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Final research report on
LEATHER BOARD PRODUCTION FROM LEATHER SHAVINGS

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Abstract

Leather product industries produce a large amount of scraps and dumped to environments. Scrap leathers can be changed to value added product. Here, we report simple method of developing leather board from leather shaving. Initially the leather shaving was characterized for its Moisture content (56.34%), Crude fat content (4.12%), Crude fiber content (2.53%), Total nitrogen content (7.37%), Sulfide content (72.71 mg/kg), pH (3.34), Chromium content (4268.06 mg/kg) and Water-soluble matter (4.06 Brix). From the result, the leather shaving contained considerable amount of chromium which is known to cause various environmental and health effects. The effect of rubber latex concentration (250 ml, 300 ml, 350 ml, 400 ml and 450 ml) on the mechanical properties of the leather board is studied. 350 ml rubber latex concentration results in a better mechanical property of Tensile strength (1.8 N/mm^2), Percentage elongation (6.8%), Tear strength (13.35 N/mm) and Water absorption (46.9%). All the measurements revealed that developed leather board could find a potential application in the manufacture of leather goods and footwear.

Key words: Chromium; Environment; Leather shaving; Leather board; Mechanical properties; Value added

1. Introduction

1.1 Background

Ethiopia has the largest livestock population in Africa with 27 million heads of cattle, 24 million sheep, and 17 million goats. The animal resource has encouraged the establishment of tannery industries in Ethiopia. At present there are 26 tanneries in Ethiopia where most are privately owned. Since almost all of them have no satisfactory treatment process, the environment is under extreme pressure from solid and liquid wastes of leather manufacturing and this has created significant pollution problem (Kebede F. et.al, 2009).

Solid wastes create a major problem for leather industry in terms of both their variety and quantity. A high amount of reusable waste is generated in the leather industry. It is possible to recycle these products and even use them as raw materials for different industries. The variety and quantity of solid wastes depends on animal species, breeding conditions, slaughterhouse practices, conservation conditions, leather process stages, mechanical operations, qualification of the personnel, and chemicals used in processes. Yet this fact causes uncertainties in reusing the generated wastes (Colak S. et.al, 2005)

Solid waste is produced during the manufacture of leather; waste such as cuttings, leather dust and shavings. To reduce or correct the thickness of leather, the material is usually shaved with knife rolls, normally after the chrome tannage. These shavings can be treated with a latex and possibly further tanning agents on a paper making machine to produce leather board (K. Kolomaznik et.al, 2003).

Leather board is a type of fiber board having a portion as tanned or untanned leather or collagen fiber. It is a material which can be used as a lining material in shoes or trunks or for bookbinding. It is mostly used by footwear and travel goods industry. Board of proper grade and quality used as various footwear components are expected to function properly in wear provided the footwear is correctly designed and constructed and the substances of the boards are adequate (Karabay S., 2008).

1.2 Statement of the Problem

Tanning operations involved in the transformation of hides into leather generate both liquid and solid pollution loads at various processing stages. The processing of one metric ton of raw hide provides 200 kg of a leather-final product, along with 250 kg of non-tanned waste, 200 kg of tanned waste, and 50,000 kg of wastewater. Thus, only 20% of the raw material weight is converted to leather (K. Kolomaznik et.al, 2003). Though Ethiopia is resourceful in leather byproducts, it does not process to usable product.

Due to improper disposal of the solid waste from different production of leather processing, there is environmental pollution. This research will alleviate challenges regarding proper utilization of the byproducts. This not only the environment but also it improves the socio-economic interactions of the country.

Currently shoe manufacturers in Ethiopia imports insole made from leather board from abroad, this costs a lot of currencies for the country. This research is intended to maximize import substitute of leather board which has wide applications in different areas.

One goal of the growth and transformation plan of Ethiopia is improving the leather and leather product industry capacity. This will not be mate unless there is proper integration through production of leather and utilization of its byproducts obtained during production

1.3 Objectives

1.3.1 General objective

The general objective of this research was to manufacture better quality leather board from leather shavings.

1.3.2 Specific objectives

The specific objectives of this research were to:

- Characterize leather shaving from leather factory
- Study the effect of different concentrations of binding agent for the leather board making
- Characterize the leather board through mechanical properties

2 Literature Review

2.1 Leather Industry in the World

Leather is a globally acclaimed product and there is an ever-increasing demand for leather and its related products. The current trade value of the leather industry is estimated to be approximately US\$ 70 billion per year. The industry in total produces about 18 billion square feet of leather a year, with developing countries producing over 60% of the world's leather. About 65% of the world production of leather is estimated to go into leather footwear. Its major expansion has taken place in developing and newly industrialized countries rather than in developed economies. In developing and newly industrialized countries solid waste and wastewater treatments are not state of the art and labor intensive processes are involved in the conversion of hides and skins into leather. The United States, Germany, and other European countries remain major importers of leather products. Countries such as China, India, Thailand, and Indonesia dominate the export of leather and leather products (R. A. Ramanujam et al.,2009).

World population grew dramatically in the 20th century and it continues to grow at present. This growing population and the general increase in wealth have led to increases in the demand for meat, which in turn have kept the supply of leather raw material fairly constant. The current predictions are that the supply of leather raw material will continue to grow in step with population growth, but that higher costs and a decreasing availability of land for raising cattle and for growing grains to feed the cattle, as well as an increase in pork and poultry consumption in Asia and Africa, are now becoming apparent. At some stage, these developments may generate tighter traditional supplies and raise the importance of such non-mainstream sources of raw material as camel, kangaroo and deer (R. A. Ramanujam et al.,2009).

Leather raw materials have increasingly become available in the developing world, while in the developed countries, a declining per capita consumption of red meat has reduced the supply of hides and skins. Now, more than half of the world supply of leather raw material comes from the developing world and, increasingly, those countries with large supplies are seeking to process them through to finished leather articles (UNIDO, 2010)

2.2 Leather Industry in Ethiopia

According to a recent CSA publication on livestock resources, Ethiopia has 27 million cattle, 24 million sheep and 17 million goats (CSA, 2011). This puts the country as one of the richly endowed countries in livestock resources. It is estimated that the country can collect 3.7 million cattle hides, 8.4 million sheep skin and 7.7 million goat skin per year. The sheep skins are well known for their quality. The goat skins in particular are known for their quality and international acceptance. Both goat and sheep skins are preferred for leather garments and gloves manufacturing in addition to being used for shoe upper. The resource endowment of the country illustrates the considerable potential of the country in the leather industry (CSA, 2011).

Currently, there are 26 tannery industries in operation. The tanneries have 153,650 sheep and goat skin soaking capacity and 9,725 cowhides soaking capacity per day. Together they also employ 4577 persons. Ethiopia Tannery with 12,000 sheep and goat skin and 1,200 cows hide soaking capacity and Ethio-Leather (ELICO) with 15,500 sheep and goat skin and 1,050 cow hides soaking capacity are the two largest industries (UNIDO, 2012).

The Ethiopian tanning industry is made of both tanneries that have amortized their initial investment a long time ago and tanneries that are still in their early years. The first category benefits from large production capacity allowing them to run the plant with flexibility and quickly answer to surges in finished leather demand for instance, or buy large quantities of raw hides and skins when their price is at its lowest and process them quickly. While the second have to produce continuously at high rate in order to repay their initial debt and could be unable to answer to rising demand in finished leather. This sheds light on the fact that managing stocks efficiently could become crucial for the less flexible tanneries if the raw hides and skins' prices are too volatile (Zakaria Coppeaux et al.,2016).

