-plant level, taking three control factors into account: 'the fibres' position in leaf' (3 positions from basis to top), 'the insert level of the leaf in the plant' from the oldest to the youngest leaves (10 levels), and 'the position of the leaf at the same insert level' (2 leaves). On the inter-plant level, we have studied the variations in 5 different plants while maintaining a constant level factor. A variability study was conducted, leading to some statistical methods of analysis [6].

Results and discussions

Fibre extraction

The results obtained show the feasibility of the chemical extraction, aided by the great reactivity of the leaf vegetable parenchyma constituents to certain chemical products, and the resistance of fibres to different extraction agents, confirmed by the presence of waxy and sticky substances on their surface. By optimising the extraction conditions, sulphuric acid seems to be an interesting extraction agent from a technical and economic point of view.

Morphological and physical properties

The agave *Americana L.* fibres are white to yellowish in colour, and have a hard touch due to the existence of lignin on their surface. We can also observe longitudinal streaks which are characteristics of long vegetable fibres (Figure 3).

By examining these technical fibres with an SEM (Scanning Electron Microscope), we can see a ‘composite’ structure where ?ultimate fibres are held together by sticky and waxy substances to finally form a technical fibre with section forms which are difficult to define. The ultimate fibres show oval and irregular sections with a large lumen (Figure 3).

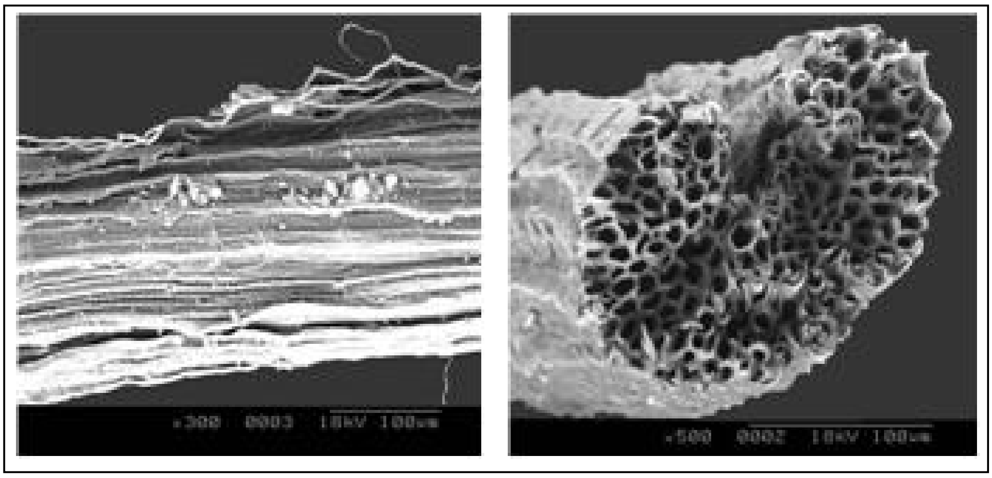

Figure 3. Longitudinal and cross-section views of an agave *Americana L.* fibre

The agave *Americana L.* fibres are coarse fibres with an average linear density equal to 24 tex, a diameter (calculated by assuming the cylindrical form of the fibre) equal to 150 µm, and an apparent diameter measured on a projection microscope equal to 263 µm. The projected apparent diameter distribution of these fibres is symmetric, uni-modal and adjustable to a normal law with an error limit equal to 5%.

Compared to other fibres from the same family [2], the agave *Americana L.* fibres are light, with a density equal to 1.36 measured at 21°C using the gradient column technique. Also, in comparison with other textile fibres, the agave *Americana L.* fibres are more hydrophilic than cotton, flax, and other vegetable fibres, with a regain equal to 17%. At this point, they are comparable to jute and wool fibres.

Mechanical behaviour

The results of tensile tests obtained are reported in Figure 4 and Table 1. These mechanical results show a specific behaviour, which recalls that of rubber, with great extensibility (50%) before rupture. Most vegetable fibres do not exceed 10%. The tenacity of agave *Americana L.* fibres is near those of vegetable fibres such as sisal or flax; their initial modulus is much less than those of the other natural fibres. The rupture work is higher than that of other natural fibres, especially vegetable ones.

