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B-08 Process Failure Of The High Pressure Co_2 Stripper Urea Plant Pusri-IB
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B-09 Next Generation in Biomass Processing: Extraction Process and Depolymerization
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B-10 Henry's Constant Of Polar Solutes In Polymer Solutions
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B-11 Optimisation Of Ls54/Dx Aqueous Two Phase System Conditionsfor Cutinase Recovery
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B-12 Principal Component Analysis of Optimum Linear Estimator in Chemical Processing System
Marthen Luther Doko
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B-13 State and Parameter Estimation of Large Scale Chemical Processing System
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B-14 A decision modeling approach to evaluate the climate change mitigation options in the Philippines

Michael Angelo B. Promentillaa, Katrina C. Angelesa Carla Angeline M. De la Cruza, Kathrina G. Tana
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B-15 Esterification of Phthalic Anhydride
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B-16 Optimization of Hydroxylation Reaction For Synthesis of Polyol FromEpoxidized Palm Oil Methyl Ester
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B-17 Design and Control of Alkali-Catalyzed Transesterification Reactors
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B-18 A Dynamic Model for Ultrasonic – Assisted Extraction of Bio-ActiveCompounds from Natural Products
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B-19 Study on Chemical Reaction Equilibrium of MethanolSynthesis in Liquid Phase
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B-20 Different Types of Observers Applied in Process Systems
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B-21 The Development of Pertamax Racing

Ery Gunarto, Murtina Dwi Lastuti
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B-22 Design and Control of Biodiesel Production in Esterification Section
Apichat Saejio, and Kulchanat Prasertsit
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B-23 Dynamic Simulation the Influence of Gas Compressor Suction Pressure Controlto Improve Anti Surge Control System Performance in Two Stages CentrifugalGas Compression System
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B-24 Optimal Design Based RSM and ANN of High Vacuum Distillation for Beta-Carotene Recovery
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B-25 Dynamic Simulation of Optimization of Load Sharing Compressor and LinePacking Utilization
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B-26 Optimization Process of Biodiesel Production with Ultrasound Assisted by Using Central Composite Design Methods
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B-27 Dynamic Simulation and Control in A Non-Interacting-Tank System
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B-28 Technical and Economics study of biodiesel production by supercritical transesterification
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B-29 Modelling of Risk Assessment Using Layer of Protection Analysis (LOPA) on Enclosed Ground Flare at Onshore Facilities
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C. Chemical Engineering Fundamentals

C-01 Improvement of Antifouling Potential on Anion Exchange Membrane by Layer by Layer Deposition
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C-02 Effect of Coalescer Height to Oil Separation in Produced Water Using Gas Flotation Vessel Cell
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C-03 Comparison of Cutinase Separation in Different Chromatographic Media
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C-04 Hydrothermal Extraction of Valuable Compounds from Kikurage (*Auricularia auricula-judae*)
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C-05 *PVT* Properties for Mixtures of Ionic Liquid 1-Butyl-3-Methylimidazoliumbis(Trifluoromethylsulfonyl)imide[C_4mim][NTf_2]with Anisole
Elisabeth Widowati, Ming-Jer Lee
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C-06 CFD Simulation and ERT visualization of Gas-Liquid Oscillatory Flow in a Baffled Column
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C-07 A Study on The Application of Orange Peel Waste as Low Cost Biosorbent for Dye Removal
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C-08 Simple Extraction Method of Galanthamine from *Narcissus pseudonarcissus* bulbs
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Leiden University, Institute of Biology, Natural Products Laboratory, 2300 RA, Leiden, The Netherlands

C-09 Incorporation of Fractional Surface Coverage on Extended Langmuir Isotherm: Binary Adsorption of Evans Blue and Malachite Green onto Organo-Bentonite
Suryadi Ismadji, Alfin Kurniawan, and Hogiartha Sutiono
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C-10 Density Based Modeling of Epicatechin Solubility in Supercritical Carbon Dioxide Fluid
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C-11 Transesterification mechanism for PET recycle by molecular orbital method
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C-12 Kinetics of Amidation for The Synthesis of Diethanolamide From Methyl Ester and Diethanolamine by Using Sulfuric Acid Catalyst

