ทรานเอสเทอริฟิเคชันแบบใช้ด่างเป็นคะตะลีสต์ ของมะเยาหลวง สำหรับการผลิตไบโอดีเซล

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ALKALI-CATALYZED TRANESTERIFICATION OF *VERNICIA MONTANA OIL* FOR PRODUCTION OF BIODIESEL

Mr.Pongsakorn Suklom

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By Mister Pongsakorn Suklom
Field of Study Chemical Engineering
Thesis Advisor Assistant Professor Montree Wongsri

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of the Faculty of Engineering
(Associate Professor Boonsom Lerdhirunwong, Dr.Ing.)

THESIS COMMITTEE

.... Chairman
(Professor Piyasan Praserthdam, Dr.Ing.)

Montree Wongsri
.... Thesis Advisor
(Assistant Professor Montree Wongsri, D.Sc.)

Soorathep Kheawhom
.... Examiner
(Assistant Professor Soorathep Kheawhom, Ph.D.)

.... External Examiner
(Prakorn Ramakul, Ph.D.)

พงศกร สุขล้อม : ทรานเอสเทอริฟิเคชันแบบใช้ด่างเป็นคะตะลีสต์ ของมะเยาหลวงสำหรับการผลิตไบโอดีเซล. (ALKALI-CATALYZED TRANSESTERIFICATION OF *VERNICIA MONTANA OIL* FOR PRODUCTION OF BIODIESEL) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.ดร.มนตรี วงศ์ศรี, 130 หน้า.

งานวิจัยนี้ศึกษาปัจจัยที่มีผลต่อกระบวนการสังเคราะห์ไบโอดีเซลจากน้ำมันมะเยาหลวงโดยใช้ปฏิกิริยาทรานส์เอสเทอริฟิเคชัน ทำการทดลองที่สภาวะของโพแทสเซียมไฮดรอกไซด์ร้อยละ 0.15, 0.35, 0.55, 0.75, 0.95 และ 1.50 โดยน้ำหนักของน้ำมันมะเยาหลวง ใช้เวลาในการทำปฏิกิริยา 10, 30, 60 และ 90 นาที อัตราส่วนโดยโมลที่ใช้ในการศึกษาในครั้งนี้ของน้ำมันมะเยาหลวงต่อเมทานอลคือ 1:3, 1:6, 1:9, 1:12 รวมถึงศึกษาผลของความเร็วรอบที่ 200, 400,และ 600 รอบต่อนาที จากการทดลองพบว่า ร้อยละของโพแทสเซียมไฮดรอกไซด์ที่เหมาะสมในการทำปฏิกิริยาคือ ร้อยละ 0.95 ต่อน้ำหนักน้ำมัน และเมื่อทำการทดลองที่อัตราส่วนโดยโมลที่ศึกษาพบว่าสภาวะที่เหมาะสมที่สุดของน้ำมันมะเยาหลวงต่อเมทานอลคือ 1:9 ความเร็วรอบกวน 600 รอบต่อนาที พบว่าปริมาณเมทิลเอสเทอร์สูงสุดที่อุณหภูมิ 50 องศาเซลเซียส 60 นาที จะทำให้ได้ร้อยละเมทิลเอสเทอร์สูงถึง 96.7 จากนั้นนำไปตวรจสอบคุณภาพของน้ำมันที่ได้พบว่าน้ำมันไบโอดีเซลที่ได้จากน้ำมันมะเยาหลวง (B5) จะให้ค่าไอโอดีนในปริมาณที่สูง และค่าความหนืดที่สูงด้วยเช่นกัน คือ 159.5 กรัมไอโอดีนต่อ 100 กรัม และ 8.22 เซนติสโตรก ตามลำดับ ซึ่งเกินเกณฑ์มาตราฐานของ CNS 15072 และ EN 14214 ที่กำหนดไว้คือ ไม่เกิน 120 กรัมไอโอดีนต่อ 100 กรัม และ 3.5 – 5.0 เซนติสโตรก ตามลำดับ ดังนั้นน้ำมันมะเยาหลวงอาจจะไม่เหมาะสมในการนำมาผลิตไบโอดีเซล นอกเสียจากจะทำให้ปริมาณของค่าไอโอดีนและค่าความหนืดให้ลดลงให้อยู่ในเกณฑ์มาตราฐานก่อนการนำมาผลิต

ภาควิชา วิศวกรรมเคมี

สาขาวิชา วิศวกรรมเคมี

ปีการศึกษา 2554

ลายมือชื่อนิสิต พงศ์

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก

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PONGSAGONS SUKLOM: ALKALI-CATALYZED TRANSESTERIFICATION OF *VERNICIA MONTANA OIL* FOR PRODUCTION OF BIODIESEL.
ADVISOR: ASST. PROF. MONTREE WONGSRI, D.Sc., 130 pp.

The objective of this research was to study the effect factors of biodiesel synthesis from *VERNICIA MONTANA OIL* using transesterification reaction. The series of experiment were carried out by using potassium hydroxide with 0.15, 0.35,0.55, 0.75, 0.95 and 1.50 wt% potassium hydroxide to *VERNICIA MONTANA OIL* between 10, 30, 60 and 90 minutes and *VERNICIA MONTANA OIL* to methanol molar ratio 1:3, 1:6, 1:9 and 1:12 in addition studied the effect of stirring speed at 200, 400, 600 round per minute. The experiment result showed that potassium hydroxide 0.95 wt% is suitable for the reaction. From the experiments at 600 rpm found that the maximum methyl ester contents obtained from the reaction at 50 degree Celsius, 60 minutes were 96.7%. The obtained biodiesel from *VERNICIA MONTANA OIL* contained high values of iodine value and kinematic viscosity 40 °C are 159.5 g $I_{2/}$100 g and 8.22 mm^2/s, respectively. Which are higher than the limit recommended biodiesel standard CNS 15072 and EN 14214 specification with iodine value lower than 120 g I_2/100 g and kinematic viscosity 40 °C during 3.5 – 5.0 mm^2/s, respectively. The *VERNICIA MONTANA OIL* may be not suitable for biodiesel product unless iodine value and kinematic viscosity 40 °C are reduced.

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Student's Signature
Advisor's Signature

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CHAPTER I

INTRODUCTION

1.1 Importance and reasons for research

Gasoline and diesel the vary importance of human activities. Be it lighting the house, agriculture, cooking especially transportation each process requires energy. Biodiesel new source of energy is the fuel of future. Biodiesel is derived from vegetable oils and hence is a renewable fuel. Gasoline and diesel come in the category of non-renewable fuel and will last for a limited period of time. These non renewable fuels also emit pollutants in the form of oxides of nitrogen, oxides of sulfur, carbon dioxide, carbon monoxide, lead, hydrocarbons, etc. during their processing and use. A renewable fuel such as biodiesel, with lesser exhaust emissions, is the need of the day.

Hence, researchers and scientific community have focused on development of biodiesel and the optimization of the processes to meet the standards and specifications needed for the fuel to be used commercially without compromising on the durability of engine parts. The interest in the use of renewable fuel started with the direct use of vegetable oils as a substitute for diesel. However, their direct use in compression ignition engines was restricted due to high viscosity which resulted in poor fuel atomization, incomplete combustion and carbon deposition on the injector and the valve seats causing serious engine fouling (Ramadhas et al., 2005). Other constraints of the direct application of vegetable oil were its low volatility and polyunsaturated character. To overcome these constraints, the processes like pyrolysis, micro-emulsification, transesterification, etc. were especially developed. Pyrolysis of the vegetable oil resulted in products with low viscosity, high cetane number, accepted amounts of sulfur, water and sediments, accepted copper corrosion values but were unacceptable in the terms of their ash contents, carbon residues, and pour points. Similarly, micro-emulsion of vegetable oil lowered the viscosity of the oil but resulted in irregular injector needle sticking, heavy carbon deposits and incomplete combustion during 200 h laboratory screening endurance test (Fukada et al.,2001).

Transesterification is a chemical reaction between triglyceride and alcohol in the presence of a catalyst. It consists of a sequence of three consecutive reversible reactions where triglycerides are converted to diglycerides, diglycerides are converted to monoglycerides followed by the conversion of monoglycerides to glycerol. In each step an ester is produced and thus three ester molecules are produced from one molecule of triglyceride (Sharma et al., 2007). Out of these three methods, transesterification is the most viable process adopted known so far for the lowering of viscosity. It also gives glycerol as a by-product which has a commercial value. Stoichiometrically, three moles of alcohol are required for each mole of triglyceride, but in general, a higher molar ratio is often employed for maximum ester production depending upon the type of feedstock, amount of catalyst, temperature, etc. Commonly used alcohols include methanol, ethanol, propanol and butanol. However, the yield of biodiesel is independent of the type of the alcohol used and the selection of one of these depends on cost and performance. Methanol is preferred over others due to its low cost (Ramadhas et al., 2005).

The conventional catalysts used are acid and alkali catalysts depending upon the nature of the oil used for biodiesel production. Another catalyst being studied is lipase. Lipase has advantage over acid and alkali catalysts but its cost is a limiting factor for its use in large scale production of biodiesel. Choice of acid and alkali catalysts depends on the free fatty acids (FFA) content in the raw oil. FFA should not exceed a certain amount for transesterification to occur by an alkali catalyst. Invariably, on all aspects of development of biodiesel, Ma et al.(1999) have done significant work. Canakci et al.(1999) and Van Gerpan et al.(2001) reported that transesterification was not feasible if FFA content in the oil was about 3%. Ramadhas et al.(2005) and Veljkovic et al.(2006) used rubber seed oil and tobacco seed oil, respectively, with higher free fatty acid content (17%). The authors reduced the FFA value to more than 2.0%, which corresponds to 4.0 mg KOH/g, by acid esterification using H_2SO_4 as a catalyst. Sahoo et al.(2007) used zero catalyzed transesterification (using toluene) and acid esterification (using H_2SO_4) prior to alkaline esterification to reduce the acid value from

22.0% to 2.0%. Sharma and Singh [3] also favored acid esterification prior to alkaline transesterification with karanja oil as feedstock having FFA of 2.54% (5.08 mg KOH/g) using H_2SO_4. In the same manner, the acid value of jatropha which corresponds to 14% FFA was reduced to less than 1% by using H_2SO_4 [9].

Table 1.1 depicts the values of initial FFA of the feedstock, the level reached after acid esterification and the amount of H_2SO_4 used. After treatment with acid catalyst, H_2SO_4, the free fatty acid (FFA) value is reduced to less than 2.0% to make transesterification reaction feasible (Sharma et al.,2008). Table.2 depicts the yield/conversion of biodiesel with different oils taken. The yield of biodiesel ranged from 56% from Chlorella protothecoides to 99% from Jatropha curcas. The conversion of biodiesel ranged from more than 80% from C.prothecoides to 98.4% from soybean oil. Various oils have been in use in different countries as raw materials for biodiesel production owing to its availability. Soybean oil is commonly used in United States and rapeseed oil is used in many European countries for biodiesel production, whereas, coconut oil and palm oils are used in Malaysia for biodiesel production (Meher et al., 2006).Transesterification of edible oils has also been carried out from the oil of canola and sunflower.

Table 1.1 Values of initial FFA content of different feedstock

Feedstock	Initial FFA (%)	FFA after treatment (%)	Amount (%) and catalyst used
Rubber oil	17.0	<2.0	0.5, H_2SO_4
Karanja oil	2.53	0.95	0.5, H_2SO_4
Tobacco oil	35.0	<2.0	1.0/2.0, H_2SO_4
Polanga oil	22.0	<2.0	0.65, H_2SO_4
Jatropha oil	14.0	<1.0	1.43, H_2SO_4
Mahua oil	19.0	<1.0	1.0, H_2SO_4
Karanja oil	2.53	0.3	KOH(appropriate amount)

Table 1.2 Yield of biodiesel with difference feed stock

Oil taken for study	Yield (%)	Conversion (%)
Karanja *(Pongamia pinnata)*	89.5	-
Tobacco *(Nicotina tabacum)*	91	-
Polanga *(Calophyllum inophyllum)*	-	85
Jatropha *(Jatropha curcas)*	99	-
Mahua *(Madhuca indica)*	98	-
Karanja *(Pongamia pinnata)*	97-98	-
Karanja *(Pongamia pinnata)*	-	92/95
Soybean *(Glycine max)*	-	98.4
Waste cooking oil	97.02	-
Canola oil *(Brassica napus)*	90.04	98
Used frying oil	87.5	94
Sunflower oil *(Helianthus annuus)*	-	Nearly complete
Chlorella protothecoides	-	>80

1.2 Objective of the Research

The current research work deals with the production of biodiesel from *Vernicia Montana oil* using an alkaline transesterification process with a mixture of methanol. The objectives of this research work are

1.2.1 To determine the quantities and compositions of free fatty acids in *Vernicia Montana* oil by produce biodiesel methyl esters from*Vernicia Montana* oil and methanol in a laboratory scale batch reactor system.

1.2.2 To determine the operating conditions of biodiesel production from *Vernicia Montana* oil and study the factors affect to the transesterification reaction consisting of catalyst concentration, molar ratio of methanol to oil, the suitable temperature reaction and stirring revolution.

1.3 Scope of the Research

The research had been carried out to study the factors affect to transesterification reaction as follow:

1.3.1 Determine the quantities and compositions of free fatty acids of *Vernicia Montana* oil, using Gas Chromatography technique.

1.3.2 Determine the effect of catalysts concentration (0.15, 0.35, 0.55, 0.75, 0.95,1.50 wt%) on the conversion of biodiesel by using Potassium Hydroxide to *Vernicia Montana* oil.

1.3.3 Determine the effect of molar ratio of methanol to oil (3:1, 6:1, 9:1 and 12:1) on the conversion of biodiesel.

1.3.4 Determine the effect of stirring speed by varying from 200, 400 and 600 rpm.

1.3.5 Determine the effect of reaction temperature by varying from 40, 50, 60,70 degree Celsius.

1.3.6 Determine the effect of reaction time varying from 10 to 90 minutes (10, 30, 60, 90 minutes).

1.4 Benefit of the Research

This study provides the suitable operating conditions for production of alternative fuel from *Vernicia Montana* oil. Process of biodiesel production from *Vernicia Montana* oil with gives the highest yield of methyl ester in the short reaction time, less energy consumption and low capital cost.

1.5 Research Methodology

1.5.1 Research and review Literature relating to biodiesel synthesis technique and *Vernicia Montana* oil.

1.5.2 Set up laboratory equipment and chemicals for the experiment.

1.5.3 Analyze chemical properties of raw material.

1.5.4 Carry out the experiments.

1.5.5 Analyze percentage of produced methyl ester using gas chromatograph.

1.5.6 Conclude the experimental result.

CHAPTER II

THEORY AND LITERETURE REVIEW

2.1 Biodiesel Production

Biodiesel is defined as methyl ester or ethyl ester from fats and oils. They are used in diesel engine and heating system which biodiesel shows the general advantages (Vicente et al., 2003)

1. It is biodegradable and non-toxic, assuring safe handing and transport.
2. It does not contain sulfur or aromatic compounds and thus it contributes to reductions of the engine exhaust emission level.
3. It comes from renewable source such as vegetable oil.
4. It can be produced domestically, reducing a country's dependency on foreign fuel.

A number of studies on biodiesel production from vegetable oils have been reported using a variety of oils, alcohols, different catalyst and reaction conditions. For alkaline catalyzed process, Jianbin et al.(2006) using an alkaline-catalyzed biodiesel production method with power ultrasonic (19.7 kHz) has been developed that allows a short reaction time and high yield because of emulsification and cavitation of the liquid–liquid immiscible system. Furthermore, hydrodynamic cavitation was used for biodiesel production in comparison to ultrasonic method. Both methods were proved to be efficient, and time and energy saving for the preparation of biodiesel by transesterification of soybean oil. Meher et al.(2006) studies on transesterification of Karanja oil with methanol for the production of biodiesel.

The reaction parameters such as catalyst concentration, alcohol/oil molar ratio, temperature, and rate of mixing were optimized for production of Karanja oil methyl ester. The fatty acid methyl esters content in the reaction mixture were quantitied by HPLC and 1H NMR method. The experimental revealed the optimum reaction conditions for methanolysis of Karanja oil was 1% KOH as catalyst, moil molar ratio 6:1, reaction temperature 65°C, rate of mixing 360 rpm for a period of 3h. The yield of methyl esters was >85% in 15min and reaction was almost complete in two hours with the yield of 97–98%. With 12:1 molar ratio of methanol to oil or higher, the reaction was completed within 1 h. The reaction was incomplete with a low rate of stirring (180 rpm), whereas stirring at high rpm was a time efficient process. Present work reports an optimized protocol for the production of biodiesel through alkaline-catalyzed transesterification of rapeseed oil. The reaction variables used were methanol/oil molar ratio (3:1–21:1), catalyst concentration (0.25–1.50%), temperature (35–65 ^{0}C),mixing intensity (180–600 rpm) and catalyst type. The evaluation of the transesterification process was followed by gas chromatographic analysis of the rapeseed oil fatty acid methyl esters (biodiesel) at different reaction times.

The biodiesel with best yield and quality was produced at methanol/oil molar ratio, 6:1; potassium hydroxide catalyst concentration, 1.0%; mixing intensity, 600 rpm and reaction temperature 65 ^{0}C. The yield of the biodiesel produced under optimal condition was 95–96%. It was noted that greater or lower the concentration of KOH or methanol than the optimal values, the reaction either did not fully occur or lead to soap formation (Rashid et al., 2007).Alternative to the catalytic process of biodiesel production is acid and alkaline catalytic. Ramadhas et al.(2005) used sodium hydroxide and sulfuric acid as a catalyst for two step biodiesel production of rubber seed oil. A two-step transesterification process is developed to convert the high FFA oils to its esters. The first step (acid catalyzed transesterification) reduces the FFA content of the oil to less than 2%.The alkaline catalyst transesterification process converts the products of the first step to its mono-esters and glycerol. The molar ratio of 6:1 of methanol to rubber seed oil, using NaOH(0.5% by volume) as catalyst, the completion of alkaline catalyzed esterification process in half an hour. The maximum ester conversion is achieved at the reaction temperature of 45±5 ^{0}C. Another example on two-step transesterification process is that of Veljikovic et al.(2006), in which the transesterification of crude tobacco seed oil (TSO) having high free fatty acids (FFA).

The TSO was processed in two steps, the first the acid-catalyzed esterification to reduced the FFA level to less than 2% in 25 min for the molar ratio of 18:1 and then followed by the second step at the molar ratio of 6:1 of methanol to tobacco seed oil, using KOH (1% based on the oil wt) as alkaline-catalyst converted the product of the first step into methyl ester and glycerol. The maximum yield of methyl ester was about 91% in about 30 min at 60±0.1 ^{0}C. Karmee et al.(2005) commonly used catalysts used for alkaline-catalyzed transesterification i.e. sodium hydroxide, potassium hydroxide and sodium methoxide, were evaluated using edible Canola oil and used frying oil. The fuel properties of biodiesel produced from these catalysts, such as ester content, kinematic viscosity and acid value, were measured and compared. With intermediate catalytic activity and a much lower cost sodium hydroxide was found to be more superior than the other two catalysts. The process variables that influence the transesterification of triglycerides, such as catalyst concentration, molar ratio of methanol to raw oil, reaction time, reaction temperature, and free fatty acids content of raw oil in the reaction system, were investigated and optimized. This paper also studied the influence of the physical and chemical properties of the feedstock oils on the alkaline-catalyzed transesterification process and determined the optimal transesterification reaction conditions that produce the maximum ester content and yield.

A technique to produce biodiesel from crude Jatropha curcas seed oil having high free fatty acids (15%FFA) has been developed. The high FFA level was reduced to less than 1% by a two-step pretreatment process. The first step was carried out with 0.60 w/w methanol to oil ratio in the presence of 1% w/w H_2SO_4 as an acid catalyst in 1h reaction at 50 ^{0}C. After the reaction, the mixture was allowed to settle for 2 h and the methanol–water mixture separated at the top layer was removed. The second step was transesterified using 0.24 w/w methanol to oil and 1.4% w/w NaOH to oil as alkaline catalyst to produce biodiesel at 65 ^{0}C. The final yield for methyl esters of fatty acids was achieved ca. 90% in 2 h(Berchmans et al., 2007).

2.2 Production of biodiesel

2.2.1 Direct use and blending

Beginning in 1980,there was considerable discussion regarding use of vegetable oil as fuel (Bartholomew, 1981) with most advanced work at that period was with sunflower oil which took place in South Africa. Caterpillar Brazil in 1980 used pre-combustion chamber engines with mixture of 10% vegetable oil to maintain total power without any alteration or adjustments to the engines. At the point, it was not practical to substitute 100% vegetable oil for diesel fuel. But a blend of 20% vegetable oil and 80% diesel fuel was successful. Some short-term experiments were successfully carried out up to 50/50 ratio. Nevertheless, the problem appeared after the engine has been operating on vegetable oil for long period of time. (Schlick et al., 1988) evaluate the performance of a direct injection 2.59 L, 3-cylinder 2600 series ford diesel engine operating on mechanically expelled unrefined soybean oil and sunflower oil blended with number 2 diesel fuels on 25.75 v/v basis. The power remained constant throughout 200 hrs of operation. Excessive car on deposition on all combustion chamber part precludes the use of these fuel blends, at least in this engine and under the specified Engine Manufacturers' Association operating conditions.

The direct use of vegetable oil and/or the use of blends of the oils has generally been considered to be not satistory and impractical for both direct and indirect diesel engines, the high viscosity, acid composition, free fatty acid content, as well as gum formation due to oxidation and polymerization during storage and composition, carbon deposits and lubricating oil thickening.

2.2.2 Microemulsions

To solve the problem of high viscosity of vegetable oils, microemulsions with solvents such as methanol, ethanol and 1-butanol have been studies. A microemulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructure with dimension generally in the 1-150 nm range, formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles (Schwab et al.,1987). It was found that microemulsion can improve spay characteristic by explosive vaporization of the low boiling constituent in the micelles (Pryde, 1984). In short term performance, ionic and non-ionic microemulsion of the lower cetane number and energy content (Goering et al., 1982). However, fuel formulated as microemulsion have low cetane number and low heating values as compared with No.2 diesel fuel (Bagby., 1987)

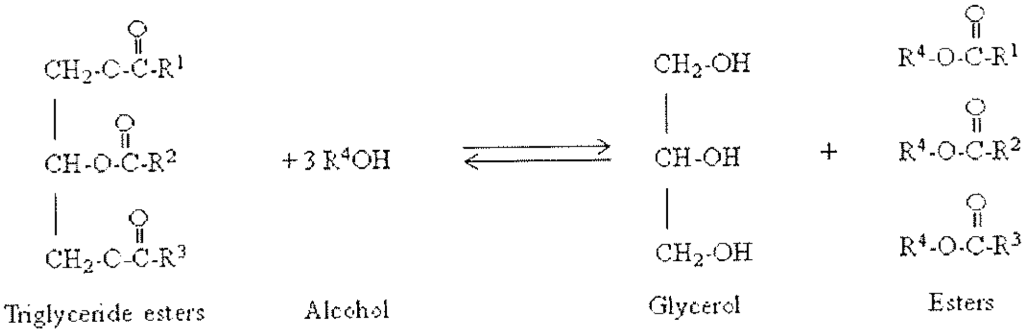
2.2.3 Pyrolysis

Pyrolysis or thermal cracking can be used to make triglyceride based biodiesel, the thermal degradation of vegetable oils by heat absence of oxygen, which results in the production of alkanes, alkenes, alkadienes, carboxylic acids, aromatic and small amount of gaseous products (Schwab et al., 1988). The starting material can be vegetable oils, animal fats, fatty acid and methyl esters of fatty acid. Soybean oil could be thermally decomposed and distilled in air and nitrogen sparged with standard ASTM distillation apparatus (Niehaus et al.,1987; Schwab et al.,1988). Schwab et al.(1988) used safflower oil as a high oleic oil control. The total identified hydrocarbons obtained from the distillation of soybean and high oleic safflower oils were 73-77% and 80-88% respectively.

Copra oil and palm oil stearin had also been cracked over a standard petroleum catalyst SiO_2/Al_2O_3 at 450 ^{0}C to produce gases, liquids and solids with lower molecular weight (Pioch etal., 1993). The condensed organic phase was fractionated to produce biogasoline and biodiesel fuels. The chemical compositions (heavy hydrocarbons) of the diesel fractions were similar to fossil fuels. This process use very high temperature consequently, when the temperature increases as the decomposition levels of the vegetable oil increases. Although the pyrolysed vegetable oils process acceptable amounts of sulfur, water and sediment and give acceptable copper corrosion values, however they give unacceptable ash, carbon residue amounts and pour point. Engine testing on pyrolysed oil has been limited to short-term tests.

2.2.4 Transesterification

Transesterification (also call alcoholysis) is a reaction of vegetable oils such as soybean oil, sunflower oil, coconut oil, rapeseed oil, palm oil, or animal fat (or known as triglycerides) to produce the fatty acid ester biodiesel, and glycerol as a co-product. This reaction takes a long time to complete, and thus generally requires some base or acid catalyst to improve reaction rate and yield. Examples of these catalysts are sodium or potassium hydroxide, or sulfuric acid. General equation of this reaction is shown in the Figure 2.1. R_1, R_2 and R_3 of the oil molecules are long chain of hydrocarbon constituting fatty acids which may be the same or different..

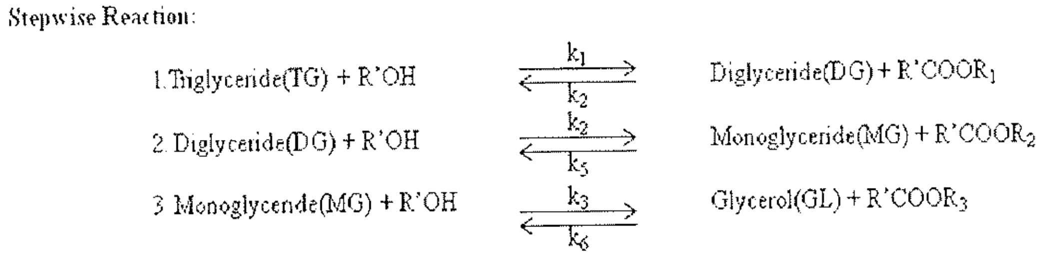


$$\begin{array}{l}CH_2\text{-}C\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^1\\ |\\ CH\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^2\\ |\\ CH_2\text{-}C\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^3\end{array} + 3\,R^4OH \rightleftharpoons \begin{array}{l}CH_2\text{-}OH\\ |\\ CH\text{-}OH\\ |\\ CH_2\text{-}OH\end{array} + \begin{array}{l}R^4\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^1\\ R^4\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^2\\ R^4\text{-}O\text{-}\overset{O}{\overset{\|}{C}}\text{-}R^3\end{array}$$

Figure 2.1 Chemical reaction of transesterification

The stoichiometry requires three moles of alcohol and one mole of triglyceride to produce three moles of fatty esters and one mol of glycerol. However, this reaction is reversible, and therefore excess alcohol is used in reaction to shift the equilibrium to the right side (products). Typically, the variables affecting reaction rate and yield include: type and amount of catalyst, type of alcohol, reaction temperature, reaction time, molar ratio of vegetable oil and alcohol, glycerol separation and quality of vegetable oil such as fatty acid composition.

The transesterification reaction shown in Figure 2.1 is indeed the overall reaction for three stepwise reactions with intermediate formation of diglyceride and monoglyceride (Figure 2.2). In the first reaction, triglyceride(TG) react with alcohol to produce diglyceride (DG), then in the second reaction, diglyceride(MG) react with alcohol to form monoglyceride(MG). Finally, in the third reaction, monoglyceride(MG) react with alcohol to give glycerol.



Stepwise Reaction:

$$\text{1. Triglyceride(TG)} + \text{R'OH} \underset{k_2}{\overset{k_1}{\rightleftarrows}} \text{Diglyceride(DG)} + \text{R'COOR}_1$$

$$\text{2. Diglyceride(DG)} + \text{R'OH} \underset{k_5}{\overset{k_2}{\rightleftarrows}} \text{Monoglyceride(MG)} + \text{R'COOR}_2$$

$$\text{3. Monoglyceride(MG)} + \text{R'OH} \underset{k_6}{\overset{k_3}{\rightleftarrows}} \text{Glycerol(GL)} + \text{R'COOR}_3$$

Figure 2.2 The transesterification stepwise reactions of vegetable oil with alcohol to esters and glycerol (Freedman et al., 1986)

Methanolysis. The classic reaction conditions for the methanolysis of vegetable oils or animal fats are 6:1 molar ratio of methanol to oil, 0.5 wt.% alkali catalyst (with respect to TAG), 600+ rpm, 60°C reaction temperature, and 1 h reaction time to produce FAME and glycerol (Freedman et al. 1984). A number of recent studies have describedoptimal reaction conditions for biodiesel production from various feedstocks using response surface methodology (RSM). Parameters that are normally optimized to produce the most biodiesel include catalyst type and amount, reaction time and temperature, amount of alcohol, and/or agitation intensity. Please refer to Table 3 for a summary of recent examples of biodiesel process optimization employing RSM. In addition to the studies listed in Table 3 are the following: Park et al. (2008a), Rashid and Anwar (2008a),Yuan et al. (2008), Wang et al. (2008), Cetinkaya and Karaosmanoglu (2004), Antolin et al. 2002. A representa- tive example of reaction conditions optimized by RSM is the work of Kumartiwari et al. (2007) in which Jatropha curcas oil methyl esters were produced (after acid pretreatment) using 0.55 wt.% KOH, 60°C reaction temperature, 5:1 molar ratio of methanol to oil, and 24 min reaction time to provide biodiesel in 99% yield. The reaction parameters do not vary by a significant amount, as seen by comparison of the classic reaction conditions to that of Kumartiwari et al. (2007) and others listed in Table 3, as discussed by Freedman et al. 1984.

Ethanolysis proceeds at a slower rate than methanolysis because of the higher reactivity of the methoxide anion in comparison to ethoxide. As the length of the carbon chain of the alkoxide anion increases, a corresponding decrease in nucleophilicity occurs, resulting in a reduction in the reactivity of ethoxide in comparison to methoxide. An example of this phenomenon is the transesterification (at 25°C) of canola oil with a 1:1 mixture of ethanol and methanol (to provide an overall molar ratio of alcohol to oil of 6:1) that results in 50% more methyl than ethyl esters (Kulkarni et al. 2007).

Ethanolysis. The classic conditions for ethanolysis of vegetable oils or animal fats are 6:1 molar ratio of ethanol to oil, 0.5 wt.% catalyst (with respect to TAG), 600+ rpm, 75°C reaction temperature, and 1 h reaction time to produce fatty acid ethyl esters (FAEE) and glycerol (Freedman et al. 1984). Ethyl esters have been prepared from a number of feedstocks for use or evaluation as potential biodiesel fuels (Issariyakul et al. 2007; Stavarache et al. 2008). In addition, mixtures of methyl and ethyl ester shave been reported whereby the transesterification reaction was conducted with both methanol and ethanol (Issariyakul et al. 2007). As in the case of methanolysis, the ethanolysis reaction has been optimized using RSM (Kucek et al. 2007)). Please refer to Table 6 for two recent examples from the literature. A representative example is that of the ethanolysis of crude Raphanus sativus oil (Domingos et al. 2008) in which 0.60 wt.% NaOH, 11.7:1 molar ratio of ethanol to oil, 38°C reaction temperature, and a 1-h reaction time afforded the corresponding ethyl esters in 99.1% yield. The reaction temperature and amount of ethanol in this case varied considerably from the conditions initially reported by Freedman et al. (1984).

Butanolysis. The classic conditions for butanolysis of vegetable oils or animal fats are 6:1 molar ratio of butanol to oil, 0.5 wt.% catalyst (with respect to TAG), 600+ rpm, 114°C reaction temperature, and 1 h reaction time to produce fatty acid butyl esters and glycerol (Freedman et al. 1984). Butyl esters have been prepared from a variety of feedstocks for use or evaluation as potential biodiesel fuels (Freedman et al. 1986; Schwab et al. 1987; Ali and Hanna 1994; Foglia et al. 1997; Nimcevic et al. 2000; Lang et al. 2001; Zhou and Boocock 2006a, b;

Rodrigues et al. 2008). To date, the butanolysis reaction has not yet been optimized by RSM.

Acid Catalyzed Processes

The transesterification process can be catalyzed by acids such as sulfuric or hydrochloric acids (Freedman et al., 1986). These catalysts give very high yield in alkyl esters, but the acid catalyzed reactions are generally slow, requiring, typically, temperatures above 100 ^{0}C and more than the several hours to complete. Methanolysis of soybean oil, in the presence of 1 mol % of H_2SO_4 with an alcohol/oil molar ratio of 30:1 at 65 ^{0}C, takes 50 hrs to reach complete conversion of the vegetable oil (>99%) while the butanolysis(at 117^{0}C) and ethanolysis (at 78 ^{0}C) using the same quantities of catalyst and alcohol, take 3 and 18 hrs, respectively (Freedman et al., 1986).

The alcohol/vegetable oil molar ratio is one of the main factors that influences transesterification. An excess of the alcohol favors the formation of the products. On the other hand, an excessive amount of alcohol makes the recovery of the glycerol difficult, so that ideal alcohol/oil ratio has to be established empirically, considering each individual process.

The mechanism of the acid catalyzed transesterification of vegetable oils in shown in Figure 2.3 for a monotriglyceride. However, it can be extended to ditriglyceride and tritriglycerides. The protonation of the carbonyl group of the ester leads to the carbocation II which, after a nucleophilic attack of the alcohol, produces the tetrahedral intermediate III. Elimination of glycerol from the new ester IV, and regenerates the catalyst H^+. According to this mechanism, carboxylic acids can be formed by reaction of the carbocation II with water present in the reaction mixture. This suggests that an acid catalyzed transesterification should be carried out in the absence of water in order to avoid the competitive formation of carboxylic acid which reduces the yield of alkyl ester.

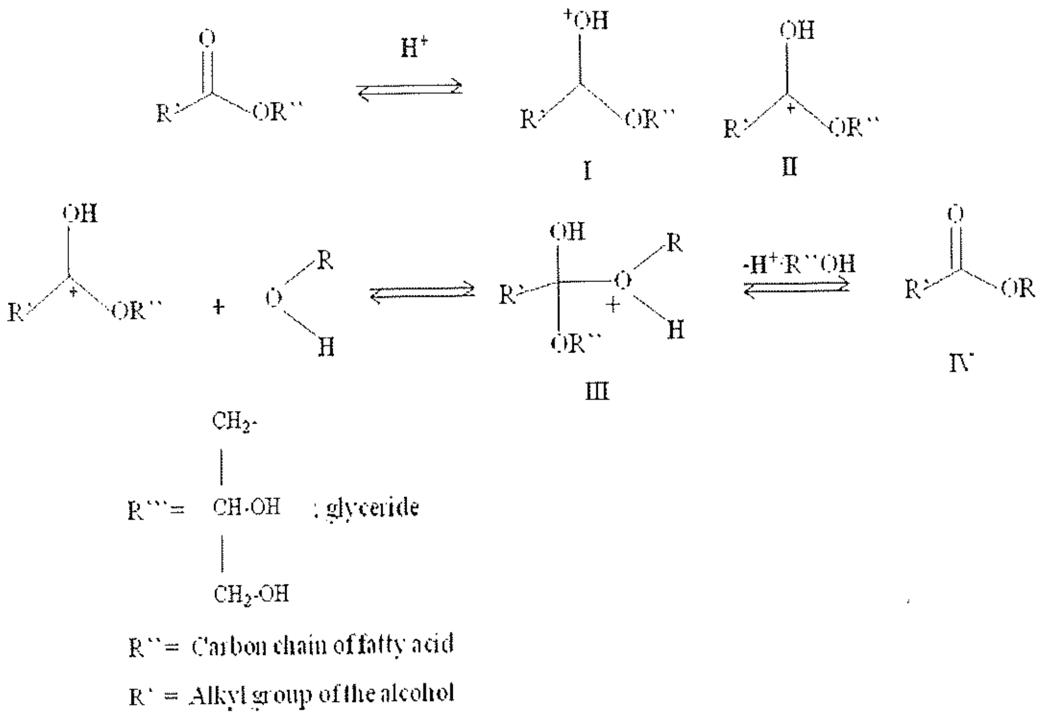


Figure 2.3 Mechanism of acid catalyzed transesterification (Schuchchardt et al., 1997)

Base Catalyzed Processes

The base catalyzed transesterification proceeds faster than acid catalyzed reaction. Due to this reason, with the fact that the alkaline catalysts are less corrosives than acidic compounds, industrial processes usually favor base catalysts, such as alkaline metal alkoxides and hydroxides as well as sodium or potassium carbonates.

The mechanisms of base catalyzed transesterification are shown in Figure 2.4. The first step Eq.1 is the reaction of the base with alcohol, producing an alkoxide and the protonated catalyst. The nucleoplilic attack of alkoxide at the carbonyl group of the triglyceride generates a tetrahedral interrmediate in Eq.2 from which the alkyl ester and the corresponding anion of the diglyceride are formed in Eq.3. The latter deprotonates the catalyst, thus regerating the active species in Eq.4 which is now able to react with a second molecule of the alcohol,starting another catalyst cycle. Diglycerides and monoglycerides are converted by the same mechanism to form a mixture of alkyl esters and glycerol.

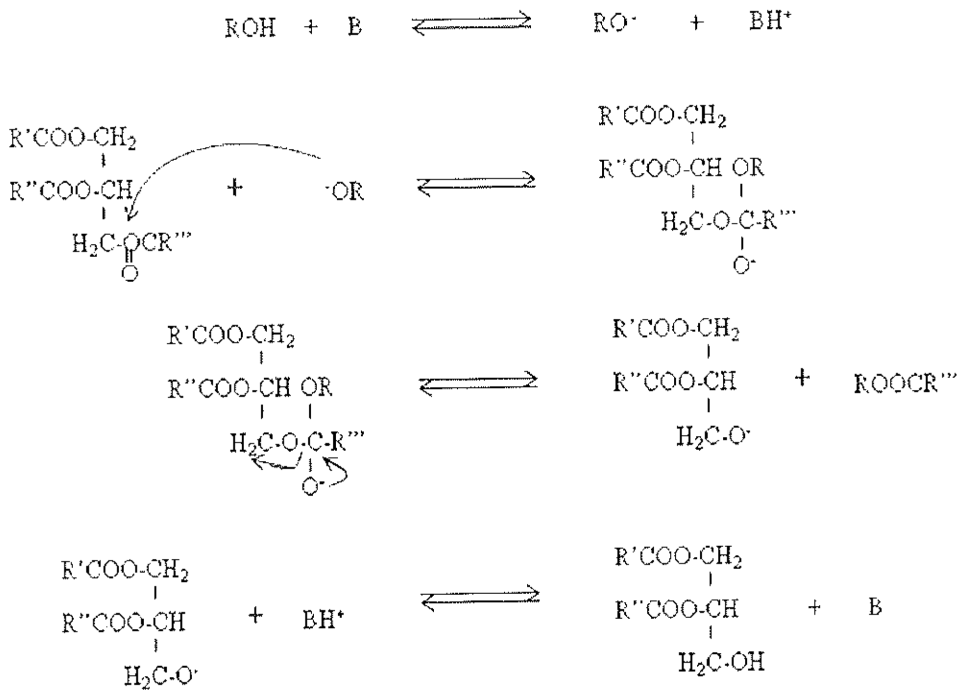


Figure 2.4 Mechanism of the base catalyzed transesterification (Schuchchardt et al., 1997)

Alkaline metal alkoxides (as CH_3ONa for the methanolysis) are the most active catalysts, since they give very high yield(> 98%) in short reaction time , about 30 minutes even if they are applied at low molar concentrations (0.5 mol%). However, they require the absence of water which makes them inappropriate for typical industrial processes. Alkaline metal hydroxides(KOH and NaOH) are cheaper than metal alkoxide, but less active. Nevertheless, they are a good alternative since they can give the same high conversion of vegetable oils just by increasing the catalyst concentration to 1 or 2 mol%. However, even if a water free alcohol/ oil mixture used, some water produced in the system by the reaction of the hydroxide with the alcohol. The presence of water gives rise to hydrolysis of some of the produced ester with consequent soap formation as shown by the reaction in the Figure 2.5. This undesirable saponification reaction reduces the ester yields and considerably difficult the recovery of the glycerol due to the formation of emulsions. Potassium carbonate, used in a concentration of 2 or 3 mol% gives high yields of fatty acid alkyl esters and reduces the soap formation. This can be explained by the formation of bicarbonate instead of water shown in Figure 2.6 which does not hydrolyse the esters.

