ESPARTO GRASS (STIPA TENACISSIMA L), RAW MATERIAL OF PAPERMAKING. FIRST PART

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The esparto is an endemic grass of North Africa, perennial plant; it constitutes a significant raw material resource for papermaking, occupant of vast territory in Algeria. It is widespread from the Mediterranean littoral of the area of Oran, until altitude of 1800 m in the south of the country; the esparto tablecloths constitute a genuine natural barrier which limits the expansion of the desert.

The esparto grass seems to prefer the calcareous soil, not very deep and permeable, with texture dominated by a high sand rate, it misses in the depressions like on the clay or the salted soils.

The esparto grass grows in circular tufts. Each tuft results from the roots of same rhizome which carries short internodes and secondary roots. On the armpits of the internodes, the sheets (bits) buds and outlines of the future secondary roots appear.

The esparto sheet is presented in the ribbon form resembling the yarn, smooth, shining, solid, and covered at the base with a hairy sheath which retains a considerable quantity of dust.

The quantity of cellulose contained in this plant, the flexibility, the smoothness and the mechanical resistance of its fibres confer to it the very required properties in papermaking; qualities recognized since a long time.

The esparto grass is a resistant plant to much branched rhizome, forming initially the compact stocks then becoming circular with the deterioration of the old branches.

**Growth area of the esparto grass**

Esparto – *Stipa tenacissima* L. is a hardy perennial grass of the family of the grasses ones. This is an endemic of the Western Mediterranean, which grows on the semi arid grounds of the North Africa and the south Spain. Boudy [1] estimated the esparto covered surface in hectares approximately at 4.5 millions in Algeria, the more recent information’s have given 3 millions only [2].

In Algeria, the species (*Stippa tenacissima* L) grows mainly on the high plateaus in mixture with the sparte (*spar-tum legium*) in an alternation of vegetation studied by the authors [3]. It is in the western south steppes of the country that one meets the vast and greatest esparto expanses (1.2 million hectares in the Saida region).

Widespread since the littoral in the hot and moderated variants of Oran area until the altitude of 1800 m in the south of the country, the sparte tablecloths constitute a genuine natural barrier which limits the expansion of the desert.

**Organization and growth of the plant**

*Self ecology.* The esparto grass is a resistant plant to much branched rhizome, forming initially the compact stocks then becoming circular with the deterioration of the old branches, as shown in the fig. 1–2.

The clay and silicic soils are well appropriate for the development of this plant which fears especially the dense and wet soil. According to Pouget [4], esparto characterizes the stony soil with a high rate of calcareous (30 to 40%) and a small percentage of gypsum (~ 2%).

Esparto grass resists at the great variation of temperature (~19 °C) in Rogassa region in the Algerian western south, while supporting the very hot summers (~40 °C). Following the observations on the ground and laboratory, Harche M [5] showed that the optimal photosynthetic activity of the esparto takes place at the temperatures ranging between 15 and 25 °C. The relatively low temperatures lower than 4 °C, slow down the assimilation and delay germination.

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In short, absent in the depressions where water remains stagnant long time, like on the soil argillaceous or salted, the esparto seems to prefer the calcareous soils, not very deep (10–25 cm) and permeable, with texture dominated by a high rate (higher than 70%) of sand.

**Phenology.** Esparto tuft, resulting from the roots of same rhizome, grows in circle. The rhizome carries the very short spaces of between the nodes and of the secondary roots. One of these roots is stretched in length and is inserted in the ground at the appreciable depth. The roots being at the stem's bases are called adventive's roots, generally, they are not very deep. At the armpits of «internodes» appear the sheets (bits), the buds and the outlines of the future secondary roots, fig. 3.

The sheet or stem is presented under the form of a thin ribbon, smooth, shining, solid, covered at the base with a hairy sheath which retains a considerable quantity of sand dust. This is in this place that one can pull out the sheet easily. The cut using a slicing tool led to the deterioration of the esparto tuft.

The observations made by Aidoud [6] on the development and the growth of the sheets, indicate that the esparto grass flowering, generally begins in May and finishes at the end of June and sometimes even, at the beginning of July, fig. 4. One can observe an early flowering in April, if the autumnal rains are sufficient and the relatively soft winter. The water requirements of the esparto grass are not studied enough. In the pasture steppes, Celles [7] speaks about a minimum of 250 to 300 mm, whereas Aidoud [6] observed the flowering for a pluviometry lower than 200 mm in the stations of Rogassa.

