

LEATHER BUFFING DUST IN COMPOSITE FABRICATION: SOLID WASTE MANAGEMENT IN TANNERY

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ABSTRACT

In process produced waste is an inevitable burden for the leather industry. Solid waste management has become a big challenge to survive in the leather industry. Earlier in leather finishing, both sides of crust leather grain/flesh are buffed to obtain an even thickness and the surface feels. In buffering, micro-fined collagenous fibres are produced which are comprised of heavy metal (chromium), tanning agents, synthetic oil, and colouring substances. Buffering dust is an airborne pollutant that harms the environment. In this study, a composite was fabricated from the leather-buffering dust incorporating various chemicals. The batch-wise composite sheet was prepared by mixing the required amount of buffering, wheat flour, binder, etc., and poured in a 210×297 mm wooden frame. The sheet was sun-dried and finally oven-dried. The fabricated composite was assessed for tensile strength, elongation at break, Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FTIR) Spectroscopy. The tensile strength and percentage elongation at break of the fabricated composite were 2.95MPa and 109, respectively. The SEM shows an even distribution of buffering dust in the binding material without structural deterioration. The TGA data implies that composite was more stable than buffering dust and sustained up to temperature 300°C. Fabrication of buffering dust-incorporated composite is a way to manage solid waste in a tannery that could be used as insole and lining materials in the footwear products industry.

Keywords: *Buffing dust, Wheat flour, Binder, Composite, Tensile strength.*

1. INTRODUCTION

Putrescible animal hide/skin is converted into imputrescible leather by different chemical and mechanical operations which generates a huge amount of solid waste (Kilic et al., 2020). These solid wastes can be divided into three categories-untanned collagen waste, tanned collagen waste and non-protein solid waste. Among them, tanned collagen waste covers the major part including shaving dust, buffering dust and trimmings which poses a serious environmental impact (Sivakumar et al., 2015). It is reported that approximately 200kg of leather and 600kg of solid waste is produced during converting 1 ton of wet salted hide/skin into the leather (Senthil et al., 2015). A huge amount of solid waste is generated from a tannery in the form of keratinous waste, skin trimmings and chrome shaving and buffering waste. The main components of this waste are protein and if these chemically treated proteins are not utilized properly it will create a serious impact on the environment (Kanagaraj et al., 2006).

According to the estimated report, for processing of 1 ton of hide/skin generally, 2-6 kg of buffering dust particle is produced. Buffering dust is a kind of fine particle-containing chromium, oil and fat, dye,

etc. (Swarnalatha et al., 2008). These micro-fined particles have carcinogenic characteristics and cause serious health issues like cancer, ulcers, kidney disease etc. (Sethuraman et al., 2013). Leather solid wastes are generally disposed of either by incineration, anaerobic digestion or landfill and also reported that both pyrolysis incineration and bioremediation are effective for buffering dust disposal (Senthil et al., 2015). Landfill of these solid waste cause soil pollution and incineration causes the emission of poisonous gases like sulfur oxide, nitrogen oxides, etc. in the air causing air pollution (Karak et al., 2012).

Researchers are trying to focus on new methods to dispose of leather solid waste. Buffering dust was used for the production of activated charcoal with greater adsorption capacity than ordinary charcoal produced from wood (Sekaran et al., 1998). Buffering dust was utilized as filler for rubbers like butadiene acrylonitrile and carboxylated butadiene acrylonitrile rubber which increased mechanical properties, electric conductivity, thermal ageing, etc. (Chronsk & Przepiorkowska, 2008). Chrome shaving dust and buffering dust (1:1) combined with zinc oxide was used as filler for nitrile rubbers which increases strength properties and thermal ageing (Chronsk & Olszewska & Przepiorkowska, 2011). Wet-blue chrome shavings and buffering dust with sawdust was used to prepare thermal insulator materials for building and reported that the thermal conductivity of prepared composite was higher than other insulators (Lakrafi et al., 2013). Finished leather waste in combination with plant fibres was used to prepare composite materials with better tensile strength (Teklay et al., 2018). Activated carbon an adsorbent material was prepared from chrome-tanned leather waste for dye adsorption in solution (Yilmaz et al., 2007). Dyed trimmings with natural fibre are used to produce flexible composite sheet material with improved mechanical strength and thermal properties compared to leather (Saikia et al., 2017). Bricks were produced from buffering dust and clay where 5% filling material was recommended for the brick production so that strength properties can be maintained properly (Bitlisli & Karacaki, 2006).