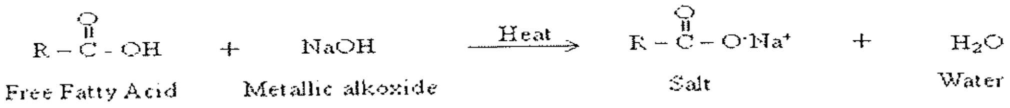


Figure 2.5 Saponification reaction of the produced fatty acid alkyl esters.(Schuchchardt et al., 1997)

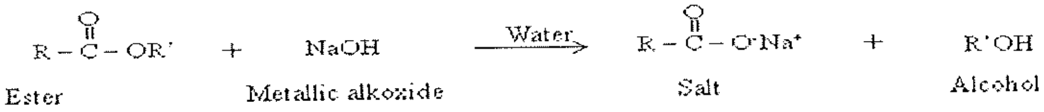


Figure 2.6 Reaction of potassium carbonate with the alcohol. .(Schuchchardt et al., 1997)

All commercial biodiesel production today employs an alkaline catalyzed transesterification process. This process is accomplished by mixing methanol (alcohol) with sodium hydroxide or potassium hydroxide to make sodium methoxide. Then the sodium methoxide is added to vegetable in a reactor at molar ratio of oil/ alcohol 6:1. The mixture was stirred and heat at 60-65 ^{0}C. After complete reaction mixture is allowed to cool to room temperature , and the ester and glycerol in were separated. Glycerol is left on the bottom and methyl esters, or biodiesel, is left on top. The ratio of 6:1 was found to be the best condition because methanol/oil molar ratio less than 6:1 the reaction resulted in incomplete reaction, and that above 6:1 methanol/oil molar ratio makes the difficult separation of glycerol, since the excess methanol hindered the decantation by gravity so that the apparent yield of esters decreased because part of the glycerol remained in the biodiesel phase (Freedman et al., 1984)

Table 2.1 Recent examples of optimization of reaction conditions for production of biodiesel from various feed stocks using response surface methodology

Feedstock oil or fat	Catalyst (wt %)	Temp (°C)	MeOH	rpm	Time (min)	Yield (wt.%)	Ref
Pork lard	1.26 KOH	65	7.5:1	n.r.[b]	20	97.8[c]	Jeong et al. 2009
Rapeseed	1.0 KOH	65	6:1	600	120	95–96	Rashid and Anwar 2008a
Sunflower	1.0 NaOH	60	6:1	600	120	97.1	Rashid et al. 2008b
Safflower	1.0 $NaOCH_3$	60	6:1	600	120	98	Rashid and Anwar 2008b
Jojoba	1.35 KOH	25	6:1	600	60	83.5	Bouaid et al. 2007
Rice bran	0.75 NaOH	55	9:1	n.r.	60	90.2	Sinha et al. 2008
Waste cooking oil	1.0 NaOH	50	9:1	n.r.	90	89.9[c]	Meng et al. 2008
Jatropha curcas	0.55 KOH	60	5:1	n.r.	24	99	Kumartiwari et al. 2007
Madhuca indica	0.70 KOH	60	6:1	n.r.	30	98	Ghadge and Raheman 2006
Pongamia pinnata	1.0 KOH	65	6:1	360	180	97–98	Meher et al. 2006b
Brassica carinata	1.2 KOH	25	6:1	600	60	97	Vicente et al. 2005
Used frying oil	1.1 NaOH	60	7:1	600	20	88.8	Leung and Guo 2006
canola	1.0 NaOH	40	6:1	600	60	93.5	Leung and Guo 2006
Cottonseed	1.07 KOH	25	20:1[d]	600	30	98	Joshi et al. 2008a, b
Raphanus sativus	0.6 NaOH	38	11.7:1[d]	n.r.	60	99.1	Domingos et al. 2008

[a] *temp* temperature of the reaction, *MeOH* mole ratio of methanol to oil, *rpm* (rotations per min) agitation intensity, *time* how long the reaction was conducted

[b] Not reported

[c] Conversion to esters (wt %) is provided instead of yield

[d] Ethanol was used to produce the corresponding ethyl esters

Two-step Catalyzed two-step Processes

Two step transesterification in which the first acid catalyzed step was followed by the second alkaline catalyzed step was developed for the production of biodiesel from oil with high free fatty acid (FFA) content. Initially, acid catalyst can be used to convert FFA to the esters and to decrease the FFA level. In the second step, alkaline catalyst can be performed for the transesterification of oil (two step). The technique overcomes the problem of a slow reaction rate with acid catalyst and the formation of soap with an alkaline catalyst and increase the ester yield. However, the problem with the removal of the catalyst is still a big issue for the two step method(Dalai et al., 2006)

Heterogeneous Catalyzed Processes

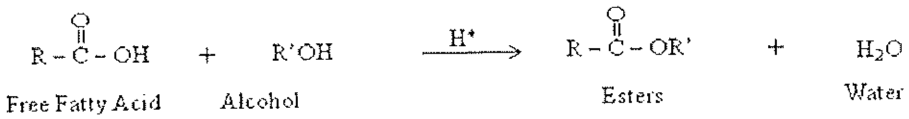
Although homogeneous catalyzed biodiesel processes are relatively fast and gives high conversions with minimal side reaction, they still have several problem such as(1) the catalyst cannot be recovered and must be neutralized at the end of the reaction,(2) there is limited use of continuous process, and(3) the processes are very sensitive to the presence of water and FFA which give rise to competing hydrolysis and saponification reactions. Nowadays, heterogeneous reaction is being considered in which the liquid catalyst is replaced by solid catalysts. This process could potentially lead to cheaper production costs because it is possible to reuse the catalysts and to carry out both transesterification and esterification simultaneous (Goodwin et al., 2005)

Enzymatic transesterification

Enzymatic transesterification of triglycerides has been suggested as a realistic alternative to the conventional physiochemical methods. Lipase is an effective enzyme for the transesterification of triglyceride. It is generally effective biocatalyst due to its substrate specificity, functional group specificity and stereo specificity in aqueous media. Lipases enzyme, present in living organisms, hydrolyse triacylglycerols. This ability has been used until now for the synthesis of many compounds in very mild conditions. Through the use of these enzymes in water media, esterification and transesterification reactions can also be carried out. The major problem with this process however is the enzyme stability and recovery. Therefore, immobilization is the most widely used method for achieving favorable stability of lipases and to make them more attractive for reaction (Cowan.,1996; Clark.,1994). Moreover immobilization provides enzyme reuse and eliminates the costly processes of enzymes recycle. The reaction generally requires the following condition: 30% enzyme based on oil weight; oil/alcohol molar ratio of 1:4; the temperature of 50^0C; and the reaction time of 7 hrs (Oznur Kose et al.,2002). In transesterification of rapeseed oil with 2-ethyl-1-hexanol and using *Candida rugosa* lipase powder gave 97% conversion of ester (Linko et al.,1998. The addition of methanol into the reaction to avoid lipase inactivation converted 98.4% of the oil to methyl esters at 30^0C after 48 hrs(Shimada et al., 1999). In this method, the recovery of glycerol is easy without any complex process and free fatty acid contain in waste oil or fat can be completely converted to methyl ester. On the other hand, The production of biodiesel fuel by enzymatic method has not often been used in industry because of the high cost of enzyme catalyst. An alternative process such as non- catalyzed transesterifition is considered.

2.2.5 Esterification

Esterification reaction occurs through a condensation reaction known as esterification. This requires two reactant, carboxylic acids (fatty acids) and alcohol (Solomon, 1996). Esterification reactions are acid catalysed and proceed slowly in the absence of strong acids such as sulphuric acid, phosphoric acid, organic acids and hydrochloric acid. The equation for and esterification reaction can be seen in Figure 2.7



$$R-\overset{\overset{\displaystyle O}{\|}}{C}-OH \quad + \quad R'OH \quad \xrightarrow{H^+} \quad R-\overset{\overset{\displaystyle O}{\|}}{C}-OR' \quad + \quad H_2O$$

Figure 2.7 The esterification reaction (Khan,2002)

Esterification can also be carried out without a catalyst, the advantage of carrying out the methyl esterification is the rapid reaction and the ease of product separation.

2.3 Effect of different parameters on production of biodiesel

Tranesterification and esterification are affected by various factors depending upon the reaction condition used. The effects of these factors are described below.

2.3.1 Effect of alcohol to oil or fatty acids ratio.

Generally known one of the most important variables affecting the yield of ester is molar ratio of alcohol to triglyceride. The stoichiometric ratio for tranesterification requires three moles of alcohol and one mole triglyceride to yield three moles of fatty acid alkyl esters and one mole of glycerol. However, transesterification is an equilibrium reaction in which a large excess of alcohol is required to drive the reaction in which a large excess of alcohol it's require to drive the reaction to the right. For maximum conversion, the molar ratio of 6:1 should be used. However, the high molar ratio of alcohol to vegetable oil interferes with separation of glycerin because there is an increase in solubility when glycerin remains in solution, it drives the equilibrium to back to the left, lowering the yield of esters.

For esterification,the molar ratio of alcohol to fatty acids is also of importance. In this case however, the stoichiometric ratio require 1:1 mole ratio of the two reactants. Fuethermore, no glycerol is produced. As a result, it is expected that lower alcohol to fatty acids molar ratio would be needed compared with triglyceride transesterification.

Table 2.2 Typical fatty acid composition (wt.%)[a] of a number of common feedstock oils[b] and fats that may be used for biodiesel production

Fatty acid[c]	CO	PO	SBO	SFO	COO	CSO	CCO	CF	BT
C6:0							1		
C8:0							7		
C10:0			-				7		
C12:0							47		1
C14:0		1				1	18	1	4
C16:0	4	45	11	6	11	23	9	25	26
C18:0	2	4	4	5	2	2	3	6	20
C20:0									
C22:0				1					
C16:1						1		8	4
C18:1	61	39	23	29	28	17	6	41	28
C18:2	22	11	54	58	58	56	2	18	3
C18:3	10		8	1	1			1	
C20:1	1								
Other									14

[a] From Gunstone and Harwood (2007); trace amounts (<1%) of other constituents may also be present

[b] CO canola (low erucic acid rapeseed oil) oil, PO palm oil, SBO soybean oil, SFO sunflower oil, COO corn oil (maize), CSO cottonseed oil, CCO coconut oil, CF chicken fat, BT beef tallow

[c] C6:0 methyl caproate, C8:0 methyl caprylate, C10:0 methyl caprate, C12:0 methyl laurate, C14:0 methyl myristrate, C16:0 meythyl palmitate, C18:0 methyl stearate, C20:0 methyl arachidate, C22:0 methyl behenate, C16:1 methyl palmitoleate, C18:1 methyl oleate, C18:2 methyl linoleate, C18:3 methyl linolenate, C20:1 methyl Eicosenoate

2.3.2 Effect of reaction temperatures

The reaction rate is strongly influenced by the reaction temperature. However, given enough time, the reaction will proceed to near completion even at room temperature. Generally, the catalytic reactions are conducted close to the boiling point of alcohol (60 to 70 ^{0}C), under atmospheric pressure.

2.3.3 Effect of reaction time

The conversion increases with reaction time. For example, Freedman et al.(1984) studies the transesterification of peanut, cotton-seed, sunflower and soybean oil under the condition of methanol to oil molar ratio of 6:1,50% sodium methoxide catalyst, and at 60 ^{0}C. An approximately yield of 80% was observed after 1 min for soybean and sunflower oils. After 1 hr, the conversion was almost the same (93-98%) for all four oils.

2.3.4 Effect of organic co-solvent

An improved process was investigated by Krisnangkura and Simamaharnnop(1992) for methanolysis and ethanolysis of fatty acid glycerides such as those found in naturally occurring fats and oils derived from plant and animal. The processes comprise solubilizing oil or fat in methanol or ethanol by addition of toluene as co-solvent in order to form a one phase reaction mixture, and addition an esterification catalyst. The processes proceed quickly, usually in less than 20 min, at ambient temperature, atmospheric pressure, and without agitation. The co-solvent increases the reaction rate by making the oil soluble in methanol, thus increasing contact of the reactant. The lower alkyl fatty acid monoesters produced by the process can be used as biofuels and are suitable as diesel replacement or additives.

2.3.5 Effect of reactant purity

The impurities present in oil also affect conversion percentages. Under the same condition, 67 to 84 % conversion into ester using crude vegetable oils can be obtained, compared with 94 to 97% when using refined oils. The free fatty acids in the original oils interfere with catalyst, however, under conditions of high temperature and pressure this problem can be overcome(Freedman et al., 1984).

2.3.6 Effect of catalyst type and concentration

Transesterification of triglyceride using catalysts are classified as alkaline, acid, enzyme or heterogeneous catalyst, among which alkaline are the most effective transesteri-fication catalyst compared to acidic catalyst. Sodium alkoxides are among the most efficient catalyst used, although KOH and NaOH can also be used. The alkaline catalyst concentration in range of 0.5 to 1.0% by weight yields 94 to 99%. The acid could be sulfuric acid, phosphoric acid, hydrochloric acid or organic sulfonic acid.Acid catalyst transesterification was studied with waste vegetable oil. The reaction was conduct at four different catalyst concentration, 0.5, 1.0, 1.5 and 2.25 HCl in presence of 100% excess alcohol and result was compared with 2.25 M H_2SO_4 . H_2SO_4 was found to have superior catalyst activity in range of 1.5-2.25 M concentration (Mohamad,2002).

2.3.7 Effect of moisture and water content

In biodiesel production, the vegetable oil used as feedstock material for transesterification should be water free since be water has negative effect on the reaction. A small amount of water (0.1%) would decrease the ester conversion which can consume the catalyst efficiency and it is believed that the presence of water could pose a greater negative effect than FFA. There, it is generally recommended that for typical transesterification of vegetable oil, the water content should be kept below 0.06% (Ma et al., 1998)

2.4 Influence of Free Fatty Acids on Biodiesel Production (Moser 2009)

A common approach in cases where the FFA content of a feedstock is in excess of 1.0 wt.% (Freedman et al. 1984; Mbaraka et al. 2003; Zhang et al. 2003; Wang et al. 2005) is two-step procedure readily accommodates high FFA-containing low-cost feedstocks for the preparation of biodiesel (Canakci and Van Gerpen 1999, 2001, 2003a).The two-step process in which acid pretreatment of the feedstock to lower its FFA content is followed by transesterification with homogenous base catalysts to produce biodiesel. In a typical acid pretreatment procedure, FFA are esterified to the corresponding FAME in the presence of heat, excess methanol, and acid catalyst, normally sulfuric acid (Ramadhas et al. 2005; Nebel and Mittelbach 2006; Veljkovic et al. 2006; Issariyakul et al. 2007; Kumartiwari et al. 2007; Sahoo et al. 2007; Meng et al. 2008; Naik et al. 2008; Rashid et al. 2008a).

Feedstock quality in large part dictates what type of catalyst or process is needed to produce FAAE that satisfies relevant biodiesel fuel standards. If the feedstock contains a significant percentage of FFA (>3 wt.%), typical homogenous base catalysts such as sodium or potassium hydroxide or methoxide will not be effective as a result of an unwanted side reaction (reaction [1], Fig. 2) in which the catalyst will react with FFA to form soap (sodium salt of fatty acid) and water (or methanol in the case of sodium methoxide), thus irreversibly quenching the catalyst and resulting in an undesirable mixture of FFA, unreacted TAG, soap, DAG, MAG, biodiesel, glycerol, water, and/or methanol (Lotero et al. 2005).

In fact, the base-catalyzed transesterification reaction will not occur or will be significantly retarded if the FFA content of the feedstock is 3 wt.% or greater (Canakci and Van Gerpen 1999, 2001).. A further complicating factor of high FFA content is the production of water upon reaction with homogenous base catalysts (reaction [1], Fig. 2). Water is particularly problematic because, in the presence of any remaining catalyst, it can participate in hydrolysis with biodiesel to produce additional FFA and methanol (reaction, Fig. 2.8). For instance, nearly quantitative yields of biodiesel are achieved with homogenous base catalysts in cases where the FFA content of the feedstock is 0.5 wt.% or less (Naik et al. 2008). However, the yield of biodiesel plummets to 6% with an increase in FFA content to 5.3 wt.% (Naik et al. 2008)

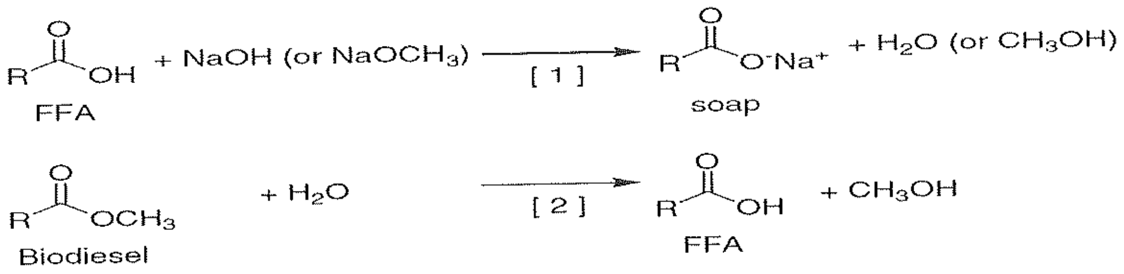


Figure 2.8 Formation of soap from reaction of free fatty acids (FFA) with catalyst and hydrolysis of biodiesel to yield FFA and methanol.

Other potential strategies for the production of biodiesel from feedstocks with high FFA content include feedstock purification such as refining, bleaching, and deodorization to remove FFA content and other undesirable materials, if present (Zappi et al. 2003). Despite the added capital costs associated with production, the integrated two-step process is being increasingly applied to prepare biodiesel from low-cost feedstock containing high numbers of FFA with good results (Lotero et al. 2005). Table 2 lists a number of recent examples of biodiesel prepared from feedstocks with high FFA content. However, feedstock refining further increases production costs as a result of the additional equipment, time, and manpower that are required. Lastly, the employment of catalysts that are not destroyed by FAA in the production of biodiesel is another alternative to the methods listed above.

Table 2.3 Examples of biodiesel production from feedstocks high in free fatty acids (FFA)

Feedstock	FFA (wt %)	Pretreatment method	Catalyst for transesterification	R[a]	Yield (wt %)	Ref
Pongamia pinnata	Up to 20	H_2SO_4	KOH	Me	97	Naik et al. 2008
Moringa oleifera	2.9/0.953[b]	H_2SO_4	$NaOCH_3$	Me	n.r.[c]	Rashid et al. 2008a
Jatropha curcas	14/<1	H_2SO_4	KOH	Me	99+	Kumartiwan et al. 2007
Madhuca indica	20	None	*Pseudomonas cepacia*	Et	96+[d]	Kumari et al. 2007
Nicotiana tabacum	35/<2	H_2SO_4	KOH	Me	91	Veljkovic et al. 2006
Calophyllum inophyllum	22/<2	H_2SO_4	KOH	Me	85	Sahoo et al. 2007
Zanthoxylum bungeanum	45.5/1.16[b]	None	H_2SO_4	Me	98	Zhang and Jiang 2008
Hevea brasiliensis	17/<2	H_2SO_4	NaOH	Me	n.r.	Ramadhas et al. 2005
Heterotrophic microalgal	8.97[b]	None	H_2SO_4	Me	n.r.	Miao and Wu 2006
Acid oil	59.3	None	H_2SO_4	Me	95	Haas et al. 2003
Fat from meat and bone meal	11	H_2SO_4	KOH	Me	45.7	Nebel and Mittelbach 2006
Brown grease	40/<1	Diarylammonium catalysts	$NaOCH_3$	Me	98+[d]	Ngo et al. 2008
Waste cooking oil	7.25/<1[b]	H_2SO_4	NaOH	Me	90[d]	Meng et al. 2008
Waste fryer grease	5.6	H_2SO_4	KOH	Me/Et	90+	Issariyakul et al. 2007
Tung oil	9.55/0.72[b]	Amberlyst-15	KOH	Me	90.2	Park et al. 2008a, b
Tall oil	100%	None	HCl	Me	n.r.	Demirbas 2008
Sorghum bug oil	10.5	None	H_2SO_4	Me/Et	77.4/97.6	Mariod et al. 2006

[a] R refers to ester head group. *Me* methyl, *Et* ethyl

[b] Acid value (mg KOH/g) was given instead of FFA. In cases where two values are given, the first value is prior to pretreatment and the second is after.

[c] Not reported

[d] Conversion to esters (wt %) is provided instead of yield

2.5 Advantages and Disadvantages of Biodiesel

Biodiesel has attracted considerable interest as an alternative fuel or extender for petrodiesel for combustion in compression–ignition (diesel) engines. Biodiesel is miscible with petrodiesel in any proportion and possesses several technical advantages over ultra-low sulfur diesel fuel (ULSD, <15 ppm S), such as inherent lubricity, derivation from a renewable and domestic feedstock, superior flash point and biodegradability, low toxicity, inferior storage and oxidative stability, lower volumetric energy content, inferior low-temperature operability versus petrodiesel, negligible sulfur content, and lower overall exhaust emissions. Important disadvantages of biodiesel include high feedstock cost and in some cases, higher NO_x exhaust emissions (DeOliveira et al. 2006; Knothe 2008). One potential solution to this problem is employment of alternative feedstocks of varying type, quality, and cost. These feedstocks may include soapstocks, acid oils, tall oils, waste cooking oils, and waste restaurant greases, various animal fats, non-food vegetable oils, and oils obtained from trees and microorganisms such as algae. However, many of these alternative feedstocks may contain high levels of free fatty acids (FFA), water, or insoluble matter, which affect biodiesel production. However, feedstock acquisition currently accounts for over 80% of biodiesel production expenses, which is a serious threat to the economic viability of the biodiesel industry (Paulson and Ginder 2007; Retka-Schill 2008).

CHAPTER III

RESEARCH METHOLOGY

3.1 General

The research had been carried out in a laboratory scale to study suitable reaction conditions for methyl ester production from *Vernicia Montana* oil via batch transesterification by using homogeneous base catalyst (Potassium hydroxide)

3.2 Experimental Equipment

1 Beaker 600 ml.

2 Stick glass

3 Spatula

4 Water bath

5 Tree blade paddle

6 Variable speed motor

7 Funnel

8 Thermometer

9 Hotplate

10 Weight scale

11 Gas Chromatograph

3.3 Experimental Chemical

1. Methanol, Analytical grade : Merk.
2. Potassium hydroxide, Analytical grade : Carlo Erba
3. Sulfuric acid, Analytical grade : J.T.Baker
4. Sodium sulphate : Carlo Erba

3.4 Raw Material

Vernicia Montana oil using in the experiments was complimentary obtained from Suraphol Farm, Aumphur Meang, Chaingrai Province.

3.5 Research Procedure

3.5.1 Analyze chemical properties of raw material for

1. Free fatty acid content
2. Free fatty acid composition in accordance with AOAC969.33, AOAC991.39 (2005)

3.5.2 Experimentation steps

1. Filter and heat the *Vernicia Montana* oil to a temperature of approximately 120 degree Celsius for 60 minute in order to remove the impured water (100 g).
2. Set condition of molar ratio on 6:1 for methanol to oil,and compare result of percent weight of potassium hydroxide by mix methanol with potassium hydroxide at 60 degree Celsius to become Methoxide (23.45 g of methanol with 0.15, 0.35, 0.55, 0.75, 0.95, 1.50 g of potassium hydroxide) with the *Vernicia Montana* oil 100 g , fix speed on 200 rpm and fix time for reaction at 90 minutes
3. After we known the highest percent of methyl ester from (2) select the percent weight of potassium hydroxide it's make the highest methyl ester to set the condition for compare molar ratio which combined ratio of methanol to oil 3:1, 6:1, 9:1 and 12:1. Mix methanol with potassium hydroxide refer result (2) at 60 degree Celsius to become Methoxide with the *Vernicia Montana* oil 100 g , fix speed on 200 rpm and fix time for reaction at 90 minutes

4 After we known the highest percent of methyl ester from (3) select the molar ratio for methanol to oil it's make the highest methyl ester to set the condition for compare reaction stirring speed from 200 to 600 rpm. Vary reaction temperature from 40 to 70 degree Celsius and reaction times from 10 to 90 min. for the process produce methyl ester.

5 Heat or cool the methoxide obtained from (2),(3),(4) to the required reaction temperature.

6 Terminate the reaction using sulfuric acid to neutralize the un-reacted base catalyst and to reduce soap produced from saponification of free fatty acids and base catalyst.

7 Pour the product into a funnel and leave it until methyl ester and glycerol is completely separated (3 hours).

8 Check the upper layer, methyl ester, of the separated product to remove the un-reacted excess methanol by distillation at a temperature approximately 100 degree Celsius.

9 Wash methyl ester with distillated water to remove the excess base catalyst, methanol and glycerol.

10 Pour methyl ester and water into a funnel and leave it until methyl ester and washing water is completely separated.

11 Wash methyl ester until the washing water is neutralize (pH7).

12 Remove washing water by heating the methyl ester at a temperature of approximately 120 degree Celsius for 1 hour duration.

13 Filter the methyl ester using filter paper no.1 and use sodium sulphate to absorb water remaining and keep the sample for the analysis of methyl ester composition by gas chromatograph.

3.5.3 Analyze percentage of produced methyl ester using gas chromatograph.

The content of fatty acid methyl ester (FAME) in product was analyzed by a GC-2010 gas chromatography (Shimadzu). Its column is SGE, BP20 GC capillary column (30m x 0.32mmi.d. x 0.25µm film thickness) capable to maintain temperature in the range of 20 – 250 degree Celsius. The temperature of the injector and the flame ionization detector (FID) was 210 and 250 °C, respectively. The chromatographic conditions are summarized in Table 3.1 below:-

Table 3.1 Chromatographic conditions

Condition	**Value**
Carrier gas (He) flow rate	30 mL/min
Detector temperature (FID)	250 °C
Split ratio	1 : 25
Injection part temperature	220 °C
Inject volume	1 µL
Column temperature	210 °C
Holding time	30 min

The ester content of fatty acid methyl ester is determined in accordance with EN14103:2003 (Fat and Oil Derivatives – Fatty Acid Methyl Ester (FAME) – Determination of ester and linolenic acid methyl ester contents) using methyl heptadecanoate ($C_{18}H_{36}O_2$) as an internal standard and use normal heptane as a solvent. Appendix B shows how to determine FAME content from gas chromatograph in accordance with EN 14103. Appendix E contains GC result for the products. Gas chromatography of the products was carried out by Scientific and Technological Research Equipment Center Chulalongkorn University.

CHAPTER IV

RESULTS AND DISSCUSION

4.1 Raw material properties

The chemical properties of the *Vernicia Montana* oil, provided from Suraphol Farm, Aumphur Meang, Chaingrai Province, from batch to batch used in the experiments were analyzed by Thailand Institute of Scientific and Technological Research using AOAC 969.33, AOAC 991.39 (2005) analytical standard with Gas Chromatography are shown in Table 4.1

Table 4.1: Fatty acid composition of *Vernicia Montana* oil

		Molecular weight	% by weight
Free Fatty acid,			0.28
Fatty acid composition;			
Lauric acid	C12:0	200	1.32
Myristic acid	C14:0	228	0.59
Plamitic acid	C16:0	256	8.05
Palmitoleic acid	C16:1 n-7	254	0.05
Heptadecanoic acid	C17:0	270	0.05
Stearic acid	C18:0	284	3.39
Cis-9-Octadecenoic acid	C18:1 n-9	282	15.64
Cis-9,12-Octadecadienoic acid	C18:2 n-6	280	33.82
Cis-9,12,15-Octadecatrienoic acid	C18:3 n-3	280	2.61
Arachidic acid	C20:0	312	0.23
Cis-11-Eicosenoic acid	C20:1 n-9	310	0.36
Behenic acid	C22:0	340	22.75
Lignoceric acid	C24:0	368	0.08
Unidentified peak			10.83
Total fatty acid composition			100
Molecular weight			819.50

4.2 Effect of catalyst concentration

The concentration of the catalyst was the first parameter studied. The effect of KOH concentration on the transesterification of the *Vernicia Montana* oil was investigated with its concentration varying from 0.15 to 1.50 wt% (based on the weight of raw oil). The operating conditions during the whole reaction process were fixed at: reaction temperature of 60°C, reaction time of 90 minutes, speed of 200 rpm and molar ratio of methanol to oil at 6:1.

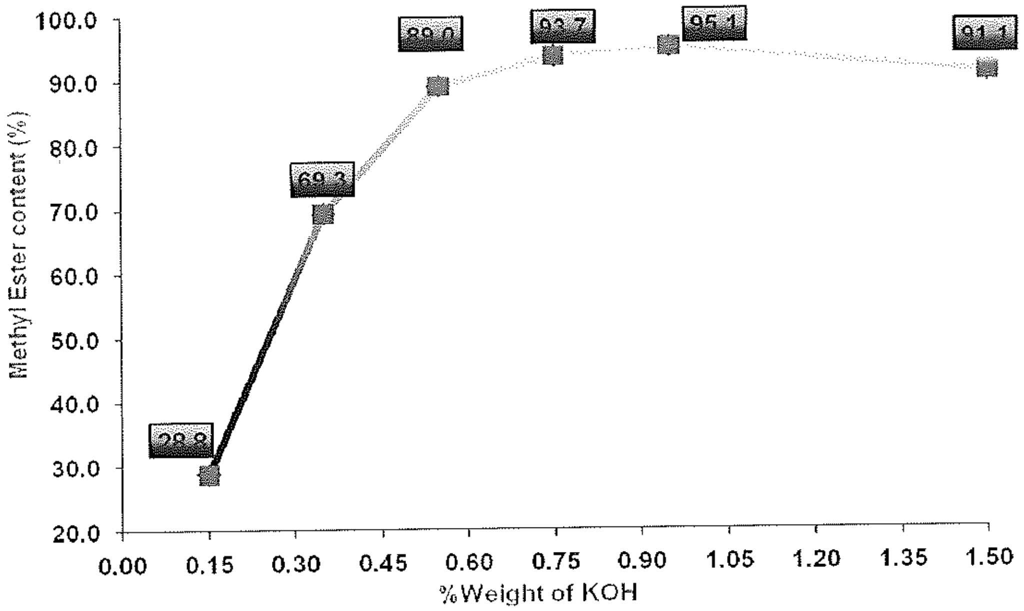


Figure 4.1 Effects of percent weight of Potassium Hydroxide to Methyl ester content(wt%)

From figure 4.1 shows that the emergence of the methyl ester, which is changed according to the weight of potassium hydroxide. The results of the experiments, we found that when we increase the weight of catalyst (potassium hydroxide) has resulted in an increasing amount of methyl ester. At the one point, the concentration of catalyst in more than enough (more than 0.95%) will create soap which is hard for product separate, which this will result in a decrease methyl ester content (wt%) respectively.The increasing of chemical catalytic activity which it's help to break free fatty acid from triglyceride to have more reaction with alcohol. From the experiments results we found that increasing of potassium hydroxide from 0.15, 0.35,0.55, 0.75, 0.95 and

1.50 wt%, which at 0.95 wt% will create soap which is the best of concentration weight it's make the highest of methyl ester at 95.1% .

4.3 Effect of molar ratio

Molar ratio of methanol to oil is an important factor for the occurrence of methyl ester from stoichiometry of transesterification will be use 3 moles of alcohol and 1 mole of triglyceride for produce 3 moles of fatty acid and 1 mole of glycerol, due to transesterification is reversible reaction. Therefore, it's necessary to use alcohol in the large quantity sufficiently to drive the reaction forward.

Once we know the results of experiments on the catalyst concentration, affecting the methyl ester, which allows us to choose the appropriate concentration to cause the maximum amount of methyl ester is 0.95 wt% and fix the operating conditions during the whole reaction process were fixed at: reaction temperature of 60°C, reaction time of 90 minutes, speed of 200 rpm. Varying molar ratio of methanol to oil at 3:1, 6:1, 9:1, 12:1 respectively.

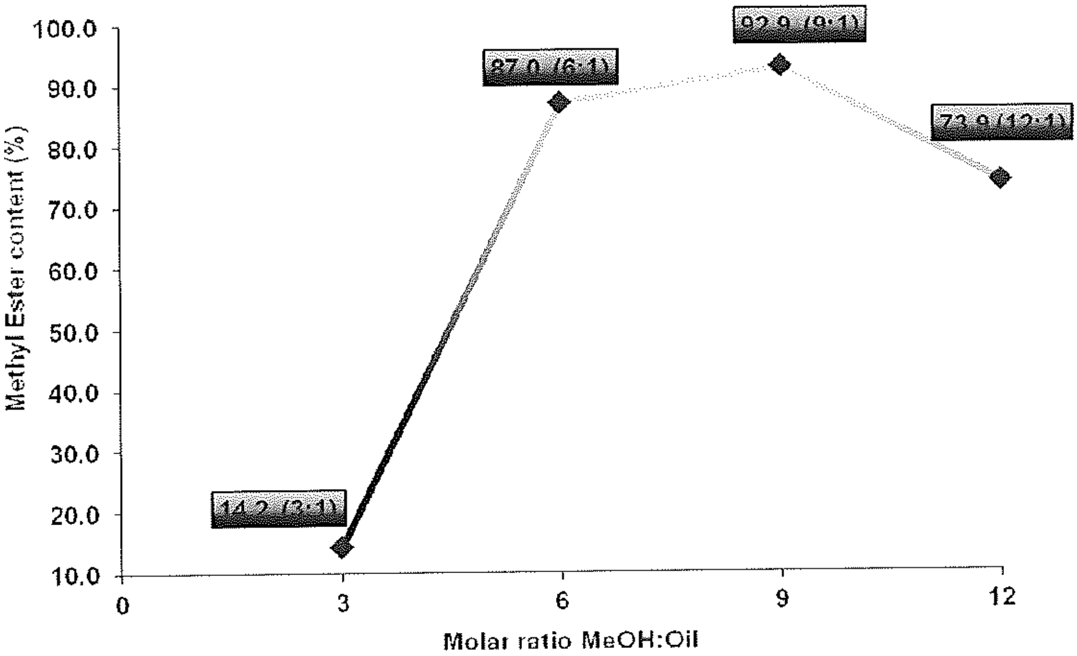


Figure 4.2 Effects of molar ratio of Methanol:Oil at Temp. 60 degree Celsius , 90 mins, 0.95% KOH

From the experimental results will be the emergence of the methyl ester contents in the product from gas chromatography analysis as shown in Figure 4.2 are:

Reaction at molar ratio of Methanol:Oil 3:1, 6:1, 9:1, 12:1 gave 14.2 %,87.0%, 92.9%, 73.9% methyl ester content, respectively.

From the result of experiment found molar ratio of methanol is increasing it's to get the methyl ester content (wt%) increased accordingly. When the methanol increasing it's make the contact surface between methanol and triglyceride increasing which methanol can to be react more with the triglyceride affect the reaction faster as well. For molar ratio 12:1 the result of methyl ester content (wt%) decreasing effective of the amount of excess methanol. The layer separation of glycerol between methyl ester of difficult due to methanol and glycerol dissolve together which made glycerol to be left over on methyl ester layer when process of prepare sample to analyst by gas chromatography as a result, methyl ester content (wt%) decline.

Which this research studied for the optimum speed using 9:1 constant catalyst concentration 0.95 wt% of potassium hydroxide to oil. Varying stirring speed of 200, 400 and 600 rpm. Varying temperature for reaction starting from 40, 50, 60 and 70 degree Celsius. Varying reaction time starting from 10, 30, 60 and 90 minutes. For the paddle used in the experiments is three blade paddle, 5 cm diameter and 2.2 cm blade diameter. The beaker is 9 cm diameter, 13 cm height with 3.2 cm chemical level in case of the reaction. Distant between blades to bottom of the beaker is 1.5 cm.

4.4 Effect of speed

Figure 4.3 to 4.6 shows that the result of the experiments which were carried to study the effects of reaction speed using 9:1 of methanol to oil, constant catalyst concentration 0.95 wt% of potassium hydroxide to oil. Vary for the reaction temperature from 40, 50, 60 and 70 °C .Varying stirring speed from 200, 400 and 600 rpm and varying reaction time form 10, 30, 60 and 90 minutes.

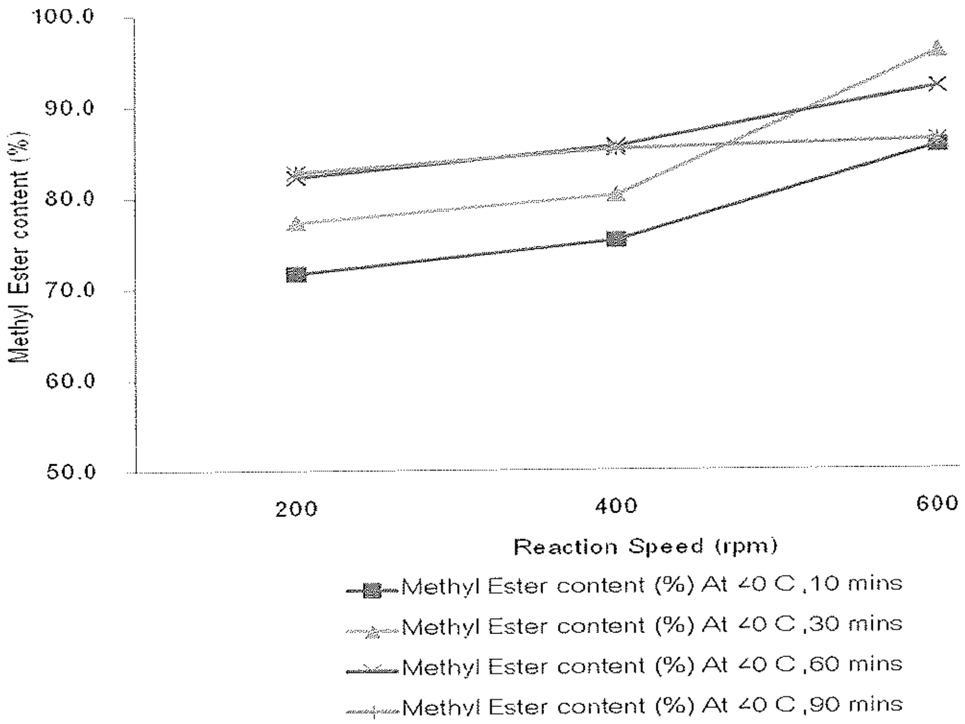


Figure 4.3 Effects of reaction speed to Methyl ester content (wt%) , At 40 °C reaction temperature,10,30,60 and 90 min for reaction time.

