



Development of Sustainable Thermo Acoustic Material from Residual Organic Wastes

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Non-destructive technique such as ultrasonic processing employed for surface modification of corn husk which changes the interfacial as well as skeletal arrangement in interlocking of fibres with polymer chain. Investigations were carried out on the organic waste obtained from the corn husk with characterization technique such as Scanning Electron Microscope (SEM), Energy Dispersive X-ray spectroscopy (EDX) and Fourier Transform Infrared Spectroscopy (FTIR) has been employed for surface analysis and study of compositional change in the modified fibre and composite material. Tensile strength of single corn husk fibre before and after surface treatment was observed to be increasing from 332.57 MPa to 345.16 MPa which confirms the strong fibrillation due to surface treatment. Further acoustic performance of the composite reveals that treated composite has a potential to absorb 94% of sound which makes it a class - A type sound absorber as per ASTM E 1154 standard. The enhanced physical, mechanical, acoustic and thermal properties of corn husk-epoxy composite confirm their suitability as potential smart sound-absorbing material.

Keywords: Biopolymer, Interface, Surface treatment, Mechanical properties

Introduction

In recent time of digital era the impact of noise pollution is rapidly increasing which creates a demand for acoustic materials that can sustain itself for dissipation of noise in everyday life. Noise pollution is one of the serious threats to human life in urban areas due to its long lasting effects. Therefore hunt for acoustic materials research is an accepted fact worldwide.¹ The need of acoustic technology was highlighted subjecting to growing noise pollution worldwide by the committee for International Noise Awareness Day (April 2021).⁽²⁾ The adoption of newly discovered sustainable materials to absorb noise has gained its importance due to their selection of materials, design and fabrication technique which can lead to high acoustic value. The development of sustainable material from different waste for different technological applications such as designing of acoustic building material, parts of automobile, aeroplane, insulating material for heat and electricity in different industries are the cutting edge research findings for material researcher. In particular the agricultural residuals of different crops such as paddy, sugarcane, banana and corn have significant

contribution in designing the carbon based composite material for various applications. Green biomaterials like fibre composites have gained much attention due to their biodegradability, cost effectiveness, non-toxicity, and environment friendly limiting the use of synthetic acoustic material. Sound-absorbing materials today largely consist of manufactured products such as foam, repurposed rubber, glass wool, and synthetic fibre that could be hazardous to human health, disruptive at work, and environmentally harmful. In present time industries and researchers are well concerned about green acoustic materials for its interesting properties like affordable, easy to make, compact, and lightweight and can absorb sound waves in a wider frequency range.³ Natural fibres are becoming increasingly popular, because of their porous structure and their comparatively low density since they are renewable, affordable, abundant, and offer lesser dangers to health while processing and handling. Though there are many biomaterials available in abundant amount but all do not possess high acoustic performance as like corn husk fibre. Fibers derived from corn husk are among the many undiscovered fibre sources. Corn husks are the outer covering of corn cob which is abundantly filled with long fibers with cellulose as main constituent. Corn husks are lignocellulosic fibres that are often

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discarded or utilized as compost fertilizer.³ Due to its heterogeneous and low-added values, lots of corn products are either incinerated or disposed which is leading to environmental pollution. A very few researchers have worked on corn based composite. Some researchers collected fibers from corn husk by chemical treatment using alkali and enzymes. From their studies they discovered that corn husk fibers consist of 80%–87% of cellulose. They combined corn husk fibers with other synthetic fibers to create yarn. The breaking strength and elongation were tested. Moreover, no comprehensive research on the morphological and physicochemical characteristics of corn husk fibre has also been published.^{4,6} Due to the fibre bridging property of natural fibres there are multiple sites of cracks on the fibre surface which occurs during fibre and matrix bonding. The presence of polar-hydroxyl group on the fibre surface increases the moisture absorbing capacity of fibre leading to very poor interfacial adhesion between fibre and matrix. In order to increase the interfacial adhesion between fibre and polymer matrix the method of surface modification should be adapted.⁷ The present work is carried out using non-destructive technique like ultrasonic treatment for well blending of surfactants like ethanol and acetone (E-A) in order to bleach the fibre surface.⁸ Various physical and mechanical properties of treated and untreated corn husk fibre are determined and compared. The brilliant mechanical strength, light weight, green syntheses are the key novelty of the present fabricated corn husk composite. Analysis of mechanical, acoustic and thermal phenomena of the synthesized composite has been done with basic principle of sound propagation.

Material and Methods

Materials

The biomaterial considered here is the residual part of corn i.e. corn husk which was collected from local area and dried in sun light that can be used as reinforcement for the synthesis of composite as shown in Fig. 1(a). For surface modification of corn husk

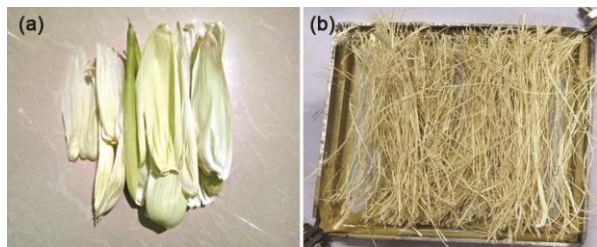


Fig. 1— (a) Corn husk (b) Corn husk fibre

fibre optimized blend of ethyl alcohol and acetone (CDH Chemicals Pvt.ltd) were used. Polymer resin like Epoxy(LY 556) and curing agent like hardener (HY-9511) with a ratio of 10:1 was used for fabrication of composite. A square mold of dimension 15 cm was taken for composite fabrication with Teflon sheet and silicon spray which was used as a releasing agent.