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C-13 Effect of Agitation on the Metastable Zone, Nucleation and Growth of Struvite Crystals in a Batch Crystallizer
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C-14 Shock Loads and Revival of Activity after Shutdown in Single Stage Stirred Tank Anaerobic Reactors fed Continuously and Intermittently
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Agricultural and Biological Engineering Department, University of Florida, Gainesville, USA
Environmental Sciences and Biotechnology, Murdoch University, Perth, Australia

C-15 Bioproduct-Based Solvents for Dissolving Styrofoam and Comparison of its Solubility with Thermodynamic Model
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C-16 Isolation and Physicochemical Properties of Starches from Vietnamese Limnophila aromatic
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C-17 Mass Transfer of stevioside in stevia rebaudiana extraction
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C-18 Thermophysical Characterization of Glycol (DEG/TEG/T_4EG) + TRIS + Water: Measurements and Correlation
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C-19 Liquid-Liquid Equilibrium of Acetonitrile + Water in the Presence of Biological Buffer MOPS
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C-20 Analysis of Flux Decline during Microfiltration of Different Types of Feed
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C-21 The Use of Ion-Exchange Resin in The Production of Clean Biodiesel
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C-22 Co-solvent Selection for Supercritical Fluid Extraction of Essential Oil andBioactive Compounds from *Polygonum minus*
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C-23 Vegetable oil reforming for high-temperature PEMFCs
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C-24 Novel heterogeneous monolithic catalyst in biodiesel production: A review
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C-25 Comparison of Pyrolysis Products between Jatropha Curcas L Waste and Jatropha Curcas L Nut
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C-26 Enhancing CO2 Adsorption Using Strong Base Anion Exchange Resin
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C-27 Liquefaction of low-molecular-weight extracts obtained from low-rank coal and biomass by degradative solvent extraction under mild condition
Dedy Eka Priyanto, Xian Li, Ryuichi Ashida, Kouichi Miura
Department of Chemical Engineering, Kyoto University – Japan

C-28 Effect of Paraffins on Benzene Photocatalytic Oxidation of Clean Room in Semiconductor Fab
Yi-Ting Wu, Yi-Hui Yu, Jeffrey Chi-Sheng Wu, Angela Yu-Chen Lin, Luh-Maan Chang, and Ming-Hao Hsu
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C-29 Kinetic Evaluation of the Graft Copolymerization of Acrylic Acid onto Starch Based on Concentration Measurements and on Torque Observation
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C-30 Identification of Potential Dyesand Developing Methods to Improve Dye-sensitized Solar Cell's Efficiency
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C-31 Separation of Aromatic Hydrocarbons from Cracked Oils by Solvent Extraction
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C-32 Prediction of Solubilities of CO, H2 and Its Mixture in Various Solvents
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C-33 Optimizing Lipase Immobilization by Entrapment Method on Chitosan as Biocatalyst for Biodiesel Synthesis
Heri Hermansyah, Merisa Bestari Faiz, Intan Afridawaty Sipangkar and Renly James Yosua
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C-34 Miscibility Development Calculation in Model Oil Injection by Flare-Flue Gas Mixtures
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C-35 Adsorption of copper(II), cadmium(II) and zinc(II) ions by SDS-functionalized mesoporous silica
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C-36 Dye Adsorption on Silica-filled ENR/PVC Beads
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C-37 Phase Behaviour Of CH_4-CO_2 Mixture in Cryogenic Heat Exchanger Process
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C-38 Optimization research into the ultrasonic-assisted extraction to separate polyphenol from green tea waste
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C-39 Kinetic Reaction Comparison of CO2 Absorption Into Promoted Potassium Carbonate (K2CO3)
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C-40 Supercritical CO2 Extraction and Micronization of Carotenoids
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C-41 Kinetic studies on the removal of reactive blue 19 and reactive yellow 145 by Putsan(tiwi) clay
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C-42 Activation of Mesoporous Carbon Synthesized from SBA-16 for CO2 Storage
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C-43 Transient Heat Transfer Analysis of Latent Heat Thermal Energy Storage System Using Phase Change Material
Panut Mulyono and Denny Andriatno Pribadi
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C-44 A Review on CFD Modeling of Fluidization Bed Gas Phase Reactor For Polyolefin Production
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C-45 Growth of Carbon Nanotube from Banana Peel Activated Carbon with Simple Pyrolisis Methode and Methane Decomposition
Praswasti Pembangun Dyah Kencana Wulan and Najma
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C-46 Mass Transfer Model for Basic Blue Adsorption onto Pillared Bentonite Clay by Taking Into Account the Intra Particle Concentration Gradient
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C-47 Removal of Terpenes from Citrus Oil Model Compounds with Supercritical CO_2 Fractionation
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C-48 Flow instabilitiesinAgitated Tanks withSide Entering Mixers
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B.GustiayuSukmawedha, A. Ratna Sari, Bayu Triwibowo
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C-49 A Computational Fluid Dynamics Study into Turbulent Characteristic that Affect the Combustion Process
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C-50 Liquid-Liquid Equilibria of Ternary System Eugenol + Isopropanol + Water at 303.15, 313.15, and 323.15 K
Zuhriyyah R.A, Rachma F., and Nur Andriani P.K , Kuswandi
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C-51 Bitumen Extraction from Asbuton Rock Using Pertasol
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D. Polymer, Petrochemical and Material Science and Technology