From the above figure 4.3, methyl ester contents in the product from gas chromatography analysis are

1) At 40 °C reaction temperature, 10 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 71.7%, 75.3%, 85.6% methyl ester content, respectively.
2) At 40 °C reaction temperature, 30 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 77.3%, 80.2%, 96.0% methyl ester content, respectively.
3) At 40 °C reaction temperature, 60 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 82.2%, 85.6%, 92.1% methyl ester content, respectively.
4) At 40 °C reaction temperature, 90 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 82.8%, 85.3%, 86.3% methyl ester content, respectively.

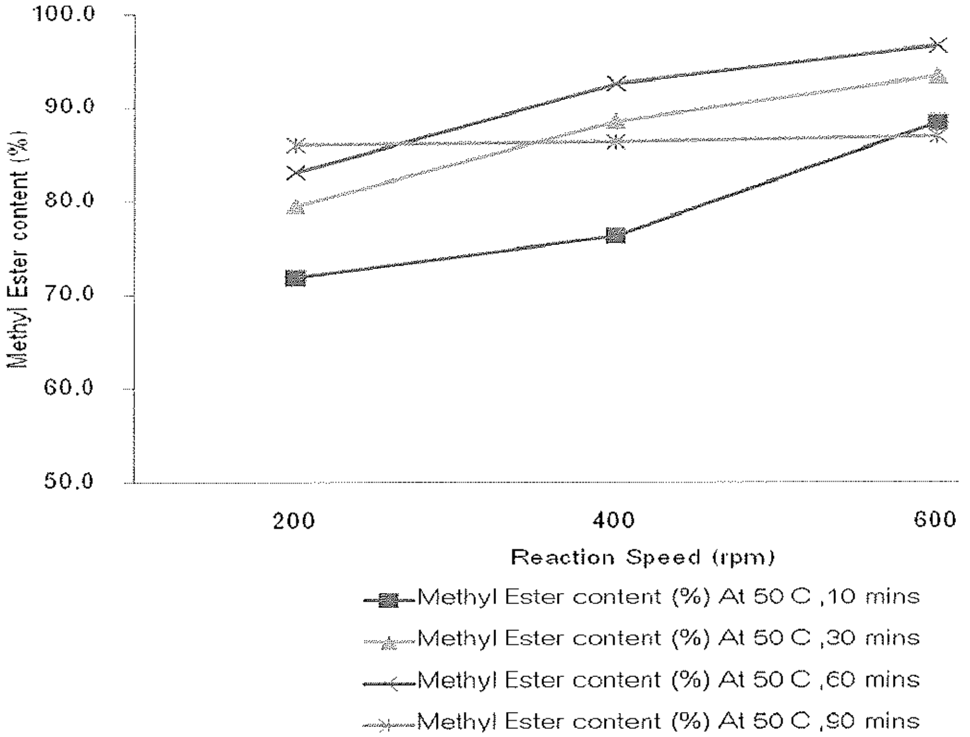


Figure 4.4 Effects of reaction speed to Methyl ester content (wt%) , At 50 °C reaction temperature,10,30,60 and 90 min. for reaction time.

From the above figure 4.4, methyl ester contents in the product from gas chromatography analysis are

1) At 50 °C reaction temperature, 10 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 71.8%, 76.3%, 88.4% methyl ester content, respectively.
2) At 50 °C reaction temperature, 30 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 79.4%, 88.5%, 93.4% methyl ester content, respectively.
3) At 50 °C reaction temperature, 60 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 83.1%, 92.6%, 96.7% methyl ester content, respectively.

4) At 50 °C reaction temperature, 90 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 86.0%, 86.3%, 87.0% methyl ester content, respectively.

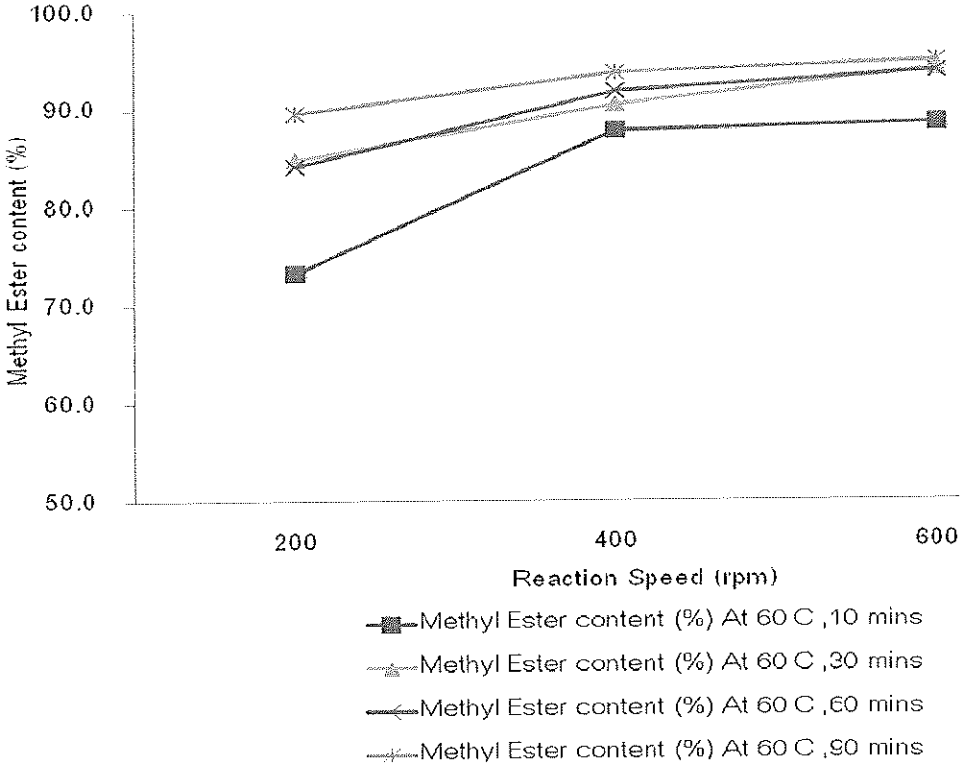


Figure 4.5 Effects of reaction speed to Methyl ester content (wt%) , At 60 °C reaction temperature,10,30,60 and 90 min. for reaction time.

From the above figure 4.5, methyl ester contents in the product from gas chromatography analysis are

1) At 60 °C reaction temperature, 10 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 73.3%, 87.8%, 88.6% methyl ester content, respectively.
2) At 60 °C reaction temperature, 30 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 84.8%, 90.4%, 94.2% methyl ester content, respectively.

3) At 60 °C reaction temperature, 60 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 84.2%, 91.8%, 93.8% methyl ester content, respectively.

4) At 60 °C reaction temperature, 90 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 89.6%, 93.7%, 94.9% methyl ester content, respectively.

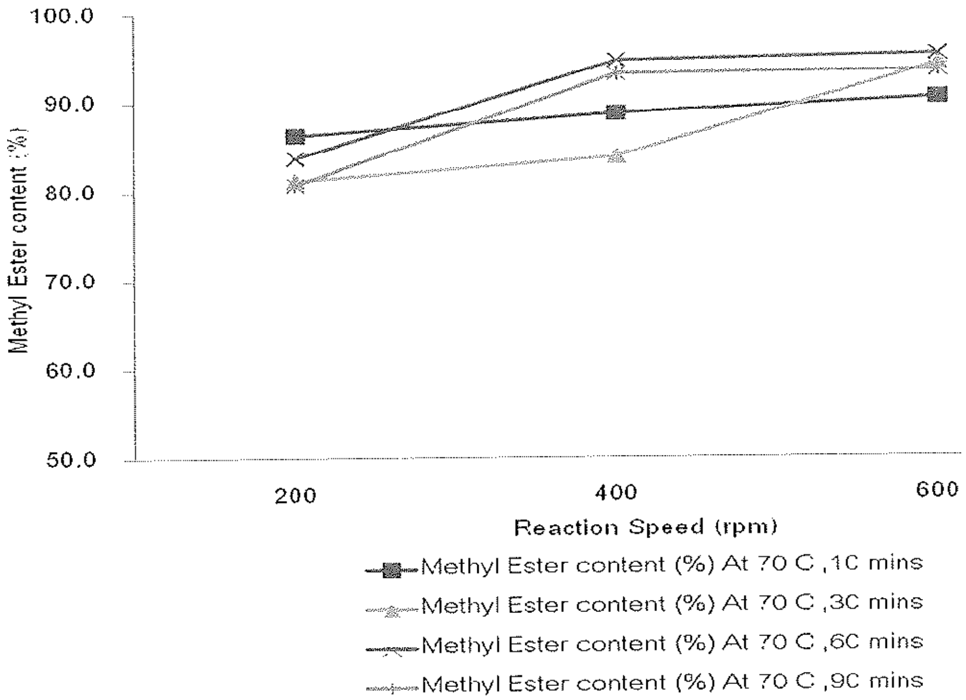


Figure 4.6 Effects of reaction speed to Methyl ester content (wt%) , At 70 °C reaction temperature,10,30,60 and 90 min. for reaction time.

From the above figure 4.6, methyl ester contents in the product from gas chromatography analysis are

1) At 70 °C reaction temperature, 10 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 86.3%, 88.8%, 90.4% methyl ester content, respectively.

2) At 70 °C reaction temperature, 30 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 81.2%, 83.9%, 94.3% methyl ester content, respectively.

3) At 70 °C reaction temperature, 60 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 83.8%, 94.7%, 95.3% methyl ester content, respectively.
4) At 70 °C reaction temperature, 90 min. for reaction time and varying reaction speed (200, 400, 600 rpm) gave 80.8%, 93.2%, 93.5% methyl ester content, respectively.

Ma et al. (1998b, 1999) studied the transesterification process of beef tallow with methanol. Because the solubility of methanol in beef tallow was 19% w/w at 100°C (Ma et al., 1998b), mixing was essential to disperse the methanol in beef tallow in order to start the reaction. They also pointed out that once the two phases were mixed and the reaction was started, stirring was no longer needed.

Figure 4.3 to 4.6 shows that increasing of stirring speed at temperature and reaction time in various will increase methyl ester content in the product because of when increasing stirring speed resulting in smaller droplet size diameter of methanol from blade shearing . This will increase reaction surface for has a great effect to the reaction. This is due to higher speed will be improve the ability of the reaction surface for methanol, catalyst and oil resulting in faster reaction rate which results in greater percent of methyl ester. It was also found that at the first 200 to 600 rpm every condition is increasing rate of methyl ester yield is quite high when reaction speed increasing from 200,400 and 600 rpm. In case of the reaction at 50 °C reaction temperature, 60 min. for reaction time and varying reaction speed 600 rpm gave 96.7% methyl ester content is the highest.

4.5 Effect of reaction temperature

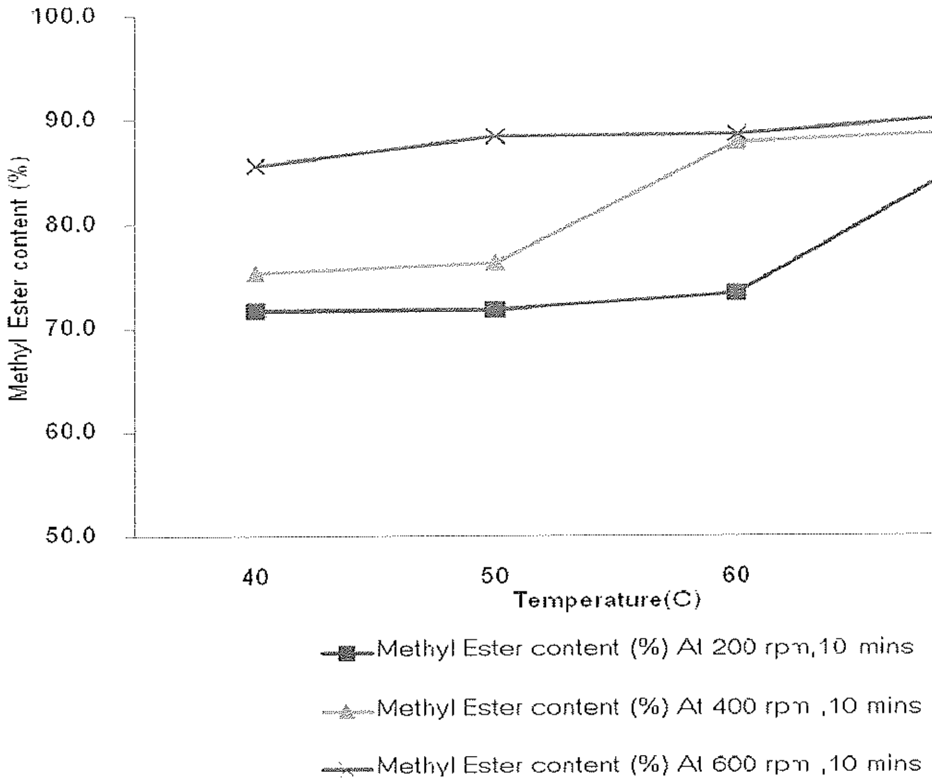


Figure 4.7 Effects of reaction temperature to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,10 min. for reaction time.

From the above figure 4.7, methyl ester contents in the product from gas chromatography analysis are

1) At 200 rpm for the reaction stirring speed, 10 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 71.7%, 71.8%, 73.3% and 86.3% methyl ester content, respectively.
2) At 400 rpm for the reaction stirring speed, 10 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 75.3%, 76.3%, 87.8% and 88.8% methyl ester content, respectively.
3) At 600 rpm for the reaction stirring speed, 10 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 85.6%, 88.4%, 88.6% and 90.4% methyl ester content, respectively.

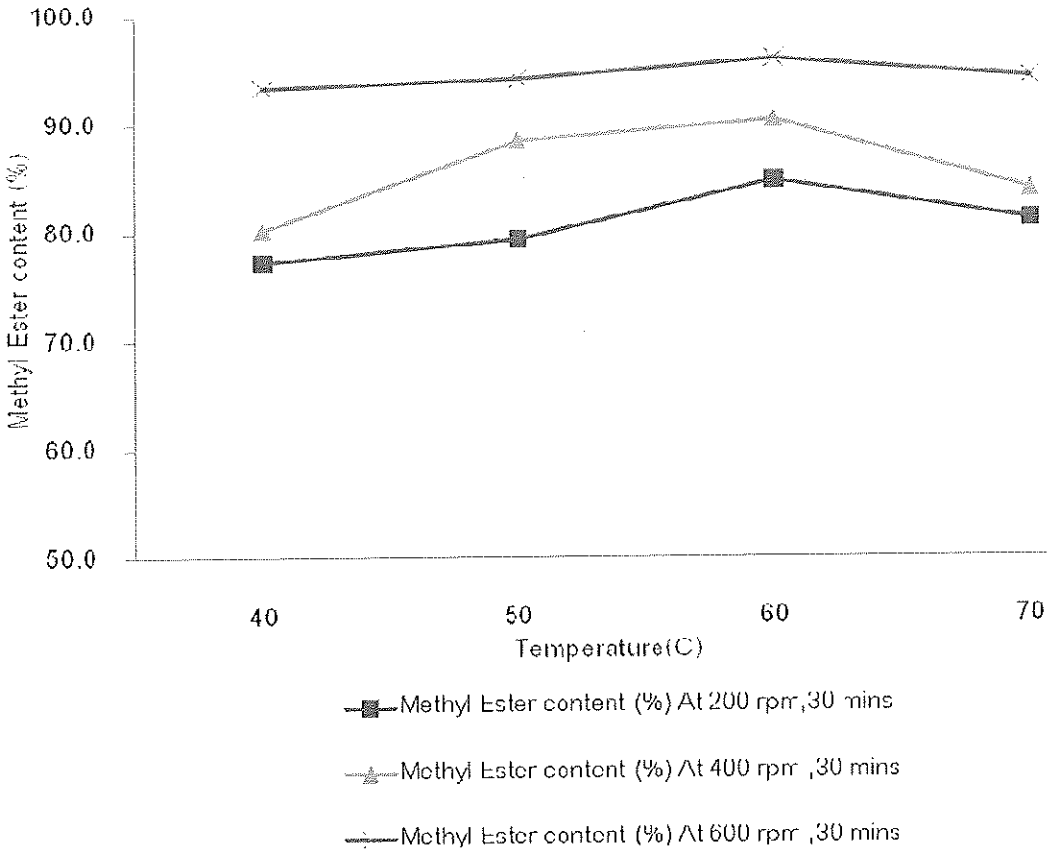


Figure 4.8 Effects of reaction temperature to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,30 min. for reaction time.

From the above figure 4.8, methyl ester contents in the product from gas chromatography analysis are

1) At 200 rpm for the reaction stirring speed, 30 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 77.3%, 79.4%, 84.8% and 81.2% methyl ester content, respectively.
2) At 400 rpm for the reaction stirring speed, 30 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 80.2%, 88.5%, 90.4% and 83.9% methyl ester content, respectively.

3) At 600 rpm for the reaction stirring speed, 30 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 93.4%, 94.2% 96.0% and 94.3% methyl ester content, respectively.

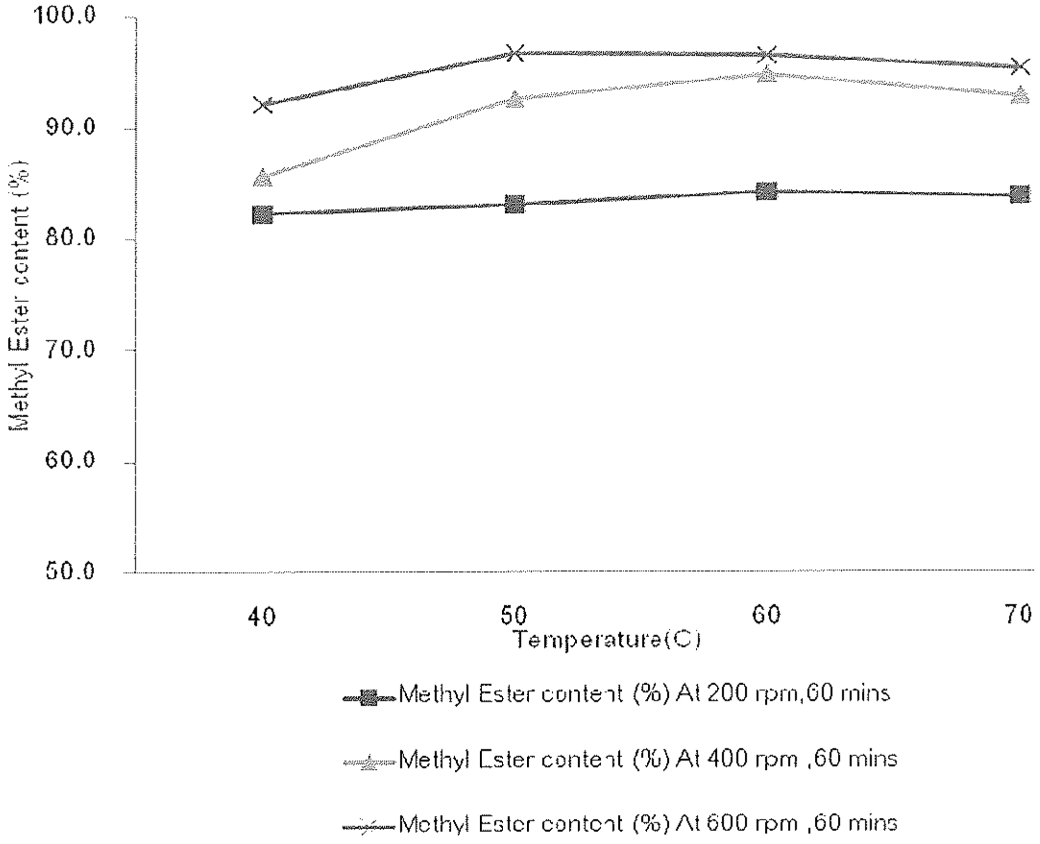


Figure 4.9 Effects of reaction temperature to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,60 min. for reaction time.

From the above figure 4.9, methyl ester contents in the product from gas chromatography analysis are

1) At 200 rpm for the reaction stirring speed, 60 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 82.2%, 83.1%, 84.2% and 83.8% methyl ester content, respectively.

2) At 400 rpm for the reaction stirring speed, 60 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 85.6%, 92.6%, 94.7% and 92.8% methyl ester content, respectively.
3) At 600 rpm for the reaction stirring speed, 60 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 92.1%, 96.7%, 96.5% and 95.3% methyl ester content, respectively.

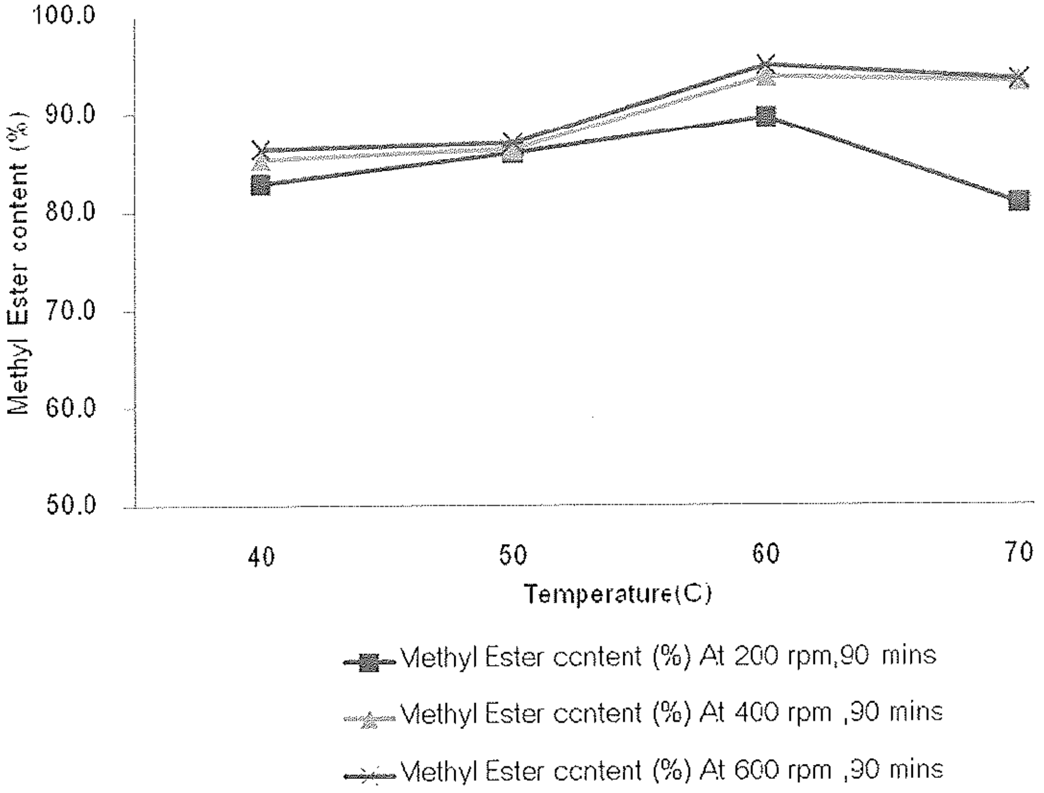


Figure 4.10 Effects of reaction temperature to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,90 min. for reaction time.

From the above figure 4.10, methyl ester contents in the product from gas chromatography analysis are

1) At 200 rpm for the reaction stirring speed, 90 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 82.8%, 86.0%, 89.6% and 80.8% methyl ester content, respectively.

2) At 400 rpm for the reaction stirring speed, 90 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 85.3%, 86.3%, 93.7% and 93.2% methyl ester content, respectively.
3) At 600 rpm for the reaction stirring speed, 90 min. for reaction time and varying reaction temperature (40, 50, 60 and 70 °C) gave 86.3%, 87.0%, 94.9% and 93.5% methyl ester content, respectively.

4.6 Effect of reaction time

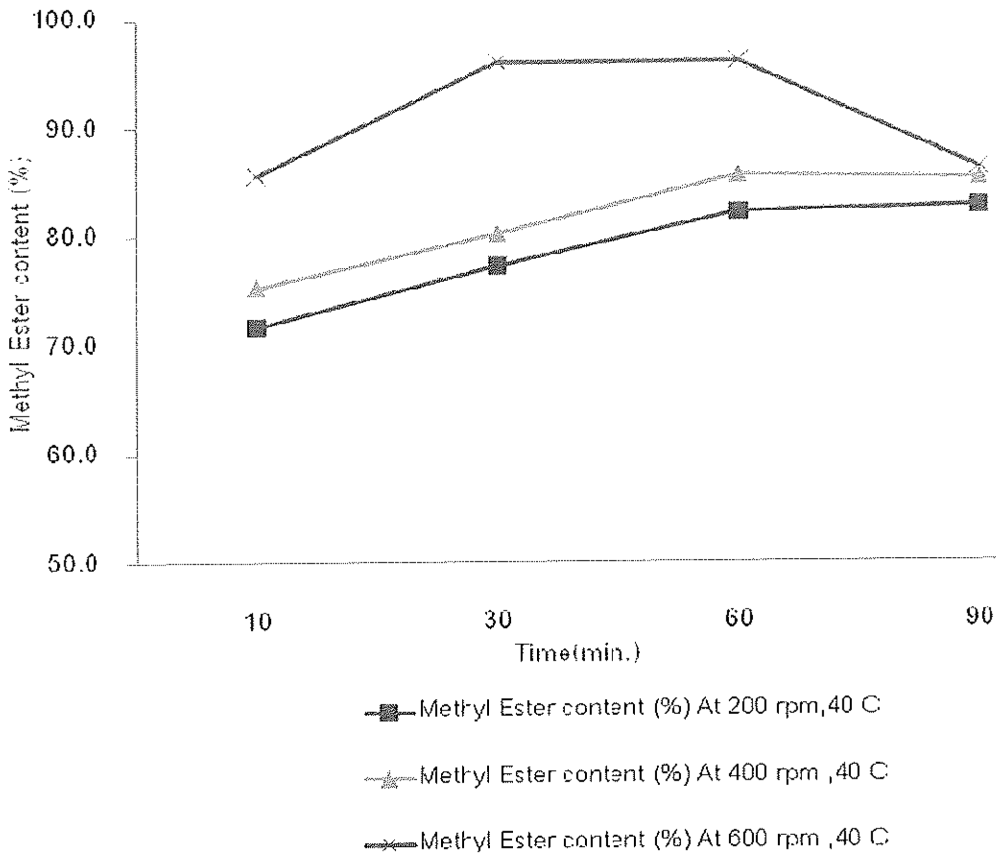


Figure 4.11 Effects of reaction time to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,40 °C for reaction temperature.

From the above figure 4.11, methyl ester contents in the product from gas chromatography analysis are

1) At 40 °C for the reaction temperature,200 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 71.7%, 77.3%, 82.2% and 82.0% methyl ester content, respectively.
2) At 40 °C for the reaction temperature,400 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 75.3%, 80.2%, 85.6% and 85.3% methyl ester content, respectively.
3) At 40 °C for the reaction temperature,600 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 85.6%, 96.0%, 96.1% and 86.3% methyl ester content, respectively.

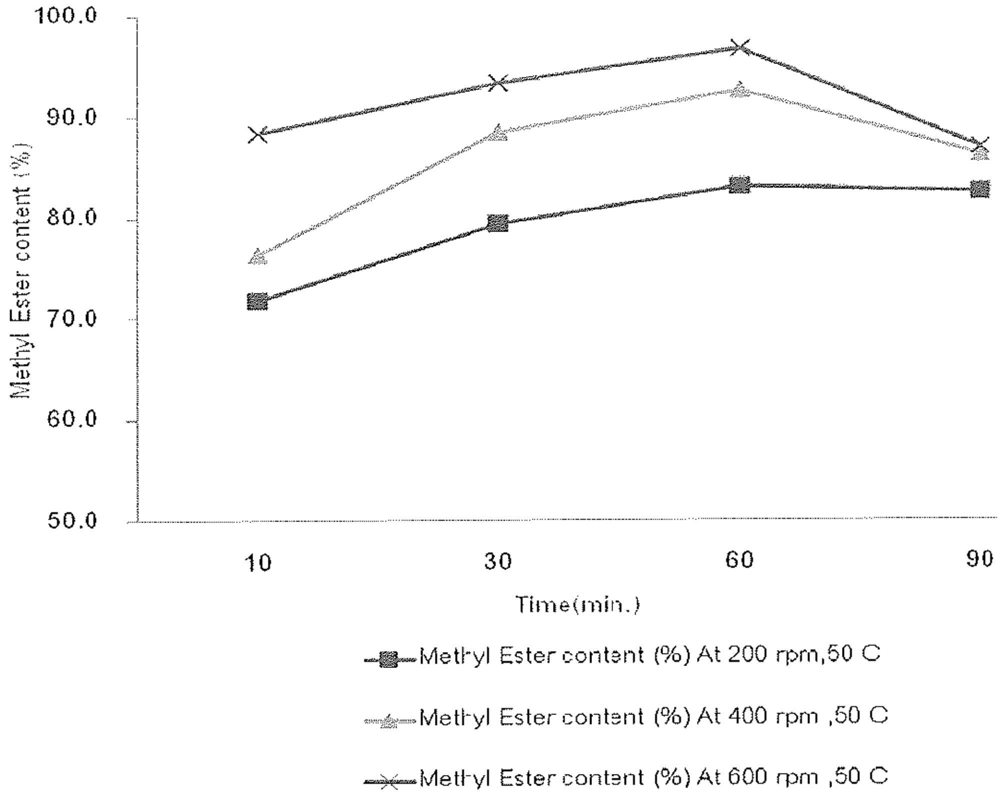


Figure 4.12 Effects of reaction time to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,50 °C for reaction temperature.

From the above figure 4.12, methyl ester contents in the product from gas chromatography analysis are

1) At 50 °C for the reaction temperature,200 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 71.8%, 79.4%, 83.1% and 82.6% methyl ester content, respectively.
2) At 50 °C for the reaction temperature,400 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 76.3%, 88.5%, 92.6% and 86.3% methyl ester content, respectively.
3) At 50 °C for the reaction temperature,600 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 88.4%, 93.4%, 96.7% and 87.0% methyl ester content, respectively.

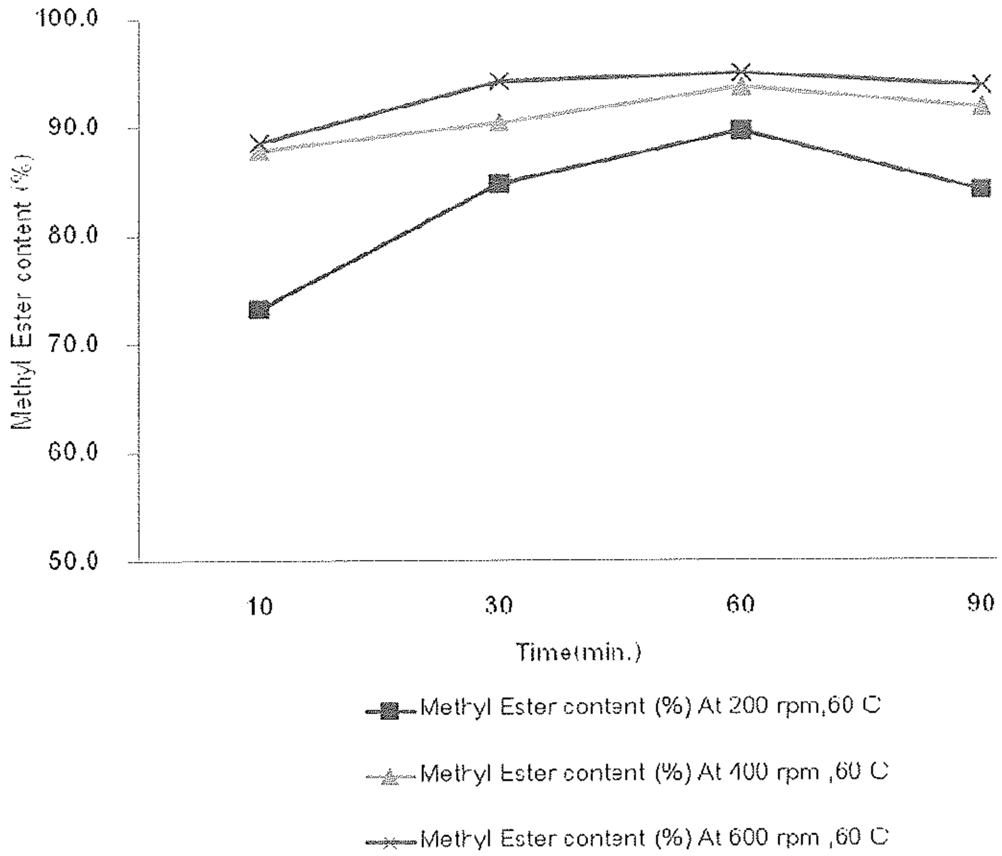


Figure 4.13 Effects of reaction time to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,60 °C for reaction temperature.

From the above figure 4.13, methyl ester contents in the product from gas chromatography analysis are

1) At 60 °C for the reaction temperature,200 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 73.3%, 84.8%, 89.2% and 84.2% methyl ester content, respectively.
2) At 60 °C for the reaction temperature,400 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 87.8%, 90.4%, 93.7% and 91.8% methyl ester content, respectively.
3) At 60 °C for the reaction temperature,600 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 88.6%, 94.2%, 94.9% and 93.8% methyl ester content, respectively.

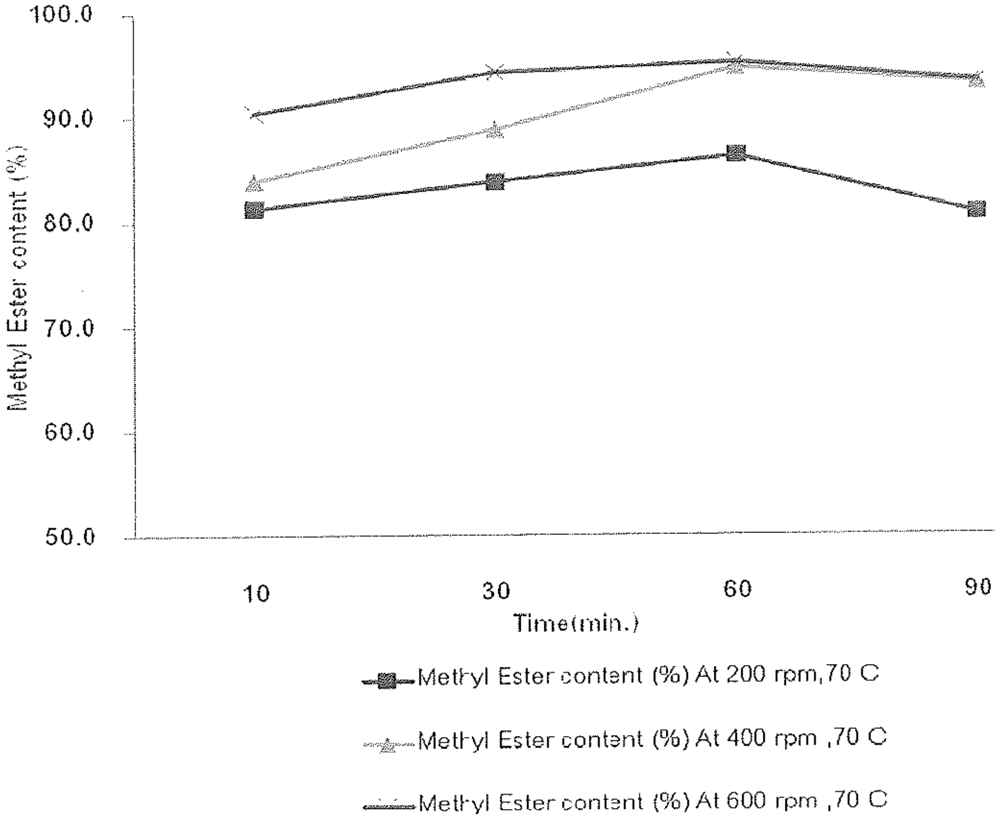


Figure 4.14 Effects of reaction time to Methyl ester content (wt%) , At 200, 400,600 rpm reaction stirring speed,70 °C for reaction temperature.

From the above figure 4.14, methyl ester contents in the product from gas chromatography analysis are

1) At 70 °C for the reaction temperature,200 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 81.3%, 83.8%, 86.3% and 80.8% methyl ester content, respectively.
2) At 70 °C for the reaction temperature,400 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 83.9%, 88.8%, 94.7% and 93.2% methyl ester content, respectively.
3) At 70 °C for the reaction temperature,600 rpm for reaction stirring speed and varying reaction time (10, 30, 60 and 90 min.) gave 90.4%, 94.3%, 95.3% and 93.5% methyl ester content, respectively.

Transesterification reaction of oil by base catalyst will be reaction temperature near boiling point of methanol is 64.7 °C so that the result experiment found temperature condition of reaction should not be exceeded boiling point of methanol with if we using reaction temperature over than boiling point of methanol, some of the methanol to evaporate before the reaction which consistent with research of Darnoko (2000). Darnoko studied the effect of reaction time on biodiesel production from palm oil via esterification reaction using 1 wt% potassium hydroxide, 50 °C reaction temperature and 90 minutes reaction time. The reaction rate is high in the first 5 minutes. Triglyceride was decreasing very fast whereas diglyceride and monoglyceride were increasing then.decreasing very fast. Reaction rate was slower after 15 minutes as can be seen from the slower increasing rate of methyl ester and the reaction tends to be in equilibrium after 30 minutes.

