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Review

Advances in industrial prospective of cellulosic macromolecules enriched banana biofibre resources: A review

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ABSTRACT

Biological macromolecules enriched resources are rapidly emerging as sustainable, cost effective and environmental friendly materials for several industrial applications. Among different biological macromolecules enriched resources, banana fibres are one of the unexplored high potential bio-resources. Compared to various natural fibres such as jute, coir, palm etc., the banana fibres exhibits a better tensile strength i.e. 458 MPa with 17.14 GPa tensile modulus. Traditionally used petroleum based synthetic fibres have been proven to be toxic, non-biodegradable and energy intensive for manufacturing. Cellulosic banana fibres are potential engineering materials having considerable scope to be used as an environmental friendly reinforcing element for manufacturing of polymer based green materials. This paper summarizes the world scenario of current production of biological macromolecules rich banana residues and fibres; major user's of banana fibres. The quality and quantity of biological macromolecules especially the cellulose, hemicellulose, lignin, wax, engineering and mechanical properties of banana biofibre resources are reported and discussed. Subsequently, the findings of the recent research on bio resource composites, materials performance and opportunities have been discussed which would be a real challenge for the tomorrow world to enhance the livelihood environmental friendly advancement.

Contents

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1. Introduction

Use of natural cellulosic fibres in composites have attracted the attention of researchers, manufactures and user agencies due to the consequence of exploitation of non-renewable resources and mismanagement of agro-industrial wastes leading to environmental and ecological imbalances [1–4]. Indeed, natural cellulosic fibres are rapidly emerging as novel low cost materials for several industrial applications [5,6]. Application of plant fibres as one of the component in polymeric materials such as reinforcement in composites have attracted greater attention due to their added advantages. Natural fibres and its composites is environment friendly as these are derived from renewable sources, and at the end of life cycle either they can be composed or calorific value can be recovered [7,8]. Compared to the natural cellulosic fibres, glass fibres have been prominently used in composites industry, as no viable technological options were available. Manufacturing of glass fibre is energy intensive and not cost effective. These fibres do have disadvantages regarding recycling issues and processing. Moreover, glass fibres are non renewable and hazardous in nature [9,10].

Some of the plant fibre such as jute, sisal and coir are currently being used in several engineering applications in efforts to avoid the use of synthetic fibres such as glass fibres in some of the applications where very high mechanical properties are not required. Among different natural cellulosic fibres, banana fibres are one of the unexplored high potential fibres. The use of banana fibre for industrial and engineering application has not yet been effectively utilized. It is estimated that universally about 288 million tonnes of banana residues, banana skins, leaves and stems have been generated and wasted annually, rather it has potential for bio-energy production, composting and waste water treatment. Essentially fibre with different dimensions can be extracted from banana pseudo-stem. It has been found that banana stem can yield about 600 kg/ha of banana fibres.

Banana i.e. *Musa sepientum* is a commercial herbaceous plant of genus musa mainly cultivated for its edible fruit in most of the developing countries [11,12]. Banana plants consist of leaf, pseudostem, root and banana fruits. Banana fruits have been used for dietary purposes as well as local therapies. Some of the pharmaceutical applications of banana fruit and stem include: use as a remedy of constipation; curing diarrhoea and dysentery; to heal the intestine lesions; useful in stomach upset and diabetes. Banana fruits are generally conserved during transportation by washing thoroughly and possible soaking in fungicide prior to packaging into cartons for transportation.

Banana residue generated after harvesting of banana fruit are leaf, pseudo stem, roots and rotten banana. This paper addresses the engineering utilities and properties of cellulosic banana fibres, banana fibre composites and their unique feature for value added engineering materials and potential industrial applications.

2. Biomass resource of cellulosic banana plant: World scenario

It is estimated that the global banana edible yield/production is about 102 million tonnes. Major banana producing and exporting countries with an area under banana cultivation, banana production with banana yield are listed in Table 1 [13]. Along with several other countries, India occupies more than 11% of world's area under banana cultivation followed by Brazil, Tanzania, Philippines and China. India accounts for more than 31% of global banana production. The average yield of banana in India is about 37.79 t/ha which is much higher than that of most of the countries. Banana is grown in almost every state of India. Maharashtra, Tamil Nadu, Gujarat, Andhra Pradesh and Karnataka are the largest banana producing state accounting almost 19% of total production in India, having highest productivity about 61.176 t/ha. Area under banana cultivation is highest in Tamil Nadu followed by Maharashtra. As a result of such large cultivation, large amount of wastes have been generated. India has a tremendous potential to extract fibres from banana stem [14].

The four most leading banana exporting countries are Ecuador, Costa Rica, Philippines, and Colombia accounting for 64% of world export. Ecuador is the largest exporter of bananas in the world (more than 30% of global banana exports). European Union, the United States of America and Japan together account for more than 70% of world total imports in 2006 [15]. India exports banana to more than 60 countries including United Arab Emirates, Saudi Arabia, Iran, Kuwait, Bahrain, Qatar, Oman, and many others. In 2010, India exported of about 56,304 tonnes [16]. With increase in banana plantation, generation of banana residues are also increasing and are cause of great concerns as these are considered as waste materials and left unused in the fields or some time burnt resulting in the environmental pollution.

3. General uses of banana residues

The residues generated with banana cultivation which includes pseudostem, leaves, roots, banana pith, rotten banana and banana peels. Fig. 1 shows banana plant and its macromolecule rich residues generated after banana fruit harvesting. This residue can be used in waste water treatment as a absorbent, in the production of bioenergy such as biogas, ethanol production and in composting as a cost effective feedstock as shown in Fig. 2.

3.1. Utilization of banana pith for waste water treatment

Banana residues are most frequently available agricultural biowaste. Polymeric groups i.e. cellulose, hemicelluloses, lignin, pectin are the main constituent of such agricultural wastes and act as centres for bioaccumulation of heavy metals [17]. Different parts of banana plants have been used for several water treatments. Banana stem juice has been used as a natural coagulant for treatment of spent coolant wastewater. It has been reported that chemical oxygen demand (COD), suspended solids (SSs), and turbidity of effluent were removed with an efficiency of 80.1%, 88.6%, and 98.5%, respectively, using banana stem juice. It was concluded from the study that banana juice stem exhibit high potential to be used as a natural coagulant for water treatment purposes [3]. Banana stem has also been used for the removal of Pb(II) metal ions from aqueous solution [12]. Interestingly it is very important to note that banana pith have been further used for removal of heavy metals rich in electromagnetic waste [18]. Toxic metal ions of Cu(II) were