International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.7, No.01, pp 223-233, 2014-2015

Bagasse Fiber – The Future Biocomposite Material: A Review

A.Balaji[1]*, B. Karthikeyan[2], and C. Sundar Raj[1]

[1]*Department of Mechanical Engineering, A.V.C. College of Engineering, Mayiladuthurai, TamilNadu, India - 609 305.
[2]Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Tamil Nadu, India - 608 002.

Abstract: A biocomposite is a material formed by a matrix and a reinforcement of natural fibers like Jute, Coir, Sisal, Pineapple, Ramie, Bamboo, Banana and Bagasse, etc. Such natural fibers composites are low-cost fibers with high specific properties, low density and eco-friendly. The development of advanced biocomposite materials made is increasing worldwide. It will be an alternative way to develop the biocomposites which can be particularly used for daily needs of common people whether it is house hold furniture, house, fencing, decking, flooring, and light weight car components or sports equipments. This effort to develop biocomposite materials with improved performance for global applications is an ongoing process. Thousands of tons bagasse is produced but most of their wastes do not have any useful utilization. These bagasse wastes can be used to prepare fiber reinforced polymer composites for commercial use. This review paper discuss about recent development of bagasse fibers reinforced polymer composites, types of matrix, processing methods, and any modification of the fiber and its applications.
Keywords: Biocomposites, Polymer Matrix, Natural fibers, Bagasse fibers, Biopolymer, Biofiber.

1. Introduction

Over the last few years, a number of researchers have been involved in investigating the exploitation of natural fibers as load bearing constituents in composite materials. The use of such materials in composites has increased due to their relative cheapness, their ability to recycle and for the fact that they can compete well in terms of strength to weight of material. Natural fibers can be considered as naturally occurring composites consisting mainly of cellulose fibrils embedded in lignin matrix. The cellulose fibrils are aligned along the length of the fiber, which render maximum tensile and flexural strengths, in addition to providing rigidity. The reinforcing efficiency of natural fiber is related to the nature of cellulose and it’s crystalline. The main components of natural fibers are cellulose, hemicelluloses, lignin, pectin’s, and waxes[1].

1.1 Advantages of biocomposite

The natural fiber reinforced polymer composites contributes to enhancing advantages like, they are environmentally friendly materials at the stage of production, processing and waste, Environmentally friendly production of natural fibers - annual renewability and lower energy inputs in production per unit, Commonly known processing methods, Excellent specific strength and high modulus, Reduced density of products, Lower cost, Corrosion resistance, High creep resistance, High toughness, Biodegradable and Some biocomposites can have much higher wear resistance than metals.

1.2 Disadvantages of biocomposites

Although natural fibers are obtained from renewable sources and the polymer composites based on them are environmentally friendly as compared to the other composites, there are also some disadvantages, like

Low impact strength (high concentration of fiber defects), Problem of stocking raw material for extended time, UV resistance– not better than plastics, Fiber degradation during processing and Fiber orientation and distribution.

1.3 Applications of biocomposites

They are widely used for different applications as Automotive Industry, Aerospace Industry, Building Industry, Furniture Industry, Bio medical Industry etc.

The need for lightweight, dimensionally stable materials for automotive and aerospace applications opened new frontiers of advanced materials[2]. Natural fiber composites are being used for manufacturing many components in the automotive sector. Typical market specification natural fiber composites include elongation and ultimate breaking force, flexural properties, impact strength, acoustic absorption, suitability for processing and crash behavior. Plant fibers are mainly used in the part of car interior and truck cabins. The use of plant fiber based automotive parts such as various panels, shelves, trim parts and brake shoes are attractive for automotive industries worldwide because of its reduction in weight about 10%, energy production of 80% and cost reduction of 5%.

The major car manufacturers like Volkswagen, BMW, Mercedes, Ford and Opel now use natural fiber composites in several applications as listed in table 1.

Tab.1 Current well-established applications of natural fibers in automotive industry [3]

Automotive manufacturer	Model applications
AUDI	A2, A3, A4, A6, A8, Roadster, Coupe Seat backs, side and back door panels, boot lining, hat rack, spare tyre lining
BMW	3, 5, 7 series Door panels, headliner panel, boot lining, seat backs, noise insulation panels
CITROEN	C5 Interior door paneling
FIAT	Punto, Brava, Marea, Alfa Romeo 146, 156
FORD	Mondeo CD 162, Focus
LOTUS	Eco Elise, Body panels, Spoiler, Seats, Interior carpets
PEUGEOT	406 Seat backs, parcel shelf
RENAULT	Clio, Twingo, Rear parcel shelf
ROVER	2000 and others Insulation, rear storage shelf/panel
SEAT	Door panels, seat backs
TOYOTA	Brevis, Harrier, Celsior, Raum, Door panels, seat backs, spare tyre cover
VOLKSWAGEN	Golf, Passat, Bora, Door panel, seat back, boot lid finish panel, boot liner
VOLVO	C70, V70 Seat padding, natural foams, cargo floor tray

Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for the following reasons: (1) natural fiber production has lower environmental impacts compared to glass fiber production; (2) natural fiber composites have higher fiber content for equivalent performance, reducing more polluting base polymer content; (3) the light-weight natural fiber composites improve fuel efficiency and reduce emissions in the use phase of the component, especially in auto applications; and (4) end of life incineration of natural fibers results in recovered energy and carbon credits[4].

