Retting of Bast Fibres: A Pretreatment Process for Development of Biocomposites

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Today, the increasing environmental concerns, growing global waste problems, continuously rising high crude oil prices and depletion of petroleum resources urged governments all over the world to increase the legislative pressure towards a bio-economy based on the exploitation of natural resources. This in turn motivates researchers, industries and farmers towards developing the concepts of environmental sustainability while reconsidering renewable resources from agriculture or forestry to obtain biobased materials or alternative energy. Fibre crops are the commodities with the longest tradition among technical and nonfood agricultural products. Actually, bio-fibres have gained popularity especially for the development of sustainable materials, thanks to their great potential for use in biocomposite materials for applications in packaging, automotive, and other industries especially as reinforcing fibres.

Natural fibres are renewable resources because they are produced as a part of the plant from photosynthesis, where O_2 is released by absorbing CO_2 gas and they decompose naturally, consequently imposing lesser burden to the environment. Natural fibres have begun to pace towards becoming the main alternative source in the modern world industry. Recently in 'environmental-friendly-era' natural fibres has definitely gained its place in the heart of most industries as it is biodegradable and most crucially, renewable. Natural fibres can be extracted from three sources i.e. plants, minerals, and animals. The main component in mineral and animal fibres is asbestos or basalt and protein, respectively. Plant fibres themselves can be recognised as a biocomposite material since they are composed mainly by cellulose, hemicelluloses, lignin, and other components. Performance of natural fibres is often influenced by their chemical composition and physical properties. Climatic, plant and geographical variations influence chemical composition of the natural fibres. Fortunately, their properties can be enhanced by giving different surface treatments.

Figure 1: Different Types of Bast Fibres

Approximately 2,000 species of natural fibres have been used as composite's reinforcement, but only a few types of fibres are dominating by holding 90% of the natural plant fibre's market. Bast fibres are the most widely used among other groups which include fruit fibres, grass fibres, root fibres, seed fibres, and leaf fibres. The use of bast fibres to prepare polymeric materials represents an interesting example of the enhancement of a natural, old resource. Retting is usually required for the successful extraction of high quality bast fibres. Bast fibres are linked among them by different compounds like pectins and waxy substances that generate unstable interfaces. After retting process, fibres are more homogeneous and fine which are suitable for the development of good quality biocomposites.

Bast Fibres

Bast fibres are cellulosic fibres that are extracted from the phloem or outer part of the plant. Since bast fibre plants are annual crops, continuous supply of fibres is one of the attractive strong points for gaining interest from nonwood biocomposite manufacturing. Bast fibre, also called phloem fibre, is a type of plant fibre that can be collected from the phloem or bast surrounding the stem of certain dicotyledonous plants. Bast fibres can be obtained either from cultivated herbs, such as flax, hemp, ramie, jute, *dhaincha* etc. or wild plants, such as linden, wisteria, mulberry etc. Epidermis, shives, woody core, and a combination of xylem must be removed in order to obtain the bast fibres. A fibre bundle consists of numerous single fibres, and each fibre is connected by the middle lamella to act as glue, composed by pectin and lignin components. The major task of retting process is to remove these gluing components and release the fibres from bundle attachment.

Retting Process

Fibre extraction from straw is the very first step in fibre processing. At this moment, the outer layer of fibre bundles must be separated from the plant by breaking off the bonds between stem cores and fibre bundles. Fibre retting is a complex process and its properties are highly dependent on the type of retting methods and parameters. During the retting process, phloem-derived fibre bundles are loosened from hemicellulose, lignin and pectin. Left-over fibres are rich in cellulose contents and exert high strength properties. Since retting is a biological process, it requires both moisture and a warm temperature for microbial action to occur. To date, several retting methods are applied; the most traditional, still widely used approaches, i.e., water retting and dew retting are based on the microbiological retting. Other approaches involve mechanical, physical, chemical, and enzymatic retting. The latter is very promising but not yet practiced on an industrial scale. All retting processes except chemical retting use enzymatic activities to extract fibres from bundles.

Techniques of Retting

Water Retting

Water retting is the oldest historical retting method. This process is famous for producing quality retted bast fibres. Retting is a biochemical process in which various decomposition is carried out in stagnant water, accumulation of these products causes hindrance to the growth and activity of the causative micro-organisms. Vary fat moving water, removes these toxic substances quickly, but it carries away the microbial population along with it resulting in uniform retting. Retting is best carried out in slow moving clear water (canal, river, etc.) with low content of materials as salts, iron and calcium content is preferable for good retting. It is desirable to change water to keep the pH about 7 and 35°C temperature. When retting water is soft, the quality of fibre is better than when hard water is used. The presence of iron, particularly ferrous iron, is not desirable as it imparts a dark colour to the fibre.

Dew Retting

In dew retting, also called field retting, harvested plants are thinly spread out for 2-10 weeks in fields. During this period, microorganisms, mainly filamentous fungi or aerobic bacteria present in soil and on plants, attack noncellulosic cell types, removing pectins, and hemicelluloses from parenchyma cells and the middle lamellae, without attacking cellulose fibres. In this process, the colonizing fungi possess a high level of pectinase activity and the capacity to penetrate the cuticular surface of the stem: thus, fibre bundles come out separated into smaller bundles and individual fibres. Currently, dew retting is the most used process for the industrial production of bast fibres, mainly flax and jute, because of its low cost. Unfortunately, the method is limited to geographic regions, where the weather is suitable for fungi proliferation. Moreover, often low and inconsistent fibre quality is produced as compared to other methods, such as water retting. Risks of under retting and over retting are also reported: they may cause difficulties in separation or weaken the fibre. Therefore, it is necessary to monitor the retting process to ensure the quality of the fibres.

