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The Performance of Fossil Diesel-Syn Gas Dual Fuel Compression Ignition Engine for 3 KW Power Generation
Bambang Sudarmanta, Prabowo, Kadarisman

Study of the Effect of Electrolyze Variable and Solvent Concentration on Extractive Yield of Patchouli Leaves and the Energy Costs with Using Electrochemical Method of Extractive Ditillation Column
Sri Haryati, M. Djoni Bustan

Comparison of Structural Damaged by Liquid Hot Water Pretreatment on Bagasse (Saccharum Officinarum SP.) and Galah Grass (Saccharum Spontaneum Linn)
Orchidea R, Lisa Febriyanti S, Khoir Lazuardi, Reza Pahlevi, Cakra Dharma M

Characterization of Furfuryl Alcohol Derived Carbon Coated Monolith
Anwar Thaib, Darmadi

Effects of the Addition of x-Catalysts (x=C(Pd), Nb_2O_5, Y_2O_3) on the Hydrogen Absorption-Desorption Characteristics of Mg-23.5Ni Alloys
Sutarsis, S. L. Lee

Various Milling Rate on Intermetallic Phase AL_3T_I Formation of Metal Matrix Composite (MMC) Mg-Al-TiO_2
H. Purwaningsih, Widyastuti, Firman Mangasa S

Strategies for Labor Productivity to Support Shipyard Competitiveness Using PLS Path Modeling
Bagiyo Suwasono, Sjarief Widjaja, Ahmad Zubaydi, M. Zaed Yuliadi

Modeling of Lateral Vibrations Using Finite Element Method and Consistent Mass Matrix on Vertical-Axis Ocean Current Turbine
Ridho Hantoro, I.K.A.P. Utama, Aries Sulisetyono, Erwandi

Laboratory-Scale Biopiles and Bio-Sorp Development for Degrading Petroleum Hydrocarbon-Contaminated Soil
Anas Miftah Fauzi, Mohamad Yani, Haripin, Dahuru, Suyeti

The Impact of Organizational Learning Capability on Firm Performance of Indonesian Manufacturing Firms
Alizar Hasan, Difana Meilani

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STUDY OF THE EFFECT OF ELECTROLYZE VARIABLE AND SOLVENT CONCENTRATION ON EXTRACTIVE YIELD OF PATCHOULI LEAVES AND THE ENERGY COSTS WITH USING ELECTROCHEMICAL METHOD OF EXTRACTIVE DISTILLATION COLUMN

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Abstract: *Research about essential oil extract from* Pogostemon Cablin Benth *(Patchouli leaves) has been done using Electrochemical Extractive Distillation Column. Some process variables that influenced in this process are weight ratio of patchouli leaves to solvent voltage and pH. This research has been divided into two methods, that are electrolyze and non-electrolyze process. For non-electrolyze process, variable used is patchouli leaves to solvent ratio 1:10, 1:15, 1:20, and pH 4 and 6. For electrolyze process, it used the same condition as non-electrolyze with voltages 3, 6, 9, and 12 volt. The extractive process occurred in an hour with temperature 80°C. In conclusion, the highest yield about 8.5 % for ratio 1:10 and pH 4 for non-electrolyze process and 12.3 % for ratio 1:10, pH 4 and 9 V for electrolyze process. The energy cost gives each kg of patchouli oil is 183,775 IDR base on highest yield. If we compare the energy cost to selling price of patchouli oil with market quality, it has good properties to SNI (The National Standard Quality of Indonesia) No. SNI 06-2385-1991. The characteristic give yellow color, fresh fragrance, viscosity 0.947, Index number 1.508, acid value max. 2.76, ester value maximum 8.54, other materials: alcohols, fat are negatives.*
Keywords: *Essensial Oil, Patchouli Oil, Electrolyze, Yield, Energy cost*

Abstrak: *Penelitian mengenai pengektraksian minyak atsiri dari daun nilam ini dilakukan dengan menggunakan peralatan Electrochemical Extractive Distillation Column dimana variable proses yang berpengaruh: Rasio daun nilam dengan pelarut, voltase dan PH. Penelitan dibagi menjadi dua metode yaitu proses non elektrolisa dan elektrolisa. Pada penelitian ini untuk proses non elektrolisa digunakan beberapa variasi variable diantaranya variasi rasio bahan baku daun nilam dengan pelarut1 1 : 10, 1 : 15, 1 : 20, variasi pH yaitu pH 4 dan pH 6 sedangkan untuk proses elektrolisa dilakukan penelitian yang sama dengan proses non elektrolisa, hanya pada proses elektrolisa ada tambahan variasi voltase 3, 6, 9, 12 volt yang digunakan. Proses pengekstraksian ini berlangsung selama 1 jam dengan temperature operasi 80°C. Untuk proses non elektrolisa diperoleh rendeman tertinggi sebesar 8.5 % pada rasio 1 : 10 dan pH 4. Sedangkan untuk proses elektrolisa, rendemen tertinggi diperoleh sebesar 12.3 % pada rasio 1 : 10 dan pH 4 serta voltase 9 volt. Biaya energi untuk menghasilkan setiap kilogram minyak nilam adalah Rp. 183.775,00 yang dihitung berdasarkan perolehan rendemen tertinggi. Biaya energi ini proporsional jika dibandingkan dengan harga jual minyak nilam dengan kualitas minyak nilam yang dihasilkan sesuai dengan standar Mutu Nasional Indonesia (SNI) dengan nomor SNI 06-2385-1991.*
Kata Kunci: *Essensial Oil, Patchouli Oil, Electrolyze, Yield, Energy Cost.*

INTRODUCTION

Patchouli oil (*Pogostemon Cablin Benth*) is one of important essential oils in Indonesia which also become export commodity of non oil and gas trade in agriculture with high economical value. Patchouli oil is produced by extractive method of leaves.