The uncrushed natural fibers were cleaned and chemical treated using Isocyanate, washing with alkaline solution, acrylic acid, and mercerization were applied. After treatment, the natural fiber was dried in an oven or atmosphere air. And then to reduce the size in ball milled at 200 to 300 rpm for 5 to 6 hours. The natural fiber and polymer matrix were mixing in the reactor or thermokinetic mixer. After the mixing composites were compressed under pressure from 6 to 10 MPa at 150°C to 170°C and finally dry the composites in dry air for proper curing.

1.4 Green Common Conversion of Biocomposite Processing

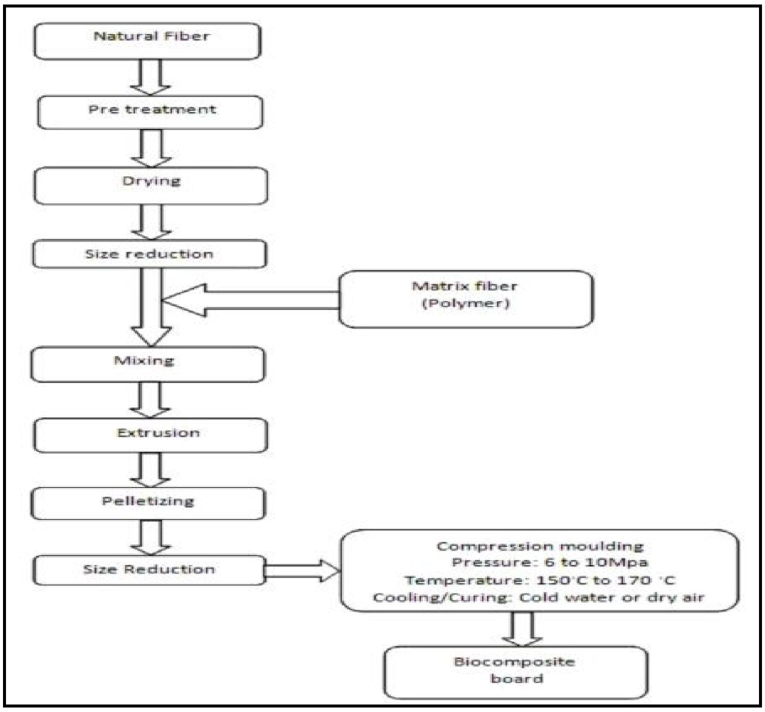

Fig. 1 Green Common Conversion of Biocomposite Processing

1.5 Polymer Matrix Composites (PMC)

Polymer Matrix Composite (PMC) is the material consisting of a polymer (resin) matrix combined with a fibrous reinforcing dispersed phase. PMC are very popular due to their low cost and simple fabrication methods. Use of non – reinforced polymers as structure materials is limited by low level of their mechanical properties: tensile strength of one of the strongest polymers – epoxy resin is 140 MPa (20000 psi). In addition to relatively low strength, polymer materials are possessing low impact resistance. PMC are characterized by High tensile strength, High fracture toughness, High stiffness, Good puncture resistance, Good abrasion resistance, Good corrosion resistance & Low cost. The main disadvantages of PMC are low thermal resistance and high coefficient of thermal expansion.

1.6 Matrixes of natural fiber

Thermosetting plastics :	Epoxy, Polyester, Phenolic, Polyurethane & Polyimide.
Thermoplastics :	Polypropylene, Polyethylene, Polyamide, Polystyrene and olyvinylchloride.
Rubber and natural polymers :	India-rubber, Modified starch and Cellulose esters, Polyhydroxy-butiric acid, Polylactide, etc.

1.7 Fiber source

The plants, which produce natural fibers, are classified as primary and secondary depending on their utilization. Primary plants are those grown for their fiber content while secondary plants are plants in which the fibers are produced as a by-product. Jute, hemp, kenaf, and sisal are examples of primary plants. Pineapple, Bagasse, oil palm and coir are examples of secondary plants[5].

1.8 Natural Fibers and Fibrous raw materials for reinforcing Composites

Bast Fibers :	Flax, Hemp, Kenaf, Banana, Bamboo, Urena, Jute, Mesta, Ramie, Roselle
Lea Fibers :	Palm trees, Caroa, Banana, Srew pine, Abaca (manila), Curaua, Sisal Cabuja, African palm Data-palm & Pineapple.

Grasses Fibers and reeds :	Bamboo , Bagasse, Wheat, Barley, Rice, Reed, Corn, Rape, Rye, Esparto, Elephant grass, Cannary grass & Oat.
Seed Fibers :	Cotton, Kapok & Capok.
Fruit Fibers :	Coir, Coconut & African palm.
Wood Fibers :	Soft & Hard wood etc.

2. Sugarcane Bagasse (SCB)

Bagasse is the fibrous residue which remains after sugarcane stalks are crushed to extract their juice. It is mainly used as a burning raw material in the sugar mill furnaces. The low caloric power of bagasse makes this a low efficiency process. Also, the sugarcane mill management encounters problems regarding regulations of clean air from the Environmental Protection Agency, due to the quality of the smoke released in the atmosphere. Presently 85% of bagasse production is burnt. Even so, there is an excess of bagasse. Usually this excess is deposited on empty fields altering the landscape. Approximately 9% of bagasse is used in alcohol (ethanol) production. Ethanol is not just a good replacement for the fossil fuels, but it is also an environmentally friendly fuel. Apart from this, ethanol is a very versatile chemical raw material from which a variety of chemicals can be produced[6].