D-01 Investigation of Rice Husk Loading on The Characterization and Water Permeation of ENR/PVC Composite Membrane
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D-02 One step synthesis of hybrid single-wall carbon nanohorns with metallic nanoparticles using arc discharge in water with nitrogen gas injection
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D-03 PreparationofAmine-GraftedMesoporousMaterialMCM-48UsingGeothermalSolidWasteSilica
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D-04 Synthesis of Furfural from Locally Available Agricultural Residues in the Philippines
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D-05 Granulation of Organic and Inorganic Mixtures
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D-06 Thermal Compression Effects on Hybrid Poplar Wood: Lignin Analysis
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D-07 Preparation of CO Gas Sensor from WO_3 Nanomaterial Synthesized via Sol-Gel Method Followed by Calcination
Diah Susanti, A.A. Gede Pradnyana Diputra, Lucky Tananta, Hariyati Purwaningsih, George Endri Kusuma, Chen-Hao Wang, Shao-Ju Shih and Ying-Sheng Huang
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D-08 Green Synthesis of Zinc Oxide Nanoparticles via Simple Precipitation Method
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D-09 Differential Scanning Calorimetry (DSC) analysis of PP/Organoclay Nanocomposites: Isothermal Crystallization Study
Achmad Chafidza, Mohammad Al-haj Ali, Rabeh Elleithya and Saeed M. AL-Zahrania
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D-10 Shape Memory Polymer Based on Benzoxazine-modifed Epoxy
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D-11 Highly Filled Graphite Based Benzoxazine Composites for an Application as Bipolar Plates in Fuel Cells
Anucha Pengdam and Sarawut Rimdusit

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D-12 Synthesis and Characterization of ZeoliteMonolith
by Ice-Templating and Steam-Assisted Crystallization
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D-13 Modeling of Gas Phase Propylene Polymerization in Fluidized Bed reactors Using Aspen Polymer Plus and Two Phase Models
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D-14 In-situ observation of convection and phase separation behavior under microwave radiation
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D-15 Production and Characterization of Polyethylene-Clay Nanocomposites through in situ Polymerization using Montmorillonite Supported Metallocene Catalyst
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Optimization Process Of Biodiesel Production With Ultrasound Assisted By Using Central Composite Design Methods

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Abstract

The objective of this research is to optimize of biodiesel production with ultrasound assisted. Optimization was used central composite design methods. Biodiesel was produced from frying oil with KOH catalyst and ultrasonic assisted. The variables were investigated temperature, catalyst concentration and ratio of methanol to oil. Biodiesel was separated from reactant and impurities with decantation process and distillation process. The results of research obtained optimum conversion 85.95% in operation condition are methanol/oil 5.05:1, catalyst concentration 1.65% and temperature reaction 50^{o}C. Mathematic modeling for describe in this process like expressed;

$$Y= 86.2107 -7.4287X_1 +1.0661X_2 + 0.6289X_3 - 2.5319X_1^2 -2.0603X_2^2 -1.0618X_3^2$$

Keywords: biodiesel; central composite design; ultrasonic assisted; yield biodiesel.

