Characterization of leather from different tanning processes as a contribution for a sustainable development of the leather industry

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Introduction

Leather, a fully biobased material derived from food industry byproducts, is a hallmark of Italian craftsmanship and sustainability. However, traditional tanning methods still rely heavily on toxic chemicals like chromium and glutaraldehyde. To drive innovation towards more sustainable production, a deep understanding of the tanning process and leather characteristics from various methods is essential. This research applies both established (**FTIR, X-rays spectroscopies and contact angle**) and novel (**instrumented indentation and surface topography, zeta potential**) characterization techniques to analyze leather from traditional (chrome, glutaraldehyde) and innovative (vegetable, carbamoyl sulphate, starch, zeolite, triazine and AVO) tanning processes.

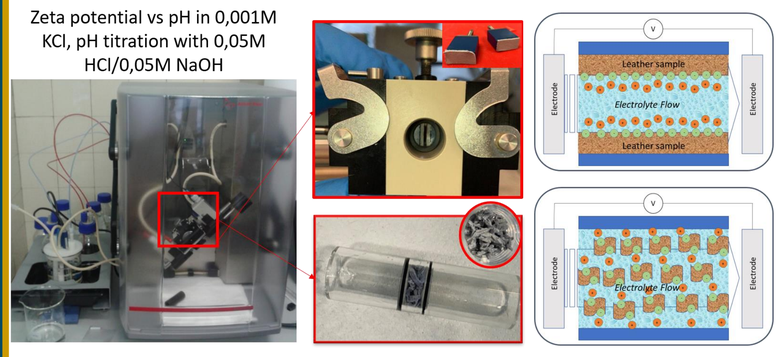
Materials

1 – Cr_wet: chrome based tanning
2 – GLU_wet: glutaraldehyde based tanning
3 – VEG_wet: vegetable tanning
4 – carb sulph_wet: carbamoyl sulphonate based tanning
5 – starch_wet: dialdehyde starch-based tanning
6 – Al-wet : Aluminum based tanning
7 - zeo_wet : zeolite based tanning
8 – Tria_wet : triazine based tanning
9 – AVO_wet: oil vegetative water based tanning

Z Potential

Electrokinetic Analyzer for Solid Samples

Zeta potential vs pH in 0,001M KCl, pH titration with 0,05M HCl/0,05M NaOH



Adjustable gap cell
- Samples should be dry (proper drying needed before the measurement)
- Plane samples, measure specific for the external surface of the sample

Cylindrical cell
- Samples suitable also without complete drying
- Measure through the sample (both sides)
- Chopped samples.

Optimization of the measurement method on samples tanned with **traditional methods** (e.g. Glutaraldehyde and Cr)

Transfer of the characterization method to **innovative tanning processes** (e.g. AVO and Triazine) developed in the framework of the project.

Figure 1: Electrokinetic Analyzer for the determination of zeta potential and test configurations