SCB wastes are chosen as an ideal raw material in manufacturing new products because of its low fabricating costs and high quality green end material. It is ideal due to the fact that it is easily obtainable given the extensive sugar cane cultivation making its supply constant and stable. The associated costs of extraction, chemical modifications and/or other pre-treatments of SCB in the transformation process to ready-to-be used materials are potentially reduced as the complex processes are simplified by the mere usage of Bagasse.

When appropriate modifications and manufacturing procedures are applied, bagasse displays improved mechanical properties such as tensile strength, flexural strength, flexural modulus, hardness, and impact strength. Bagasse is also found to be easily treated and modified with chemicals besides blending well with other materials to form new types of composite materials. It also satisfies the greening requirements by being biodegradable, recyclable and reusable[7]. The compression and injection molding processes were performed in order to evaluate which is the better mixing method for fibers (sugarcane bagasse, bagasse cellulose and benzylated bagasse) and Polymer matrixes[8].

2.1 Composition of bagasse

The bagasse fiber reinforced polymer composites performance depends on several factors, including fibers chemical composition, cell dimensions, microfibrillar angle, defects, structure, physical properties, and mechanical properties, and also the interaction of a fiber with the polymer. In order to expand the use of bagasse fibers for composites and improved their performance, it is essential to know the fiber characteristics.

Bagasse consists of approximately 50% cellulose and 25% each of hemicellulose and lignin. Chemically, bagasse contains about 50% α-cellulose, 30% pentosans, and 2.4% ash. Because of its low ash content, bagasse offers numerous advantages in comparison to other crop residues such as rice straw and wheat straw, which have 17.5% and 11.0%, respectively, ash contents, for usage in microbial cultures. Also, in comparison to other agricultural residues, bagasse can be considered as a rich solar energy reservoir due to its high yields and annual regeneration capacity[9].

Sugarcane **Sugar & Bagasse** **Bagasse fiber from Bagasse**

Fig. 2 Formation of Bagasse Biocomposite material

2.2 Properties

The physical properties of bagasse fiber are critical, and include the fiber dimensions, defects, strength and structure. Tab.2 Physico-mechanical properties of bagasse fibers[10]

Properties	Values
Tensile strength (MPa)	290
Young's modulus (GPa)	17
Density [g/cm^3]	1.25

3. Thermal and Mechanical analysis of Bagasse Fiber Biocomposite

Cao Y[11] et al investigated Biodegradable composites reinforced with bagasse fiber before and after alkali treatments were prepared, and mechanical properties were investigated. Mechanical properties of the composites made from alkali treated fibers were superior to the untreated fibers. Composites of 1% NaOH solution treated fibers showed maximum improvement. Approximately 13% improvement in tensile strength, 14% in flexural strength and 30% in impact strength had been found. Respectively, after alkali treatment, increase in strength and aspect ratio of the fiber contributed to the enhancement in the mechanical properties of the composites. Scanning Electron Microscopy (SEM) observations on the fracture surface of composites showed that the surface modification of the fiber occurred and improved fiber–matrix adhesion.

Luz S. M[12] et al confirmed the compression and injection molding processes were performed in order to evaluate the better mixer method for fiber (sugarcane bagasse, bagasse cellulose and benzylated bagasse) and matrix (polypropylene). The samples (composites and polypropylene plates) were cut and submitted to morphological, microstructural analyses and mechanical tests. The better tested method for composites obtainment was the injection molding under vacuum process, by which composites were obtained with homogeneous distribution of fibers and without blisters. The mechanical properties show that the composites did not have good adhesion between fiber and matrix; on the other hand, the fiber insertion improved the flexural modulus and the material rigidity.

Luz S.M[13] et al characterized the development of polypropylene composites reinforced with cellulose and cellulignin fibers attained from sugarcane bagasse. Moreover, the fibers were chemically modified by acetylating process and its effects on the fiber/matrix interaction were also evaluated. The chemical modification efficiency was verified by Fourier Transform Infrared (FTIR) analysis and the fibers morphological aspects of fibers by SEM. Likewise, the influence of modified fibers content in the composites was studied by mechanical (tensile, shear and flexural tests) and thermal analyses Thermo Gravimetric Analysis TGA and Differential Scanning Calorimetry (DSC). After the chemical modification, the FTIR results showed the appearance of acetyl groups and reduction of OH bonds for all fibers. Together with, SEM characterization showed that the acetylation changed the morphology of fibers, resulting in mechanical properties decreases, probably because of the new morphological aspect. The thermal characterization of composites based on untreated and treated cellulose and cellulignin presented intermediary stability in respect to matrix and fiber. Finally, DSC results revealed that the composites reinforced with untreated fibers were more crystalline than neat PP.

Daniella R[14]. Mulinari et al evaluated the high density polyethylene/pre-treated and modified residues from SCB cellulose composites were analyzed. Composites were produced by a thermokinetic mixer. The microstructural analyses of fracture surface from composites can be easily evaluated by microscopic techniques. Results showed that the modification of SCB cellulose with zirconium oxychloride was successfully accomplished and that this reinforcement material with high density polyethylene showed tensile strength higher than non-modified SCB cellulose.