1. Introduction

Nowadays, demands of fossil energy in Indonesia are significantly increasing while oil reserves will be diminishing within 20 years (Ibrahim et.al, 2010). As a consequence, there are serious attempts in finding new alternative energy i.e. hydrogen cells, solar energy and wind power. However, the above technologies are still at the development stage, and still not feasible to be applied from economic point of view (Haeni et.al, 2008). The feasible option is developing the technology for biodiesel production as it is biodegradable and non-toxic product. Biodiesel also has low undesirable emission, and environmental friendly. Biodiesel can be produce from vegetable oils which is generated from renewable resources. They practically have less sulphur content, offer no storage difficulty, and they have excellent lubrication properties. Moreover, converting vegetable oils to become biodiesel indirectly can improve the absorption of carbon dioxide compare to the direct burning (conventional method in generating energy) (Ikwuagwu, et.al, 2000). The Government of Indonesia has begun to support the development of biodiesel, bioethanol, bio-oil, bio-gas, the fuel of natural gas (Anonymous, 2005).

Biodiesel can be produced from vegetable oils or fats by transesterification- esterification reaction. The source materials are commonly used vegetable oils such as palm oil (*Elaeis*) (Kalam and Masjuki, 2002), coconut oil (Jitputti et.al, 2006, Hadiyanto et.al, 2010), jatropha oil (*Jatropha curcas*)(Ginting et.al, 2011, Gubitz et.al, 1999) and rubber seeds oil (*Hevea Brasilienis*) (Ikwuagwu et.al, (2000), Ramadhas et.al,(2005), (Ragavan et.al, (2011)), Widayat and Suherman (2012), Widayat and Kiono, (2012)). Biodiesel production process can be conducted by using a homogenous acid catalyst process (Furukawa et.al, 2010), supercritical process (Desphande et.al, 2010), enzymatic process (Sotoft et.al, 2010), heterogeneous acid catalyst (Ilgen at.al, 2007, Jitputti et.al, 2006) and ultrasonic assisted (Ragavan et.al, 2011).

Today, have developed a new technique for solid-liquid extraction product that is ultrasonic waves assisted. Food processing are also not spared take advantage of this technique (Mason et al., 1996). This technique is known as sonochemical effects that is using ultrasonic waves to affect the changes that occur in chemical processes.

Sono-esterfication is term to express application of esterification assisted by ultrasound technology. At present, biodiesel is primarily produced in batch reactors in which the required energy is provided by heating accompanied by mechanical mixing. Since fats and alcohols are not totally miscible, the conventional transesterification reaction in batch processing is relatively slow, and phase separation of the glycerin is time-consuming. Whereas, ultrasonic processing used in biodiesel

production delivers a biodiesel yield in excess of 99% in thirty minutes or less, compared to one hour or more using conventional batch reactor systems. With the saponification of esters the reaction proceeds on the boundary between the aqueous acid or base phase and not in the water-soluble ester phase. Ultrasound accelerates the particle transition at the phase boundary and thus the reaction, compared with the classical reaction procedure with heating and stirring. Ultrasonic wave has the advantage in energy usage as shown in Figure 1. Teixeira et al., (2009) stated that the biodiesel production process with ultrasonic wave takes time less than 1 hour, so the efficiency can be achieved with this process.

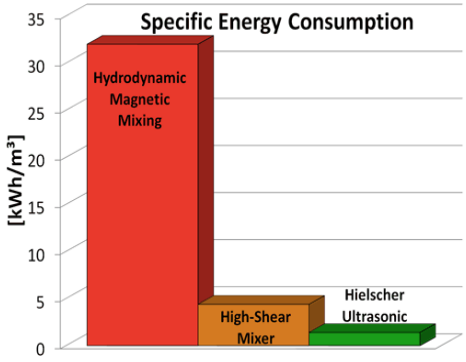


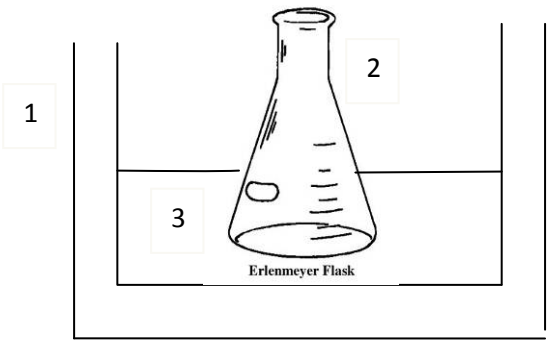
Figure 1 Comparison of the energy usage of ultrasonic wave generating devices with conventional mixing

