LIQUID-SOLID CIRCULATING FLUIDIZED BEDS: AN IMMOBILIZED BIOREACTOR SYSTEM FROM A PRODUCT INHIBITION PERSPECTIVE.

Umang J. Trivedi, Amarjeet S. Bassi, Jesse Zhu*
The University of Western Ontario
London, ON N6A 5B9, Canada
Tel.: (519) 661 2111, Extn. 88324; Fax : (519) 661 3498, E-mail : abassi@uwo.ca

ABSTRACT

In this investigation, soybean seed hull peroxidase enzymes were immobilized within the sol-gel/calcium-alginate matrix to produce artificial phenolic polymers from the phenolic waste streams. The soybean peroxidase enzymes are having a rapid ability to polymerize phenols in the presence of hydrogen peroxide. The produced polymers are having comparable properties with the phenol-formaldehyde resins. This enzymatic property has been investigated to produce a value-added product from the waste streams. The phenolic resins are widely used in the automotive sector, aircraft construction, building construction, mechanical equipment industries, and refractory industries. However, in many areas applicability of phenolic resins is restricted due to the toxic nature of formaldehyde. The proposed enzymatic process can eliminate the usage of formaldehyde solvent and the reaction conditions are much milder than the conventional technique.

In order to use the enzymes for a long time, they are immobilized within the porous matrix. However, it has been observed that the product phenolic polymer form a black layer coating on/within the biocatalyst and the enzymatic activity is decreased drastically within a short time. To overcome the product inhibition, a liquid solid circulating fluidized bed system has been proposed and studied for this enzymatic reaction. This system will allow a simultaneous reaction and a regeneration of the biocatalysts.

EXPERIMENTAL

Figure 1 shows an experimental set up of the liquid-solid circulating fluidized bed system. It consists a riser, a downcomer, a liquid-solid separator, a top and a bottom connection lines between the riser and the downcomer, a top washing section and a bottom washing section. In this study, the height of the riser is 4.0 m and 38 mm in a diameter. The downcomer is 3.5 m high and 120 mm in a diameter. In this system, a riser is a fast fluidization vessel. In the riser, the particles containing the soybean peroxidase enzymes were carried in a cocurrent fashion by the combination of the main liquid stream and an auxiliary liquid stream. In order to transfer the particles from the riser to the downcomer, a total liquid velocity must be kept above the terminal velocity of the particles. The particles were transferred in the downcomer from the top of the riser through a liquid-solid separator.

A downcomer is a conventional fluidization vessel and here the liquid velocity was kept just enough to fluidize the particles. It should be lower than the terminal velocity of the particles. The particles will travel in a downward direction in the downcomer and the liquid was

injected at the bottom of the downcomer through a designed distributor. Likewise, a downcomer will operate in a counter current fashion and the particles will be continuously circulated between the riser and the downcomer. An auxiliary liquid stream will control the circulation rate of the particles.

The pressure balance of the system is very important to establish a steady state hydrodynamic operation in a liquid-solid circulating fluidized bed system. The dynamic seals formed at the top washing section and at the bottom washing section will separate the two liquid streams of different properties in this system. The wash water liquid streams are critical in order to establish the dynamic seals.

RESULTS AND DISCUSSION

The phenolic stream was injected in the riser and a hydrogen peroxide stream was injected as an auxiliary liquid stream in the riser. The particles were carried in the upward direction in a plug flow manner and the immobilized SBP enzymes (biocatalysts) in the riser polymerized the phenols. Almost 60% phenols were polymerized in the riser and the particle activity was monitored at the outlet of the riser. Figure 2 shows the continuous profile of this operation. The particle velocity was 0.65 cm/s in the riser. The initial drop in the particle activity indicates the deactivation of the biocatalysts. During the enzymatic polymerization, the black polymeric layer was deposited on the biocatalysts. In order to remove the polymeric layer biocatalysts were transferred in the regenerator (downcomer) through a liquid-solid separator. A molar ratio of phenol to hydrogen peroxide was maintained to 1:2 in the riser and an initial substrate concentration was 1 mmol in this experimental study. The maximum biocatalysts holdup in the riser is a function of an auxiliary liquid stream and a main liquid stream, a total inventory of the biocatalysts in the system and a static bed height of the biocatalysts in the downcomer.