4.7 Compare Quality with Other Feedstock

The experiment result showed that potassium hydroxide 0.95 wt% is suitable for the reaction. From the experiments at 600 rpm found that the maximum methyl ester contents obtained from the reaction at 50 degree Celsius, 60 minutes were 96.7%. Which we bring the sample obtained from the experiment for test the property of oil and compare the results consist of Acid Value, Density@ 15 °C, Iodine Value, Kinematic Viscosity 40 °C and Oxidation Stability with Canola oil and Palm oil (Yi-Hung Chen,Jhih-Hong(2010))

Table 4.2 Comparisons Properties of Canola, Plam and *Vernicia Montana oil*

Property	Unit	Canola	Palm	Vernicia1	Vernicia2	Vernicia3
Acid Value	mg KOH/g	0.133	0.615	1.452	1.456	1.454
Density@ 15 °C	Kg/m^3	922	915	941	941	942
IV	g I_2/100 g	113.9	48.8	161.3	161.5	161.2
KV@40C	mm^2/s	34.33	40.80	102.7	103.8	102.2
Oxidation Stability	h	5.1	24.0	0.8	0.8	0.8

The results of test showed that *Vernicia Montana* oil gave Acid Value average 1.454 mg KOH/g, Density@ 15 °C average 941 Kg/m^3, Iodine Value average 161.3 g I_2 per 100 g of oil, Kinematic Viscosity 40 °C average 102.9 mm^2/s and Oxidation Stability average 0.8 hour.

The properties of the feedstock including the Canola oil and Palm oil It is apparent that the acid value, density, IV, and KV of the Canola oil were the highest among Palm oils. One should note that the IV of the Canola oil was 113.9 and 48.8 respectively, due to an abundance of the Cis-9-Octadecenoic acid. Similarly a KV at 40 °C of 34.33 mm^2/s of the Canola oil and 40.80 mm^2/s of palm oils, respectively. The high

KV could also be attributed to the polymerization of the Canola oil and Palm oil. (Yi-Hung Chen,Jhih-Hong(2010))

So from the experimental results can be explained of IV, and KV of the *Vernicia Montana* oil were the highest among Canola oil and Palm oils due to an abundance of the Cis-9,12-Octadecadienoic acid. Similarly a KV at 40 °C of the *Vernicia Montana* oil. The high KV could also be attributed to the polymerization of the *Vernicia Montana* oil.

4.8 Comparisons Quality with Other Biodiesel Type

When take the sample from 4.7 blend with diesel fuel (B5).The experiment result showed following Table 4.3 Which we bring the sample obtained from the experiment for test the property of Biodiesel and compare the results consist of Acid Value, Density @ 15 °C, Iodine Value, Kinematic Viscosity 40 °C, Oxidation Stability and Methyl ester content with Canola oil and Palm oil (Yi-Hung Chen,Jhih-Hong(2010))

Table 4.3 Comparisons Quality with Other Biodiesel Type of Canola, Plam and *Vernicia Montana oil*

Property	Unit	Canala	Palm	Vernicia	CNS 15072	EN 14214
Acid Value	mg KOH/g	0.152	0.129	0.126	0.5 max	0.5 max
Density@ 15 °C	Kg/m^3	884	875	902	860-900	860-900
IV	g I_2/100 g	114.1	49.6	159.5	120 max	120 max
KV@40 °C	mm^2/s	4.31	4.43	8.22	3.50-5.0	3.50-5.0
Oxidation Stability	h	2.7	16.5	0.5	6.0 min	6.0 min
Methyl Ester	%wt	99.5	99.8	96.2	96.5 min	96.5 min

The results of test showed that *Vernicia Montana* oil gave Acid Value 0.126 mg KOH/g, Density@ 15 °C 902 Kg/m^3, Iodine Value 159.5 g I_2 per 100 g of oil, Kinematic Viscosity 40 °C 8.22 mm^2/s and Oxidation Stability 0.5 hour and methyl ester content 96.2%wt.

When the test results compared with CNS 15072 and EN 14214 specification which the test result is lower than both specification is Oxidation Stability and Methyl ester content, the test result is higher than both specification is Iodine Value, Kinematic Viscosity 40 °C and Density@ 15 °C .However, The result of Acid Value is still on both specification.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. In this study, also found the appropriate concentration of catalyst, KOH, is 0.95 wt% which this concentration to get the maximum amount of methyl ester content is 95.1% by the operating conditions during the whole reaction process were fixed at: reaction temperature of 60°C, reaction time of 90 minutes, speed of 200 rpm and molar ratio of methanol to oil at 6:1.

2. After that we known the result of effect of catalyst concentration ,use this catalyst concentration at 0.95 wt% to study effect of molar ratio which this study the experimental results will be the emergence of the methyl ester contents in the product from gas chromatography analysis by the molar ratio of Methanol : Oil is 9:1 gave maximum of methyl ester content 92.9%.

3. In this study, the experiments to observe the effects of stirring speed also had been carried out by varying stirring speed from 200,400, 600 rpm which 600 rpm, using 9:1 molar ratio of methanol to oil, 0.95 wt% KOH, 50 °C and 60 minutes reaction time, found that the maximum methyl ester contents for the reaction were 96.7wt%.The high stirring speed of agitator is to get the methyl ester higher than low stirring speed due to the high speed and size drops of methanol , resulting in a smaller surface area for reaction, the reaction more quickly by the stirring speed of agitator is affects with the rate of reaction.

4. In this study, the experiments to observe the effects of temperature also had been carried out by varying temperature from 40,50,60,70 °C, which 50 °C for reaction temperature, using 9:1 molar ratio of methanol to oil, 0.95 wt% KOH,60 minutes reaction time, found that the maximum methyl ester contents for the reaction were 96.7wt%.

5. In this study, the experiments to observe the effects of time also had been carried out by varying temperature from 10,30,60,90 min., which 60 minutes for the reaction time, using 9:1 molar ratio of methanol to oil, 0.95 wt% KOH, 50 °C, found that the maximum methyl ester contents for the reaction were 96.7wt%.

6. Select this condition to get the maximum methyl ester contents to compare with the Canola oil and Palm oil and (Yi-Hung Chen, Jhih-Hong(2010)) following the result showed that Table 4.2 consist of acid value, density @ 15 °C, iodine value, kinematic viscosity 40 °C, oxidation stability which from the experimental results can be explained of iodine value, and kinematic viscosity 40 °C of the *Vernicia Montana* oil were the highest among Canola oil and Palm oils due to an abundance of the Cis-9,12-Octadecadienoic acid. Similarly a kinematic viscosity 40 °C of the *Vernicia Montana* oil. The high kinematic viscosity 40 °C could also be attributed to the polymerization of the *Vernicia Montana* oil.

7. When take the sample from item 6 blend with diesel fuel (B5).The experiment result showed following Table 4.3 which we bring the sample obtained from the experiment for test the property of biodiesel and compare the results consist of acid value, density @ 15 °C, iodine value, kinematic viscosity 40 °C, oxidation stability and methyl ester content with Canola oil and Palm oil (Yi-Hung Chen, Jhih-Hong(2010)) when the test results compared with CNS 15072 and EN 14214 specification which the test result is lower than both specification is oxidation stability and methyl ester content, and iodine value, kinematic viscosity 40 °C and density @ 15 °C test result is higher than both specification but the result of acid value is still on both specification.

8. The obtained biodiesel from *Vernicia Montana* oil contained high values of iodine value and kinematic viscosity 40 °C which are higher than the limit recommended biodiesel standard CNS 15072 and EN 14214 specification with iodine value lower than 120 g I_2/100 g (Biofuel System, 2010; Kulkarni et al., 2005; TBOS, 2010; Wang et al., 2007). The iodine value parameter is associated with the air pollution emission of biodiesel fuels.

A higher iodine value result in a higher NO_x emission (Hess et al., 2007). The *Vernicia Montana* oil may be not suitable for biodiesel product unless iodine value and kinematic viscosity 40 °C are reduced (McCormick et al. (2006)).

5.2 Recommendations

1. From the test result item 6 of conclusion we found that the Iodine Value of B100 of *Vernicia Montana* oil is highly which consequent abundance of the Cis-9-Octadecenoic acid which is double bond, Iodine Value is the index indicates the quantity of double bond. This means that the quantity of unsaturated fatty acid as a component in a large quantity which when we produce biodiesel the unsaturated fatty acid in biodiesel will result with cumulative on fuel handing system and filter of engine although have effect with the oxidation stability which it's make short shelf life.

2. The high Kinematic Viscosity 40 °C could also be attributed to the polymerization of the B100 of *Vernicia Montana* oil which have effect with quality of biodiesel from the test result of B5 of *Vernicia Montana* oil is over specification of CNS 15072 and EN 14214.

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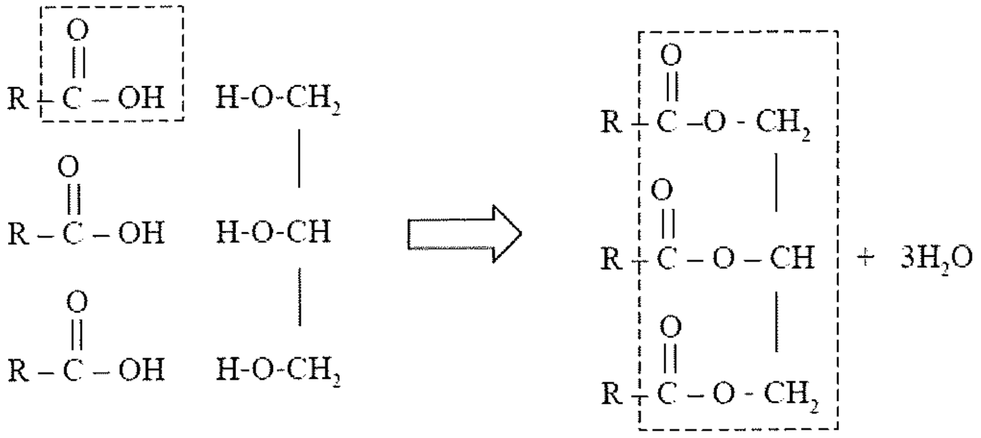
APPENDICES

APPENDIX A

REACTION CHEMISTRY CALCULATION

Vernicia Montana oil Molecular Weight Calculation



3 Fatty Acids + Glycerol Triglyceride + Water

From Triglyceride formation reaction, the molecular weight of triglyceride can be obtained from the following equation:-

$$MW_{TG} = 3\ R_{avg} + 38$$

$$R_{avg} = \sum \frac{[\%F_{AN} \times MW_n] + 38}{100}$$

Where

MW_{TG} is average molecular weight of triglyceride

R_{avg} is average Molecular weight of fatty acid less COOH

$\%F_{AN}$ is %wt of each fatty acid in waste *Vernicia Montana oil*

MW_n is Molecular weight of each fatty acid

R_{AVG} = (1.32x200.32) + (0.59x228.36) + (8.05x256.43) + (0.05x254.41) + (0.05x270.45) + (3.39x284.48) + (15.64x282.46) + (33.82x280.45) + (2.61x280.45) + (0.23x312.53) + (0.36x310.51) + (22.75x340.59) + (0.08x368.64) = 260.50 g/mol

MW_{TG} = (3x260.50) +38

= 819.50 g/mol

Table A1 Chemical physical properties

Chemical	Density (g/ml)	Boiling Point (°C)	Molecular Weight
Vernicia Montana oil	-	-	819.50
Methanol	0.79	64.7	32.04

Methanol Quantity Calculation

Molar ratio of methanol to oil is 3:1

The experiment used *Vernicia Montana* oil 100 g

Waste cooking oil 100 g equals to 100/819.50 = 0.122 mol

Hence, methanol used is 3 x 0.122 = 0.366 mol or 0.366 x 32.04 = 11.73 g

or 11.73/ 0.79 = 11.85 ml

Molar ratio of methanol to oil is 6:1

The experiment used *Vernicia Montana* oil 100 g

Waste cooking oil 100 g equals to 100/819.50 = 0.122 mol

Hence, methanol used is 6 x 0.122 = 0.732 mol or 0.732 x 32.04 = 23.45 g

or 23.45/ 0.79 = 29.69 ml

Molar ratio of methanol to oil is 9:1

The experiment used *Vernicia Montana* oil 100 g

Waste cooking oil 100 g equals to 100/819.50 = 0.122 mol

Hence, methanol used is 9 x 0.122 = 1.098 mol or 1.098 x 32.04 = 35.18 g

or 35.18/ 0.79 = 44.53 ml

Molar ratio of methanol to oil is 12:1

The experiment used *Vernicia Montana* oil 100 g

Waste cooking oil 100 g equals to 100/819.50 = 0.122 mol

Hence, methanol used is 12 x 0.122 = 1.464 mol or 1.464 x 32.04 = 46.90 g

or 46.90/ 0.79 = 59.38 ml

Catalyst Quantity Calculation

The experiment used 0.15 %wt catalyst Vernicia Montana oil

Hence, catalyst quantity used is (0.15/100) x 100 =0.15 g

The experiment used 0.35 %wt catalyst Vernicia Montana oil

Hence, catalyst quantity used is (0.35/100) x 100 =0.35 g

The experiment used 0.55 %wt catalyst Vernicia Montana oil

Hence, catalyst quantity used is (0.55/100) x 100 =0.55 g

The experiment used 0.95 %wt catalyst Vernicia Montana oil

Hence, catalyst quantity used is (0.95/100) x 100 =0.95 g

APPENDIX B

DETERMINATION OF METHYL ESTER CONTENT

Analysis of Methyl Ester Content in the Product

Methyl ester content in the product is determined from gas chromatograph in accordance with EN 14103: 2003 using methyl hetadecanoate (C17:0) as an internal standard and uses normal heptane (n-C_7H_{16}) as a solvent. Methyl ester content is calculated using the following formula:

$$C = \frac{(\sum A) - A_{EI}}{A_{EI}} x \frac{C_{EI} x V_{EI}}{m} x100$$

Where

$\sum A$ is the total peak area from methyl ester in C14 to that in C24:1

A_{EI} is the peak area corresponding to methyl heptadecanoate

C_{EI} is the concentration, in mg/ml, of methyl heptadecanoate solution being used

V_{EI} is the volume, in ml, of the methyl haptadecanoate solution being used

m is the mass, in mg, of the sample

APPENDIX C

ERROR ANALYSIS

In order to check the accuracy/ error of the experimental result, three samples were tested at the same reaction conditions, i.e. 9:1 mol MeOH/ Oil, 0.95 wt% KOH, 50 °C, 60 minutes, 600 rpm, The results are shown in the figure below.

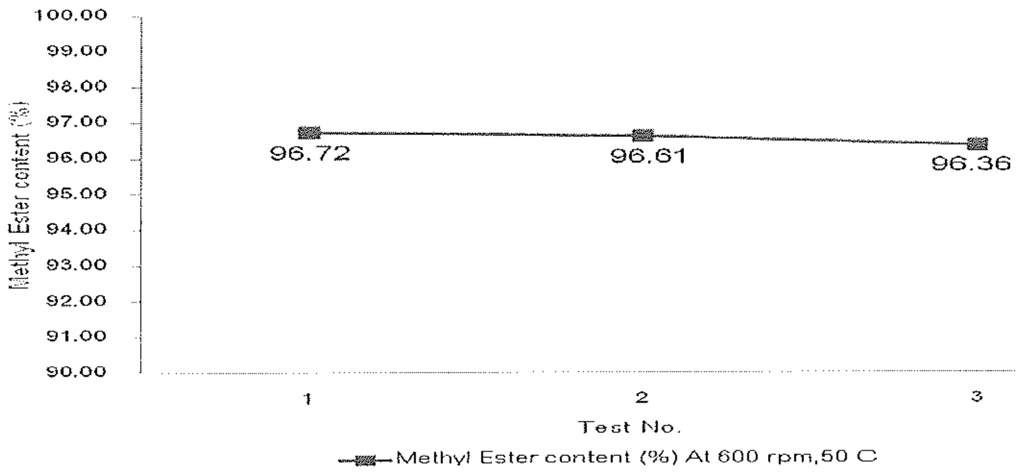


Fig. C.1 Methyl ester content from experiments at the same reaction conditions

Reaction condition: 9:1 mol MeOH/ Oil, 0.95 wt% KOH, 50 °C, 60 minutes, 600 rpm.

From the above results

- average methyl ester content is 96.57 wt%
- maximum methyl ester content (from experiment no. 1) is 96.72 wt% or +0.15% error from the average value
- minimum methyl ester content (from experiment no. 3) is 96.36 wt% or -0.21 % error from the average value

It can be concluded that if the different of methyl ester content from the different experiment conditions is less than 0.36 wt% (96.36 – 96.72), the result can be considered that these conditions yield the same methyl ester content.

APPENDIX D

EXPERIMENTAL DATA

1. Experimental Data

1.1 Compare %KOH

Table D.1 Compare %KOH

Sample No.	Reaction Condition						Sample ID
	Ratio of MeOH:Oil	MeOH (g): 100g of oil	%KOH	Speed (rpm)	Temperature (°C)	Times (min)	
C1	6:1	23.45	0.15	200	60	90	1
C2	6:1	23.45	0.35	200	60	90	2
C3	6:1	23.45	0.55	200	60	90	3
C4	6:1	23.45	0.75	200	60	90	4
C5	6:1	23.45	0.95	200	60	90	5

1.2 Compare molar ratio of MeOH : Oil

Table D.2 Compare molar ratio of MeOH : Oil

Sample No.	Reaction Condition						Sample ID
	Ratio of MeOH:Oil	MeOH (g): 100g of oil	%KOH	Speed (rpm)	Temperature (°C)	Times (min)	
M1	3:1	11.73	0.95	200	60	90	1
M2	6:1	23.45	0.95	200	60	90	2
M3	9:1	35.18	0.95	200	60	90	3
M4	12:1	46.90	0.95	200	60	90	4

1.3 Compare speed, temperature and times

Table D.3 Compare speed, temperature and times

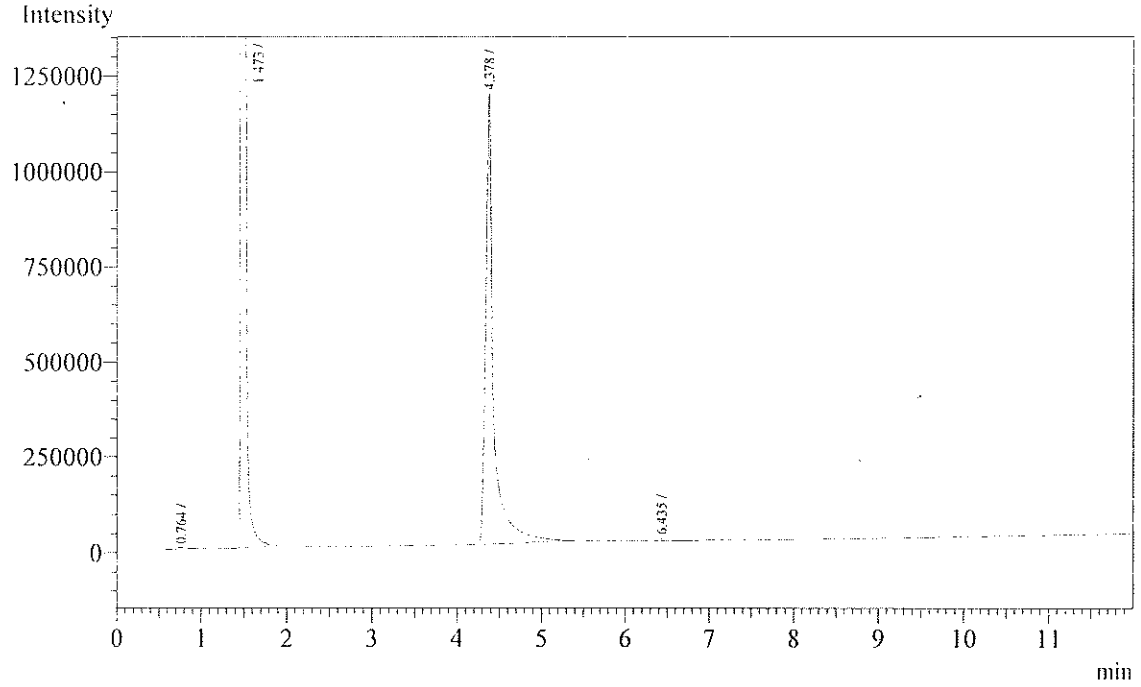
Sample No.	Reaction Condition					
	MeOH:Oil	MeOH (g) : 100 g of oil	%KOH	Speed (rpm)	Temperature (^{0}C)	Times (min)
V1	9:1	35.18	0.95	200	40	10
V2	9:1	35.18	0.95	400	40	10
V3	9:1	35.18	0.95	600	40	10
V4	9:1	35.18	0.95	200	50	10
V5	9:1	35.18	0.95	400	50	10
V6	9:1	35.18	0.95	600	50	10
V7	9:1	35.18	0.95	200	60	10
V8	9:1	35.18	0.95	400	60	10
V9	9:1	35.18	0.95	600	60	10
V10	9:1	35.18	0.95	200	70	10
V11	9:1	35.18	0.95	400	70	10
V12	9:1	35.18	0.95	600	70	10
V13	9:1	35.18	0.95	200	40	30
V14	9:1	35.18	0.95	400	40	30
V15	9:1	35.18	0.95	600	40	30
V16	9:1	35.18	0.95	200	50	30
V17	9:1	35.18	0.95	400	50	30
V18	9:1	35.18	0.95	600	50	30
V19	9:1	35.18	0.95	200	60	30
V20	9:1	35.18	0.95	400	60	30
V21	9:1	35.18	0.95	600	60	30
V22	9:1	35.18	0.95	200	70	30
V23	9:1	35.18	0.95	400	70	30
V24	9:1	35.18	0.95	600	70	30
V25	9:1	35.18	0.95	200	40	60
V26	9:1	35.18	0.95	400	40	60
V27	9:1	35.18	0.95	600	40	60
V28	9:1	35.18	0.95	200	50	60
V29	9:1	35.18	0.95	400	50	60
V30	9:1	35.18	0.95	600	50	60
V31	9:1	35.18	0.95	200	60	60
V32	9:1	35.18	0.95	400	60	60
V33	9:1	35.18	0.95	600	60	60
V34	9:1	35.18	0.95	200	70	60
V35	9:1	35.18	0.95	400	70	60
V36	9:1	35.18	0.95	600	70	60
V37	9:1	35.18	0.95	200	40	90
V38	9:1	35.18	0.95	400	40	90
V39	9:1	35.18	0.95	600	40	90

Sample No.	Reaction Condition					
	MeOH:Oil	MeOH (g) : 100 g of oil	%KOH	Speed (rpm)	Temperature (^{0}C)	Times (min)
V40	9:1	35.18	0.95	200	50	90
V41	9:1	35.18	0.95	400	50	90
V42	9:1	35.18	0.95	600	50	90
V43	9:1	35.18	0.95	200	60	90
V44	9:1	35.18	0.95	400	60	90
V45	9:1	35.18	0.95	600	60	90
V46	9:1	35.18	0.95	200	70	90
V47	9:1	35.18	0.95	400	70	90
V48	9:1	35.18	0.95	600	70	90
V49	6:1	23.45	1.50	200	60	90

2. Gas Chromatography Analysis for Methyl Ester Content in Product

Analysis Date & Time : 30/8/2554 10:07:57
User Name : Admin
Vial# : 1
Sample Name : 1
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

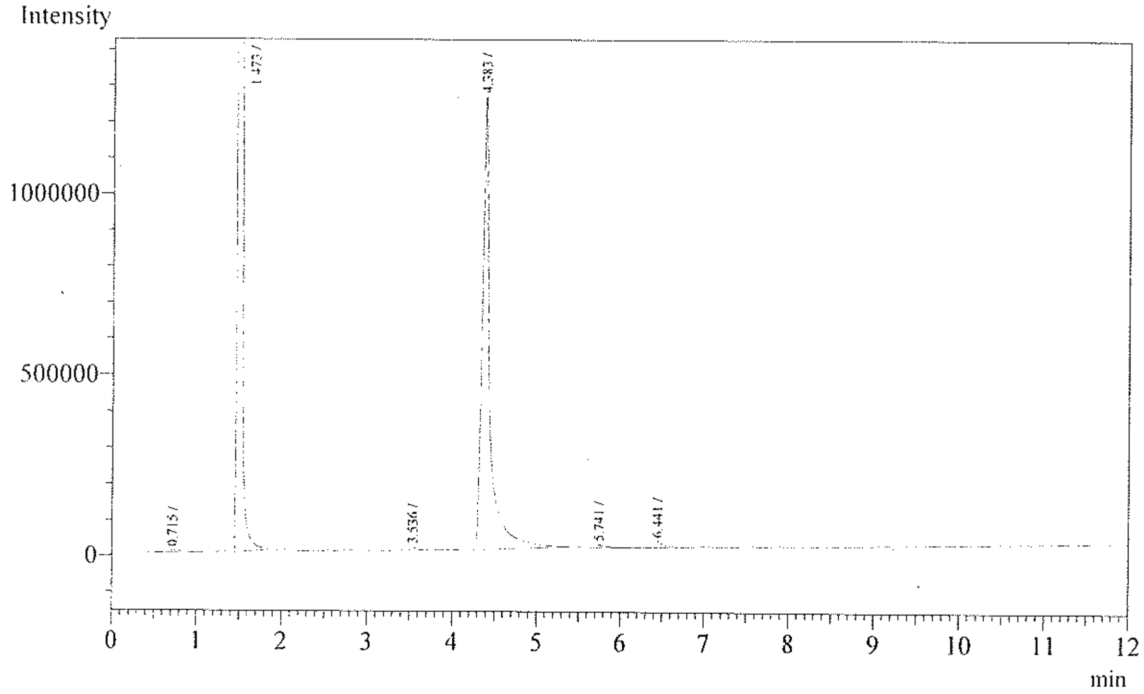
Data Name : D:\ACID\FA3.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.764	53805	4508	0.000				
2	1.473	645850426	55541940	0.000				
3	4.378	7635228	1176994	0.000				
4	6.435	56380	7481	0.000				
Total		653595839	56730923					

Analysis Date & Time : 30/8/2554 9:54:21
User Name : Admin
Vial# : 2
Sample Name : 2
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

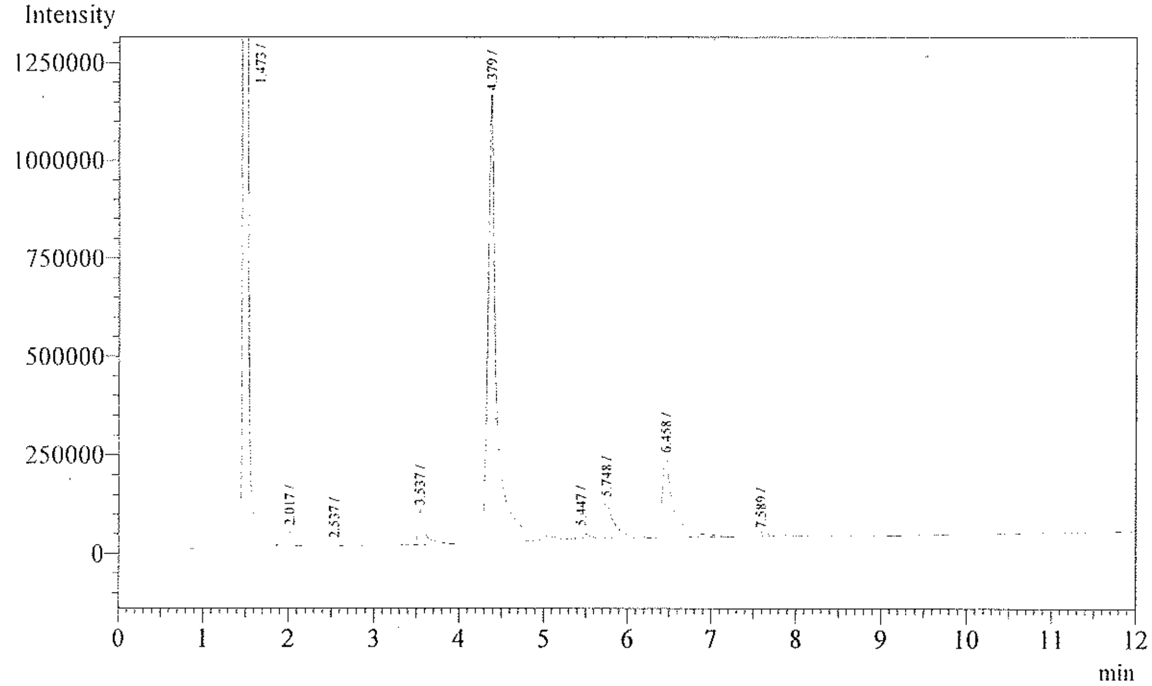
Data Name : D:\ACID\FA2.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.715	83239	6060	0.000				
2	1.473	638832741	52426153	0.000				
3	3.536	36338	8366	0.000				
4	4.383	8157877	1246823	0.000				
5	5.741	57629	7661	0.000				
6	6.441	140067	17453	0.000				
Total		647307891	53712516					

Analysis Date & Time : 30/8/2554 10:21:34
User Name : Admin
Vial# : 3
Sample Name : 3
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

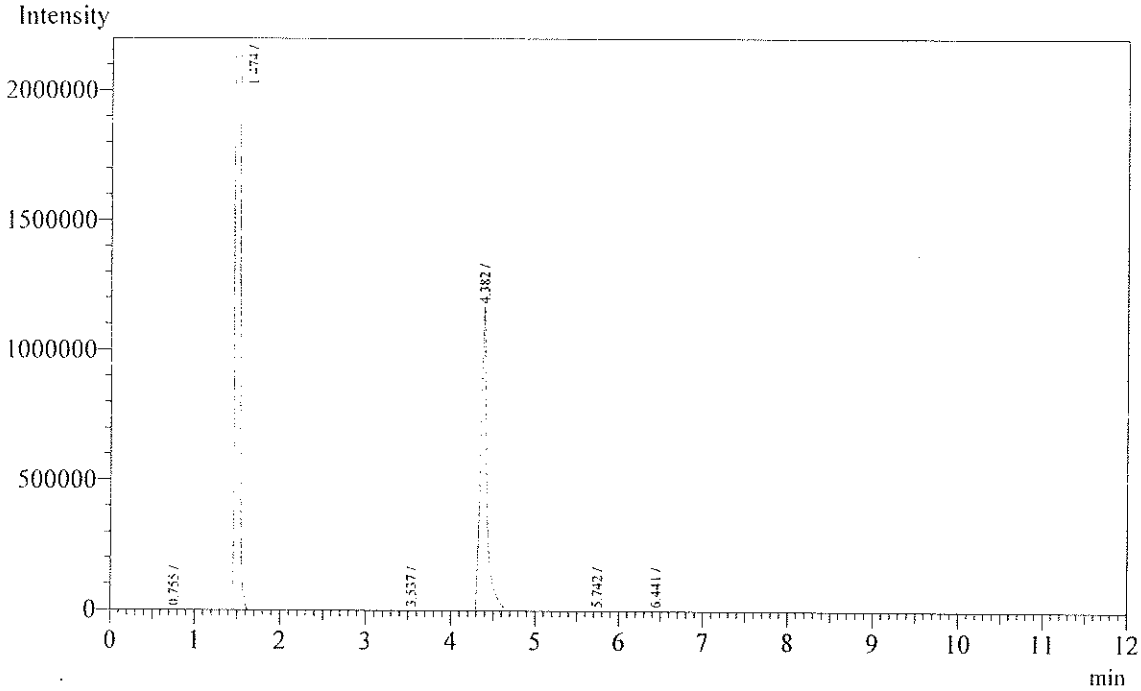
Data Name : D:\ACID\FA4.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.473	632948045	45018074	0.000		S		
2	2.017	98790	41992	0.000				
3	2.537	37524	12365	0.000				
4	3.537	495588	90489	0.000				
5	4.379	8176661	1138097	0.000				
6	5.447	146252	22481	0.000				
7	5.748	824064	94795	0.000				
8	6.458	1994076	205483	0.000		S		
9	7.589	82948	10986	0.000		V		
Total		644803948	46634762					

Analysis Date & Time : 30/8/2554 9:40:41
User Name : Admin
Vial# : 4
Sample Name : 4
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

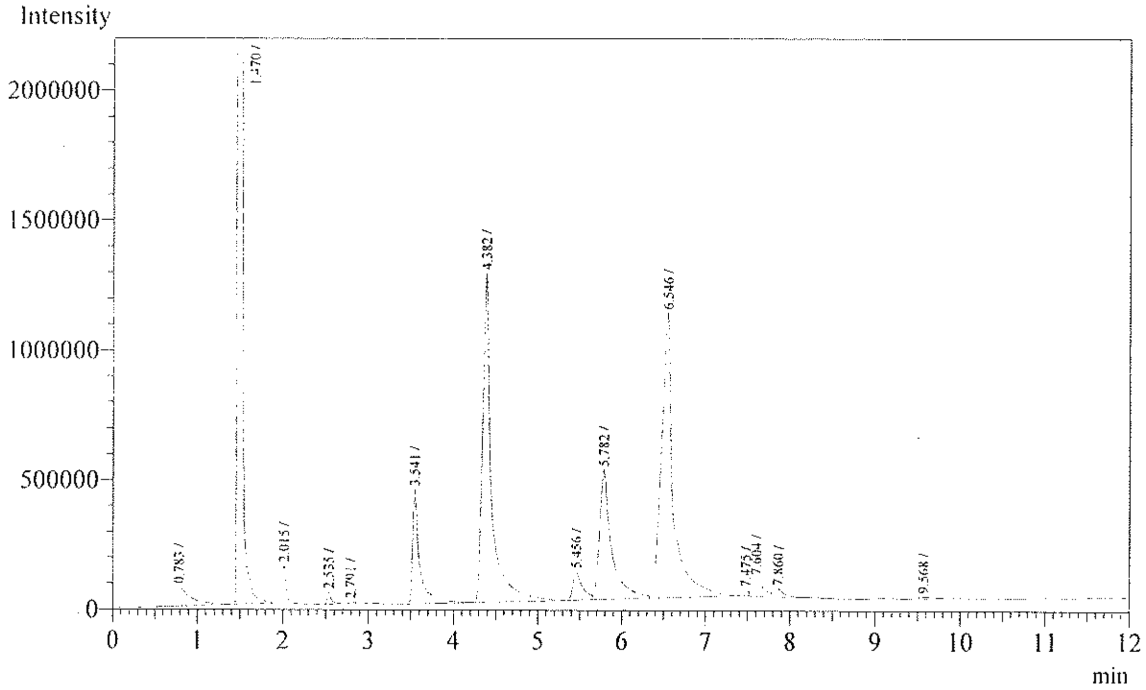
Data Name : D:\ACID\FA1.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit Mark ID#	Cmpd Name
1	0.755	150340	6049	0.000		
2	1.474	665282592	67687276	0.000		
3	3.537	42186	9691	0.000		
4	4.382	8719891	✓1204716	0.000	→ STD	
5	5.742	72764	9674	0.000		
6	6.441	145495	19639	0.000		
Total		673413268	68937045			

Analysis Date & Time : 30/8/2554 10:35:11
User Name : Admin
Vial# : 5
Sample Name : 5
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

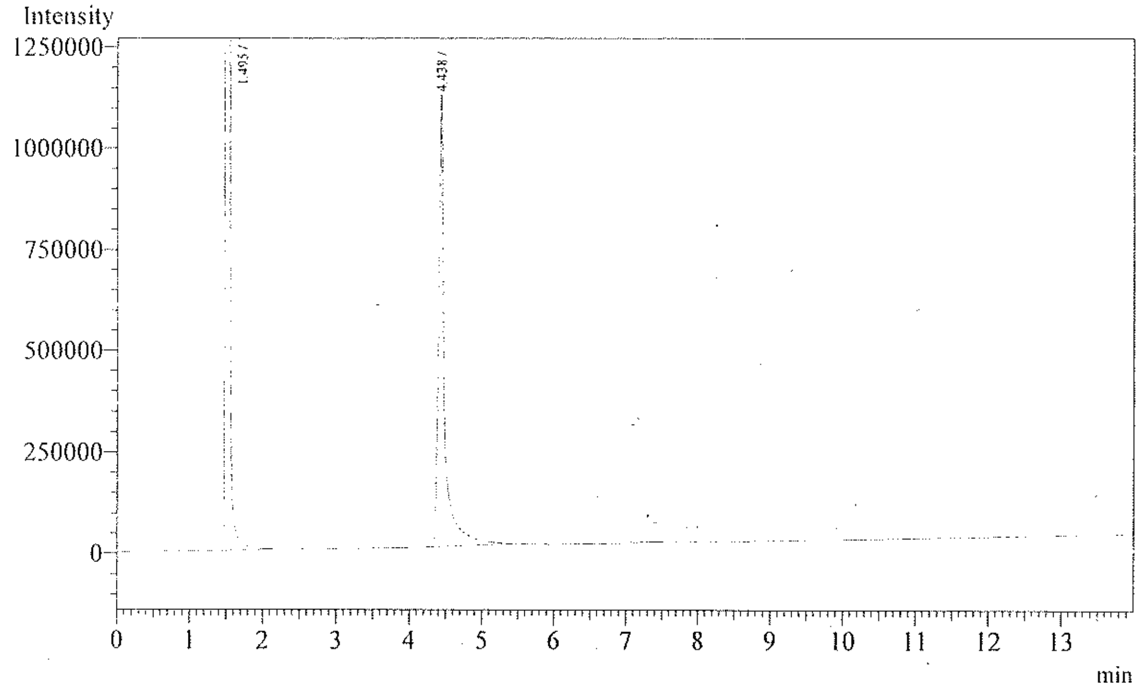
Data Name : D:\ACID\FA5.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.783	1220187	72551	0.000				
2	1.470	784207411	35628007	0.000		S		
3	2.015	354567	144340	0.000				
4	2.535	148785	45069	0.000				
5	2.791	50341	6005	0.000		V		
6	3.541	2589220	439321	0.000				
7	4.382	9523388	✓1263922	0.000				
8	5.456	880476	107592	0.000				
9	5.782	5015005	498080	0.000		V		
10	6.546	11009377	1096380	0.000		V		
11	7.475	112520	22345	0.000				
12	7.604	593139	68199	0.000		V		
13	7.860	280997	29741	0.000		V		
14	9.568	97281	7730	0.000				
Total		816082694	39429282					

Analysis Date & Time : 1/9/2554 13:33:07
User Name : Admin
Vial# : 1
Sample Name : STD-BL
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

