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Research Paper

Application of microwave energy in degumming of hemp stems for the processing of fibres

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Microwave assisted-degumming/retting of hemp stems was established and the changes in the components like cellulose, hemicellulose and lignin during microwave treatment were studied by near infrared (NIR) analysis of the fibres processed from the treated hemp stems. Pre-soaked hemp stems subjected to microwave assisted degumming/retting at various power levels showed significant increase in the cellulose content from 72.1% to 79.8% when compared with the control samples. The percentage of hemicellulose and lignin were the key factors in binding the fibres together, which showed significant decrease when subjected to microwave treatment. Hemicellulose decreased from 14.5% to 12.1% and lignin from 8% to 5.5%. These compositional changes proved the effect of microwave energy in fibre separation. Measurements of diameter distribution and tensile strength, and colorimetric analysis, were performed to verify the effect on the physical properties. Thirty five percent of control sample hemp fibre diameters were <23 μm whereas the microwave-assisted retted samples contained more than 50% of fibre diameter were <23 μm. Colorimetric tests and tensile strength tests did not show any specific trends but the results confirmed that the microwave energy did not have any significant influence in the changes of the physical qualities during the process. The above studies showed the efficiency of microwave treatments for the degumming of hemp fibres.

1. Introduction

Hemp (*Cannabis sativa* L.) is a fibrous plant, grown in many countries such as China, France, Chile, Russia, Turkey, United States and Canada. The cultivation of hemp is restricted by licensing in most of the countries due to its similarity with marijuana, which belongs to the same Cannabis family. Industrial hemp contains only 0.3–1.5% of tetrahydrocannabinol (THC), but marijuana contains about 5–10% of THC, which is the reason why it is used as a psychoactive drug or medicine (Wayne & Wendy, 2000). Hemp has a lot of potential applications in various areas like apparel industries, paper

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Nomenclature

A	cross sectional area of the fibre (m^2)
a^*	redness/greenness (CIE)
b^*	yellowness/blueness (CIE)
F_{max}	maximum force applied (N)
L^*	whiteness or brightness/darkness (CIE)
ΔE	total colour difference (CIE)
ΔL^*, Δa^* and Δb^*	colour difference values (CIE)
σ_t	tensile strength (Pa)

industries and in bio-composites (Ouajai & Shanks, 2005). Hemp stems can be separated into two components: the stem tissues outside the vascular cambium (bark) and the stem tissues inside the vascular cambium (core). The bark consists of the epidermis, the cortex and the phloem. In the phloem, sieve tubes and primary bast fibres arise from the prodesmogen. The phloem may contain secondary bast fibres arising from the cambium. Hemp fibres are of high quality and are widely used as replacements for synthetic fibres, but they are more expensive (Kymalainen, 2004). This is mainly due to various difficult stages involved in the processing of hemp fibre from its stem. The most important, and energy intensive, step in hemp stem processing is degumming/retting, which is the separation or loosening of bast fibres from shive and other non-fibre fractions, leading to a major problem in natural fibre processing (Foulk, Akin, & Dodd, 2001; Sharma & Faughey, 1999). Microwave energy can be used to release the fibre from the plant cell walls of hemp to separate the fibres from plant stem. Microwaves are a form of electromagnetic radiation with frequency ranging between 300 MHz and 300 GHz (Banik, Bandyopadhyay, & Ganguly, 2003). Microwave energy in primarily used for heating in various post-harvest operations (Kim, Choi, Kim, Kwon Seol, & Jung, 2011). Biological changes that occurred in plant materials due to microwave energy is due to its thermal effects (Gandhi, 1987). Under the influence of microwave energy, soaked hemp stems are subjected to dielectric heating, which takes place when dipole molecules inside the hemp stem try to rotate vigorously in order to orient themselves to the direction of applied electric field. Under electromagnetic field treatment, hemp stems act as non-homogeneous materials that allow more polar components to absorb microwave energy and create "hot spots" within the stems. Our hypothesis is that this unique method of heating results in an "explosion" effect in the more polar particles and that leads to a disruption of the lignocellulosic structures of hemp stem. Also, the non-thermal effects of the electromagnetic field accelerate the disintegration of the lignocellulosic compounds (de la Hoz, Antonio, Diaz-Ortiz, & Moreno, 2004; Yin, 2012). At 2450 MHz, the frequency of a commercial microwave oven, by applying Planck's law the energy carried by microwave photons is approximately 1 J/mol. This energy is far too low to initiate any chemical activity in the material. Therefore, microwave radiation alone is not able to cause structural and chemical changes within biomaterials. Only when the biomaterial to be treated contains polar molecules, and the ions are exposed to microwave radiation, can the chemical, biological and physical processes be accelerated (Sridar, 1998).

Thus, the objective of this study was to establish and optimise the microwave assisted degumming/retting process of the hemp stems.

2. Materials and methods

2.1. Hemp stems

The non-retted hemp straws were obtained from National Research Council, Royalmount Avenue, Montreal, QC, Canada. The stems were cut into 80 mm lengths in order to fit inside a test tube. The initial moisture content of the hemp stems was found to be 3.93% w.b. by oven dry method. The middle part of the plant stem was chosen for the experiment to ensure uniformity in carrying out retting experiments. Hemp straw samples (5 g) were placed in a test tube of 50 ml capacity containing water for various soaking times at room temperature to ensure fully wet conditions (Nair, Rho, & Raghavan, 2013; Nair, Rho, Yaylayan, & Raghavan, 2013).

2.2. Microwave-assisted retting apparatus

The retting of hemp straw was performed using a microwave apparatus designed in the Post-harvest Technology Laboratory, Macdonald Campus, McGill University, Sainte Anne de Bellevue, QC, Canada (Fig. 1). The microwave generator was operated at 2450 MHz with a variable power from 0 to 750 W. The temperatures of the hemp stems were measured with the help of an optical fibre probe (Nortech EMI-TS series, Quebec City, Canada). The temperature probes were connected to an Agilent 34970A data acquisition unit and that unit was connected to a computer. A hot air supply was attached to the microwave oven to pass hot air through the microwave oven to remove the moisture generated by the samples (Nair, Liplap, Gariepy, & Raghavan, 2011; Nair, Rho, & Raghavan, 2013; Nair, Rho, Yaylayan, et al., 2013; Nair et al., 2014).

2.3. Experimental procedure

2.3.1. Microwave treatment

Non-retted hemp stems of 5 g each were soaked in water at room temperature in separate test tubes of 50 ml capacity. The soaking periods were 12, 24 and 36 h. The pre-soaked hemp stems of 5 g containing 50 ml water were subjected to microwave treatment in the microwave chamber at varying

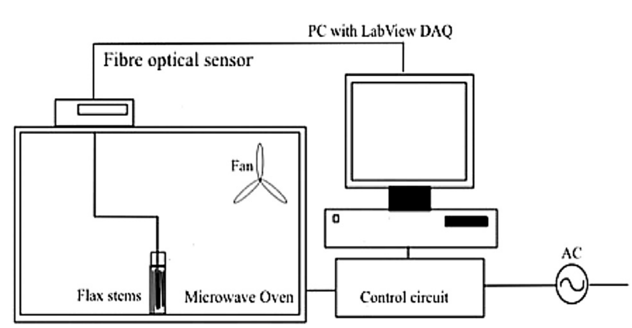

Fig. 1 – Microwave apparatus for retting of hemp.