TECHNICAL BRIEF

CIRCULARITY

Waste Valorisation: Production of protein-based surfactant using leather processing waste

INTRODUCTION

The leather industry converts raw hides and skins into finished products through water-and chemical-intensive processes, generating significant solid waste. These wastes include untanned residues such as trimming and fleshing, and tanned by-products like shavings, buffing dust, and chromium-bearing sludge. Leather shavings alone account for approximately 20 - 30% of total solid waste and are rich in collagen protein.

Improper disposal of these wastes poses environmental and health risks, contaminating soil, water, and air with hazardous substances such as chromium and sulphides. Valorising leather waste through circular economy approaches offers an opportunity to convert it into secondary raw materials, minimise environmental impact, and improve resource efficiency while reducing greenhouse gases.

OBJECTIVE

This pilot in collaboration with Pakistan Council of Scientific and Industrial Research (PCSIR) aimed to convert wet blue shaving waste into a biodegradable surfactant for leather manufacturing, reducing waste, improving resource efficiency, and demonstrating the feasibility of circularity in Pakistan's leather sector.

METHODOLOGY

1. Raw Material Selection

Wet blue shavings were selected due to their high collagen content, making them an ideal protein source for surfactant synthesis.

2. Protein Extraction by Alkaline Hydrolysis

An alkaline solution of sodium hydroxide (NaOH), magnesium oxide (MgO), and calcium hydroxide [$Ca(OH)_2$] was prepared in a ratio of 1:2:3 and mixed with wet blue shavings in the reaction vessel. The mixture was heated at 100°C for 2 hours to extract soluble collagen protein. After hydrolysis, the solution was filtered to separate the protein-rich filtrate from residual solids to be further used for surfactant synthesis.

$$\text{Protein} + NaOH + MgO + Ca(OH)_2 + H_2O \rightarrow \text{Soluble hydrolysed protein}$$

3. Surfactant Synthesis

The extracted protein solution was heated to 55°C under continuous stirring. A pre-mixed solution of lauric acid ($C_{12}H_{24}O_2$) (fatty acid component to introduce the hydrophobic chain) and concentrated hydrochloric acid (HCl) (employed to create the required acidic medium) was added slowly and reacted for 30 minutes. Sodium hydroxide (NaOH) was then added gradually to adjust pH to alkaline i.e. 7-8 and complete the reaction. The mixture was cooled to room temperature for 2 hours and stabilized overnight.

$$\text{Protein} + \text{Lauric Acid} \rightarrow \text{Protein-Fatty Acid Surfactant} + H_2O$$

4. Product Testing and Validation

The synthesized surfactant was evaluated for:

- Foaming properties
- Moisture content
- Solid content
- Hydrophilic-lipophilic balance (HLB) value
- Storage and stability

Comparative trials were conducted in leather processing to assess performance relative to commercially available surfactants.

5. Reintegration into Leather Manufacturing

296 kg of wet blue shavings were used to yield 167 kg of biodegradable surfactant, diverting 181 kg of waste from the environment. The surfactant was applied in wet processing/crust preparation stages. Thin leather crust was produced and evaluated against leather treated with commercial surfactants for the performance parameters such as softness, and mechanical properties based on ISO-3377-1 (2011) and ISO 3376:2020 (tear load and tensile strength).

RESULTS

The following are the real time results obtained by applying surfactant on a production lot.

MECHANICAL PROPERTIES

296 kg of wet blue shavings were used to yield 167 kg of biodegradable surfactant, diverting 181 kg of waste from the environment. The surfactant was applied in wet processing/crust preparation stages. Thin leather crust was produced and evaluated against leather treated with commercial surfactants for the performance parameters such as softness, and mechanical properties based on ISO-3377-1 (2011) and ISO 3376:2020 (tear load and tensile strength).

Tear Load Test			
		COMMERCIAL SURFACTANT	**PILOT SURFACTANT**
Test	**Standard**	**Value**	
Test Method	ISO-3377-1 (2011)		
Machine Used	CRE-Type (100 mm/min)		
Specimen Size	70 x 40 mm		
Mean Tear Load Direction 1 (N)		90.89	137.4
Mean Tear Load Direction 2 (N)		72.18	131.3
Mean Thickness (mm)		1.35	1.22

Tensile Properties of Leather				
Test Method	ISO 3376:2020			
Machine Used	CRE-Type			
Specimen Size	110 x 20 mm			
	COMMERCIAL SURFACTANT		**PILOT SURFACTANT**	
Direction	Tensile Strength (MPa)	Elongation at Break (%)	Tensile Strength (MPa)	Elongation at Break (%)
Direction 1	22.82	79.7	22.5	76.1
Direction 2	21.06	51.5	24.4	74.1

KEY FINDINGS

Following are the key findings of the tests conducted to compare both commercial and pilot surfactant:

- Tear strength improved significantly with pilot surfactant.
- Tensile strength and elongation were comparable to commercial surfactants.
- The softness of leather was maintained.

ENVIRONMENTAL IMPACT

Alongside commercial viability, the surfactant produced demonstrated measurable environmental benefits:

- 181 kg of wet blue shaving waste diverted from disposal.
- Biodegradable surfactants has reduced reliance on synthetic chemicals.
- Potential reduction in GHG emissions due to waste diversion from traditional solid waste streams.

PILOT OUTCOMES

- Successful extraction of collagen-based proteins from wet blue shavings.
- Synthesis of a biodegradable, protein-based surfactant feasible at pilot scale.
- Comparable technical performance to commercial surfactants.
- Reintegration into leather production demonstrated a closed-loop circular economy approach.
- Validated the use of wet blue shavings as a viable raw material in industrial production.

CONCLUSION

The circularity pilot successfully demonstrated that wet blue shaving waste can be transformed into a biodegradable surfactant and reintegrated into leather manufacturing. This intervention confirms the technical feasibility, environmental benefits, and economic potential of waste valorisation in Pakistan's leather sector.

Raw Material Selection Wet Blue Shavings (Collagen Source)

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Preparation of Alkaline Medium
$NaOH + MgO + Ca(OH)_2 + H_2O$

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Alkaline Hydrolysis (100°C, 2 h)
Protein + $NaOH + MgO + Ca(OH)_2 + H_2O$ → Soluble Hydrolysed Protein

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Filtration
Filtrate: Protein Solution

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Heating of Protein Solution
55°C, Continuous Stirring

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Addition of Lauric Acid + HCl
Reaction Time: 30 min

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Surfactant synthesis
Protein + Lauric Acid → Protein–Fatty Acid Surfactant + H_2O

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Addition of NaOH
pH Adjustment

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Final Product
Protein-Based Surfactant