Patchouli is traded in the world market with Patchouli Oils name. Its largest chemical compound is Patchouli Alcohol (30%-40%). The use of these oils as fixative perfume in perfumery can not be changed by other oils. It makes these essential oils become significant need in perfumery world.

Fluctuated value of Patchouli oils in the world markets depend on need, stock and quantity. In 1984, Indonesia supplied almost 90% of world Patchouli oils consumption. In that year, need of Patchouli oils in the world market is around 500-550 tons in which 450 tons is from Indonesia, 50-80 tons is from China, 1-3 tons is from Brazil and else from other countries. Importer countries are United State of America, France, England, Germany, and Netherlands.

In the year 1989, total export of Indonesia's Patchouli oil reached 750 tons with value 12.7 million dollar US, which is from Aceh. In monetary

crisis, the price of Patchouli oils had bounced up because Rupiah's value decline and decrease in oil stock. Early 1998, the price of these oils has reached US $100 per kilogram (Statistic Bureu of Indonesia, 1999). Meanwhile, recent data stated that the exchange value of Patchouli oil export is 33 million dollar US, 50% from total exchange of essential oils export. (Nuryani, 2004)

The bright future prospect of these oils has not yet followed by the farmer's enthusiasm to increase and develop these oils production. As many constrain to face technically and administratively in the field and commence.

General quality problem is important thing in essential oils commence. Export requirements should has quality certificate which is used by Chemical Research Association or other pointed laboratories. (Anonim, 1987). Another farmer problem is a low rendemen quality of Patchouli oils where a low quality would get a low profit.

One of the important factors that need to be concerned to get quality and quantity of Patchouli oils is the process works of extraction (Guenther, 1949). Generally research done by direct extractive steam method with operation condition is 100 °C and 1 atm. For traditional boiler within capacity 40 Kg needs 3-4 hours process with rendemen around 3% (Small industry Directorate, 1983. It is seen that high energy needed to extract essential oil of Patchouli leaves with steam extractive process. So, it is important to redesign the technology of extractive method. To reduce energy consumption and to get high quality and quantity of oils.In this research, technology to extract the Patchouli leaves has been designed to reduce the energy consumption of the process, which is equal to its quality and rendemen of Patchouli oils produced. Process used consists of electrolyze, extraction and distillation process in the same tank. This technology process hopefully could stimulate farmers to increase their productivity in cultivate the Patchouli plant and at the end will give a positive contribution to agricultural industry in South Sumatra.

THE ESSENTIAL OIL OF THE PATCHOULI LEAVES

The Extraction Process of Essential Oils

Most of the essential oils generally produced by the extraction process through the use of steam or called hydro distillation process. Separation of the essential oils from plants through extraction process principally consist of two processes that occur in simultaneously; first extract the essential oils from plant with hot water or steam then steamed it, second condensed it.

Such method in extraction process called "hydro distillation", which are distinguishable of three steps:

1. Extraction with water (water distillation).
2. Extraction with water and steam (water and steam distillation).
3. Extraction with direct steam (direct steam distillation).

Patchouli Varieties

Patchouli oils components produced are depended on the variety of the Patchouli proceeded, because each variety has different quantity and quality of oil produced.

For instance, it is needed to know the three varieties of Patchouli plant in Indonesia, which are:

1. Pogostemon Cablin Benth/Patchouli Aceh.
2. Pogostemon Heyneaus Benth/Patchouli Java.
3. Pogostemon Hortensis Backer/Patchouli Soap.

Morphological characteristics of each variety are shown in table 1.

Chemical Compounds

General chemical composition of the essential oil

Generally the essential oils consist of various chemical compounds that formed by Carbon (C), Hydrogen (H), Oxygen (O) and some of Nitrogen (N) and Sulfur (S). Chemical compounds of the essential oils divided into two groups are:

1. Hydrocarbon, particularly consist of terpene compounds.
2. Oxygenated hydrocarbon.

Most of the essential oils consist of hydrocarbon and oxygenated hydrocarbon compounds. Besides that the essential oils consist of resin and wax in the small amounts that are not vaporized.

Chemical composition of Patchouli oils

Patchouli oil is consists of terpene compounds that along with alcohol, aldehid, and ester

compounds that gives specific scent.

The important terpene is Patchouli alcohol which is in gas chromatograph gives the attractive chromatogram. Generally, essential oils has aroma that caused by ester compounds. Chemical compositions of Patchouli oils are shown in table 2.

Table 1. Morphological characteristics of Aceh Patchouli and Java Patchouli

Morphological Characteristics	Aceh Patchouli	Java Patchouli / Soap Patchouli
Height of plant	66.2	63.65
Color of dark stem	Brownish green	Brownish green
Color of light stem	Green	Green
Total Leaves	22.05	23.55
Length of leaf	7.64	6.33
Width of leaf	6.25	5.34
Thickness of leaf	0.039	0.033
Length of leaf stalk	3.79	3.01
Width of leaf stalk		
Thickness of leaf	0.3	0.31
stalk	4.65	4.09
Total leaves in branch	22.05	23.55
Color of light leaf		
Color of dark leaf	Light green	Green
	Green	Purplish
Flower		green
Rendemen of oils	No	Yes
	2.50%	1.50%

Table 2. Chemical composition of Patchouli oils compiler

Components	Total (%)	Boiling Point (°C)	Molecular Weight	Formula
Sesqui terpene	40 – 45			
Patchouli Alcohol	55 – 60	208,37	222,37	$C_{15}H_{26}O$
Benzal-dehida		214		
Eugenol Benzoat		69 – 70	164,2	$C_{10}H_{12}O$
Sinnamal		208	132,16	C_9H_8O
Aldehida				
Alcohol		54 – 95		

Quality Standard of Indonesia's Patchouli Oils

Quality standard of Indonesia's Patchouli oils is defined by National Standardization Council or Standar Nasional Indonesia (SNI) 06-2385-1991.