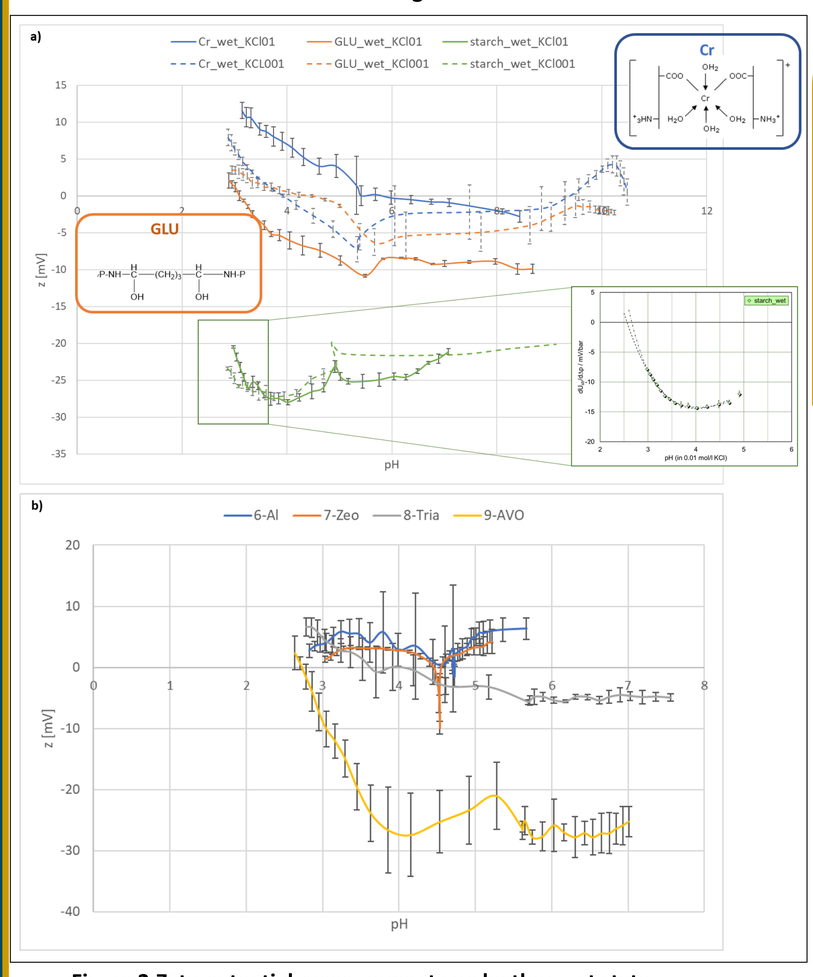


Figure 2:Zeta potential measurements on leather wet state

Effect of Tanning Agents:

→ The zeta potential analysis shows different isoelectric points (IEP) for leather samples based on tanning agents.

Swelling and Zeta potential behaviour:

→ High ionic strength reduces leather swelling and measurement artifacts, allowing more reliable zeta potential measurements on leather at the wet state.

FTIR

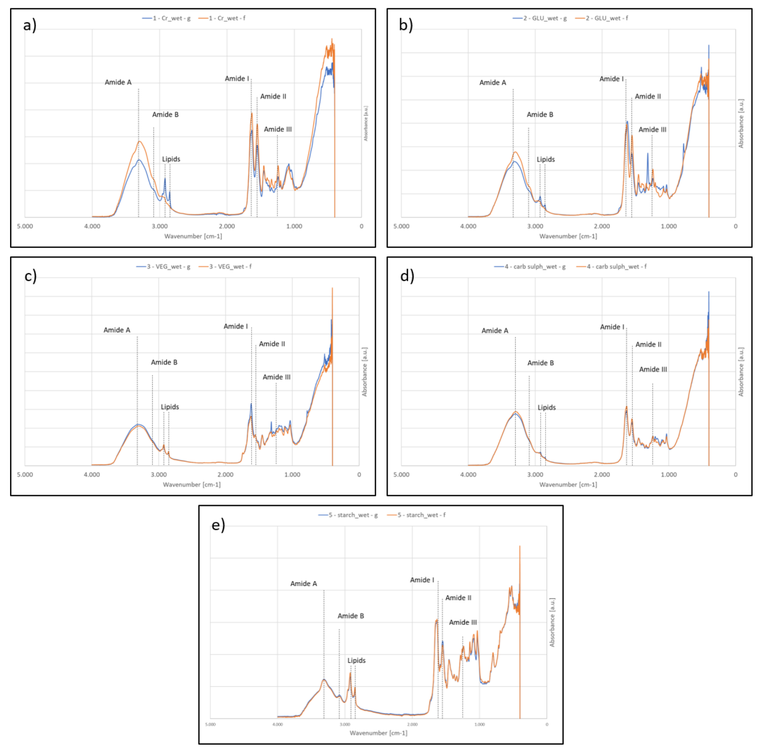


Figure 6: FTIR on leather in wet state

→All leathers exhibit typical collagen absorption bands. The two amide bands (I-II) are due to C=O stretching, C-N stretch and NH deformation and are found in all type of tanned leathers at 1638, 1540 cm^{-1}, respectively . Considering the Amide III band, collagen is characterised by three main peaks centred at 1284, 1240 and 1202 cm^{-1}. These represent the structure of collagen (random coil or crystalline) and actually change according to the type of tanning. Amide A peak (around 3300 cm^{-1}) is presented clearly in all the leathers due to hydrogen bonding. There are two additional bands presented in all leathers at 2920 cm^{-1} and 2850 cm^{-1},which are related to lipids.