2.3 Leather Manufacturing Processes

The leather processing stages can be categorized in to four main stages as follows (H. Ozgunay et al.,2007):

i. Beam house processes

Generally, the conventional conversion process of hides/skins to leather involves ‘do-undo’ operations. The conserved skins/hides are first subjected to a trimming process for removing the unwanted parts called skin/hide trimmings, and then they are soaked to restore the lost water due to the common salt applied during curing process and to remove substances like dirt, blood and conservation salt at alkaline condition (pH ranging from 9.5 to 10.5) using wetting agents, sodium carbonate or sodium hydroxide. This is called soaking process. After soaking process, the skins/hides are subjected to liming/un-hairing process which is treating the materials in alkaline (pH ranging from 12 to 13) solution of lime ($\text{Ca}(\text{OH})_2$) and sodium sulphide (Na_2S) to remove hair and swell up the skin/hide. After liming/un-hairing process the flesh and fat adhering to the hide/skin is removed by a mechanical process called fleshing process. Another mechanical operation called splitting after fleshing process is applied most of the time to cattle hides to split into two or three layers or to remove some unwanted layers of the hide. De-liming is chemical process performed to decrease the pH to 8.0 to 9.0 so that to remove the lime added during liming process and to make the hide/skin more receptive to the chemicals that will be used in further stages. After de-liming process, hides/skins are exposed to an enzymatic effect for both opening up the structures of hides/skins, and the removal of unwanted proteins by a process called bating. Following the bating process, a degreasing process is applied for removing the excess natural fat using aqueous emulsification with detergents, or solvent extraction. After degreasing process, the hides/skins are treated in a solution composed of salt and acids in acidic solution at an average pH of 2.5 so as to obtain a homogeneous distribution of tanning material that will be applied in the tanning process. This process is called pickling process and the product at this stage is named as pickle.

ii. Tanning processes

After the hides/skins are conditioned as above, the tanning process is applied with various tanning materials (materials able to form stable bonds with collagen) in order to provide the leather with a stable form and high thermal stability. Tanning materials such as vegetable tannins, mineral

tanning materials and syntans (synthetic organic tanning materials) are used in tannage. Among mineral tanning materials, chrome tanning is the most widely used in leather production due to the unique features chrome that it gives to the leather; thermal stability. Chrome tanning is carried out in acidic solution at a pH ranging from 2.5 to 3.0. Aluminium and vegetable tanning materials are also widely used in leather production. The product of chrome tanning process is called as wet blue because of its color.

iii. Re-tanning processes

At re-tanning stage, the wet blue hide/skin is changed to crust leather. In this stage, structural differences within wet blue leathers are compensated to obtain uniform structure. It involves the following chemical and mechanical operations:

- **Shaving:** is a mechanical process to even the hide thickness and permit greater precision than is possible by splitting.
- **Neutralizing:** is removal process of the free acid present in the leather, to assure stability in heated conditions and resistant to boiling.
- **Re-tanning:** is a process to give the material the required uniform fullness and ability to retain their consistency after the drying process that tend to flatten the hides and reduce their thickness. This is carried out at a pH ranging from 3.5 to 5.0.
- **Fat liquoring:** is done to lubricate the dermic fibers to avoid gluing and to provide the finished article with fullness and softness.
- **Dyeing:** is a process of giving the required color characteristics. A good dyeing has good color uniformity, maximum color depth with the least amount of dye possible, good defect cover and high color and light fastness.
- **Setting out:** is a process of pressing the leather to reduce the residual moisture in the hide from 100% to 65-70%. It also helps the hide to be widened and the grain to be flattened.
- **Drying:** is an operation to reduce the moisture content from 70% to 20-22%. It is performed in the company through Vacuum drying, toggle frames, or overhead chain. After this stage, it is called as crust leather and prepared for finishing processes.

iv. Finishing processes

Finishing operation is the mechanical modifications on the appearance of the leather such as elasticity, softness and feels by applying an aesthetic covering polymeric film to the derma.

Finishing operation involves surface coatings and mechanical operations. Some of the finishing processes are given as follows:

- **Conditioning:** is a process to provide moisture in to the dried hide or skin to eliminate the occurrence of cracking for the next operation.
 - **Staking:** is mechanical operation applied to increase smoothness of the leather.
 - **Milling:** is a mechanical process to improve the softness of the leather and gives the grain a more precise design. A drum similar to the one used in the wet phases is used.
 - **Spreading on toggle frame:** is a useful operation of spreading out the hide under tension on the toggle frame and allow drying in a hot air tunnel for a short period of time, but long enough to reduce the humidity from 22-24% to 15-16%. The objective of this operation is to take the advantage of the detachment of the fibers to spread and flatten the hides as much as possible.
 - **Buffing:** is a mechanical operation to remove the grain completely and to obtain soft and opaque surface, to make the flesh side of the leather to be refine and smooth, or to remove a more or less significant amount of surface material from low quality hides.
 - **Impregnation:** is an operation aims at increasing the ability to adapt to the extension and compression caused by folding, generating a more elegant behavior.
 - **Coating:** is the application of natural or synthetic products, generally water-based, for coloring, covering, sealing effects and for giving body to the leather.
 - **Ironing:** is pressing operation to make the leather smooth. It is performed in two different machines, flat presses that work in a discontinuous manner or cylindrical rotary presses that work in a continuous manner.
 - **Polishing:** is the last finishing operation to provide a shiny appearance and pleasant feel.
- Figure 2.1 below shows the leather manufacturing process flow.

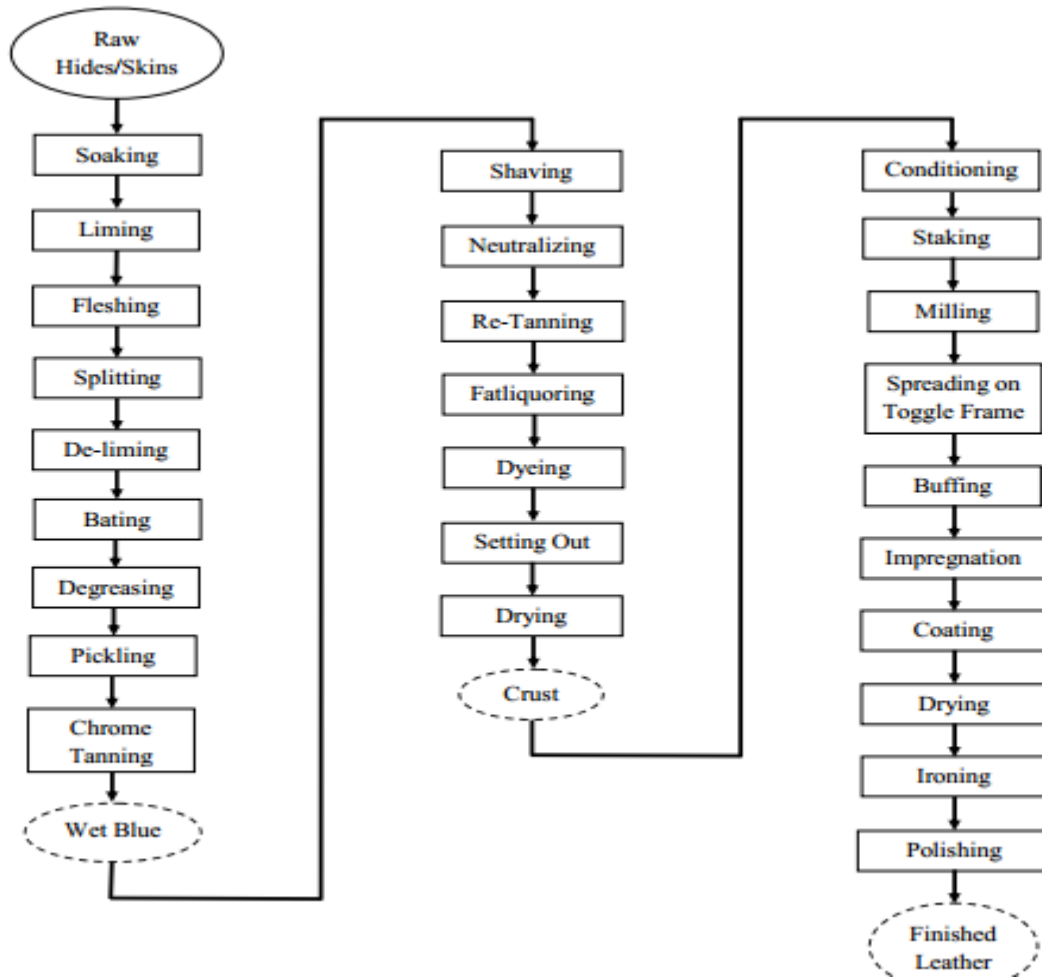


Figure 2.1 Leather manufacturing process flow (J Kanagaraj et al.,2006).

