ELECTROMICROFILTRATION FOR SEPARATION OF MINERAL PARTICLES IN DAIRY PROCESSING

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Abstract

Electromicrofiltration, where an external electric field is imposed on a traditional microfiltration unit, has been studied for several years. Reports in this field have covered the filtering separation of china clay, kaoline, anatase and a surfactant from water. Some recent investigations concerning the utilization of electromicrofiltration for bioseparations has led to a growing interest in applying this method to dairy processing. The objective of this work was to explore the characteristics of an electromicrofiltion unit and examine the potential of utilizing this for mineral (calcium phosphate) removal in the dairy industry. Two stainless steel membranes with nominal pore sizes of 5μm and 25μm, respectively, were used in this study. This material provides the membrane with some unique properties such as electrical conductivity; resistance to high pressure operation and backflushing; and resistance to chemical cleaning agents. Alamin particles, a by-product separated from whey, was used as the primary feed particle. The average particle size is about 5μm and the chemical composition is mainly calcium phosphate. Another particle, calcite (calcium carbonate), was used for comparison. Experiments were performed on a laboratory electromicrofilter (the tubular membrane dimension is 380mm in length and 13.5mm in diameter) in which the voltage(0-50V) and current (0-3A), transmembrane pressure (0-250kPa), and crossflow velocity (0-3m/s) could be measured and controlled.

Between 20% ~ 100% transient improvement in permeate flux was obtained when an electric field was applied. For example, the permeate flux increased from 120LMH to 165LMH at the condition of 50kPa transmembrane pressure, 36V/cm electric field strength and 2.28m/s crossflow velocity, in which the membrane was negatively charged and the solution was pH=7. This polarity was used because the zeta potentials for most of the colloid or particulate material in the dispersed system are generally negative in the normal pH range (pH=4~8). The permeate flux gain was largely voltage and particle concentration dependent. The principle of this was further studied and two mechanisms influencing flux were identified: (1) the electricstatic repulsion to the particles or colloids by the charged membrane; and (2) the displacing effect of the cathodic gas bubble on the deposited particles. Microscopic examination showed that the electrophoretic speed of Alamin particles around 1μm in size under 36V/cm electric strength was ~43μm/s. However, continuous application of the electric field was found raised the permeate to pH 11 or higher; this appeared to reduce the solubility of calcium salt in the solution, and eventually caused more severe fouling as fine particles precipitated and obstructed the membrane. Therefore pulsatile application of electric field is recommended. On the other hand, formation of the gas bubbles caused an additional false permeate increase of about 25(LMH) for a 1A membrane current in this electromicrofiltration unit.

Using a positively charged membrane, in contrast, acidified the permeate to pH 3~3.5 and resulted in dissolution of the deposited calcium salts. For this reason the steady state permeate flux was improved. For example, the permeate flux for the Alamin solution (0.7%w/v) was 103(LMH) at 100 mins after filtration start if no electric field was applied, but at the same condition the permeate flux was 190(LMH) if the membrane was positively charged at 33V/cm field strength. However, the anodic corrosion was evident if chloride ion (Cl^-) was proved above a minimal valum in the solution. This hamful aspect had been emphsised in this research, and the use of a titanium anode is suggesed to avoid corrosion in the future studies. Moreover, anodic oxidation and its potential to change the chemical nature of the filtrated substance must be take into consideration when applying electriofiltration in a bioseparation processes.

A hydrodynamic analysis revealed that the flow pattern over the whole membrane module was fully developed turbulent flow at 2.28m/s crossflow velocity. The thickness of the laminar sub-layer on the membrane wall was about 81μm, which is roughly one order larger than the mean particle size in this study. The drag force acting on a deposit particle was estimated as 2.33×10^{-9} (N), which is 230 times higher than the static electric field force, and the electric field repulsing force acting on a deposit mean size particle is 9 times higher than the particle self weight. The sum of these forces inhibited the particle from depositing on the membrane surface. Considering that the nominal membrane pore sizes used (5μm and 25μm, respectively) was relatively large (around 0.2-1μm only for normal MF) and the particle size distribution, the fouling mechanism is more likely to be pore plugging rather than the cake formation on the surface.

Investigation of cleaning methods showed that the effectiveness of backflushing was basically pressure dependent. A 30kPa backflushing pressure restored 85% of filtration performance for the 25μm membrane; and a stop-and-restart operation(in which about 15mm H_2O column backpressure was provided by the permeate) restored approximately 60% of its filtration performance. However over 250kPa backflush pressure was needed to restore 85% of filtration performance on the 5μm membrane. Use of backflushing can greatly reduce the consumption of chemical cleaners and it is recommended the membrane be charged as an anode when performing the backflushing operation. This can be an effective alternative to acid cleaning if the backflushing water has less than 0.1ppm chloride ion content.

Lastly the formation of the cathode deposit on the membrane as the electric field was applied was observed to act as a 'formed-in-place' dynamic filtering layer, and its potential application may be worth investigation in a future study.

Keyword: membrane; sintered stainless steel; microfiltration; electrofiltration; separation; electric field; dairy processing

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