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A Review of Some Significant Research Breakthroughs in Banana Fibre

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Abstract

The article reviews some significant research trends in the banana fibre. Bannana is a natural fibre and belongs to the category of bast fibres. One area of research explore the areas of applications, particularly in handicraft products such as mat, rope and twines, but only 10% of its pseudo stem is being used for making products and the remaining is used as waste or fertilizer. Owing to its many special properties it can be beneficial to farmers and also serve as a good raw material for the textile and packaging industry. In another area of research, flame retardant functionality has been imparted in cellulosic fabric using mixed formulation of banana psueudo stem sap and boric acid. Flame retardant characteristics of both the control and treated fabrics have been analyzed in terms of limiting oxygen index, vertical flammability, and temperature generation profile during burning. Another area of research reports the influence of treatment with caustic soda at various concentrations, on the physical, morphological, structural and thermal properties. An interesting study has focused on the production of bannana fibre yarns for textile reinforced composites. Thus the viability of spinning a yarn from banana fibres and weaving for the composite is explored. Attempt has been made to produce reinforced composite by weaving enzyme treated banna fibres.

Keywords: Bannana fibres; enzymatic treatment; value addition, composites; Alkali treatment; enzymatic treatment; reinforcement, sustainability

Introduction

The banana plant not only yields fruit, but also fibre which finds use in textile and related applications. It grows under tropical conditions. All varieties of banana fibres have fibres in abundance. The banana fibre is basically a bast fibre, and is obtained after the fruit is harvested. After the plant yields the fruit, its trunk the pseudo stem largely goes as agricultural waste. These pseudostems can be effectlvely utilized in production of the banana fibres, as annually about 1.5 million tons of dry banana fibres can be produced from the outer sheath of pseudostem. Biomass (pseudostem) waste, a rich source of natural fibres the pseudostem can be profitably utilized for numerous applications and preparation of various products. Cotton being a cellulosic material is flammable and hence can create problems for health and life of mankind. Considerable attempts have been made over the years for enhancement of flame-retardant property of cotton textile materials through utilization of different synthetic chemicals and a number of them are commercially available. Of these, the common ecofriendly admixture formulation of boric acid and borax is considered the simplest [1]. But, higher quantity of chemicals used in this formulation degrades the treated fabric quality. The present days are witnessing increased use of natural lingo cellulosic fibres in composite production [2]. Natural lignocellulose fibres, such as sisal, hemp, coir, kenaf and jute, have low density, good thermal properties, better specific strength, ecofriendly nature and can be used as replacement for glass fibres during composite manufacturing [3,4]. Banana fibres, due to its high specific strength can be used as replacement of glass fibres as reinforcement in the manufacture of composites. Banana fibre is extracted from the pseudo stem waste of the plant after harvesting the fruits. Like any other ligno cellulosic fibre, the major constituents of these fibres are cellulose, lignin, and hemicelluloses [5]. The rising interest in natural fibers in the composites field is undeniable, mainly due to sustainability, but also because of their good mechanical properties and low cost. The differences observed among different natural fibers are due to their chemical composition, origin, climate conditions, etc. On average, vegetable fibers are made of 60%–70% of cellulose, 10%–20% of hemicellulose, 5%–15% of lignin and up to 2% of pectin and waxes [6]. Banana fiber is obtained from the superimposed leaves forming the pseudostem of the plant, which currently has no use, apart from a low percentage dedicated to cattle feed. It belongs to Musa genre, as a monocot. Banana is the most important crop in Canary Islands, which are the most important producers of bananas in Europe. It is important to highlight that fibers are obtained from the pseudostems of the plant once the fruit has been harvested, and that each plant only bears fruit once; this is one of the main benefits of banana fibers in comparison with other natural fibers, as this one is obtained from an agricultural residue.

Potential of Banana Fibre for Product Development

Lignocellulosic are used for various applications depending on their composition and physical properties. All varieties of banana trees abound in fibres. In fact almost each and every part of the banana plant gives fibres of various strength, color and beauty and staple length which can be used for various purposes.All varieties of banana trees abound in fibres. In fact, almost each and every part of the banana plant gives fibres of various strength, color and beauty and staple length which can be used for various purposes. Out of the 14-18 sheaths available in a stem, the outermost 4-6 sheaths yield coarse fibre, the outer 6-8 sheath soft lustrous fibre and the rest middle sheath excluding the innermost 4-6 sheaths yield very soft fibres. The quantity of fibre in each sheath depends upon its width and its location in the stem, as does its quality. In addition to fruit production, huge quantity of biomass (pseudostem, leaves, suckers etc.) is generated [7,8].In india, the fibres extracted from pseudostem of banana plant, is being used for preparing ropes, handicrafts, etc. which otherwise can be used for making home furnishings and good quality papers. The major problem of non-adoption of fibre extraction technology is low recovery of fibres leading to high transport cost. This plant has long been a good source for high quality textiles in many parts of the world especially in japan and Nepal [9-11].

