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Non-conventional supercritical fluids as solvents for biomaterial processing

Gregor Kravanja[1,2], Željko Knez[1,3], Mateja Primožič[1], Maja Leitgeb[1,3*],
1 University of Maribor; Faculty of Chemistry and Chemical Engineering; Laboratory of separation processes and product design; Smetanova ul. 17; 2000 Maribor; Slovenia

2 University of Maribor; Faculty of Civil Engineering, Smetanova ul. 17; 2000 Maribor; Slovenia

3 University of Maribor, Faculty of Medicine, Taborska ulica 8, 2000 Maribor; Slovenia

**Corresponding author E-Mail: maja.leitgeb@um.si*

1. Introduction

The demand for new products with special features and the design of new sustainable technologies is shifting the industrial processes towards high pressure [1]. Absorption of supercritical fluids in polymer matrices results in a wide spectrum of possible applications in the field of biomaterial processing, such as production of fibers, microparticles, and foams [2]. Using supercritical fluids as blowing agents for the fabrication of polymeric foams provides certain advantages. For example, they enable control of the pore size and distribution of pores by selecting suitable processing conditions, including temperature, depressurization rate and solubilization pressure (gas concentration in the polymer) [3]. Substances beyond a specific temperature and pressure (the critical point) become a supercritical fluid, a state with fine-tuned properties. Typical thermophysical properties of supercritical fluids are low viscosity, high diffusivity, density and the dielectric constant of the supercritical fluid, which can easily be changed by varying the operating pressure and/or temperature (Figure 1). Supercritical CO_2 is an ideal gas since its supercritical conditions (304 K, 7.38 MPa) are easily attained and can be easily removed from the processed material by simple depressurization [4].

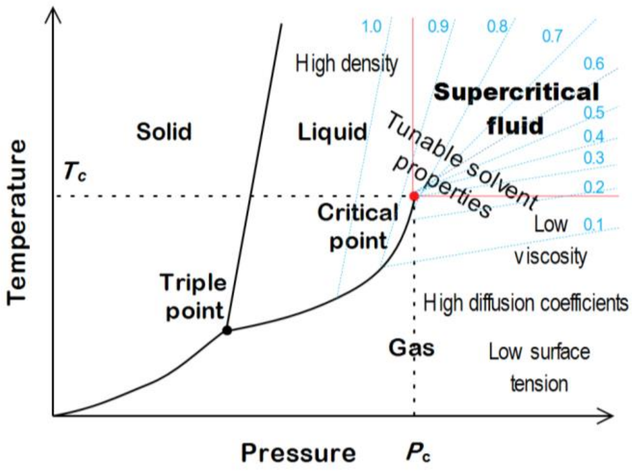

Figure 1: P-T diagram for supercritical fluid with typical thermophysical properties.

2. Methods

Porous biomaterial composites have been fabricated in a high-pressure view cell made of stainless steel (Sitec AG, Zurich, CH) designed to operate up to a pressure of 50 MPa and a temperature of 423 K. The pressure inside the cell was measured by an electronic pressure gauge (WIKA Alexander Wiegand GmbH & Co. KG, Germany). The temperature of the cell was kept constant using a heating jacket and was observed using a calibrated thermocouple immersed in the cell. The uncertainty of the pressure was 0.01 MPa and the total uncertainty of the temperature was 0.1 K. Supercritical CO_2 has been proposed both as a mixing environment for obtaining new porous composite biomaterials and as a plasticizer for processing under mild temperatures. Sensitive bioactive molecules have been introduced in the high-pressure reactor during biomaterial processing stages.

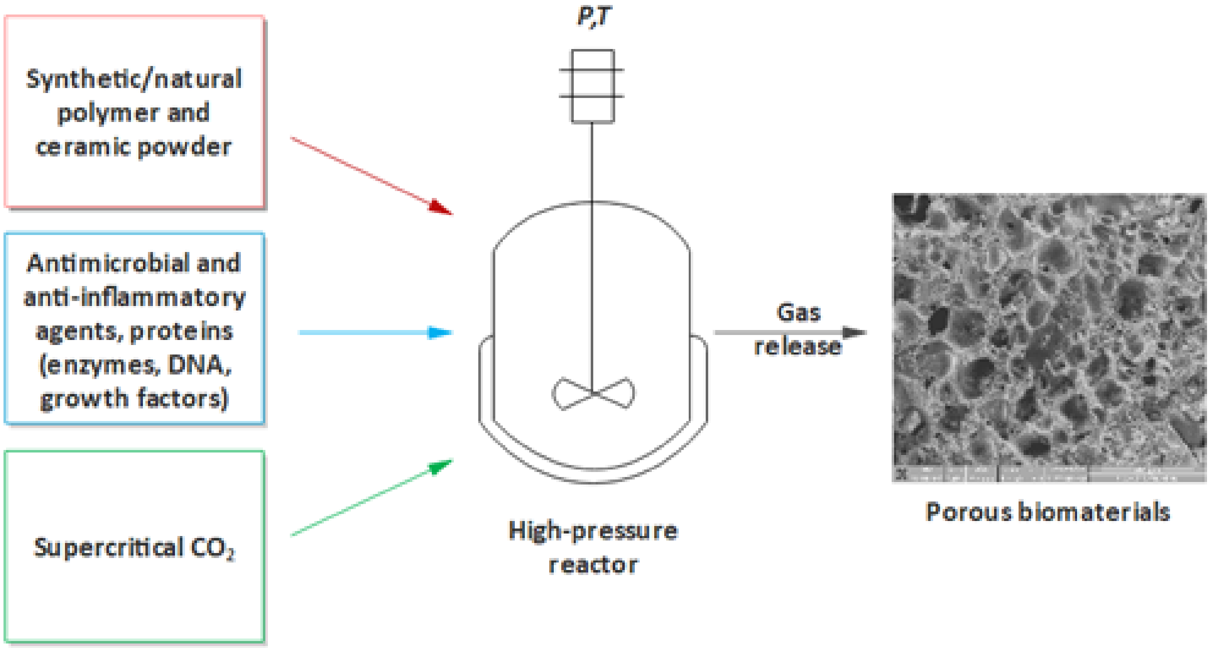

Figure 2: Preparation of high-value porous scaffolds using supercritical CO_2.

3. Results and discussion

The porous structure of composite scaffolds was fabricated by the supercritical CO_2 foaming technique at 15.5 MPa and 310.15 K. For the pore growth period, a constant depressurization rate of 0.6 MPa/s was selected. Increasing pressure results in a higher rate of dissolved gas in the biomaterial matrix, which creates more nuclei and decreases the number of suitable pore sizes for tissue engineering. Obtained scaffolds possess a porous microstructure with high porosity (exceeding 70%) and, in many cases, a large open pore geometry, that allows enough space for the growth of cells and channels for nutrient transport, a suitable pore sizes, sufficient mechanical compressive strength and stability of entrapped model bioactive compounds (proteins, drugs). Biodegradability, biocompatibility and proper degradation rate of scaffolds match the rate of the neo-tissue formation.

4. Conclusions

In most current technologies for the preparation of scaffolds, toxic solvents such as chloroform or methylene chloride are used to dissolve a biomaterial, elevated temperatures are applied to melt material, and high mechanical agitation of the solution is required. Using non-conventional supercritical fluids as green solvents could provide an excellent non-toxic alternative for biomaterial processing.

References

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