OPTIMIZATION OF OIL PALM EMPTY FRUIT BUNCH FIBER COMPOSITION AS AN ADSORPTION UNIT IN PALM OIL MILL EFFLUENT TREATMENT

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ABSTRACT

FRANS EDVAN SETIAWAN. Optimization of Oil Palm Empty Fruit Bunch Fiber Composition as an Adsorption Unit in Palm Oil Mill Effluent Treatment. Supervised by ALLEN KURNIAWAN and SITI NIKMATIN.

The large volume of waste generated by the palm oil industry in Indonesia, consisting of approximately 23% Oil Palm Empty Fruit Bunches (OPEFB) and 65% Palm Oil Mill Effluent (POME), presents a significant environmental challenge. Waste reduction was conducted by integrating a physical process (adsorption using OPEFB) with a biological process (modified AnRBC) for POME treatment. The composition of OPEFB (spikelet and stalk) in the adsorption unit and the HRT in the AnRBC unit were varied. The 75:25 (spikelet:stalk) composition achieved the highest O&G removal efficiency (50.44%), while 25:75 showed the highest SCOD removal (8.09%). Kinetic modeling indicated that the Pseudo-First-Order (PFO) model outperformed other models, supported by higher Pearson correlation. Validation using actual effluent data confirmed its suitability, with Spearman's Rho showing weak to strong correlations and ANOVA revealing no significant differences. The PFO model further demonstrated that the 75:25 composition had higher adsorption capacity (69.563 mg/g O&G; 223.335 mg/g SCOD), while the 25:75 composition had higher adsorption rates (0.219 1/d O&G; 0.008 1/d SCOD).

***Keywords*:** oil and grease (O&G), pseudo-first-order, SCOD, spikelet, stalk

ABSTRACT

FRANS EDVAN SETIAWAN. Optimization of Oil Palm Empty Fruit Bunch Fiber Composition as an Adsorption Unit in Palm Oil Mill Effluent Treatment. Dibimbing oleh ALLEN KURNIAWAN dan SITI NIKMATIN.

Tingginya volume limbah yang dihasilkan oleh industri kelapa sawit di Indonesia, yang terdiri atas sekitar 23% Tandan Kosong Kelapa Sawit (TKKS) dan 65% Limbah Cair Kelapa Sawit (LCKS), menjadi masalah bagi lingkungan. Upaya pengurangan limbah dilakukan dengan mengintegrasikan proses fisik (adsorpsi menggunakan TKKS) dan proses biologis (modifikasi AnRBC) untuk pengolahan LCKS. Penelitian ini memvariasikan komposisi TKKS (spikelet dan stalk) dalam unit adsorpsi serta HRT dalam unit AnRBC. Komposisi 75:25 (spikelet:stalk) menghasilkan efisiensi penurunan O&G tertinggi (50,44%), sementara komposisi 25:75 menunjukkan penurunan SCOD tertinggi (8,09%). Pemodelan kinetika menunjukkan bahwa model Pseudo-Orde-Pertama (PFO) memiliki kinerja terbaik dibandingkan model lainnya, ditunjukkan oleh nilai korelasi Pearson yang lebih tinggi. Validasi dengan data efluen juga menunjukkan kesesuaian, didukung nilai korelasi Spearman's Rho lemah-kuat dan ANOVA tanpa perbedaan signifikan. Model PFO juga menunjukkan bahwa komposisi 75:25 memiliki kapasitas adsorpsi lebih tinggi (69,563 mg/g O&G; 223,335 mg/g SCOD), sementara komposisi 25:75 memiliki laju adsorpsi lebih tinggi (0,219 1/hari O&G; 0,008 1/hari SCOD).

Kata kunci: minyak dan lemak, pseudo-orde-pertama, SCOD, spikelet, stalk

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PREFACE

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C_0, C_t, and C_e	= The liquid-phase concentration of O&G at initial, at any time, and at equilibrium (mg/L)
V	= Volume of the POME (L)
m	= Mass of the OPEFB (g)
q_e and q_t	= Adsorption capacity at equilibrium and any time (mg/g)
$S(\theta)$	= Objective function, which quantifies the total error as the sum of squared residuals
Y_i	= Actual observed value at the i-th data point
$f(X_i,\theta)$	= Model-predicted value at input point X_i with parameter vector θ
n	= The total number of observations
θ	= Parameter vector to be estimated
x_i and y_i	= Individual data points from two variables
$\bar{x}, \bar{y}$	= Mean of the observed values
k_1, k_2, and k_3	= The PFO (1/d), PSO (g/mg.d), PTO rate constant (g^2/mg^2.d)
$p(\lambda)$	= The parameter update vector for the next iteration
J	= Jacobian matrix of the residual function
λ	= Damping factor, adjusting the convergence rate
D	= Diagonal matrix implementing regularization control
f	= Residual factor
r	= Pearson correlation

GLOSSARY

Seeding	:	The process to grow and breed microorganisms that would be used in treating waste.
Acclimatization	:	A process that facilitates the adaptation of microorganisms to the waste being treated, enabling their survival and adjustment to new environmental conditions.
Biomass	:	The total mass of living and active microorganisms participating in anaerobic digestion plays a crucial role in the degradation of organic matter and biogas production.
Palm Oil Mill Effluent (POME)	:	An organic wastewater generated from the processing of oil palm fruits is characterized by high concentrations of dissolved organic matter, oil and grease, and suspended solids.
Oil Palm Empty Fruit Bunches (OPEFB)	:	A solid lignocellulosic biomass waste is generated after separating fruits from the bunch during palm oil processing.
Adsorption	:	A physicochemical process in which molecules of a substance (adsorbate) accumulate on the surface of a solid or liquid phase (adsorbent), without penetrating its internal structure.
Anaerobic Biological Contractor (AnRBC)	:	A biological wastewater treatment system that utilizes rotating discs covered with anaerobic biofilm to degrade organic matter without oxygen.
Biogas	:	A gas produced through the anaerobic fermentation of organic matter by microorganisms, primarily composed of methane (CH_4) and carbon dioxide (CO_2), is utilized as a renewable energy source.
Hydraulic Retention Time (HRT)	:	The average time that a fluid remains in a reactor or treatment unit is a critical parameter to ensure effective degradation or purification of wastewater.
Pseudo-First-Order (PFO), Pseudo-Second-Order (PSO), Pseudo-Third-Order (PTO)	:	Adsorption kinetic models are used to describe the rate and mechanism of sorption. The PFO model assumes that the adsorption rate is proportional to the number of unoccupied active sites. PSO model represents a chemisorption process dominated by chemical interactions and PTO model is employed to capture more complex kinetic behaviors.
Analysis of Variance (ANOVA)	:	The statistical test method used was suitable for comparing the means of three or more independent variable groups, allowing the determination of the effect of fiber type composition on O&G adsorption efficiency.