2.4 Waste from Leather Industry

Leather industry has been categorized as one of the highly polluting industries and there are concerns that leather-making activity can have adverse impact on the environment. The global production of about 24 billion m² of leather by 2005 presents a considerable challenge to the industry considering the harmful nature of some of the chemicals used in leather processing. The tannery effluents are characterized by high contents of dissolved, suspended organic and inorganic solids giving rise to high oxygen demand and potentially toxic metal salts and chromium metal ion. The disagreeable odor emanating from the decomposition of proteinous waste material and the presence of sulphide, ammonia and other volatile organic compounds are also associated with tanning activities. Solid wastes generated in leather industries contribute mainly skin trimmings, Keratin wastes, fleshing wastes, chrome shaving wastes and buffing wastes. It constitutes protein

as the main component. If these protein and other chemicals, which are present in the chemical treated protein, are not utilized properly it will pose hazardous pollution problem to the environment (J Kanagaraj et al.,2006).

2.4.1 Gaseous waste

Tanneries discharge odorous gas, smoke and dust in to the atmosphere. Rehydration of salted hides and skins generally emit odor of volatile fatty acid and amino acid evolved in the course of biological decomposition in presence of water. Hydrogen sulfide and ammonia are the major gases emitted during the washing of drum with ammonia, effluent of delimiting agent and mixing of tanning and delimiting effluent. Nitrogen and sulfur compounds are also the main source of bad odor in a tannery. Ammonia escaping from delimiting operation is odorous and pungent. The end product of anaerobic decomposition or decaying of protein is odorous. Sulphide, fatty acids like butyric acid, valeric acid and caproic acid and caproic acids, solvents, lacquers, formalin and some of the chemicals used finishing operations are also some of source of bad odor in leather industry. The stinky odor is increased because of unhygienic practice in skin and hide processing and delayed disposal of liquid and solid waste. In many tanneries it is the foul of odor which emits from the putrescible solid and liquid wastes which account for much of the smell traditionally associated with the tanneries. Phenolics (monohydric, dihydric and trihydric) are emitted in to air during the processes like post tanning and finishing operations. In addition, emission of hydrogen Sulphide and ammonia gases which are emitted during different processes are a health hazard for the workers (Aftab et al., 2006).

2.4.2 Liquid waste

Tanneries consume large quantity of water. Approximately 30-40 liters of water is used for processing 1kg of raw hide to finished leather. The liquid waste from tannery contains vegetable tannins, non-tannins and high amount of protein, especially when a hair pulping unhairing system is used.

Chrome tanning process associated with generation of heavy metal containing solid wastes and toxic effluents. During these processes, only 75-80% commercial chrome sulfate exhausted in leather industry the remaining goes to liquid waste.

Waste water which is emitted from tannery process consists of pollution of varying pH values. Similarly, a large variation exists in every parameter BOD, COD, Chloride, Sulphate, etc. Discharge of these chemicals into wastewater is hazardous for the environment. Tannery's wastewater is highly contaminated and the contamination observed is many times beyond the limits set by Environmental Quality Standards for all wastewater parameters (Nawaz et al.,2010).

2.4.3 Solid waste

Apart from liquid and gaseous wastes, large quantities of solid wastes are also generated during leather processing and subsequently during effluent treatment. Although some of the wastes find limited applications, the safe disposal of the bulk of the solid wastes has posed serious problems. Out of which some portion of chromium containing hazardous wastes are also generated. These chrome containing wastes are categorized as hazardous wastes. The main sources of solid wastes are from trimming, fleshing, splitting and shaving processes. A further potential source of solid waste is the sludge from the effluent treatment plant. Tannery effluent treatment plants produce large amounts of sludge: generally, 10% of the total weight of goat and sheep skins and 14% of cow/buffalo hides (Idris et al.,2010).

The solid waste generation from tannery process in the world is estimated at 6 million tons per year. At an average 80% of solid waste is generated from tanning industry per ton of raw hide processed. The types of solid wastes generated in a tannery processing one ton of raw skins/hides have been quantified in Table 2.1 as below (Anbalagan et al.,1997).

Table 2.1: Nature and quantity of solid wastes produced from processing 1 ton of raw

Skins/hides

No	Nature of solid waste	Quantity (kg)
1	Salt from handshaking	80
2	Salt from solar pans (not realized)	220
3	Hair (pasting ovine)	100
4	Raw trimmings	40
5	Lime sludge (mostly bovine)	60
6	Fleshing	120
7	Wet blue trimmings (grain splits)	30
8	Chrome splitting (bovine)	65
9	Chrome shavings (mostly bovine)	95
10	Buffing dust (including shaving bovine after crust)	65
11	Dyed trimmings	35
12	Dry sludge from ETP	125

(Mahdi A. et al.,2007).

2.5 Characteristics of Tannery Solid Waste

The chemical composition of solid wastes generated from beamhouse operations (fleshings, trimmings, splits) depends mainly on a kind and quality of the raw material, treatment type and process conditions. The main components are proteins and fat, up to 10.5% (w/w) for both groups. Water content is high; moisture amounts up to 60%. These wastes contain small amounts of mineral substances, 2-6% (w/w). Chromium compounds are not present in the material (J. Kanagraj, 2008).

The tanned leather wastes are mainly useless splits, shavings and trimmings. These waste groups differ mostly in size and shape; the chemical composition is comparable for each. They contain 3-6% (w/w) of fat and about 15% (w/w) of mineral components, including 3.5-4.5% (w/w) of chromium as Cr₂O₃. Sludge from wastewater treatment plants contains mostly water (up to 65% (w/w)), organic substances (30% (w/w)) and chromium (III) compounds (about 2.5% (w/w)) (J. Kanagraj et al., 2006).

Some research work on tannery sludge shows that the level of chromium content is 500 mg kg⁻¹ and this is five folds higher than that should be present in the soil (100 mg kg⁻¹). It has a moisture content (60.6%), pH (7.4), Organic Carbon (20%), Total Nitrogen (1.0) and carbon to nitrogen ratio (20). Due to the low solubility of chromium, only a little (Cr) is bioavailable, which means that even when crops are grown in soils treated with sludge relatively high in Cr, phytotoxicity is rarely observed (Mahdi A. et al.,2007).