Figure 3 shows a regeneration profile in the downcomer, where the diluted ethanol stream was injected at velocity of 0.2 cm/s to wash the particles. A total inventory of the biocatalysts in the system was approximately 10 kg and a static bed height of the biocatalysts in the downcomer was 1 m. The particle samples were collected at a different level of height in the downcomer and the activity was measured by using a guaiacol as a substrate. In presence of hydrogen peroxide, the biocatalysts can convert a guaiacol into a tetraguaiacol. This reaction (the change in color from colorless to dark brown) was monitored in the spectrophotometer by using a 3ml capacity polystyrene cuvette at 420 nm wavelength.

The Figure 4 indicates an operating window of the system. It shows that the particle velocity in the riser is a function of the total liquid velocity. The Figure 5 shows the biocatalysts holdup versus the total liquid velocity profile with a varying particle velocity. At a constant particle velocity, the biocatalysts holdup was reduced with increasing the liquid velocity in the riser.

FIGURES

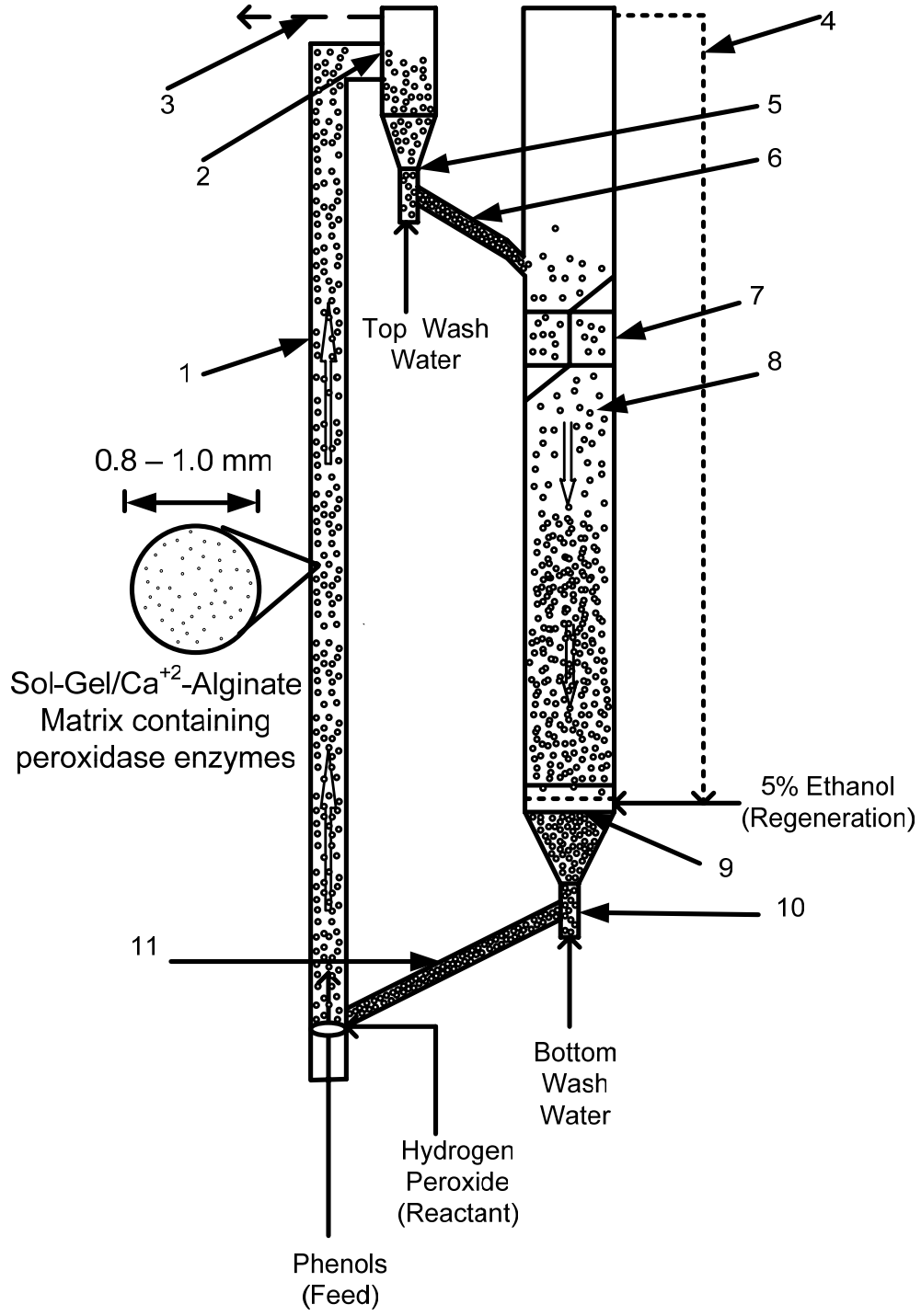

Figure 1: Schematic of a Liquid-Solid Circulating Immobilized Bioreactor System. 1) riser; 2) liquid-solid separator; 3) liquid outlet of the riser vessel; 4) liquid outlet of the downcomer vessel; 5) top washing section; 6) top particles returning line; 7) particle circulation measuring device; 8) downcomer; 9) distributor for the liquid inlet; 10) bottom washing section; 11) bottom particles returning line.