Table 3. Quality requirements of Patchouli oils

Characteristics	Requirements	Testing Method
-Color	Light yellow to dark brown	Visual
-Spesific gravity, 25°C/25°C	0.943 – 0.983	SP-SMP-17-1975 (ISO R 279-1962 E)
-Reflection Index, 20°C	1.506 – 1.516	SP-SMP-16-1975 (ISO R 280-1962 E)
-Solubility in ethanol 90% with room temperature 25°C ± 3°C	Soluble	SP-SMP-19-1975 (ISO R 2073-1962 E)
-pH maximum	5	SP-SMP-26-1975
-Ester maximum		(ISO R 2073-1973 E)
-Kruing oil	10	SP-SMP-35-1975
	Negative	SP-SMP-25-1975
Others	Negative	SP-SMP-23-1975
-Alcohol		SP-SMP-24-1975
-Fatty		SP-SMP-41-1975
-Pelican oil		(SI No. 25/SI/73)

This standard involved in quality requirements, quality testing, packing procedure, definition, quality type, sampling and recommendation. Patchouli oil is only group in one type of quality with the name "patchouli oils". The quality requirements of Patchouli oils are shown in table 3.

Chlorophyll as Main Pigment of Light Absorbent

Chlorophyll is a green pigment functionalize as light energy receptor in photosynthesis, consists of magnesium-porfirin complex compounds. Porfirin consists of four pyroll chains which are needed by one carbon's bond. Mg activates the form of Chlorophyll aggregate, to easily get light, and hydrophobic long chain is not only placed in but also directed the chlorofil to the lipid double membrane.

Chlorophyll also has long isoprenoid chain which is consist of esterified fitol alcohol with carboxyl subsituen in chain.

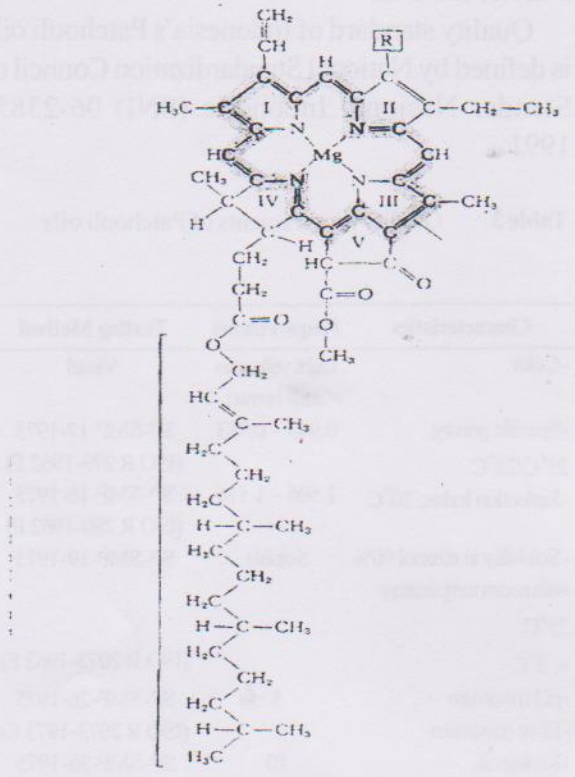

Figure 1. Chlorophyll Molecule Formula

Two types of Chlorophyll l compounds in a leaf are:

1. Chlorophyll a
   Bluish green, with molecule $C_{55}H_{72}MgO_5N_4$, molecular weight 893,49.
2. Chlorophyll b

Yellowish green, with molecule $C_{55}H_{70}MgO_6N_4$, molecular weight 906,51.
Form of Chlorophyll molecules is shown in figure 1.

Energy Absorption by Leaf

Sun's radiation is absorbed by various gases, vapor and particles in the atmosphere with a various level before it reached to the earth. Light absorbed in certain amounts by leaf, reflected and forwarded to the leaf. The amounts of light absorbed by leaves are depended on the structure of leaf and another factor, but it could reach 50% of sun's light to the leaf that will give energy to photosynthesis.

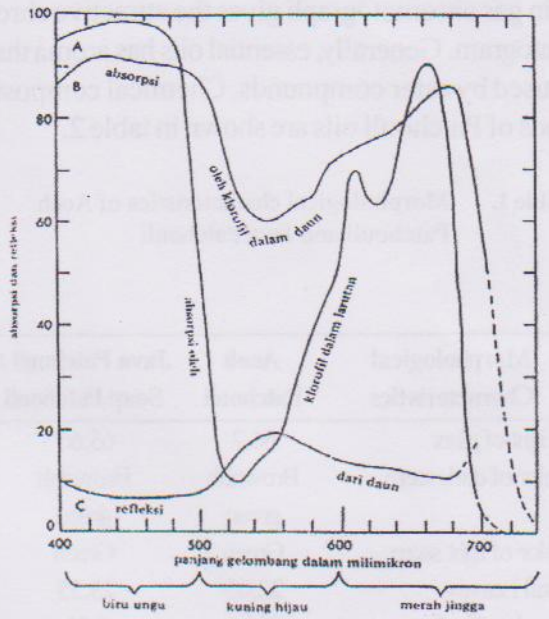

Figure 2. Absorption and reflection of light by chlorophyll

Visible color in each spectrum of light is as a function of wave length. Spectrum zone consists of purple, blue, green, yellow, Chinese red, and red, in which length measured in nanometers (nm). Visible zone in purple is around 400 nm to 700 nm in red zone. In figure 2 below, shows that A curve is a light absorbed by chlorofil in solvent, B curve is a light absorbed by chlorofil in leaf and C curve is a green color in leaf as a reflection of chlorofil.