Indentation Test and Topography

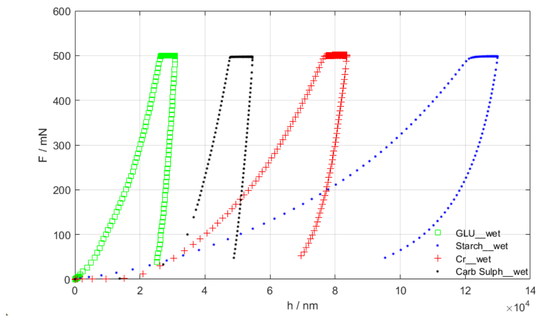


Figure 3:Indentation curves (IC) collected by micro-IIT

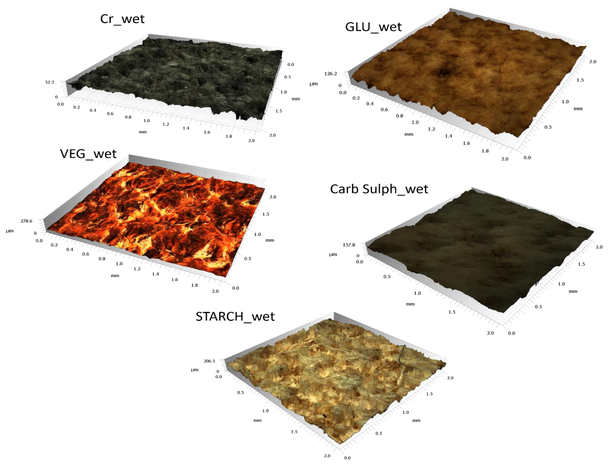


Figure 4: Measured topographies in true colours.

Indentation
→Significant difference in the mechanical response can be appreciated due to the different tanning treatments.
Topographical measurements
→reveal that Cr_wet and GLU_wet samples have a more uniform surface with fewer features, while VEG_wet and starch_wet samples show irregular surfaces with visible fibers and pores. The carb sulph_wet sample falls in between, with an intermediate surface texture. Additionally, the processing significantly affects the color of the specimens

XRD

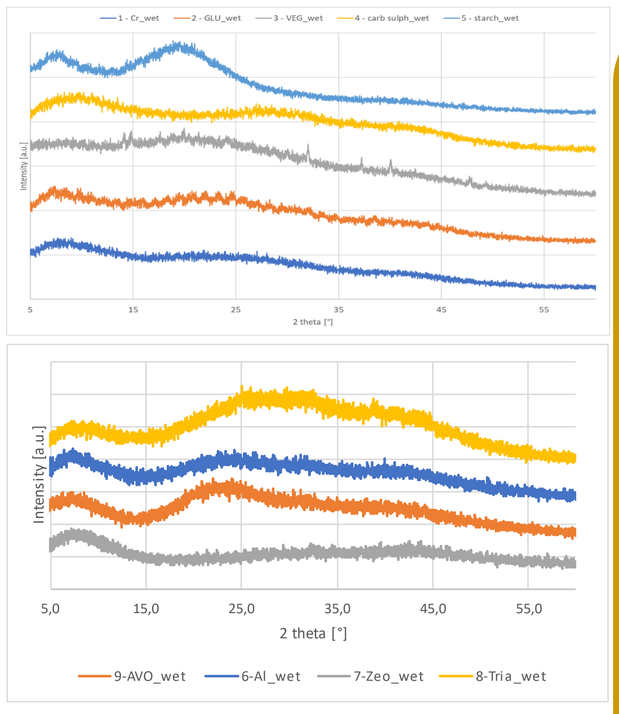


Figure 7: XRD on leather in wet state

XRD Peaks in Traditional Tanned Leathers:
→XRD spectra of leathers show key contributions at 8° and 20°, with 8° indicating collagen fibril packing and 20° reflecting amorphous scattering. Effective tanning, as seen in Cr_wet and GLU_wet leathers, enhances the 8° peak.

Variation Among Tanning Methods:
→Starch-tanned leather shows both peaks (8° and 20°), while VEG_wet only shows the 20° peak, indicating an amorphous structure. The carb sulph_wet sample's signals are shifted to higher 2theta values compared to the others.
Al_wet and Zeo_wet show significant 8° signals and negligible 20° one.
AVO presents both 8° and 20° signals

Conclusions

Leather samples at the wet state, coming from traditional (e.g. Chrome and Glutaraldehyde) and innovative (e.g. AVO and Triazine) tanning processes have been deeply characterized from the physical and chemical standpoints. Well established characterizations, such as FTIR and XRD, have been applied. In addition, new and unconventional methods for the leather field, such as surface topography characterization, instrumented indentation and zeta potential electrokinetic measurements were applied and optimized for this type of samples defining a set of techniques for the in-depth characterization of leather samples from different tanning processes. These measurements will allow the comparison and understanding of different tanning processes with excellent detail for the first time, a crucial step for the innovation in this field.

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