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Conversion of finished leather waste incorporated with plant fibers into value added consumer products – An effort to minimize solid waste in Ethiopia

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Presently, the leftovers from leather product industries are discarded as waste in Ethiopia. The objective of the present study was therefore, to prepare composite sheets by incorporating various plant fibers like enset (*Ensete ventricosum*), hibiscus (*Hibiscus cannabinus*), jute (*Corchorus trilocularis* L.), palm (*Phoenix dactylifera*) and sisal (*Agave sisal*) in various proportions into the leather waste. Resin binder (RB) and natural rubber latex (NRL) were used as binding agents for the preparation of the composite sheets.

The composite sheets prepared were characterized for their physicochemical properties (tensile strength, elongation at break, stitch tear strength, water absorption, water desorption and flexing strength). Composite sheets prepared using RB having 10% hibiscus, 20% palm and 40% sisal fibers showed better mechanical properties than their respective controls. In composite sheets prepared using NRL having 30% jute fiber exhibited better mechanical properties than its control. Most of the plant fibers used in this study played a role in increasing the performance of the sheets. However, as seen from the results, the contribution of these plant fibers on performance of the composite sheets prepared is dependent on the ratio used and the nature of binder. The SEM studies have exhibited the composite nature of the sheets and FTIR studies have shown the functional groups of collagen protein, cellulose and binders. The prepared sheets were used as raw materials for preparation of items like stiff hand bags, ladies' purse, keychain, chappal upper, wallet, wall cover, mouse pad and other interior decorating products. By preparing such value added products, we can reduce solid waste; minimize environmental pollution and thereby securing environmental sustainability.

1. Introduction

Africa's livestock population represents over 14%, 20% and 28% of the global cattle, sheep and goats population respectively and with the estimate of 220 million cattle heads, 214 million sheep and 257 million goats flock (FAO, 2013). Ethiopia, one of the east African Countries, is blessed for having diverse agro ecology that made it suitable to be the home for many livestock species. The livestock population of the country according to the estimates of (FAO, 2015) is 55.694 million bovine; 26.537 million sheep and 25.035 million goats. This fact made Ethiopia to rank 1st in Africa and 10th in the world in its livestock population (EFDRE, 2015). The huge livestock resource according to John (2007) is basis for the development of a vibrant leather and leather products industry in the country.

Tanning, a series of collagen stabilizing processes by the tanning agents, such that the skin/hide is no longer susceptible to putrefaction or rotting (HMIP, 1995), is an age long art which has transcended generations (Thosmason, 1985). The leather industry generally uses hides and skins as raw materials, which are the by-products of meat and meat products industry. In this respect, the leather industry could have easily been distinguished as an environmentally friendly industry, since it processes waste products from meat production (Lang et al., 1999). However, the leather industry has commonly been associated with high pollution due to the bad smell, organic wastes and high water consumption caused during manufacturing processes (Taylor et al., 1998).

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Different forms of biological wastes emerge during the transformation of hides and skins into leathers, in the leather industries all around the world; have negative impacts on the environment (Ozgunay et al., 2007). From one ton of wet-salted hide, only about 200 kg is converted into finished leather and the rest is discarded as waste (Lang et al., 1999).

Recently, due to the increase in population and very high competition on resource; natural resources are being exploited substantially as an alternative to synthetic materials. For this reason, utilization of natural fibers for the reinforcement of the composites has been receiving increasing attention. Natural fibers have many remarkable advantages over synthetic fibers. Nowadays, various types of natural fibers (Taj et al., 2007) have been investigated for use in composites including flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm, sisal, coir, water hyacinth, pennywort, kapok, paper mulberry, banana fiber, pineapple leaf fiber and papyrus (Wikipedia, home page, 2010). Composites are a versatile and valuable family of materials that can solve problems of different applications. They facilitate the introduction of new properties in the materials. Recycling and renewing natural resources are giving a new dimension in discovering new materials (Khan et al., 2010).

Nowadays alternative options for utilizing tannery solid wastes are taking worldwide significance for preparation of different products, among which is crust leather trimmings/finished leather scraps used for making leather boards and production of bricks (Zhang et al., 2006).

The objective of the present work therefore, is to prepare leather composite sheets, from finished leather scrap, in combination with plant fibers of enset, hibiscus, jute, palm and sisal using **r**esin binder (RB) and natural rubber latex (NRL).

