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Preparation of Biocomposite Sheet Incorporation of Buffing Dust and Sugarcane Fiber: It's Application for Footwear as a Reinforcing Material

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ABSTRACT

This study aims to prepare flexible composite sheets from buffing dust waste and post-extracted sugarcane fiber waste through a simple solution casting technique. Natural rubber latex (NRL) was used as a binder material in different mixing ratios. To verify the chemical bonding between buffing dust and sugarcane fiber, FTIR was performed. Whole sole flexing endurance test, Bally Flexometer Test, Ross Flex Tester Test were performed to check the stability of composite. The physical and mechanical properties such as tensile strength, elongation, hardness, water absorption and density of prepared composites with optimum NRL content were augmented by 19, 21, 10, 15 and 21%, respectively, to compare with pure buffing dust sheets. As a consequence, these simple, low-cost, and flexible composite sheets might be a potential material for packaging, interior design, as well as reinforcing element for footwear.

Keywords: Composite, Latex, Solid waste, Sugarcane fiber, Buffing dust.

1. Introduction

The growing demand for leather and associated goods is what propels the annual expansion of tanning operations. As a result of the production of several organic and inorganic pollutants as byproducts during the conversion of raw hides and skins into finished leather, the environment and ultimately the bionetwork are seriously threatened [1]. Particularly, the tannery wastes include a variety of solid wastes like trimming, shaving, and splitting, which pose with animal fats and minerals, as well as liquid wastes like highly polluted wastewater and sludge with organic substantial amount of solid waste because only a small portion of raw materials (20- 25%) is converted into finished leather, while the remaining (75-80%) are released into the environment as trash [2]. Therefore, proper disposal of these solid wastes is essential, and numerous waste management techniques, including anaerobic digestion, landfilling, and thermal incineration, are often used. Recently, an effort has been made to switch out non-biodegradable polymeric materials for biodegradable polymeric materials by using bio composites consisting of natural, eco-friendly ingredients to replace conventional naturally-derived composite materials like Polylactic Acid (PLA) (Ambone et al., 2016). In order to characterize the structure, the authors The poly (vinyl butyral)-leather fiber composites showed a considerable improvement in elastic modulus and shore hardness, but a significant decrease in tensile strength and abrasion resistance[3].

The tensile modulus, percentage of water absorption, and percentage of crystallinity of the PCL matrix were all improved with the addition of BF to PCL at increasing concentrations. Ambone et al. (2016) discovered that adding more BF improved the tensile properties of biocomposites based on biodegradable polymers and decreased the percentage crystallinity of the PLA matrix. Therefore, in this work, an effort has been made to produce a composite material using sugarcane fiber that has been removed after sugarcane was extracted as well as buffing dust from the leather industry [4].

NRL and PU rubber solution were taken into account as a binder for the development of composite materials that would be suitable for the packing and interior decoration sectors. The good's physical-mechanical characteristics, or the composite materials', were assessed in accordance with the American Society for Testing and Materials' standards for tensile strength, density strength testing, hardness testing, flexibility testing, and biodegradability testing (ASTM). To describe the final product and the raw materials, Fourier Transform Infrared Spectroscopy (FTIR) was analyzed.

2. Materials and methods

2.1 Materials

Buffing dust was collected from "SAF" Leather Industry Ltd., Noapara, Jessore, Bangladesh. Sugarcane fiber waste was pro- cured from the local area of Khulna, Bangladesh. Analytical graded NRL, polyethylene glycol (PEG), aluminum sulfate ($Al_2(SO_4)_3$), and sulfuric acid (H_2SO_4) were purchased fromDhaka, Bangladesh.

2.2 Sample preparation

2.2.1 Preparation of composite

In 1L of dilute water, 100 g of fiberized buffing dust (BF) was soaked for 12 hours. Then the ingredients were minced to create a fine paste. To the prepared paste, add 200 ml of natural rubber latex, 1.5 percent aluminum sulfate, 10 ml of polyethylene glycol (PEG), 10 ml of PU rubber solution, and 10 ml of binders, plasticizers, and stabilizers, in that order. Then, completely combine. Following that, 4L of di-ionized water was diluted with 5 mL of H_2SO4 in a 1:3 ratio in order to bring the pH level down to 5. At next, prepared composite was added at different proportions (%w/w), like sample

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1(C1): 100% BF, sample 2(C2): 85% BF with 15% SF(sugarcane fiber), sample 3(C3): 90% buffing dust with 10% SF, sample 4(C4): 95% buffing dust with 5% SF and sample 5(C5): 97% buffing dust with 3% SF. Afterwards, a fiberize machine was used to process the mixes (SDL868, USA). In order to create sheets, the samples were lastly poured into a 30 cm x 30 cm mold and put under 30 seconds of 130 bar, 90C, pressure processing. The process is shown by **Fig**.1.