Fibre Extraction Process

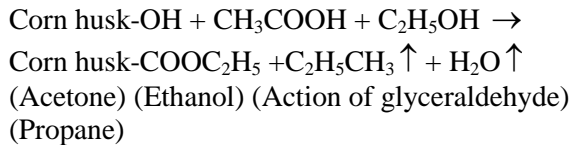
The collected corn husks were soaked into water for 24 hours in order to allow microbiological deterioration for smooth removal of fibre. Corn husk were brushed with a comb to separate the fibres from the husk. The extracted corn husk fibres were washed thoroughly with normal water and kept in oven at 80°C for removal excess moisture. Further the dried corn husk fibre was cut into length of 15 cm using scissor as shown in Fig. 1(b).

Chemical Treatment of Corn Husk Fibre

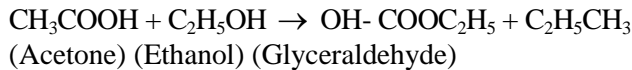
Surface treatment of residual corn husk was performed by the compatible optimum blends of the surfactants. The compatibility of ethyl alcohol and acetone (E-A) were determined by computation of compressibility of the surfactants determined from ultrasonic velocity data in different mole fraction. An appropriate amount of ethyl alcohol and acetone were mixed in different concentration and stored in airtight containers for ultrasonic measurement from which optimized compatible blends are to be selected for surface modification of corn husk fibres. Ultrasonic velocity has been determined in the prepared solution using a multi frequency ultrasonic interferometer (M-84S). Ultrasonic velocity measurement has been performed with an accuracy of ± 0.01 m/s. The densities of the blended solution as well as the pure chemicals were measured with the help of a double limbed pycnometer with accuracy up to ± 0.0001 kg/m³. The temperature of the sample was maintained constant with the help of a temperature controlled bath with a precision of ± 0.01 K. The mixture was kept inside the sonicator for 1 hour for well compatibility of the surfactants. Further corn husk fibres of uniform length were soaked in the surfactant for 12 hours. The treated fibres were then dried in normal room temperature which is ready to be used in fabrication of composite. The treatment of corn husk fibre with alcohol can cause the alignment of highly packed crystalline cellulose to shift to an amorphous zone.⁹ The possible chemical reaction of C₂H₅OH with corn

husk fibre takes place on the surface of the fibres modifies the surface of the corn husk to a large extent by removal of OH group in the fibre. This treatment changes the fibre becomes hydrophobic by evaporating water by the reaction of ethanol blended acetone on the surface of the corn husk fibre. Aside from that, the alcohol treatment aids in the cleaning of the fibre surface by eliminating lignin, hemicelluloses, wax, pectin, and oil which reduces the dimension of cellulosic material of the corn husk converting from hydrophilic to hydrophobic.^{10,11} The resulting reaction that causes the modification on surface corn husk is represented by the necessary chemical reaction followed by removal of water as follows:

Main reaction



Side reaction



Experimental Details for Fabrication of Corn Husk Fibre Composite

After surface treatment the fibres were washed with distilled water to neutralise the pH. The treated fibres

were kept in oven at 60°C for four hours for post curing process. For well-mixing of polymer and the curing agent, appropriate amount of epoxy LY-556 and hardener HY-951 with a ratio of 10:1 by weights were stirred continuously for 20 minutes. The colour of epoxy resin changes from colourless to light yellow transparent viscous liquid. The surface modified corn husk fibres were then positioned longitudinally within the well mixed matrix of epoxy and hardener in a square mould of dimension 15 cm. The inner side of the mould was coated by the releasing agent (silicone spray) to lubricate the surface of the mould for smooth release of composite. The sample was given pressure with four C-clamps from four sides and allowed to set for 24 hours. After 24 hours the composite was removed and was cut for various testing. The general method of collection of raw materials and preparation of samples is shown in Fig. 2.

Measurement of Physical Properties of Corn Husk Fibre

Any biocomposite to be effectively act as sound absorber and dampening insulator must have to possess the physical and mechanical characteristics which are well described by acoustic parameters such as porosity (ε), airflow resistivity (σ) and tortuosity (ϕ). The other physical properties like density, water content, diameter and thermal conductivity are

