Response surface methodology directed modeling of the biosorption of progesterone onto acid activated *Moringa oleifera* seed biomass: Parameters and mechanisms

Abstract

In this study, chemically activated fat-free powdered *Moringa oleifera* seed biomass (*MOSB*) was synthesized, characterized, and utilized as a cost-effective biosorbent for the abstraction of progesterone (PGT) hormone from synthetic wastewater. Natural PGT is a human steroid hormone from the progestogen family. Synthetic PGT is approved for the regulation of the menstrual cycle, aiding contraception, and is administered as a hormone replacement therapy in menopausal and post-menopausal women. PGT is an endocrine disrupting chemical (EDC) with negative health impacts on biota. The X-ray diffractogram (XRD), Scanning electron microscopy-Energy-dispersive X-ray spectroscopy (SEM-EDS), and Brunauer–Emmet–Teller (BET) analyses displayed a porous, amorphous biosorbent with an elemental composition of 72.5% carbon and 22.5% oxygen and a specific surface area of 210.0 $m^2\ g^{-1}$. The process variables including temperature (298–338 K), pH (2–10), contact time (10–180 min), adsorbate concentration (20–500 μg L^{-1}), and adsorbent dosage (0.1–2.0 g) were optimized using response surface methodology (RSM) to obtain the greatest efficacy of *MOSB* during biosorption of PGT. The optimum parameters for PGT biosorption onto *MOSB* were: 86.8 min, 500 μg L^{-1} adsorbate concentration, 298 K, and 0.1 g adsorbent dosage. PGT removal from aqueous solutions was pH-independent. The Langmuir isotherm best fitted the equilibrium data with maximal monolayer biosorption capacity of 135.8 μg g^{-1}. The biosorption rate followed the pseudo-first-order (PFO) kinetic law. The thermodynamic functions ($\Delta G < 0$, $\Delta H = -9.258$ kJ mol^{-1} and $\Delta S = +44.16$ J mol^{-1}) confirmed that the biosorption of PGT onto *MOSB* is a spontaneous and exothermic process with increased randomness at the adsorbent surface. The biosorption mechanism was physisorption and was devoid of electrostatic interactions. The findings from this study indicate that *MOSB* is an inexpensive, low-carbon, and environmentally friendly biosorbent that can effectively scavenge PGT from aqueous solutions.

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