The Power of Keratin

Protein-Derived Bio-based Materials for Advanced Manufacturing

New Zealand Institute for Bioeconomy Science Limited

The global shift toward sustainability is driving rapid innovation in materials science. Conventional materials, largely derived from petroleum, pose significant environmental and end-of-life challenges. Bio-based materials offer a compelling alternative—combining renewable origins with degradability and reduced ecological impact.

Among these, proteins such as keratin from wool and feathers stand out for their unique properties, including responsiveness to environmental stimuli and inherent biocompatibility. These characteristics open the door to applications that go far beyond traditional plastics and composites.

At the Bioeconomy Science Institute, we leverage deep expertise in protein chemistry, fibre science, materials engineering, and biotechnology to transform agricultural bioresources into advanced materials. This multidisciplinary capability enables us to design solutions that meet stringent environmental, social, and cultural expectations while delivering economic value. Our research spans fundamental science through to applied technologies, ensuring that innovations are both scientifically robust and commercially viable.

Through this integrated approach, we are pioneering new classes of materials that combine sustainability with functionality. From keratin-based bioplastics that reduce microplastic pollution to protein formulations for additive manufacturing, our work demonstrates how natural building blocks can be engineered for high-performance applications. These innovations not only address pressing global challenges but also position bio-based materials as a cornerstone of future manufacturing systems.

Our Core Capabilities

1 Protein Chemistry

Extraction, modification, and functionalisation of keratin and other proteins for tailored material properties.

2 Fibre and Materials Science

Development of wool and protein-based materials with enhanced strength, flexibility, and responsiveness.

3 Advanced Manufacturing

Formulation and processing for additive manufacturing (3D printing) and thermoforming applications.

4 Composite and Hybrid Development

Integration of bio-based components into composites for structural and functional uses.

5 Material Characterisation

Mechanical, thermal, and chemical analyses to ensure performance and reliability.

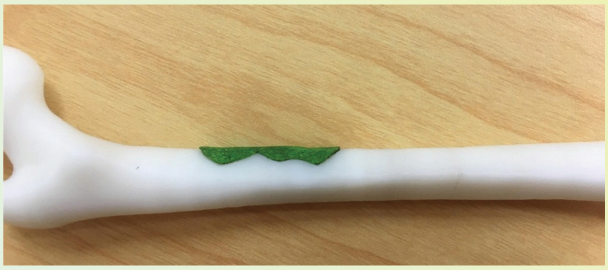
6 Biodegradation and Sustainability Testing

Evaluating in-use and end-of-life behaviour to meet environmental goals.

Our capabilities are demonstrated through a portfolio of projects that turn protein resources into practical solutions. From additive manufacturing to bioplastics and porous structures, these examples highlight the versatility of keratin and other proteins in creating sustainable, high-performance materials.

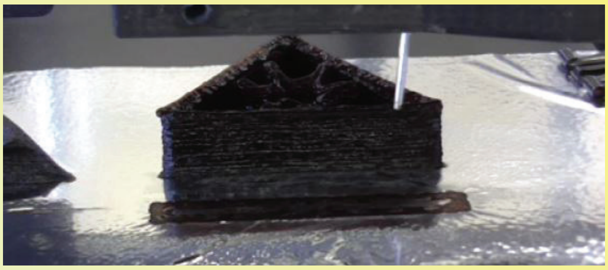
Additive Manufacturing with Protein

The Bioeconomy Science Institute is at the forefront of sustainable innovation in additive manufacturing. By leveraging the unique properties of proteins—particularly keratin—we are creating materials that go beyond conventional polymers. Proteins are biocompatible, biodegradable, and inherently responsive to environmental stimuli, making them ideal for applications where performance and sustainability must coexist. Our science enables customised solutions for advanced manufacturing challenges. We have developed a suite of protein-based formulations specifically designed for 3D printing, each tailored to meet different functional requirements.