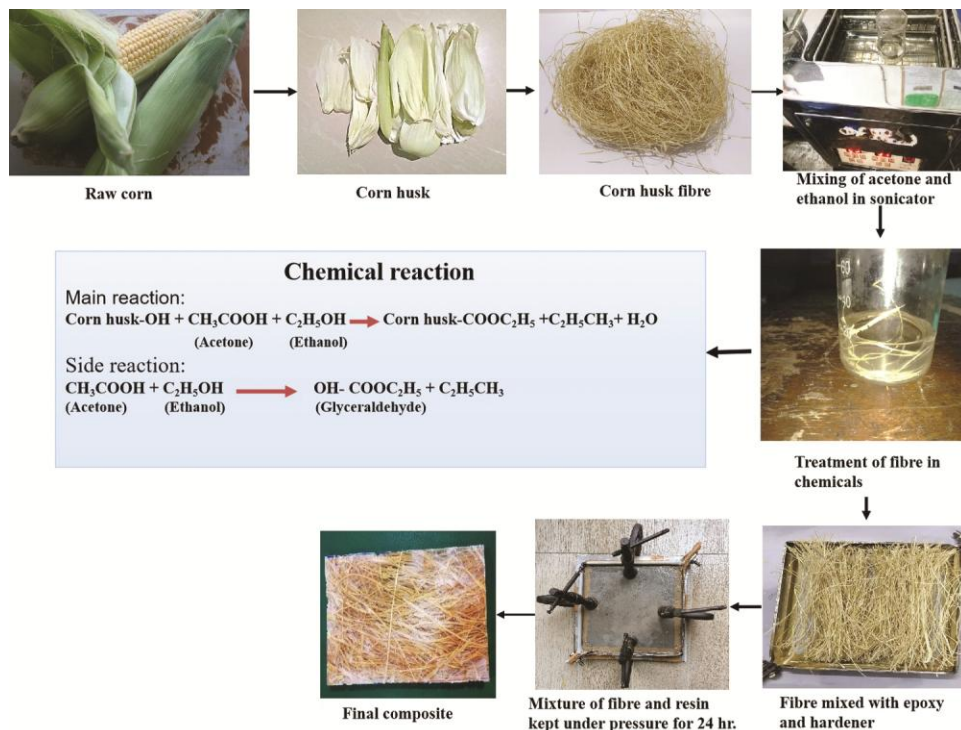


Fig. 2 — Preparation process of corn husk composite

determined to support the sound absorption efficiency of the material. As a carbon rich bio material, corn husk fibre used as a potential reinforcement for acoustic material with polymer resin matrix associated with the above characteristics. The acoustic parameters related to composites are computed theoretically which are well observed in analysis of composite material as sound absorber. In a non-acoustic approach, the porosity of the corn husk fibre was determined using the water saturation technique with confined value varying between 0 to 1.⁽¹⁵⁾ At 105°C, the fibres were dried for one day. They were then weighed before being submerged in water. After completion of 24 hours, the fibres were removed and weighed. Porosity of the fibres were determined with the formula $\varepsilon = V_w / V_s$, where V_w denotes the volume of the fibre occupied by water and V_s denotes the total volume of the fibre. The volume of water estimated by the formulas.¹⁴

$$V_w = \frac{M_{wet} - M_{dry}}{\rho_w}$$

where, M_{wet} is the wet mass of the fibre and M_{dry} is the dry mass of fibre, ρ_w is density of normal water.

Airflow resistivity is the resistance experienced by air when passing through a material. Using the value of porosity, the flow resistivity of corn husk fibre was determined theoretically by using the formula¹⁶

$$\sigma = \frac{(6.8 \times \eta \times (1 - \varepsilon)^{1.298})}{(d^3 \times \varepsilon^3)}$$

where, ρ is the viscosity of the air (1.84×10^{-5} Pa), ε is the porosity and d is the radius of the fibres. Tortuosity is a structural characteristic in porous materials showing the amount of sound waves entering the material space. The tortuosity (ϕ) is computed from the porosity (ε) data as¹⁷

$$\phi = 1 + \frac{(1 - \varepsilon)}{2\varepsilon}$$

The variations in fibre size are one of the primary factors of the sound absorption for any porous materials. The diameter of the fibre was measured with a micrometre screw gauge with accuracy up to ± 0.01 mm. The material density is considered as an important characteristic that impacts the compatibility of the sound absorption in a composite which is computed by the formula:

$$Density(\rho) = \frac{W_a}{W_a + W_w - W_b} (\rho_{water})$$

where, W_a denotes the weight of the specimen in air, W_w denotes the weight of the partially immersed wire specimen holder, W_b denotes the weight of the specimen completely immersed in distilled water, and ρ_{water} denotes the density of distilled water at the temperature being measured. The moisture content was determined by dividing the quantity of water vapour absorbed by the sample's dry weight. The moisture content of the fibres was determined using the ASTM (D 2495-01) standard test procedure.¹⁸ The ratio of the mass of moisture in the fibre to the weight of dried fibre expressed as a percentage ($M_t\%$) at each time period t is used to determine the quantity of moisture absorbed by a fibre.

$$M_t\% = \frac{m_t - m_d}{m_d} \times 100$$

where, m_t is the fibre mass at time t , m_d is the mass of the dried fibre and $M_t\%$ is the moisture absorbed by the fibre at time t . Thermal conductivity of corn husk composite was measured using thermal analyzer (KD2-Pro meter logger). A rectangular sample of the composite was taken with three regions located at different distances for average data. The regions are greased by thermal grease for well conduction of heat as well as for swift movement of the sensor tip. The TR-3 thermal sensor (2.4mm diameter and 100mm length) was inserted into the hole and the measurement was recorded in the thermal analyzer. The TR-3 thermal sensor uses an infinite Line Heat Pulse Technique (ILHP) to measure the thermal conductivity and resistivity of the composite.