Daniella Regina Mulinari[15] et al studied were both pre-treated and modified residues from sugarcane bagasse. Polymer of High Density Polyethylene (HDPE) was employed as matrix in to composites, which were produced by mixing high density polyethylene with cellulose (10%) and Cell/ZrO_2_nH_2O (10%), using an extruder and hydraulic press. Tensile tests showed that the Cell/ZrO_2_nH_2O (10%) HDPE composites present better tensile strength than cellulose (10%)/HDPE composites. Cellulose agglomerations were responsible for poor adhesion between fiber and matrix in cellulose (10%)/HDPE composites. HDPE/natural fibers composites showed also lower tensile strength in comparison to the polymer. The increase in Young's modulus is associated to fibers reinforcement. SEM analysis showed that the cellulose fibers insertion in the matrix caused an increase of defects, which were reduced when modified cellulose fibers were used.

Aigbodion V.S[16] et al developed the thermal ageing behavior model of Al-Cu-Mg/Bagasse ash particulate composites with 2-10 wt% bagasse ash particles produced by double stir-casting method in terms of weight fraction of bagasse ash, ageing temperature and time. Hardness values measurement was used in determining the ageing behavior, after solution and age-hardened heat-treatment. The experimental results demonstrate that the bagasse ash was the major parameter in the ageing behavior, followed by ageing temperature. The hardness values decreased as the ageing time increases. Moreover, the optimal combination of the testing parameters could be predicted. The predicted hardness values were found to lie close to that of the experimentally observed ones. The developed mathematical model can be employed for optimization of the process parameters of the ageing behavior of Al-Cu-Mg/Bagasse ash particulate composites with respect to hardness values.

Sandra M. Luz[17] et al analyzed of such a strategy for a material that is used extensively in the auto industry, namely polypropylene composites, as we have quantified the environmental impacts when sugarcane bagasse-reinforced polypropylene substitutes for talc-filled polypropylene (PP). To achieve these goals, a comparative Life Cycle Assessment (LCA) was performed for the two alternatives, from raw extractions to the end-of-life (EOL) phase of sugarcane bagasse-PP and talc-PP composite, where data gathered in different industries in Brazil were included in the LCA GaBi software. Our analysis shows that in addition to similar mechanical performance, natural fiber composites showed superior environmental performance throughout the entire life cycle. This superior performance is because: (1) in the cultivation phase, sugarcane absorbs carbon through the photosynthesis process while growing, thus reducing the global warming impact of the materials used; (2) the production process is cleaner; (3) sugarcane bagasse-reinforced composites are lighter for equivalent performance, which reduces the amount of polypropylene used; and (4) the economic reuse proposed for the EOL sugarcane bagasse-PP composite was the best alternative to minimize environmental impacts.

Julien Bras[18] et al reported cellulose whiskers were isolated from bleached sugar cane bagasse kraft pulp. The length of the isolated whiskers was in the range 84–102nm while the width was in the range 4–12 nm. They were used as reinforcing elements in natural rubber matrix. The effect of whiskers loading on tensile properties, thermal properties, moisture sorption, water vapor permeation, and soil biodegradation was studied. Significant improvement of Young's modulus and tensile strength was observed as a result of addition of whiskers to the rubber matrix especially at high whiskers' loading. Dynamic mechanical thermal analysis (DMA) and DSC results showed no change in the glass transition temperature (T_g) of the rubber matrix upon addition of cellulose whiskers but at softening of rubber, cellulose whiskers have reinforcing effect on the rubber. Presence of bagasse whiskers resulted in an increase in moisture sorption of rubber films up to 5% whiskers loading while at higher whiskers' loading the moisture sorption tended to decrease. Barrier properties to water vapor decreased on increasing cellulose whiskers up to 7.5% whiskers loadings then increased with further increase in whiskers loading. Presence of cellulose whiskers increased the rate of degradation of rubber in soil.

Punyapriya Mishra[19] et al determined the abrasive wear behavior of bagasse fiber reinforced epoxy composite in different directions, namely parallel orientation (PO), anti-parallel orientation (APO) and normal orientation (NO) by using a two body abrasion wear tester. Three different types of abrasives wear behavior have been observed in the composite in three orientations and follow the following trends: WNO<WAPO<WPO, where WNO, WAPO and WPO are the wear in normal, anti-parallel and parallel directions of fibers orientation, respectively. The fiber bundles present in the composite provide unique directional abrasive wear properties. Wear anisotropy magnitude of the composite is found to be a function of load and abrasive grit size. The worn surfaces were observed by using a SEM after the wear test. It has been found that in PO type samples the abrasion takes place due microploughing, where as in APO and NO type samples micro cutting found to be responsible for the wear process.

Rahman Muhammad Bozlur[20] et al investigated a method to fabricate short bagasse /bamboo fiber reinforced biodegradable composites and investigated their flexural properties. Bagasse/bamboo fibers were simply randomly mixed with biodegradable resin, and composite specimens were fabricated by a cylindrical steel mould by the press forming. The effects of holding time and fibers content on the flexural properties of bagasse / bamboo fiber composites were investigated. The flexural properties of bagasse / bamboo fiber reinforced biodegradable composites were strongly affected by the holding time and amount of fiber content. During fiber processing on different holding time, it was found that flexural properties increased with the increased the holding time up to 10 min. Above 10 min. flexural properties decreased due to insufficient resin. In processing on fiber content, it was observed that the flexural properties increased with the increase the fiber content up to 50% & above 50% flexural properties decreased due to high fiber weight fraction and poor bonding between fiber and matrix. The flexural modulus for holding time showed maximum of 2384 MPa for bagasse and 2403 MPa for bamboo composites. The cross sectional structure of bagasse fiber was porous and bamboo fiber was solid.