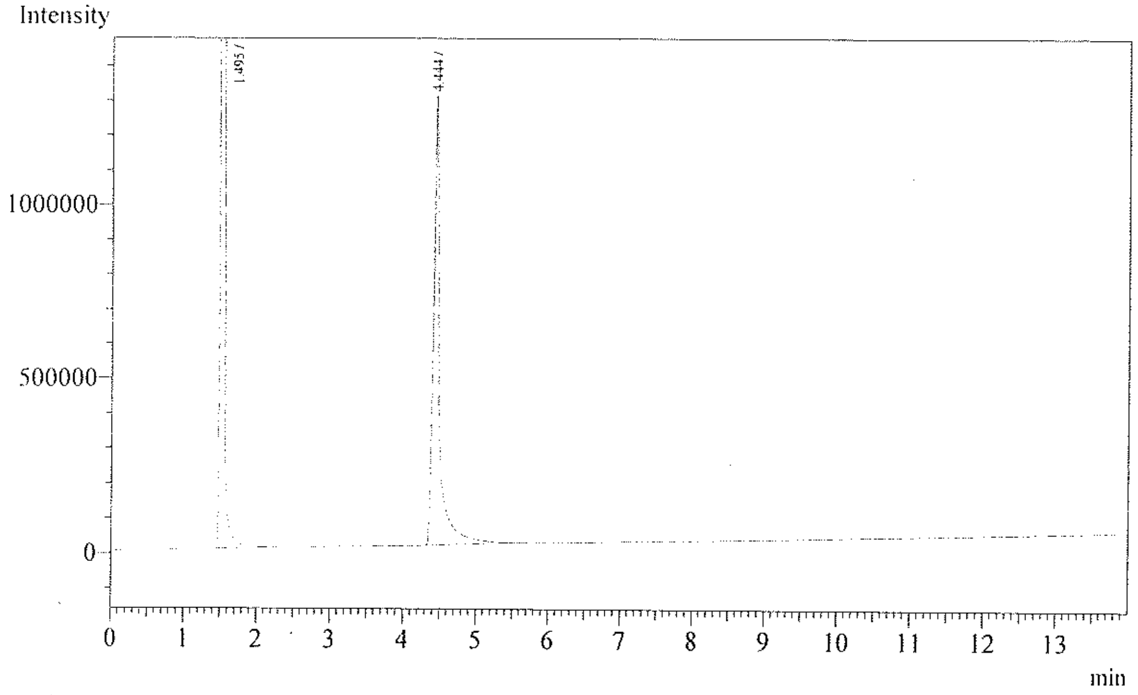
Data Name : D:\ACID\FA6.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.495	692903785	75119900	0.000				
2	4.438	6508820	1108605	0.000				
Total		699412605	76228505					

Analysis Date & Time : 1/9/2554 13:48:47
User Name : Admin
Vial# : 2
Sample Name : M1
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

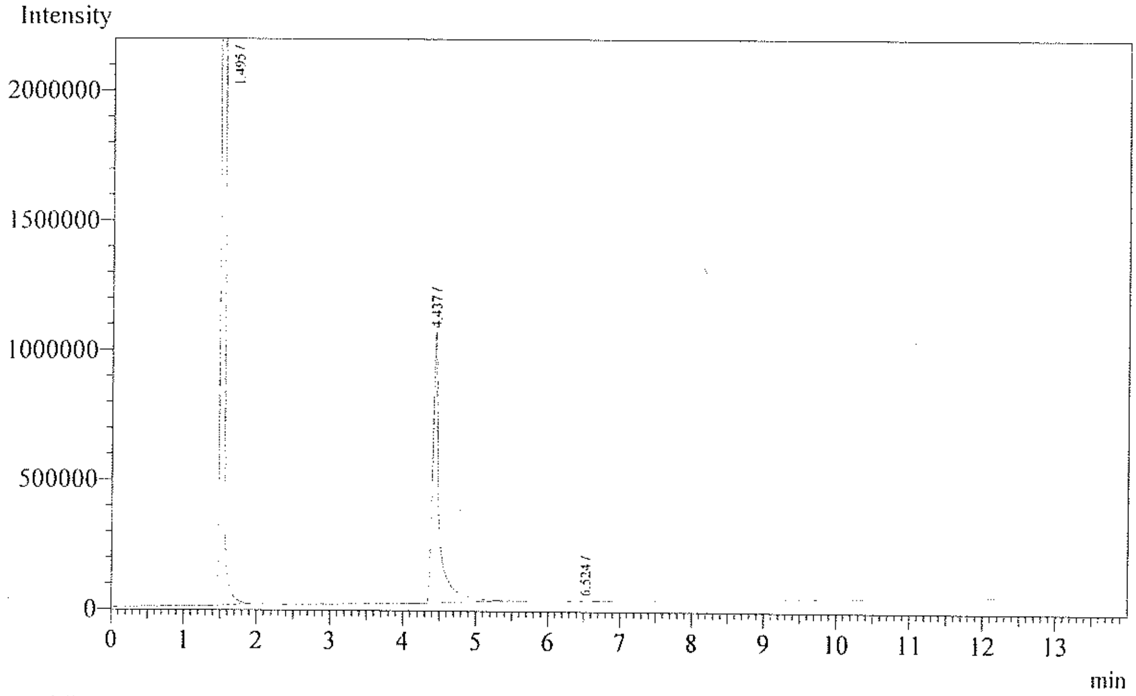
Data Name : D:\ACID\FA7.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.495	665843913	62632525	0.000				
2	4.444	7731799	1288798	0.000				
Total		673575712	63921323					

Analysis Date & Time : 1/9/2554 14:04:26
User Name : Admin
Vial# : 3
Sample Name : M 1.1
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

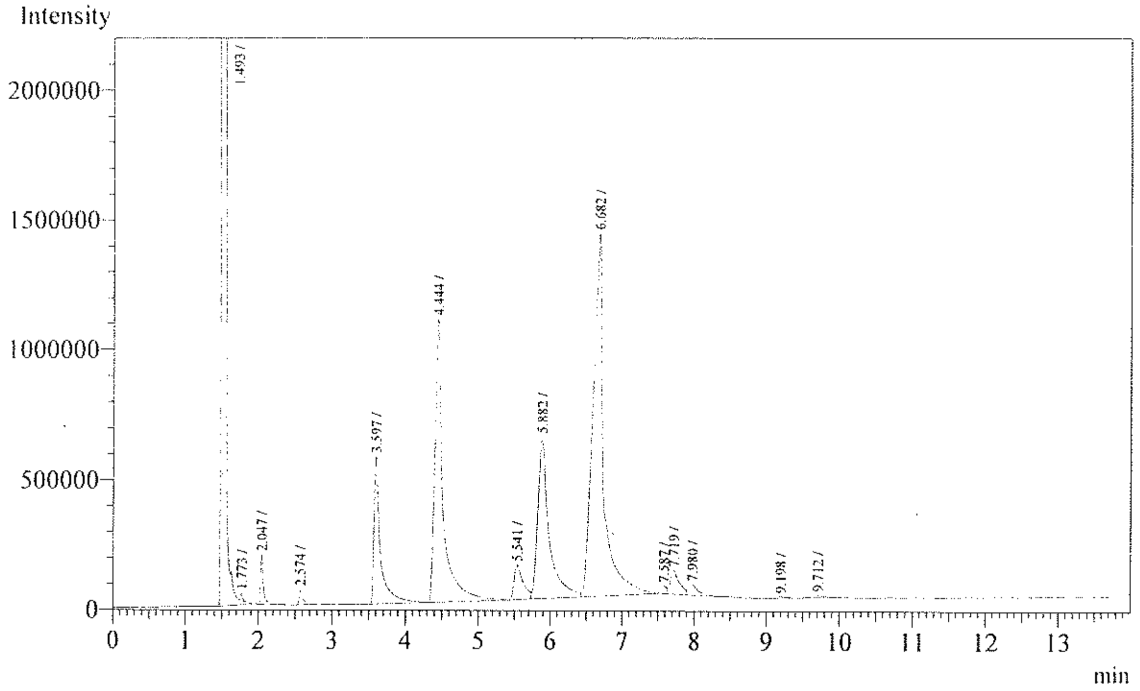
Data Name : D:\ACID\FA8.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.495	630942182	40766903	0.000				
2	4.437	7080279	1044639	0.000				
3	6.524	50288	6804	0.000				
Total		638072749	41818346					

Analysis Date & Time : 1/9/2554 14:20:03
User Name : Admin
Vial# : 4
Sample Name : M 2
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

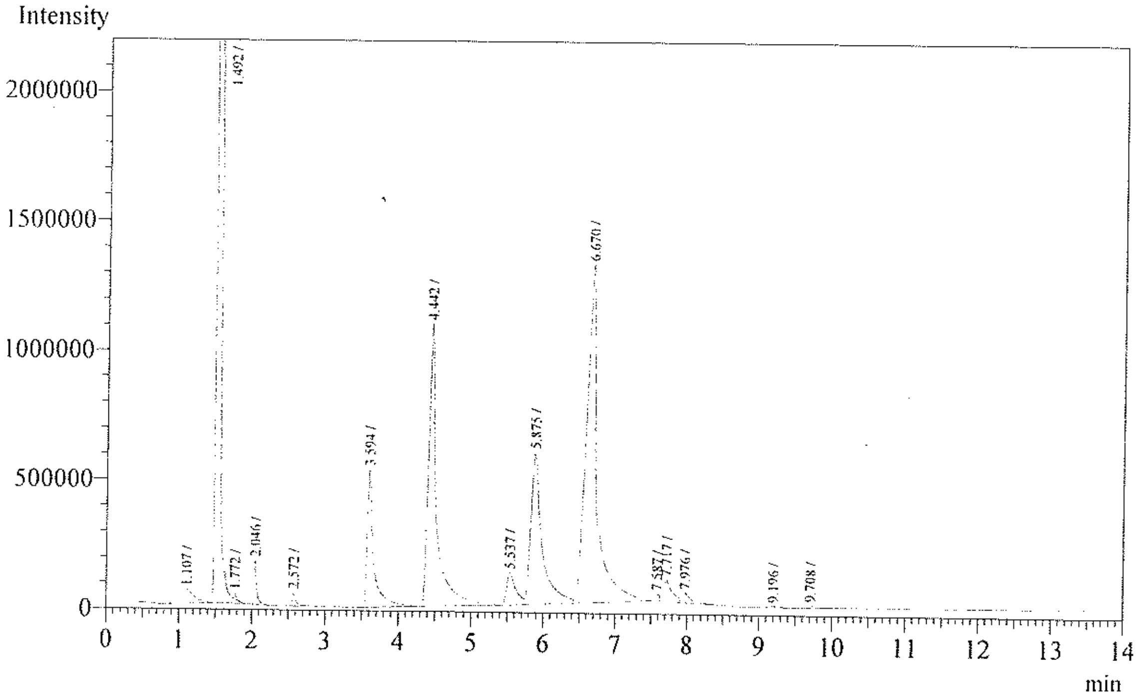
Data Name : D:\ACID\FA9.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.493	747242528	12499681	0.000		S		
2	1.773	50213	28282	0.000		T		
3	2.047	484617	189717	0.000				
4	2.574	208616	59095	0.000				
5	3.597	3515838	566469	0.000				
6	4.444	8676038	1083265	0.000				
7	5.541	1169566	132963	0.000				
8	5.882	6822057	622618	0.000		V		
9	6.682	14929401	1391411	0.000		V		
10	7.587	144123	28989	0.000				
11	7.719	807781	90542	0.000		V		
12	7.980	375980	39744	0.000		V		
13	9.198	56564	5715	0.000				
14	9.712	128291	10047	0.000				
Total		784611613	16748538					

Analysis Date & Time : 1/9/2554 14:35:41
User Name : Admin
Vial# : 5
Sample Name : M 3
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

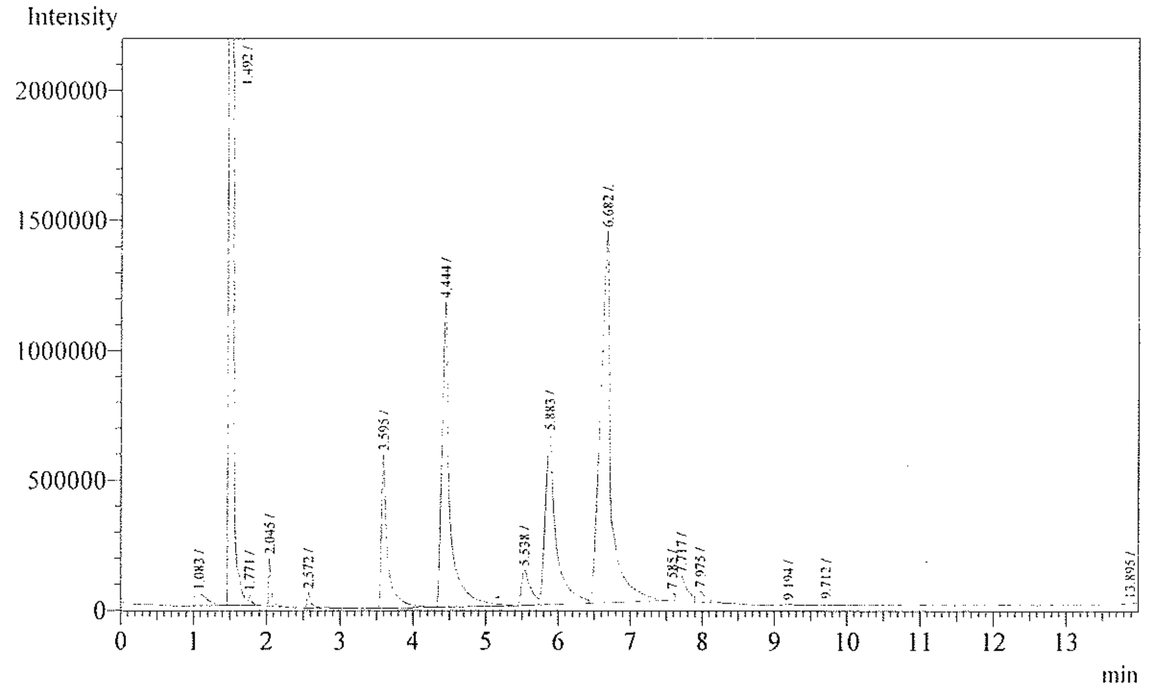
Data Name : D:\ACID\FA10.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.107	762168	52735	0.000				
2	1.492	752949491	18363285	0.000		S		
3	1.772	39357	23367	0.000		T		
4	2.046	423595	167417	0.000				
5	2.572	186522	53671	0.000				
6	3.594	3292965	529092	0.000				
7	4.442	8687977	1090021	0.000				
8	5.537	1079345	125299	0.000				
9	5.875	6365101	586016	0.000		V		
10	6.670	14018467	1299414	0.000		V		
11	7.587	137771	26879	0.000				
12	7.717	742226	84286	0.000		V		
13	7.976	348035	37441	0.000		V		
14	9.196	53016	5469	0.000				
15	9.708	114284	9188	0.000				
Total		789200320	22453580					

Analysis Date & Time : 1/9/2554 14:51:20
User Name : Admin
Vial# : 6
Sample Name : M 4
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

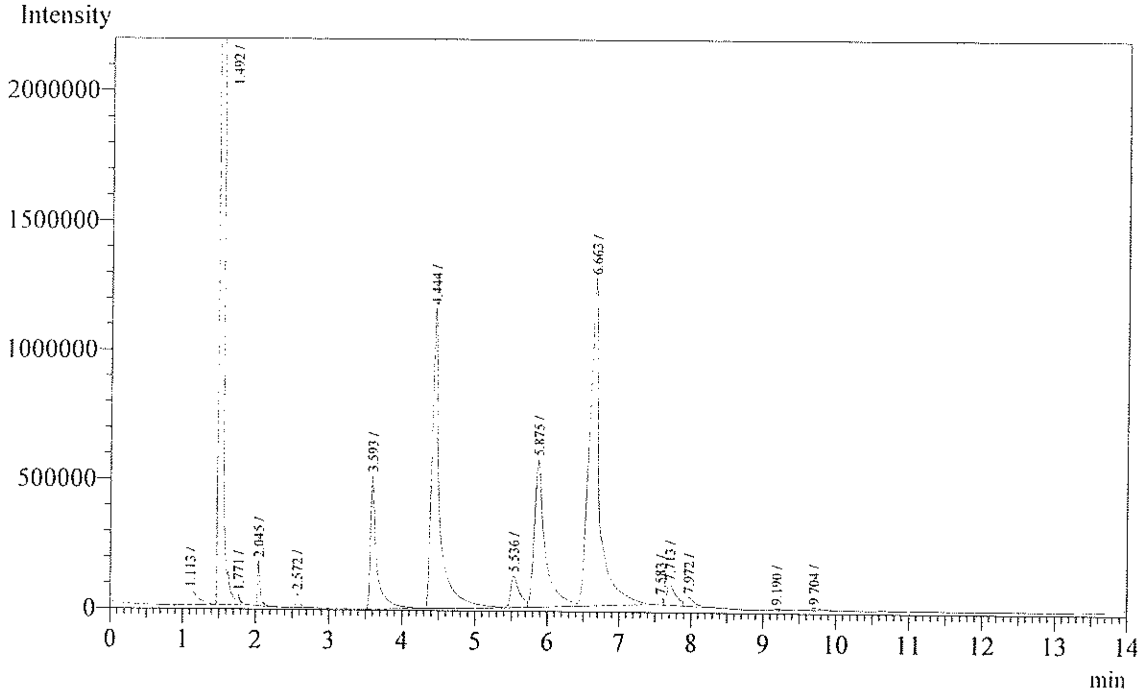
Data Name : D:\ACID\FA11.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.083	690221	47443	0.000				
2	1.492	747277225	15291956	0.000		S		
3	1.771	43672	25688	0.000		T		
4	2.045	444961	182739	0.000				
5	2.572	202188	59495	0.000				
6	3.595	3442580	589734	0.000				
7	4.444	8844479	1172782	0.000				
8	5.538	1188799	137749	0.000				
9	5.883	6811205	654408	0.000		V		
10	6.682	14816218	1425751	0.000		V		
11	7.585	154693	30619	0.000				
12	7.717	821076	95517	0.000		V		
13	7.975	375798	40716	0.000		V		
14	9.194	58876	6036	0.000				
15	9.712	128967	10382	0.000				
16	13.895	31018	3865	0.000				
Total		785331976	19774880					

Analysis Date & Time	: 1/9/2554 15:06:55
User Name	: Admin
Vial#	: 7
Sample Name	: V1
Sample ID	: UNK-0001
Sample Type	: Unknown
Injection Volume	: 1.00
ISTD Amount	:

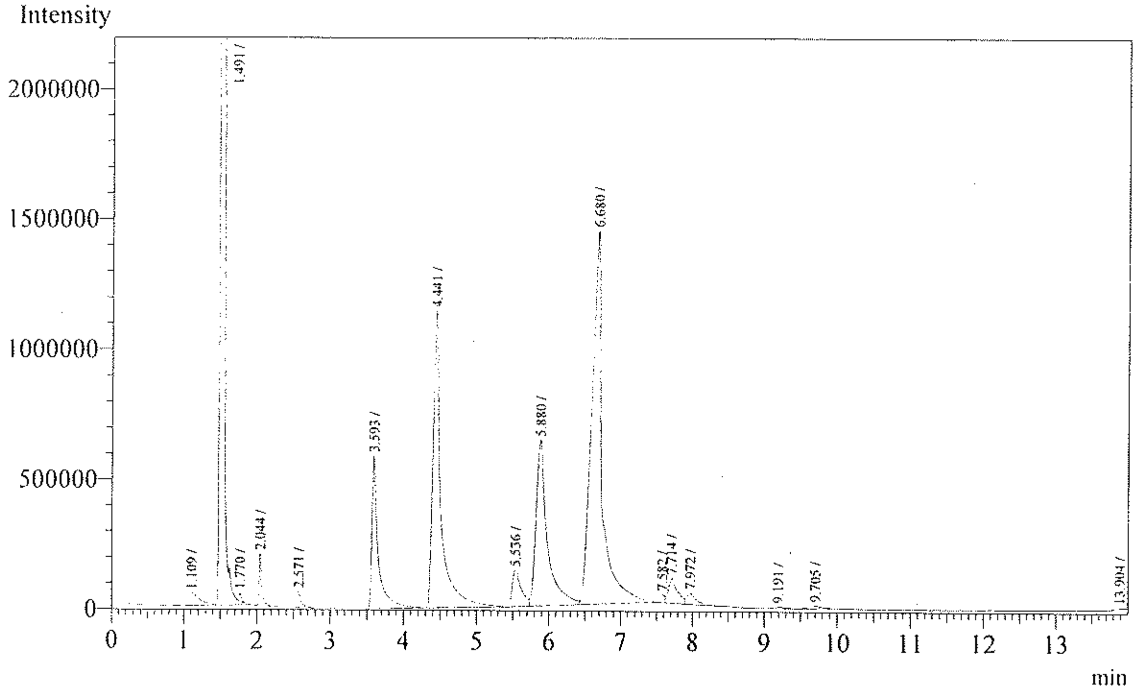
Data Name	: D:\ACID\FA12.gcd
Method Name	: D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.113	765038	54203	0.000				
2	1.492	746500385	13846930	0.000		S		
3	1.771	44314	25453	0.000		T		
4	2.045	425871	170078	0.000				
5	2.572	183796	53520	0.000				
6	3.593	3057847	511716	0.000				
7	4.444	8843352	1154635	0.000				
8	5.536	1032403	123108	0.000				
9	5.875	5948248	567354	0.000		V		
10	6.663	13056913	1262027	0.000		V		
11	7.583	134524	26573	0.000				
12	7.713	719489	81558	0.000		V		
13	7.972	334891	35391	0.000		V		
14	9.190	50822	5307	0.000				
15	9.704	109446	8912	0.000				
Total		781207339	17926765					

Analysis Date & Time : 1/9/2554 15:22:32
User Name : Admin
Vial# : 8
Sample Name : V2
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

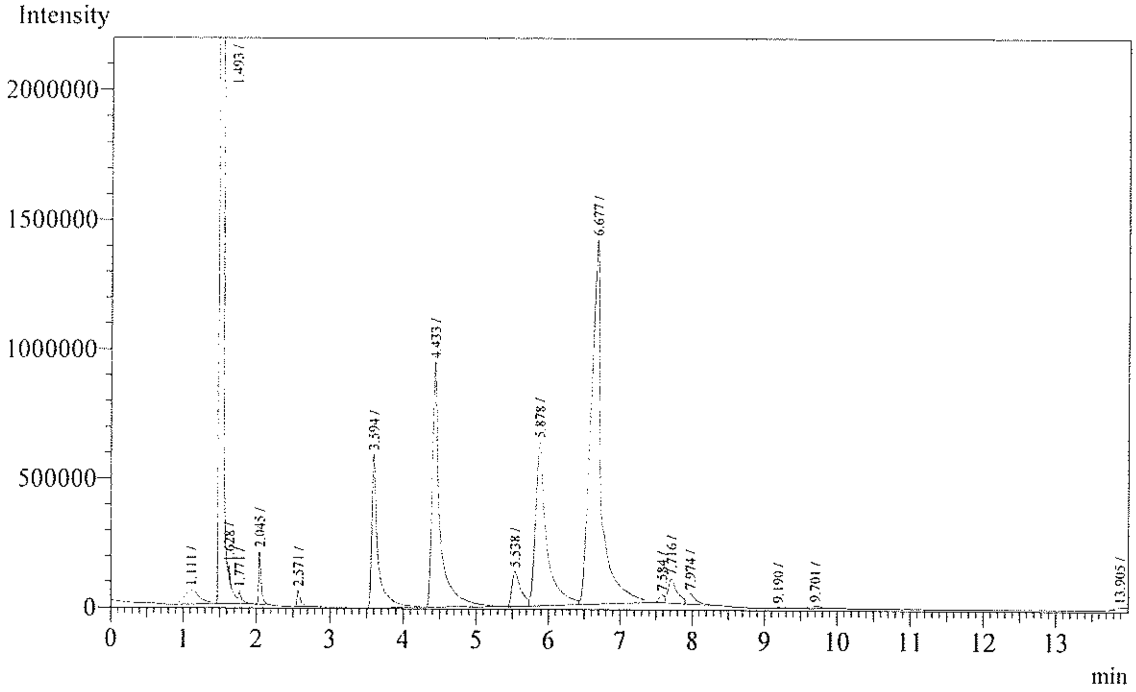
Data Name : D:\ACID\FA13.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.109	683316	47535	0.000				
2	1.491	742702396	11419297	0.000		S		
3	1.770	54155	30266	0.000		T		
4	2.044	480126	197058	0.000				
5	2.571	211079	61932	0.000				
6	3.593	3543719	587872	0.000				
7	4.441	8812942	1139728	0.000				
8	5.536	1199991	138925	0.000				
9	5.880	6909185	638319	0.000		V		
10	6.680	15168834	1432577	0.000		V		
11	7.582	150244	30776	0.000				
12	7.714	835960	94866	0.000		V		
13	7.972	395563	41888	0.000		V		
14	9.191	59869	6138	0.000				
15	9.705	126456	10186	0.000				
16	13.904	33093	3601	0.000				
Total		781366928	15880964					

Analysis Date & Time : 1/9/2554 15:38:08
User Name : Admin
Vial# : 9
Sample Name : V3
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

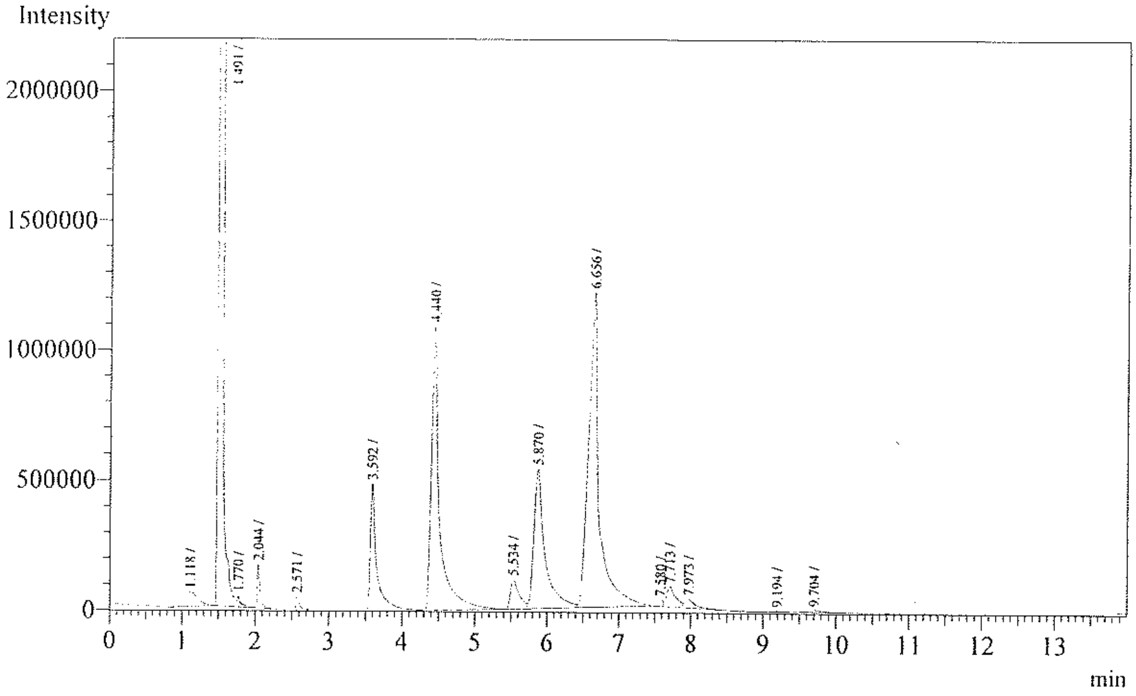
Data Name : D:\ACID\FA14.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.111	783244	54357	0.000				
2	1.493	592112867	12958264	0.000		S		
3	1.628	44388	37704	0.000		T		
4	1.771	51223	30533	0.000		T		
5	2.045	471759	200749	0.000				
6	2.571	203512	62827	0.000				
7	3.594	3453113	592414	0.000				
8	4.433	7092058	944143	0.000				
9	5.538	1173727	136178	0.000				
10	5.878	6742741	635253	0.000		V		
11	6.677	14755441	1405633	0.000		V		
12	7.584	153826	29912	0.000				
13	7.716	809672	93010	0.000		V		
14	7.974	374120	40658	0.000		V		
15	9.190	58275	5889	0.000				
16	9.701	124417	10030	0.000				
17	13.905	34348	4017	0.000				
Total		628438731	17241571					

Analysis Date & Time : 1/9/2554 15:53:45
User Name : Admin
Vial# : 10
Sample Name : V4
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

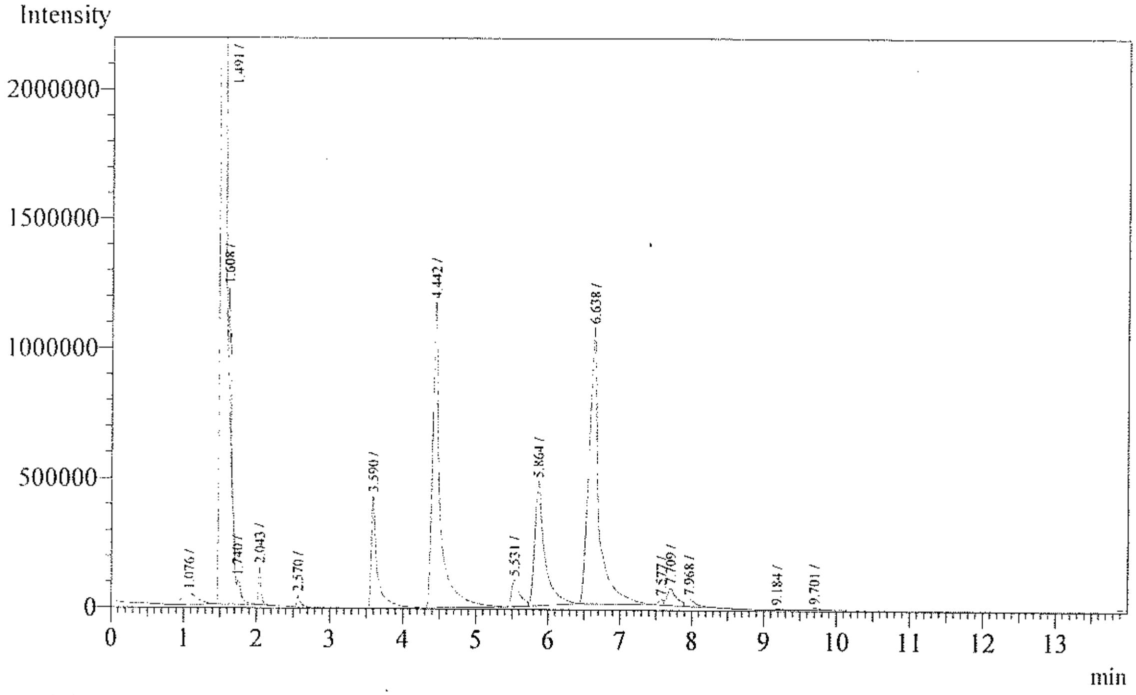
Data Name : D:\ACID\FA15.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.118	834487	56860	0.000				
2	1.491	751244786	15682587	0.000		S		
3	1.770	39792	23737	0.000		T		
4	2.044	418648	167024	0.000				
5	2.571	180125	52297	0.000				
6	3.592	3002671	488545	0.000				
7	4.440	8644818	1091568	0.000				
8	5.534	985087	115049	0.000				
9	5.870	5764547	537001	0.000		V		
10	6.656	12752248	1208153	0.000		V		
11	7.580	119892	24814	0.000				
12	7.713	699478	78449	0.000		V		
13	7.973	331695	34386	0.000		V		
14	9.194	47833	4834	0.000				
15	9.704	103746	8366	0.000				
Total		785169853	19573670					

Analysis Date & Time : 1/9/2554 16:09:23
User Name : Admin
Vial# : 11
Sample Name : V5
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

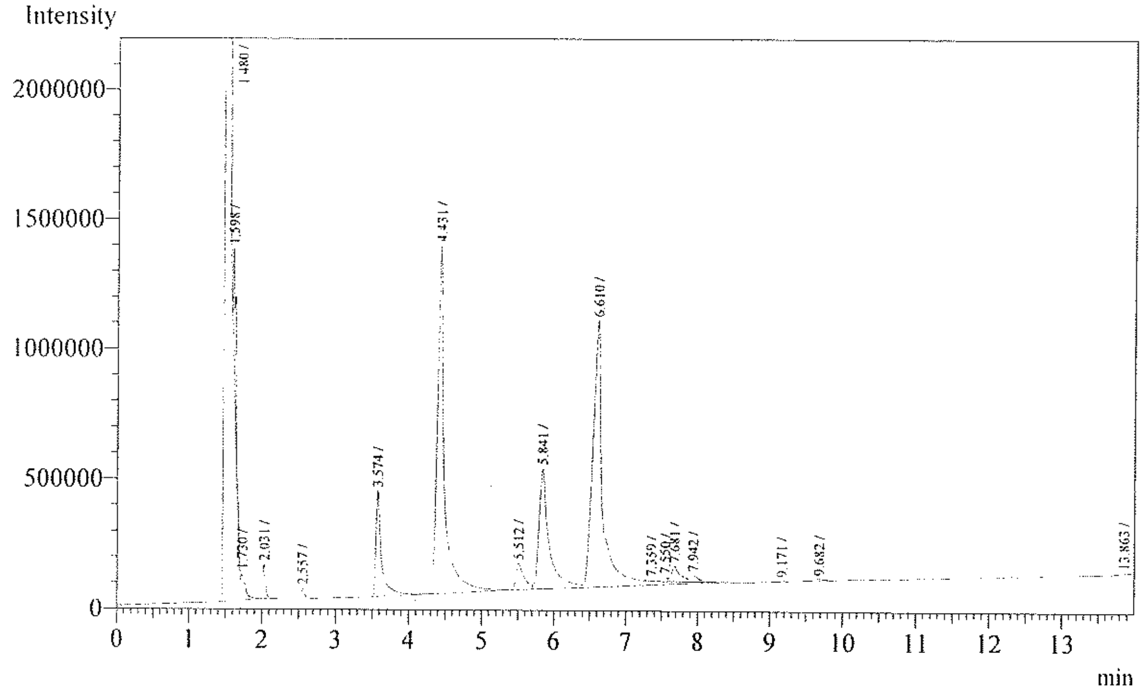
Data Name : D:\ACID\FA16.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.076	658986	44713	0.000				
2	1.491	763549187	12023594	0.000		S		
3	1.608	948597	334713	0.000		T		
4	1.740	78773	27078	0.000		T		
5	2.043	340859	145148	0.000				
6	2.570	151143	45991	0.000				
7	3.590	2512697	432665	0.000				
8	4.442	8751228	1174208	0.000				
9	5.531	826503	103726	0.000				
10	5.864	4627637	479398	0.000		V		
11	6.638	10460776	1062594	0.000				
12	7.577	108954	21925	0.000				
13	7.709	593665	67477	0.000		V		
14	7.968	282238	29156	0.000		V		
15	9.184	41616	4294	0.000				
16	9.701	90744	7409	0.000				
Total		794023603	16004089					

Analysis Date & Time	: 2/9/2554 8:41:51
User Name	: Admin
Vial#	: 1
Sample Name	: V6
Sample ID	: UNK-0001
Sample Type	: Unknown
Injection Volume	: 1.00
ISTD Amount	:

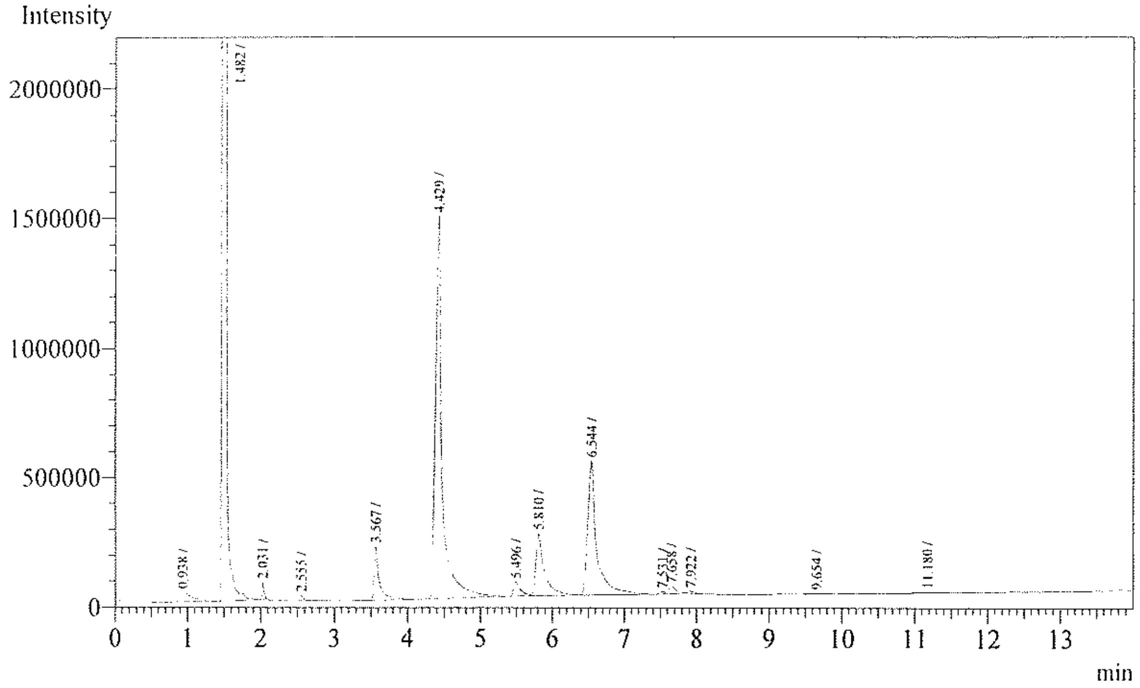
Data Name	: D:\ACID\FA17.gcd
Method Name	: D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.480	807876061	25900063	0.000		S		
2	1.598	1079572	376227	0.000		T		
3	1.730	86587	32873	0.000		T		
4	2.031	298382	131035	0.000				
5	2.557	131066	41477	0.000				
6	3.574	2174181	406088	0.000				
7	4.431	9241470	1338121	0.000		SV		
8	5.512	787235	100460	0.000				
9	5.841	4431740	462413	0.000		V		
10	6.610	10350049	1020608	0.000		SV		
11	7.359	40956	5388	0.000		T		
12	7.550	72334	16039	0.000		T		
13	7.681	496942	59116	0.000		TV		
14	7.942	233600	26396	0.000		TV		
15	9.171	31590	3718	0.000				
16	9.682	88878	6930	0.000				
17	13.863	38800	4018	0.000				
Total		837459443	29930970					

Analysis Date & Time : 2/9/2554 8:57:33
User Name : Admin
Vial# : 2
Sample Name : V7
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