Characterization of Corn Husk Fibre and its Composite

A scanning electron microscope (HITACHI SU 3500) operating at 5 kV was used to investigate the morphological changes that occur throughout different phases of the processing of corn husk fibre. The composite specimens were cut into slice and mounted over the specimen (aluminium) stub using an adhesive tape with coating of gold was used. A pressure of about 0.1 torr and current of 18mA was applied to make the sample conductive. The surface pictures at various magnifications were captured in different orientation to provide a clear picture of the surface alteration. Elementary composition of

the composite was investigated using energy dispersive X-Ray spectroscopy (EDX) according to ASTM F 1375 standard.¹⁹ In addition, details of the distinct functional groups present on the untreated and treated corn husk fibre were obtained using Fourier Transform Infrared spectroscopy (FTIR) (Bruker Alpha-II USA) working under ASTM E 1790 standard with the wave number ranging from 4000-500 cm^{-1} in the transmittance mode.²⁰

Experimental Setup for Sound Absorption Measurement

Sound absorption measurement of the synthesized corn husk composite was measured using impedance tube (HOLMARC-HO-ED-A-03) method. The system consists of a solid brass tube of length 1000mm with a speaker at one end and the sample holder at the other end. A pair of microphones separated by a defined distance was attached to this tube using microphone holders. These microphones were connected by means of signal conditioners and a data gathering system to a digital signal analyser. The speakers in the impedance tube were powered by a function generator. The irregular variations of peaks at different frequencies ranging from 500 to 3150 Hz were recorded with the system compatible to impedance tube. The complete experimental setup for sound absorption tests is shown in Fig. 3.

Mechanical Property

Tensile strength and Young's modulus of single corn husk fibre before and after surface treatment was measured using INSTRON Universal Testing Machine (UTM) with 10N load cell. The corn husk fibres were attached to the holder at 28°C with 78% of relative humidity. The crosshead speed was set to 1mm/min and gauge length of sample was taken 50mm. For each treated as well as untreated condition, three samples were tested and the average values are calculated according to standard ASTM D-3379-75 value. The preparation for testing of sample with experimental setup is shown in Fig. 4.

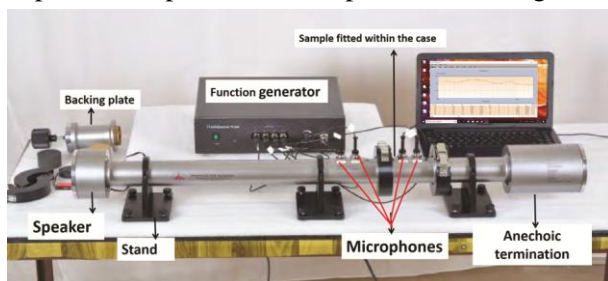


Fig. 3 — Experimental setup of sound absorption test using impedance tube

Results and Discussion

Various physical properties such as fibre diameter, porosity, tortuosity, density of raw and treated corn husk fibre has been measured and tabulated in Table 1. It is observed that the diameter of the treated fibre becomes shrunk from 0.2 mm to 0.12 mm which may be due to the removal of micro voids in the fibre structure leading to decrease the aspect of length to diameter ratio. The decrease in length to diameter ratio of the fibre results in increase of sound absorption which indicates the increase in fibre volume with increase of fibre materials and enhances the sound absorption efficiency.¹⁹⁻²¹ It is observed that the porosity of corn husk fibre increases from 71% to 87% with increase of fibre volume due to interlocking between the fibres and matrix material. Further, it is very clearly found that the porosity increases when the corn husk fibres are bleached with alcohol blended acetone. The peculiarity behind this treatment is that when fibrous material are dipped in to mixture of ethanol and acetone the interaction of carbonyl group of acetone with -OH group of the fibre takes place readily. As a result the ethanol blended acetone capable to removal -OH polymer group from the cellulose of lignocelluloses material converting it into hydrophobic from hydrophilic. The increase in porosity of fibre results in decrease of the elongation path focusing on the lumen structure of the fibre which decreases the tortuosity of the fibre. The sound absorption coefficient fluctuates more when the tortuosity is decreases from 1.02 to 0.98 as shown in Table 1.⁽²²⁻²³⁾ This indicates the air flow resistivity increases due to vibration of the air molecules inside the porous structure. Presence of air inside the porous structure decreases the incident phonon scattering which lowers the thermal conductivity of the



Fig. 4 — (a) Set up for tensile strength test (b) Single fibre specimen for tensile strength test

Table 1 — Physical properties of corn husk fibre

Sl. no	Type	fibre diameter (mm)	Porosity	Tortuosity	Density (gm/cm ³)	Moisture content (%)	Air flow resistivity (PaSm ⁻²)
1	Untreated	0.2	71	1.02	1.42	28	1825
2	Treated	0.12	87	0.98	1.36	16	1648

composite. Thus, the more is tortuosity of porous material, higher is the thermal resistivity.²⁴