Most of the banana fibers produced today is used for ropes and cordage. The resistance of the fibre to the sea water and its natural buoyancy has created a ready market for it in the manufacture of shipping cables. It is also widely used for making power transmission ropes and cordage, wall drilling cables, fishing nets, lines and other types of cordage. Banana fibers are being utilized in various ways in different countries. In japan, banana fibres are being used for making traditional dresses like kimono and kamishimo during earlier periods. Due to its being lightweight and comfortable to wear, it is still being preferred by people there as summer wear. Banana fiber is also used to make fine cushion covers, neck ties, bags, table cloths, curtains, etc. Rugs made from banana silk yarn fibers are also very popular world over. Owing to its high tenacity, banana fibre made as single composite withstands more strain before failure in tensile testing than the hybrid fiber composite. The fiber was extracted by hand stripping using a stripping device applying low pressure to prevent the fibres from breaking [12,13].

Several products have been made from banana fibres around the globe. These include paper board, tissue paper, natural absorbent, bio remediation agent for bacteria in natural water purifier, mushroom production, handicrafts, quality paper cards, tea bags, string thread, high quality fabric material, paper for currency notes, rope for tyeing, dress materials, wedding gowns and barongs, and many more. It is interesting to note that banana fibre is also being used as lining for car interiors [14-16]. Development of softening processes have been reported for the inherently coarse banana fibres making it more suitable for spinning operations, spinning of the softened fibres into yarns, after blending them with suitable natural fibres and testing the physical and mechanical properties of the yarns.The yarns were further converted into fabrics and again assessed for their physical and mechanical properties. The fabrics were further passed through various finishing processes and then tested for all the mechanical and physical properties. The fabrics were further taken for dyeing with two classes of dyes and then assessed for the various fastness properties [17].

The development of green packaging from banana fibre for instant food products has been studied. Variables considered in this issue include packaging design of green packaging from banana fibre for instant food products of the envelope(stand up pouch), box(paper box), paper cups(paper cup), paper bags(zip lock paper bag). Banana fibre has been used to produce packaging to select the quality of the physical, chemical and consumer product safety. Packaging is recycling based that is ecofriendly disposal [18].

Banana is cultivated in about 2.3 lakh hectares of land and the fibre yield is about 8.7 tons. Though banana fibre extraction is not done on any large scale at present, banana fibres are reported to have been spun on the jute spinning machinery and used for hand bags and other fancy articles [19]. Agro based bio fibres have the composition, properties and structure that make them suitable for uses such as composite, textile, pulp and paper manufacture. In addition, bio fibres can also be used to produce fuels, chemicals, enzymes and food. Byproducts produced from the cultivation of corn, wheat, rice, sorghum, barley, surgarcane, pineapple, banana and coconut are the major sources of agro based bio fibres. Likewise, banana fibre based production processes, structure, properties and suitability of these biofibres are to be identified for various industrial applications.

Influence of Alkali Treatment on Fibre Properties

The use of natural lignocellulose fibres in the manufacture of composites is increasing day by day [20]. Natural lignocellulose fibres, such as sisal, hemp, coir, kenaf and jute, have low density, good thermal properties, better specific strength, ecofriendly nature and can be used as replacement for glass fibres during composite manufacturing [21,22]. Banana fibres, due to its high specific strength can be used as replacement of glass fibres as reinforcement in the manufacture of composites. Banana fibre is extracted from the pseudo stem waste of the plant after harvesting the fruits. Like any other ligno cellulosic fibre, the major constituents of these fibres are cellulose, lignin, and hemicelluloses [23]. The removal of lignin and hemicellulose substances and roughening of surface is required to improve the interfacial strength of composites [24]. Banana fibres are hydrophilic and have poor adhesion with the matrix materials. To improve adhesion of the natural fibres with matrix materials various treatments, such as alkali, acetylation and benzoylation, are given. Among all these treatments, mercerization or alkali treatment is a versatile one, which brings about changes in dimensions, fine structure, chemical composition, morphology, and crystalline component as well as it improves the wettability, resin pick up of natural fibres like coir, sisal, flax and cotton [25,26]. Alkali treatment improves adhesion between these hydrophilic fibres and the hydrophobic matrix by roughening and exposing more cellulose on the surface.

