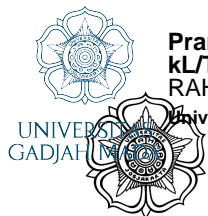


INTISARI

Bioetanol merupakan sebutan untuk etanol yang diproduksi dari biomassa yang memiliki kandungan gula, pati dan selulosa. Bioetanol dapat dimanfaatkan dalam bidang transportasi, industri minuman, kosmetik, kesehatan, maupun industri kimia sebagai bahan baku. Sebagian besar bioetanol dimanfaatkan sebagai bahan bakar alternatif (*fuel grade*) yang menjadi komplementer dari bensin dengan berbagai komposisi. Bioetanol dengan konsentrasi 99,5% dapat menjadi bahan bakar yang ramah lingkungan ketika dicampur dengan bensin karena memiliki *research octane number* (RON) 116-129 dan menghasilkan lebih sedikit emisi SO₂ dan CO₂. Bioetanol dapat diproduksi dari berbagai biomassa, salah satunya adalah batang kelapa sawit.

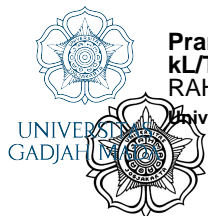
Pabrik bioetanol dari limbah batang kelapa sawit dirancang pada kapasitas 40.000 kL per tahun dengan kebutuhan batang kelapa sawit sebanyak 10,2 ribu ton per tahun. Pabrik beroperasi semi-*batch* selama 24 jam sehari dalam 330 hari setahun. Proses diawali dengan persiapan bahan baku yang meliputi *wood chipping* hingga berukuran 5 cm dan *pretreatment* berupa *steam explosion*, *hot water treatment*, dan *alkaline treatment*. Proses *steam explosion* berlangsung pada tekanan 5,92 atm dan suhu 180°C. *Hot water treatment* dilakukan dengan melakukan pencucian bahan baku menggunakan air pada suhu 80°C dan *alkaline treatment* dilakukan menggunakan NaOH 2% w/v dengan solid loading 40% w/v. Proses dilanjutkan dengan sintesis yang terdiri dari hidrolisis enzimatis dan fermentasi menggunakan metode *Pre-hydrolysis and Simultaneous Saccharification and Fermentation* (PSSF). Proses pre-hidrolisis dilakukan menggunakan enzim selulase dengan menyiapkan larutan *buffer* berupa asam sitrat dan natrium sitrat untuk menjaga pH larutan pada range 4,8-5,0 serta nutrisi untuk pertumbuhan *yeast* berupa *yeast extract* dan *peptone*. Pre-hidrolisis berlangsung di suhu 50°C pada tekanan atmosferis dan dilanjutkan proses hidrolisis lanjutan dan fermentasi serentak di suhu 35°C pada tekanan atmosferis. Larutan hasil fermentasi berupa *slurry* dialirkan ke *rotary drum vacuum filter* (RDVF) untuk memisahkan larutan bioetanol dari padatan *yeast*, enzim selulase, dan BKS. Larutan bioetanol dengan kadar rendah dimurnikan menggunakan menara distilasi. Bioetanol terambil dari distilat kemudian didinginkan dan didehidrasi menggunakan membran pervaporasi pada suhu 70°C hingga kemurniannya mencapai 99,5°C. Bioetanol 99,5% didinginkan hingga suhu 40°C dan dialirkan menuju tangki penyimpanan produk.

Pabrik direncanakan berdiri di Kawasan Industri Tenayan Riau, Provinsi Riau dengan luas area sebesar 29.700 m² dan menyerap 129 orang pekerja. Pabrik ini membutuhkan listrik sebesar 3,0 MW, udara *boiler* sebesar 131.477,95 m³/jam, dan udara instrumen sebesar 159,03 m³/jam. Pabrik ini didirikan dengan *fixed capital* sebesar \$45.518.047,81 dan dijalankan dengan *working capital* sebesar \$15.645.402,04.



Produk bioetanol *fuel grade* dijual dengan harga \$1,5/Liter, sehingga diperkarakan *profit before tax* pabrik ini adalah sebesar \$8.131.272,81. Pabrik ini dikategorikan sebagai *low risk* karena kondisi operasi pabrik yang tidak terlalu tinggi, bahan proses yang memiliki *hazard* rendah, dan memiliki target pasar yang jelas dengan dukungan kebijakan pemerintah.