The density of a fibre is one of the most effective criteria that determine how well the sound gets absorbed by the composite. With increasing in fibre density the sound absorption value in the middle and higher frequencies range increases. The data presented in Table 1 shows that the density of untreated corn husk fibre is 1.42 gm/cm³ whereas the density of treated corn husk is 1.44 gm/cm³. This is because surfactants have a dissolving impact on non-cellulosic constituent such as Hemi-cellulose and Lignin which lowers the mass of natural fibre.²⁵ Consequently, fibre volume reduces and increases the density of the fibre. It is observed that with alcohol treatment the moisture content decreases from 36% to 28% which inferred that the surface treatment of corn husk fibre with alcoholic treatment increases hydrophobicity by the substitution of hydroxyl group of cellulose with hydrophobic alcohol components.¹² The alcohol treatment reduces the diameter of the fibre and changes fibre elasticity, increases the resistance to airflow and enhances composite porosity. As porosity increases, the amplitude of the sound wave diminishes due to its motion through the void spaces on the fibre surface.²⁶ As sound waves travel the rough and convoluted path of materials, sound energy is converted into heat energy radiated to surrounding making the corn husk composite as good sound absorber.

The Scanning Electron Microscopy (SEM) images of untreated and treated fibre as well as composite of corn husks fibre are shown in Fig. 5 (a)–(e), where there is a major transformation in fibre surface which is important to analyse the interfacial bonding between the corn husk fibre and epoxy resin for the synthesis of bio composite. The surfaces of the untreated corn husk fibres are covered by impurities associated with shallow grooves like structures are observed in both longitudinal and cross sectional structures of the fibre as shown in Fig. 5 (a) and (b). Fig. 5 (c–d) shows scanning of electron micro graphs of surface modified corn husk fibre. Due to the action of surfactants on the fibre impurities like wax, lignin, cellulose and hemicellulose are removed from the

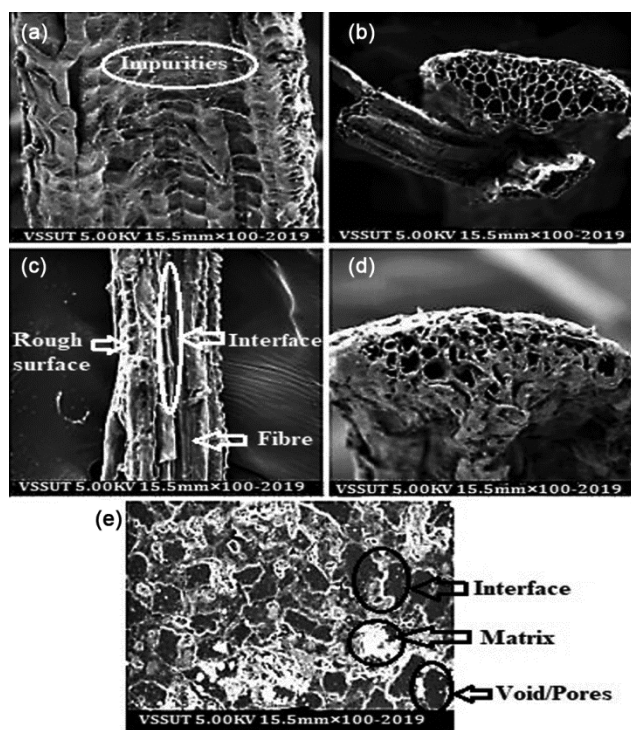


Fig. 5 — Scanning Electron Microscope (SEM) of Corn husk: (a, b) untreated fibre, (c, d) alcohol treated fibre, and (e) corn husk composite

fibre surface resulting in distinct view of fibrils with larger number of pores/voids as shown in Fig. 5 (c) and (d).¹³ The presence of multiple voids on the surface of the composite indicates the porous nature of the biocomposite which are created due to bonding between the fibres and polymer matrix as shown in Fig. 5 (e). Due to hydrophobic nature of the treated fibres there is large no. of voids or pores are present with interlocking of fibres and polymer resins.²⁷

The Energy-Dispersive X-ray Spectroscopy (EDS) of a corn husk dust composite is shown in Fig. 6. The graph displays the atomic weight percentages and elemental peaks in corn husk fibre. From the EDS data it is observed that the main compositions of corn husk composite are carbon and oxygen. In the corn husk composite the percentage of carbon is 60.62% which is more than that of other natural fibres. This might be because of existence of additional non-cellulosic constituents in corn husk fibre²⁸. Due to treatment of alcohol, the oxygen weight % decreases

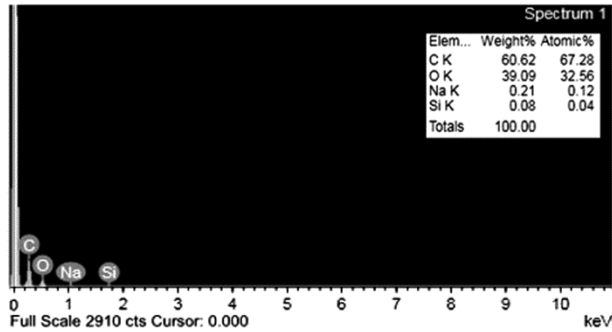


Fig. 6 — EDS of corn husk dust composite

as compared to carbon weight % which is due to elimination of hemicellulose, lignin and other cellulosic components from the fibrils material and there is trace levels of silica, sodium, and other elements are detected in the corn husk fibre. The presence of silica enhances the stiffness property by enhancing the fibre and matrix adhesion which in further increases the tensile strength of the composite.²⁹ There is a very little trace of about 0.21% of sodium was found in the alcohol treated composite which suggest that before chemical treatment there is lack in proper washing of the fibre for which some traces of inorganic particles like Na are left deposited. During chemical treatment of corn husk the presence of different elements are identified with their weight percentage. From the EDS of treated corn husk fibre composite presence of 39.09% of oxygen was found. This indicates the presence of oxygen related functional group like Glyceraldehyde which creates active sites for absorption process. The hydrophobicity and the reorientation of other functional group lead to roughness and porosity on the surface of the corn husk which is major contribution to the sound absorption phenomena.