Sun's light Absorption of Excitation Molecule

Visible light of the sun is an electromagnetic radiation with wave length around 400 – 700 nm. Sun's light caused by fusion reaction of nucleus of hydrogen atom to form helium and electron. This process occurs in a very extremely high temperature in the inside of sun.
The entire reaction is

$$4H \rightarrow {}^{4}He + 2e + hv$$

where hv is energy light quantum, called photon.

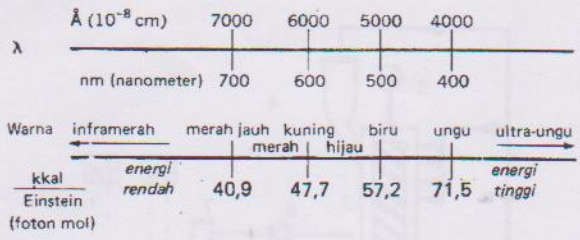

Figure 3. Energy content of the various wave length of visible light

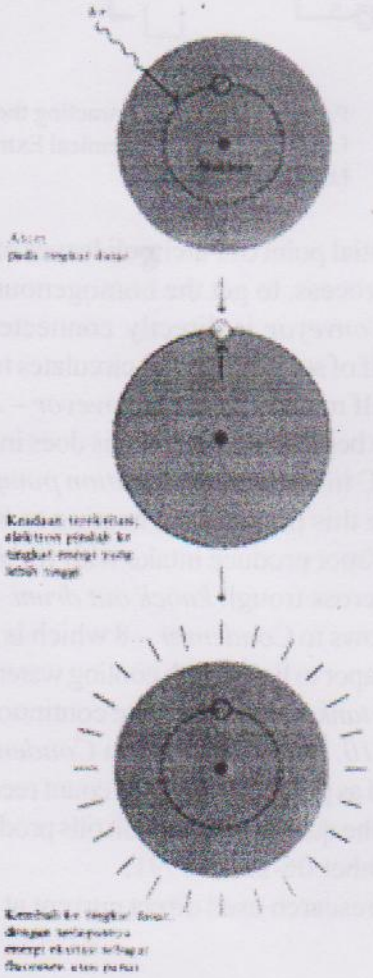

Figure 4. Atomic excitation by light absorption

Max Planck quantum theory mentioned that light consist of energy packets called quantum. Energy for one photon in this theory is formulized in this equation:

$$E = h.f = h.\frac{C}{\lambda}$$

From the above equation, it is seen that energy brought by photon inversely to light wave length, shows in figure 3. Photon with short wave length is in violet end of visible light spectrum and has the highest energy.

The ability of chemical compounds to absorb light depends on electron structure around its atom nucleus of its compounds. When photon absorbed by molecule, electron is increased to the higher level.

Molecule that absorbs photon will exist in the excitation level with a high energy and in unstable condition. If light source is stop, the electron with high energy level will get back to its normal orbit in low energy level with stable condition, called base level. When electron back to its base level, sum of energy absorbs in excitation molecule will release again as beam or heat. Light that arrayed in the energy reduction of molecule excitation shows in figure 4.

METHODOLOGY

To solve the problem in taking the essential oils from Patchouli leaf, some steps has been done such as:

1. Determining research variables.
2. Designing technology process.
3. Analyzing research result.
4. Estimating energy costs.

Variables

Variables influenced in the extraction process of Patchouli leaf with ethanol and boric acid solvents are Patchouli – solvent feed ratio, voltage in potential different, and pH. From these steps, variables which influence rendemen of Patchouli oils with *Electrochemical Extractive Distillation Column* method are known.

Procedures

In this research, method used is *Electrochemical Extractive Distillation Column* (EEDC) with volatile solvent, consists of five steps are shown in figure 5.

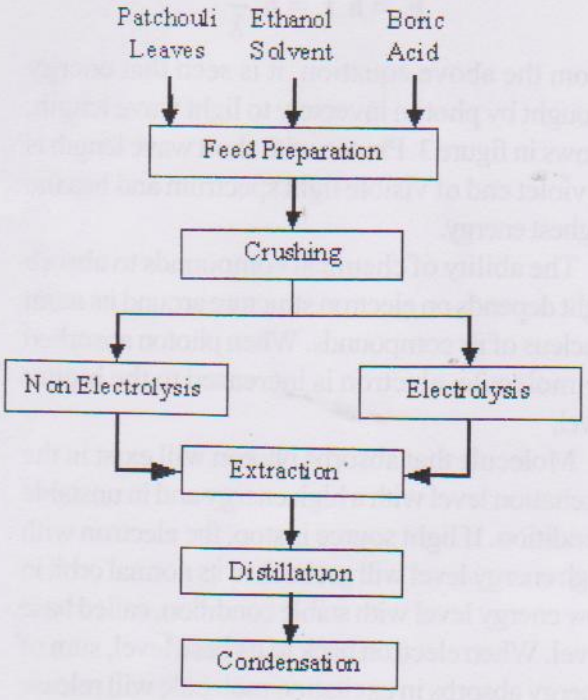

Figure 5. Process flow of extracting the Patchouli leaves with Electrochemical Extractive Distillation Column

1. Feed preparation with weighing the Patchouli leaves sample and measuring the ethanol solvent 10%.
2. Electrolysis with using cathode and anode.
3. Extraction with using volatile solvent.
4. Distillation.
5. Condensation.

