Leather tanning using Al(III)-Phloroglucinol based metal complex combined with vegetable tannin as chrome free approach

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Leather tanning using Al(III)-Phloroglucinol based metal complex

combined with vegetable tannin as chrome free approach

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Abstract

Chrome tanning is the most widely used method for converting raw hides into durable leather. One of the primary difficulties arises in chrome tanning process is oxidation of Cr(III) into the more toxic Cr(VI) form. This creates both environmental and occupational health concerns. The present study explores a hybrid tanning approach of Al(III)-phloroglucinol complex (PHO- AL) with vegetable tannin (GS powder) to achieve enhanced hydrothermal stability, durability, and resistance to environmental degradation as an alternative approach to Chrome tanning. Vegetable tannin reinforces crosslinking through hydrogen bonding and hydrophobic interactions while phenolic ligand phloroglucinol enables chelation with $Al^{3}z$, improving its affinity toward carboxyl and amine groups in collagen. FT-IR and MALDI-TOF characterisation techniques confirm the formation of PHO-AL. Hydrothermal shrinkage (Ts) temperature of the hybrid (PHO-AL & GS Powder) tanned leather is 79oC. Morphology of the collagen crosslinking has been analysed through FE-SEM. Further, Physical strength and Organoleptic properties of the tanned leathers are comparable to the commercial leathers. The combined tanning strategy demonstrates an ecofriendly, chromium-free pathway capable of delivering leathers with superior performance and sustainability. This work highlights the potential of integrated inorganic–organic tanning technologies as an alternative to Chrome tanning process.

Keywords: Chrome-free tanning, Phloroglucinol, Aluminium, Vegetable tannin

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1. Introduction

Chrome tanning remains the dominant leather tanning method worldwide; however, increasing environmental and health concerns have driven interest in chrome-free tanning approaches. During processing and waste disposal, Cr(III) can be oxidized to toxic and carcinogenic Cr(VI)1, leading to serious risks to human health and contamination of water and soil, while chromium resources are also non-renewable and poorly recyclable.

Consequently, research has focused on eco-friendly alternatives such as vegetable, aldehyde, non-chrome metal, and bio-based tanning agents, aiming to achieve sustainable leather production with reduced environmental impact2.

In this paper, Aluminium-Phloroglucinol complex and GS (powder) combined tanning system has been explored toward leather making. Our aim is to develop feasible chrome-free tanning technologies to counter ecological constraints and stricter requirements for leather performance properties. The combination tanned leather was evaluated and compared with conventional chrome tanning. The permeation process of Aluminium-Phloroglucinol complex determine hydrothermal stability of the leathers were investigated based on the tanning of pickled pelt.

2. Methodology 2.1 Preparation of PHO-AL

Phloroglucinol anhydrous & Aluminium nitrate

pickling water - - - - -

nonahydrate are mixed in 1:3 molar ratio, added ethanol and kept for stirring under 70oC for 12 hrs and removed solvents using rotary evaporator. Then kept in oven at 60oC until it completely got dried

Process chemical quantity

duration

/%

/min

NaCl 8 20 - - -

formic acid 0.5 3*20 - - 1:10 dilution

sulfuric

0.6 2*30 - 3.0 -

acid

Chrome

basic chromium

8 150 - - -

tanning

sulfate

sodium formate

1 60 - 3.0 -

sodium bicarbonate

2 6*30 + 30 - 3.8–4.0 1:20 dilution

PHO-AL

GS powder 2 60 - 5-5.5 -

+GS tanning

Sodium

1 30 - - -

Citrate

PHO-AL 6 120 35 5-5.5 -

Formic

0.5 3*20 - 4 fixing

acid

Table-1 Procedure followed during leather tanning process

2.2 Leather Tanning Process

The procedure followed for tanning process has mentioned in table-1.

temperature

pH Remarks

/°C

3. Result & Discussion:

3.1 Characterisation of PHO-AL

The shift in peak position and intensities of Phloroglucinol anhydrous and PHO-AL confirms the formation of the product as shown in Table-2.3

Wavenumber(cm-1) Inference

Phloroglucinol PHO-AL Functional

Group

3479 3424 -OH

1620 1614 Aromatic C=C

1160 1155 C-O stretching

Table-2 Result of analysis of FT-IR spectrum

3.2 Shrinkage Temperature (Ts)

Shrinkage temperature of the tanned leather have been analysed for both the control and the Combination tanned leather. Commercial Cr-tanned leather exhibits 118oC4 while combined GS powder and PHO-AL tanned leather exhibits 79oC as shown in Table-3. Even though GS+PHO-AL tanned leather does not satisfy commercial Cr-tanned leather but it exceeds commercial Aluminium tanned leather's stability.

SI.NO. Sample/Leather Ts(oC)

1 Control-Cr

118

tanned

2 PHO-AL +GS

79

tanned

Table-3 Shrinkage Temperature (Ts) of the tanned leather

3.3. FE-SEM

The cross-sectional morphology of the tanned leather showed organized and densely packed collagen fibre matrix with clear fibre orientation and reduced interfibrillar spaces. The uniform distribution of fibres across

the cross section5 indicates effective penetration of the tanning agent, while the compact structure suggests strong collagen crosslinking and improved structural stability of the leather. (Fig-1)

a

b

Fig-1 FE-SEM images of cross-section morphology of GS-2% (a) and GS&PHO-AL (b) tanned leather

1. Conclusion:

The current study involves synthesis of AluminiumPhloroglucinol based metal complex and characterisation study confirms the formation of the complex. The synthesised complex combined with GS powder has been subjected to tanning of leather as an alternative for commercial BCS tanning, Shrinkage temperature of tanned leathers has been observed as 79oC and 118oC respectively. Cross-sectional morphology of the tanned leather has also been analysed. Thus, an approach towards integrated organic and inorganic tanning technology as an alternative to Cr tanning has been performed.

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