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Novel soy protein scaffolds for tissue regeneration: Material characterization and interaction with human mesenchymal stem cells

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ABSTRACT

Soy protein modified with heat treatment and enzyme crosslinking using transglutaminase in maltodextrin was used to fabricate novel, porous three-dimensional scaffolds through lyophilization. Physical properties of scaffolds were characterized using scanning electron microscopy, mercury intrusion porosimetry, moisture content analysis and mechanical testing. Human mesenchymal stem cells (hMSC) were seeded and cultured in vitro on the scaffolds for up to 2 weeks, and changes in stem cell growth and morphology were examined. The resulting scaffolds had rough surfaces, irregular pores with size distributions between 10 and 125 μm, <5% moisture content and compressive moduli ranging between 50 and 100 Pa. Enzyme treatment significantly lowered the moisture content. Increasing amounts of applied enzyme units lowered the median pore size. Although enzyme treatment did not affect the mechanical properties of the scaffolds, it did increase the degradation time by at least 1 week. These changes in scaffold degradation altered the growth and morphology of seeded hMSC. Cell proliferation was observed in scaffolds containing 3% soy protein isolate treated with 1 U of transglutaminase. These results demonstrate that controlling scaffold degradation rates is crucial for optimizing hMSC growth on soy protein scaffolds and that soy protein scaffolds have the potential to be used in tissue engineering applications.

1. Introduction

Tissue engineering involves the fabrication of constructs which aid in the repair and regeneration of damaged tissue, providing proper structure, function and integration with the host tissue. One frontier of tissue engineering lies in using a biomaterial scaffold to deliver cell-based therapy. Porous scaffolds provide three-dimensional microenvironments, which can mimic the extracellular matrix and can allow for cell infiltration and space for matrix deposition by cells to form new tissue. An ideal scaffold material should stimulate the formation of tissue which is structurally and functionally robust, while being safe and cost-efficient to obtain, process and manufacture [1,2]. The use of natural proteins to form biomaterials is an attractive therapy because of the ability of the natural material to control stem cell adhesion and growth through inherent binding sites. Human mesenchymal stem cells (hMSC) seeded on collagen and silk protein scaffolds have been shown to proliferate and differentiate into osteoblasts and chondrocytes that were fully functional, biocompatible and able to form tissues resembling native tissue structure and function [3,4].

Soy protein, an isolated component of the soybean, has recently emerged as an attractive alternative to animal-derived protein sources for biomedical applications. The US has led the world production of soybeans for over 50 years, generating 81 million metric tons in 2008 [5]. Soybeans are a natural and abundant resource, which contains 40% pure protein [6]. Two major subunits in the globular structure of soy protein include conglycinin (7S) and glycinin (11S), which contain all amino acids but are rich in glutamate, aspartate and leucine [6]. Soy protein exhibits versatility in processing and is shown to have good biodegradable and biocompatible qualities [7–13].

Different processing strategies of soy protein have been developed to alter its material properties. Thermal and chemical modifications have the capability of tailoring bulk and surface properties during the fabrication of soy structures [10,12]. Heat treatment of soy protein has been shown to induce thermoplasticity, which allows a wide variety of shapes and structures to be formed, including films, granules/pellets and gels [9,13–15]. Glyoxal and tannic acid have been used to extend degradation times of extruded soy protein pellets [12], and soy protein films crosslinked with varying amounts of formaldehyde were capable of controlling model drug release [13]. Transglutaminase, a physiological

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