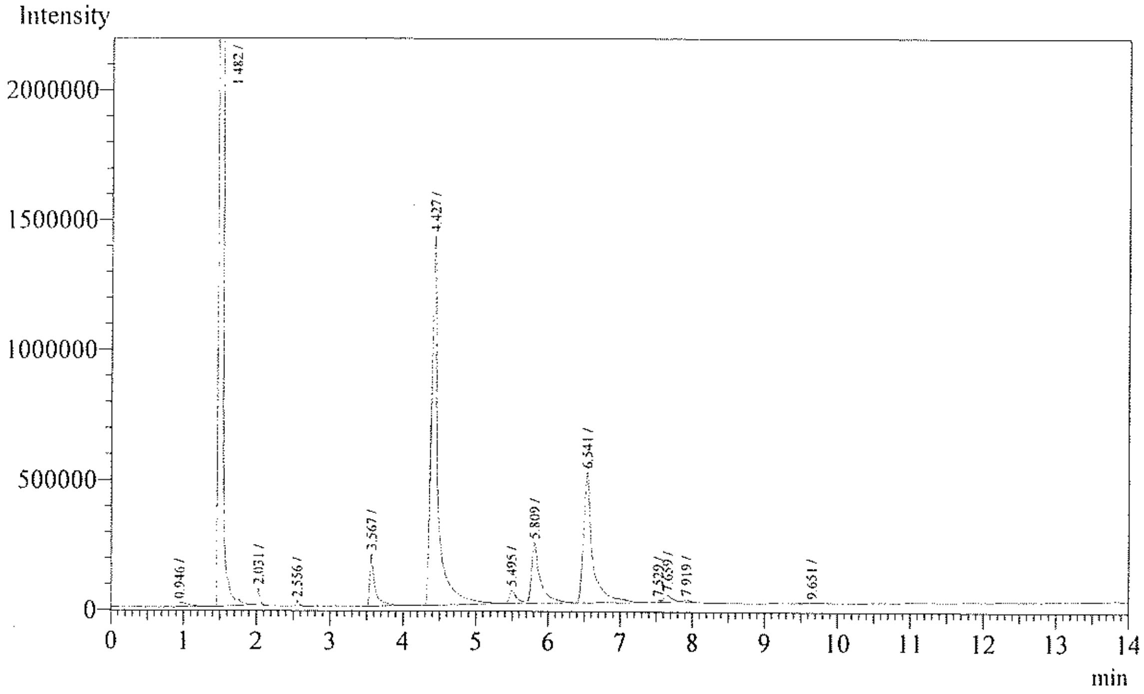
Data Name : D:\ACID\FA18.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.938	582914	36609	0.000				
2	1.482	823078986	62115642	0.000		S		
3	2.031	143298	65546	0.000				
4	2.555	63423	21486	0.000				
5	3.567	1059619	207032	0.000				
6	4.429	9522929	1468972	0.000				
7	5.496	369812	54287	0.000				
8	5.810	1974608	240421	0.000		V		
9	6.544	4473505	516564	0.000		S		
10	7.531	42620	9068	0.000				
11	7.658	196554	27385	0.000		V		
12	7.922	48172	8211	0.000				
13	9.654	35989	3196	0.000				
14	11.180	61871	2630	0.000				
Total		841654300	64777049					

Analysis Date & Time : 2/9/2554 9:13:11
User Name : Admin
Vial# : 3
Sample Name : V8
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

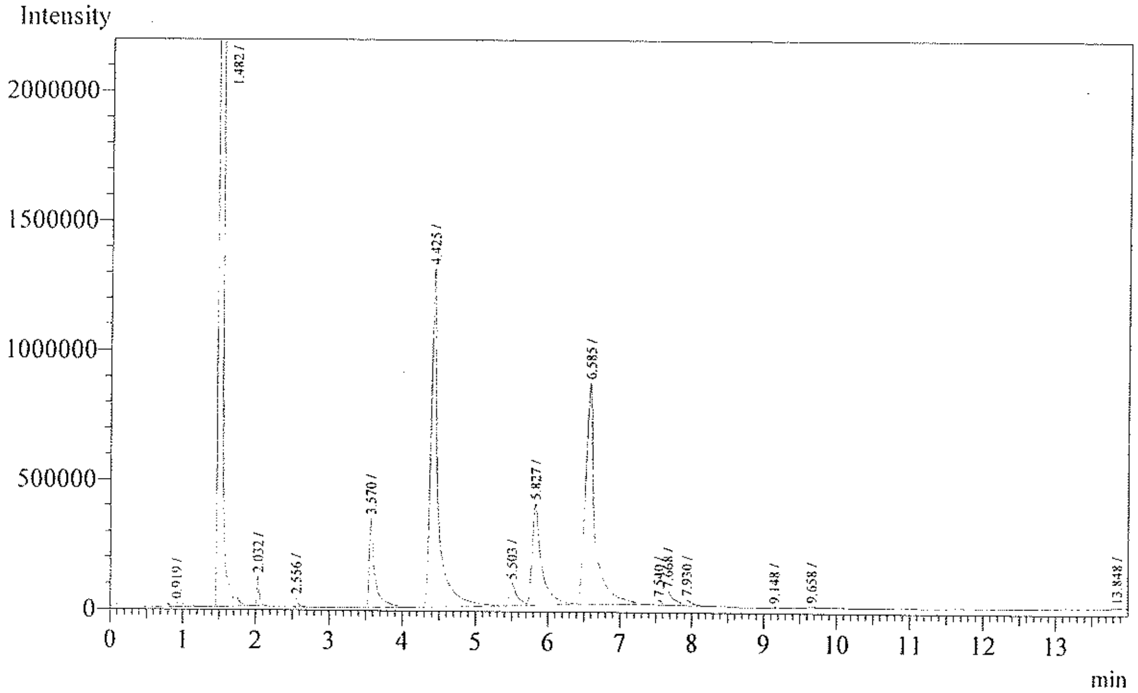
Data Name : D:\ACID\FA19.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.946	264560	17109	0.000				
2	1.482	815707373	58686107	0.000		S		
3	2.031	143156	64097	0.000				
4	2.556	63881	20923	0.000				
5	3.567	1058392	201153	0.000				
6	4.427	9375670	1420245	0.000				
7	5.495	365736	53037	0.000				
8	5.809	1963428	233365	0.000		V		
9	6.541	4444579	500494	0.000				
10	7.529	41267	8670	0.000				
11	7.659	192693	26467	0.000		V		
12	7.919	48617	8127	0.000				
13	9.651	40633	3341	0.000				
Total		833709985	61243135					

Analysis Date & Time : 2/9/2554 9:28:51
User Name : Admin
Vial# : 4
Sample Name : V9
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

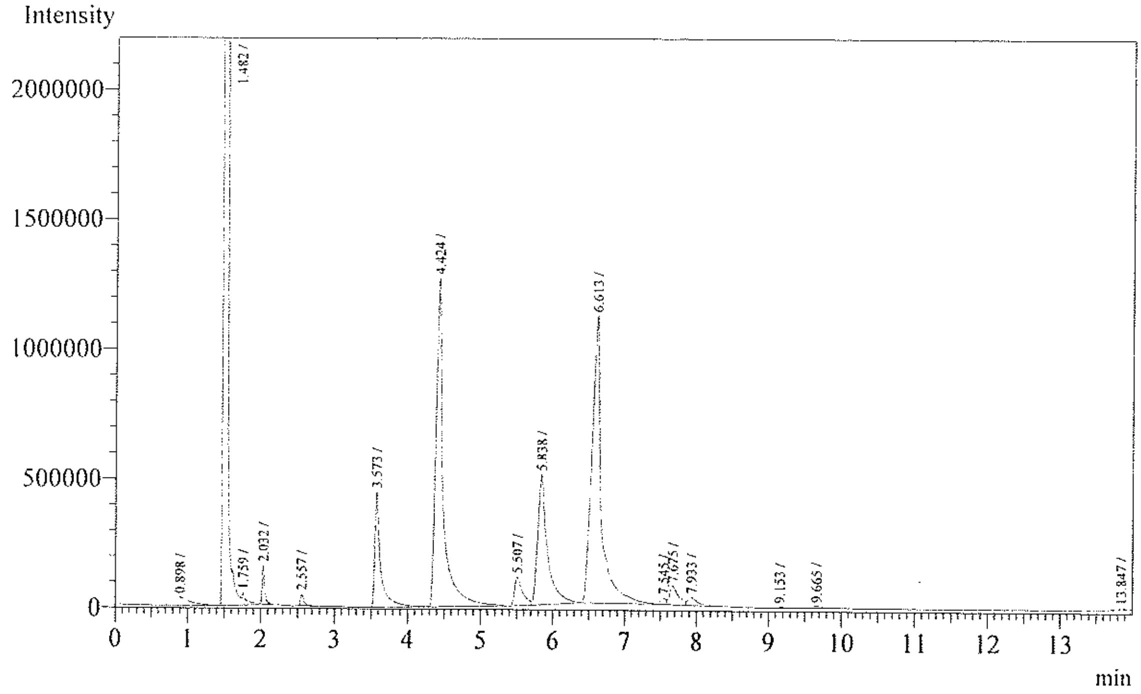
Data Name : D:\ACID\FA20.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.919	251857	16837	0.000		V		
2	1.482	794700543	45606724	0.000		S		
3	2.032	258421	111971	0.000				
4	2.556	115945	35929	0.000				
5	3.570	1916597	342898	0.000				
6	4.425	9191012	1300868	0.000				
7	5.503	647407	85901	0.000				
8	5.827	3554594	389702	0.000		V		
9	6.585	8023798	850775	0.000				
10	7.540	87048	17082	0.000				
11	7.668	461500	52327	0.000		V		
12	7.930	213478	22819	0.000		V		
13	9.148	33344	3471	0.000				
14	9.658	76865	5965	0.000				
15	13.848	35879	3709	0.000				
Total		819568288	48846978					

Analysis Date & Time : 2/9/2554 9:44:34
User Name : Admin
Vial# : 5
Sample Name : V10
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

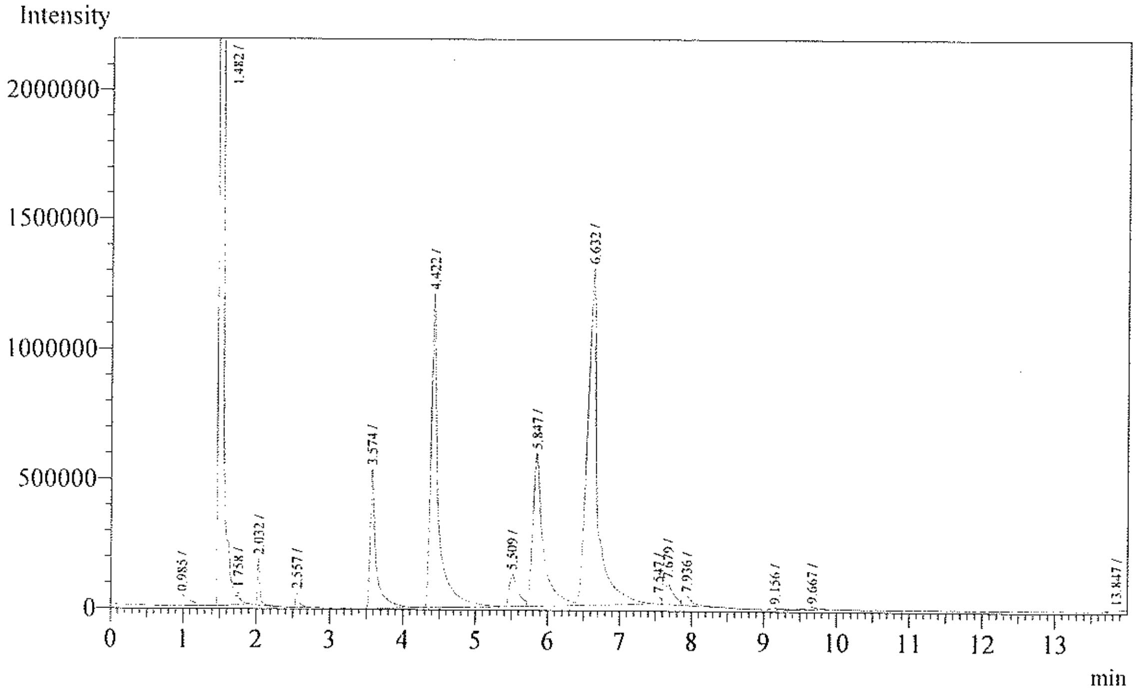
Data Name : D:\ACID\FA21.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.898	503733	31432	0.000				
2	1.482	775090651	34518552	0.000		S		
3	1.759	41921	23271	0.000		T		
4	2.032	344458	147569	0.000		T		
5	2.557	147036	46135	0.000				
6	3.573	2505055	445996	0.000				
7	4.424	9003537	1263453	0.000				
8	5.507	864179	109006	0.000				
9	5.838	4714263	501207	0.000		V		
10	6.613	10553278	1104342	0.000				
11	7.545	116922	23376	0.000				
12	7.675	615150	71459	0.000		V		
13	7.933	284038	30498	0.000		V		
14	9.153	42692	4427	0.000				
15	9.665	96394	7781	0.000				
16	13.847	47296	4738	0.000				
Total		804970603	38333242					

Analysis Date & Time : 2/9/2554 10:00:14
User Name : Admin
Vial# : 6
Sample Name : V11
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

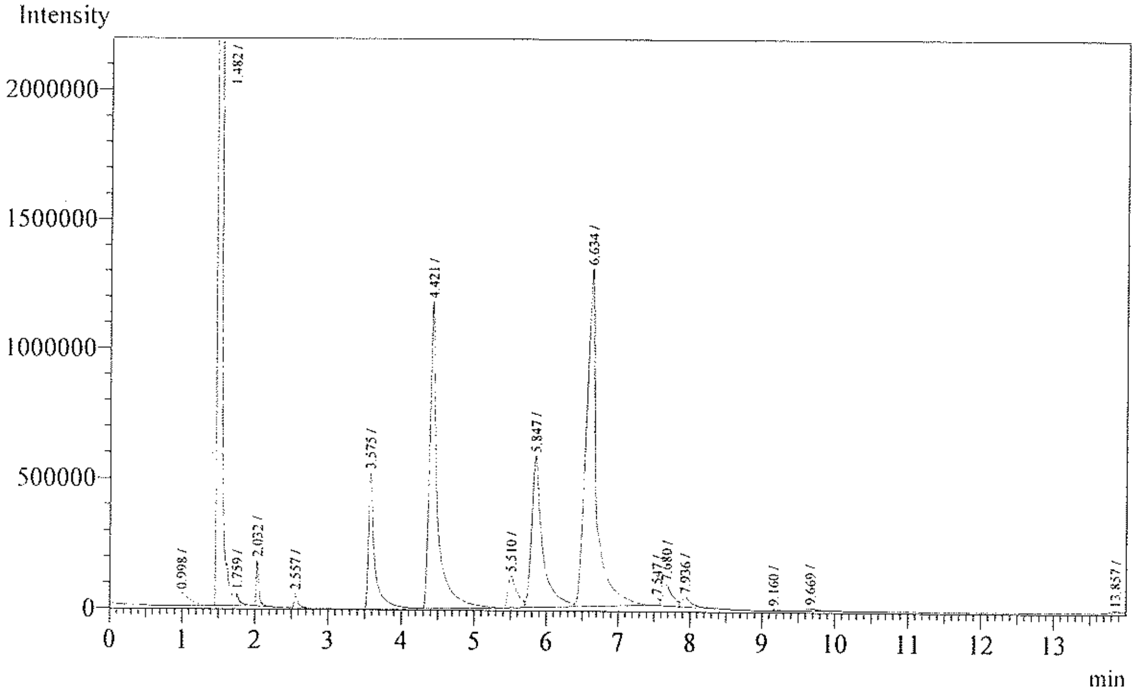
Data Name : D:\ACID\FA22.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.985	641881	41267	0.000				
2	1.482	778855885	31912655	0.000		S		
3	1.758	37119✓	24280	0.000		T		
4	2.032	425534	179539	0.000				
5	2.557	182959x	56763	0.000				
6	3.574	3051247	538105	0.000				
7	4.422	8767907	1207762	0.000				
8	5.509	1043446	127112	0.000				
9	5.847	5940350	589196	0.000		V		
10	6.632	13065941	1293021	0.000		V		
11	7.547	141777✓	27794	0.000				
12	7.679	724719	84988	0.000		V		
13	7.936	339700	36481	0.000		V		
14	9.156	51351✓	5416	0.000				
15	9.667	114769✓	9216	0.000				
16	13.847	52617✓	5236	0.000				
Total		813437202	36138831					

Analysis Date & Time : 2/9/2554 10:15:52
User Name : Admin
Vial# : 7
Sample Name : V12
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

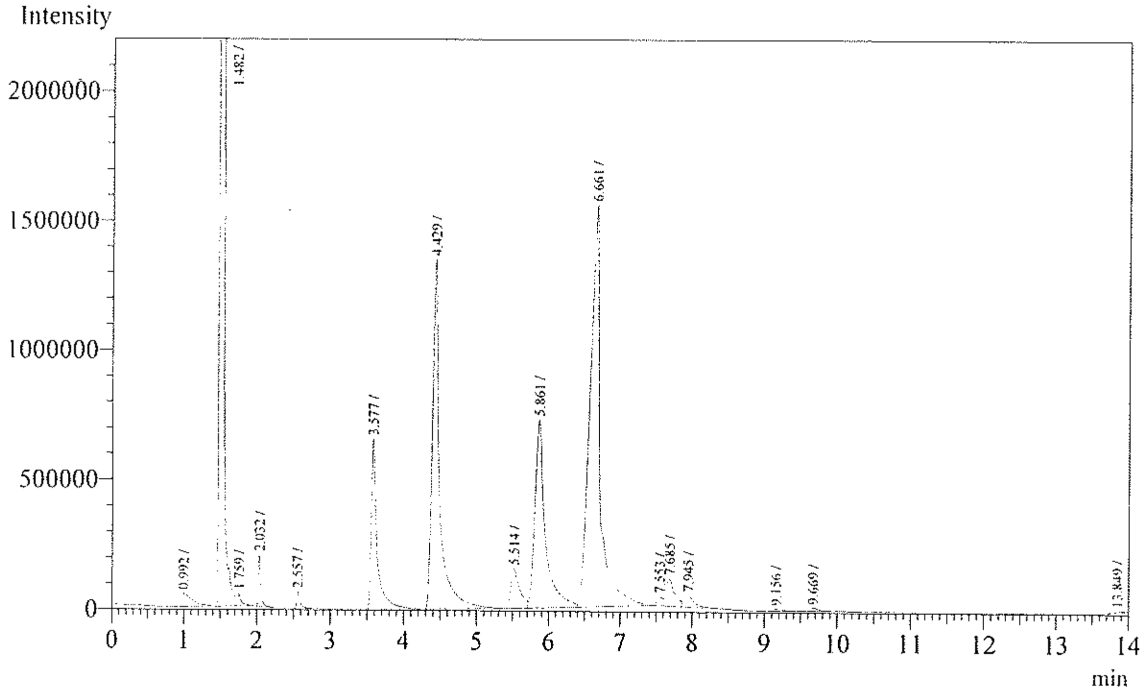
Data Name : D:\ACID\FA23.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.998	740471	49349	0.000				
2	1.482	769020908	28001060	0.000		S		
3	1.759	44081	25449	0.000		T		
4	2.032	426725	173918	0.000				
5	2.557	186805	54831	0.000				
6	3.575	3110629	520421	0.000				
7	4.421	8957065	1177747	0.000				
8	5.510	1066894	123658	0.000				
9	5.847	6111032	578277	0.000		V		
10	6.634	13397185	1296495	0.000		V		
11	7.547	131482	27102	0.000				
12	7.680	756157	83301	0.000		V		
13	7.936	347602	37140	0.000		V		
14	9.160	51204	5207	0.000				
15	9.669	111928	8937	0.000				
16	13.857	51247	4749	0.000				
Total		804511415	32167641					

Analysis Date & Time : 2/9/2554 10:31:32
User Name : Admin
Vial# : 8
Sample Name : V~~1~~3-43 [illegible]
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

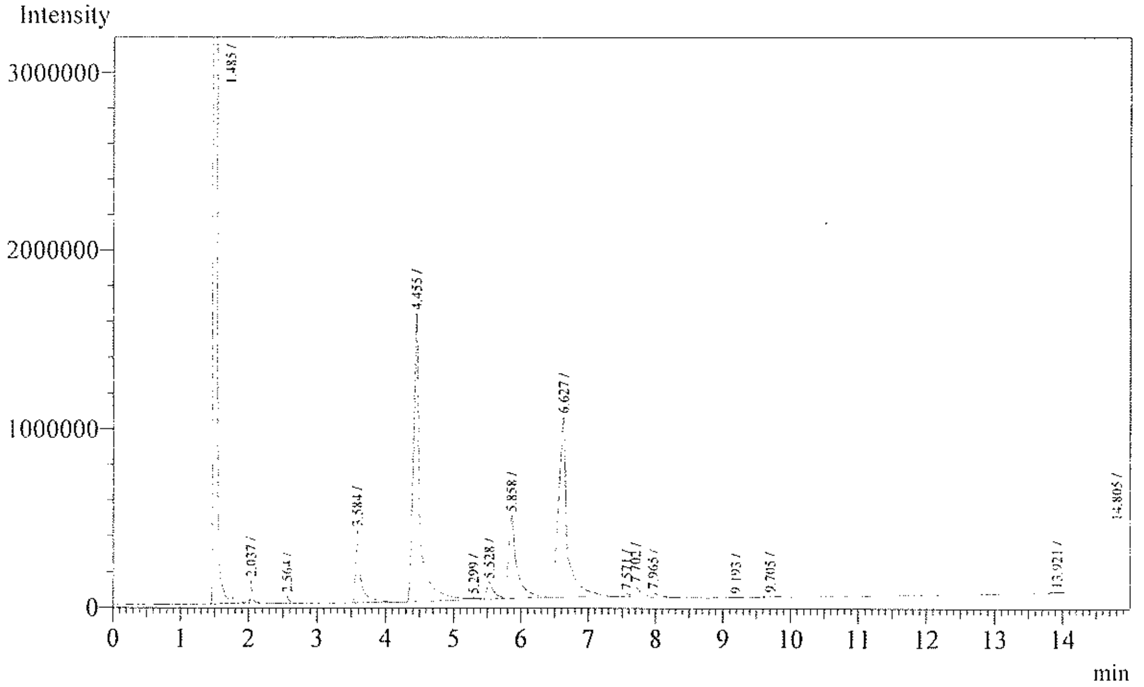
Data Name : D:\ACID\FA24.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.992	803239	50884	0.000				
2	1.482	766035028	26394323	0.000		S		
3	1.759	43534	26525	0.000		T		
4	2.032	457772	196869	0.000				
5	2.557	208610	65554	0.000				
6	3.577	3641444	655887	0.000				
7	4.429	9637229	1346411	0.000				
8	5.514	1299765	153412	0.000				
9	5.861	7296477	724496	0.000		V		
10	6.661	15787154	1544476	0.000		V		
11	7.553	174966	34957	0.000				
12	7.685	896170	106402	0.000		V		
13	7.945	417549	46169	0.000		V		
14	9.156	65497	6911	0.000				
15	9.669	136303	11805	0.000				
16	13.849	58925	5958	0.000				
Total		806959662	31371039					

Analysis Date & Time : 5/9/2554 9:32:32
User Name : Admin
Vial# : 1
Sample Name : 13
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

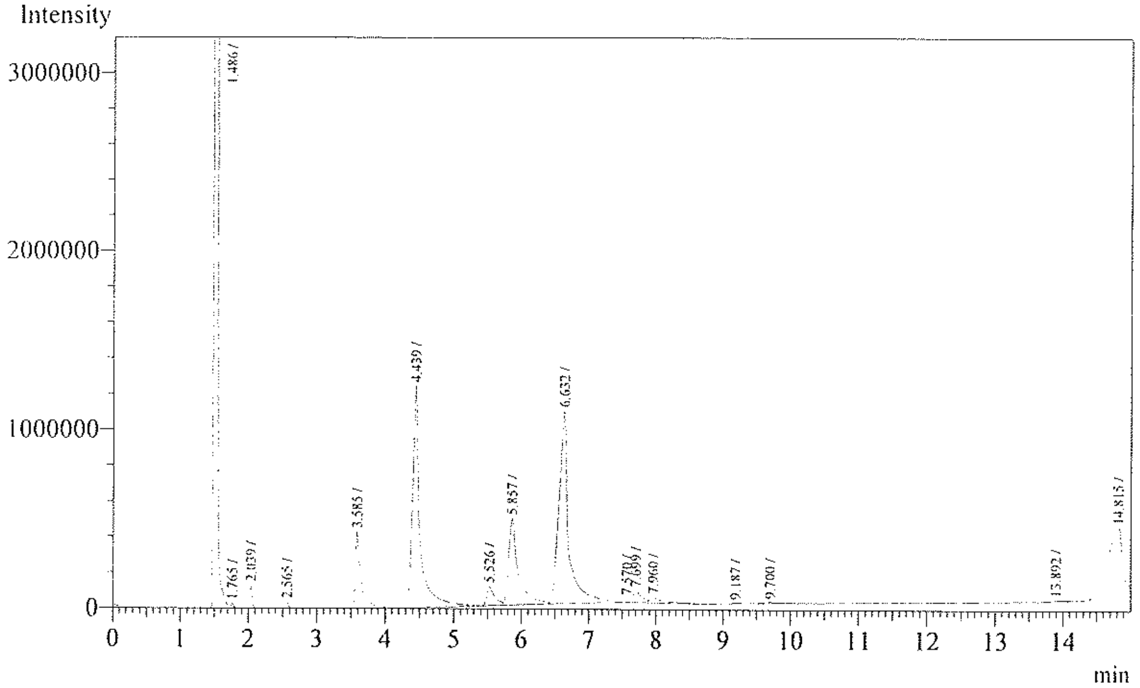
Data Name : D:\ACID\FA25.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.485	808865065	38861144	0.000		S		
2	2.037	279898	122936	0.000				
3	2.564	119279	38115	0.000				
4	3.584	2157508	404813	0.000				
5	4.455	11066020	1610375	0.000		S		
6	5.299	54193	6224	0.000		T		
7	5.528	675339	95098	0.000				
8	5.858	4047699	463321	0.000		V		
9	6.627	9208109	1005497	0.000				
10	7.571	95631	19432	0.000				
11	7.702	496853	59740	0.000		V		
12	7.965	229431	25003	0.000		V		
13	9.193	36979	3966	0.000				
14	9.705	79787	6613	0.000				
15	13.921	42839	3688	0.000				
16	14.805	4650104	326145	0.000				
Total		842104734	43052110					

Analysis Date & Time : 5/9/2554 9:49:13
User Name : Admin
Vial# : 2
Sample Name : 14
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

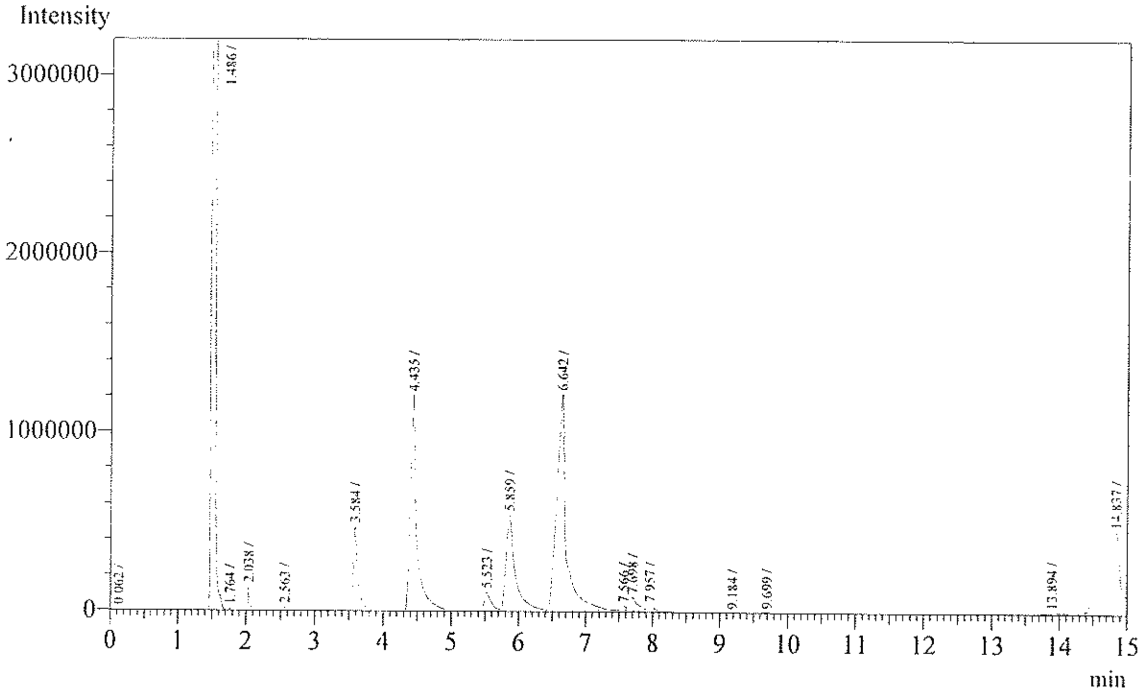
Data Name : D:\ACID\FA26.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.486	789003534	38283937	0.000		S		
2	1.765	32540	19211	0.000		T		
3	2.039	330629	136439	0.000				
4	2.565	145045	43261	0.000				
5	3.585	2431985	432471	0.000				
6	4.439	9328465	1239039	0.000				
7	5.526	847144	105089	0.000				
8	5.857	4909436	483958	0.000		V		
9	6.632	10821449	1076501	0.000		V		
10	7.570	106154	21565	0.000				
11	7.699	595255	66540	0.000		V		
12	7.960	362995	30463	0.000		V		
13	9.187	41804	4454	0.000				
14	9.700	89613	7168	0.000				
15	13.892	77217	5543	0.000				
16	14.815	5232209	344353	0.000				
Total		824355474	42299992					

Analysis Date & Time : 5/9/2554 10:05:51
User Name : Admin
Vial# : 3
Sample Name : 15
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

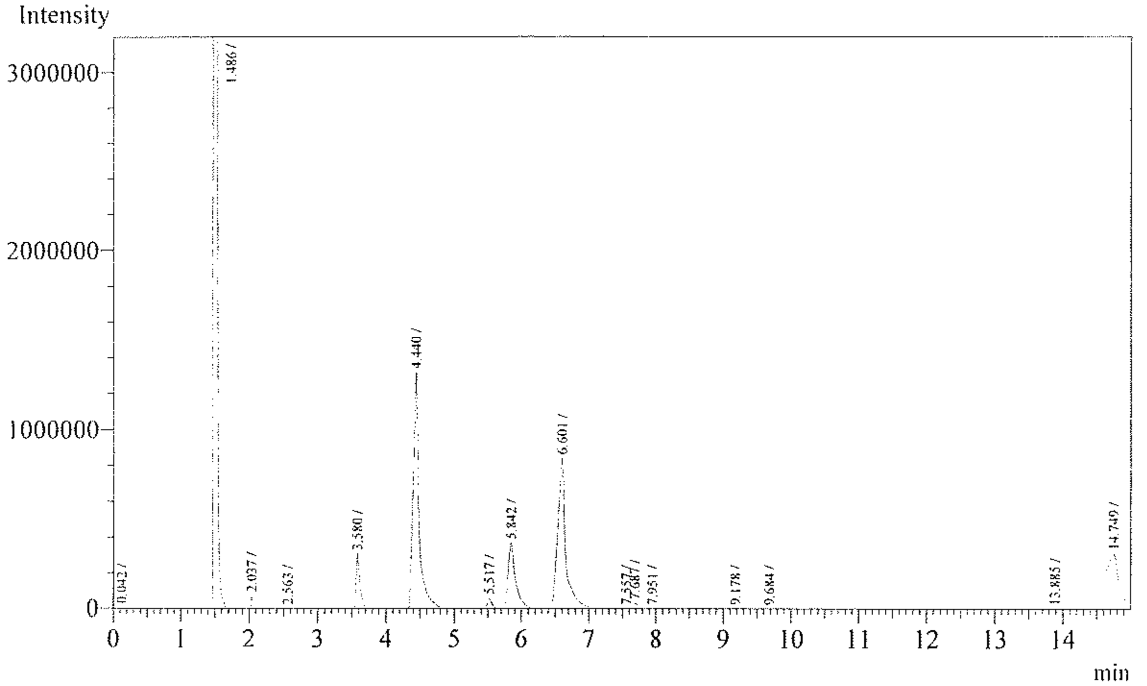
Data Name : D:\ACID\FA27.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.062	91484	11740	0.000				
2	1.486	791421353	36170187	0.000		S		
3	1.764	39908	23501	0.000		T		
4	2.038	386229	161169	0.000				
5	2.563	166141	50115	0.000				
6	3.584	2888751	501172	0.000				
7	4.435	9117037	1225680	0.000				
8	5.523	955115	118795	0.000				
9	5.859	5555368	548465	0.000		V		
10	6.642	12222130	1211923	0.000		V		
11	7.566	123233	24714	0.000				
12	7.698	657819	76344	0.000		V		
13	7.957	306860	32645	0.000		V		
14	9.184	47294	5021	0.000				
15	9.699	105114	8246	0.000				
16	13.894	107093	6894	0.000				
17	14.837	5862047	378300	0.000				
Total		830052976	40554911					

Analysis Date & Time : 5/9/2554 10:22:29
User Name : Admin
Vial# : 4
Sample Name : 16
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

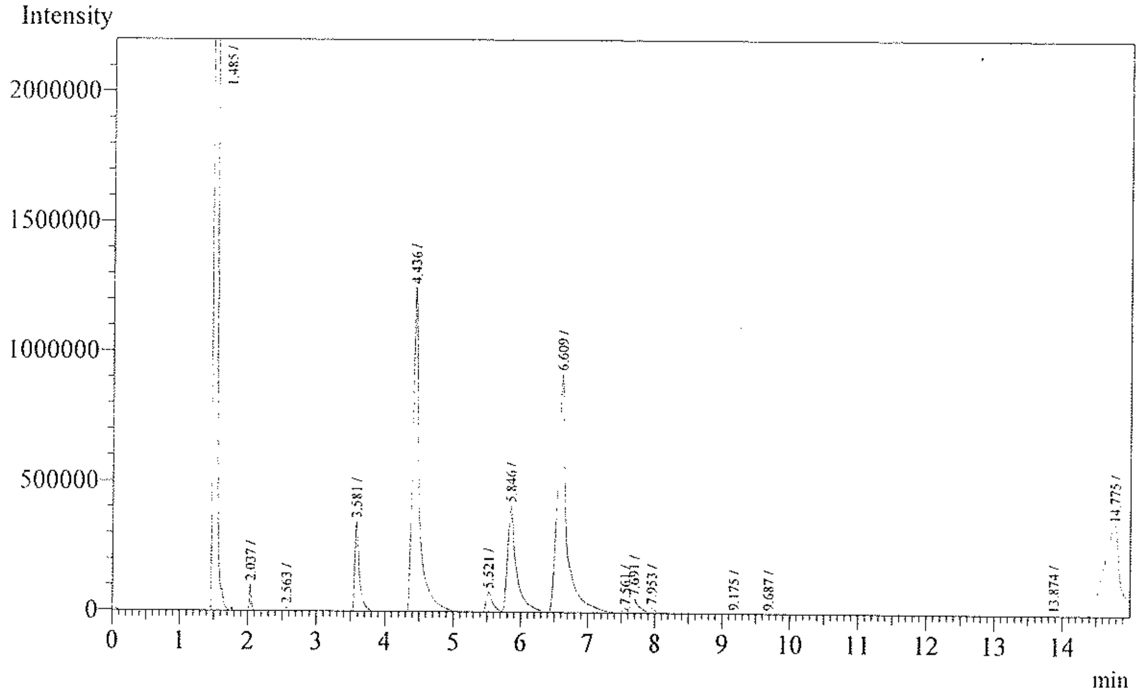
Data Name : D:\ACID\FA28.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.042	60942	9103	0.000				
2	1.486	793290315	36466811	0.000		S		
3	2.037	261780	110747	0.000				
4	2.563	116338	35345	0.000				
5	3.580	1925423	347721	0.000				
6	4.440	9572345	1354183	0.000				
7	5.517	645653	86451	0.000				
8	5.842	3564181	394219	0.000		V		
9	6.601	7957692	860847	0.000				
10	7.557	85365	17169	0.000				
11	7.687	454493	52064	0.000		V		
12	7.951	212763	22486	0.000		V		
13	9.178	33992	3499	0.000				
14	9.684	71702	5722	0.000				
15	13.885	74385	4999	0.000				
16	14.749	4251002	294733	0.000				
Total		822578371	40066099					

Analysis Date & Time : 5/9/2554 10:39:06
User Name : Admin
Vial# : 5
Sample Name : 17
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

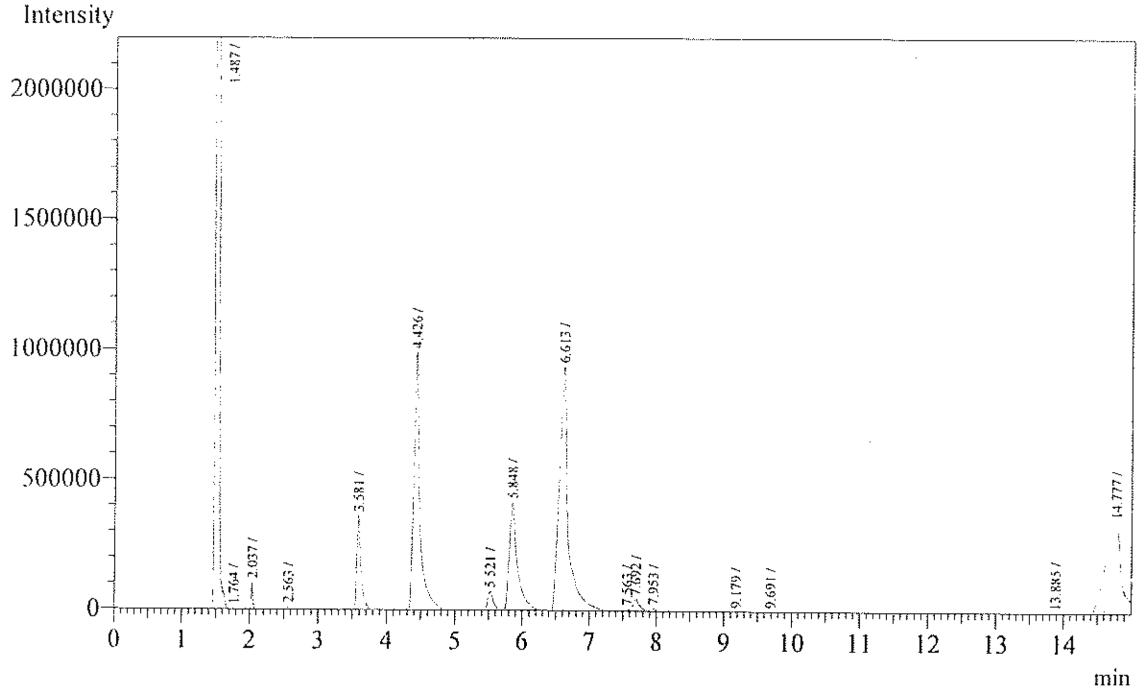
Data Name : D:\ACID\FA29.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.485	783484663	27663266	0.000		S		
2	2.037	291122	121100	0.000				
3	2.563	126520	38040	0.000				
4	3.581	2166644	367320	0.000				
5	4.436	9494778	1266735	0.000				
6	5.521	701312	89499	0.000				
7	5.846	3930507	414942	0.000		V		
8	6.609	8851680	912793	0.000				
9	7.561	90697	18463	0.000				
10	7.691	500882	56280	0.000		V		
11	7.953	232841	24412	0.000		V		
12	9.175	37564	3783	0.000				
13	9.687	87851	6675	0.000				
14	13.874	39319	3925	0.000				
15	14.775	4605705	307390	0.000				
Total		814642085	31294623					

Analysis Date & Time : 5/9/2554 10:55:47
User Name : Admin
Vial# : 6
Sample Name : 18
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