In this study, an attempt was initiated to prepare a composite sheet from leather buffering dust and wheat flour. This research aims to convert hazardous chrome containing buffering dust into a useful bi-product, which ultimately reduces environmental pollution. Composite sheets were prepared by mixing buffering dust, wheat flour, glycerin, Busan 30L, latex adhesive and fish oil. The prepared composite sheet was characterized for its mechanical properties like tensile strength, percentage (%) of elongation at break etc., and physicochemical properties like Thermogravimetric Analysis (TGA), Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FTIR) spectroscopy.

2. METHODOLOGY

2.1 Materials

Leather buffering dust was collected from SAF Leather Industries Ltd., Noapara, Jashore, Bangladesh. Wheat flour was collected from a nearby local market, Fulbarigate, Khulna, Bangladesh. Analytical grade chemicals were used in this research and all these chemicals were purchased from a local scientific store, Khulna, Bangladesh.

2.2 Preparation of composite sheet

2.2.1 Moisture count in buffering dust

Water content in the buffering dust was determined by following the standard method (ASTM D 2216). About 3g buffering dust was taken. Samples were weighted in analytical balance and then kept in a drying oven at $105\pm1^{\circ}\text{C}$ for 24 hours. After drying for 24 hours, samples were cooled in a desiccator and the final weight of samples were taken. Finally, the moisture content of the samples was calculated by a standard formula. For accurate data, each experiment was done three times.

2.2.2 Wheat flour optimization

Four samples were prepared for optimizing the dose of wheat flour in composite formation. Each sample contained 25g of buffering dust, 3g of glycerin, 7g of fish oil, 1g of Busan 30L (preservative) but the amount of wheat flour were varied for each sample such as 5, 10, 15 and 20g. For binding 60g of latex was added to each sample and made a paste. Finally, a composite sheet was made. Firstly the sheet was sun-dried then dried in an oven at $105\pm1^{\circ}\text{C}$ for about 48 hours. The fabricated sheets were analyzed for tensile strength and percentage (%) of elongation to optimize the dose of wheat flour in composite preparation.

2.2.3 Adhesive optimization

Six samples were made for the optimization of adhesive dose in composite preparation. Each sample was contained 25g of buffering dust, 15g of wheat flour, 3g of glycerin, 7g of fish oil and 1g of Busan 30L. Adhesive doses were varied- 40, 50, 60, 70, 80 and 90g. The ingredients were mixed to make a paste and a composite sheet was made. Firstly, the sheet was sun-dried and finally, oven-dried at $105\pm1^{\circ}\text{C}$ for about 48 hours. Prepared sheets were analyzed for tensile strength and percentage (%) of elongation to compare strength properties and optimize the dose of adhesive in the composite.

2.2.4 pH optimization

Four samples were made containing 25g of buffering dust, 60g of adhesive, 15g of wheat flour, 3g of glycerin, 7g of fish oil and 1g of Busan 30L. pH was maintained by adding sulfuric acid 8.2, 8.7, 9.2 and 9.7 for each sample. Ingredients for each sample were mixed homogenously and made paste. A sheet was formed and which was sun-dried at first then finally oven-dried at $105\pm1^{\circ}\text{C}$ for about 48 hours. Then the prepared sheet was assessed for tensile strength and percentage (%) of elongation to compare strength properties between prepared composite and to optimize the pH.

2.3 Assessment of mechanical properties of composite sheet

For mechanical properties determination, samples were prepared by following the standard procedure (ISO 3376:2011). Tests were carried out at temperature $20 \pm 2^{\circ}\text{C}$ and relative humidity $65 \pm 2\%$ for 48 h. For accuracy, each test was done three times.

