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Chemical characterisation and suitability for papermaking applications studied on four species naturally growing in Tunisia

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ABSTRACT

Four plants species namely *Astragalus armatus*, *Retama raetam*, *Pituranthos chloranthus* and *Nitraria retusa* were collected from Kasserine (Tunisia) to study their suitability for pulp and papermaking. Their chemical composition revealed that the α-cellulose content in *R. raetam* was lower than the normal range of hardwood, but the others were acceptable for pulp production. The Klason lignin content in these species was lower than 20%, except for *N. retusa* (26%). The amount of extractives in organic solvents was quite high (close to 10%) in *R. reatam* and *P. chloranthus*. The previous raw materials were pulped by using the soda-anthraquinone cooking process, the morphological properties, kappa number and the degree of polymerisation of the pulps obtained were determined. Finally, laboratory handmade standard sheets were prepared from the unrefined pulps of *P. chloranthus* and *A. armatus*. Their characterisation showed that the prepared papers present low density values and quite good mechanical properties particularly for the unbleached pulp. This study demonstrates the high potentiality of these two species for papermaking applications.

1. Introduction

In Tunisia, the flora is very rich in species which produce valuable natural substances such as essential oils, organic and wide-ranging aromas, all of which are vital to the agro food, pharmaceutical and cosmetics industries. However, only a limited number of plants have been studied and validated for their suitability for papermaking applications. This work aims at the valorisation of four lignocellulosic materials, as an alternative source of fibres, namely: *Astragalus armatus*, *Nitraria retusa*, *Pituranthos chloranthus* and *Retama raetam*.

Astragalus armatus Willd (Fabaceae, Fig. 1); an endemic medicinal shrub, constitutes a significant element of the North African vegetation. It is available in large quantities in arid regions where grazing is important but is still growing in extensive areas because of its low palatability (Hanafi and Jauffret, 2008).

Nitraria retusa (Nitrariaceae, Fig. 1); is a perennial shrub that is known locally as Ghardeq. This plant is widespread in central and south Tunisia and it can also be found in Algeria, Mauritania, Senegal and Saudi Arabia. Its exploitation as a source of medicine produces large amounts of residues, which are currently valorised (Boubaker et al., 2012, 2011; Hadj Salem et al., 2011).

Pituranthos chloranthus (Apiaceae, Fig. 1); is a small aromatic plant which grows in North-Africa and is locally named Guezzah (Touil et al., 2006). This perennial plant is devoid of stem leaves. It is often branched and its fruits are egg-shaped strips. There are many phytochemical studies on this species, especially, about its essential oils, which has been studied from the point of view of mutagenic and antimutagenic activities (Neffati et al., 2009), antimicrobial activities (Yangui et al., 2009), polyphenols content, antioxidant and antimicrobial activities (Bouaziz et al., 2009) and antibacterial activity (Dahia et al., 2007).

Retama raetam (Fabaceae, Fig. 1); a spontaneous shrub legume, is common to arid ecosystems around the Mediterranean basin. This plant is widely abundant in Tunisia and is known locally as Rtam. In fact, flower oils are used as natural preservative ingredient in food and pharmaceutical preparations (Edziri et al., 2010). Among others, antibacterial, antifungal and antioxidant activities

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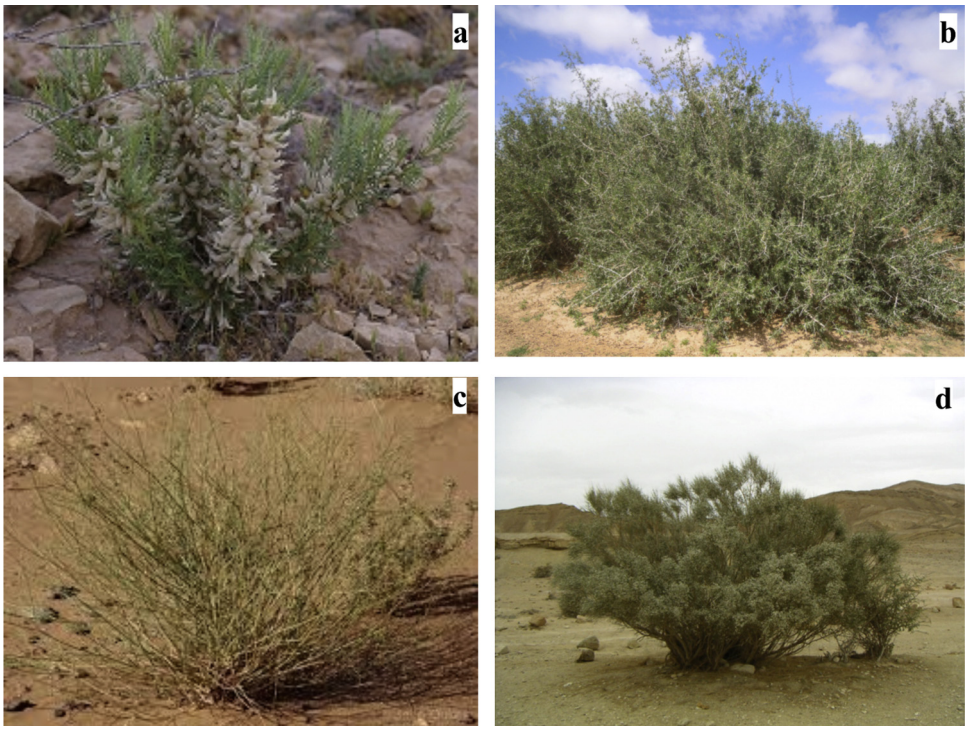