The powder sample of corn husk fibre was characterized using FTIR spectroscopy as shown in Fig. 7 (a) and (b) for untreated and treated corn husk fibre respectively. A broad band of absorption peak is observed from 2925.8 cm^{-1} to 1640.49 cm^{-1} which confirms the O-H stretching. The absorption bands at 1740.1, 1638.4, 1605.1, and 1514.1 cm^{-1} are unnoticeable in treated corn husk fibre. On the treated corn husk spectra, the spectra at 1514.1 cm^{-1} is absent, while spectrum at 1249.5 cm^{-1} is substantially decreased at treated fibre than untreated one. Nonexistence of the absorption spectrum from 1440.65 cm^{-1} to 1640.49 cm^{-1} in the treated corn husk fibre spectra clearly implies that most of the lignin has been eliminated. As seen in the graph, the huge

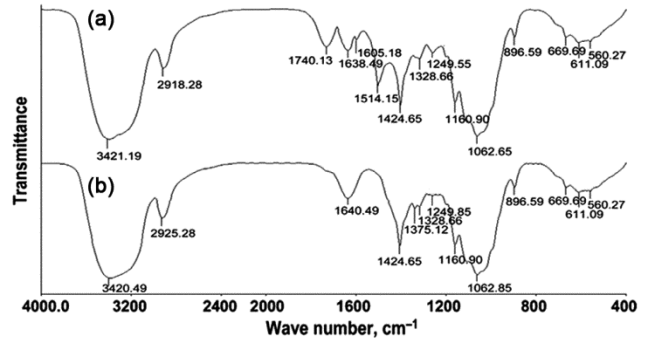


Fig. 7 — FTIR spectra of (a) untreated corn husk fibre and (b) treated corn husk fibre

absorption spectra 3421.1 cm^{-1} is connected to the stretching frequency of O-H group, whereas a spectra 2918.2 cm^{-1} is attributed to stretching frequency of -CH- group. Existence of novel and strong absorption spectra 1740.1 cm^{-1} endorses the stretching of -C-O-O- group, and carboxyl groups as salts are assigned at 1424.65 cm^{-1} wave number. The -OH stretching and -C-O-C- stretching are seen in the bands at 1160.90 cm^{-1} and 1062.65 cm^{-1} respectively.³⁰ Presence of 1,4- β glycoside of cellulose is observed at a wavelength of 896.59 cm^{-1} . This confirms the presence less trace of cellulose and lignin in the fibre after the surface treatment. From the absorbance spectra of both untreated and treated corn husk fibre a slight shifting in band position is observed. This shifting in bond is due to the increase in intermolecular hydrogen bonding responsible for increased compatibility and stronger adhesion of fibre with polymer matrix.³¹ During treatment of corn husk with acetone and ethanol, different functional groups are identified with their absorbance intensity. From the FTIR spectra a wide peak was observed for OH group, indicating the loss of OH group making hydrophobic nature of the treated corn husk. The hydrophobicity and the reorientation of other functional group in the spectra lead to roughness and porosity on the surface of the fibers making the composite suitable for sound absorption.³² The porous nature and development of the elastic skeletal structure in the composite was confirmed from the SEM image that contributes the acoustic analysis of the material.

Alcohol blended surface modification causes a tremendous effect on tensile and elasticity property of corn husk fibre.³² Since chemical composition of both corn husk fibre and epoxy resin are completely different, there is a need of strong interfacial adhesion for stronger tensile strength as well as bonding throughout the interface. Tensile characteristics and

young's modulus of both untreated and treated corn husk fibre are compared in Fig. 8 (a) and (b). There is an increase in young's modulus as well as tensile strength value of corn husk fibre when treated with 0.4 molar concentrations of acetone and ethanol. Untreated corn husk fibre shows a tensile strength of 332.57 MPa which rises to 345.16 MPa after surface modification of fibres. The secondary hydroxyl and epoxy groups present in epoxy polymer reacts with curing agent (hardener) and forms a three-dimensional network structure which makes the cured resin have strong cohesive force and good adhesion between the fibre and polymer matrix. Modulus of elasticity (Young's modulus) for untreated corn fibre was 17.02235 GPa which rises to 17.958 GPa after surface treatment. The young's modulus of all treated samples improved due to the elimination of amorphous components during alcohol treatment. The graph in Fig. 8 (c) shows that the improvements are due to the reduction in fibre diameter from 0.2 mm to 0.12 mm after the surface modification of corn husk fibre. The decrease in fibre diameter is due to the damage of cellulose, lignin, and related hemicellulose

in fibre with the alcoholic treatment which improves the strength of the corn husk fibres.³³ The fiber's aspect ratio and surface roughness are increased as a result of the surface treatment, which boosts the tensile strength of the composite as well.