For the papermaking use, the limbs or the sheets become ripe (yellows and hard) are ripped from July to November and are laid out in boots which one compresses in bales of 200 to 250 kg. One cubic meter of esparto in a hurry weights 260–280 kg. The esparto picking is still manual and painful. The yield at the exploitation varies with the density of the esparto tablecloth of 400 to 2000 kg /ha [8].
Ultra structure of the cells walls and the fibres morphology of esparto pulp

Ultra structure of the cells wall of esparto fibres

According to Harche M. and Bounaga D. [11], the principal elements of the chemical constitutional skeleton of the limb of esparto sheet would be a series of polysaccharides among which the cellulose, pectin, water, uronids and minerals. The whole, regularly shared out in layers and under layers relatively at the functions governed by the elaboration of vegetal cellular tissue and tied by omnipresent lignin, by giving at the same time mechanical resistance; the resistance to the chemicals and biological agents. The authors [12] visualize these various elements, their development, their evolution in time, their function like their site in the networks complex of vegetable fabric. This work underlines structural heterogeneity, summarizing the existence of lignin practically at all the levels and of the relative quantities to the maturity degree of the vegetable cells, fig. 5.

However, according to several authors, the lignification affects the middle lamella initially and the primary cell wall; then is spread in the secondary wall. The middle lamella and the primary cell wall, in general, are more lignified, there where are located 73% of lignin. Thiery J.P. [13] and Roland J.C [14] like Harche M emphasize great variability of polysaccharides in the esparto case; which would be relative at to some extent to the layers of the wall. In their work, they arbitrarily distinguish the distribution from the hemicelluloses rather on the primary cell wall, the cellulose in the layers of the secondary wall in the form of micro fibrils intercalated by significant thicknesses of lignin.

The chemical analyses carried out by the authors [15] would fix a rate of carbohydrates at 74,5% and the lignin rate at 18,5%.

Morphology of esparto fibres

In the esparto chemical pulp observed under the biological microscope, the fibres appear in the form of regular cylinders at the thin ends which resemble to phloem fibres of hardwood fig. 6–8. They are thin with one narrow lumen and often carry nodes and folds. These fibres are accompanied by many characteristic additional elements:
- The epidermal cells at the shape of comb and hairs.
- The sclerous cells in the form of nodes and sticks.
- A living and active parenchymatous cells in the vegetal elaboration.
- Imperfect vessels at the shape of rings and spiralled.

Fig. 5. Ultra structure of the cells walls of Esparto grass, electronic photography [12]

Fig. 6a. Fibres morphology of and cuticle's cell of esparto

Fig. 6b. Cellulosic fibres in esparto plant. (×500)
Generally, these fine elements are eliminated during washing and sometimes they are at the origin of obstruction of the cloths pores on the washing filter.

The fibers dimensions are closely related to the quality of the cellulosic pulp. Janin G and Ory. J.C even affirm that one of the major problems posed by the use of the paper pulp is the knowledge of the composition of pulp at point of view from the distributions of fibers length. According to these authors [16], the length of fibers depends on the age of the esparto grass. They give using an apparatus «histofibre» the following average length for esparto fibers: L = 1.66 mm.

**Biometry of cellulosic fibres**

The average dimensional specifications of the fibres of the sample which we had analysed, using zinc chloride iodine like dye and a biological microscope, are summarized as follows: length (mm) L: 1.56; diameter (mm) D: 0.012. The report L/D = 130, testifies of the good felting capacity which characterizes esparto fibres.

**Another industrial applications**

The cellulose quantity which contains this vegetal, the flexibility, the smoothness and the mechanical resistance of its fibres confer to him properties very required in papermaking; qualities recognized since long time.

Indeed, the esparto cellulosic pulp makes it possible to prepare papers of comparable qualities to those obtained from old rags.

Recent research works have widens the application field, by proving the performances of the cellulosic pulp, obtained from esparto cooking mixture with eucalyptus shavings [9].

Except its use in papermaking, the esparto grass finds also another use which is traditional in the espadrille manufacture and basket making. The young sheets incompletely lignified constitute a considerable fodder food. Lastly, an esparto grass from 2 to 3 years of age has a calorific value of 5100 kcal/kg [10].

