INNOVATIVE: Journal Of Social Science Research
Volume 4 Nomor 6 Tahun 2024 Page 8709-8716
E-ISSN 2807-4238 and P-ISSN 2807-4246
Website: https://j-innovative.org/index.php/Innovative

Study of The Mass Transfer Coefficient from Lignin Removal Process of Coffee Husk in a Baffled Reactor

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Abstrak

Metode delignifikasi organosolv menggunakan pelarut organik seperti etanol untuk menghilangkan lignin dari biomassa. Penelitian ini bertujuan untuk mengetahui koefisien perpindahan massa pada proses delignifikasi kulit kopi. Jamur busuk putih Phanerochaete chrysosporium digunakan untuk mendegradasi komponen lignin pada proses inkubasi biomassa sekam kopi, kemudian dilakukan proses hidrolisis asam dengan menggunakan asam sitrat untuk mendegradasi kandungan polisakarida (selulosa dan hemiselulosa). Proses penghilangan lignin dilakukan pada suhu 50°C, konsentrasi etanol 25%, kecepatan pengadukan (500-700 rpm) dan waktu pengadukan (30-180 menit). Efek perpindahan massa dievaluasi untuk variasi laju pengadukan dan waktu pengadukan. Hasil koefisien perpindahan massa (K_L a) berkisar antara 0,0550/s dan 0,6710/s. Hasil ini menunjukkan peningkatan waktu pengadukan dan laju pengadukan menyebabkan koefisien perpindahan massa semakin tinggi.

Kata Kunci: *Proses Penyisihan Lignin, Koefisien Perpindahan Massa, Jamur Busuk Putih, Organosolv*

Abstract

The organosolv method of delignification uses organic solvents such as ethanol to remove lignin from biomass. The aims of this research to determine mass transfer coefficient in the delignification process of coffee husk. The White rot fungus, *Phanerochaete chrysosporium,* was used to degrade lignin component in incubation process of coffee husk biomass, then acid hydrolysis process was carried out by using citric acid to degrade the polysaccharides content (cellulose and hemicellulose). The lignin removal process was conducted at temperature of 50°C, an ethanol concentration of 25%, stirring rates (500-700 rpm) and stirring time (30-180 minutes). The effects of mass transfer were evaluated for variation of stirring rates and stirring time. The results of mass transfer coefficient $(K_L a)$ ranged on 0.0550/s and 0.6710/s. This result indicates an increase in stirring time and stirring rate leads to a higher mass transfer coefficient.

Keywords: *Removal Lignin Process, Mass Transfer Coefficient, White Rot Fungus, Organosolv*

INTRODUCTION

The delignification process is the process of removing lignin. Mostly, the delignification process was carried out by using NaOH solution (King, 1982). Meanwhile, delignification process, which are uses NaOH solution, will not harmful to the surrounding environment. As an alternative process, which isn't effect the surrounding environment, there was an Organosolv method. The organosolv process was carried out by using the organic solution such as ethanol, acetic acid and phenol. Based on Kurniastiti (2012), the best results for delignification process using ethanol solution for solvents with the conditions were the process time of 150 minutes, ethanol concentration of 40% and the yield of 63.20%. Before and after the delignification process, lignin content approximately 196.5955 mg/l and 2.0995 mg/l, respectively. So, a 98.9% of lignin content was decreasing after the delignification process.

The application of eco-friendly technology such as using the biological processes. This process can used the ability of an organism, which is they can degrade lignin. Some of the white rot fungus has been tested for their ability to degrade lignin. The *Phanerochaete chrysosporium* fungus is a white rot fungus on the wood. This fungus produce extracellular enzymes LiP, MnP, and Laccase (Bajpai, 1999). Based on Fadilah (2008), the biodelignification process for corn stalks with white rot fungi can degrade the lignin content approximately 81.4%.

Mechanism of Solid-Liquid Mass Transfer

In this study, the mass transfer of solid liquid can be determine during the delignification process using ethanol as a solvent. The delignification process was carried out by mixing coffee husk biomass with ethanol solution at temperature of 50°C. The ethanol solution go through the gap between the fibers and effects the dissolution of ether bonds between the lignin molecules so the lignin can dissolve into the solvent. Based on Heradewi (2012), if the solvent concentration more higher, so it can make more easier for solvent to going through the fiber gaps. It also effect more faster the dissolution of bonding between lignin molecules, so the degradation of lignin is higher and the more dissolved lignin occurs.