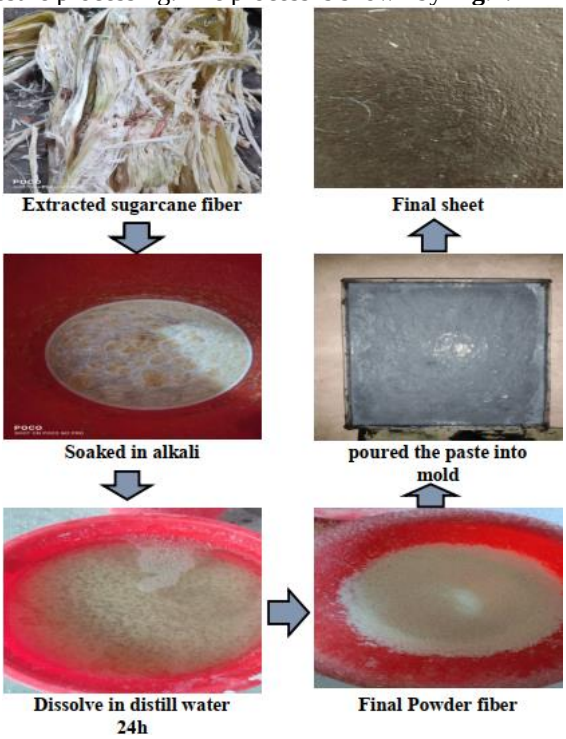

Fig.1 Preparation of composite from BF and SF

3. Characterization

Different physical and chemical analyses were carried out to check the properties of the newly developed composite. Regarding physical testing, tensile strength (SATRA TM137), flexing endurance (SATRA STM 465), density, and hardness (ASTM D2240) tests were carried out.On the other hand chemical analysis including Fourier Transform Infra- red (FTIR) (between 2850 and 3376 cm−1 spectral range with a resolution of 4 cm−1) by using Nicolet 6700 spectrometer (Thermo Scientific, USA).

4. Results and discussion

4.1 FTIR analysis

FTIR analysis of pure buffing dust and newly fabricated composite (95% buffing dust with 5% SF) are representing in Fig. 2.

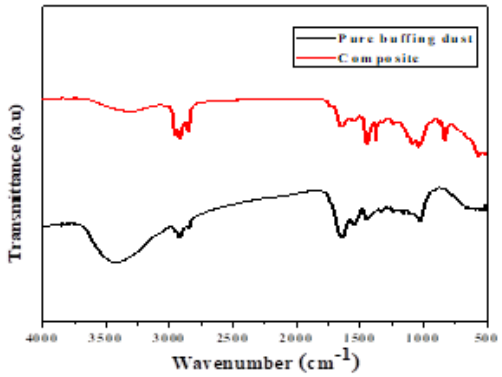

Fig.2 FTIR analysis of pure buffing dust and composite

In FTIR graph the peak of two composites almost same. The presence of leather is characterizes by amide I bond present at1642 and 1,665 cm-1 may be considered as a proof of leather fiber The presence of ester carbonyl group at 1150 cm-1 of incorporated buffing composite and sugarcane fiber waste represent the presence of sugarcane fiber. But basically the difference between two peaks in the range 2850 cm-1 to 3376 cm-1 which proofs that this peak for mixture of BF and SF

4.2 Tensile strength test

Table 1 shows the tensile strength of sheets made of sugarcane fiber and pure buffing. According to an experimental investigation by Senthil et al. [5], pure buffing dust initially imparts tensile strength of 4.15 MPa. The material's strength is simultaneously increased by the reinforcement of 5% sugarcane fibers. At 20% fiber content in composites, El-Shekeil et al. [6] and Prasad et al. [7] attained the maximum tensile strength. As a result, the strong connection between the reinforcement and the matrix is greatly aided by the entanglement of sugarcane fiber. The tensile strength of the material was found to be drastically reduced by the extra integration of natural fibers (at 30%) [8].