**Chemical composition**

The raw material having been the subject of our study comes from the Algerian western south region. The whole of the chemical tests carried out on esparto grass required the preparation of approximately 500 g of finely crushed plant with particles of homogeneous size, sifted on sieve n° 24 and n° 27.

- Determination of moisture: the test sample approximately 2g is weighed with a precision of 10^{-3} g, then it is dried at 105 °C until constant weight.
- Determination of the ash content: the test sample, 3g of sawdust is weighed with a precision of 10^{-3} g, was calcined at the temperature of 575 °C in a muffle furnace during three hours. Ash obtained is weighed.
- Extraction with ebullient water: TAPPI T 207 bones-75 normalize.
- Extraction with perchlorethylene.
- Determination of insoluble lignin: TAPPI T 222 bones-75 normalize.
ESPARTO GRASS (STIPA TENACISSIMA L) …

- The cellulose rate, according to the method of KURSCHNER and HOFFER.
- Determinations of the furfural index with the dinitrophenylhydrazin D.N.P.H normalized (NF T12 008).

The presence of the important quantity of pentosans (xylans) in the esparto partly explains the great ease to be refined the chemical pulp extracted in this graminacea, and these pentosans can also constitute a considerable source of extraction of furan and it's derived after hydrolysis.

The lignin and cellulose rates are very nearby to those of hardwood, for example the eucalyptus [9].

**Table 1. Raw material chemical composition**

<table>
<thead>
<tr>
<th>Composition</th>
<th>Proportion (% report/ratio of the absolute dry plant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracted with ebullient water</td>
<td>5.08</td>
</tr>
<tr>
<td>Extracts with cold water</td>
<td>–</td>
</tr>
<tr>
<td>Extracted with perchlorethylene</td>
<td>2.53</td>
</tr>
<tr>
<td>Cellulose rate.</td>
<td>43.81</td>
</tr>
<tr>
<td>Lignin rate</td>
<td>18.76</td>
</tr>
<tr>
<td>Furfural number</td>
<td>17.6</td>
</tr>
<tr>
<td>Pentosans rate</td>
<td>28.4</td>
</tr>
<tr>
<td>Ash content</td>
<td>4.66</td>
</tr>
<tr>
<td>Silica</td>
<td>1.76</td>
</tr>
<tr>
<td>Moisture</td>
<td>10.2</td>
</tr>
</tbody>
</table>

**Mineralogical Analysis of ashes after calcinations of the esparto limbs**

**Table 2. Ashes mineral components of esparto**

<table>
<thead>
<tr>
<th>Elements, %</th>
<th>SiO2</th>
<th>CaO</th>
<th>Al₂O₃</th>
<th>FeO</th>
<th>MgO</th>
<th>K₂O</th>
<th>P₂O₅</th>
<th>TiO₂</th>
<th>Na₂O</th>
<th>Cl</th>
<th>Cr₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>34.13</td>
<td>6.57</td>
<td>4.64</td>
<td>2.51</td>
<td>1.45</td>
<td>1.31</td>
<td>0.5</td>
<td>0.31</td>
<td>0.29</td>
<td>0.28</td>
<td>0.102</td>
<td></td>
</tr>
</tbody>
</table>

**Losses on the ignition:** 47.50% with 1100 °C

The silica is very present in the composition of the esparto grass; it constitutes even one of the reasons for which the delignification of this grass is carried out by the alkaline processes, with soda or sulphate.

**Conclusion**

In North Africa, the esparto – Stipa tenacissima L, constitutes an essential element of fight against the turning into a desert and an essential factor of the maintenance of balance pastoral; from the economic point of view, it is of industrial interest some: like raw material of papermaking.

Currently the combined action of the many clearing and repeated, the excessive pasture, a prolonged cycle of dryness to which the ignorance of the plant is added partly, make that we attend a progressive regression of the esparto tablecloths. Very few investments intellectual or financial were consented there, at the moment when the country attaches a great importance to the natural resources.

Safeguarding, the development and the rational exploitation of the esparto tablecloths are major trumps necessary for the development of the Algerian steppe areas. Scientific research in the esparto field is a precondition to achieve these goals, moreover, paramount. On this subject, several studies and research, as our work, were carried out by public organizations, but the impact is dependent on a national plan of rehabilitation of the esparto grass grasses, which takes into account all the aspects from where the priorities and the objectives will emanate.

**Bibliography**

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