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Fabrication and characterization of cow dung- Polyvinyl Alcohol composite film

Ajitanshu Vedrtnam[a,b,*]

[a] Department of Mechanical Engineering, Invertis University, Bareilly, UP 243001, India
[b] Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad, Allahabad, UP 211004, India

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ABSTRACT

A novel polymer composite film of cow dung fibers (soaked in 5% NaOH solution) and Polyvinyl Alcohol (PVA) was fabricated. The thermal and mechanical properties of the fabricated film were determined using standard methods. It was observed that flexural, tensile strength and hardness of the composite film were the maximum when 5–7% of cow dung fiber was mixed; further increasing the cow dung proportion gradually degraded the strength and hardness. It was also observed that increasing the cow dung fiber quantity decreases the thermal conductivity of the composite film. The scanning electron microscope (SEM) micrographs, Fourier-transform infrared spectroscopy (FTIR) and X-ray powder diffraction (XRD) revealed a good correlation between morphology and property variations of the composite film. The SEM micrographs, FTIR and XRD also revealed that the alkali treated cow-dung-fiber-composite (CDFC) film was having increased bounding and reduced fiber pullout resulting superior mechanical properties. The work suggests one of the suitable use for the large volume of cow dung produced throughout the globe.

1. Introduction

Natural fibers are biodegradable, environment-friendly, easily available, and impressive physicomechanical properties. The natural fiber-matrix composites are becoming popular day-by-day due to their lighter weight, higher strength [1,2] biodegradability [3], higher stiffness [4], lower friction coefficient [5] and good corrosion resistivity [6]. The application areas of natural fiber composites include automotive, packing, structural components, construction material, and aerospace applications [7–16]. The demand for natural fiber is increased due to increased environmental awareness, the environmental regulations, increased requirement of renewable, biodegradable, recyclable, eco-friendly and sustainable materials [17–22]. The natural fibers composites are renewable [23–29] and also have light-weight, low-cost, good thermal and acoustic insulation properties [30–32]. Hybrid natural fiber composites are also discussed widely in the cited literature [33–41].

Now-a-days cow dung is used as sequestering heavy metals from wastewater [42], source of green energy (bio gas production) [43], construction [44], cheap thermal insulator [45], composting [46], reductant (Iron recovery from iron ore slime) [47], stabilization of subgrade soil [48], an ideal fermentation medium for amylase production [49], and microbial safety control [50]. The cow dung contains 12–13% CaO, 0.8–1.0% MgO, 0.3–0.4% $CaSO_4$, 18–22% Al_2O_3, 18–22% Fe_2O_3 and 58–62% SiO_2. However, the chemical composition of cow dung may vary and may depend on source from which cow dung is obtained and also on treatment method.

The present manuscript reports a novel use of cow-dung. A novel cow dung-PVA composite film is prepared, treated, and characterized. However, Reddy et al. [51] have reported fabrication of the cow dung based composite and evaluated the effect of the cow dung/ glass fiber reinforcement on flexural and compressive strength of hybrid composite. A cow dung-PVA composite film was prepared using hand layup technique. Mechanical and thermal properties of the composite film are evaluated. The SEM, FTIR, and XRD analysis are conducted for establishing the correlation between morphology and property variations of untreated/ alkali treated CDFC film. The cow dung-PVA composite film is having comparable mechanical properties with the available laminating and packaging films. Biodegradability is an added advantage of the prepared composite film.

2. Materials and methods

2.1. Fabrication of CDFC film

The CDFC film was fabricated following the listed steps,

* Corresponding author at: Department of Applied Mechanics, Motilal Nehru National Institute of Technology Allahabad, Allahabad, UP 211004, India.
E-mail address: ajitanshu.m@invertis.org.

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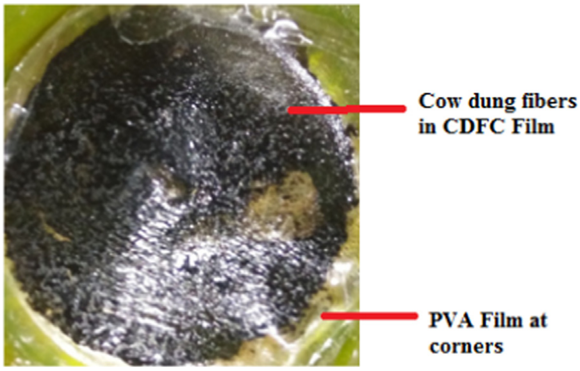

Fig. 1. Photograph of CDFC film.

1. Firstly, 100 ml distilled water was taken and maintained at 25 °C in a clean glass mug.
2. Further, 1 g PVA (low density) was mixed in distilled water using stirrer at 1000 RPM up to the complete dissolution of PVA (about two hours) in distilled water.
3. The cow dung was obtained from a local source, it is dried in sunlight, and further, the homogeneous cow dung fibers (powder form) were soaked in 5% NaOH for 30 min (which remove fatty material, hemi cellulose) and washed in distilled water and further dried under sunlight. This makes cow dung fibers suitably "clean" and "homogeneous" for packaging applications.
4. The mixture of PVA + distilled water was then added with cow dung fibers in right proportions and mixed with the help of stirrer at 1200 RPM for around 2 hours.
5. The cow dung fibers were added to the PVA solution in the proportions of 0%, 2%, 4%, 6%, 8% and 10% by weight of the resin.
6. Finally, the solution was dried in the sunlight to obtain the CDFC film of the uniform thickness. Fig. 1 shows the photograph of prepared CDFC film.

