Medical & healthcare, Tissue engineering, Metabolic disease research

Cationic polymer effect on brown adipogenic induction of dedifferentiated fat cells

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Abstract

This study investigated how cationic polymers influence the brown adipogenic differentiation of dedifferentiated fat (DFAT) cells within a fibrin matrix. Various natural and synthetic polymers were compared, and among them, poly-L-lysine (PLL) exhibited the most pronounced enhancement of UCP1 expression and mitochondrial activity in DFATs cultured in brown adipogenic medium. These results indicate that electrostatic interactions between PLL and medium components such as triiodothyronine (T3) and insulin facilitate their local retention, thereby promoting thermogenic differentiation.

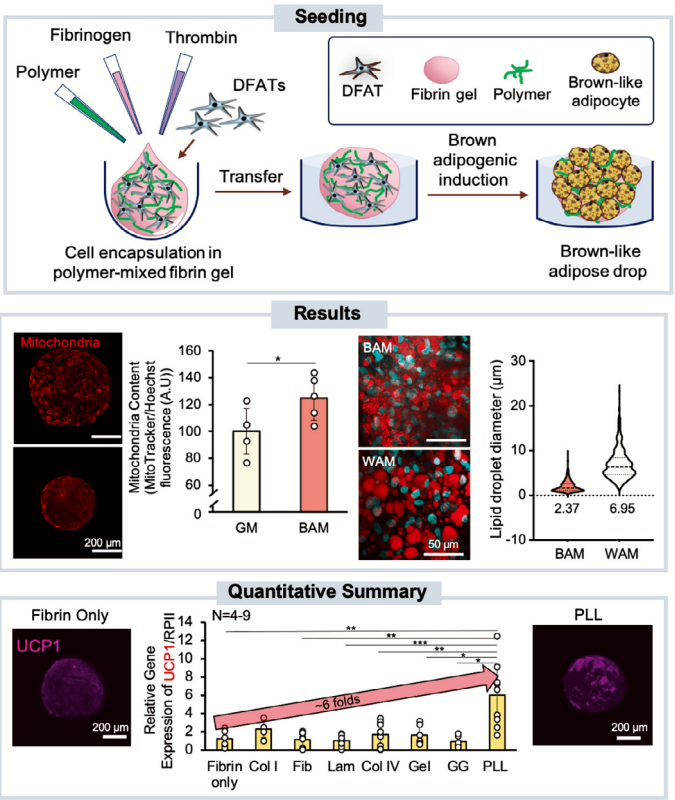
Background & Results

Brown adipose tissue (BAT) dissipates energy as heat via UCP1, playing a key role in metabolic homeostasis. When mature adipocytes are cultured under ceiling conditions, they lose cytoplasmic lipids and acquire fibroblast-like morphology, giving rise to dedifferentiated fat (DFAT) cells. These DFATs exhibit mesenchymal stem cell–like features and retain strong adipogenic potential, making them an excellent model for investigating white-to-brown adipocyte conversion.

In this study, DFATs embedded in fibrin gels were induced toward brown adipogenesis using a brown adipogenic medium (BAM) containing thyroid hormone (T3), insulin, and supplemented polymers. Morphological and molecular analyses demonstrated that, compared to white adipogenic differentiation medium (WAM), BAM induced smaller, multilocular lipid droplets and higher mitochondrial density, consistent with BAT-specific characteristics. Among the tested polymers, poly-L-lysine (PLL) markedly upregulated UCP1, PGC-1α, and CIDEA expression, confirming brown-specific differentiation. Quantitative analyses showed ~6-fold higher UCP1 mRNA, and higher UCP1 protein relative to fibrin-only gels. Oxygen consumption over 24 h was significantly increased, indicating enhanced metabolic activity. Overall, these findings demonstrate that PLL promotes efficient brown adipogenic differentiation of DFATs through electrostatic enrichment of key hormonal factors at the cell interface.

Significance of the research and Future perspective

This work identifies PLL as a simple, biocompatible polymer that enhances brown adipogenic induction through local retention of hormonal inducers rather than genetic manipulation or chemical browning agents. The approach enables a reproducible, controllable model for studying thermogenic adipogenesis and metabolic regulation. Incorporating PLL into 3D tissue constructs or co-culture systems may further improve functional adipose tissue engineering. Future research will apply this strategy to scaffold design and translational models addressing obesity and metabolic disease.



Patent
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