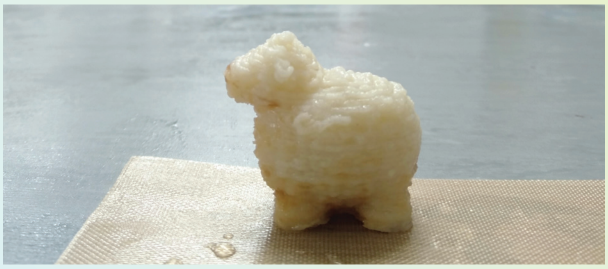
Rigid Structural Matrices

Designed for medical implants and bone repair, these formulations allow precise printing of scaffolds that fit complex defects. Over time, natural bone integrates with the matrix, reducing the need for secondary surgeries.



Hydrogels for Regenerative Medicine

These porous, protein-rich structures support cell migration and tissue growth, making them ideal for wound healing and tissue engineering.



Dual-Material Printing

Our capability includes printing intricate geometries using dissolvable support matrices, enabling designs that were previously impossible with conventional methods.

Stimuli-Responsive Materials

Imagine a printed orthotic that adjusts its shape in response to pressure or heat. Our research makes this a reality, opening doors to smart medical devices and adaptive components.

Behind these innovations is a powerful combination of expertise in **protein chemistry**, **advanced 3D printing technologies**, **mechanical testing**, and **dynamic material analysis**. This integrated approach ensures that every formulation is scientifically validated and engineered for performance.

Whether you are seeking customised medical solutions, next-generation bio-based materials, or adaptive manufacturing technologies, we can provide the science and capability to make it happen. Our work demonstrates that sustainability and high performance are not mutually exclusive—they can be designed into every layer of your product.

Keratin-Based Bioplastics

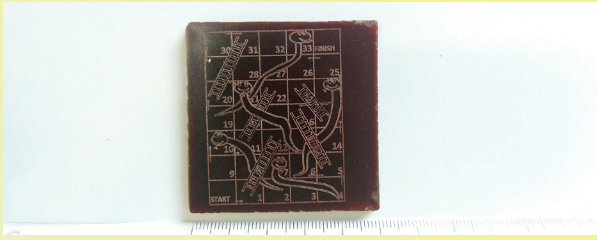
Plastic pollution is one of the most pressing environmental challenges of our time. Microplastics—tiny fragments shed from synthetic plastics—are now found in oceans, soils, and even human bodies, posing risks to ecosystems and health. The Bioeconomy Science Institute is tackling this problem head-on by developing keratin-based bioplastics that combine sustainability with functionality.

Keratin, a fibrous structural protein abundant in wool, feathers, and other natural sources, offers unique advantages over conventional plastics. It is renewable, biodegradable, and inherently flame-resistant, making it an ideal candidate for replacing petroleum-derived materials in selected applications. Our research has produced keratin bioplastics with rigidity, translucency, and thermoformability, enabling them to be shaped through processes such as compression moulding and extrusion.

Key features of our keratin bioplastics

Thermoformable Performance

While the material does not fully melt, it softens under heat, allowing shaping by draping over forms or using compression moulding techniques.

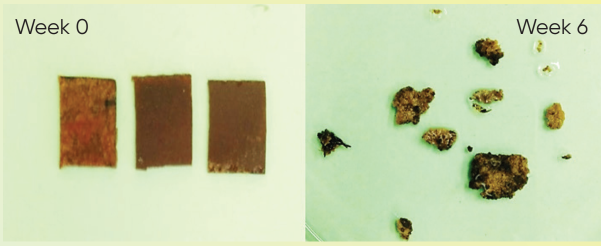


Customisable Properties

Strength and stiffness can be tailored by incorporating bio-based plasticisers, broadening the range of potential applications.

Moisture Responsiveness

Thin sheets can be made pliable by brief water exposure, enabling reshaping and drying to retain new forms—ideal for adaptive designs.



Environmental Advantage

Composed of natural protein, these bioplastics degrade rapidly at end-of-life. In our studies, chicken feather-based bioplastic lost **86%** of its mass in just six weeks when buried in garden soil, far outperforming conventional plastics.