The objective of this paper is to find optimum condition in biodiesel production from frying oil by ultrasonic waves assisted. The optimum conditions include of temperature, catalyst concentration and ratio of reactants. Optimization methods did use Central Composite Design (CCD).

2. Material and Methods

2.1. Materials

The raw material used is bulk frying oil that obtained from Banyumanik market, Semarang Central Java. Frying oil was analyzed of free fatty acid. The results analysis shown free fatty acid content below 0.5%, so the biodiesel production just use transesterification reaction (Krawczyk, 1996; Kalam and Masjuki, 2002). Potasium hydroxide (KOH) as a catalyst has analytical specification (Merck). Methanol has industrial specification. Equipment for biodiesel production process as shown in Figure 2 where the reactor using a capacity of 250 ml erlenmeyer (Pyrex) with bulk coconut palm oil. To generate ultrasonic waves using Ultrasonic Bronsonic with a frequency of 40 kHz capability. This equipment is equipped with a heater to reach operating temperature (which has been determined in accordance temperature variable) and degassing timer / ultrasonic. It is also equipped with a filter that serves to put the reactor equipment.



Description:
1.Ultrasonic cleaner
2.Erlenmyer
3. water

Figure 2. Experimental apparatus for biodiesel production with ultrasonic assisted

2.2. Biodiesel Production Processing

Experiment about biodiesel production was conducted in three stages involve methoxide reaction, transesterification reaction and biodisel separation. In methoxide reaction stages, methanol reacted with KOH in erlenmeyer and conducted in magnetic stirrer and 10-15 minutes. The addition

of methanol, the operation variables and the corresponding base catalyst for the transesterification reaction, where the variation of operation as shown in Table 2. Transesterification reaction stages, conducted with ultrasonics assisted (Figure 2). 100 gram of frying oil added with potasium methoxide and took in ultrasonic cleaner. Degassing time was adjust in 5 minutes and ultrasonic time in 30 minutes. The operation temperature/ solution was adjust in experiments design (Table 2). This stages finished about in 35 minutes. In transesterification process, glycerol produced as by product. Biodiesel separated with decantation and distilation process. Glycerol was separated with decantation process as bottom product. Biodiesel as top product then separated with distilation as bottom product. Methanol was evaporated and obtained as top product. Glycerol and Biodiesel was analyzed viscosity, density, weght of biodiesel, acid number, iodine number and saponification number.

2.3. Central Composite Design Methods

The method used to design this experiment is Response Surface Metodology (RSM). This experiment used Box-Wilson Central Composite Designed (CCD) that number of independent variable is three (3) (Box et.al, 2005). The three independent variablese are the ratio of methanol-bulk frying oil, the percent of the catalyst and temperature reaction. So the response is the conversion of biodiesel or yield of biodiesel. Experimental design and the realization are presented in Table 1. Yield of biodiesel was calculated with equations 1. Data processing is performed by software Statistica 6.

$$Y_{biodiesel} = \frac{\text{Mass of biodiesel}}{\text{Mass of raw material (Frying oil +methanol)}} x100\% \qquad (1)$$

