ADSORPTION AND STRIPPING OF ETHANOL FROM AQUEOUS SOLUTION USING SEPABEADS207 ADSORBENT

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To my beloved family

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ABSTRACT

There is a problem of increasing of CO_2 and CO in environment from the use of fossil fuel. Ethanol is a good alternative fuel or additive to gasoline to improve octane number, using ethanol will decrease CO and CO_2 emissions. For these reasons, production of ethanol by fermentation is a promising solution. This work aimed to evaluate suitable technique of separation using adsorption method. Best conditions of adsorption and stripping processes were studied in this work. The ethanol solution with 10wt% concentration, i.e., similar to the product of fermentation process was used as feed. The separation was occurred in adsorber tube containing polymer Sepabeads207 at different temperatures (20 – 40°C), also (pH) (4 – 7), time of adsorption (5 – 25 minutes). Also time of stripping (desorption) was studied between 15 and 35 minutes at different temperatures of air (80 – 95°C). The evaporated ethanol was condensed by cold water and the concentration of liquid ethanol was measured using refractometer and gas chromatography. The results show the best conditions for adsorption process are: time = 5 minutes; temperature = 20 °C and pH= 4, while the best conditions for striping process are: time = 15 minutes and temperature = 80 °C. By applying the best conditions for both adsorption and stripping processes, ethanol concentration of 46wt% was able to be obtained. The adsorbent capacity of Sepabeads207 is 0.22g ethanol/g adsorbent, while the adsorbent selectivity is 7.75 $\frac{\text{g ethanol/ g water (adsorbed)}}{\text{g ethanol /g water (original solution)}}$ and the efficiency of adsorbent is 100%. From this study can be concluded that using of Sepabeads207 to adsorb ethanol in static solution better than continues with applying best conditions.

ABSTRAK

Terdapat masalah dengan peningkatan CO_2 dan CO dalam persekitaran hasil daripada penggunaan bahan api fosil. Etanol adalah pilihan bahan api yang baik atau sebagai bahan tambah dalam petrol untuk meningkatkan nombor oktana, penggunaan etanol akan mengurangkan pelepasan CO dan CO_2. Justeru, penghasilan etanol melalui penapaian merupakan bakal jalan penyelesaian. Kajian ini bertujuan untuk menilai teknik pemisahan yang sesuai dengan kaedah penjerapan. Keadaan terbaik proses penjerapan dan pelucutan telah dikaji. Larutan etanol berkepekatan 10wt%, iaitu kepekatan yang sama dengan produk proses penapaian digunakan sebagai suapan. Pemisahan berlaku dalam turus penjerapan yang mengandungi polimer Sepabeads207 pada suhu (20 - 40°C), juga pH (4-7), dan masa penjerapan (5 - 25 minit) yang berbeza. Juga masa pelucutan (penyahjerapan) dikaji di antara 15 dan 35 minit, dan pada suhu udara yang berbeza (80 - 95°C). Etanol tersejat telah dicairkan dengan air sejuk dan kepekatan cecair etanol diukur dengan refraktometer dan gas kromatografi. Keputusan menunjukkan keadaan terbaik untuk proses penjerapan ialah: masa = 5 minit; suhu = 20°C dan pH = 4, manakala keadaan terbaik untuk proses pelucutan ialah: masa = 15 minit dan suhu = 80°C. Dengan menggunakan keadaan terbaik untuk kedua-dua proses penjerapan dan pelucutan, kepekatan etanol 46wt% telah diperolehi. Muatan penjerap Sepabeads207 ialah 0.22g etanol / g penjerap, manakala pemilihan penjerap ialah 7.75 dan kecekapan 100%. Daripada kajian ini dapat disimpulkan bahawa Sepabeads207 menjerap etanol lebih baik dalam larutan statik berbanding turus dengan mengenakan keadaan terbaik.

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LIST OF SYMBOLS

μ	-	Adsorbent capacity
S	-	Adsorbent selectivity
η	-	Efficiency of adsorbent
Al	-	Aluminum
Co	-	Cobalt
CO_2	-	Carbon Dioxide
Ge	-	Germanium
G^E	-	Gibbs Energy
H_2O	-	Water
HCl	-	Hydrochloric Acid
Mg	-	Magnesium
Mn	-	Manganese
N_2	-	Nitrogen
NaA	-	Zeolite
NaOH	-	Sodium Hydroxide
nD	-	refractive index
–N-H	-	Nitric Group
NOx	-	Nitrogen Oxygen Compound
O_2	-	Oxygen
–O-H	-	Hydroxide Group
P	-	Phosphor
Pi	-	Pressure of component i
pH	-	Magnitude of acidity
P^{sat}	-	Saturated Pressure
R	-	Gas Constant
S	-	Solvent

Si-O-H	-	Silanol groups
SOx	-	Sulfur Oxygen Compound
T	-	Temperature
X	-	Mole / Mass Fraction in Liquid Phase
Xi	-	Mole Fraction of i Component in Liquid phase
Y	-	Mole / Mass Fraction in Gas Phase
Zn	-	Zinc