Punyapriya Mishra[21] et al carried out to study the effects of impingement angle and particle velocity on the solid particle erosion behavior of Bagasse Fiber Reinforced Polymer Composites (BFRPCs). The erosive wear is evaluated at different impingement angles from 30° to 90° at four different velocities of 48, 70, 82 and 109 m/s. The erodent used is silica sand with the size range 150 – 250 μm of irregular shape. The result shows brittle behavior with maximum erosion rate at 90° impingement angle. The morphology of the eroded surfaces was examined by using SEM.

Cerqueira E. F[22] et al investigated the fibers were pretreated with 10% sulfuric acid solution, followed by delignification with 1% sodium hydroxide solution. These fibers were mixed with the polypropylene in a thermokinetic mixer, and compositions with 5 to 20 wt% of fibers were obtained. The mechanical properties were evaluated by means of tensile, 3-point bending and impact tests. Results showed improve the tensile, flexural and impact strength of the composites in comparison to the polymer pure.

Maria E. Vallejos[23] et al reported the potential of the fibrous material obtained from ethanol–water fractionation of bagasse as reinforcement of thermoplastic starches in order to improve their mechanical properties. The composites were elaborated using matrices of corn and cassava starches plasticized with 30 wt% glycerin. The mixtures (0, 5, 10 and 15 wt% bagasse fiber) were elaborated in a rheometer at 150 ◦C. The mixtures obtained were pressed on a hot plate press at 155^0C. The test specimens were obtained according to ASTM D638. Tensile tests, moisture absorption tests for 24 days (20–23^0C and 53% RH, ASTM E104), and dynamic-mechanical analyses (DMA) in tensile mode were carried out. Images by SEM and X-ray diffraction were obtained. Fibers (10 wt% bagasse fiber) increased tensile strength by 44% and 47% compared to corn and cassava starches, respectively. The reinforcement (15 wt% bagasse fiber) increased more than fourfold the elastic modulus on starch matrices. The storage modulus at 30^0C increased as the bagasse fiber content increased, following the trend of tensile elastic modulus. The results indicate that these fibers have potential applications in the development of biodegradable composite materials.

Arturo Zizumbo[24] et al reported bagasse Fibers of sugarcane were modified with dichloro-methylvinylsilane and consecutively grafted with polystyrene. For unmodified fibers, TGA showed two maximum decomposition peaks at 320^0C and at 370^0C. For silanized fibers, the most stable stage was shifted to a higher temperature of 470^0C and to 510^0C for silanized and polystyrene grafted fibers. Young modulii of composites increased from 1.9 GPa for non-treated fibers to 3.3 GPa for silanized and polystyrene grafted fibers.

Ricardo José Brugnago[25] et al investigated a pretreatment option to SCB fibers for their use in composite preparation with unsaturated polyester. SCB fibers modified by (i) steam explosion and (ii) alkali washing after steam explosion, along with (iii) as-received bagasse fibers were characterized. Steam explosion significantly reduced the amount of hemicelluloses and acid-soluble lignin of bagasse fibers, while acid-insoluble lignin increased proportionally. Alkaline washing of steam-exploded fibers removed nearly 60% of their acid-insoluble lignin. Polyester matrix composites containing 10 wt.% of these fibers were prepared by compression molding. Density, thermal stability, water absorption and thermomechanical analysis of the composites containing steam explosion treated bagasse fibers showed improvement in these properties over those of the untreated fiber containing composite. These are explained in terms of the chemical modifications that occurred due to the steam explosion treatments.

Gope P. C[26] et al developed bagasse-glass fiber reinforced composite material with 15 wt%, 20 wt%, 25 wt% and 30 wt% of bagasse fiber with 5 wt% glass fiber mixed in resin. SEM shows that bagasse fibers 13.0 μm in diameter and 61.0 μm in length are well dispersed in the resin matrix. Addition of fiber increases the modulus of elasticity of the epoxy. Mixing of bagasse with glass fiber also improves the modulus of elasticity. Addition of bagasse fibers decreases the ultimate tensile strength. But addition of glass fiber further increases the ultimate tensile strength in comparison to commercially available bagasse based composite. Bagasse-glass reinforced fibers improve the impact strength of epoxy materials due to fiber has more elasticity in comparison to matrix material. Addition of fibers increases the capacity of water absorption. This test is necessary where composites are used in moisture affected areas. Addition of bagasse fiber reduces bending strength. But addition of glass fiber further increases the bending strength in comparison to commercially available bagasse based composite.

Sherif Mehanny[27] et al prepared starch-based matrix and bagasse fibers Native corn starch was mixed with glycerin and water, emulsified then added to the bagasse fibers previously prepared and treated by NaOH. The composite was preheated then pressed for 30 minutes at 5 MPa and 170^{0}C. SEM showed good adhesion between fibers and matrix up to 60wt% fibers. Density measurements showed low porosity for all composite samples up to 60wt% fibers. Both the tensile and flexural strengths increased as the fiber weight fraction increased from 0% to 60%. Water Uptake and thermal degradability tests showed higher stability for composite with increasing fiber content. The results show that the 60wt% bagasse fiber starch-based composite is an eco-friendly and inexpensive candidate for many applications.