Measurement of sound absorption coefficient is performed using impedance tube. It is observed from Fig. 9 (a) that sound absorption coefficient increases with the increase in frequency from 500 Hz to 3000 Hz. The absorption at low frequencies is comparatively smaller than higher frequencies with an increasing trend after 500 Hz in both treated and untreated corn husk composite. Since the corn husk fibres are treated with E-Abled surfactants, the sound reflection becomes less, which leads to higher sound absorption because of the elimination of cellular impurities and increase in carbon and oxygen content. However, the absorption value fluctuates a little bit and is influenced by specific properties like density and porosity of corn husk fibres. The presence of air molecules in the void places vibrate spontaneously when porous surfaces of the material are exposes to a high sound intensity. The elastic

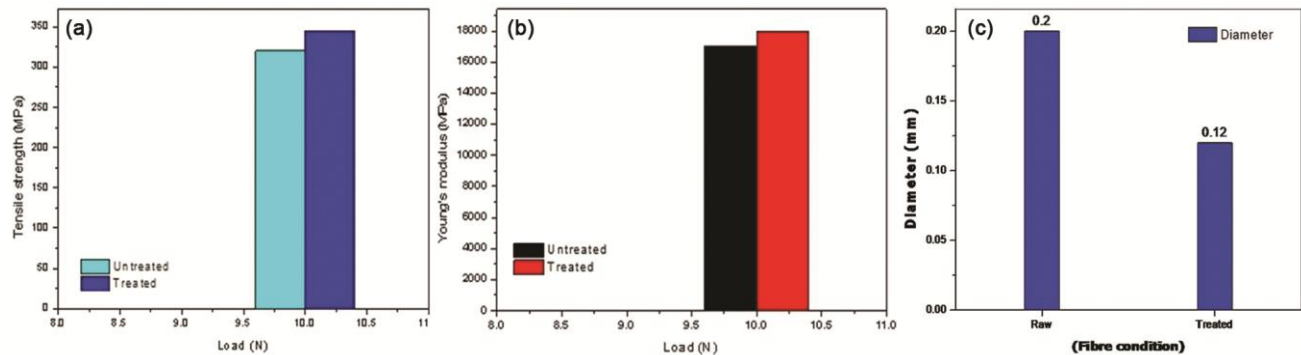


Fig. 8 — (a) Tensile strengths of corn husk fibre, untreated and treated (b) Young's modulus graph for untreated and treated corn husk fibres (c) Average diameter graph of raw and treated corn husk fibres

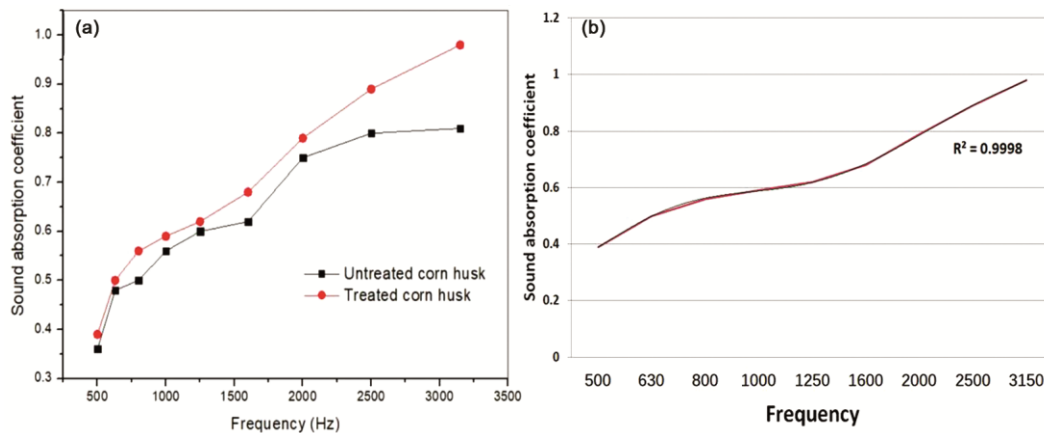


Fig. 9— (a) Variation of sound absorption coefficient with frequency (b) Regression graph

skeletal structure as observed in images of SEM undergoes mechanical vibrations and obstruct the flow of sound in its propagation causes the decrease in tortuosity. The loss of vibrational energy inside the composite appears as radiated heat energy changing thermal conductivity of the material. The E-A blended on corn husk reduces the diameter of the fibrils which increased the airflow resistivity within the void places. Decreasing in fibre diameter leads to increase in number of fibres per unit area which increases the porosity of the composite. From the graph it is confirmed that the treated corn husk composite shows better sound absorption which increases from 0.86 to 0.94 in the composite made up of untreated corn husk compared to treated corn husk. This is due to formation of better elastic skeletal structure and increase in porosity of the material due to E-A treatment. At higher frequency the wavelength of sound decreases to $\frac{1}{4}$ octave waves which increases superposition of incident and reflected sound inside the porous structure of composite which results in larger sound absorption.³⁵ Thus the composite may be utilized as class-A sound absorber according to Standard SREN ISO 11654-2002 value. The linear regression analysis for accuracy of sound absorption coefficient of corn husk composite is shown in Fig. 9 (b). The coefficient of correlation (R^2) of treated corn husk composite was determined to be 0.9998. Because the R^2 value is quite high nearer to 1, the error fluctuations across composite are very less.³⁴ From polynomial trend line it can be seen that for frequency 800 Hz the sound absorption coefficient should be 0.46 for treated composite but according to the experiment the sound absorption

coefficient should be 0.44. Thus it can be concluded that the experimental data is nearer to the predicted data.