Fig. 1. General view of the four plant species used in this study: *Astragalus armatus* (a), *Nitraria retusa* (b), *Pituranthos chloranthus* (c) and *Retama raetam* (d).

have been described (Edziri et al., 2012). It is also used to stabilise sand dune and desertification (Ferchichi, 1996).

To the best of our knowledge, there are no reports dealing with the valorisation of these plants as a source of cellulosic fibres. Therefore, the present paper reports data about their chemical composition, the characterisation of the pulp and the physical properties of the hand sheet papers prepared from them.

2. Experimental

2.1. Raw materials

The aerial parts of these four species were collected in central western part of Tunisia, particularly the Kasserine Region (latitude 35°10′3″ N and longitude 8°50′11″ E) in December 2012. These species were dried under natural conditions during January 2013 (average relative humidity: 63%; average temperature: around 16 °C). All types of materials were ground and the 60–80 mesh fractions were selected in order to establish their chemical composition. Before pulping, these plants were cut into 1–3 cm pieces and extensively washed with distilled water in order to remove the contaminants.

2.2. Chemical analysis

The samples were first analysed for extractive substances in different liquids according to common TAPPI standards, namely: cold and hot water T207 cm-08, 1% sodium hydroxide solution T212 om-07 and ethanol–toluene T204 cm-07. The ashes content was determined by calcinations of the materials at 525 ± 25 °C for at least 4 h, according to the standard procedure TAPPIT211 om-07 and the elemental analysis of these residues was also carried out at the Service Central d'Analyse, Vernaison (CNRS). The amounts of lignin and α-cellulose were assessed by using the following respective TAPPI methods: T222 cm-99; T203 cm-99, whereas the holocellulose content was determined according to the method described by Wise et al. (1946). All the experiments were duplicated and the difference between the two values was within an experimental error of 5%.

2.3. Pulping

The pulping of these plant species was carried out using a soda-anthraquinone process which is known to be the most suitable for annual plants (Abrantes et al., 2007). It was carried out according to the procedure described by (Moussaoui et al., 2011) with total alkali charge of 5% expressed in NaOH, a cooking temperature of 140 °C and a cooking time at constant time of 120 min. The amount of anthraquinone was kept at 0.1% (w/w), with respect to oven dried (o.d.) initial solid material and the liquor to solid ratio was fixed at 10. A time of 90 min and a temperature of 120 °C were also tested. In all experiments, the heating time before reaching the desired constant temperature was 60 min. The resulting fibres were then washed extensively with water until a neutral pH. After pulping experiments, there were no rejects; therefore we decided to simplify the procedure and to avoid additional screening procedures.

2.4. Pulp and paper characterisation

The obtained pulps were characterised in terms of yield, kappa number and degree of polymerisation (DP). The cooking yield was calculated as the ratio of the weight of o.d. material after washing to that of the o.d. initial raw material. The kappa number was determined according to the standard method T236 om-06. The degree of polymerisation (DP) was determined thanks to the following equation proposed by Sihtola et al. (1963):

$$DPv = [0.75\,(954\log_{10}\eta - 325)]^{1.105}$$

where η (mPa s) is the intrinsic viscosity in a cupriethylenediamine (CED) solution and it was determined according to the standard method TAPPI T230 om-99.