Table 1. Experimental design for 3 variable with CCD methods

Run	Block	X_1	X_2	X_3	Y	Oil : methanol	% catalyst	Reaction Temperature (^{0}C)	Yield of biodiesel (%)
1	1	-1	-1	-1	Y_1	1 : 6	1	40	81.972
2	1	-1	-1	1	Y_2	1 : 6	2	40	82.792
3	1	-1	1	-1	Y_3	1 : 10	1	40	83.611
4	1	-1	1	1	Y_4	1 : 10	2	40	84.431
5	1	1	-1	-1	Y_5	1 : 6	1	55	76.104
6	1	1	-1	1	Y_6	1 : 6	2	55	76.836
7	1	1	1	-1	Y_7	1 : 10	1	55	77.567
8	1	1	1	1	Y_8	1 : 10	2	55	78.299
9	1	0	0	0	Y_9	1 : 8	1.5	45	83.511
10	2	-1.76	0	0	Y_{10}	1 : 8	1.5	31.77	93.648
11	2	1.76	0	0	Y_{11}	1 : 8	1.5	58.2	77.326
12	2	0	-1.76	0	Y_{12}	1 : 4.5	1.5	45	85.831
13	2	0	1.76	0	Y_{13}	1 : 11.5	1.5	45	86.604
14	2	0	0	-1.76	Y_{14}	1 : 8	0.618	45	87.377
15	2	0	0	1.76	Y_{15}	1 : 8	2.382	45	88.151
16	2	0	0	0	Y_{16}	1 : 8	1.5	45	88.924

Where : X_1 = coding for variable of ratio molar of bulk frying oil to methanol
X_2 = coding for variable of catalyst consentration
X_3 = coding for variable of temperature reaction
Y = Yield of biodiesel

3. Result and Discussion

3.1. Interactions between process variables

The coefficients of (5) were determined by multiple regression analysis with data for yield biodiesel and independent variables (Table 1). This analysis includes all the independent variables and

their interactions, regardless of their significance levels. The best-fitting response surfaces found can be written as follows:

$$Y= 86.2107 -7.4287X_1+1.0661X_2+ 0.6289X_3 - 2.5319X_1^2-2.0603X_2^2-1.0618X_3^2-0.0879\ X_1X_2 - 0.0439X_1X_3 \quad (2)$$

Table 2. Analysis of variance (ANOVA)

Factor parameter	SS	Degree of Freedom	MS	F	p
Blocking	154.1518	1	154.1518	70.43448	0.000394
X_1	195.8419	1	195.8419	89.48340	0.000223
X_1^2	16.6300	1	16.6300	7.59852	0.039998
X_2	4.0336	1	4.0336	1.84301	0.232655
X_2^2	11.0113	1	11.0113	5.03126	0.074928
X_3	1.4037	1	1.4037	0.64139	0.459554
X_3^2	2.9245	1	2.9245	1.33627	0.299925
X_1 X_2	0.0155	1	0.0155	0.00707	0.936259
X_1 X_3	0.0039	1	0.0039	0.00177	0.968096
X_2 X_3	0.0000	1	0.0000	0.00000	1.000000
Error	10.9429	5	2.1886		
Total SS	386.7508	15			

Coefficients also evaluated of variance. The results of analysis presented Table 2. Table 2 show that single variable and quadratic variable have F value greater than the price p. For interaction variables have F value less than p value. Table 4 can also observed that the linear term of ratio molar methanol to frying oil (X_1) and catalyst concentration (X_2) has a large effect on the biodiesel yield significantly due to the high F-value. Ratio molar methanol to bulk frying oil, F-value 195.84 more significant than catalyst concentration, F-value 4.03. The quadratic term of ratio molar methanol to frying oil (X_1^2), F-value 16.63 is more significant than catalyst concentration (X_2^2), F-value 11.01. Each variable can be analyzed and optimized separately because the effect of each variable does not result in a increase yield of biodiesel significantly. For this analysis, mathematical model in 3 equation can be written follow as:

$$Y= 86.2107 -7.4287X_1+1.0661X_2+ 0.6289X_3 - 2.5319X_1^2-2.0603X_2^2-1.0618X_3^2 \quad (3)$$

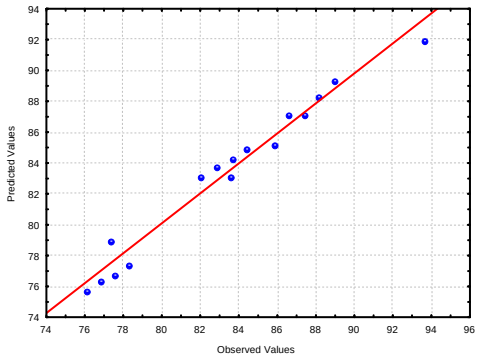


Figure 3. Predicted versus experimental yield of biodiesel

To test the fit of the model, the regression equation and determination coefficient (R^2) were evaluated. In this case, the value of the determination coefficient (R^2 = 0.9717) indicates that the sample variation of 97.17% for FAME yield is attributed to the independent variables and only 2.83% of the total variations are not explained by the model. Fig. 4 shows the predicted versus actual. A higher value of the correlation coefficient (R^2 = 0.9205) justifies an excellent correlation between the independent variables (Yuan et al., 2008). Abdul Halim et.al, (2009) also have determination coefficient (R^2=0,9772) in biodiesel production from waste cooking oil with packed bed reactor.