Process Descriptions

This research uses fresh Patchouli leaves from Muara Enim in variety of *Pogostemon Cablin Benth* and species *Labiatae which* scheme of the process is shown in figure 6.

Each research uses 500 grams of Patchouli leaves and ethanol 10% as solvent. Ratios of Patchouli leaves to ethanol are 1:10, 1:15, 1:20

Solvent feed into the *Electrochemical Extractive Distillation Column* – 1 through *Feeder* - 4 which has already mixed with boric acid in pH 4 and pH 6. After that *Motor – 3* turn on to move the *Screw Conveyor* – 2, so the leaves will screw under pressure,

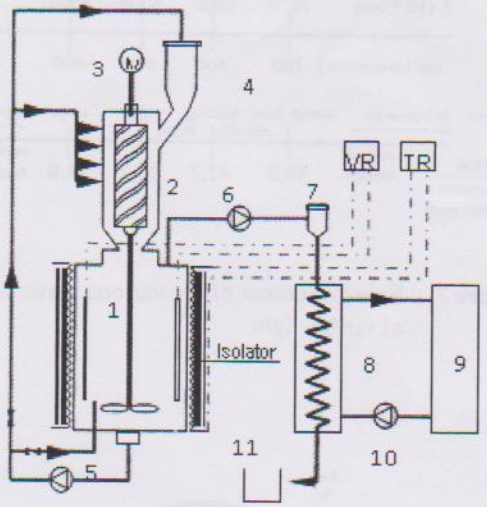

Figure 6. Process Scheme of Extracting the Patchouli Leaves with Electrochemical Extractive Distillation Column

as the initial point of Patchouli leaves extraction. Along process, to get the homogenous mixing, *Screw Conveyor* is directly connected to rod. Then half of solution in tank circulates to *Feeder*-4 and half more to *Screw Conveyor – 2*.

In the beginning, electrolysis does in temperature 60°C in an hour. *Circulation pump – 5* turn on while this process and heating to 80°C with heater. Vapor produce intake with *vacuum pump – 6* and cross trough *knock out drum – 7*. Then vapor flows to *Condenser* – 8 which is condensing the vapor to liquid with cooling water collected in *water tank – 9* and circulate continuously with *pump – 10*. Yield output from *Condenser* – 7 is collected as product. After that count reedmen and analyze the quality of Patchouli oils produced with SNI number 06-2385-1991.

This research used direct current at 3,6,9 and 12 Volt.

Analytical Methods

Quality analysis and rendemen of Patchouli oils significantly influenced by characteristics of physical, chemical and work of extraction equipment.

1. Physical characteristics by color indicator, aroma, specific gravity, reflection index and solubility in alcohol.
2. Chemical characteristics by acid number, ester number which refers to SNI 06-2385-1991.

3. Performance of extraction equipment with rendemen indicator.

Analysis of Energy Needed

1. Calculating each components mass (m_i)

$$Mass_i = (Volume)_i \; x \; (Density)_i$$

$$\text{Total Mass} = \Sigma (components\ mass)_i$$

2. Calculating each components fraction(x_i)

$$\text{Components Fraction i}\,(x_i) = \frac{\text{Component Mass}\,(m_i)}{\text{Total Mass}\,(m_{mixture})}$$

3. Calculating each components heat capacity (Cp_i)
   Counting heat capacity of mixture (Cp_m)

$$Cp_m(T) = \sum_{comp.mix} y_i \; x \; Cp_i\,(T)$$

4. Calculating total heat of mixture $(Q_T)_{mixture}$

$$\text{Total Heat of Mixture } (Q_T)_{mix} = \Sigma\,(\text{Sensibel Heat Component i}\,(Q)_i$$

5. Calculating the electric needs to each equipments used
   a. Calculating the electrical energy consumption in circulation pump.
   b. Calculating the electrical energy consumption in motor.
   c. Calculating the electrical energy consumption in cooling water pump.
   d. Calculating the electrical energy consumption in vacuum pump.
   e. Calculating the electrical energy consumption in electrolysis.

6. Calculating total of electric needs.
   Total of electrical energy needs =
   Total heat of mixture (convert to power unit) +
   Total of electrical needs in equipments

7. Estimating the energy costs
   Converting unit from energy to power

$$\text{kW hour} = \frac{\text{Kkal}}{\text{0,239006 kkal/s}} \Big| \frac{\text{1 kW}}{\text{3600 s}} \Big| \text{1 hour}$$

Energy unit = Kkal
1 kW = 0,239006 Kkal/s
1 hour = 3600 second

Energy costs for 1 kg Patchouli oils

$$\text{Energy costs} = \frac{\text{kW hour PLN costs for 1000 gr}}{\text{1 kW hour Rendemen (gr)}}$$

$$\text{Energy costs} = \frac{\text{Rupiah (Rp)}}{\text{Kg } \textit{Patchouli} \text{ oils}}$$

RESULTS AND DISCUSSIONS

For qualitative analysis from the result, the extraction oil of Patchouli leaves has clear yellow color and aroma. This is because of the Patchouli alcohol compounds in it. Patchouli alcohol compounds are the main compounds of Patchouli oils. Beside that, Patchouli alcohol has small amounts of eugenol, sinnamaldehide, benzaldehide and sesquiterpen compounds.