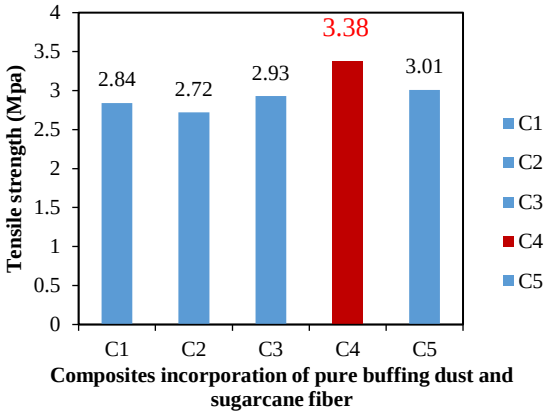

Fig 3: Tensile strength test for different ratio of BF and SF

4.3 Percentage of elongation

Table 1 highlights the percentage of elongation for materials reinforced with sugarcane fiber and pure buffing dust. Buffing dust is seen to impart 32.48% elongation at the early stage, and Ugbaja et al. [9] also mentioned this proportion for materials of this type. During the studies, the elongation percentage increased modestly with each addition of sugarcane fiber but significantly declined at 10% SF content. This can be attributed to the possibility that more fiber ends during composites loading could initiate cracks quickly [10]. Therefore, taking this into account, the ideal range was determined to be 95% buffing dust and 5% SF.

4.4 Hardness test

Table 1 in this study shows the hardness of composite materials that are pure or mixed. The initial hardness of the buffing dust in this instance was 69.67 Pascal, which is very comparable to the findings of Moses et al [11] 's research. Due to the higher modulus and stiffness of the fibers, the steady addition of SF initially increased the composite hardness while simultaneously lowering it when the fiber % was greater than 5. Due to the decreased dispersion and increased aggregation of integrated fibers, this may suggest inadequate fiber-matrix boning [12]. As a consequence, the ideal ratio was determined to be 95% buffing dust and 5% SF.

4.5 Density test

A density test was carried out and represented in Table 1. From the table, it is clear that the density of composites is slowly increasing with the increment of fiber percentage. The same phenomena were also mentioned by Mulinari et al. [13], where sugarcane fiber was used as reinforcement. So due to the slow development of density in terms of experimental values, 95% buffing dust with 5% SF was considered as the optimum level to minimize additional fiber consumption.

Table 2 makes it evident that using leather fiber reinforced with natural plant fiber results in a composite with a better tensile strength than using leather fiber alone at lower percentages. More cellulose in plant fibers may be directly responsible for the strength of composite materials. However, a decrease in cellulose % results in a decrease in the strength of composite materials that have been manufactured [14]. Additionally the composite's ultimate tensile strength is being strengthened by the consistent networking of natural fiber and collagen. Due to the high availability of collagen, a considerable portion of the composite in our experiment contains buffing dust, which is the cause of the experiment's greatest elongation percentage (approximately 39.34).

Table 1: Mechanical properties of buffing dust and composites

Sample (MPa)	Tensile strength	% of Elongation	Hardness (Pascal)	Density (g/cm^3)
C1	2.84	32.48	69.67	.685
C2	2.72	28.6	57.67	.694
C3	2.93	38.15	68.33	.653
C4	3.38	39.34	76.33	.770
C5	3.01	36.76	71.46	.694

4.6 Water absorption test

In this test technique, the mass of a certain sample is determined, then the sample is wet at a conditioning temperature, after which the mass is computed again, and lastly the sample is maintained dry. The water absorption value of the alkali-treated composite material was greatest. It is observed that superior water absorption characteristics seem to be null in nature in wet reinforced SF of ratio 95:05 .The result is shown by Fig 4.

