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From Soybean Waste to 3D Printing: A New Biomaterial for Skin Repair

An interdisciplinary study coordinated by the University of Milan has transformed okara, a by-product of soybean processing, into a source of bioactive peptides to obtain a biodegradable, 3D-printable material, with potential applications in the development of devices for pain management during breastfeeding and following breast cancer surgery. The study was published in Communications Materials

Milan, 1 October 2026 – Transforming a soybean processing by-product into an innovative material for skin protection and repair. This is the prospect outlined by **a study that used okara, a residue from the production of tofu and soy-based beverages, to obtain a bioactive, biodegradable, 3D-printable biomaterial.**

A solution that could contribute, in the future, to the development of devices for the local treatment of pain associated with breastfeeding and post-operative recovery following breast cancer surgery.

The interdisciplinary research was coordinated by **Carmen Lammi**, Professor at the Department of Pharmaceutical Sciences of the **University of Milan**, in collaboration with the team led by Professor **Serena Graziosi** of the Department of Mechanical Engineering at **Politecnico di Milano**, and with **Raffaele Pugliese**, a researcher at the NeMO Lab Research Center – **Niguarda Hospital** in Milan. The study is among the outcomes of the **3DBioPad research project** (*Design and 3D printing of a biocompatible and bioactive pad for the topical treatment of breastfeeding and breast cancer post-surgery pains*), coordinated by Professor **Serena Graziosi** and funded by the European Union – NextGenerationEU, under the resources provided by PNRR M4C2 I1.1 – PRIN 2022. The project integrates **expertise in mechanical design, materials science and engineering, food and pharmaceutical sciences, product design and additive manufacturing.**

Published in *Communications Materials*, the study addresses a twofold challenge: reducing environmental impact by valorizing food-industry by-products and developing new biomedical solutions.

At the heart of the research is the okara, which, although generally considered a waste product, retains a significant protein component and can therefore represent a sustainable source of biologically active molecules. **From this by-product, the researchers obtained a protein hydrolysate** rich in bioactive peptides, short chains of amino acids derived from proteins, **and studied its effects on human dermal fibroblasts**, cells that are essential for maintaining skin structure and for tissue repair processes. **In vitro tests showed that the okara hydrolysate exerts antioxidant and anti-inflammatory activity and promotes fibroblast migration, an important process for wound healing.**

To translate these findings into a technological solution, the okara hydrolysate was incorporated into poly(ε-caprolactone), or PCL, a biocompatible and biodegradable polymer already used in biomedical research. This resulted in **a bioactive blend suitable for 3D printing**.

Mechanical, thermal and structural analyses showed that the addition of the hydrolysate preserves the main properties of PCL and enables **the extended release of bioactive peptides over time**.

The researchers then verified that, **even after 3D printing, the blend retains its antioxidant, anti-inflammatory and pro-regenerative features**. The ability to produce structures with complex geometries also confirmed the versatility of the material and its potential for the design of customisable devices.

"*The research will continue with the 3D printing of a biomimetic phantom, an experimental model capable of reproducing some of the main characteristics of breast skin tissue. The system will make it possible to study the behaviour of the biomaterial under controlled conditions and to further investigate its properties and functionality before the subsequent validation phases, thus contributing to the development of sustainable and customisable solutions for women's health*," says **Carmen Lammi.**

"*The possibility of using 3D printing to produce complex geometries with this bioactive material opens up new opportunities for the development of devices dedicated to women's health, with potential applications in other biomedical fields as well. In the 3DBioPad project, the valorization of the okara is part of a design approach that considers, from the outset, product function and geometry, material properties and the manufacturing process as interdependent elements. It is through this integration that we aim to combine the development of new solutions for people's health with a more sustainable use of resources*," explains **Serena Graziosi**.

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