2.6 Environmental Impacts of Tannery Solid Waste

Solid wastes generated from tanning industries contain different chemicals which are used during leather manufacturing process. These tannery solid wastes have different characteristics as different chemical and mechanical processes are applied to the raw hides/skins. If these solid wastes generated during various tanning operations are not properly utilized or disposed, they are likely to cause a number of problems on the environment. Salt dust or de-dusted salt if stored in heaps outside the tanneries or dumped in open dumping area is likely to be washed away during rains and cause groundwater pollution. Hair waste and lime sludge if discharged along with the effluents are likely to choke the drains. Raw and green fleshings, limed fleshings, splits (splitting waste) and trimmings putrefy easily and give rise to noxious smells. In many tanneries, it is the foul odor which emanate from some of these putrescible solid wastes which accounts for much of the smell traditionally associated with tannery wastes. Some of the bio-degradable tannery solid wastes are sources of pathogenic bacteria and volatile organic compounds emission. Vegetable and chrome tanned shavings and splits do not easily decompose. If they are not utilized, problems of disposal are encountered. Primary and secondary sludge obtained during the treatment of tannery wastes are also putrescible (Anita S. et al.,2010).

Excess heavy metal accumulation in soil is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible. Some of tannery solid waste contains chromium metal which is the most widely used in tanning industries as chromium salt and it causes carcinogenic effect when it enters human body through food chain. The standard safe limit for chromium metal in the soil is 150ppm (Anita S. et al.,2010).

In general, where tanning industries have long been established there has been usually a simultaneous growth in industries which can use tannery solid wastes to produce some valuable products. This pattern is especially helpful to the tanning industry in the case of obnoxious rag and limed fleshings, trimmings and splits which are lifted by glue and gelatin units (Anita S. et al.,2010). When solid waste is disposed off on land in open dumps or in improperly designed landfills (e.g. in low lying areas), it causes the following impact on the environment (Palanisamy T., 2007)

- Ground water contamination by the leachate generated by the waste dump
- Surface water contamination by the run-off from the waste dump
- Bad odor, pests, rodents and wind-blown litter in and around the waste dump
- Generation of inflammable gas (e.g. methane) within the waste dump
- Bird menace above the waste dump which affects flight of aircraft
- Fires within the waste dump
- Erosion and stability problems relating to slopes of the waste dump
- Epidemics through stray animals
- Acidity to surrounding soil
- Release of greenhouse gas.

2.7 Waste Management in Leather Industry

2.7.1 Solid waste management

Solid waste consists of all solid and semi solid materials which are discarded to the environment. Solid waste management is a complex process because it involves many technologies and regulations. These include technologies related with the generation (including source reduction), on-site handling and storage, collection, transfer and transportation, processing, and disposal of solid wastes. Disposal of solid wastes is described as placement of the waste so that it no longer impacts society or the environment. The wastes are either digested so that they can no longer be identified in the environment, as by incineration to ash, or they are hidden well enough so that they cannot be readily found. Solid waste may also be processed so that some of its components may be recovered, and used again for a beneficial purpose (Ruth F. et al.,2003).

The management of solid and contaminants which is removed by treatment has been continues to be one of the most difficult and expensive problem. There is regulation for reuse and disposal of solid wastes. So that selecting of the appropriate methods for solids processing and reuse and disposal must consider the regulations. The regulations were designed to protect public health and environment from any reasonable expectation of harm full pollutants present in the solid waste (George et al.,2003).

Land application, surface disposal, pathogen and vector reduction in treating biosolid and incineration. Land application is reuse of biosolids in all form to land for beneficial uses at agronomic rate that is rates designed to provide the amount of nitrogen needed by crop or vegetation while minimization the amount that passes below the root zone (Desrochers P.,2001). Repeated applications of tannery wastes as soil amendment material, millet crops could accumulate heavy metals to toxic levels. Surface disposal is the other method to treat solid waste. Surface disposal does not include placement of solids for storage or treatment purpose. Alternatively, biosolids can be treated by pathogen and vector reduction processes that reduce pathogens beyond detectable level (Tudunwada et al., 2007).

2.7.2 Integrated waste management system

Integrated waste management (IWM) can be defined as the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. The EPA has identified four basic strategies for IWM these are source reduction, recycling and composting, combustion (waste-to-energy facilities), and landfills. As proposed by the EPA, these strategies are meant to be interactive. It should be noted that some states have chosen to consider the management options in a hierarchical order (Joseph A. et al.,2003). Figure 2.2 shows interactive and hierarchical integrated waste management system.

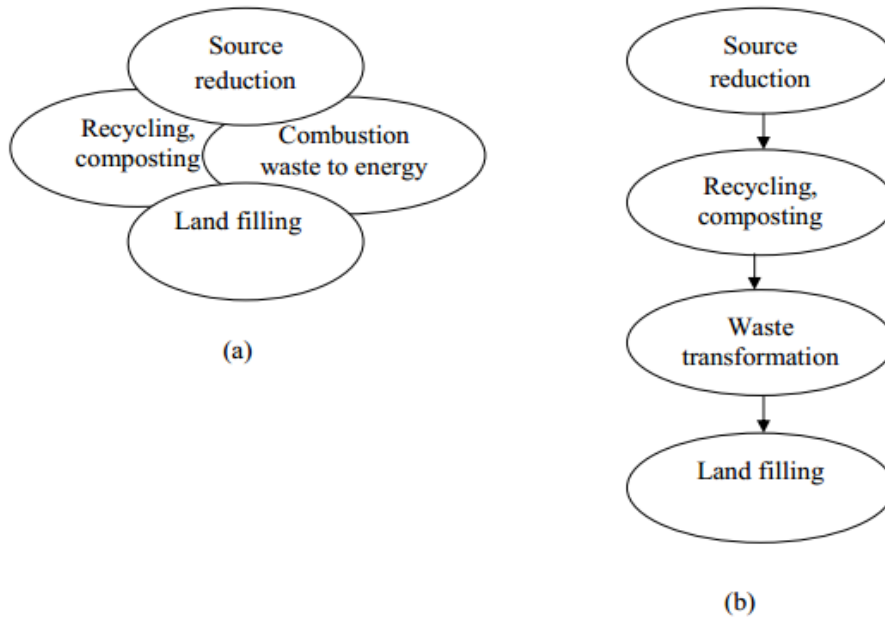


Figure 2.2. Integrated solid waste management: (a) interactive; (b) hierarchical (Mahdi A. et al.,2007).

2.8 Leather Shavings

Leather industry, one of the polluting industries because of generation of huge amount of liquid and solid wastes, also emits obnoxious smell because of degradation of proteinous material of skin and generation of gases such as NH_3 , H_2S and CO_2 . Solid wastes are raw trimmings, fleshings, chrome shavings, buffing dusts and keratin wastes. Accumulation of these wastes lead to sludge problem and choking of treatment pipes and finally results in reduction in efficiency of treatment plant. Treatment of solid wastes also is not cost effective, posing economic burden to the tanners. Leather industry in the developing countries is facing lot of solid wastes problem and many tanneries closed for not meeting bio-chemical oxygen (BOD) demand and total dissolved solids (TDS) norms.

When tanners shave the bottom sides of chrome-tanned hides to give them a uniform thickness, so-called chrome shavings end up as waste that must be hauled to landfills at a price. Wastes can be utilized to generate useful by-products. The solid wastes coming from leather tanning with trivalent chrome salts (scraps leather and shavings) need a special attention due to the amount produced. One tonne of wet hide yields only 200 kg of leather but over 600 kg of solid waste or

by-product (Rao J R et al., 2002). It has been reported that about 600,000 of solid wastes each year worldwide are generated by the leather industry and approximately 40-50% of the hides are lose shavings and trimmings (Rao J R et al., 2002).

Chrome shavings constitute about 75% of the solid waste containing chromium in the tanning process. Chromium exists in environment both as trivalent [Cr(III)] and hexavalent [Cr(VI)] forms of which the hexavalent form is 500 times more toxic than the trivalent one. Human toxicity of Cr(VI) includes skin irritation to lung cancer, as well as kidney, liver and gastric damage (Tahiri S et.al., 2004). Since chromium is known for its toxicity, the disposal of chrome shavings has been identified as a serious problem from the environmental point of view. Sastry et al developed two processes to offer an alternative and better solution for the disposal of chrome shavings. The first process is preparation of parchment-like membrane and the second process is related to development of leather-like material. The utilization of the chrome shavings in preparation of those two products not only reduces the environmental pollution but at the same time value added products can also be obtained (Tahiri S et.al., 2004).