2.4 Physicochemical characterization of composite sheet

FTIR was done to determine the change and formations of functional groups in the prepared composites. FTIR analysis was done in the spectral range between 500-4000 cm^{-1} at 4 cm^{-1} resolution by using Nicolet 6700 Spectrophotometer (Thermo Scientific, USA). TGA was performed to check the thermal stability of the prepared composites. Analysis was carried out using High Resolution 2950 TGA Thermogravimetric Analyzer. For TGA, samples between 10-20mg weight were kept in platinum-plated with a programmed temperature range at 0-800°C with a heating rate of 5°C/min under nitrogen atmosphere with a flow rate of 50 mL/min. The surface morphology of the prepared composite was visualized by scanning electron microscope using SEM Model LEICA Stereo Scan 440.

3. RESULTS AND DISCUSSION

3.1 Moistness count in buffering dust

Moisture content was checked to determine the amount of water content present in the buffering dust. Because too much moisture poses a risk of fungus attack in the composite. To ensure antifungal activity Busan 30L was used in each composite formation. According to data, the moisture content in samples 1, 2, 3 were 9.667, 9.625 and 9.449%, respectively. There was an almost similar amount of moisture present in all three samples. As the water content in buffering dust was very lower, it helps against fungal attacks.

3.2 Wheat flour optimization

For wheat flour optimization, four samples were prepared and their recipe of formation and associated strength properties are shown in Figure 1. Four samples were prepared by using 25g of buffing dust, 3g of glycerin, 7g of fish oil, 1g of Busan 30L but the amount of wheat flour were varied for each sample- 5, 10, 15 and 20g. For binding 60g of latex, adhesive was added to each sample. Figure 1 shows that for 5g of wheat flour tensile strength and percentage (%) of elongation were 0.69 MPa and 87. When wheat flour amount was increased to 10g tensile strength and percentage (%) of elongation were increased 0.87MPa and 90, accordingly. For 15g of wheat flour, tensile strength and percentage (%) of elongation both were increased 2.95MPa and 109, individually. During 20g of wheat flour, tensile strength and percentage (%) of elongation both were decreased 1.59MPa and 107, respectively. Tensile strength and percentage (%) of elongation values were decreased because a higher amount of wheat flour can not form a bond with adhesive and buffing dust in the composite as a result strength values were decreased.

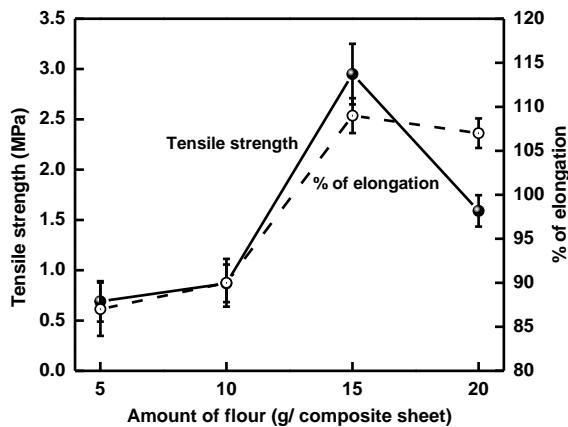


Figure 1: Wheat flour optimization for the composite sheet

3.3 Adhesive optimization

For adhesive optimization, six samples were prepared and their ratio and associated strength properties were shown in Table 1. Six samples were prepared using 25g of buffing dust, 15g of wheat flour, 3g of glycerin, 7g of fish oil and 1g of Busan 30L. Adhesive doses were varied like 40, 50, 60, 70, 80 and 90g for six composites. Table 1 shows that tensile strength and percentage (%) of elongation values for 40, 50, 60, 70, 80 and 90g adhesive were 1.11MPa & 87, 1.42MPa and 97, 2.95MPa and 109, 2.35MPa and 114, 2.25MPa and 119, 1.64MPa and 96, respectively. Tensile strength and percentage (%) of elongation values were increased up to 60g of adhesive dose then values were decreased for further variation because if binder content is too high there is no sufficient reinforcement material to create a polymeric bond with the excess binder matrix which results in lower physical strength.