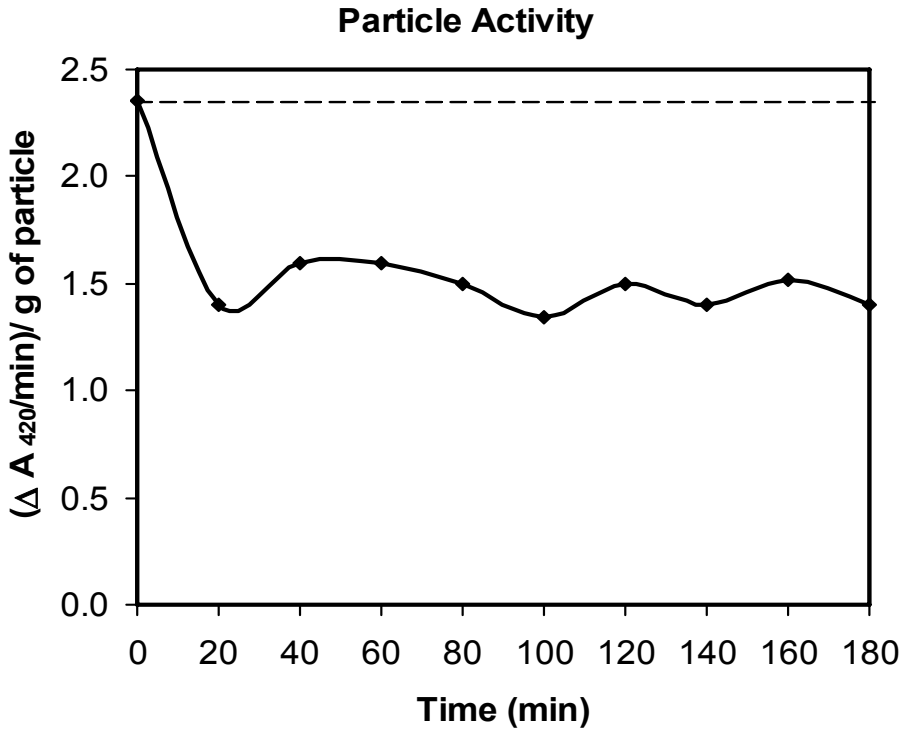

Figure 2 : A continuous operation in the LSCFB System. Particle activity measured at the outlet of the riser (4.0 m height).

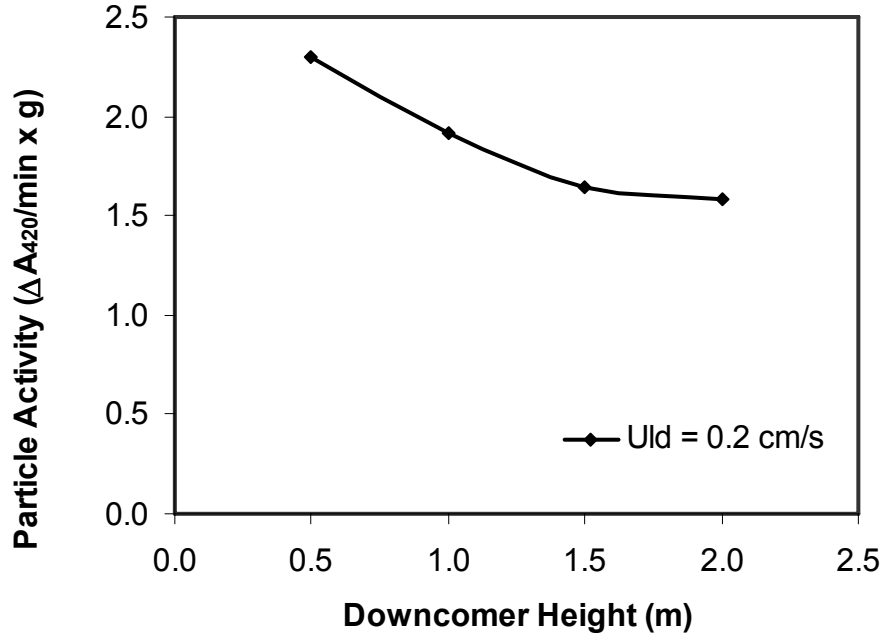

Figure : 3 A continuous regeneration operation in the downcomer.