2.9 Leather board Manufacturing Technologies

Leather board is one of the products made from leather waste. It retains the leather look which other boards do not possess. Besides, far superior flexibility and durability as compared with card board or any other types of boards. It is cheaper than leather since the board is manufactured in economically with waste materials.

There have been different ways to prepare leather board for different purpose, including processes or method of producing. The product which employ some of the techniques used in the paper and cardboard industries. As described by the author Ostberg (Ostberg, A. J., 1910), water proof leather board which is produced by using waste from tanned hides such as the neck and knee portions together with waste scrap leather from boots-making and similar manufactories, paper and resin binder. It was largely used in the manufacture of the cheaper class of boots and shoes, the insoles, quarters or counters, and the lifts of the heels. The research found that a very low resistance to strength, tearing or rupturing because of short fiber length of Kraft fiber and absence of the fiber interlocking found in neck and knee which is the area of low-quality zone.

Vedaraman N. et.al., produced leather board from chromium tanned leather shaving in combination with cotton and Kraft pulp, from the result obtained the board are used to upper

component of shoe for medium components. They improve the board of John by using cotton besides Kraft plant fiber and the strength of the leather scrap is good than tanned hide and was used for medium quality upper components (Vedaraman N et.al., 2002). Shiyin also produced reconstituted leather by a dry method by using leather scrap from leather goods by pulverizing the leather to form a fine powder which is then treated to polarize the particles and form them into aggregates which are intermixed with ethylene-vinyl acetate copolymer which is used as cheap mid sole. The continuous resin film renders the products impervious and they do not "breathe" as do leather (Shiyin, 2003). The general leather board manufacturing process described as follows:

➤ ***Collection and preparation of shavings***

The collection and preparation of the wet blue shaving from tanneries is the first operation that has to be carried out in the manufacture of leather board.

➤ ***Soaking***

The raw material, wet blue shaving first should be soaked using 200% water for 6-12 hours to compensate the moisture loss during storage.

➤ ***Grinding***

Grinding is a mechanical operation by which the shaving presented in the form of water suspension from soaking operation needs to be broken down until it is homogenized and pulp is formed.

➤ ***Mixing***

With the aim of modifying the properties of the pulp, products are added that are classified as additives (binding agents, aluminum sulphate, fat liquor, pigments). The pulp and additive will be mixed thoroughly using mixing machine.

➤ ***Pulp dewatering***

The water available in the pulp will be removed using vacuum pump filter.

➤ ***Sheet formation***

Once the leather pulp has been provided with the necessary properties and the mixture of raw materials has been correctly prepared (binding agent, additives, pigments, etc.) during mixing, the formation of the sheet will be carried out, which involves transforming a volume of the diluted pulp into a fine, wide and uniform laminate, with all the components perfectly distributed.

➤ *Drying*

When the sheet of paper comes out of the dewatering, it contains high amount of water content. From this point it is not possible to eliminate more water by physical means; this can only be done through the application of heat. This is carried out in the drying operation, whereby the moisture of the paper will be reduced to 2-5% water, which is the content that it must have at the end of the manufacturing process.

The drying operation is carried out in an area known as the drying section, in which the heat causes the water in the leather sheet to evaporate leaving it dry. At the end of this operation, the board will have eliminated practically all the water it contained, leaving a slight dampness (approximately 2- 5%) which is necessary in its final composition to maintain physical properties

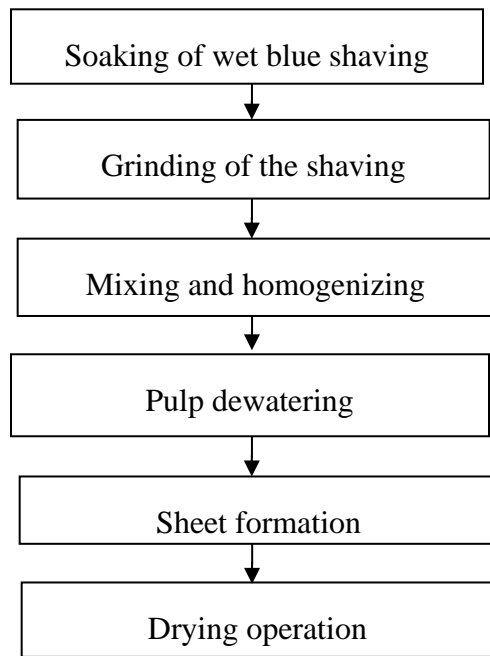


Figure 2.3 Leather board manufacturing process

3 Materials and Methods

3.1 Characterization of Leather shavings

3.1.1 Determination of moisture content

The moisture content of the sample was determined according to AOAC (2006) method No. 925-10. First dry the empty dish and lid in the oven at 105 °C for 3 hr and transfer to desiccator to cool. Weigh the empty the dish and lid. Then weigh about 3 g of sample to the dish and spread the sample with spatula. Place the dish with sample in the oven and dry for 3 hr at 105 °C. After drying, transfer the dish with partially covered lid to the desiccator to cool. Reweigh the dish and its dried sample.

Calculation

$$\text{Moisture (\%)} = \frac{(W1 - W2) \times 100}{W1}$$

Where: W1=weight (g) of sample before drying

W2= weight (g) of sample after drying

3.1.2. Determination of crude fat content

The crude fat content of the sample was determined by taking 50g dried sample and running through Soxhlet apparatus for 2-3 hours using Hexane as a solvent by following the procedure described in AOAC (2006) Method No. 920-39.

Calculation

$$\text{Crude fat (\%)} = \frac{\text{Wt. of fat}}{\text{Wt. of sample}} \times 100$$

3.1.3. Determination of crude fiber content

Crude fiber in fat free sample was estimated by digesting firstly with 1.25% H₂SO₄ for 30 min and then with 1.25% NaOH solution through Labconco Fibertech apparatus as described in AOAC (2006) Method No. 978-10. Afterwards, sample was filtered and washed with distilled water. The dry residue of the sample was weighed and placed in muffle furnace at temperature of 600 °C till grey or white ash was obtained. The crude fiber percentage was estimated according to the following expression.

$$\text{Crude fiber (\%)} = \frac{\text{Weight of digestive sample} - \text{Weight of ash}}{\text{Initial weight of sample}} \times 100$$

3.1.4. Determination of total Nitrogen content

The nitrogen content of sample was determined by using kjeldahl method described by European standard (ES,2013). In the method all nitrogen was converted to ammonia by digestion with a mixture of concentrated Sulphuric acid and concentrated Orthophosphoric acid containing Potassium sulphate as boiling point raising agent and selenium as catalyst. The Ammonia released after alkalization with Sodium hydroxide was steam distilled into Boric acid and titrated with Sulphuric acid. Weighing out the sample transferred into a tecator tube, Place it in the tecator rack. Add 5 ml NH₄Cl solution in to each tecator tubes and 6 ml of the acid mixture that was mixed of 5 parts of concentrated Orthophosphoric acid with 100 parts of concentrated Sulphuric acid. It has mixed the sample and acid carefully. 3.5 ml of Hydrogen peroxide was added step by step. There was a violent reaction. Add 3 g of the catalyst mixture for 30 min before digestion. Digestion was going on for more than 3 hr at 370 °C. Distillation has been placed on a 250 ml conical flask contain 25 ml of the Boric acid, indicator solution under the condenser of the distiller with its tip immersed into the solution. Transfer the digested and diluted solution into the sample compartment and added 25 ml of the 40% Sodium hydroxide solution into the compartment, it has been rinsed down with a small amount of water, and switch on the steam. It has been distilled until 100 ml then continued until a total volume of a few ml of water before the receiver was removed. Then it was titrated with 0.1N Sulphuric acid to a reddish color using the radio meter pH stat.