Zuqiang Huang[28] et al investigated the pretreatment of SCB by mechanical activation (MA) using a self-designed stirring ball mill and surface modification of SCB using aluminate coupling agent (ACA). The untreated and differently treated SCBs were used to produce composites with poly (vinyl chloride) (PVC) as polymer matrix. The activation grade (Ag) measurement and FTIR analysis of SCB showed that MA enhanced the condensation reaction between ACA and hydroxyl groups of the SCB fibers, which obviously increased the hydrophobicity of SCB. It was found that the mechanical properties of both the PVC composites reinforced by SCB with and without ACA modification increased with increasing milling time (t_M). SEM analysis showed that MA pretreatment significantly improved the dispersion of SCB in the composites and interfacial adhesion between SCB and PVC matrix, resulting in better mechanical properties of the composites.

Agunsoye J.O[29] et al confirmed Bagasse filled recycled polyethylene bio-composites were produced by the compounding and compressive molding method. Two sets of composites were produced using uncarbonized (UBp) and carbonized (CBp) bagasse particles by varying the bagasse particles from 10 to 50 wt%. The surface morphology and the mechanical properties of the composites were examined. The results showed that the uniform distribution of the bagasse particles in the microstructure of the polymer composites is the major factor responsible for the improvement of the mechanical properties. The bagasse particles added to the RLDPE polymer improved its rigidity and the hardness values of the composites. The tensile and bending strengths of the composite increased with increasing percentage of the bagasse to a maximum of 20 wt% UBp and 30 wt% CBp. The impact energy and fracture toughness decreases with wt% bagasse particles. The developed composites have the best properties in the ranges of 30 wt% bagasse particle additions and for optimum service condition, carbonized bagasse particles addition should not exceed 30 wt%.

Amine Moubarik[30] et al performed Cellulose fibers were isolated from Moroccan sugar cane bagasse by using three distinct stages. Firstly bagasse was subjected to (1) a hot water (70^{0}C) treatment to eliminate hemicellulose, then to (2) an alkaline aqueous solution (15% of sodium hydroxide (NaOH), 98^{0}C) treatment to eliminate lignin, and finally to (3) a bleaching stage. Sugar cane bagasse cellulose fibers were analyzed by different complementary analysis (FT-IR; 13C NMR and TG). The reinforcing capability of cellulose fibers extracted from sugar cane bagasse was investigated using low density polyethylene as matrix. The cellulosic preparations were free of bound lignin. The intrinsic viscosity, the viscosity average and the molecular weight were respectively 511 ml/g, 1769 and 286578 g/mol. An enhance on mechanical properties of composites was found, a gain of 72% in Young's modulus at 25 wt.% fiber loading and a gain of 85% in flexural modulus at 25 wt.% fiber loading, as a results of a good interface adhesion between cellulose fibers and matrix.

Arrakhiz F.Z[31] et al investigated mechanical properties of alfa, coir and bagasse fibers reinforced polypropylene (PP) composites. In order to improve the composite's mechanical properties, fibers were alkali treated before compounding to remove natural waxes and other non cellulosic compounds. The mechanical properties of the composites obtained with these three fibers were found to be superior to those of the neat polymer. Addition of various amount of reinforcement fibers yielded noticeable increases in both tensile and flexural modulus as well as the torsion parameter. 56–75% increases in tensile modulus were observed by the use of alfa, coir and bagasse while the flexural modulus increased by 30–47% when compared to neat PP. An increase in torsion modulus is also observed when the fiber content exceeds a threshold level. A power law model was developed using an experimental data to calculate the torsion modulus of fiber-reinforced composites at various fiber loading and frequencies.

Mohammad K[32] et al evaluate the effect of chemical treatment on the tensile, thermal, and morphological properties of single sugarcane fiber bundles. Surface modification of fiber bundles was accomplished by performing alkali treatment and neutralized by acetic acid solution. The fiber bundles were then rinsed with water and dried at 80^0C for about 24 h in an oven. Tensile tests, TGA, DSC, and FTIR were carried out on single fiber bundles.

Le Duy Khuong[33] et al Optimization of alkaline pretreatment of SCB for consolidated bioprocessing fermentation by the cellulose-fermenting fungus Phlebia sp. MG-60 was studied. The lignin and xylan contents of bagasse were decreased and ethanol production from each pretreated SCB by MG-60 was increased in an alkaline concentration-dependent manner. The fungus produced cellulase and xylanase rapidly over 120 h. When this fungus was cultured with 20 g L^{-1} of SCB pretreated with NaOH (0.8 wt%, 121^0C, 60 min), 4.5 g L^{-1} ethanol was produced, equivalent to 210 mg ethanol per gram of the original untreated bagasse after 240 h fermentation, giving ethanol yields of 65.7% of the theoretical maximum. These data suggest that Phlebia sp. MG-60 is a potential candidate for ethanol production from alkali-pretreated bagasse in a single bioreactor, without enzymatic or chemical hydrolysis.

