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Polyhydroxyalkanoates as a Kidney Tissue Engineering Scaffold

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Introduction

Kidney failure resulting from acute kidney injury (AKI) and chronic kidney disease (CKD) damages the glomerulus, which is responsible for filtering the blood in the kidney [1]. Existing treatments like hemodialysis are unable to fully replicate the normal functions of a healthy kidney, and the availability of kidneys for transplantation is limited. Therefore, there is significant interest in developing a bioartificial filtration barrier that incorporates living kidney cells. This study focuses on exploring the potential of Polyhydroxyalkanoates (PHAs), which are polymers derived from bacteria, as a biomaterial for engineering a bioartificial glomerular filtration unit. PHAs are known to be biocompatible and widely used in various biomedical applications [2]. Two specific types of PHAs have been selected for evaluation, and their suitability for processing into fibers and woodpile structures has been investigated. Furthermore, the compatibility of these PHAs with human glomerular cells that have been conditionally immortalized has also been examined.

Experimental

PHA production was conducted using a 30 L fermenter, where a specific bacterial strain was supplied with fatty acids to produce a medium chain-length PHA (mcl-PHA), which has elastomeric properties, and glucose to produce a short chain-length PHA (scl-PHA), which is a stiffer variant of PHA [3]. The resulting polymers underwent thorough characterization to assess their thermal, chemical, and mechanical properties. In order to evaluate the biocompatibility of the PHAs, conditionally immortalized human podocytes (CIHP) and conditionally immortalized glomerular endothelial cells (ciGEnC) were used in monoculture and co-culture experiments [4, 5]. To engineer an in vitro model of the kidney filtration barrier, the PHAs were processed through electrospinning and 3D printing using Fused Deposition Modeling (FDM) techniques.

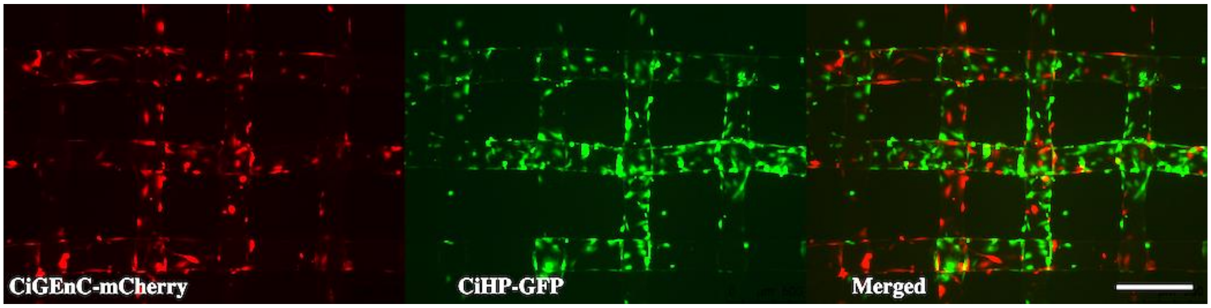

Figure 1. A co-culture of CIHP cells (shown in green) and ciGEnC cells (shown in red) was successfully achieved on a printed PHA strut. The scale bar in the image represents a length of 500 µm.

Results and Discussion

The cytocompatibility studies revealed that the PHAs demonstrated a high level of biocompatibility with glomerular cells. This finding highlights the potential of PHAs as a sustainable material for applications in kidney tissue engineering. The PHAs were produced through bacterial fermentation, resulting in a substantial yield of 40-80% dry cell weight. Tensile testing confirmed the elastomeric properties of the mcl-PHA and the stiffer characteristics of the scl-PHA. Electrospinning techniques were successfully employed to create a blend of scl-mcl-PHA fibers and the PHAs were printed precisely using FDM technology. These fabrication methods generated structures that supported the growth and differentiation of kidney glomerular cells, further demonstrating the suitability of PHAs for three-dimensional culture of glomerular cells.

Conclusions

Our findings provide evidence that the various fabrication techniques employed for PHAs led to the creation of fibres and structures that effectively facilitated the adherence, growth, and differentiation of kidney cells. This approach holds great promise in the development of a highly functional bioartificial kidney filtration barrier. Moving forward, the bioartificial filtration barrier that we have developed will undergo further evaluation to determine its potential as an *in vitro* model of the kidney glomerulus.

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Biography

Syed Mohammad Daniel Syed Mohamed is a PhD student from the Department of Materials Science and Engineering, The University of Sheffield, Sheffield, United Kingdom. He has over 8 years of experience in materials science, and characterization, focusing on biopolymer called polyhydroxyalkanoates (PHAs). He authored and co-authored in 6 papers in peer-reviewed journal during his studies on PHAs as biomaterial. His PhD is funded by The Government of Malaysia under a scholarship programme called “Excellence Student Programme”.