Calculation

$$\text{Total percent of Nitrogen in a sample} = \frac{(T - B) \times N \times 14 \times 100}{W}$$

Where, T =Volume in ml of the standard Sulphuric acid solution used in the titration for the test

B = Volume in ml of the standard Sulphuric acid solution used in the titration for the blank determination

N =Normality of standard Sulphuric acid

W = Weigh in grams of the test material

3.1.5. Determination of Sulfide content

The Sulfide content of the sample was determined by Iodometric method described by APHA 4500 S²-F. Measure from a buret into a 500-mL flask an amount of standardized 0.025N Iodine solution estimated to be an excess over the amount of sulfide present. Add distilled water, if necessary, to

bring volume to about 20 ml. Add 2 ml 6N HCl. Pipet 200 ml sample into flask, discharging sample under solution surface. If Iodine color disappears, add more Iodine until color remains. Back-titrate with 0.025N Na₂S₂O₃ solution, adding a few drops of starch solution as end point is approached, and continuing until blue color disappears. If sulfide was precipitated with Zinc and ZnS filtered out, return filter with precipitate to original bottle and add about 100 ml water. Add Iodine solution and HCl and titrate the solution in the flask with standard 0.025N phenyl arsine oxide or 0.025N sodium thiosulfate solution until the amber color fades to yellow. Add enough starch indicator for the solution to turn dark blue and titrate until the blue disappears. Record the volume of titrant used.

Calculation

One milliliter 0.025N Iodine solution reacts with 0.4 mg S²⁻:

$$S^{-2} \text{ (mg /L)} = \frac{[(A \times B) - (C \times D)] \times 16\,000}{\text{mL sample}}$$

Where: A = ml Iodine solution,

B = normality of Iodine solution,

C = ml Na₂S₂O₃ solution, and

D = normality of Na₂S₂O₃ solution.

3.1.6. Determination of Chromium content

Atomic absorption spectrophotometer at laboratory of JIJE analytical testing service was used to determine chromium (Cr) contents of the sample leather solid wastes. The samples were first treated with an acid digestion process and sample solutions were filled up to 100 ml with pure water after they reached room temperature (it may be filtered through filter paper if necessary). Desired measurements were later done in these obtained solutions by using atomic absorption. The amount of Cr in the sample solid wastes were detected with Perkin-Elmer 2380 Atomic Absorption Spectrophotometer. Cr was measured at 357.9nm with 0.7 slit intervals by using a mixture of air and acetylene (C₂H₂).

3.1.7. Determination of pH

The pH of the sample was determined by shaking 5 gm of sample in 100 ml of distilled water for 16 - 24 hours followed by direct measurement of the pH according to the standard methods of SLC 13 (IUC 11; BS 1309:9).

3.1.8. Determination of water soluble matter

The water soluble matter is determined by SLCS (IUC 6; BS 1309) method. Weigh accurately to the nearest mg 15 to 20 gm of the test sample and transfer the weighed sample into a clean 250 ml beaker. Add 100 ml of distilled water and mix the contents thoroughly with the help of a glass rod. Gently boil the beaker and its contents and filter using whatman filter paper. After that, collect the filtrate in a clean dry previously weighed evaporating dish. Evaporate the water carefully and when dry cool in desiccator and reweigh the evaporating dish.

Calculation:

$$\text{Water soluble matter \%} = \frac{(C-A) * 100}{B}$$

Where , A = wt. of empty evaporating dish

B = wt. of the test sample

C = wt. of evaporating dish with the water soluble

3.2 Pre- optimization of binder

Pre-Optimization process were carried out to identify optimal natural rubber latex concentration. The concentration of natural rubber latex was taken 200 mL, 300 mL, 350 mL,400 mL,450 mL and 500mL for fixed 180g of leather scrap. 350mL provides better tensile strength and bulk properties and taken as optimal value for leather boards development.

3.3Leather board preparation

3.3.1 Preparation of leather fiber from leather shavings

Finished leather shavings were sorted their type, color and cleaned it from foreign materials. These were cut into small pieces of convenient size by using plastic grind mill and then converted to leather fiber with the help of laboratory cutting mill.

3.3.2 Preparation of leather board

Fiberized materials (180 g) were soaked in water for 12 hours. Later, they were beaten using beater machine. It was collected and agitated in disintegrated machine for 15 min by adding 2 ml ammonia, 3 ml fat liquor, 350 ml of natural rubber latex and alum. Finally, 5 ml of ethylene glycol was added and mixed thoroughly and poured into vacuum pump and water was drained completely. The prepared

wet sheet was dried for 100°C for 12hrs. The leather board formed was pressed for 80°C at 100 bar using sheets press to uniform the shape and increase the strength.

3.4 Quality Analysis for the Product

3.4.1 Tensile strength test

The tensile strength test gives a reliable indication of the quality of the leather. Improperly lubricated and partially degraded leathers give low values for tensile strength. The method is done according to ISO 3376:2011. This test method is excellent for development, control, specification acceptance, and service evaluation of leather.

This test method covers the determination of the load required to rupture a leather test specimen having a 1/2-in. (12.7-mm) width. The load to rupture divided by the original unstretched cross-sectional area gives the tensile strength. It may be used for all types of leather that are smooth and firm enough to permit accurate thickness measurements.

Apparatus: testing machine, power-driven: the applied load shall be indicated on a dial, scale, or chart. The load indicator shall record or indicate the maximum load at the time of rupture of the specimen. The machine shall be equipped with a set of grips for clamping the specimens. The faces of the grips should be knurled or otherwise roughened to prevent slipping of the specimen. The gripping surfaces shall be at least 1 by 1 1/2 in. (25.4 by 38 mm). The grips shall be mounted with the longer dimension perpendicular to the direction of the application of the load. The speed of the power-activated grip shall be uniform speed of 10 ± 2 in. / min when running free. The error of the machine up to a load of 50 lbf (222 N) shall not exceed 2 %; at loads of more than 50 lbf the error shall not exceed 1 %.

Procedure: first measure the thickness of the specimen to the nearest 0.001 in. (0.025 mm) at one point, the mid-point of the narrow section. Measure the width of the narrow section of the spectrum to the nearest 0.02 in. (0.5 mm) at one place on the grain side, at the mid-point. Then mount the specimen symmetrically with the distance between the jaws $4 \pm 1/8$ in. (102 ± 3.2 mm). Determine the elongation of the specimen. Record the load in pounds-force (or newtons) to rupture the specimen. Reject any specimen that slips or breaks within 3/4 to 1 in. (19 to 25.4 mm) of the jaws and test a similar specimen.

3.4.2 Percent elongation at break

ISO 3376:2011 test method also covers the measurement of the elongation or stretch characteristics of leather produced by a tensile load. This test method is intended for use on all types of leather and with all of the breaking load tests.

The elongation measurement may be made at any designated load and is expressed as a percentage of the original distance between the jaws or between bench marks of the unstretched specimen. The speed of the machine is important. Speeds under or more than 10 ± 2 in./min (4.2 ± 0.8 mm/s) will give variables in the results, thus affecting the reproducibility of the method. The direction relative to the backbone and the width of the test specimen determines the magnitude of the elongation. This test method is excellent for development, control, specification acceptance, and service evaluation of leather board.