Mass Transfer Coefficient

At a steady state condition, the velocity of mass transfer can be expressed by the equation (1): (Treyball,1981)

$$N_A = K_{L.} A \times \Delta C_A = K_{L.} A_s \times (Cs\text{-}C) \quad (1)$$

The mass transfer in solid-liquid extraction is a function of the two phases which contact each other due to the difference solute concentration between the two phases. The delignification process was batch process, while the mass balance as follows in equation (2) - (4):

$$\text{Rin} - \text{Rout} + \text{Rtransfer massa} = \text{R akumulasi} \quad (2)$$

$$0 - 0 + K_{L.} A \times (Cs\text{-}C) = \frac{dC.V}{dt} \quad (3)$$

$$K_{L.} A_s \times (Cs\text{-}C) = C\frac{dV}{dt} + V\frac{dC}{dt} \quad (4)$$

Assuming there is no change in volume with time, dV/dt = 0. The concentration of lignin in solids will be equal to the concentration of lignin in solution at an infinite time. So that the equation becomes:

$$V\frac{dC}{dt} = K_L . A_s x\,(C_s - C) \quad (5)$$

$$\frac{dC}{dt} = K_{LA}\,\frac{A_s}{V} x\,(C_s - C) \quad (6)$$

where, As/V = a, So the equation becomes down below:

$$\frac{dC}{dt} = K_L a\; x\,(C_s - C) \quad (7)$$

If they integrated at t=0 and t=t, then C=Co and C=Ct, the equation become:

$$\int \frac{dC}{C_s - C} = \int K_L a x\, dt \quad (8)$$

$$\ln\left[\frac{(C_s - C_o)}{(C_s - C_t)}\right] = K_L a\; x\; t \quad (9)$$

$$K_L a = \frac{1}{t}\; x \ln\left[\frac{(C_s - C_o)}{(C_s - C_t)}\right] \quad (10)$$

where N_A is Flux molal (mg/sec.cm^2); As is Surface area of solid (cm^2); a is Surface area of mass transfer per volume (cm^2/cm^3); K_La is Mass Transfer Coefficient (1/sec); t is Stirring time (sec); C_s is Concentration for saturated condition (mg/L); Co is Lignin Concentration at t = 0,5 hours (mg/L); C_t is Concentration of Lignin at t (mg/L).

RESEARCH METHOD

In this research, coffee husk waste was used for raw material. Ethanol and Citric Acid were the solvents for delignification and hydrolysis process. An aquadest also used for solvent. The instrument of stirred reactor shows in figure 1.:

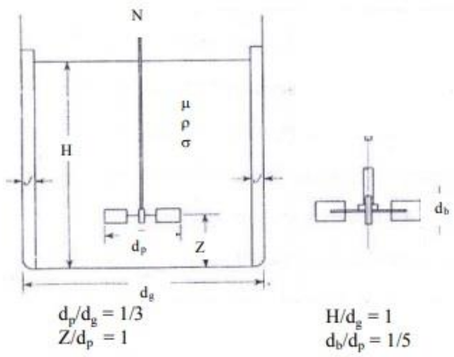

Figure 1. Illustration for Baffled Reactor

Preparation, the raw material biomass (coffee husk) was dried and analyzed for the composition. Incubation process, the dried biomass was incubated with white rot fungi for 5 days. Hydrolysis process, biomass was mixed with citric acid at temperature of 80˚C, speed of 600 rpm and stirring time of 75 minute. The solution was filtered, and precipitate was used for the next process. Delignification process, the precipitate was mixed with ethanol 25%. The different of speed (500, 600, 700 rpm) and different of stirring time (30-180 minutes) was used. The delignification solution was filtered and filtrate was tested for dissolved lignin concentration.

RESULT AND DISCUSSION

The lignin was degraded and transferred from solid/biomass to the ethanol as a solvent. To determine amount of lignin content that transfer to the solvent, Spectrophotometry instrument was used. The degradation of lignin concentration for different speed was obtained as shown at Table 1. Table 1 also shows that the longer of stirring time, the bigger lignin concentration will be taken during the delignification process. However, the concentration of lignin becomes constant, after 4 hours, due to no mass transfer occurs. The concentration of lignin was increased at 700 rpm compared to 500 rpm and 600 rpm. It occurs due to the increased of speed will make contact between ethanol (solvent) and the solid (coffee husk biomass) more effective, so it also effect to increase the mass transfer that occurs.