Table 1: Adhesive dose optimization for the composite sheet

Amount of adhesive (g)	Tensile strength	
	(MPa)	% of elongation
40	1.11±0.063	87±3.055
50	1.42±0.115	97±3.055
60	2.95±0.699	109±7.023
70	2.35±0.246	114±6.110
80	2.25±0.760	119±5.033
90	1.64±0.165	96±4.000

3.4 Optimization of pH

pH optimization was done by preparing four composites, composite recipe and associated strength properties are shown in Figure 2. Four samples were prepared using 25g of buffering dust, 60g of adhesive, 15g of wheat flour, 3g of glycerin, 7g of fish oil and 1g of Busan 30L and pH values were 8.2, 8.7, 9.2 and 9.7 for each sample. Figure 2 indicates that at pH 8.2 tensile strength and percentage (%) of elongation were 2.34MPa and 106. As the pH increases to 8.7 tensile strength and percentage (%) of elongation values, 2.95MPa and 109 were also increased. For pH 9.2 tensile strength and percentage (%) of elongation, both values 2.27MPa and 119 were decreased. On the other hand, at pH 9.7 tensile strength was increased but the percentage (%) of elongation was decreased.

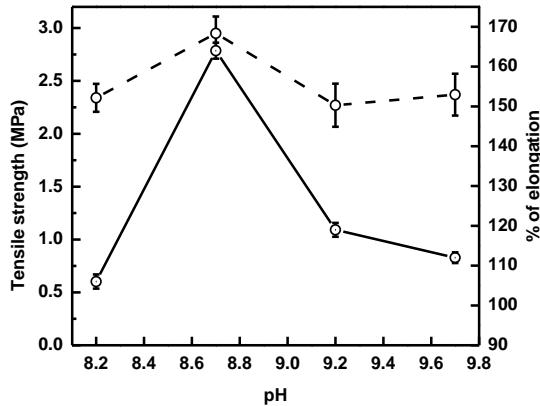


Figure 2: pH optimization for the composite sheet

3.5 Optimized mechanical properties and application of composite sheet

Analyzing optimized factors such as dose of wheat flour, adhesive and pH, different mechanical properties were obtained. A combination of 25g of buffering dust, 15g of wheat flour, 60g of natural rubber latex binder, 3g of glycerin, 7g of fish oil and 1g of Busan 30L exhibited greater mechanical properties. An artificial grain finish was applied on the surface of the prepared composite. The finished composite was smooth on surface feel (Figure 3), light-weight, flexible and elastic in nature. An increase in natural rubber latex amount significantly increases tensile strength and elongation properties which incorporates elastic nature in the composite and reduces brittleness. Tensile strength and percentage (%) of elongation at break for finished composite maintaining optimal factors were 2.95MPa and 109, respectively. Results indicate that comparative physical properties such as tensile strength were almost similar but elongation at break was increased for a higher amount of latex dose than previous studies shown in Table 2 and it is suitable for making insole and lining materials for the footwear products industry.

Table 2: Mechanical properties of the fabricated composite

Parameters	This study	Senthil et al., 2015
Tensile strength, (MPa)	2.95±0.699	4.19±0.44
Elongation at break (%)	109±7.023	3.99±0.81



Figure 3: The finished surface of the prepared composite

3.6 FTIR analysis

In the FTIR analysis (Table 3), a band stretching was observed at 2900 cm⁻¹ attributed to the vibration of the –CH bond (Swarnalatha et al., 2008). Aromatic –CH bending vibration was identified at 1186 cm⁻¹, and a –CO stretch vibration was observed at 1052 cm⁻¹. The intense bands around 1643 cm⁻¹ and 1540 cm⁻¹ were attributed to the C-O stretching vibration and N-H bending vibration of protein particles (Prochon et al., 2020). A band at 1370–1380 cm⁻¹ was observed which could be due to phenolic extending vibration of –OH and aliphatic –CH misshapen in methyl groups of latex. The exceptional stretching at the top around 852 cm⁻¹ was for vibration of the Cr(III) species (Swarnalatha et al., 2008).

Table 3: FTIR analysis of the prepared composite sheet

Serial no.	Wavelength (cm ⁻¹)	Functional groups
1.	852	Cr (III)
2.	1052	-CO
3.	1186	Aromatic -CH
4.	1370-1380	-OH and aliphatic - CH
5.	1540	N-H
6.	1643	C-O
7.	2900	-CH

3.7 TGA analysis

TGA was performed to check the thermal stability of raw buffering dust and the fabricated composite. Figure 4 (a) & (b) depicts the thermal stability of raw buffering dust and fabricated composite. For buffering dust, initial weight loss was observed around 110°C and for the composite was around 160°C. This weight loss could be due to the moisture present in the buffering dust and composite (Senthil et al., 2015). Next weight loss was observed around 130-270°C for buffering dust and around 180-290°C for prepared composite. This weight loss happened because organic compounds present in buffering dust and composite such as tannin substances, fatty matter and proteins were broken down into intermediate compounds (Islam et al., 2021). On the other hand, natural rubber latex showed thermal degradation between 200-440°C (He et al., 2013). The net weight of remaining buffering dust and composite was 22.58% and 25.08% that means complete degradation above temperature 300°C.