The alkali treatment modifies the chemical constituents which results in changes in mechanical properties, surface roughening, crystallinity and also in the thermal behavior of fibres [27,28]. Available literature reveals that NaOH treatment removes the binding materials, depending on the treatment time, concentration of NaOH used, temperature of treatment and liquor ratio. Study on effect of NaOH treatment on properties of banana fibre has already been performed by few researchers [29,30]. The effect of NaOH concentration on fibre yield (extraction) from the pseudo stem has also been reported [31]. However, the changes in the fibre due to such treatment at various levels are unknown. This is essential for optimum use of alkali and also to avoid degradation of fibres which will happen at higher concentration treatments. Similarly, the effect of NaOH concentration on the other fibre properties is not yet been studied. Hence in this study, the banana fibres are treated with sodium hydroxide (NaOH) at three different concentrations of 10, 15 and 20% and the treated fibres are tested for chemical composition and physical, morphological, structural and thermal properties.

It is found that the hemicellulose and lignin removal occur till 15% NaOH treatment concentration, and after that there is no much removal occurred. In line with those finding, the density of the fibre also shows an increment up to 15% NaOH and further increment in alkali percentage reduces the density. The moisture regain of the banana fibre also shows the same trend as that of density [32]. At 20% NaOH treatment, the moisture regains are found higher than at 15% NaOH treatment. Increment in the NaOH concentration also increases the lignin and hemicelluloses removal percentage, which is confirmed by the scanning electron microscope analysis. The breaking strength and the tenacity values of the banana fibre increase with NaOH concentration up to 15%. Further increment in alkali concentration degrades the fibre. The removal of lignin and hemicellulose contents from the banana fibre is confirmed by the FTIR and crystallinity analyses. The thermal stability analysis also confirms that the alkali treatment improvs the thermal stability value up to 15% NaOH concentration. The colour assessment studies show that the appearance of banana fibre becomes darker and red in colour due to the alkali treatment.

Production of Technical Textile Reinforced Composites

The rising interest in natural fibers in the composites field is undeniable, mainly due to sustainability, but also because of their good mechanical properties and low cost. The differences observed among different natural fibers are due to their chemical composition, origin, climate conditions, etc. On average, vegetable fibers are made of 60%–70% of cellulose, 10%–20% of hemicellulose, 5%–15% of lignin and up to 2% of pectin and waxes [33]. Banana fiber is obtained from the superimposed leaves forming the pseudostem of the plant, which currently has no use, apart from a low percentage dedicated to cattle feed. It belongs to Musa genre, as a monocot. Banana is the most important crop in Canary Islands, which are the most important producers of bananas in Europe. It is important to highlight that fibers are obtained from the pseudostems of the plant once the fruit has been harvested, and that each plant only bears fruit once; this is one of the main benefits of banana fibers in comparison with other natural fibers, as this one is obtained from an agricultural residue.

The use of natural fibers as reinforcement of polymeric parts has been widely studied, special focusing on injection molding technology. In fact, around 21,000 tons of natural fibers were used in 2003 in the European industry; the

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most relevant fibers for the industrial production of plastic composites are flax, sisal and hemp. Natural fibers are less harmful to humans, machinery and the environment, thus being realistic alternatives to glass fiber [34]. Some studies have also been carried out for the compression molding technology, some withlong fibers and others with woven fibers, both for thermoset and thermoplastic polymers [35-39]. These studies show that specific mechanical properties of natural fibers composites are similar to those reinforced with glass fiber, although mechanical properties under humid conditions show an important decrease for the natural fiber composites, due to their moisture absorption. These studies mainly focus on the production of non-structural parts for the automotive sector. It is known that mechanical properties of composites strongly depend on the orientation of the fibers, getting better properties when the fiber is woven and placed in the composite in an appropriate orientation. The BANTEX project (MAT2013-47393-C2-1-R) is aimed at obtaining a composite material made of woven banana fibers. Woven fabrics have the advantage of enabling the orientation of the fibers, allowing control of the density of the fabric and its mechanical properties. Nonwovens provide multiaxial orientation but lower and non-predictable mechanical properties. There is wide bibliography about the production of composite materials with natural fibers (flax, hemp, jute) in woven and non-woven fabrics [40-43]; however, no references have been found in the use of banana fibers to produce them. Furthermore, the use of banana fibers to produce yarns for technical textile products has not been reported.