4. Conclusions

The sustainable tomorrow for future generation lies with the present industrial development towards eco efficiency of industrial products and their process of manufacturing. High performance, biodegradable materials and renewable plant materials can form new platform for sustainable and eco-efficient advance technology products and compete with synthetic/petroleum based products presently dominated in market which are diminishing natural petroleum feedstock. Biocomposites reinforced with natural fibers and/or biopolymers have developed significantly over the past years because of their significant processing advantages, biodegradability, low cost, low relative density, high specific strength and renewable nature. These composites are predestined to find more and more application in the near future.

Natural fibers and biocomposites made from natural sources integrate the sustainable, eco-friendly and well designed industrial products which can be replace dominance of petroleum based products in future. Interfacial adhesion between natural fibers and matrix will remain the key issue in terms of overall performance, since it dictates the final properties of the composites. Many studies are examined, reviewed and highlighted in this review paper regarding the importance of the interface, the influence of various types of surface modifications, different types of matrices used for the composites, as well as fabrication methods, and the performance of composites.

Bagasse fiber is obtained from a source which is known for its renewability in terms of fast growth and better mechanical properties. The utilization of bagasse fibers for fabrication of biocomposites by using advance technology transforms future of coming generation. The well designed and engineered products from the bagasse fibers can help in making new revolution to sustain our natural resources. Thereby, based on this brief review the bagasse fibers can be utilized for advance and engineered product development for different applications.

Further research is required to overcome obstacles such as moisture absorption, inadequate toughness, and reduced long-term stability for outdoor applications. In particular, different weathering conditions, such as temperature, humidity, and UV radiation all affect the service life of the product.

It will be an alternative way to develop the biocomposites which can be particularly used for daily needs of common people whether it is house hold furniture, house, fencing, decking, flooring, and light weight car components or sports equipments. Their low cost, easy availability and aesthetic designs will be the main driving force to transform the depended present to sustainable future. Significant research is currently underway around the world to address and overcome the obstacles mentioned above. This effort to develop biocomposite materials with improved performance for global applications is an ongoing process.

References:

1. Maya Jacob John and Sabu Thomas. Biofibres and biocomposites, Carbohydrate Polymers 71 2008, 343–364.
2. Karthikeyan B., Ramanathan S., Ramakrishnan V. Thermo physical property measurement of metal-matrix composites, Materials and Design 31 2010, S82 - S86.
3. Suddell B. Industrial Fibres: Recent and Current Developements. In Proceedings of the Symposium on Natural Fibres. 2009, p. 71 - 82.

4. Joshi S.V., Drzal L.T., Mohanty A.K., Arora S. Are natural fiber composites environmentally superior to glass fiber reinforced composites?, Composites: Part A 35 2004, 371 – 376.
5. Staiger MP., Tucker N. Natural-fibre composites in structural applications. In: Pickering K, editor. Properties and performance of natural-fibre composites. Cambridge, UK: Wood head Publishing; 2008, 269 – 300.
6. Paturau J.M. By-Products of Sugar Cane Industry, 3rd Edition, Elsevier, Amsterdam 1989.
7. Loh Y.R., Sujana D., Rahman M., Dasb C.A. Sugarcane bagasse — The future composite material: A literature review, Resources, Conservation and Recycling 75 2013, 14 - 22.
8. Luz SM., Goncalves AR., Del'Arco Jr AP. Mechanical behavior and microstructural analysis of sugarcane bagasse fibers reinforced polypropylene composites. Composites Part A: Applied Science and Manufacturing 2007; 38: 1455 – 61.
9. Ashok Pandey, Carlos R. Soccol, Poonam Nigam, Vanete T. Soccol. Biotechnological potential of agro-industrial residues. I: sugarcane bagasse. Bioresource Technology 74 2000, 69 – 80.
10. Hattallia S., Benaboura A., Ham-Pichavant F., Nourmamode A., Castellan A. Adding value to alfa grass (Stipa tenacissima L.) soda lignin as phenolic resins. 1. Lignin characterization. Polymer Degradation and Stability 2002; 76 : 259–64.
11. Cao Y., Shibata S., Fukumoto I. Mechanical properties of biodegradable composites reinforced with bagasse fibre before and after alkali treatments, Composites: Part A 37 2006, 423–429.
12. Luz S.M., Goncalves A.R., Del'Arco Jr A.P. Mechanical behavior and microstructural analysis of sugarcane bagasse fibers reinforced polypropylene composites, Composites: Part A 38 2007, 1455 – 1461.
13. Luz S.M., Del Tio J., Rocha G.J.M., Goncalves A.R., Del'Arco Jr A.P. Cellulose and cellulignin from sugarcane bagasse reinforced polypropylene composites: Effect of acetylation on mechanical and thermal properties, Composites: Part A 39 2008, 1362 – 1369.
14. Daniella R. Mulinari , Herman J.C. Voorwald , Maria Odila H. Cioffi , Maria Lúcia C.P. da Silva , Sandra M. Luz. Preparation and properties of HDPE/sugarcane bagasse cellulose composites obtained for thermokinetic mixer, Carbohydrate Polymers 75 2009, 317 – 321.
15. Daniella Regina Mulinari, Herman J.C. Voorwald, Maria Odila H. Cioffi, Maria Lúcia C.P. da Silva,Tessie Gouvêa da Cruz, Clodoaldo Saron. Sugarcane bagasse cellulose/HDPE composites obtained by extrusion, Composites Science and Technology 69 2009, 214 – 219.
16. Aigbodion V.S., Hassan S.B., Dauda E.T., Mohammed R.A. The Development of Mathematical Model for the Prediction of Ageing Behaviour for Al-Cu-Mg/Bagasse Ash Particulate Composites, Journal of Minerals & Materials Characterization & Engineering, 9 2010, 907 - 917.
17. Sandra M. Luz, Armando Caldeira-Pires, Paulo M.C. Ferrao. Environmental benefits of substituting talc by sugarcane bagasse fibers as reinforcement in polypropylene composites: Ecodesign and LCA as strategy for automotive components, Resources, Conservation and Recycling 54 2010, 1135 – 1144.
18. Julien Bras, Mohammad L. Hassan, Cecile Bruzesse, Enas A. Hassan, Nahla A. El-Wakil, Alain Dufresne. Mechanical, barrier, and biodegradability properties of bagasse cellulose whiskers reinforced natural rubber nanocomposites, Industrial Crops and Products 32 2010, 627 – 633.
19. Punyapriya Mishra & Acharya S. K. Anisotropy abrasive wear behavior of bagasse fiber reinforced polymer composite, International Journal of Engineering, Science and Technology Vol. 2, No. 11, 2010, 104 -112.
20. Rahman Muhammad Bozlur, Shinichi SIBATA, Siddiqua Farah DIBA and Magali UONO. Effect of holding time and the amount of fiber content on the flexural properties of Bagasse /bamboo fiber reinforced biodegradable composite, Proc. of International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan, 2010.
21. Punyapriya Mishra and Acharya S. K. Solid particle erosion of Bagasse fiber reinforced epoxy composite, International Journal of Physical Sciences Vol. 5 (x), 2010, xxx - xxx.
22. Cerqueiraa E. F., Baptistab C. A. R. P., Mulinaria D. R. Mechanical Behaviour Of Polypropylene Reinforced Sugarcane Bagasse Fibers Composites, Procedia Engineering, 2011, 10, 2046–2051.
23. Maria E. Vallejos, Aprigio A.S. Curvelo, Eliangela M. Teixeira, Fernanda M. Mendes, Antonio J.F. Carvalho, Fernando E. Felissia, Maria C. Area. Composite materials of thermoplastic starch and fibers from the ethanol–water fractionation of bagasse, Industrial Crops and Products 33, 2011, 739–746.
24. Arturo Zizumbo, Angel Licea-Claveríe, Eder Lugo-Medina, Edgar García-Hernández, Domingo Madrigal1 and Roberto Zitzumbo. Polystyrene Composites Prepared with Polystyrene Grafted-fibers of sugarcane Bagasse as Reinforcing Material, J. Mex. Chem. Soc. 2011, 55(1), 33-41.