For quantitative analysis, variables to show the standard of quantity and quality of Patchouli oils are rendemen, specific gravity, reflection index, acid number and ester number.

In this research, the highest rendemen for non electrolysis is 8.5% in ratio Patchouli leaves to solvent 1:10 and pH 4. While for electrolysis, the highest rendemen is 12.3% in ratio Patchouli leaves to solvent 1:10, pH 4 and voltage 9 volt. This results use laboratory analysis in chemical research bureau with SNI defined by National Standardization Council SNI number 06-2385-1991.

Effects of voltage variation and ratio of Patchouli leaves to solvent volume to the rendemen of Patchouli Oils

Voltage variation shows different percentage of rendemen result. From the research result, it is seen that the highest rendemen is in process with voltage 9 volt. For electrolysis process with using voltage 3 and 6 volts, percentage of rendemen result in this process is lower than process with 9 volt.

If the voltage process upper than 9 volt such 12 volt in this research, the percentage of rendemen will constant. It is because of solvent has been saturated. This phenomenon could be seen in figure 7 and 8.

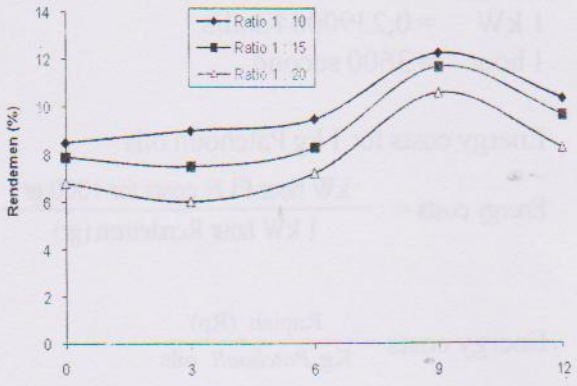

Figure 7. Graph of effects of voltage variation and ratio Patchouli leaves to solvent volume to the rendemen of Patchouli Oils in pH 4.

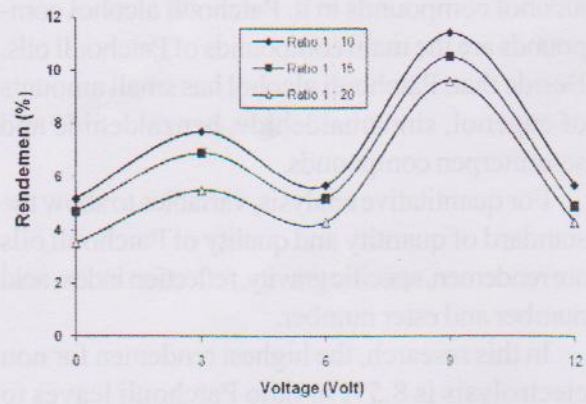

Figure 8. Graph of effects of voltage variation and ratio Patchouli leaves to solvent volume to the rendemen of Patchouli Oils in pH 6.

From research with the same pH shows that solvent volume 5000 ml with weight of fresh Patchouli leaves 500 gr or ratio 1:10 has percentage of rendemen higher than solvent volume 7500 ml and 10000 ml with weight of fresh Patchouli leaves 500 gr or ratio 1:15, 1:20. In other words that more higher the solvent volume is, more lower the rendemen percentage resulted.

Effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result

In the electrolysis, the highest rendemen reached in ratio of Patchouli leaves to solvent volume 1:10, pH 4 and voltage 9 volts. In analysis that with high ratio of Patchouli leaves to solvent

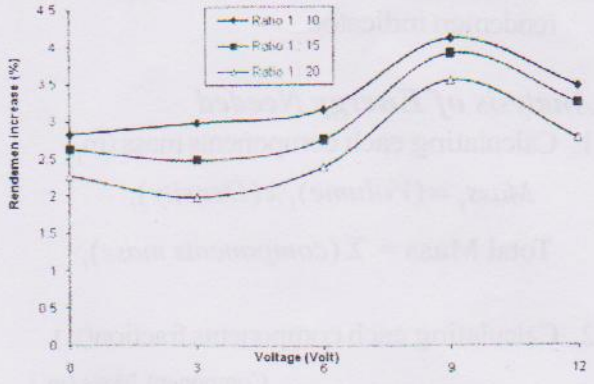

Figure 9. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result at pH 4.

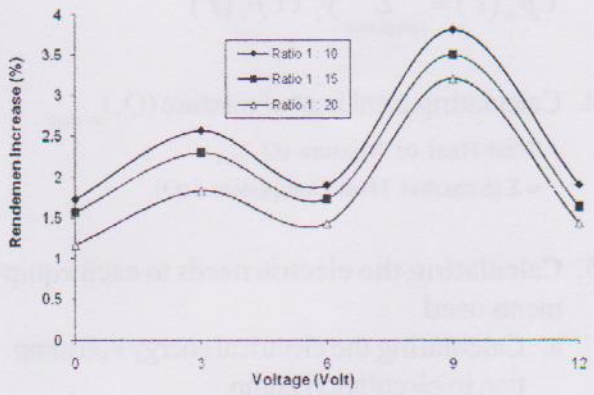

Figure 10. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result at pH 6

volume and low concentration of hydrogen atom in the solution (pH increase) with certain voltage, the rendemen resulted will be high. From the research data, it is clearly seen that voltage gives significant influence to the rendemen resulted. Using voltage can increase rendemen in comparison to M.T&A = 20 Kg, M.T&A=50Kg, and Ketaren. Phenomena of the increase of percentage rendemen show in figure 9 and 10 below.

