Leather Coatings Enhancing Thermal Comfort of Leather Through PCM-Based-Syntan Production of Chrome-Free Tanning Agents from Agricultural Waste:

Conference: 13th AICLST, Kolkata, 6–8 March 2026

Paper reference: TI-34/P

Printed pages: 377–379

Source: *Leather 2050: Challenges & Opportunities*, ILTA (2026)

Enhancing Thermal Comfort of Leather Through PCM-Based Syntan

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Ref. No. TI-34/P

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Abstract

Phase change materials (PCMs) have become a viable option for thermal management applications due to their capacity to absorb and release heat during phase transitions. By integrating PCMs into leather, its thermal insulation qualities are further enhanced, making it ideal even in extreme cold climates. In this work, we have developed a formaldehyde-free phenolic syntan incorporating PCM, which offers excellent body filling during retanning, in addition to providing better thermoregulation.

The encapsulation of the PCM in syntan was confirmed through TEM analysis, and encapsulation efficiency was computed from the DSC thermogram.

Physical tests were performed on the treated leathers to determine their mechanical properties. A temperature difference of 4.15°C with respect to the control leather was observed from cold insulation analysis. In addition to improving leather’s thermal performance, PCM incorporated syntans also increased leather’s organoleptic and mechanical properties. This work highlights the potential of the formaldehyde-free phenolic resin as non-toxic and sustainable shell material for PCM encapsulation, providing a unique method for creating highperformance thermoregulating leathers for upholstery, footwear and garments in extreme cold environments.

Keywords: PCM, Phenolic syntan, encapsulation, retanning, sustainability, thermoregulation

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1. Introduction

Although leather is typically used as a thermoregulator in cool environments, it can be difficult to use in exceptionally cold conditions1. The study’s background is that employing PCMs could improve a material’s ability to regulate its temperature. PCM’s are substances that absorbs, stores and releases large amounts of thermal energy during their phase transition. They are classified based on their transition phases as solid-solid, solid-liquid and solid-gas. High heat storage tendency and minimum change in volume is observed in solid-liquid PCM. Hence, this type of PCM is preferred widely. By encasing the desired PCM in a phenol-based polymer system synthesized through condensation polymerization, this work presents a unique formaldehyde-free method that provides a stable and suitable choice for leather. This method is phenolfree, providing both health and ecological safety, in contrast to traditional encapsulating and Retanning process. Uniform temperature management is made possible by the addition of mPCM slurry to the leather without sacrificing crucial performance metrics. The integration of the mPCM slurry in the leather Retanning process substitutes the traditional syntans with a dual system that functions as a cold insulator in addition to improving the filling property of the leather.

2. Materials and Methodology

Chrome-tanned Buffalo hide was used as the raw material for leather trials. Phenol (99.5%),1- Heptanol (98%), Glyoxal (40% aqueous solution), PCM, Sodium dodecyl sulfate (99%), KOH (85%), Chloroform (99.5%), Hexane (98%), Ethyl acetate, were purchased. All the reagents were used without further purification.

The Phenolic polymer was synthesised by the addition of Phenol, KOH and Glyoxal at controlled temperature conditions. The reaction mixture was isolated after 2h and washed with Chloroform to remove the free Phenol. Oil in water emulsion was prepared with PCM, and was added slowly to the phenol-based polymer at controlled conditions to obtain the mPCM slurry.

To evaluate the penetration, mechanical and thermal properties of leathers, a process with 8% Retanning agent, 10% fatliquor followed by fixing with 3% formic acid in chrome-tanned buffalo leather was adapted. The Retanning agent in the control process was substituted with an equal amount of mPCM slurry in the experimental leather.

3. Results and Discussion

The structure and the functional groups present in the phenol-based polymer were analysed using 13C NMR and FT-IR spectroscopy techniques. The plausible structure of the Phenolic resin2 is shown in Scheme 1.

Scheme 1: Scheme for the synthesis of the phenol-

based polymer.

Micro-encapsulation of the PCM in the phenol-based Polymer was confirmed via FE-SEM and HR-TEM studies. The encapsulation efficiency of the developed mPCM was analysed using DSC thermogram. The computed Encapsulation Efficiency was 87.5%.

The organoleptic properties and the mechanical strength studies of the control (without mPCM) and the experiment (with mPCM) leathers showed that the experiment leather

did not loose its inherent properties due to the addition of the mPCM slurry. The mechanical strength study is presented in Table 1.

Figure 1. FE-SEM image of the developed mPCM.

Properties	Control Leather	Experiment Leather
Tensile strength (N/mm2)	8.41±0.88	8.603±0.19
Double hole stitch tear (Kgf/cm)	60.13±2.29	67.05±3.16
Elongation at break (%)	36.67±0.34	39±2.51
Softness (mm)	2.35±0.45	2.55±0.40

Table 1: Mechanical strength studies of the control

and experimental leathers

Cold insulation analysis shown in Table 2 report a temperature difference of +4.15°C greater than the control leather, making the developed mPCM incorporated leather suitable for extreme cold environments.

	Initial Temperature (°C)	Final Temperature (°C)	Temperature Difference (°C)
Control	23.6 ± 0.14	-15.75±0.2	39.35±0.07
Experiment	23.65 ± 0.7	-11.55±1.3	35.2±0.5
Temperature difference achieved:			4.15±0.43

Table 2: Cold Insulation analysis of the control and

experimental leathers

4. Conclusion

The developed mPCM slurry with PCM encapsulated in the phenol-based polymer confirmed encapsulation in FESEM and HR-TEM analysis, showing spherical morphology and core- shell structure, respectively. The mPCM slurry incorporated leather did not compromise on its inherent leather properties while introducing the thermoregulating property. A temperature difference of 4.15±0.43 °C greater than the control leather was observed, making the developed mPCM incorporated leather suitable for extreme cold environments.

5. Acknowledgement

The authors acknowledge CSIR-Central Leather

Research Institute (CSIR-CLRI) for providing the necessary research facilities and infrastructure. We sincerely thank the MMP035201 project for the financial support towards this work.

References

1. Sharma, R.; Venkatesan, N.; Fathima, N. N.

Engineered Leathers for Extreme Cold Weather Application. Mater. Lett. 2022, 329, 133166. https://doi.org/10.1016/j.matlet. 2022.133166.

2. Siahkamari, M.; Debnath, D.; Wang, T.; Nejad,

M. A Fundamental Study of Lignin Reactions with Formaldehyde and Glyoxal. Green Chem. 2025, 27 (8), 2342–2358. https://doi.org/ 10.1039/D4GC05695G.