Beyond performance, keratin bioplastics offer design flexibility and sustainability credentials that align with global environmental goals. While early trials in injection moulding revealed limitations for mainstream plastic replacement, they uncovered promising opportunities in niche applications where moisture absorption, softness, and biodegradability are valued. These findings open pathways for specialised products in packaging, consumer goods, and agricultural uses.

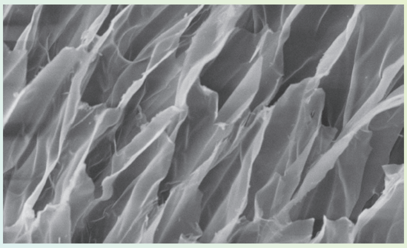
Our capability spans **protein chemistry**, **mechanical and thermal testing**, **flammability analysis**, and **biodegradation studies**, ensuring that every material is rigorously evaluated for both performance and environmental impact. By combining scientific depth with practical innovation, we are creating bioplastics that not only reduce reliance on fossil resources but also deliver new functionalities for a circular economy.

High-Porosity Keratin Materials

Porosity is a game-changer in material design. It enables lightweight structures, controlled fluid movement, and the delivery or absorption of active molecules—all critical for advanced applications in healthcare, agriculture, and environmental technologies. The Bioeconomy Science Institute is harnessing the unique chemistry of keratin and other proteins to create highly porous materials that combine sustainability with exceptional functionality.

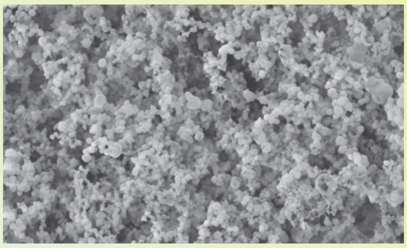
Our research focuses on engineering foams, cryogels, aerogels, and electrospun mats from keratin and hybrid protein systems. These materials offer biocompatibility, biodegradability, and tunable porosity, making them ideal for high-tech uses such as wound healing, tissue scaffolds, filtration, and controlled release of active compounds.

Key Innovations



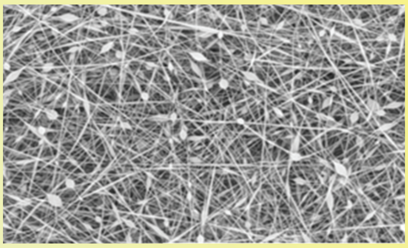
Cryogels

Produced using aqueous chemistry and freeze-drying, these solid foams exhibit macro-porous structures with densities as low as 3–30 g/L. Their open architecture supports biological applications, including microbial stabilisation and mammalian cell growth for tissue engineering.



Protein Aerogels

Leveraging advanced drying techniques, we create aerogels with sub-micron pore sizes—perfect for controlled delivery of pharmaceuticals, nutraceuticals, cosmetics, and agrichemicals. These materials combine ultra-low density with high surface area for superior performance.



Electrospun Nanofibrous Mats

Using electrospinning, we produce membranes of keratin and hybrid biopolymers that can be functionalised for wound dressings, filtration, or coating applications. Their nanoscale fibres provide exceptional porosity and adaptability.

High-porosity keratin materials enable safer chemistries and environmentally positive outcomes compared to petrochemical-based products. They can deliver active molecules precisely where, and when, needed, absorb contaminants, or act as scaffolds for tissue regeneration—all while breaking down naturally at end-of-life.

The institute brings together **protein chemistry**, **materials processing**, **porosity analysis (electron microscopy and gas physisorption)**, and **advanced characterisation techniques** to design and validate these materials. This integrated expertise ensures that every product meets performance requirements while aligning with sustainability goals.

From medical devices and drug delivery systems to agricultural solutions and filtration technologies, our high-porosity keratin materials open new frontiers for bio-based innovation.

Our work demonstrates how science and sustainability can come together to create innovative, high-performance materials. From additive manufacturing to bioplastics and porous structures, our capabilities enable solutions that meet environmental goals while unlocking new possibilities for industry and research.

If you're interested in exploring collaboration opportunities or learning more about how these technologies can support your projects, please reach out to our team.

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