Tissue engineering aims to fabricate functional tissue for applications in regenerative medicine and drug testing. The most widely used bioprinting method is extrusion-based bioprinting, in which inks are dispensed continuously from nozzles and deposited along digitally defined paths to fabricate 3D structures layer by layer. However, one of the challenges of this method is the difficulty in retaining the 3D structures and shapes of materials like hydrogels, cells, and biopolymers without additional support.

To overcome this challenge, scientists at Nanyang Technological University, Singapore (NTU Singapore), report they have developed a 3D printing ink material using sunflower pollen, that could be used to fabricate parts useful for tissue engineering, toxicity testing, and drug delivery.

The findings are published in the journal *Advanced Functional Materials* in a paper titled, "Engineering natural pollen grains as multifunctional 3D printing materials."

The pollen-derived ink was shown to hold its shape when deposited onto a surface.

“The development of multifunctional 3D printing materials from sustainable natural resources is a high priority in additive manufacturing,” the researchers wrote. “Using an eco-friendly method to transform hard pollen grains into stimulus-responsive microgel particles, we engineered a pollen-derived microgel suspension that can serve as a functional reinforcement for composite hydrogel inks and as a supporting matrix for versatile freeform 3D printing systems.”

As a proof-of-concept, the scientists printed a five-layer tissue engineering scaffold, useful for culturing cells, in 12 minutes. Collagen was then added to the scaffold to provide anchor points that cells can adhere to and grow.

They then seeded human cells on the scaffold and found it to have a high cell-seeding efficiency of 96–97%. This is comparable performance to the inverted colloidal crystal (ICC) hydrogels that are widely utilized as 3D cell culture platforms but that are time-consuming and laborious to fabricate.

Pollen responds to pH changes, which prompted the researchers to also test the viability of the 3D scaffold as a stimulus-responsive drug delivery system. When a fluorescent red dye was dripped onto the scaffold, the scientists found that the pollen microgel particles released the dye into the scaffold gradually. This showed that there is potential for the pollen scaffold to be used as a drug delivery system with controlled release, said the scientists.

“Pollen microgel particles have a hollow shell structure, which means they could potentially be used to carry drugs, cells, or biomolecules in drug delivery platforms with customized 3D structures. We are now looking at how we can use these pollen microgel scaffolds for 3D cell culture platforms in various biomedical applications,” said Cho Nam-Joon, PhD, professor of the NTU School of Materials Sciences and Engineering.

“There is also potential for the pollen-based scaffold to be used as a smart drug carrier, given pollen’s stimulus-responsive nature. For instance, we can further slow down the release of drugs by coating the pollen-based scaffold with a thin layer of alginate, and stimulate the release by introducing an acid.”

The scientists also found that the soft and flexible pollen microgel particles, derived from tough pollen grains, could potentially serve as a recyclable support matrix, for use in freeform 3D printing, in which soft ink is deposited. The support matrix prevents the collapse of the printed structure as the ink cures.

To test the feasibility of their approach, the scientists fabricated a 3D printed silicon rubber mesh for the elbow using pollen microgel as the support that would retain the elbow mesh’s shape as it is being printed.

After curing the printed product at 75°C (167°F) for 24 hours inside the pollen microgel, the scientists found that the printed 3D silicone rubber mesh could adapt to the human elbow curvature. They also found that the mechanical properties of the silicone rubber samples printed and cured in the pollen microgel supporting matrix were similar to those of samples fabricated via the traditional casting method.

The team is now looking to collaborate with members of the industry to refine their 3D printing innovation and advance its commercial uptake.

“Compared with other classes of natural materials, pollen grains have several compelling features, including natural abundance, renewability, affordability, processing ease, monodispersity, and tunable rheological features, which make them attractive candidates to engineer advanced materials for 3D printing applications,” the researchers wrote.