Enabling technologies for novel generations of sustainable and smart leathers

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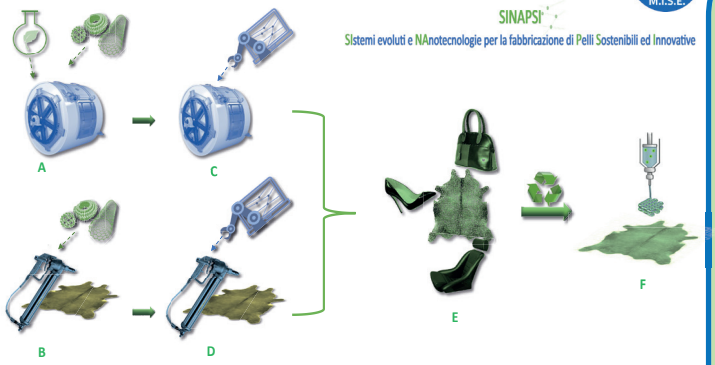
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Automation, eco-sustainability and circularity for the manufacturing of nanofunctionalized leathers

SINAPSI
SIstemi evoluti e NAnotecnologie per la fabbricazione di Pelli Sostenibili ed Innovative



A: wet processes using tanning agents with reduced chromium content or chrom-free tanning molecules associated with nanostructured agents;

B: finishing processes through the use of nanostructured agents for the functionalization of leathers (functionalized TiO_2, Ag and SiO_2 nanoparticles), in order to provide to leather specific features, such as antimicrobial, antioxidant and self-cleaning peoperties, increased resistance to light and fluorescence properties;

C e **D**: upgrading and efficiency of the machines (in the wet and finishing phases) to improve the monitoring of the process, with a view to minimize water, energy and chemicals consumption , and in order to safeguard the health of the operators;

E: production of new generation of leathers for automotive, footwear and leather goods with high added value and low environmental and eco-toxicological impact;

F: valorization of waste also through innovative technologies.

Abstract

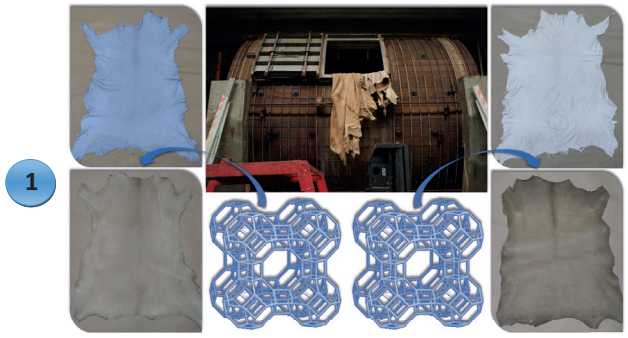
In a highly competitive production scenario, concerning materials for fashion and for automotive industry, expected features on leather grow progressively over the time: there are many current needs for innovation and sustainability of the material, indeed, which include the need to guarantee high performance and quality, high sustainability and circularity of the product, minimization of water, energy and chemicals consumption during the production process, beside the progressively increasing need to obtain functionalized materials with high added value, able to meet specific requirement for customization by companies that use leather.

Meeting all these needs at the same time is currently a great challenge for the leather supply chain and the technological solutions to be adopted must be suitably evolved.

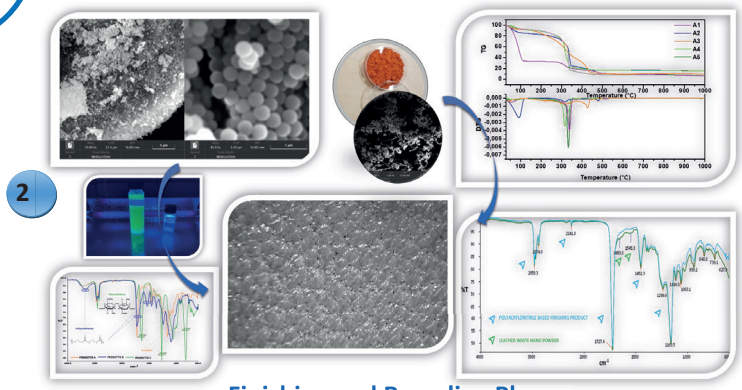
*This work explores the potential of combined use of enabling technologies for tanning, with particular reference to the use of 4.0 approaches for process control, in the context of the production of novel families of functionalized leathers using nanotechnologies; these approaches specifically aim at optimizing processes for obtaining highly sustainable leathers, with increased performance, in terms of antimicrobial characteristics, and of increased durability and resistance to aging (particularly with self-cleaning and antioxidant features); the work starts from a challenging Research and Development Project, co-financed by the Italian Ministry of Economic Development: SINAPSI - **"Automation, eco-sustainability and circularity for the manufacturing of nanofunctionalized leathers ".***