Procedure: mount the specimen symmetrically with the jaws separated a distance of 4 in. (102 mm). Operate the machine so that the movable grip travels at a speed of 10 ± 2 in./min (4.2 ± 0.8 mm/s). Follow the distance between the jaws or the difference between bench marks with the dividers until the load at which the elongation is desired has been reached. Take all measurements between the inner edges of the jaws or between the inner edges of the bench marks. Measure the distance between the points of the legs of the dividers to the nearest 0.02 in. (0.5mm). An autographic attachment is preferred for determining the elongation. With this arrangement the elongation may be obtained from the chart at any desired load. If the elongation is determined as a span shorter than the distance between the jaws, use a 2-in. (51-mm) bench marker. Mark the specimen over the span at which it is desired to make the elongation measurement.

Calculation: calculate the elongation to the nearest 0.1 % of the original distance over the span as follows:

$$\text{Elongation, \%} = \frac{D_2 - D_1}{D_1} * 100$$

where: D_1 = span of the original unstretched specimen, in. (mm), and

D_2 = span of the stretched specimen, in. (mm), when the required load has been applied.

3.4.3 Single edge tear

This test method is done according to ISO 3377-1:2011. This part of ISO 3377 specifies a method for determining the tear strength of leather using a single edged tear. A rectangular test specimen partially slit from one short edge is pulled so that a tear is propagated from the end of the slit.

Apparatus: *tensile testing machine*, with:

- a force range appropriate to the specimen under test;
- a means of recording the force to an accuracy of at least 2 % as specified by Class 2 of ISO 7500-1;
- a uniform speed of separation of the jaws of 100 mm/min \pm 20 mm/min;
- a means of recording the force - e.g. as an extension curve;
- Jaws, minimum width 50 mm-2 mm.

Thickness gauge, as specified in ISO 2589.

Press knife, as specified in ISO 2419, capable of cutting a test piece. All parts of the press knife shall lie in the same plane.

Sampling and sample preparation: sample in accordance with ISO 2418. From the sample, cut 6 test pieces in accordance with ISO 2419, 3 test pieces with the longer sides parallel to the backbone and 3 test pieces with the longer sides perpendicular to the backbone.

Procedure

1. Set the jaws of the tensile testing machine 50 mm apart.
2. Clamp approximately 20 mm of one leg of the test piece in the lower jaw of the tensile test machine. Fold the other leg through 180 °C and clamp in the upper jaw. Ensure that the long edges of the test piece are parallel to the direction of traverse of the machine.
3. Run the tensile test machine until the test piece is torn apart and record the force-extension plot.
4. To determine the arithmetic mean of the forces, divide the peak trace, beginning with the first peak and ending with the last peak, into four equal parts. The first and last parts shall not be used for the calculation of the mean value. From each of the two remaining subsections, select and note the two highest and two lowest peaks. A peak suitable for calculation is characterized by a 10 % minimum rising and falling of force.

5. For each test piece, calculate the arithmetic mean in Newtons of the peak values obtained according to 4. For electronic calculations, each individual peak will be analyzed. Consequently, the results may differ from the manual method.
6. Repeat 2 to 5 for other test pieces.

3.4.4 Static water absorption of leather

In this test method which is ISO 2417:2002 the amount of water absorbed by a leather specimen is measured at room temperature with all surfaces exposed to water. This test method is used to determine compliance with specifications for water absorption of leather board. The significance of the test method is limited by the static conditions employed, and the results do not reflect the water absorption under dynamic conditions of flexing. This test method covers the determination of the amount of water absorbed by leather at $23 \pm 2^\circ\text{C}$ by immersion under static conditions.

Procedure

2. Weigh the specimen to the nearest 0.01 g and record the mass as W_1 .
3. One to three specimens shall be completely immersed in a 1000 mL beaker of distilled water at $23^\circ\text{C} \pm 2^\circ\text{C}$. This should be done in such a manner that the surface of the specimens do not touch each other.
4. After 1 h 61 min immersion, the specimens shall be removed from the beaker and the surface water from each removed by lightly blotting the specimen with blotting paper prior to weighing.
5. The specimen shall then be weighed immediately and the mass recorded as W_2 .

$$\text{Water absorbed, \%} = \frac{W_2 - W_1}{W_1}$$

where: W_1 = weight of the original specimen, grams, and

W_2 = weight of the specimen after water immersion

Statistical analysis: Results are presented as mean \pm standard deviation (SD) of three individual experiments ($n = 3$).

4. Results and Discussions

4.1 Result on Raw Material Characterization

The physiochemical properties of leather shaving depend mainly on a kind and quality of the raw material, treatment type and process conditions. Leather shavings collected from Batu tannery have been characterized for various constituents, and the results are presented in table 4.1.

Table 4.1 Characteristics of leather shavings

No	Characteristics	Unit	Results obtained in laboratory
1	Moisture content	%	56.34 ± 0.32
2	Crude fat	%	4.12 ± 0.23
3	Crude fiber	%	2.53 ± 1.23
4	Total Nitrogen content	%	7.37 ± 0.92
5	Sulfide	mg/kg	72.71 ± 0.39
6	Chromium	mg/kg	4268.06 ± 0.98
7	pH		3.34 ± 0.34
8	Water soluble matter	Brix	4.06 ± 1.43

*Values were means ± standard deviation for three samples (n= 3)

4.1.1 Moisture content

The main components of leather shavings is the moisture content which is 56.34 % . These values are in agreement with the previous report which was 58.99% (H. Ozgunay et al., 2006). Due to the high moisture content of leather shaving wastes, infusion of the chemicals, into soil, surface and ground water causes the deterioration of the natural structures of these receiver environments. Therefore, chrome shaving wastes has to be used for production of valuable products such as leather board.

4.1.2 Crude fat

The crude fat value (4.12%) determined in this study was higher than the value reported from previous researcher which is 1.43% (Jonnalagad Daraghava R., 2002). As Bienkie-wicz 1983 reported fat content varies between 0.5% and 4% in cattle and horse hides, 3% and 30% in sheep skin, 4% and 40% in pig skin, and 3% and 10% in goat skin over dry weights. For this reason, vast

amounts of fat in hides are removed before tanning by applying a degreasing process. Unless the fat in rawhide structure is removed, it affects other processes in a negative way by prohibiting the penetration of chemicals into the hide in further processes, and may also cause a strong smell, an increase in micro-organism activity and defects like spew on leathers.

4.1.3 Crude fiber

The crude fiber content of shaving waste was 2.53%. This is due to the conventional fiber opening process causes osmotic swelling due to ionic imbalances built up in the matrix. The hydrostatic pressure built up would enhance the splitting up of fiber bundles, separation of unwanted interfibrillar materials such as proteoglycans, globular proteins, reticulin, etc., and easy removal of flesh (Gilles et al. 1996).

4.1.4 Total nitrogen content

Determination of nitrogen in shaving wastes gives an idea about proteins as the main component of leather, and therefore about the effect of leather processes on proteins. The results obtained from nitrogen determination analysis conducted with the Kjeldahl method in waste samples have revealed that shaving wastes with 7.37% nitrogen had the lowest amount of nitrogen, and this is due to the minimum protein content.

4.1.5 Sulfide content

The Sulfide content of leather shavings is 72.71 mg/kg and this value indicates that it is much higher than the standard safe limits of the amount of Sulfide. This Sulfide is coming from beam house processes, according to the type of desired leather products, hides/ skins are treated with an intense alkali solution and sodium sulfide for hair and wool removal and opening up the structure (H. Ozgunay et al.,2006). Therefore, the leather shaving should not be disposed to the open dumping area; it should be used for valuable products.

4.1.6 Chromium content

The highest value of chromium was recorded in this study which is 4268.06 mg/kg as this is the solid waste generated just after chrome tanning operation and this value indicates that it is much higher than the standard safe limits of the amount of chromium metal (Putshaka J. et al.,2016).