Table 1. The result of mass transfer coefficient for variations of stirring speed

Stirring speed (rpm)	Stirring time (minutes)	Lignin concentration (mg/L)	$K_L a$ (1/s)
500	30	25.80	0.0815
	60	29.80	0.1834
	90	30.30	0.2755
	120	31.00	0.3374
	150	34.60	0.4063
	180	38.10	0.5381
600	30	28.80	0.0550
	60	31.80	0.1104
	90	36.30	0.1004
	120	37.40	0.1587
	150	41.50	0.4738
	180	45.40	0.5500
700	30	28.60	0.0671
	60	33.60	0.1080
	90	38.90	0.1290
	120	42.70	0.2241
	150	48.80	0.5047
	180	51.80	0.6710

Equation (10) was used to determine the mass transfer coefficient. The higher lignin concentration will affect to mass transfer coefficient. The mass transfer coefficient was increased by the increasing of time. However, coefficient mass transfer value will be constant due to the no more mass transfer occurs from solid or biomass to solvent or ethanol.

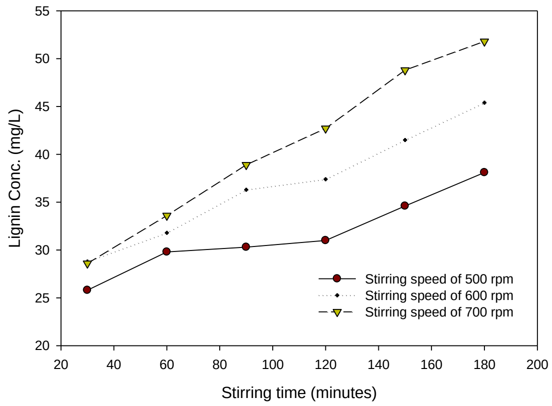

Figure 2. Effect of stirring time on delignification process
at stirring speed of 500, 600, 700 rpm

Figure 2. shows that the increasing time, it will affect to increasingly of lignin concentration. It is due to the longer stirring time will affect more and more lignin content transfer to the ethanol. So, degradation process was occurred. The highest lignin concentration of 51.80 mg/L was obtained by using speed of 700 rpm at stirring time of 180 minutes.

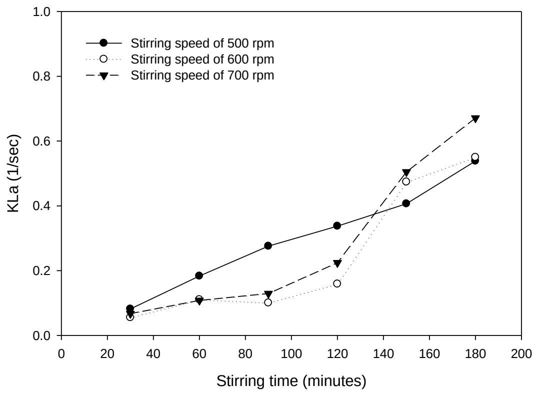

Figure 3. Effect of stirring time on mass transfer coefficient ($\boldsymbol{K_L a}$)
at stirring speed of 500, 600, 700 rpm

Figure 3. shows that the longer of stirring time, it affect to higher mass transfer coefficient. It's due to the length of time stirring has an effect on the mass transfer coefficient. However, at some point, the mass transfer coefficient was 0, due to the lignin concentration was constant so the mass transfer does not occur and no mass transfer coefficient value. The highest mass transfer coefficient (K_La) of 0.6710 was obtained by using speed of 700 rpm at stirring time of 180 minutes.

Variations in stirring speed affect the rate of solute transfer into the solvent due to the forced diffusion of the solute into the solvent body. The amount of solute transferred increases over the same time interval; however, this does not significantly reduce the mass transfer resistance, resulting in a relatively unchanged mass transfer coefficient. This can be observed in Figure 4.1, which illustrates that the effect of stirring speed on solute concentration acquisition over the same time interval is minimal, with the data points closely overlapping. This indicates that variations in stirring speed during the experiment have a negligible impact on the K_La value. The intended reduction of resistance in the film layer through stirring speed variation proves ineffective in altering the K_La value, as the film layer thickness has already reached its minimum, rendering the resistance nearly constant.

CONCLUSION

The mass transfer coefficient of delignification process was determined by using equation. The value of mass transfer coefficient was increased depend on the stirring time on the baffled reactor. Mass transfer coefficient also increases due to an increasing of stirring speed (rpm). The highest mass transfer coefficient of 0.6710/sec was achieved at stirring time of 180 minutes and stirring speed of 700 rpm.

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