From the graphs of data analysis, it is seen that the average increase of rendemen from this process is around 1 to 4 times than the usual extraction.

Both for non electrolysis and electrolysis process, it is seen that high pH used makes low the rendemen percentage. And from figure 9 and 10,

the highest rendemen is in pH 4, whereas in pH 4 electrons resulted more than in pH 6. Increasing of rendemen is higher than M.T&A = 20 Kg, M.T&A=50Kg, and Ketaren.

Effects of voltage variation and ratio of Patchouli leaves to solvent volume to the rendemen ratio (E=Re/Rne) in electrolysis and non electrolysis process

In the electrolysis process, the highest rendemen is in ratio of Patchouli leaves to solvent 1:10, pH 4 and voltage 9 volts.

In analysis that with high ratio of Patchouli leaves to solvent volume and low concentration of hydrogen atom in the solution (pH increase) with certain voltage, the rendemen resulted will be high.

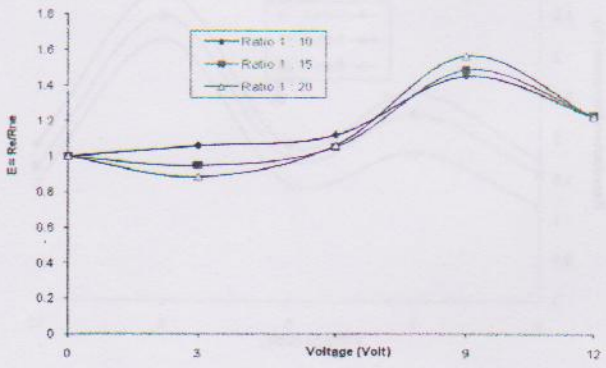

Figure 11. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the rendemen ratio (E=Re/Rne) in electrolysis and non electrolysis process at pH 4.

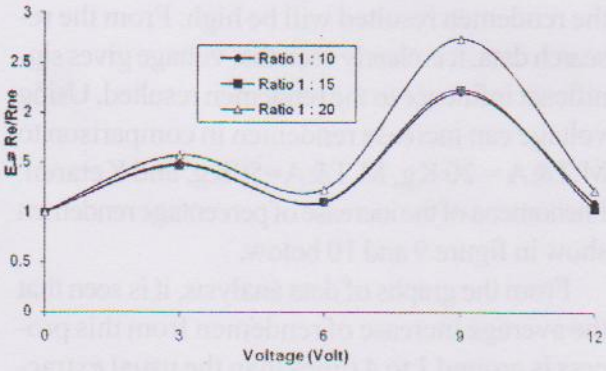

Figure 12. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the rendemen ratio (E=Re/Rne) in electrolysis and non electrolysis process at pH 6.

From the research data, it is clearly seen that voltage gives significant influence to the rendemen resulted. In rendemen comparison between non electrolysis process and electrolysis process in figure 11 and 12, it is seen that in ratio Patchouli leaves to solvent 1:20, voltage 9 volts and same pH, the ratio of rendemen is higher than in ratio 1:10 and 1:15.

It is because of voltage significantly influenced the increase of rendemen in ratio 1:20 if it process is in non electrolysis. While in ratio 1:10 and 1:15, voltage not influenced much.

Electrolysis help to crack bound in Patchouli structure, so solvent addition in process help to increase rendemen.

Quality Analysis of Patchouli Oils

After physical and chemical analyses in laboratory, Patchouli oils produced submit the criteria for quality assurance from National Standardization Council. For quality specifications of Patchouli oils are rendemen, specific gravity, reflection index, acid number and ester number. Standard of Patchouli oils quality in this research show in table 4.

Table 4. Quality of Patchouli Oils Produced.

Characteristics	National Standar (SNI) 06-2385-1991	Coniwanti dkk
Color	Light yellow to dark brown	Light yellow
Aroma	Fresh, specific aroma of Patchouli oils	Fresh, specific aroma of Patchouli oils
Specific Gravity, 25°C/25°C	0.943 – 0.983	0.947
Reflection Index, 20°C	1.506 – 1.516	1.508
Solubility in ethanol 90 % at temperature 25°C ± 3 °C	Cleared solution	Cleared solution
Acid number, max.	5	2.76
Ester number, max.	10	8.54
Others	Negative	Negative
a. Alcohol		
b. Fatty		
c. Pelican Oils		

Estimation of Energy Costs Consumption in Patchouli Extraction.

Beside from quality analysis and rendemen quantity produced, the successful of this research could also be seen from the decrease of energy consumption to produce Patchouli oils. In this re

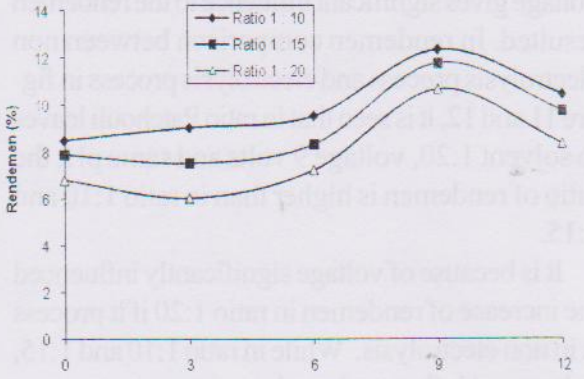

Figure 7. Graph of effects of voltage variation and ratio Patchouli leaves to solvent volume to the rendemen of Patchouli Oils in pH 4.