2. Materials and methods

2.1. Materials

Finished leather scraps were collected from ELICO (Ethiopian Leather Industry Corporation). Texbinder LS was purchased from Textan Co. India. Natural rubber latex, Polyethylene glycol and Al_2 (SO_4) were purchased from Sastha PLC Chennai India. Plant fibers such as Jute (*Corchorus trilocularis* L.), Hibiscus (*Hibiscus Cannabinus*), and Palm (*Phoenix dactylifera*) were collected from Chennai and Andhra Pradesh, India. The fibers of sisal (*Agave sisalana*) and Enset or Ethiopian banana (*Ensete ventricosum*) were collected from Ethiopia and other chemicals used in this study were of laboratory grade chemicals.

2.2. Methods

Preparation of leather fiber (LF) and plant fibers (PFs):

Finished leather scrap was cut into small pieces of convenient size to use in the pulverizing machine (length 5–10 cm and width 2–3 cm) using Swing ARM Clicker (Porielli S. 20, VIGEVANO-ITALIA) and converted into leather fiber (LF) with the help of Hinged Hammer Pulverizing machine (Sturtevant, SDL868, USA). Similarly, all long uneven plant fibers were cut into small pieces to convert them into smooth and short fibers. The average fiber size ranged between 1.5 and 2.5 cm in length and 0.2–0.7 mm in width according to the procedure of Satyanarayana et al. (1990).

2.3. Optimization of binders

Leather sheets (LS) were prepared using leather fiber and two different binders namely resin binder (RB) and natural rubber latex (NRL) at different levels of (30, 60, 90, 120 and 150 ml) and tested for their tensile strength to take the optimum result as reference for the binders.

2.4. Preparation of NRL leather sheets (NRL-LS)

About 130 g of fiberized leather fiber was soaked in 1000 ml of water for 12 h, minced in the food mincing machine (La Minerva C/E 680 N) (three times minced to reduce the particle size) and made into fine paste. To this paste 120 ml of NRL, 10 ml of PEG and 4% of Al_2 $(SO_4)_3$ was added and mixed thoroughly. Later, 10 ml of 1:3 ratio diluted H_2SO_4 is added and pH adjusted to below 5 by thorough mixing, the mixture was diluted using 4000 ml water so that slurry was formed. Then the sample was poured into the sheet making machine of (30 cm × 30 cm) and wet sheet was pressed using hydraulic press (polyhydron 4DL10SGS-10) at a pressure of 217.5 kPa for 10 s. The pressed sheet was air dried and plated using hydraulic press at a pressure of 13,789 kPa at 80 °C for 10 s.

2.5. Preparation of RB leather sheet

The process was same as above (NRL-LS preparation) the change is only binder, instead of NRL, RB was used.

2.6. Preparation of plant fiber incorporated leather composite sheets

To the prepared LF, already extracted and fiberized PFs were added individually in the proportions of 10%, 20%, 30% and 40%, mixed with the LF, and then fiberized in the fiberizer machine (SDL868, USA). Composite sheets containing LF and different species of PFs were then prepared separately following the same procedure as that of control sheet. The details of the composite sheets prepared are noted as follows:

1. Composite sheets made from finished leather scraps and binders served as a control.
2. Composite sheet made from finished leather scraps (FLS) and enset fiber labeled as FLS-E
3. Composite sheet made from finished leather scraps (FLS) and hibiscus fiber labeled FLS-H
4. Composite sheet made from finished leather scraps (FLS) and jute fiber labeled FLS-J
5. Composite sheet made from finished leather scraps (FLS) and palm fiber labeled FLS-P
6. Composite sheet made from finished leather scraps (FLS) and sisal fiber labeled FLS-S

2.7. Characterization of control and composite sheets

Finished leather scraps (FLS) and composite sheets (CSs) were characterized for their physicochemical properties such as mechanical studies, thermal stability, formation and changes in the functional groups (FT-IR) and surface morphology.

2.7.1. Mechanical properties

Mechanical properties were assessed using three dumbbell shaped specimens of 4 mm wide and 10 mm length. Tensile strength (MPa), elongation at break (%) and stitch tear strength (N/mm) were measured using Universal Testing Machine (INSTRON model 3369) at an extension rate of 5 mm/min. Water absorption and desorption (%) capacities of the different control leather and composite sheets were determined according to Sekar et al. (2007). Flexing endurance was also assessed using SATRA fiber board flexing (TER 74) machine according to (STM 129) test method.