CDFC films without alkaline treatment (referred as untreated CDFC film) were also prepared following the same procedure for a comparative study. The fabrication and testing of CDFC film was performed in laboratory where 24 °C temperature was maintained as both PVA and cellulose fibre are hygroscopic and their properties may vary strongly with environment, thus controlled environmental conditions were maintained.

2.2. Mechanical and thermal property testing

The ASTM standard tests were used to evaluate the mechanical and thermal properties of the polymer matrix films. ASTM D882 was used to evaluate tensile strength. The cross head speed used was 10 mm/min, width of CDFC film was 6.4 mm, thickness 0.9 mm, and the initial gauge length between grips was 50 mm during tensile test. The flexural tests were performed according to ASTM D256. "Shore A" hardness testing was used to obtain the hardness of the films. The steady-state electrical heating method (based on Fourier's law of heat conduction) was employed to obtain thermal conductivity of the films. FTIR was performed using a FTIR-8400 S spectrophotometer, XRD was performed using XRD-6100 made at Shimadzu Co., Japan. A Japan-made Joel JSM-6400 was used for the SEM analysis.

3. Results and discussion

3.1. Mechanical and thermal testing of CDFC films

Five samples of each type were tested for all tests and an average value was taken as the final property value (statistical analysis for variability check was not required (standard deviation was less than 1%) as the values of the properties reported were quite close in all the tests for same type of CDFC film). Fig. 2 represents a plot between tensile strength and cow dung proportion (%). It reflects that the tensile strength increases with cow dung proportion (%) up to 6% than after it gradually degrades. The maximum tensile strength of treated CDFC film and untreated CDFC film are 159 MPa and 147 MPa respectively at 6% cow dung proportion. The tensile strength of CDFC film is considerably higher than the biodegradable PVA-lignin packaging film reported in [52]. The treated CDFC film has the higher tensile strength at all the cow dung proportions. The higher tensile strength has resulted in the decreased elongation at break. The % elongation at break varied from 198.23% to 266.13%, the maximum for PVA film having 0% cow dung and the minimum for treated CDFC film having 6% cow dung proportion (Fig. 3(a)). Tensile strength was increased by 21.8% for CDFC film (6% cow dung) in comparison to PVA film and treated CDFC film has the higher tensile strength for all the proportions of cow dung in CDFC film. Fig. 3(b) represents the plot between flexural strength and cow dung proportion (%). Flexural strength also follows the same pattern as tensile strength has followed. The maximum flexural strength varies 120 MPa to 159 MPa for treated CDFC film, maximum at 6% cow dung and minimum at 0% whereas for untreated CDFC film flexural strength varies from 143 MPa (at 6% cow dung) to 120 MPa (0% cow dung). The flexural strength of treated CDFC film was 24.5% higher than the PVA film and the flexural strength of treated CDFC films were higher than the untreated CDFC films for all the proportions of cow dung. Fig. 3(c) represents a plot between hardness (Shore A) and cow dung proportion (%). The hardness of both untreated and treated CDFC film increases gradually up to cow dung proportion of 6% and further, it slightly decreases; the hardness of treated CDFC film is higher than the untreated CDFC film. A slightly different trend is observed in hardness variation as it becomes almost same after 6% cow dung proportion. The maximum hardness for treated CDFC film is 90 shore "A" and 86 Shore "A" for untreated CDFC film. Fig. 3(d) shows the variation of thermal conductivity of treated and untreated CDFC films with the proportion of cow dung. The thermal conductivity decreases with the increment of cow dung proportion for both treated and untreated CDFC film. It can also be concluded from the Fig. 3(d) that untreated CDFC film is thermally more stable than the treated CDFC film.

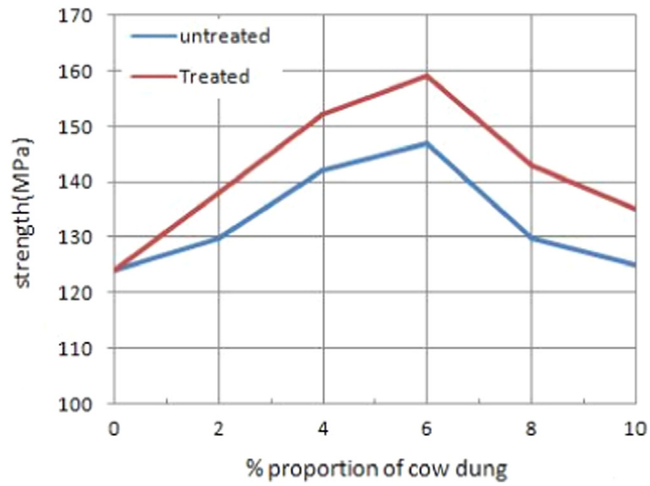

Fig. 2. Tensile strength Vs. Cow dung proportion (%).

3.2. Structure-property relationship

FTIR, XRD, and SEM analysis are conducted for treated and untreated CDFC film samples having 6% cow dung proportion to establish the property-structure relationship in CDFC films. The FTIR spectra of the treated and untreated CDFC films are shown in Fig. 4. The figure reflects that untreated CDFC film has weak bands, that are absent in the