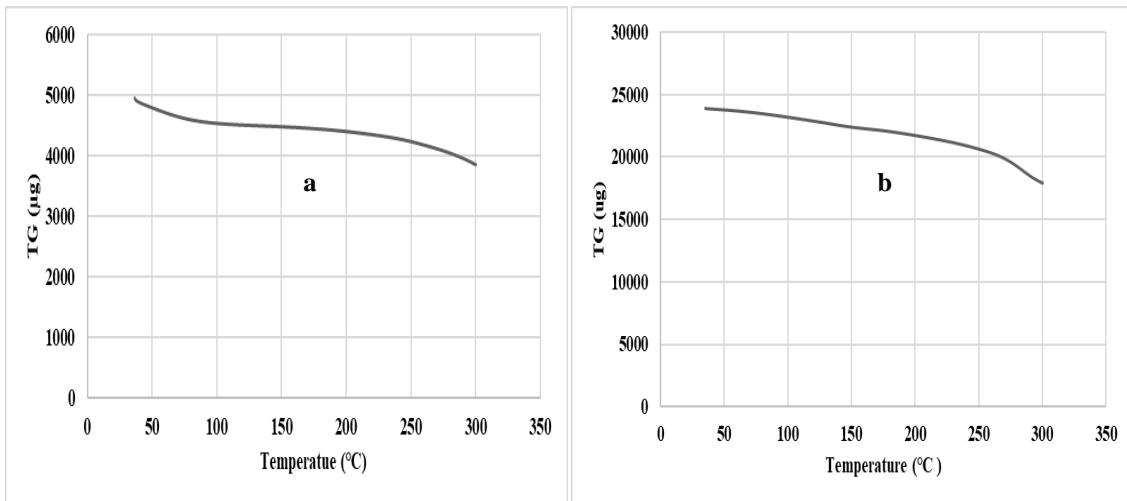


Figure 4: TGA analysis of buffering dust (a) and fabricated composite (b)

3.8 SEM analysis

SEM image of the fabricated composite is depicted in Figure 5. SEM analysis manifests that composite preparation did not alter the fibre orientation of buffering dust. The figure showed that the fine granular buffering dust particles are uniformly dispersed in the latex matrix. Latex properly binds with the particles and showed better bonding strength and associated functional properties.

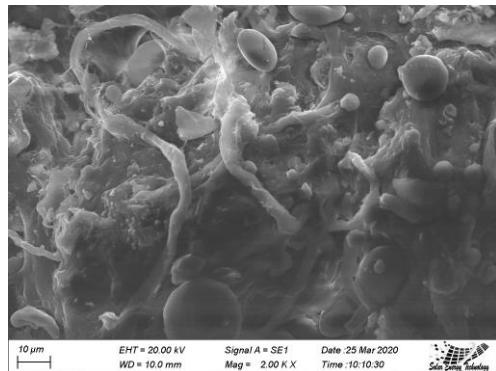


Figure 5: SEM image of the fabricated composite material

4. CONCLUSIONS

This research investigates that there is a potential of preparing composite sheets from buffering dust and wheat flour using natural rubber latex binder. Among all the optimization process, 25g of buffering dust, 15g of wheat flour, 60g of natural rubber latex binder, 3g of glycerin, 7g of fish oil and 1g of Busan 30L showed the best physical properties with smooth surface feel. This prepared composite can be used as insole and lining materials in the footwear industry, leather products industry and various household applications. The composite sheet is prepared from hazardous chrome containing leather buffering dust into a useful byproduct which ultimately reduces environmental pollution. The fabrication process was cost-effective and easy due to the availability of raw materials and low cost. This proposed method could reduce environmental pollution and produce a valuable byproduct. It could be a viable option for leather solid waste management.

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