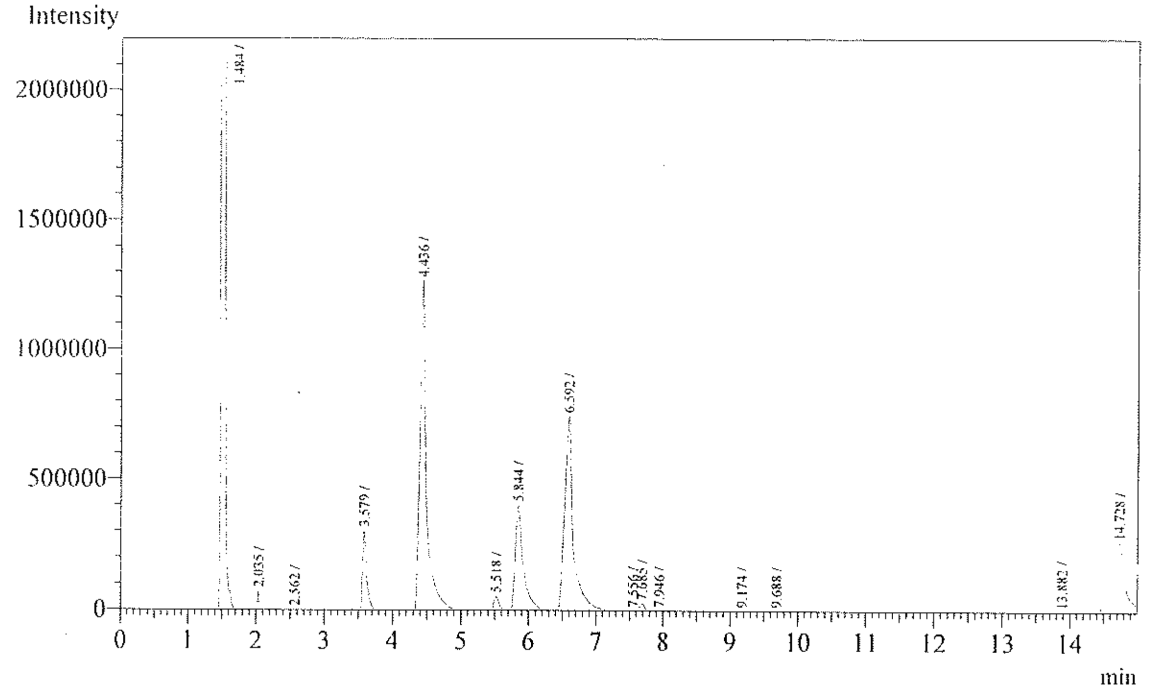
Data Name : D:\ACID\FA30.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.487	629458253	46635849	0.000		S		
2	1.764	31031	19095	0.000		T		
3	2.037	302426	131835	0.000				
4	2.563	133036	41113	0.000				
5	3.581	2201154	392598	0.000				
6	4.426	7307372	1016290	0.000				
7	5.521	720376	93496	0.000				
8	5.848	4033462	431330	0.000		V		
9	6.613	9083429	943935	0.000				
10	7.563	95097	19053	0.000				
11	7.692	509569	58748	0.000		V		
12	7.953	236438	25417	0.000		V		
13	9.179	37080	3806	0.000				
14	9.691	78472	6357	0.000				
15	13.885	86759	5626	0.000				
16	14.777	4797932	321326	0.000				
Total		659111886	50145874					

Analysis Date & Time : 5/9/2554 11:12:25
User Name : Admin
Vial# : 7
Sample Name : 19
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

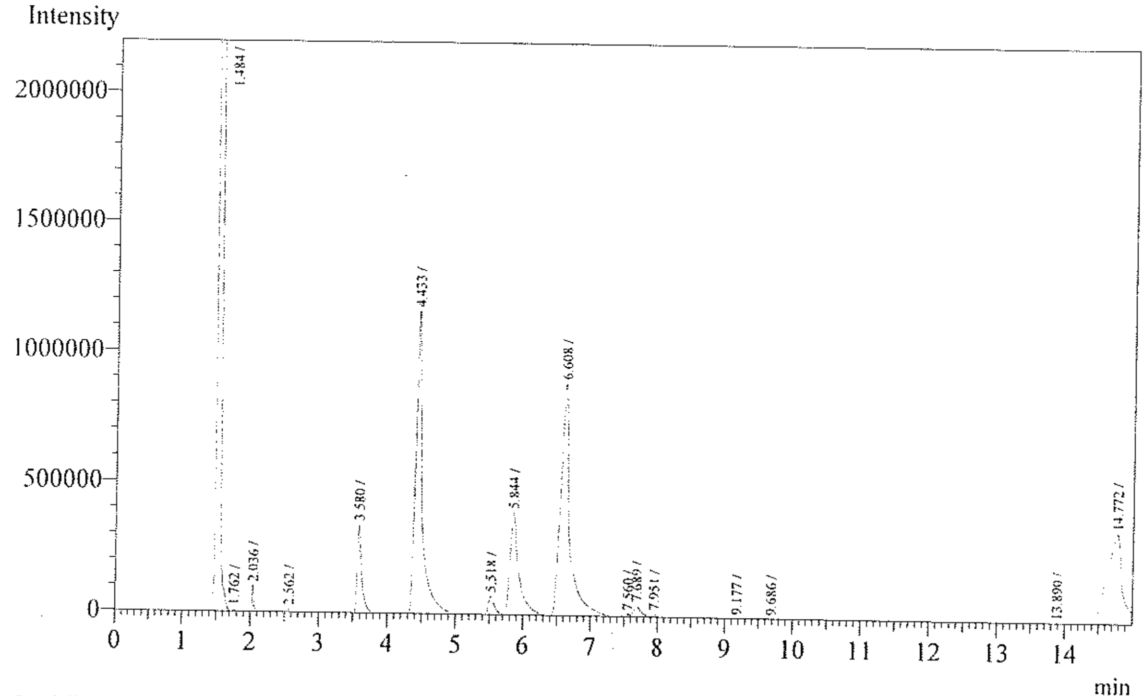
Data Name : D:\ACID\FA31.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.484	785007956	31229687	0.000		S		
2	2.035	243403	99897	0.000				
3	2.562	110109	33146	0.000				
4	3.579	1976203	337366	0.000				
5	4.436	9675558	1296898	0.000				
6	5.518	571286	75917	0.000				
7	5.844	3887148	420405	0.000		V		
8	6.592	7352721	756479	0.000				
9	7.556	59924	12442	0.000				
10	7.685	294360	40392	0.000		V		
11	7.946	72226	11989	0.000				
12	9.174	31251	3116	0.000				
13	9.688	63785	5089	0.000				
14	13.882	75771	4991	0.000				
15	14.728	3802878	257215	0.000				
Total		813224579	34585029					

Analysis Date & Time : 5/9/2554 11:29:09
User Name : Admin
Vial# : 8
Sample Name : 20
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

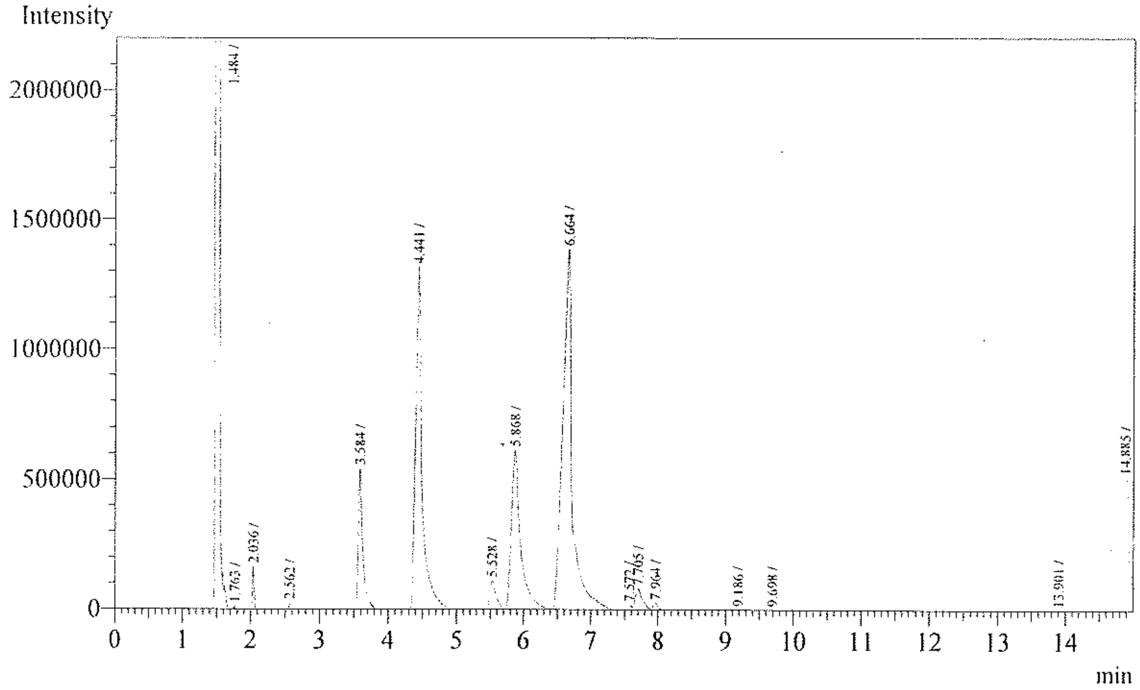
Data Name : D:\ACID\FA32.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.484	783619372	32098151	0.000		S		
2	1.762	30316	18198	0.000		T		
3	2.036	301357	122075	0.000				
4	2.562	128529	38549	0.000				
5	3.580	2181014	364937	0.000				
6	4.433	9161011	1186173	0.000				
7	5.518	694791	88206	0.000				
8	5.844	3954157	406030	0.000		V		
9	6.608	8999180	894617	0.000				
10	7.560	90882	17713	0.000				
11	7.689	491439	55795	0.000		V		
12	7.951	241169	24364	0.000		V		
13	9.177	33480	3477	0.000				
14	9.686	76601	6159	0.000				
15	13.890	85461	5383	0.000				
16	14.772	4624968	315135	0.000				
Total		814713727	35644962					

Analysis Date & Time : 5/9/2554 11:45:48
User Name : Admin
Vial# : 9
Sample Name : 21
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

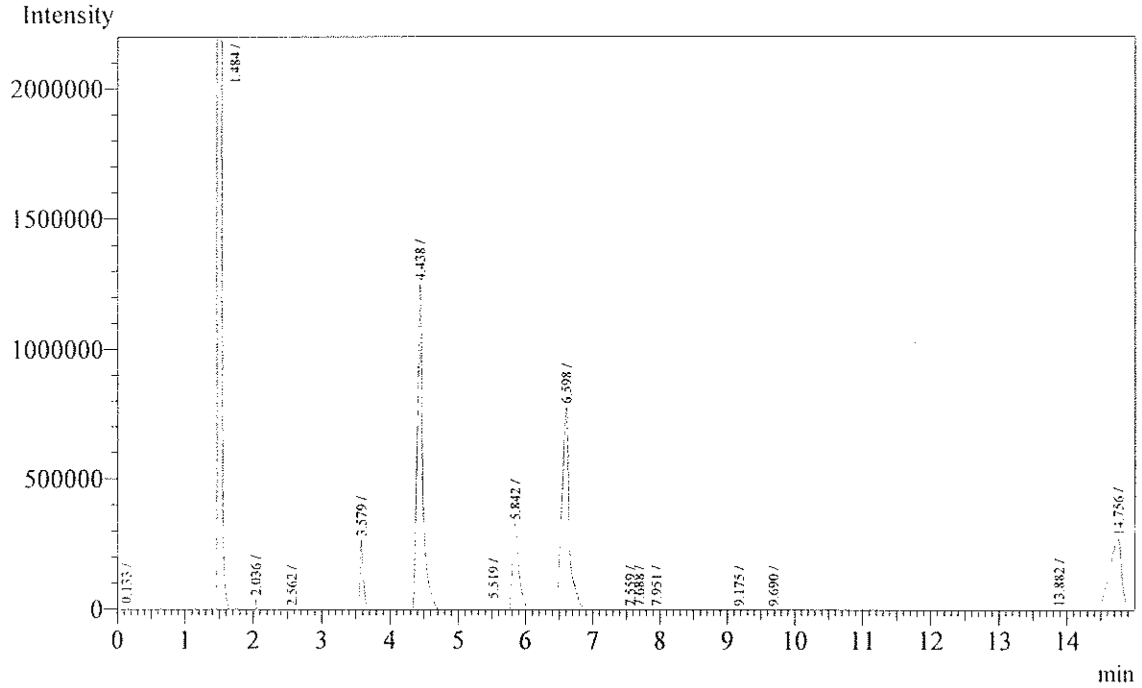
Data Name : D:\ACID\FA33.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.484	757242104	17344730	0.000		S		
2	1.763	50501	29267	0.000		T		
3	2.036	474992	193487	0.000				
4	2.562	205739	61278	0.000				
5	3.584	3477696	579444	0.000				
6	4.441	10334731	1349690	0.000				
7	5.528	1151999	136847	0.000				
8	5.868	6714366	638421	0.000		V		
9	6.664	14706042	1400387	0.000		V		
10	7.572	147979	29623	0.000				
11	7.705	804084	91877	0.000		V		
12	7.964	381802	40713	0.000		V		
13	9.186	56403	5778	0.000				
14	9.698	128041	10209	0.000				
15	13.901	155804	9445	0.000				
16	14.885	6854768	426727	0.000				
Total		802887051	22347923					

Analysis Date & Time : 5/9/2554 12:02:23
User Name : Admin
Vial# : 10
Sample Name : 22
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

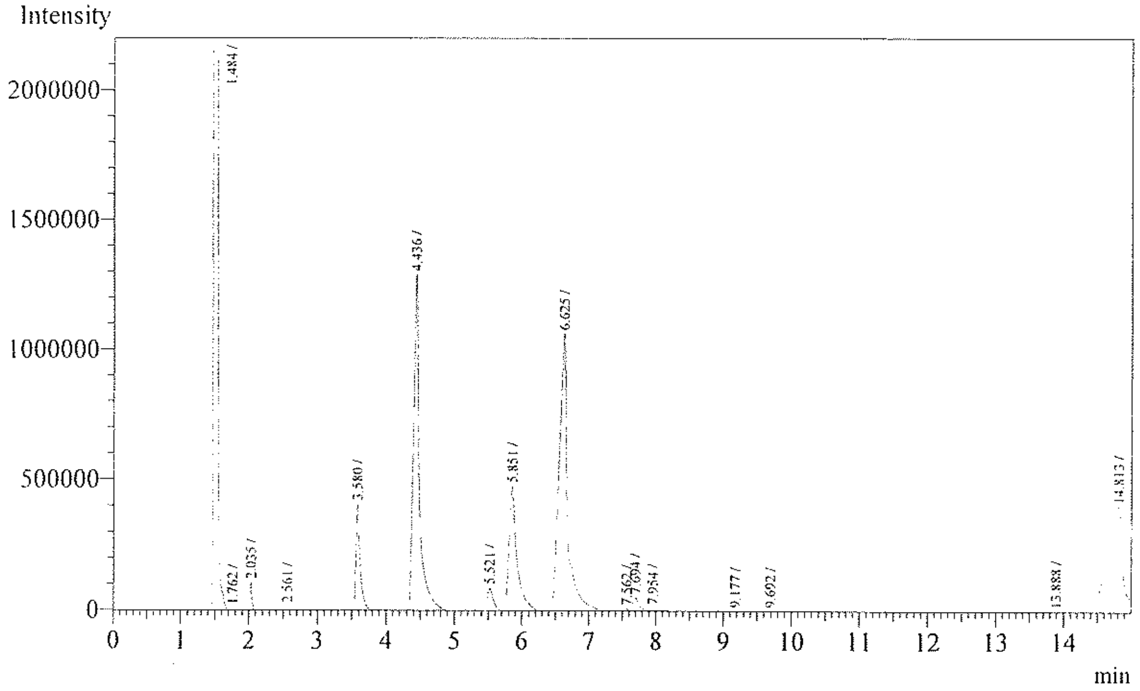
Data Name : D:\ACID\FA34.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.133	434280	41453	0.000				
2	1.484	785245331	39265909	0.000		S		
3	2.036	231329	97206	0.000				
4	2.562	106103	32593	0.000				
5	3.579	1859630	330411	0.000				
6	4.438	9320529	1313515	0.000				
7	5.519	639915	85165	0.000				
8	5.842	3489466	383584	0.000		V		
9	6.598	7780683	826184	0.000				
10	7.559	84007	16866	0.000				
11	7.688	443056	50022	0.000		V		
12	7.951	211614	22131	0.000		V		
13	9.175	34403	3469	0.000				
14	9.690	72590	5840	0.000				
15	13.882	83290	5226	0.000				
16	14.756	4351897	295435	0.000				
Total		814388123	42775009					

Analysis Date & Time : 5/9/2554 12:19:06
User Name : Admin
Vial# : 11
Sample Name : 23
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

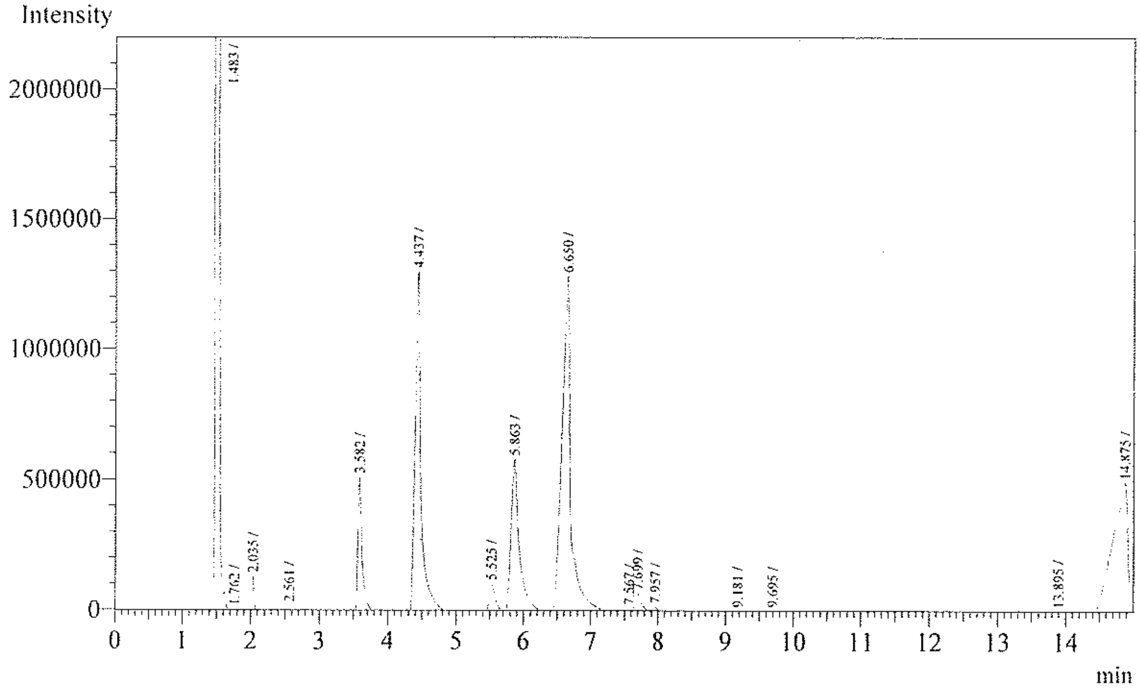
Data Name : D:\ACID\FA35.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.484	781333397	35397487	0.000		S		
2	1.762	30073	18146	0.000		T		
3	2.035	299842	128365	0.000				
4	2.561	137879	42972	0.000				
5	3.580	2370065	433758	0.000				
6	4.436	9080210	1315255	0.000				
7	5.521	824112	107535	0.000				
8	5.851	4493031	491616	0.000		V		
9	6.625	9956713	1071248	0.000				
10	7.562	110571	22194	0.000				
11	7.694	574603	66514	0.000		V		
12	7.954	262689	28648	0.000		V		
13	9.177	44466	4609	0.000				
14	9.692	90100	7445	0.000				
15	13.888	122336	7393	0.000				
16	14.813	5504549	369301	0.000				
Total		815234636	39512486					

Analysis Date & Time : 5/9/2554 12:35:51
User Name : Admin
Vial# : 12
Sample Name : 24
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

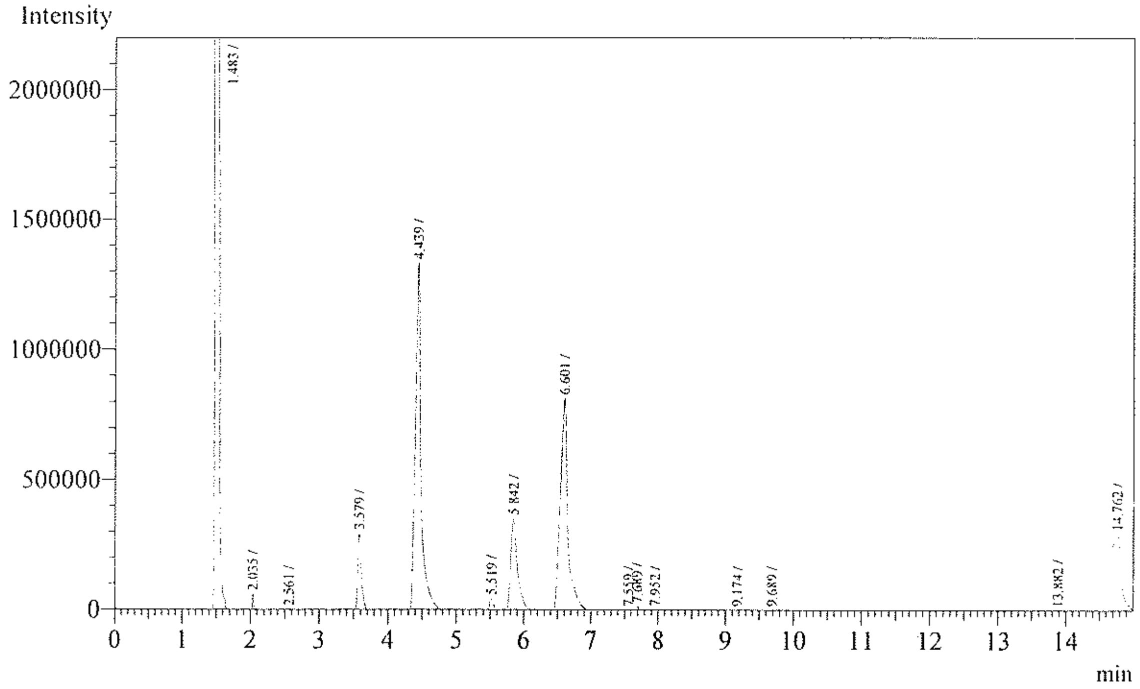
Data Name : D:\ACID\FA36.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.483	776667829	35264730	0.000		S		
2	1.762	38089	22926	0.000		T		
3	2.035	373587	161442	0.000				
4	2.561	169256	53790	0.000				
5	3.582	2961781	547331	0.000				
6	4.437	9252869	1331492	0.000				
7	5.525	1044438	131249	0.000				
8	5.863	5849050	605289	0.000		V		
9	6.650	12698515	1302284	0.000		V		
10	7.567	136696	27701	0.000				
11	7.699	708908	85263	0.000		V		
12	7.957	324948	36266	0.000		V		
13	9.181	56342	5974	0.000				
14	9.695	111826	9585	0.000				
15	13.895	132433	8225	0.000				
16	14.875	6761716	439263	0.000				
Total		817288283	40032810					

Analysis Date & Time : 5/9/2554 12:52:35
User Name : Admin
Vial# : 13
Sample Name : 25
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

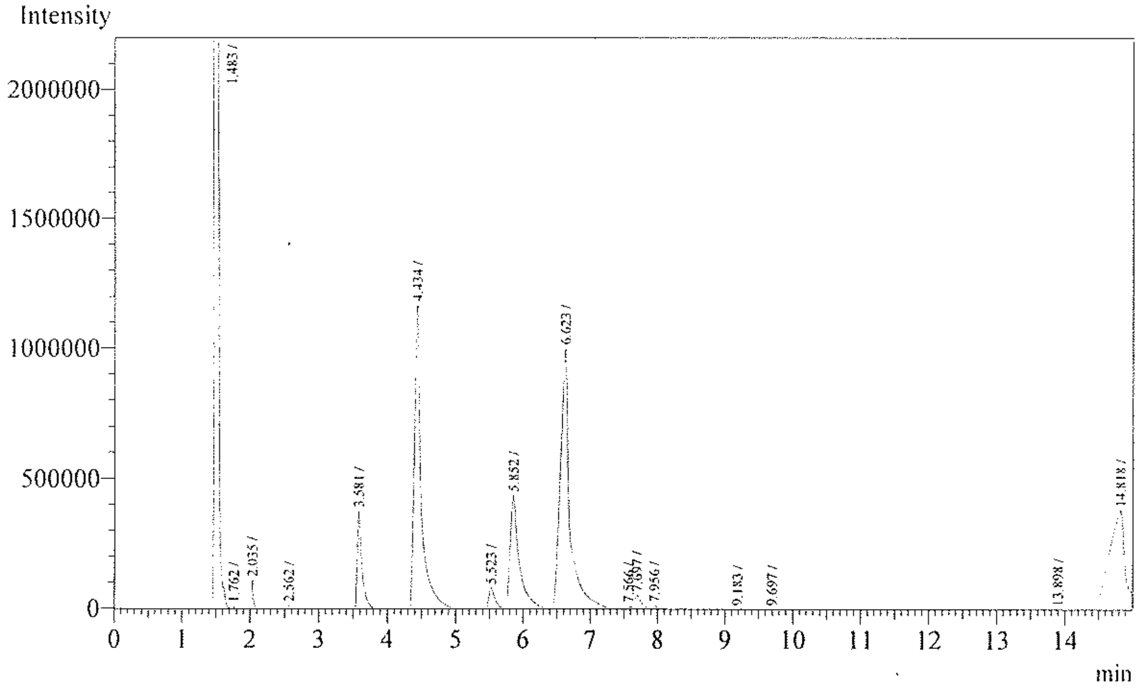
Data Name : D:\ACID\FA37.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.483	783250041	38765883	0.000		S		
2	2.035	242312	104432	0.000				
3	2.561	109544	34297	0.000				
4	3.579	1878776	344278	0.000				
5	4.439	9542325	1378186	0.000				
6	5.519	645991	86649	0.000				
7	5.842	3517679	391286	0.000		V		
8	6.601	7867269	849954	0.000				
9	7.559	85312	17413	0.000				
10	7.689	455152	52518	0.000		V		
11	7.952	213515	22764	0.000		V		
12	9.174	34236	3428	0.000				
13	9.689	73459	5928	0.000				
14	13.882	93625	6121	0.000				
15	14.762	4408860	304342	0.000				
Total		812418096	42367479					

Analysis Date & Time : 5/9/2554 13:09:18
User Name : Admin
Vial# : 14
Sample Name : 26
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

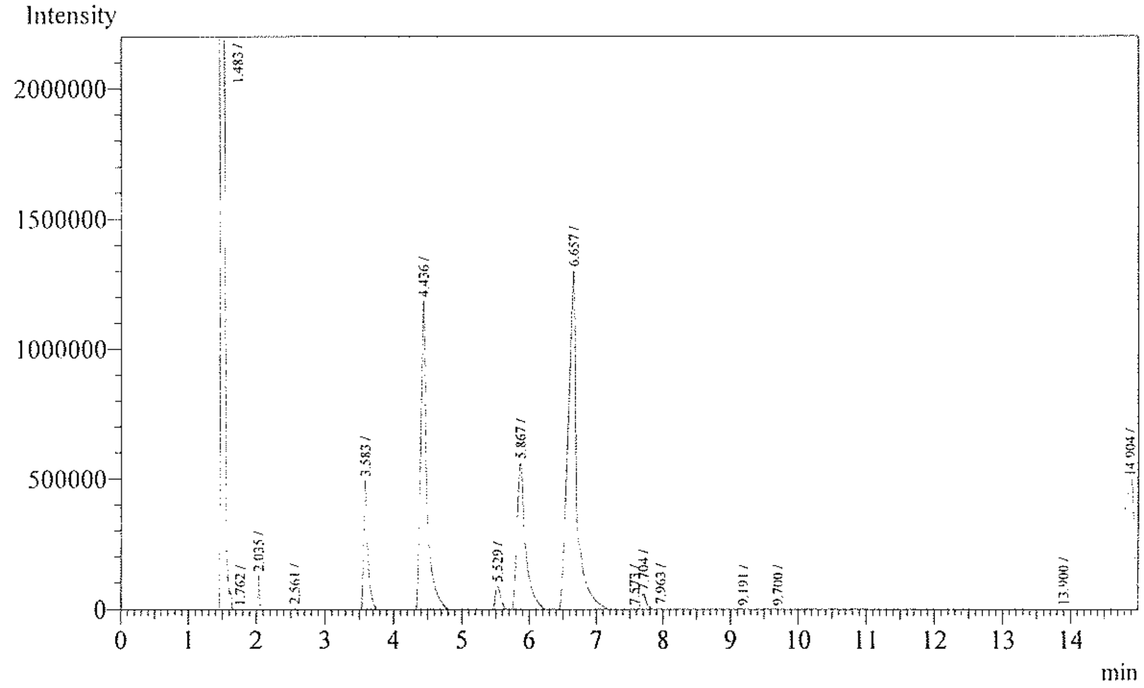
Data Name : D:\ACID\FA38.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.483	780108160	39326040	0.000		S		
2	1.762	32941	19493	0.000		T		
3	2.035	330157	131909	0.000				
4	2.562	144928	41750	0.000				
5	3.581	2499262	406098	0.000				
6	4.434	9420264	1192489	0.000				
7	5.523	803393	98637	0.000				
8	5.852	4761056	454669	0.000		V		
9	6.623	10520337	1011526	0.000		V		
10	7.566	99822	19827	0.000				
11	7.697	552962	62285	0.000		V		
12	7.956	264798	27127	0.000		V		
13	9.183	39275	3965	0.000				
14	9.697	87317	6835	0.000				
15	13.898	97953	6158	0.000				
16	14.818	5154184	338405	0.000				
Total		814916809	43147213					

Analysis Date & Time : 5/9/2554 13:26:02
User Name : Admin
Vial# : 15
Sample Name : 27
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

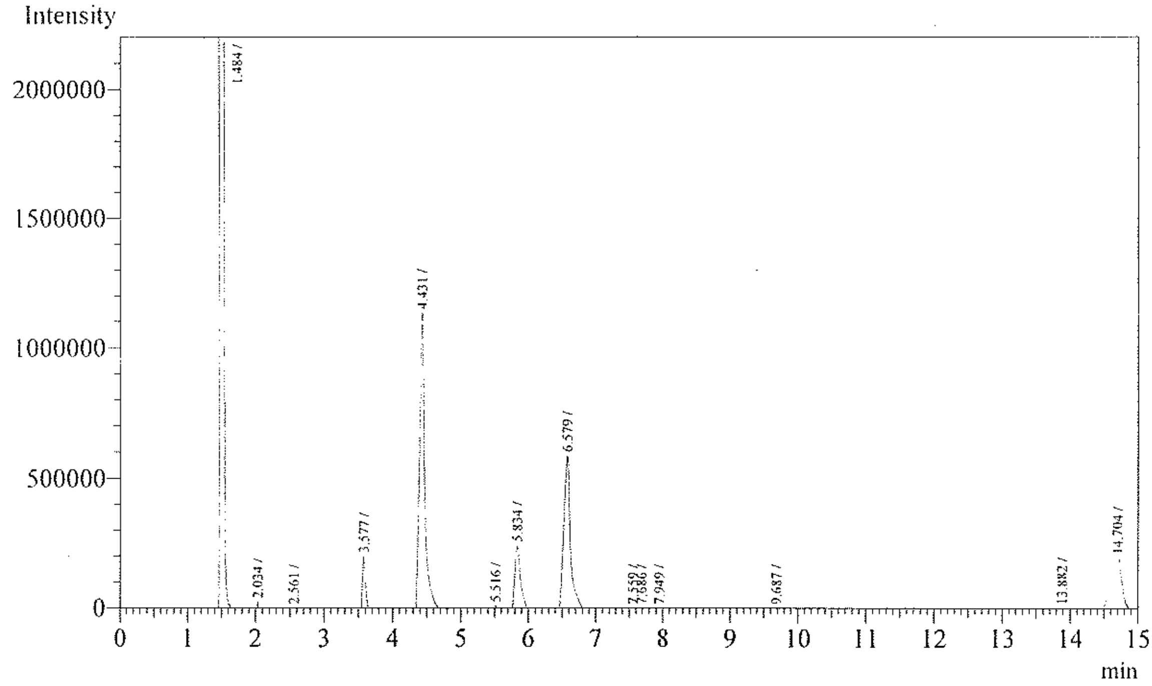
Data Name : D:\ACID\FA39.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.483	769941415	32744106	0.000		S		
2	1.762	44136	25758	0.000		T		
3	2.035	422219	173727	0.000				
4	2.561	186782	55765	0.000				
5	3.583	3218296	544408	0.000				
6	4.436	9284577	1231664	0.000				
7	5.529	1080503	129605	0.000				
8	5.867	6270147	599704	0.000		V		
9	6.657	13713762	1333301	0.000		V		
10	7.573	136795✓	27687	0.000				
11	7.704	744864	85819	0.000		V		
12	7.963	346109	36911	0.000		V		
13	9.191	52659✓	5597	0.000				
14	9.700	114616✓	9445	0.000				
15	13.900	126333✓	8025	0.000				
16	14.904	6569515	419282	0.000				
Total		812252728	37430804					

Analysis Date & Time : 5/9/2554 13:42:46
User Name : Admin
Vial# : 16
Sample Name : 28
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

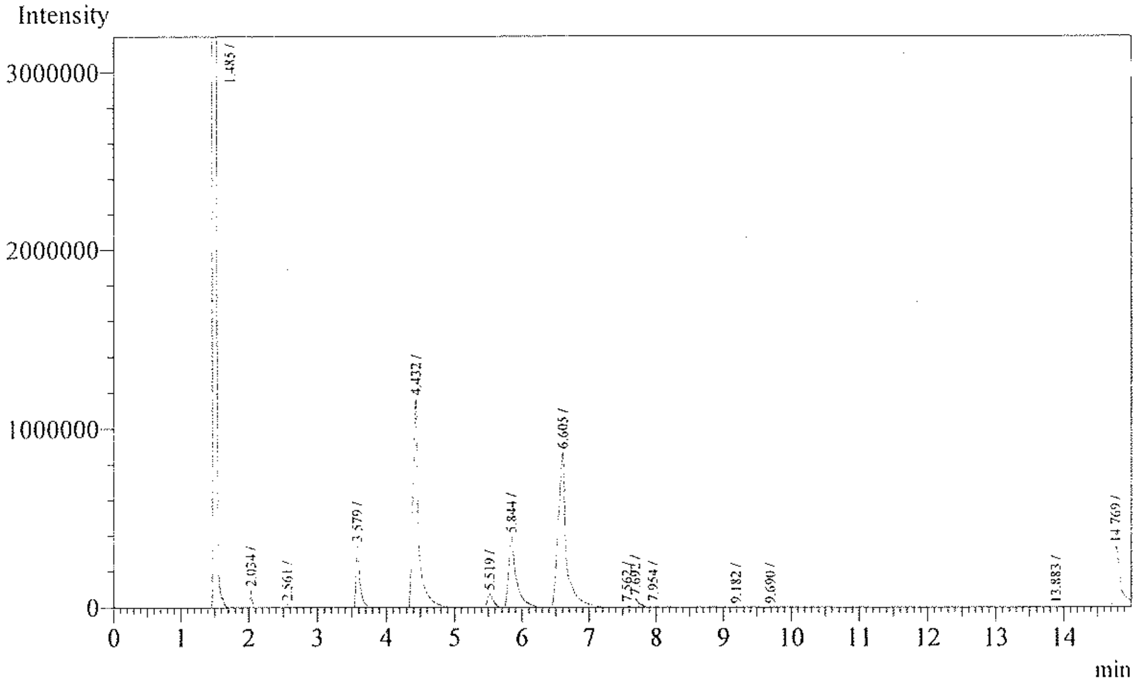
Data Name : D:\ACID\FA40.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.484	647429580	53868193	0.000		S		
2	2.034	181606	83424	0.000				
3	2.561	81988	27125	0.000				
4	3.577	1342392	262634	0.000				
5	4.431	7871761	1196297	0.000				
6	5.516	471007	66620	0.000				
7	5.834	2527719	297063	0.000		V		
8	6.579	5666320	640800	0.000				
9	7.559	52630	10992	0.000				
10	7.686	244567	34561	0.000		V		
11	7.949	62369	10458	0.000				
12	9.687	56168	4440	0.000				
13	13.882	55785	4128	0.000				
14	14.704	3285328	234887	0.000				
Total		669329220	56741622					

Analysis Date & Time : 5/9/2554 13:59:26
User Name : Admin
Vial# : 17
Sample Name : 29
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

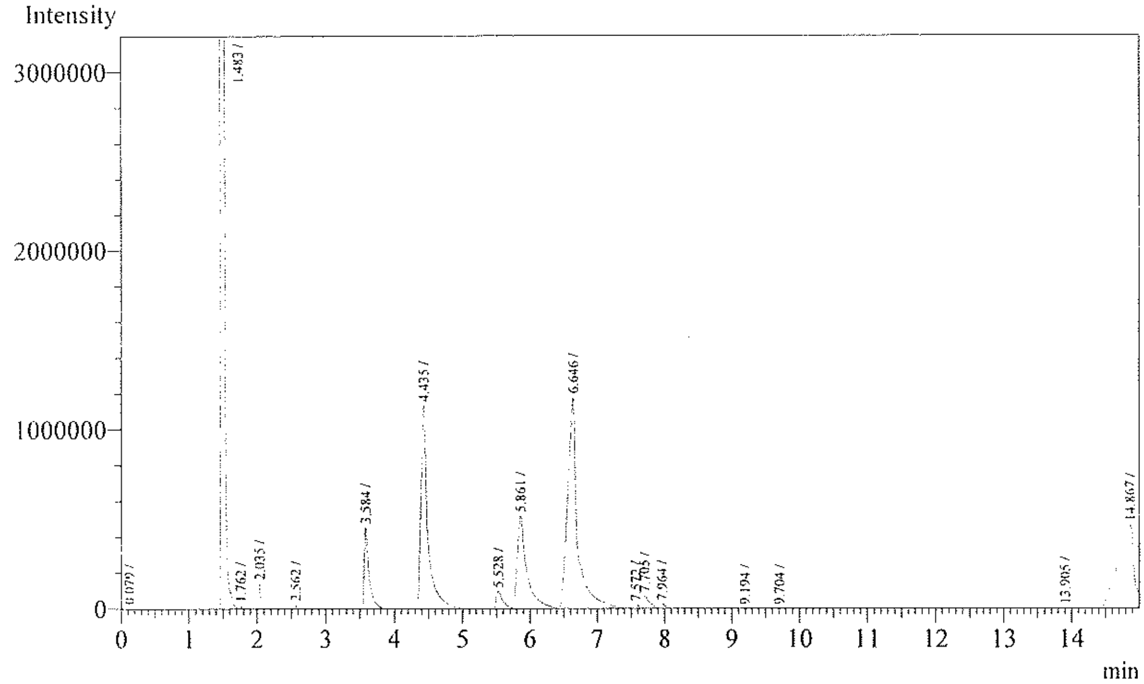
Data Name : D:\ACID\FA41.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.485	638618854	40842799	0.000		S		
2	2.034	249672	114800	0.000				
3	2.561	111801	37663	0.000				
4	3.579	1847924	365193	0.000				
5	4.432	7675499	1185200	0.000				
6	5.519	647015	90389	0.000				
7	5.844	3473048	406862	0.000		V		
8	6.605	7741824	872500	0.000				
9	7.562	90106	18330	0.000				
10	7.692	452702	54508	0.000		V		
11	7.954	203990	23078	0.000		V		
12	9.182	33791	3605	0.000				
13	9.690	68423	5844	0.000				
14	13.883	85182	5803	0.000				
15	14.769	4475819	315785	0.000				
Total		665775650	44342359					