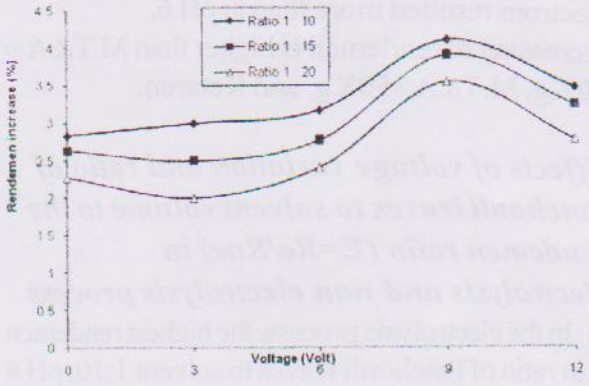

Figure 9. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result at pH 4.

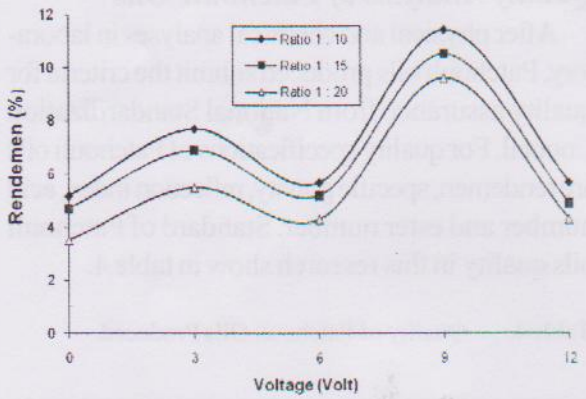

Figure 8. Graph of effects of voltage variation and ratio Patchouli leaves to solvent volume to the rendemen of Patchouli Oils in pH 6.

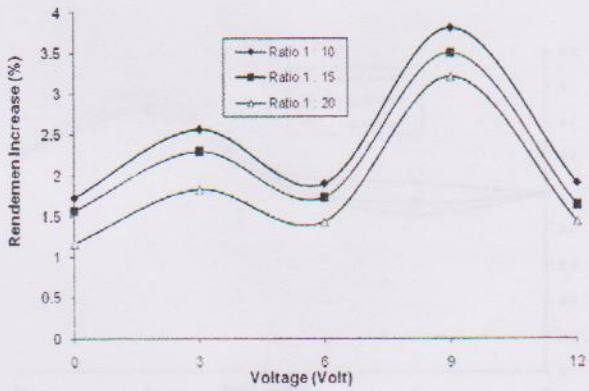

Figure 10. Graph of effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result at pH 6

From research with the same pH shows that solvent volume 5000 ml with weight of fresh Patchouli leaves 500 gr or ratio 1:10 has percentage of rendemen higher than solvent volume 7500 ml and 10000 ml with weight of fresh Patchouli leaves 500 gr or ratio 1:15, 1:20. In other words that more higher the solvent volume is, more lower the rendemen percentage resulted.

Effects of voltage variation and ratio of Patchouli leaves to solvent volume to the increase of rendemen in recent and former research result

In the electrolysis, the highest rendemen reached in ratio of Patchouli leaves to solvent volume 1:10, pH 4 and voltage 9 volts. In analysis that with high ratio of Patchouli leaves to solvent volume and low concentration of hydrogen atom in the solution (pH increase) with certain voltage, the rendemen resulted will be high. From the research data, it is clearly seen that voltage gives significant influence to the rendemen resulted. Using voltage can increase rendemen in comparison to M.T&A = 20 Kg, M.T&A=50Kg, and Ketaren. Phenomena of the increase of percentage rendemen show in figure 9 and 10 below.

From the graphs of data analysis, it is seen that the average increase of rendemen from this process is around 1 to 4 times than the usual extraction.

Both for non electrolysis and electrolysis process, it is seen that high pH used makes low the rendemen percentage. And from figure 9 and 10,

Table 5. Research Comparison

PARAMETER	Made Tasma & Azhari		Ir. S. Ketaren	Coniwanti dkk
Capacity (gr)	20	50	40	500
Extraction Type	Direct vapor	Direct vapor	Direct vapor	Extraction and Electrolysis
Solvent	Water	Water	Water	Ethanol 10 %
Operation Temperature (oC)	100-110	100-140	100-125	70-80
Extraction Time (Minute)	300	420	420	60
Rendemen	1.5	2	3	12,3
Energy Costs (Rp) per kg Patchouli oils	411.300,00	369.200,00	203.000,00	162.200,00

search the estimation costs to produce 1 kg of Patchouli oils are lower than former researches, show in table 5.

CONCLUSIONS

Qualitatively from the laboratory analysis in chemical research bureau, Patchouli oils produced in this research submit the criteria of National Standard of Patchouli oils with SNI number 06-238501991, which has light yellow color, specific aroma of Patchouli oils, cleared solution in ethanol, specific gravity 0.47, reflection index 1.508, acid number 2.76 and ester number 8.54.

Quantitatively for non electrolysis, the highest rendemen is 8.5% in ratio 1:10 and pH 4. While for electrolysis process, the highest rendemen is 12.3% in ratio 1:10, pH 4 and voltage 9 volts. The highest rendemen result is 4 times higher than the highest rendemen from former research by. Ketaren.

Energy costs in this research around 183,775.00 Rupiah per kilograms of Patchouli oils, which is much lower than the market price of Patchouli oils 400,000.00 Rupiah.

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