The solutions explored include the use of nanostructured materials, both for the wet (zeolites) and finishing phases (such as functionalized TiO_2, Ag and SiO_2 nanoparticles), where the critical parameters capable of influencing the effectiveness of the applications used were considered, and the elements of machine upgrading and automated control approaches were identified, with a view to improving dispersion of nano-agents, and make the process more efficient to ensure the sustainability and quality of the productions; in this context, non-destructive approaches were explored, for products and processes control, such as sensors using functional near infrared (NIR) spectroscopy, through which it is possible to measure specific commodity and chemical properties of products continuously in a non-invasive way.

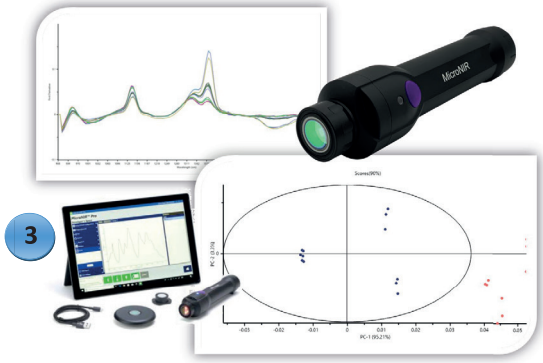
Experimental Results



Wet Phases



Finishing and Recycling Phases



Machines Upgrading and 4.0 Process Control

This feasibility study allowed to highlight the versatility of MicroNIR in acquiring reliable and robust spectral information, both for solid and liquid samples. In both cases, through the application of the principal component analysis, it was possible to demonstrate how the NIR is able to discriminate the different samples analysed. By increasing the number of samples and providing additional data, it will be possible to develop highly specific applications for the automated non-destructive control of the process and of the quality features of new generation of leathers.

1: For the identified intended uses (automotive, footwear and leather goods), specific approaches have been developed for the use of zeolites, both as main tanning systems and as retanning agents; the joint use of zeolites and other traditional tanning agents, such as chromium and glutaraldehyde, allowed to significantly minimize the use of these; for mixed chrome tanning, for example, it was possible to obtain articles with high performance and product characteristics, with a reduction of 50% of the chromium content.

2: For the finishing processes, nanoparticles were synthesized and functionalized for the increased properties desired in the finished products; the dispersion and compatibilization of NPs in finishing chemicals has been improved both through the introduction of hydrophilic molecules, and through the development of approaches including the use of ultrasound sources; leather nanofibers, deriving from waste, obtained by means of an ultracentrifugal miller, with dimensions between 50 nm-5 mm, were also inserted in the novel finishes; the novel circular finishes thus obtained exhibited greater mechanical resistance to abrasion and improved product properties.

3: The main process parameters have been studied, allowing to identify suitable sensor approaches for product and process control; in addition to the use of traditional pH, temperature and conductivity sensors, challenging studies have been launched for the use of "near infrared" (NIR) spectroscopy, a consolidated technique for product analysis and controls, which allows to investigate the chemical-physical properties of the samples through the use of the infrared region of the electromagnetic spectrum, from about 900 nm to 1700 nm. NIR spectroscopy is initially supported by the use of chemometric methods and by multivariate statistical analysis of the data: in this specific case, a system of acquisitions was finalized using a MicroNIR OnSite-W for leather and with a dedicated accessory to the acquisition of liquid samples (side-view vial holder); through this system, samples of leather, chemicals and tanning waters were studied. In the specific example reported, tanning waters were analyzed before and after the selected processes: the differences in terms of intensity suggest a certain discrimination between the samples, where applying multivariate statistical methods, such as principal component analysis (PCA), it was possible to appreciate and identify groups in the acquired data, suggesting the potential of the technique in the further development of an automated process management system.