The effect of catalyst concentration and reaction temperature on the yield of biodiesel is shown in Fig. 4. At higher reaction temperature, its relevancy to the augmentation of yield is enormous. For instance, as can be seen in Fig. 4, the yield increases at higher catalyst concentration and higher reaction temperature. But when catalyst concentration increased at any constant reaction temperature, the yield will decreased. Reaction temperature plays a crucial role in determining the reaction rate in transesterification ultrasonic assisted reaction which influence the total yield of biodiesel produced. For instance, higher temperature induces faster reaction rate compared to lower temperature (Levenspiel, 1972).

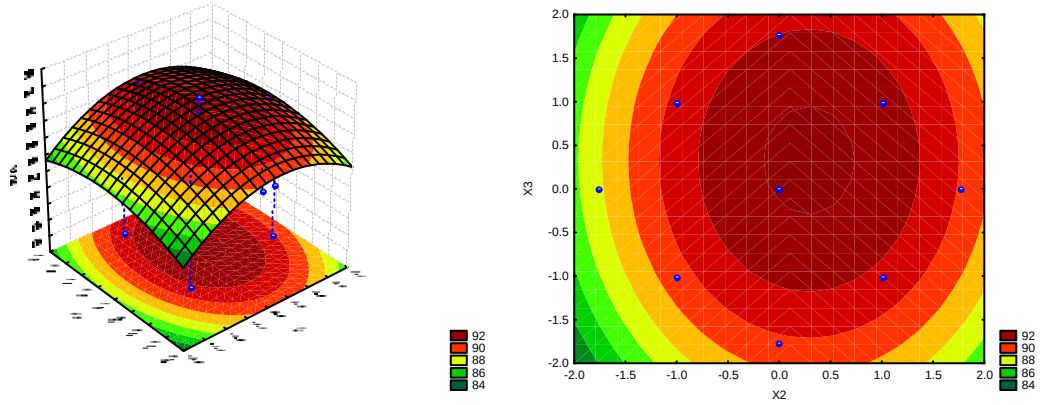


Figure 4. Effect of catalyst concentration and reaction temperature of biodiesesl in three dimensional response surface

In surface contours figuring in color areas, so it can be seen from this graph the points of interaction of two variables is clear, where most interactions are optimal in the red region of the oldest. The critical value in Fig 4 presented in Table 3 For X_1, X_2 and X_3 and in these condition obtained yield of biodiesel 85.95%. To obtain the actual value of the variable, use the equation 4. The optimum condition for yield biodiesel obtained in ratio molar methanol to frying oil 5.05:1, catalyst KOH concentration 1.65% and temperature 50^{o}C.

Table 3. Optimization constrains used to obtain the optimum value for biodiesel yield

Variable	Observed Minimum	Critical Values	Observed Maximum
X_1	-1.76000	-1.47485	1.760000
X_2	-1.76000	0.29021	1.760000
X_3	-1.76000	0.32670	1.760000

4. Conclusion

The central composite design (CCD) employed for optimization and analysis of transesterification of bulk frying oil with ultrasound assisted. The experiments conducted in ultrasonic cleaner and batch system. The optimum conditions of molar ratio methanol to bulk frying oil 5.05;1, KOH catalyst concentration 1.65% and operation temperature 50^{o}C. Biodiesel yield was determined under this condition and obtained 85.95%. Mathematical model that describe for biodiesel production with ultrasound assisted like expressed:

$$Y= 86.2107 -7.4287X_1+1.0661X_2+ 0.6289X_3 - 2.5319X_1^2-2.0603X_2^2-1.0618X_3^2$$

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