Chemical retting

With respect to water retting or dew retting, chemical processes are sometimes preferable since they produce fibres characterized by high-constant quality, regardless of weather conditions, usually in shorter times. Numerous chemical treatments can be performed on the fibres depending on their type. In chemical retting, the cementing material can be removed by dissolution with certain chemicals. The fibre obtained by chemical method of retting seems to be a little coarser, rough in the feel and stiff. The fibre strands after drying needs to be softened by rubbing with hand to open up the fibre and to remove the stiffness of the strand. The most used chemical process is alkalization, a treatment aimed at removing hemicelluloses: it is usually carried out with sodium hydroxide, added as an aqueous solution at a variable concentration in the range 1-25% by weight.

Enzyme Retting

Enzyme retting process has been introduced for some years back as a potential substitution to other retting methods. Dew retting process is often constrained by the poor and inconsistent fibre quality as well as geographical region, which require optimum temperature and moisture to promote microbial growth. Therefore, it is less efficient in countries with dry climate. A modification of water retting is the enzymatic treatment, also called bioscouring, where degrading enzymes are directly added to tank water or in a bioreactor. This technique has been demonstrated to be a promising replacement for traditional retting methods in terms of time-saving, ecology friendliness, and convenient characteristics. The duration of enzymatic retting ranges from 8 to 24 h. The high energy input and non reusability of enzymes are the main concerns, which affect the cost-effectiveness of the process. Pectinases are the main enzymes employed for retting, in order to free the fibres from other tissues.

Mechanical Retting

The mechanical extraction of fibres consists of various steps, as developed since ancient times, mainly to recover hemp and flax fibres. Today, this treatment is a completely automated process but steps have not changed which includes breaking, scutching and hackling to obtain clean and uniform fibres. Another process currently used to mechanically separate the fibres is called decortication and can be performed by hammermilling or rollermilling. The choice of the preferable mechanical retting depends on the type of the fibre, its final application and type of ensuing treatments. Therefore, with these multiple variables in mind, it is continuously under investigation.

Physical Retting

Among the physical treatments of fibres, the processes using electromagnetic radiation, high temperature, and/or pressure can be considered. Steam explosion is an autohydrolysis process involving the use of saturated steam at high pressure followed by a sudden decompression, which causes the substantial breakdown of the lignocellulosic structure, the hydrolysis of the hemicellulose fraction, the depolymerization of the lignin components, and the defibrillation. High decompression rates lead to improved fibre freeness but shorter fibre length. During the process, high temperature softens the material and mechanical action during the high-pressure discharge results in fibre separation. Another interesting physical treatment to extract the fibres is based on the hydrothermal method: the lignins and hemicellulose are degraded by using water at elevated pressure and temperature. To specifically modify the surface of fibres in order to improve their compatibility with polymeric matrix, the plasma treatment is an effective physical method, which can be performed at both atmospheric and high pressure under the flow of different types of gas usually oxygen or argon.

Application of Retted Bast Fibres in Biocomposites

The use of natural fibres for biocomposites is an attractive field from an environmental and sustainable perspective. In particular bast fibres, given their high cellulose and low lignin content, are particularly suited to composite applications and are the most promising replacement for glass fibres in composites. Bast fibres have long been valued for their high strength and remarkable length, and were extensively used in the fabrication of ropes and sails, as well as for paper and textiles. Nowadays they are also used as a (partial) substitute for synthetic fibres, such as glass, carbon or metallic fibres for the reinforcement of polymer based matrix. They are especially employed in the automotive industry for the manufacture of some parts of the interior, in the building and furniture industries due to their good thermal, mechanical, acoustic and aseptic properties. They are also a low-cost raw material and can act as a vector of development for local agricultural resources in emerging countries well as an industrial output for crops in developed countries.

The development of lignocellulosic fibres-based biocomposites requires the selection of an appropriate biopolymer matrix, suitable surface treatments of the fibres, along with low-cost but high-speed fabrication techniques. The retting process is a successful pretreatment for the improvement of matrix/fibre adhesion and the development of high-grade biocomposites. A wide range of biodegradable products has been produced using biopolymers containing lignocellulosic fibres for different applications, ranging from automotive vehicles including trucks, construction, and insulation panels, to special textiles (geotextiles and nonwoven textiles). Other identified uses for these materials include bathtubs, archery bows, golf clubs, boat hulls, maintenance-free roofing panels, and longer lasting and better-looking lightweight components, such as cosmetic packaging, tableware, and furniture. Furthermore, thanks to their loadbearing potential, the use of natural fibre-based biocomposites has spread to various sectors, including aircraft, grain and fruit storage, and footwear. Due to the identification of all such new applications, a remarkable growth of the market for these new biocomposites is expected in a next future.

Conclusions

In recent years, the various retting techniques have experienced a sizable evolution and improvements that tend to minimize the lack of consistency in fibre qualities and the high levels of variability in fibre properties. As more and more innovative research is being conducted on natural bast fibre-reinforced biocomposites in advanced sectors, bast fibres with high performance must be achieved. Bast fibre retting process is the first and the most important process for obtaining promising strength. Water retting process used to be the most recommended retting process for quality bast fibre production. Nevertheless, generation of large amounts of wastewater has it prohibited by most countries. Chemical and dew retting was then applied to substitute water retting process. However, high chemical cost and low retted fibre quality, of chemical and dew retting process, respectively, have driven people to look for another suitable process. Enzyme retting is claimed to have a more environmentally friendly process by reducing wastewater products, shorter retting period, and controllable fibre biochemical components under mild incubation conditions. Retting process, especially enzyme retting, could offer a tremendous benefit to bast fibres as green composite reinforcements and, at the same time, increases the value of nonfood crops by optimizing its potential as advanced materials.

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