Abstract

A closed-loop system controls plasma-protein precipitation in real time by combining at-line and in-tank analytics with adaptive reagent dosing. A sanitary slip-stream loop draws liquor from a temperature-controlled precipitation vessel through a flow-cell that houses at least one optical solids-proxy sensor—turbidity, laser-diffraction or ultraviolet absorbance—and at least one non-optical sensor—ultrasonic attenuation, acoustic-resonance or dielectric spectroscopy.

Signals are fused by a confidence-weighted algorithm to yield a precipitation-percentage estimate, \hat{P}\%, which is compared with a programmable set-point. A controller modulates a reagent-metering pump by model-predictive, rule-table or pulse-width-modulated logic to reach the target while minimising over-dose. Filtration readiness is verified downstream by monitoring the slope of trans-membrane pressure; liquor is automatically recycled when fouling rates exceed a defined threshold. Embodiments include tri-sensor ultraviolet clarification, temperature-ramped ethanol cuts, dual pH-shift / polyethylene-glycol cascades, cloud-supervised digital-twins and self-testing disposable cartridges, thereby improving protein yield, solvent economy and GMP traceability.