The loss of skeletal muscle mass and resulting deformities affect physical appearance and functionality, impacting daily activities. Innovative and cost-effective solutions are needed to address skeletal muscle loss while promoting sustainability and enhancing muscle regeneration.

Gelatin hydrogels from *Catla catla* scales have been explored to combat skeletal muscle loss using sustainable and cost-effective materials. These hydrogels, fabricated by enzymatic crosslinking with varying microbial transglutaminase (mTG) units, showed different crosslinking degrees (69-87%) and mechanical properties. *In vitro* studies revealed high cell viability and proliferation, with the 20% gelatin-10U mTG hydrogel significantly improving myogenic differentiation and mature myotube formation. Hydrogels also facilitated neovascularisation in both CAM assays and *in vivo* studies. Hemolysis tests indicated strong blood-scaffold compatibility, and in rat models, the hydrogels integrated well at injury sites with minimal inflammation, displaying significant myogenic marker expression (MyoG, Myh1, and ACTN1). Biowaste-recycled hydrogels show promise for improving muscle regeneration after loss. However, larger defects may risk necrosis, affecting nutrient supply and waste removal.

Customising hydrogels is crucial for optimal scaffold-tissue contact and enhanced healing, as skeletal muscle defects differ widely among patients. Fish gelatin in extrusion-based 3D printing faces challenges due to its low mechanical strength. Sustainable inks made from gelatin from *Catla catla* scales, xanthan gum (XG), and mTG were formulated for fabricating tailored porous hydrogels. These hydrogels supported cell proliferation and aligned growth. Studies with C2C12 and human amniotic membrane stem cells (HAMSCs) showed improved myogenic differentiation. In Wistar rat models of volumetric muscle loss (VML), hydrogels promoted muscle regeneration, as evidenced by increased expression of key myogenic markers. Fish gelatin hydrogels offer a promising and sustainable approach to enhancing muscle regeneration.

Human placenta ECM-fish gelatin-based 3D printed hydrogels were explored for skeletal muscle tissue engineering to increase bioactive constituents. ECM was extracted via ultrasonication-assisted decellularisation, preserving structure while removing cellular content. Placenta-gelatin ink formulations were used for scaffold printing, forming a hydrogel with an interpenetrating network. Rheological analysis revealed that the placenta-fish gelatin ink had a higher storage modulus than fish gelatin alone. Myogenic studies showed organised myotube formation and myoblast alignment with C2C12 and HAMSCs, respectively. CAM assay indicated improved angiogenesis and microvascular growth with minimal hemolysis. This research presents biowaste-derived, bioactive, and stretchable ECM hydrogels for skeletal muscle engineering without needing sacrificial templates or synthetic crosslinkers.

Keywords: fish scale gelatin, hydrogel, bioactive, stretchable, extrusion 3D printing, human placenta, decellularisation, myogenic differentiation, skeletal muscle