Naturally, Cr ion was not detected in fleshing wastes. Chromium has two important oxidation states: trivalent (Cr⁺³) and hexavalent (Cr⁺⁶). Trivalent chromium is of low toxicity and is an

essential trace ion necessary for several biological activities, whereas hexavalent chromium is of high toxicity. Tannery wastes normally contain only trivalent chromium. The production of chromium-containing solid wastes (including chrome shavings) in a tannery has been recognized as a problem for many years but recently pressure from environmental authorities has given the problem increasing urgency (D. Shapcott and J. hubert, , 1979). As a result, many scientific groups have oriented their research to find a process to recycle these wastes. The chemical composition of chrome shavings makes it suitable for leather board processing.

4.1.7 pH

The pH value of leather shaving was 3.34 report shows that the finishing processes are carried out at acidic condition (Agustín M. et al.,2013). Acid-base reactions are among the most important matters regarding the environment. Most of the living organisms are very sensitive to environmental pH. another situation is that, when pH is forced to extreme limits, chemical balance reactions slide to the left or right, causing the occurrence of undesired sediments or gases. Hence, in order to protect the current ecosystem, wastes should be subjected to a neutralization process before they are disposed to the environment.

4.1.8 Water soluble matter

The water soluble matter of leather shaving was 4.06 %. The level of water-soluble matter present in leather can indicate the degree of unbound tans, salts and other substances present. The tanning process and chemicals/substances used resulted in a proportion of the tannins being bound to the skin collagen structure via hydrogen bonding. This quantification revealed that there was a proportion that will remain unbound and these, along with water soluble salts and unfixed dyes. The result obtained in this research had some variation with the report made by S. Sivasubramanian et al, 2008.

4.2 Result on the Effect of Natural Rubber Latex on Product Quality

Natural rubber latex plays a major role in determining the mechanical properties of leather board. Table 4.2 shows that the effect of natural rubber latex content on different mechanical properties. Increasing in natural rubber latex concentration has led to significant effect in tensile strength, tear strength and elongation at break until the concentration reaches 350 ml. However, the water absorption showed insignificant effect with increment in natural rubber latex concentration. From

the experiment we observed that as the concentration of natural rubber latex reaches at 350 ml, the mechanical properties showed acceptable result. But, as the concentration increases beyond 350 ml, the mechanical properties of leather board decreased significantly (Figure 4.1). Besides the concentration increment also showed very sticky behavior which was inconvenient for processing. Furthermore, it could be attributed to the elastic nature of natural rubber latex, which tends to reduce the brittleness (Shey et al. 2006).

Better mechanical properties exhibited by leather boards could also be attributed to the good interfacial compatibility between nonpolar natural rubber latex and leather shaving. The mechanical properties and dimensional stability of leather board are strongly affected by their nature of water absorption. Hence, the water absorption values play an important role in their characterization. It is clearly evident from the above results that leather board prepared using 350 ml of natural rubber latex possessed better mechanical properties, which could find potential applications in the manufacture of leather goods and footwear.

Table 4.2 Effect of natural rubber latex on mechanical properties

S.No	Natural Rubber Latex (ml)	Tensile strength (Mpa)	Percentage elongation at break (%)	Tearing strength (N/mm)	Water absorption (%)
1	250	1.47	4.68	11.05	45.69
2	300	1.63	5.2	12.79	46.05
3	350	1.8	6.8	13.35	46.9
4	400	1.78	6.2	12.98	45.32
5	450	1.53	5.78	11.89	43.79

Presently, finished cutting leathers scraps are being discarded as waste material in most of the leather goods and footwear industry. Leather board prepared from leather waste possessed better properties, which could be used for the manufacture of footwear, leather goods products etc. Mechanical properties of leather boards play a major role in determining their end user applications (Senthil et al. 2014). This research is focused in making and analyzing the leather board production from leather shaving which is discarded as a waste from Batu Tannery Sh.co. These properties are shown in [table 4.2](#).

4.2.1 Tensile strength

Tensile properties of leather board are given in [table 4.2](#). From this table it can be observed that the tensile strength of the leather board was 1.8 N/mm². The leather board exceeds approximately four times as compared to the result with leather fiber which is 0.38 N/mm². Besides, as compared to the leather board made from shaving dust which is 1.68 N/mm², the board made from shaving showed better result. It could be explained that natural rubber latex used in production of the board contributed to the strength (vijayan sumathi l and rethinamsenthil, 2016). This strength test showed that it is suitable to manufacture different leather goods from this board.

4.2.2 Percentage elongation

The Percentage elongation at break result also showed better result as compared to the leather board made from shaving dusts. According to R. Senthil et al. (2014), the Percentage elongation at break of the leather board made from shaving dust was 1.99%. Whereas, the result obtained from this experiment was 6.8%. Considering the characteristics, it could be explained that natural rubber latex contributed to the strength and elastic property of leather board. It could also be attributed to the elastic nature of natural rubber latex, which tends to reduce the brittleness (Shey et al. 2006).

4.2.3 Tearing strength

According to Prompunjai and Sridach (2010), the composites prepared using cassava starch, sawdust and natural rubber latex had better tearing strength. Tearing strength of the leather board made from dust shaving was significantly lower than the leather board made from the shaving in this research.

The tear strength of was higher when 350 ml natural rubber latex was used as an additive. Better mechanical properties exhibited by leather boards could also be attributed to the good interfacial compatibility between nonpolar natural rubber latex and the leather shavings.

4.2.4 Water absorption

It is clearly evident from the table 4.2 the leather board that we prepared using leather shaving had lower water absorption 46.9% as compared to the leather board made from shaving dusts which is 57.18% (Jian et al., 2013). The leather board prepared from shaving possessed better mechanical properties, which could find potential applications in the manufacture of leather goods and footwear.

The mechanical properties and dimensional stability of leather board are strongly affected by their nature of water absorption. Hence, the water absorption values play an important role in their characterization. Due to the non-polar nature of natural rubber latex (Jian et al., 2013), increase in its concentration has led to decrease in water absorption values. Leather boards with decreased water absorption value is highly encouraged properties for use in footwear and leather goods preparation, since it aids in maintaining a dry product surface, thereby preventing slipperiness or microbial growth (Senthil et al. 2014). High water absorption capacity can lead to swelling of the

fibre, forming voids and microcracks at the fibre matrix interface region which may result in a reduction of the mechanical properties and dimensional stability of the board (Alomayri T. et al., 2014).

5. Conclusion and Recommendations

5.1. Conclusion

The leather shaving, which is the raw material for the production of leather board, was characterized for its physicochemical properties. Leather boards were made by using different amounts of natural rubber latex (250 ml, 300 ml, 350 ml, 400 ml ,450 ml and 450 ml). Leather shaving was converted to powder using grinding mill and mixed with water and binder (natural rubber latex). Prepared paste was poured into sheet forming mold to remove water and prepare board. The board was characterized for its mechanical properties. The leather board fabricated using 350 ml natural rubber latex possessed enhanced mechanical properties. The leather board made through indicated techniques have capacity to be used for production of home furniture, home partitions and shoe insoles. The results proved the process of conversion of leather waste into value added products are cost effective, environmentally friendly and can create jobs.

5.2. Recommendations

This research identified that leather board manufactured by using natural rubber latex has a potential application for shoe insole. However, due to limited time and knowledge on this area we didn't explore all potential applications and optimize certain parameters. Hence, we recommend further research in this area and enhance flexibility of the board to use for shoe insole and optimize the thickness of the board. We also recommend further study on techno-economic feasibility for leather board production .

6. References

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Appendix

Appendix : Photos of laboratory equipments during laboratory session



Solubilizing rubber latex



Solubilizing rubber latex



rubber latex



Soaking of leather shaving



*Leather board from leather Dust
(Trial)*



Solution preparation for casting