LIST OF ABBREVIATIONS

ACN	-	Acetonitrile
C2H5OH	-	Ethel alcohol (Ethanol)
DMF	-	Dimethethylformanide
E10	-	10 percent ethanol and 90 percent gasoline
E85	-	85 percent ethanol and 15 percent gasoline
HPLC	-	High Performance Liquid Chromotography
MTBE	-	Methyl t-butyl ether
NMP	-	N-methyl-pyrrolidone
PDMS	-	Polydimethylsiloxane
PDMS	-	PS IPN polydimethysiloxane-polystyrene interpenetrating polymer network
PVA	-	Polyvinyl acetate
SBUs	-	Secondary Building Units
THF	-	Tetrahydrofuran
VLE	-	Vapor Liquid Equilibrium

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Fuel grade bioethanol production has gained interest globally because of its use as fuel oxygenate and as alternative fuel. Bioethanol is repeatedly being utilized as a fuel oxygenate instead of methyl t-butyl ether (MTBE) or fuel additive to increase the octane number. Fermentation process is the main way to produce bioethanol fuel from the sugar; although there are many ways to manufacture ethanol by the chemical process or as a by-product of some chemical processes (Vane, 2005). The main sources of bioethanol are sugar from crops including corn, maize and wheat crops. Recently, there is more research has been done to produce bioethanol from lignocellulosic biomass such as from oil palm biomass, woods and plant waste.

Bioethanol or chemically called ethyl alcohol (C_2H_5OH) is a clear colorless liquid, low in toxicity, biodegradable, and makes little pollution to the environment if spilt (O'Brien and Craig, 1996). Burning of ethanol produces water and carbon dioxide. Bioethanol is applicable alternative fuel and virtually limitless potential for growth. The production of alternative fuel is due to the limitation of fossil fuel such as crude oil, hence the going towards more different sources of renewable of energy.

Generally, ethanol is going to be one of alternative environmental friendly fuel friendly and harmless to the environment than gasoline. Using ethanol as a fuel for vehicles introduce benefit to minimize emissions of carbon dioxide and carbon monoxide, the same or lower emissions levels of hydrocarbon and oxides of nitrogen. For example E85 fuel is produced by blending of 85 percent ethanol and 15 percent gasoline, this blending decreases the consumption of fossil fuel and has lower percent of volatile components than pure gasoline, leading to the decrease of emissions occurred by evaporation. Low percentage of blending ethanol with gasoline, such as 90 percent gasoline and 10 percent ethanol (E10) leads to reduce emissions of carbon monoxide and improving the octane number for the fuel. Fuel of the vehicles becomes more flexible by using (E85). In United States, the use of E85 is growing due to the increase number of fuel stations (ethanolrfa, 2013).

1.2 Problem Statement

Mostly, the production of bioethanol involves pretreatment stage with acid or base solution, hydrolysis either with sulphuric acid, and fermentation with yeast broth. Usually, the end stream contained ethanol, and impurities. There are many techniques to separate ethanol from ethanol / water mixture such as distillation process, extractive distillation with Salt, solvent liquid or with ionic liquid, pervaporation process and adsorption process. It is critical to find the most suitable method to separate ethanol from the impurities that requires less energy, simple and low cost, yet, is efficient.

The difficulty of separation of ethanol from water (broth of fermentation) is come from the generation of an azeotrope in the mixture at certain temperature. This azeotropic behavior appears because of presence of hydrogen bonds. Hydrogen bonds lead to interaction between molecules of ethanol and water. This interaction makes separation of ethanol become difficult. The Azeotropic point appears at composition of 95.6(wt) % for ethanol and the rest is water. Traditional technique like distillation consumes high energy. Hence, adsorption techniques will be studied as it is expected to give good separation at low cost, especially for low ethanol concentration in water and impurities stream.

1.3 Objectives

In general, this work is aimed to study the efficiency of the adsorption technique to achieve good purity of bioethanol production by manipulating the operating condition, such as time of adsorption, time of stripping, mass ratio ethanol/adsorbent (capacity of adsorbent), temperature and acidity of the feed. Following are the objectives of this study.

i) To study the effect of operating conditions on the efficiency of the adsorption technique to achieve good purity of bioethanol.
ii) To evaluate the best operating conditions for adsorption of model bioethanol mixture.
iii) To evaluate the best operating conditions of stripping process, i.e., air temperature and time.

1.4 Scope

The simulated mixture of bioethanol has concentration 10wt%. Sepabeads207 was used in the adsorption and stripping processes. The operation parameters of adsorption such as time of adsorption (5 – 25 min.), temperature

(20 – 40 ^{o}C) and acidity of the feed (4-7) were varied and evaluated the best conditions. The stripping process parameters were studied time (15- 35 min.) and temperature (80-95 ^{o}C). The yield of bioethanol was determined by direct volume measurement whereas the purity of bioethanol was analysed by gas chromatography and refractometer.

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