Banana fibers are made of cellulose (43.6%), hemicellulose (14%), lignin (11%) and other substances (such as pectin, wax, 31.4%) [44]. Chemical methods for fiber extraction are usually performed with NaOH, although other chemicals are also used (KMnO4, benzoyl chloride, stearic acid, among others); these processes may cause environmental problems due to the need for treating the residues produced. Mechanical means are not able to remove the non-cellulosic constituents (lignin). An alternative is the use of biological processes, such as the immersed or solid-state fermentations. Enzymatic means are considered more environmentally friendly, and also avoid the fibers breakage, while altering the properties of the cellulosic fibers [45-48]. There are different parameters which affect the enzyme choice, such as the type of substrate, composition, size, lignin content, etc. Previous studies show Pectinase and Xylanase as the most suitable ones for fiber extraction [49,50]. Enzymatic treatments have been applied to hemp, flax or pineapple for fiber refining. Celullases are used to remove fibrils from the surface and increase the smoothness of the fiber, although this treatment can also damage the fibers and reduce their mechanical properties. Pectinases are used in the textile industry for retting and degumming fiber crops, as they are capable of breaking down complex molecules of plant tissues into simpler ones, such as galacturonic acid; on the other hand, endoglucanases only act on amorphous celluloses [51].

Hemicellulases are able to reduce water absorption by pentosan hydrolysis; xylanase and mannanase are used to dissolve hemicellulose (mainly xylan and glucomannan, respectively) [52]. Tests have been performed using a cocktail of two different enzymes made of pectinase and hemicellulase. In this research, different formulations of the enzymatic treatment have been applied to the banana fibers in order to determine the optimal conditions (time, temperature, enzymes content, bath renewal, fiber/enzymes ratio, etc.) for the refining process, in order to obtain a banana textile grade fiber. Fibers have been characterized prior to and after the enzymatic treatment, in terms of length, diameter and thermal stability. The spinning process at the lab scale has taken place, resulting in the production of a yarn with enough quality to be woven and produce a technical textile suitable for composite reinforcement.

The enzymatic treatment has proven to be useful for banana fiber treatment, achieving an improvement in terms of cleanliness and fibrillation. The most effective enzyme for banana fiber treatment is poligalacturonase (Biopectinase K), showing a high specific activity and being specific for substrates not damaging the cellulosic structure of fibers [53]. Long duration treatments (24 h, 48 h and 7 days) did not provide good results, due to enzyme deactivation. 6 h was optimal to obtain a textile grade banana fiber.Optimal conditions for banana fiber enzymatic treatment are: 100% Biopectinase K, 6 h; 45oC, pH = 4.5, with bath renewal after 3 h.Stability studies have demonstrated that over 80% of its activity takes place in the first 3 h; afterwards, the enzyme activity decreases reaching 12% 24 h later.Enzymatic treatments improve the thermal stability of fibers by the removal of pectin and hemicellulose, while producing a slight decrease in mechanical properties, probably due to defibrillation found under SEM observations. Banana fiber can be spun to produce yarns, mixed or not mixed with other fibers, while the most suitable for industrial scale-up without major equipment changes would be the blend of banana fiber and wool. Banana/PP yarn shows higher tenacity than flax/PP yarn and is more homogeneous

Conclusion

Banana is a natural bast fibre which has wide range of uses in handicraft product developments such as mat, rope and twines, but only 10% of its pseudo stem is being used for making products and remaining is waste or used as fertilizer. As it has a property like weather proof, UV protection (because of lignin content), moisture absorption, anti-oxidant and biodegradable, etc., it can be used to make a variety of products that help farmers economically and have wide scope to create new market. Recent studies have indicated that banana fibre possesses a lot of advantageous physical and chemical properties which can be used a very good raw material for the textile and packaging industry [54]. Banana fibres treated with varied concentrations of caustic soda show improvement in cellulose content, lignin removal, tenacity, crystallinity, and thermal resistance till 10% concentration, and after that no improvement is observed beyond 15%. Colour has turned the fibre towards darker side slightly aesthetically unappealing. It is noted that the 15% NaOH concentration is optimum for treating banana fibres used as reinforcement.

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