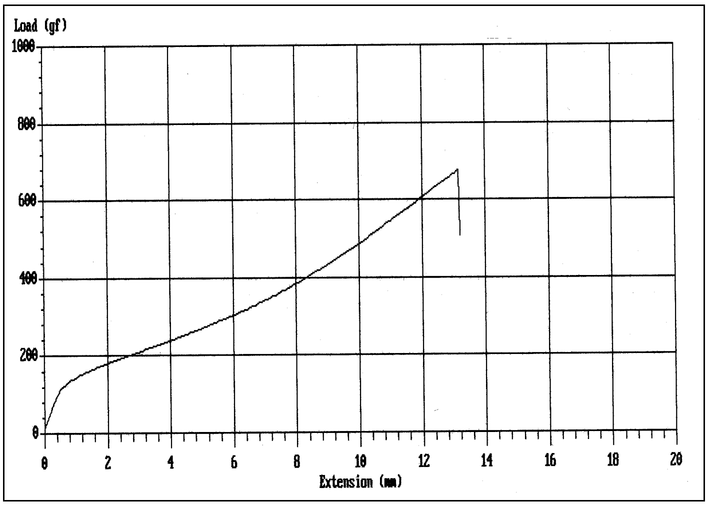

Figure 4. Stress-strain curve of an agave *American L.* fibre

Table 1. Experimental results of tensile tests (sample of 50 fibres)

Parameter	Load (N)	Tenacity (cN/Tex)	Stress (MPa)	Strain (%)	Initial modulus (cN/tex)	Work fracture (J)
Average	6.92	28.29	384.66	49.64	61.01	0.046
CV%	22.92	22.92	22.92	12.5	55.67	30.14
CI (95%)	0.45	1.84	0.25	1.76	9.65	0.004

The tensile fracture morphology examined with the SEM shows that fibres have brittle fracture (Figure 5); this can be explained by the composite structure of the fibre, in which ultimate fibres are blocked by natural gums.

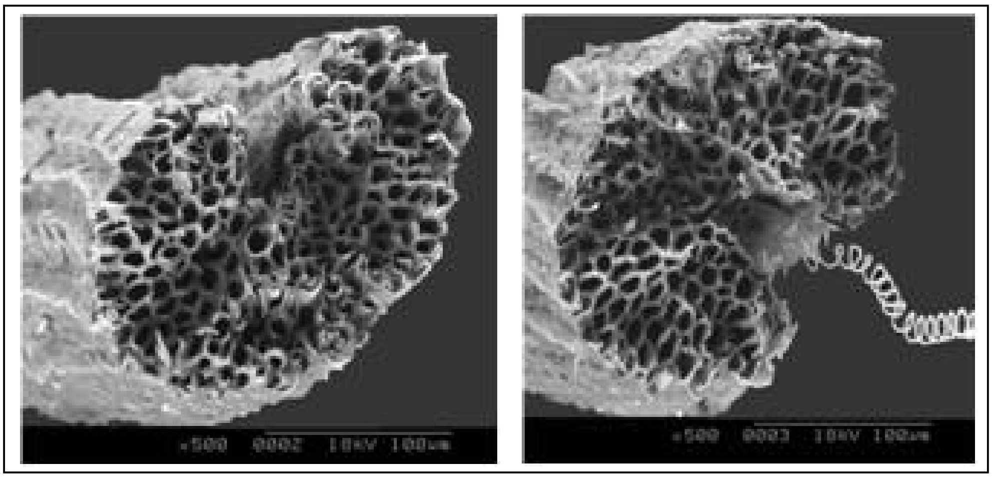

Figure 5. The tensile fracture morphology of an agave *Americana L.* fibre

When exposed to the influence of some external factors, the agave *Americana L.* fibres globally present a high resistance to chemical agents such as acids and alkalis, as well as to UV (108 hours). Nevertheless, they become very fragile when exposed to high temperatures (up to 180°C). Their behaviour after immersion in pure water or seawater is similar, and leads to classical softening, causing a decrease in initial modulus without any important loss in tenacity or failure strain.

Intrinsic variability of physical and mechanical properties

The results obtained show that the factor 'fibres position in leaf' and 'insert level in leaves' seem to be very significant for the variations observed, with the weight effect going from 60 to 80% for the all the mechanical parameters, and up to 100% for fineness parameters. The interactions between these two factors frequently have a considerable influence. The factor 'leaf position in a same level' seems to be the factor with the weakest influence on all the variations observed.

The 'plant' factor seems to be negligible for fineness, explaining 20 to 30% of the variation in the principal mechanical properties.

In all cases, those properties fall from bottom to top in the plant and from the base to the summit of the leaf, showing the maturity and ageing degrees which one would expect to observe in this kind of vegetable.

Conclusion

The results obtained from agave *Americana L.* fibres show the fairly important textile potential demonstrated by the fibres' important resistance, lightness properties and composite structure. Indeed, the exploration of mechanical and physical properties and the study of the possibility of accelerating extraction, a limiting factor for economic development, constitute an important step for the procedure of valorising this textile raw material source. Thus, according to their properties, agave *Americana L.* fibres can be used in technical applications such as reinforced materials and geotextiles.

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