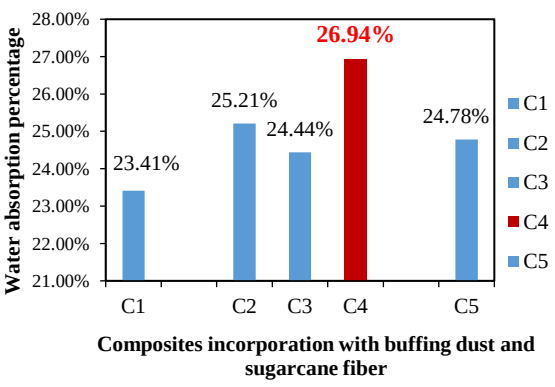

Fig 4: Water absorption percentage of BF and SF composite

Table 2: Comparison of mechanical properties of various composite materials

Name of the composites	Tensile strength (MPa)	% of Elongation	Hardness (Pascal)	Density	References
Composite from buffing dust and Sugarcane fiber (95:5)	3.38	39.34	76.33	.770	-
Buffing dust with natural rubber with (90:10)	6.80	21.00	-	-	[9]
Dyed trimmings with jute fiber (50:50)	52.67	13.89	-	0.698	[15]
Finished leather fiber with coconut fiber (50:40)	5.88 ± 0.09	5.62 ± 0.07	-	-	[16]
Finished leather fiber with sisal fiber (60:40)	9.08 ± 0.91	7.73 ± 1.34	-	-	[17]
Finished waste leather fiber with enset fiber (80:20)	2.78 ± 0.24	19.12 ± 2.07	-	-	[18]

4.7 Whole sole flexing endurance test

The aim of this method is to evaluate the resistance of materials to cut growth during repeated flexing. International Standard: ISO-17707, SATRA TM 161 is used for measuring the value. The specimen was pierced at three points at equal distance with a two mm width along the flexing line of the composite material where the maximum bonding stress required. The sample was inserted in the clamps. The motor wheel was turned by hand until the composite was extended repeatedly flex the sole with a flexing cycle at a rate of 140 flexes minutes with 90 bending action and 1000cycles split. Then the sample inspected and checked. The process was carried out for 10000, 20000, 30000, 40000, 50000, 600000, 70000, 800000, 1000000 cycles. The result is shown in table 3:

4.8 Bally Flexometer Test

The test specimen is folded in half then one end is secured in a clamp. The test specimen is then turned inside out and the free end secured in a second clamp at 90 degrees to the first. The first clamp is repeatedly oscillated through a fixed angle at a defined rate causing the test specimen to flex. At set intervals the number of flexing cycles is recorded and the damage to the test specimen is visually assessed. The test can be carried out with wet or dry test specimens and at ambient or sub-zero temperatures. Operate the flexing machine at a rate of 100 ± 5 flexing cycles/minute. Test result is shown in table 3.

4.9 Ross Flex Tester Test

The Ross rubber flexing machine (as per ASTM D 1424 & DIN 53862) is designed to determine resistance of vulcanized or synthetic elastomers to cut growth. It conforms to ASTM method D 1052, as well as ISO 4643. This model

can test 12 samples simultaneously. Digital preset table counter for memory cycles. The result is shown in table 3.

Table 3: Physical propertiesof buffing dust and composites

Characteristics	**C1**	**C2**	**C3**	**C4**	**C5**
Whole sole flexing endurance test	1mm crack after 75000 cycles	1mm crack after 75000 cycles	2mm crack after 75000 cycles	1mm crack after 1000000 cycles	2mm crack after 75000 cycles
Bally Flexometer Test	Slight crackin g after 75000 cycles	Slight crackin g after 75000 cycles	Severe crackin g after 100000 cycles	Slight crackin g after 100000 cycles	Severe cracki ng after 10000 00 cycles
Ross Flex Tester Test	1mm crack after 75000 cycles	2mm crack after 75000 cycles	1mm crack after 75000 cycles	1mm crack after 85000 cycles	2mm crack after 75000 cycles

5. Conclusions

To verify chemical bonding, eco-friendly and high-performance composites were pre-pared and evaluated by FTIR. The mechanical stability of the created composites was then verified through additional physical examination. Compared to pure buffing sheet, composite made of extracted sugarcane and included buffing had superior thermal stability.

Three different composites were created and analyzed by FTIR to validate chemical bonding, heat stability, and the respective. Once they had been completely created, the composites were gathered for mechanical and chemical characterization testing. The physical and mechanical properties such as tensile strength, elongation, hardness, water absorption and density of prepared composites with optimum NRL content were augmented by 19, 21, 10, 15 and 21%, respectively, to compare with pure buffing dust sheets. A comparison was done in each test by assessing the test data to identify which composite provided the most superior attribute. A comparison between this research and a prior research study was also made. So, based on this research and explanation, it can be concluded that the newly produced biodegradable composite may be utilized commercially at a cheap cost as a packaging material and for interior design.

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