Thermal conductivity of the synthesized composite is mainly influenced by the effect of uniform fibre dispersion patterns in the polymer matrix. The thermal conductivity of both treated and untreated corn husk fibre with respect to temperature is shown in Fig. 10 (a). The thermal conductivity value increases from 0.0625 to 0.0689 W/mK in treated corn husk fibre. From the Figure, it can be concluded that at 46°C the composite attain saturation point which means above 46°C the thermal conductivity value starts decreasing. Consequently, when the temperature rises and the vibrations increase, a balance between phonon propagation and scattering is established and thermal conductivity decreases as the temperature rises further. In present biocomposite as corn husk fibres are blended with the epoxy polymer and distributed homogeneously, the compactness of the material decreases. As a result the thermal wave moves slowly through the composite. Another reason is that, the presence of large no of void places filled with air makes the composite as bad conductor of heat for which the thermal conductivity value increases progressively.³⁶ A linear regression analysis of treated corn husk composite was done to confirm the trend of experimental and predicted values of thermal conductivity which is shown in Fig. 10 (b) According to the predicted data the thermal conductivity for treated composite should be 0.06 W/m.K but the experimental value is 0.056 W/m.K. The coefficient of correlation (R^2) between both the experimental and calculated values was determined to be 0.9949, which

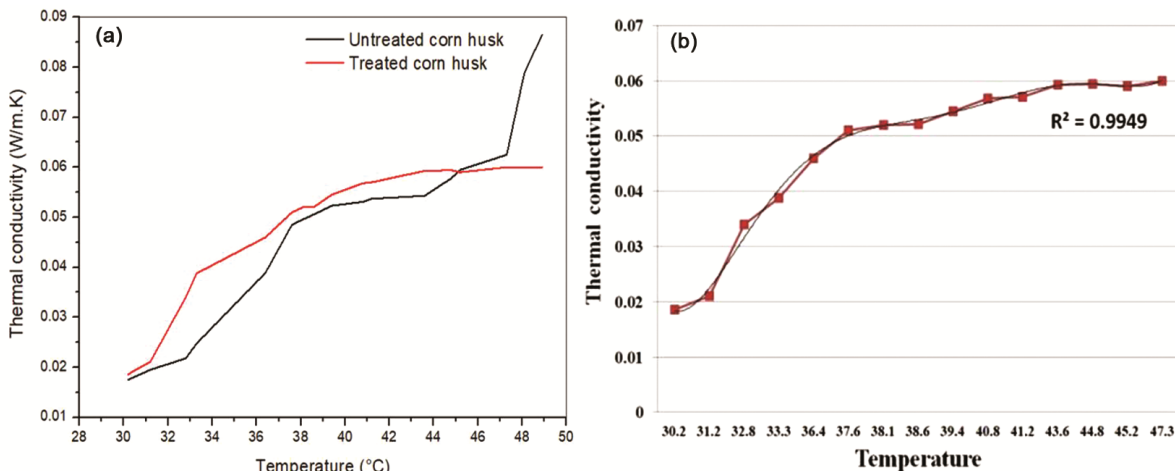


Fig. 10 — (a) Thermal conductivity of corn husk composite at different temperature (b) regression graph

is close to 1.⁽³⁷⁾ Thus, the experimental values follows similar trend with the predicted value.³⁸

Conclusions

Ultrasonic technique for compatibility and surface treatment was employed for selection of blending surfactant. E-A treatment increases the durability, surface roughness and bond strength of corn husk fibre. Various physical properties like porosity, tortuosity, density, moisture content; airflow resistivity of the fibre was calculated using theoretical approach. The result showed better physical property of treated corn husk fibre than the untreated fibre. On alcoholic treatment the porosity of the fibre increased leading to decrease in tortuosity and increase in flow resistivity. With decrease in tortuosity a shorter path is created for air to flow through a porous medium. With increase in air flow resistivity higher sound absorption was achieved. The different characterization like FTIR, SEM and EDS confirms the different mechanical, physical and shielding performance for sound and heat of the composite. Ductility and yield strength of the fibre has been studied using destructive tensile strength test indicate the deformation in cellulose as well as anti cellulose. Form analysis of thermal properties of the composite it is concluded that the bio composite has ability to absorb heat due to random distribution of fibres and interfacial adhesion of the fibre- polymer matrix which makes the composite an insulator. The optimum sound absorption coefficient was found to be 0.94 at a frequency of 3000 Hz which is classified as class-A type acoustic shielding material as per the International standard EN ISO 11654. The synthesized acoustic material may be proposed for its commercial and industrial application particularly as a noise absorber in different home appliances, machineries, and automobile parts.

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