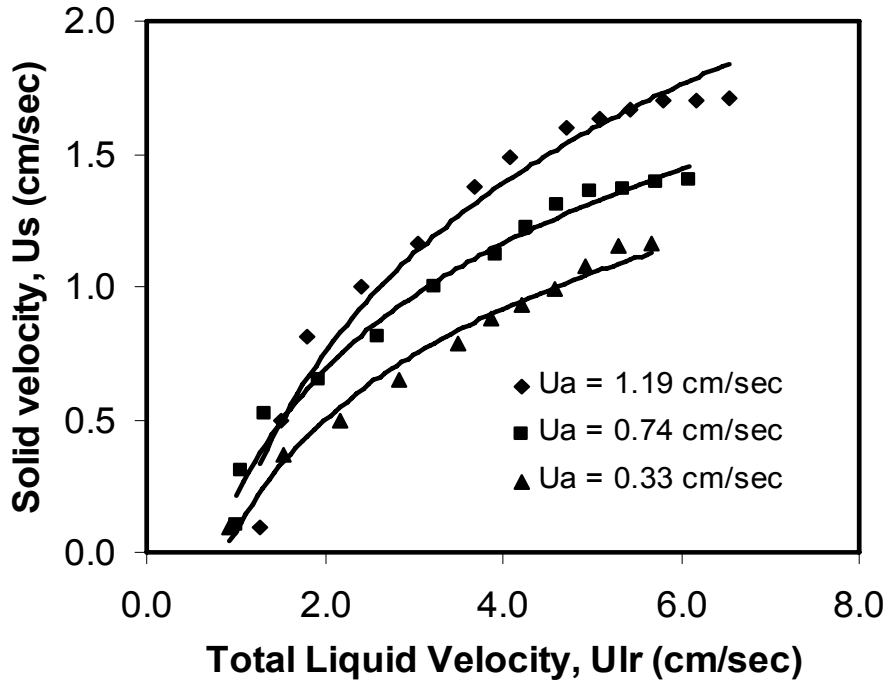

Figure : 4 An operating window for the LSCFB System. Particle velocity profile as a function of total liquid velocity with varying an auxiliary liquid stream.

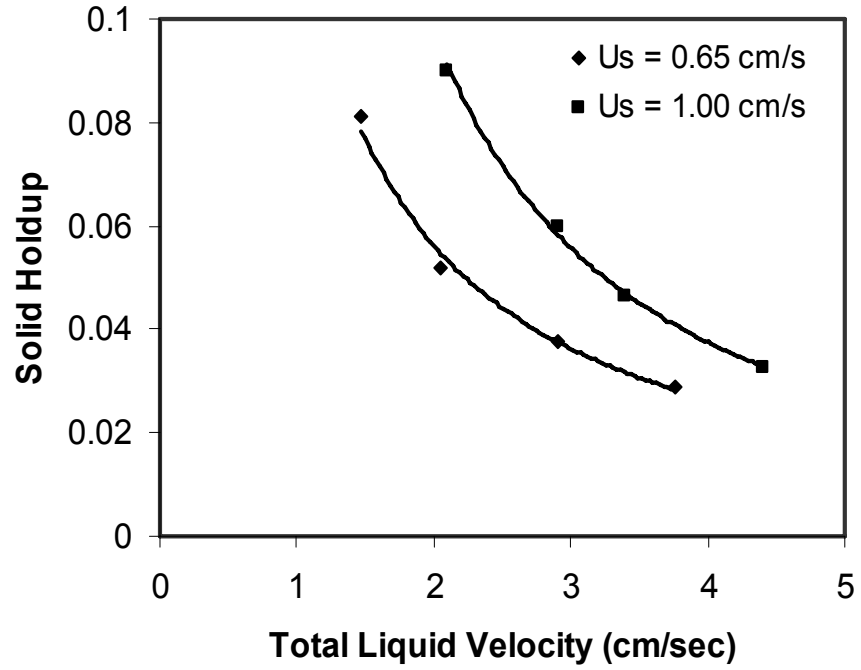

Figure : 5 Biocatalyst holdup in the riser as a function of total liquid velocity with varying a solid velocity in the riser.