Nilai *return on investment (ROI) before tax* terhitung sebesar 17,86%, *payout time (POT) before tax* sebesar 3,59 tahun, dan *discounted cash flow rate of return (DCFRR)* sebesar 6,00%, *break event point (BEP)* sebesar 49,04%, dan *shutdown point (SDP)* sebesar 14,20%. Harga jual bioetanol *fuel grade* menjadi parameter yang paling sensitif terhadap nilai DCFRR. Hasil evaluasi teknis dan ekonomi menunjukkan bahwa pabrik ini perlu untuk dikaji lebih lanjut sebelum didirikan.

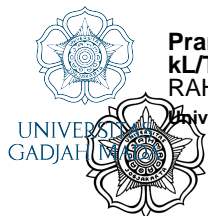


ABSTRACT

Bioethanol is a term for ethanol produced from biomass which contains sugar, starch and cellulose. Bioethanol can be used in the transportation, beverage, cosmetic, health and chemical industries as raw materials. Most of the bioethanol is used as an alternative fuel (fuel grade) which is complementary to gasoline with various compositions. Bioethanol with a concentration of 99.5% can be utilized as an environmentally friendly fuel when mixed with gasoline because it has a research octane number (RON) of 116-129 and produces fewer SO₂ and CO₂ emissions. Bioethanol can be produced from a variety of biomass, one of which is oil palm trunks.

The bioethanol plant from waste oil palm trunks is designed at a capacity of 40,000 kL per year with a demand for oil palm trunks of 10.2 thousand tons per year. The factory operates semi-batch 24 hours a day 330 days a year. The process begins with the preparation of raw materials which includes wood chipping up to 5 cm in size and pretreatment in the form of steam explosion, hot water treatment, and alkaline treatment. The steam explosion process takes place at a pressure of 5.92 atm and a temperature of 180°C. Hot water treatment is carried out by washing the raw materials using water at a temperature of 80°C and alkaline treatment is carried out using 2% w/v NaOH with a solid loading of 40% w/v. The process was followed by a synthesis consisting of enzymatic hydrolysis and fermentation using the Pre-hydrolysis and Simultaneous Saccharification and Fermentation (PSSF) method. The pre-hydrolysis process was carried out using the cellulase enzyme by preparing a buffer solution in the form of citric acid and sodium citrate to maintain the pH of the solution in the range of 4.8-5.0 and nutrients for yeast growth in the form of yeast extract and peptone. Pre-hydrolysis took place at a temperature of 50°C at atmospheric pressure and continued with a further hydrolysis process and simultaneous fermentation at a temperature of 35°C at atmospheric pressure. The fermented solution in the form of a slurry is flowed into a rotary drum vacuum filter (RDVF) to separate the bioethanol solution from yeast solids, cellulase enzymes, and BKS. Bioethanol solution with low concentration was purified using a distillation tower. Bioethanol is taken from the distillate then cooled and dehydrated using a pervaporation membrane at a temperature of 70°C until the purity reaches 99.5%. Bioethanol 99.5% is cooled to a temperature of 40°C and transported to the product storage tank.

The plant is planned to be established in the Tenayan Riau Industrial Estate, Riau Province with an area of 29,700 m² and require 129 workers. This plant requires electricity of 3,0 MW, boiler air of 131,477.95 m³/hour, and instrument air of 159.03 m³/hour. The factory was established with a fixed capital of \$45,518,047.81 and operated with a working capital of \$15,645,402.04. Bioethanol fuel grade products are



sold at a price of \$1.5/liter, so the estimated profit before tax for this factory is \$8,131,272.81. This plant is categorized as low risk because the operating conditions of the plant are not too high, the process materials have a low hazard, and have a clear target market with the support of government policies.

The return on investment (ROI) before tax is calculated at 17.86%, the payout time (POT) before tax is 3.59 years, and the discounted cash flow rate of return (DCFRR) is 6.00%, the break event point (BEP) of 49.04%, and the shutdown point (SDP) of 14.20%. The selling price of fuel grade bioethanol is the most sensitive parameter to the DCFRR value. The results of the technical and economic evaluation indicate that this plant needs to be studied further before being established.