25. Ricardo José Brugnago , Kestur Gundappa Satyanarayana , Fernando Wypych, Luiz Pereira Ramo. The effect of steam explosion on the production of sugarcane bagasse/polyester composites, Composites: Part A 42, 2011, 364–370.
26. Maneesh Tewari, Singh V. K., Gope P. C., Arun K. Chaudhary. Evaluation of MechanicalProperties of Bagasse-Glass Fiber Reinforced Composite, J. Mater. Environ. Sci. 3 (1) 2012, 171-184.
27. Sherif Mehanny, Mahmoud Farag, Rashad R. M., Hamdy Elsayed. Fabrication and Characterization of Starch Based Bagasse Fiber Composite, Materials and Manufacturing, Parts A, B, and C, Houston, Texas, USA, 2012, 9–15,.
28. Zuqiang Huang , Nan Wang, Yanjuan Zhang , Huayu Hu , Yuanwei Luo. Effect of mechanical activation pretreatment on the properties of sugarcane bagasse/poly (vinyl chloride) composites, Composites: Part A 43, 2012, 114–120.
29. Agunsoye J.O., Aigbodion V.S. Bagasse filled recycled polyethylene bio-composites: Morphological and mechanical properties study, Results in Physics 3, 2013, 187–194.
30. Amine Moubarik, Nabil Grimi, Nadia Boussetta. Structural and thermal characterization of Moroccan sugar cane bagasse cellulose fibers and their applications as a reinforcing agent in low density polyethylene, Composites: Part B 52, 2013, 233 – 238.
31. Arrakhiz F.Z., Malha M. , Bouhfid R., Benmoussa K., Qaiss A. Tensile, flexural and torsional properties of chemically treated alfa, coir and bagasse reinforced polypropylene, Composites: Part B 47, 2013, 35 – 41.
32. Mohammad K. Hossaina, Mohammad R. Karima, Mahmudur R. Chowdhurya,Muhammad A.Imamb, Mahesh Hosurb, Shaik Jeelanib, Ramsis Faragc. Comparative mechanical and thermal study of chemically treated and untreated single sugarcane fiber bundle, Industrial Crops and Products 58, 2014, 78 – 90.
33. Le Duy Khuong, Ryuichiro Kondo, Rizalinda De Leon , To Kim Anh ,Kuniyoshi Shimizu , Ichiro Kamei. Bioethanol production from alkaline-pretreated sugarcane bagasse by consolidated bioprocessing using Phlebia sp. MG-60, International Biodeterioration & Biodegradation 88, 2014, 62 - 68.

*****