Analysis Date & Time : 5/9/2554 14:16:03
User Name : Admin
Vial# : 18
Sample Name : 30
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

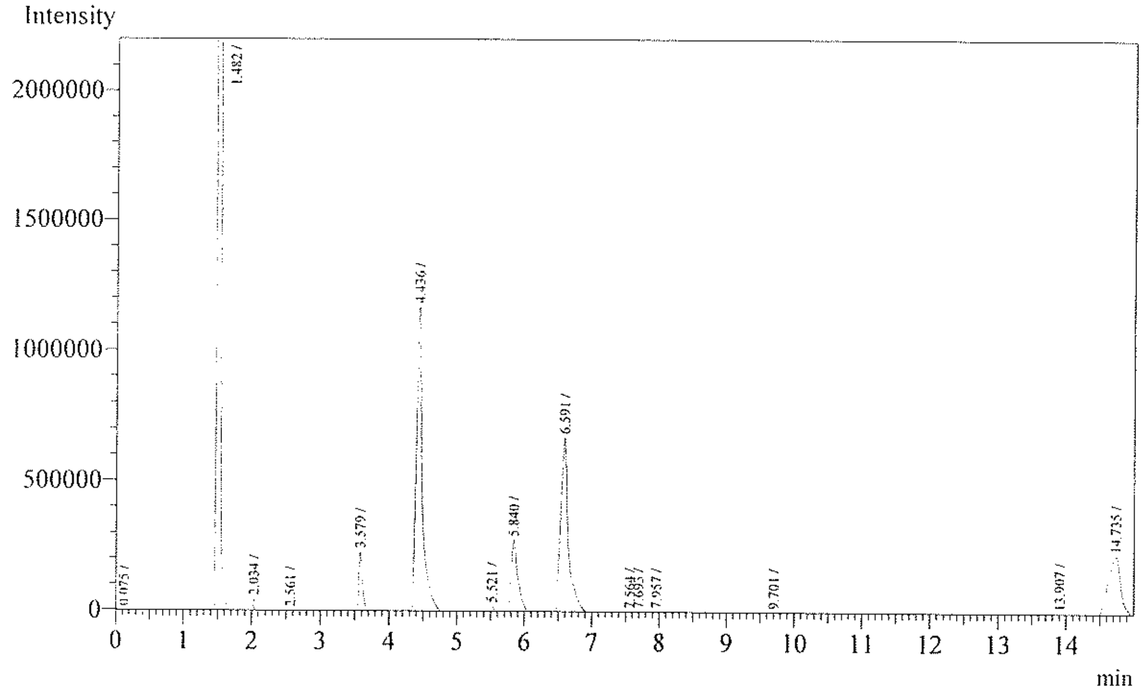
Data Name : D:\ACID\FA42.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.079	95461	11852	0.000				
2	1.483	767642416	29662945	0.000		S		
3	1.762	41870	24722	0.000		T		
4	2.035	400888	163027	0.000				
5	2.562	175269	51186	0.000				
6	3.584	2948156	482965	0.000				
7	4.435	9067910	1159082	0.000				
8	5.528	957024	114387	0.000				
9	5.861	5651386	532354	0.000		V		
10	6.646	12458740	1185643	0.000		V		
11	7.572	117586	23922	0.000				
12	7.705	666317	75154	0.000		V		
13	7.964	319847	33187	0.000		V		
14	9.194	45025	4841	0.000				
15	9.704	101659	8084	0.000				
16	13.905	115549	7029	0.000				
17	14.867	5859031	385880	0.000				
Total		806664134	33926260					

Analysis Date & Time : 5/9/2554 14:32:41
User Name : Admin
Vial# : 19
Sample Name : 31
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

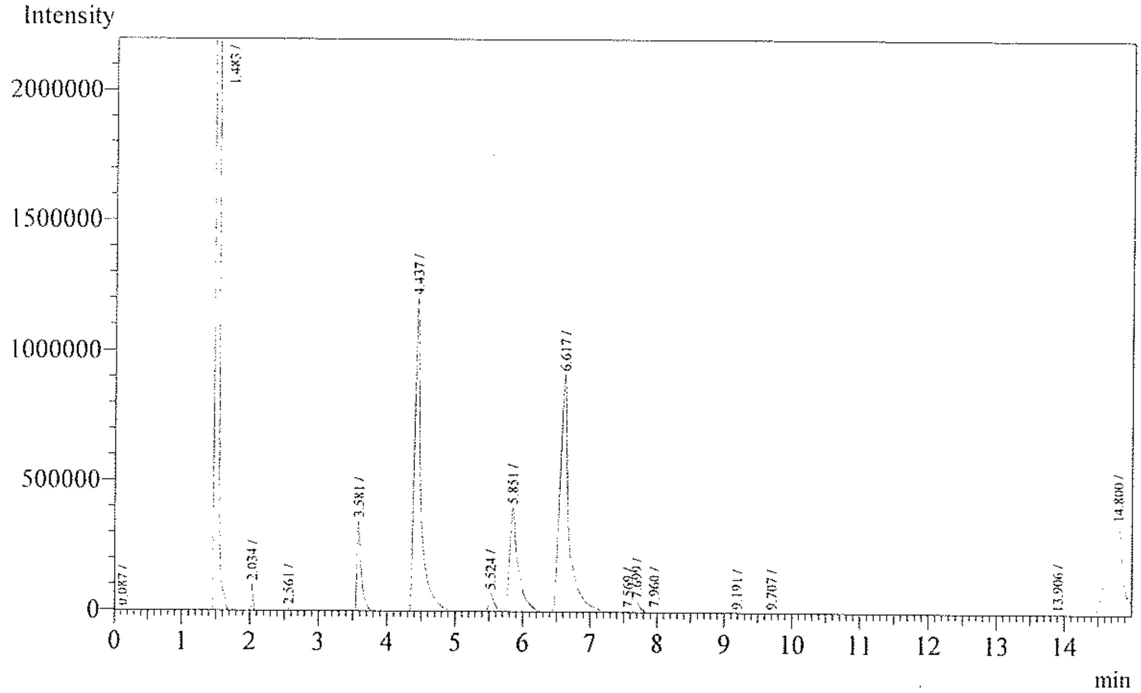
Data Name : D:\ACID\FA43.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.075	113317	15076	0.000				
2	1.482	785250733	42271162	0.000		S		
3	2.034	230265	97105	0.000				
4	2.561	103982	30792	0.000				
5	3.579	1724330	288354	0.000				
6	4.436	9329262	1225674	0.000				
7	5.521	540807	70778	0.000				
8	5.840	3101264	325057	0.000		V		
9	6.591	7070826	714544	0.000				
10	7.564	57031	11966	0.000				
11	7.693	281904	37894	0.000		V		
12	7.957	68518	11097	0.000				
13	9.701	84672	5001	0.000				
14	13.907	80051	5070	0.000				
15	14.735	3629084	248140	0.000				
Total		811666046	45357710					

Analysis Date & Time : 5/9/2554 14:49:18
User Name : Admin
Vial# : 20
Sample Name : 32
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

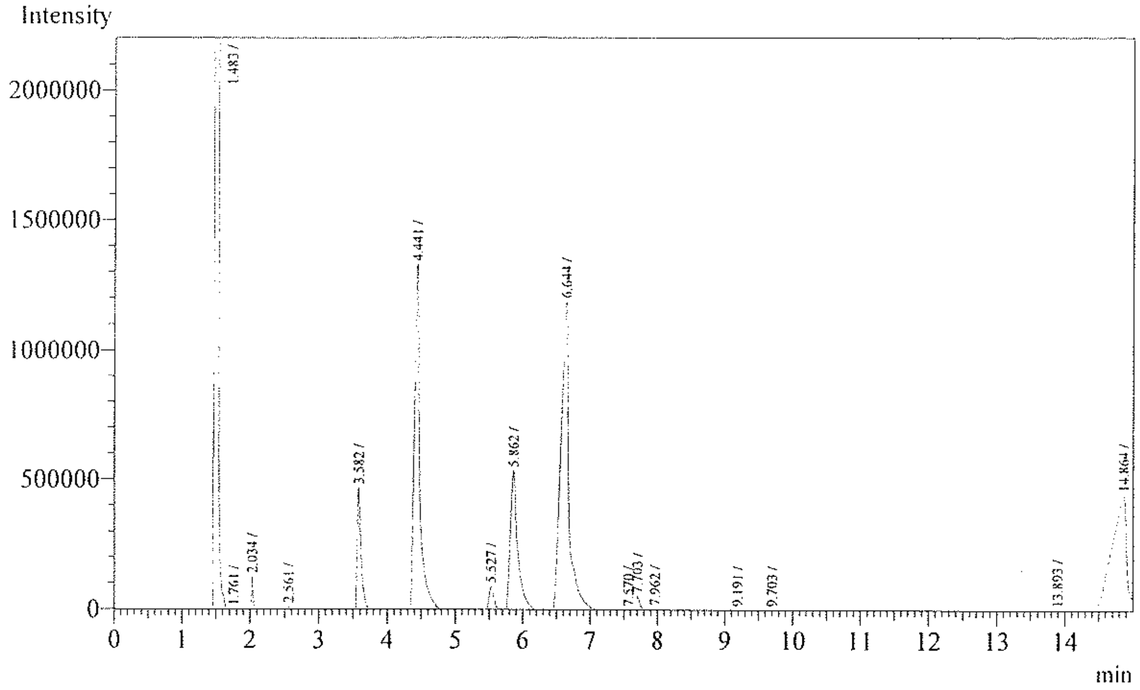
Data Name : D:\ACID\FA44.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	0.087	107321	11334	0.000				
2	1.483	785522512	43427949	0.000		S		
3	2.034	299944	125336	0.000				
4	2.561	133734	39912	0.000				
5	3.581	2238756	376472	0.000				
6	4.437	9370760	1230318	0.000				
7	5.524	709425	91004	0.000				
8	5.851	4032182	417269	0.000		V		
9	6.617	9154404	922053	0.000				
10	7.569	90066	18419	0.000				
11	7.699	507403	56799	0.000		V		
12	7.960	244476	25056	0.000		V		
13	9.191	37411	3811	0.000				
14	9.707	80258	6345	0.000				
15	13.906	100074	6339	0.000				
16	14.800	4671785	317278	0.000				
Total		817300511	47075694					

Analysis Date & Time : 5/9/2554 15:06:02
User Name : Admin
Vial# : 21
Sample Name : 33
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

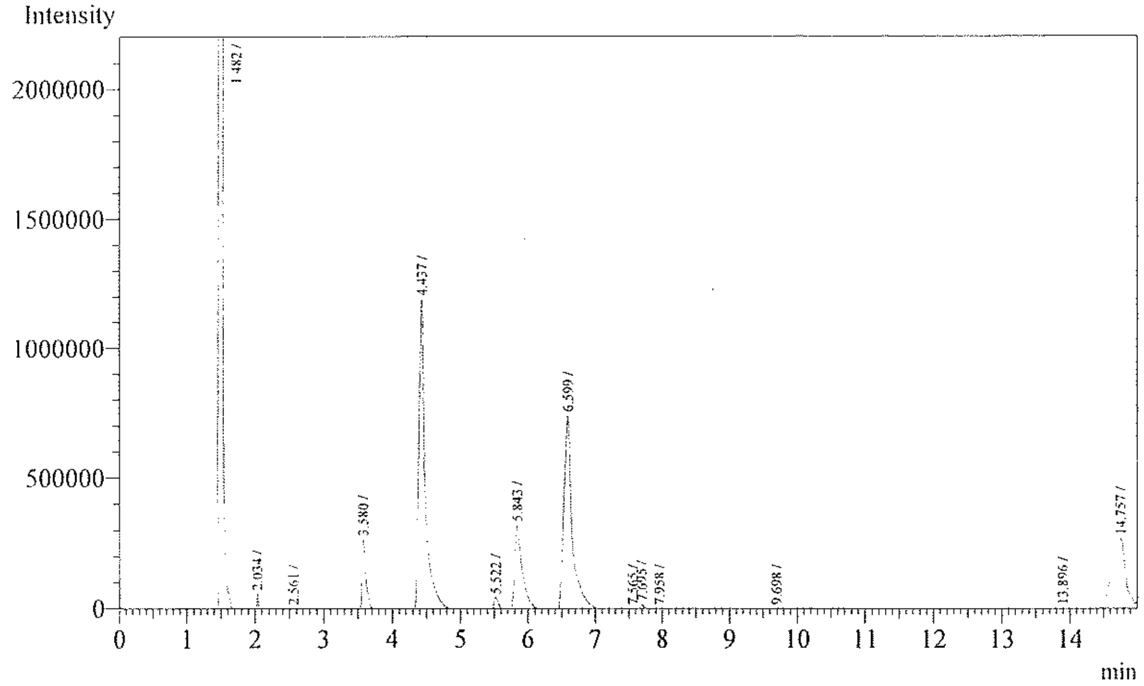
Data Name : D:\ACID\FA45.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.483	780566760	41097541	0.000		S		
2	1.761	37670	22623	0.000		T		
3	2.034	360735	161995	0.000				
4	2.561	160624	52781	0.000				
5	3.582	2655342	510497	0.000				
6	4.441	9029479	1367658	0.000				
7	5.527	927936	123021	0.000				
8	5.862	5021074	564339	0.000		V		
9	6.644	11174962	1209851	0.000				
10	7.570	132280	26141	0.000				
11	7.703	653798	79373	0.000		V		
12	7.962	304808	33629	0.000		V		
13	9.191	45761	5171	0.000				
14	9.703	76686	7694	0.000				
15	13.893	117894	7777	0.000				
16	14.864	6198782	409488	0.000				
Total		817464591	45679579					

Analysis Date & Time : 5/9/2554 15:22:46
User Name : Admin
Vial# : 22
Sample Name : 34
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

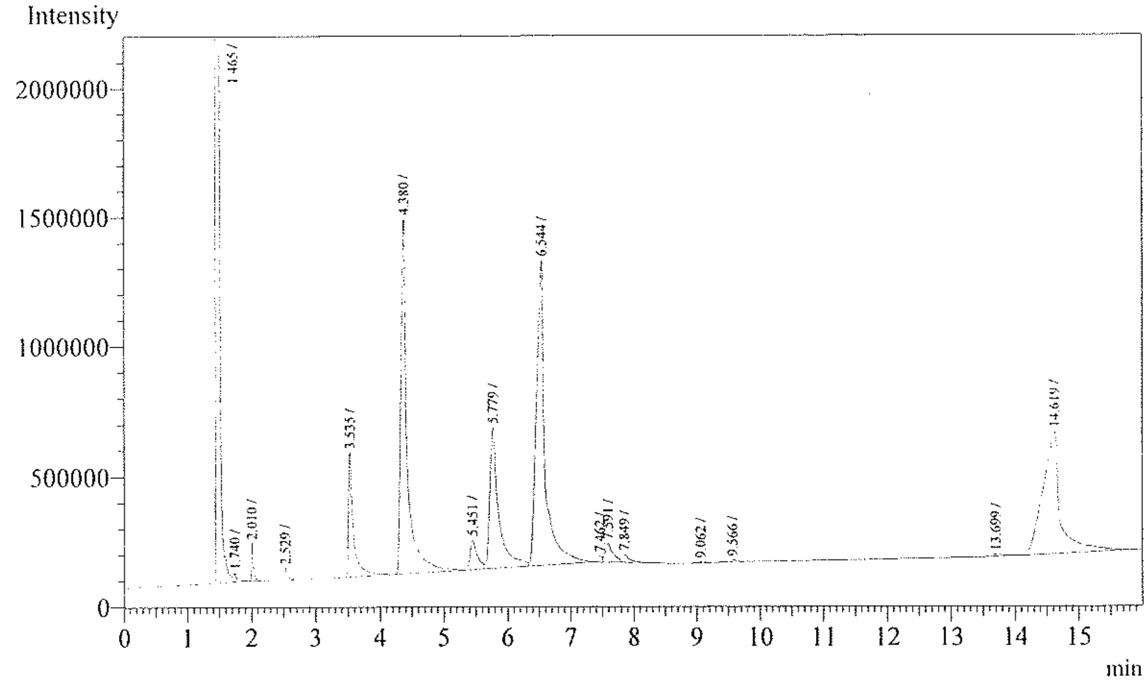
Data Name : D:\ACID\FA46.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.482	788237091	43909339	0.000		S		
2	2.034	226956	95417	0.000				
3	2.561	104043	31162	0.000				
4	3.580	1824345	308957	0.000				
5	4.437	9285026	1232715	0.000				
6	5.522	595058	77294	0.000				
7	5.843	3356722	350911	0.000		V		
8	6.599	7562813	767012	0.000				
9	7.565	76125	14879	0.000				
10	7.695	413667	46257	0.000		V		
11	7.958	199011	20749	0.000		V		
12	9.698	64538	5130	0.000				
13	13.896	82361	5354	0.000				
14	14.757	3916550	269939	0.000				
Total		815944306	47135115					

Analysis Date & Time : 6/9/2554 9:06:58
User Name : Admin
Vial# : 1
Sample Name : 35
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

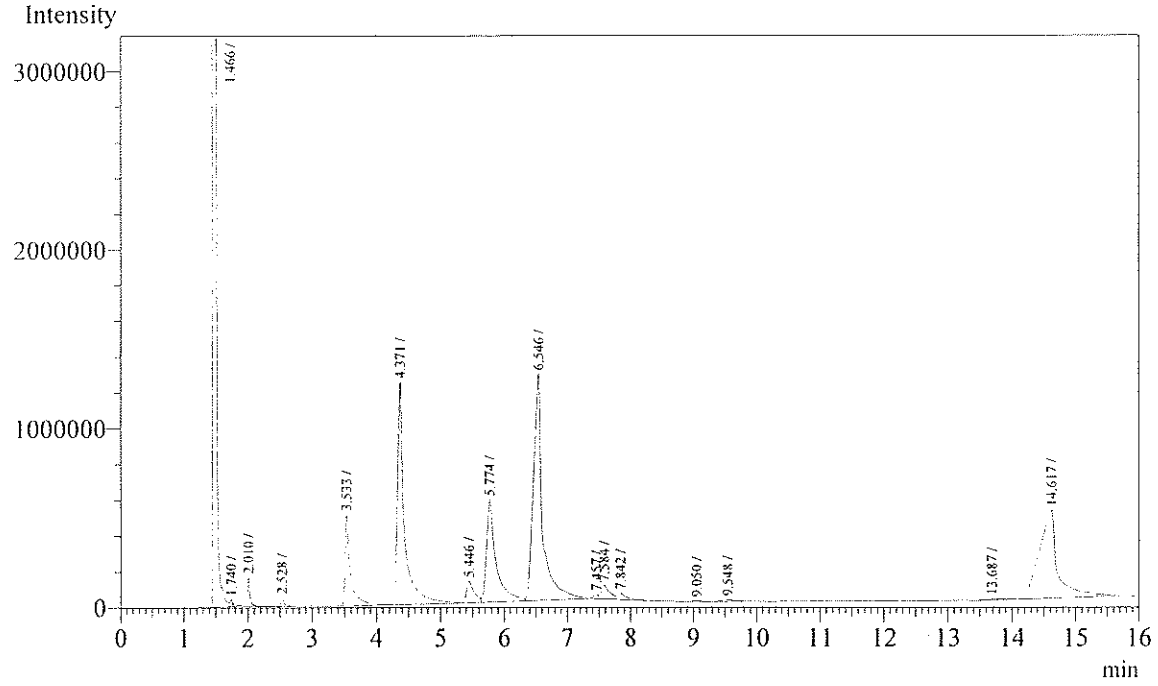
Data Name : D:\ACID\FA47.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	831599299	55341524	0.000		S		
2	1.740	33149	20094	0.000		T		
3	2.010	328445	144683	0.000				
4	2.529	142760	46458	0.000				
5	3.535	2588250	478059	0.000				
6	4.380	9488894	1366976	0.000				
7	5.451	898287	116564	0.000				
8	5.779	5208713	542172	0.000		V		
9	6.544	11246765	1172779	0.000		V		
10	7.462	116010	23926	0.000				
11	7.591	614942	73807	0.000		V		
12	7.849	283790	31504	0.000		V		
13	9.062	43886	4850	0.000				
14	9.566	96515	8105	0.000				
15	13.699	102188	6923	0.000				
16	14.619	8940843	469807	0.000				
Total		871732736	59848231					

Analysis Date & Time : 6/9/2554 9:24:37
User Name : Admin
Vial# : 2
Sample Name : 36
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

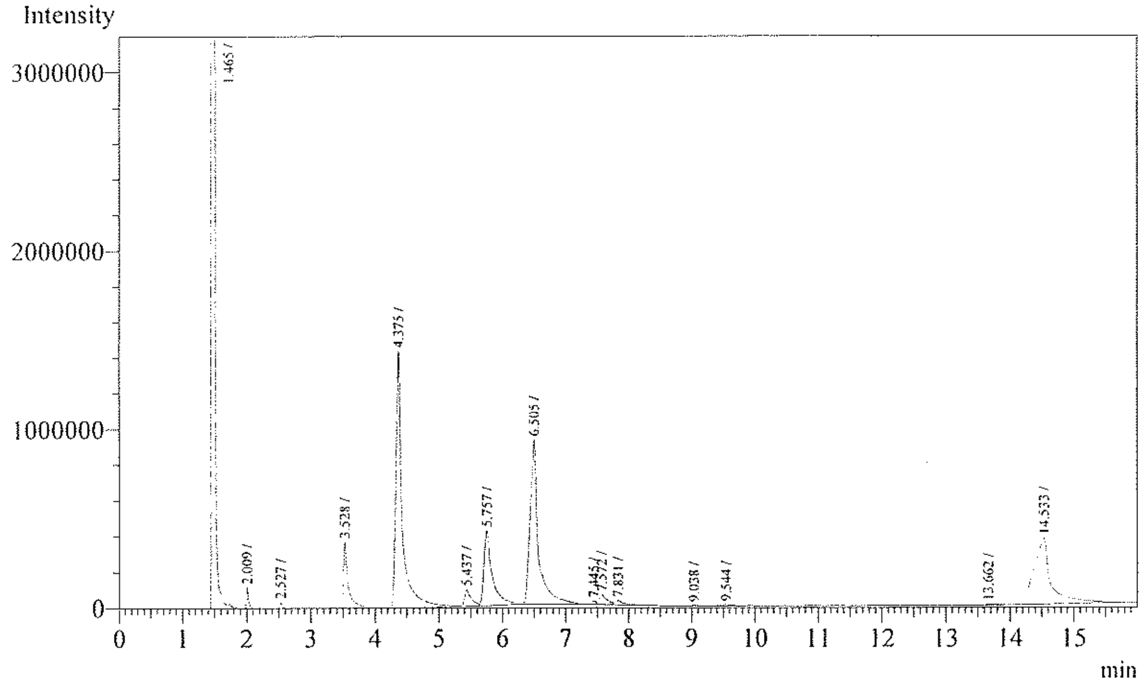
Data Name : D:\ACID\FA48.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	803839045	43929281	0.000		S		
2	1.740	38739	22960	0.000		T		
3	2.010	384863	160909	0.000				
4	2.528	171249	51463	0.000				
5	3.533	3010400	511392	0.000				
6	4.371	9442886	1243370	0.000				
7	5.446	996914	121818	0.000				
8	5.774	5883783	572525	0.000		V		
9	6.546	12883098	1265112	0.000		V		
10	7.457	121300	25495	0.000				
11	7.584	714726	79865	0.000		V		
12	7.842	367354	37422	0.000		V		
13	9.050	46022	4956	0.000				
14	9.548	110261	8850	0.000				
15	13.687	134305	8339	0.000				
16	14.617	9989925	494717	0.000				
Total		848134870	48538474					

Analysis Date & Time : 6/9/2554 9:42:16
User Name : Admin
Vial# : 3
Sample Name : 37
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

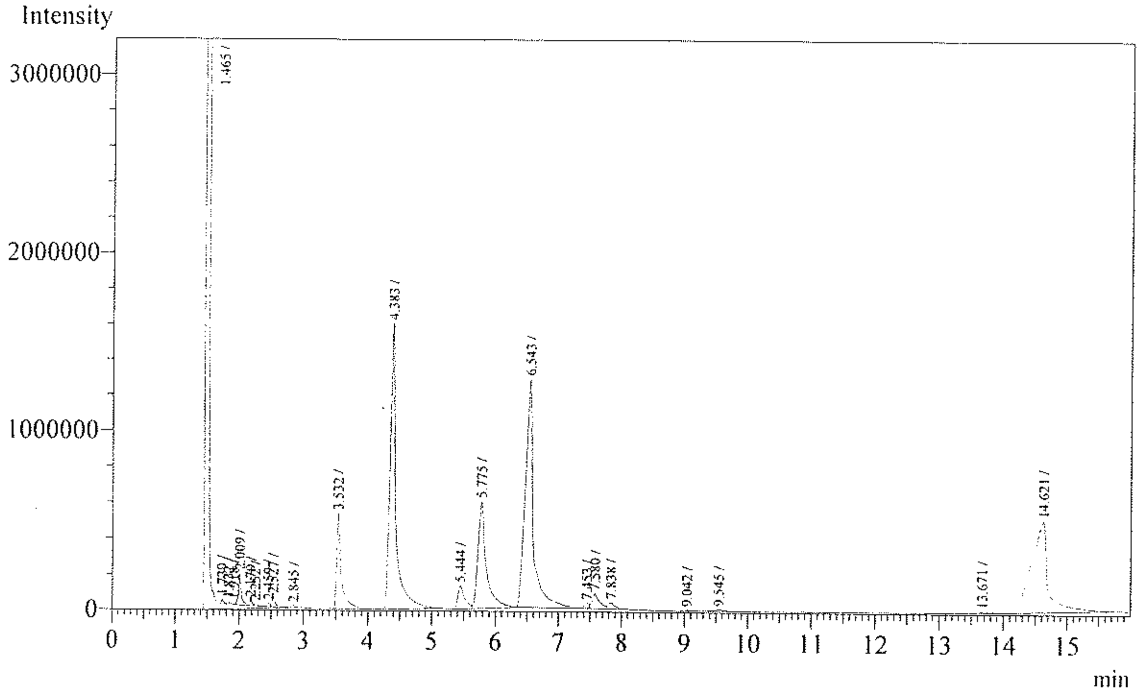
Data Name : D:\ACID\FA49.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	811937749	48757081	0.000		S		
2	2.009	266636	115619	0.000				
3	2.527	119631	37473	0.000				
4	3.528	2049252	371600	0.000				
5	4.375	9991082	1435295	0.000				
6	5.437	682418	92596	0.000				
7	5.757	3777011	419337	0.000		V		
8	6.505	8515843	917733	0.000				
9	7.445	92149	18363	0.000				
10	7.572	477331	56420	0.000		V		
11	7.831	226795	24334	0.000		V		
12	9.038	34179	3652	0.000				
13	9.544	78855	6333	0.000				
14	13.662	89106	5773	0.000				
15	14.533	6974055	369251	0.000				
Total		845312092	52630860					

Analysis Date & Time : 6/9/2554 9:59:54
User Name : Admin
Vial# : 4
Sample Name : 38
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

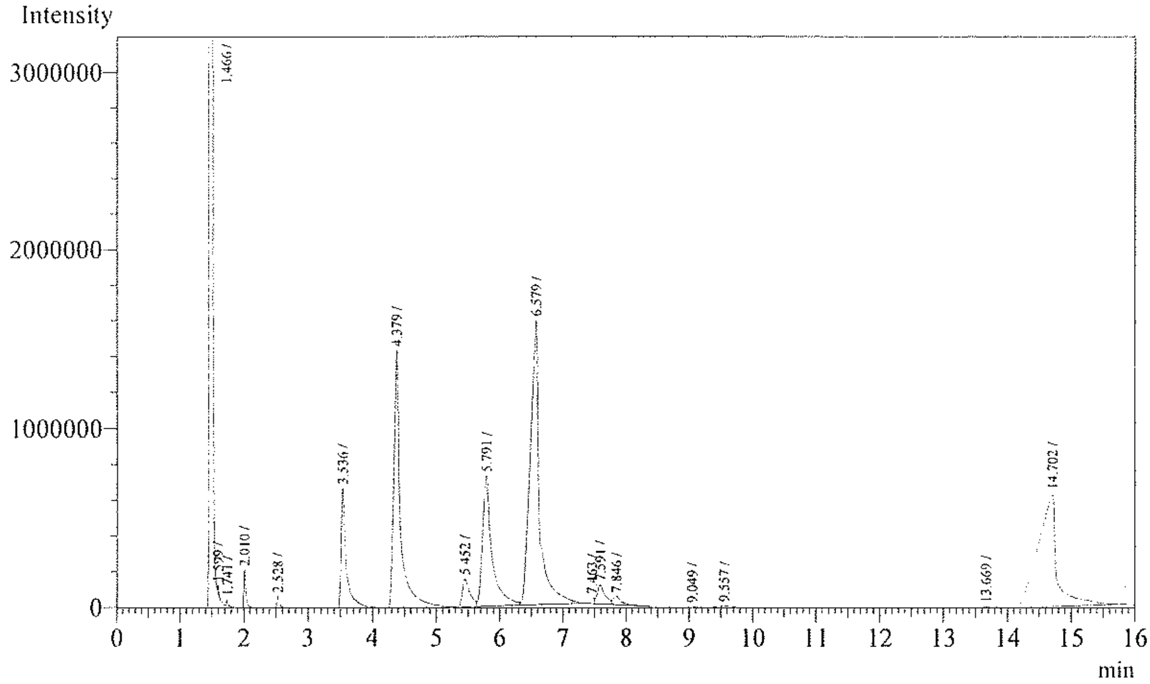
Data Name : D:\ACID\FA50.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	793486722	39099550	0.000		S		
2	1.739	69569	29171	0.000		T		
3	1.832	35816	16592	0.000		TV		
4	1.918	33074	10890	0.000		TV		
5	2.009	516061	174892	0.000		TV		
6	2.179	90052	30996	0.000		TV		
7	2.252	50261	9233	0.000		TV		
8	2.459	54095	19681	0.000		T		
9	2.527	201047	56201	0.000		TV		
10	2.845	37955	11472	0.000				
11	3.532	2705803	528788	0.000				
12	4.383	10513294	1590931	0.000				
13	5.444	964599	128594	0.000				
14	5.775	5272431	593026	0.000		V		
15	6.543	11716396	1270393	0.000				
16	7.453	133235	27372	0.000				
17	7.580	683288	82603	0.000		V		
18	7.838	307788	35667	0.000		V		
19	9.042	49287	5545	0.000				
20	9.545	107870	9151	0.000				
21	13.671	121934	8013	0.000				
22	14.621	9666898	506163	0.000				
Total		836817475	44244924					

Analysis Date & Time : 6/9/2554 10:17:31
User Name : Admin
Vial# : 5
Sample Name : 39
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

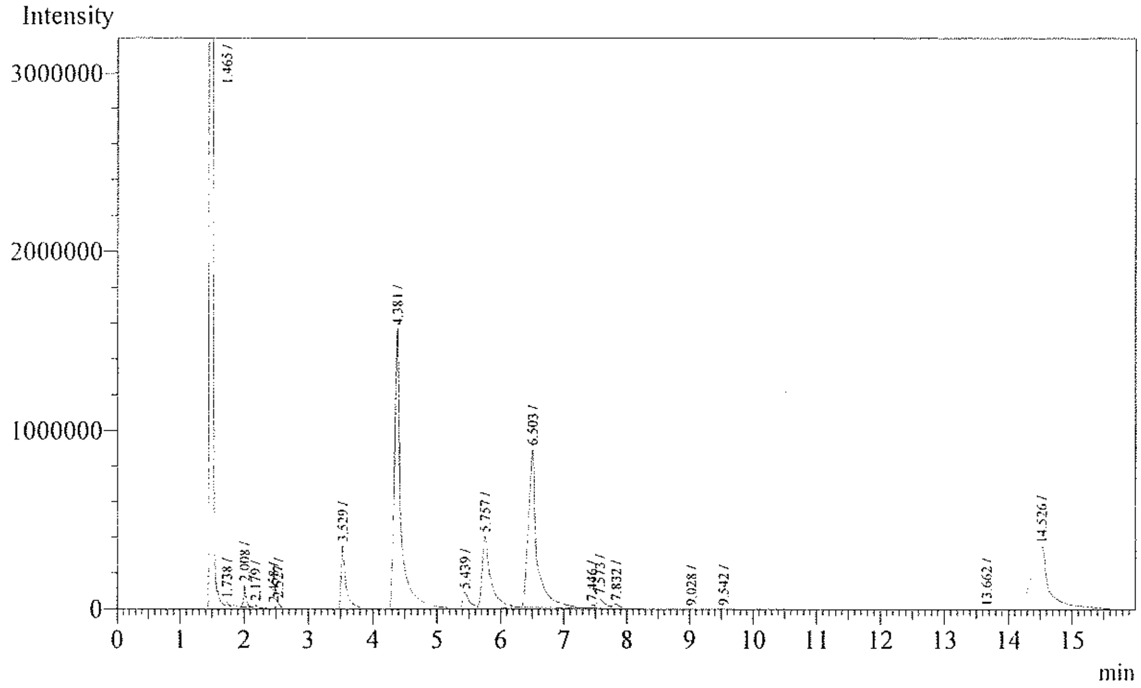
Data Name : D:\ACID\FA51.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	780012924	30249083	0.000		S		
2	1.599	39593	34750	0.000		T		
3	1.741	54622	31690	0.000		T		
4	2.010	503696	213511	0.000				
5	2.528	222256	68278	0.000				
6	3.536	3830673	675858	0.000				
7	4.379	10542918	1435163	0.000				
8	5.452	1303792	156781	0.000				
9	5.791	7524680	729159	0.000		V		
10	6.579	16405953	1588784	0.000		V		
11	7.463	170274	34616	0.000				
12	7.591	909554	108719	0.000		V		
13	7.846	423472	47123	0.000		V		
14	9.049	65095	7006	0.000				
15	9.557	146091	11806	0.000				
16	13.669	147938	9333	0.000				
17	14.702	13237407	632795	0.000				
Total		835540938	36034455					

Analysis Date & Time : 6/9/2554 10:35:08
User Name : Admin
Vial# : 6
Sample Name : 40
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

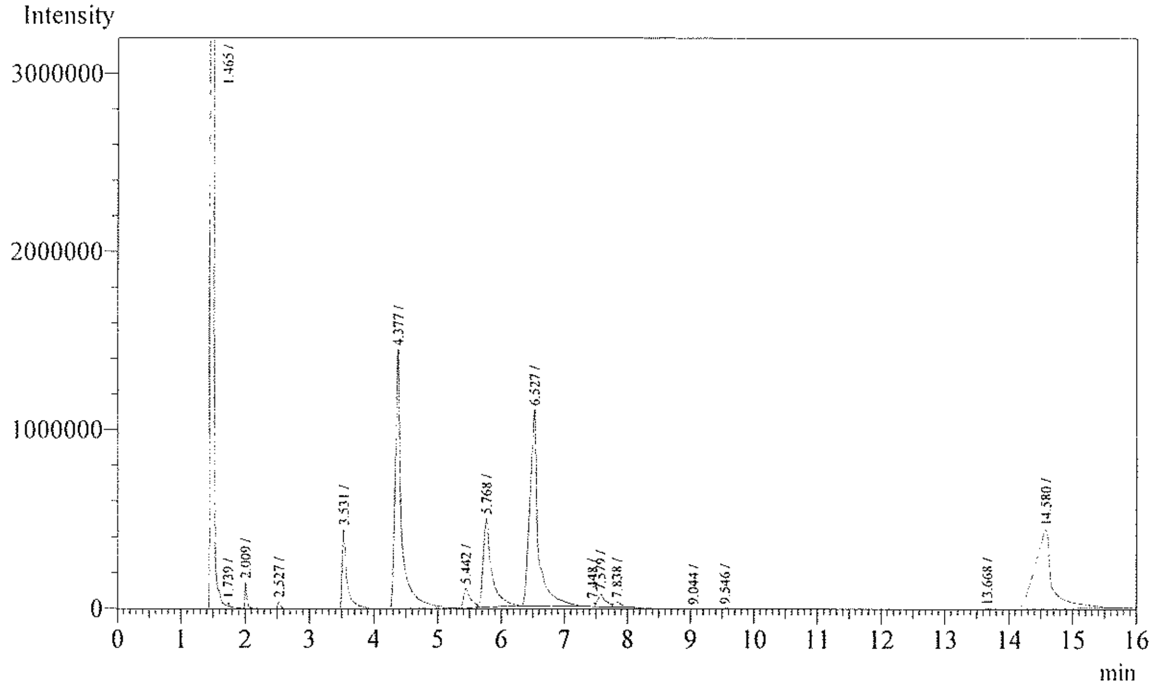
Data Name : D:\ACID\FA52.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	796402405	39084193	0.000		S		
2	1.738	43646 ✓	20449	0.000		T		
3	2.008	328810	120513	0.000		T		
4	2.179	70975	17511	0.000		TV		
5	2.458	37682	13192	0.000				
6	2.527	151890 ✓	39989	0.000		V		
7	3.529	1965711	355889	0.000				
8	4.381	11488001	1569641	0.000				
9	5.439	663624	88705	0.000				
10	5.757	3731666	403722	0.000		V		
11	6.503	8430030	886852	0.000				
12	7.446	87253 ✓	17621	0.000				
13	7.573	474486	54345	0.000		V		
14	7.832	222415	23813	0.000		V		
15	9.028	34398 ✓	3505	0.000				
16	9.542	88208 ✓	6447	0.000				
17	13.662	86864	5658	0.000				
18	14.526	6897825	351903	0.000				
Total		831205889	43063948					

Analysis Date & Time : 6/9/2554 10:52:45
User Name : Admin
Vial# : 7
Sample Name : 41
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

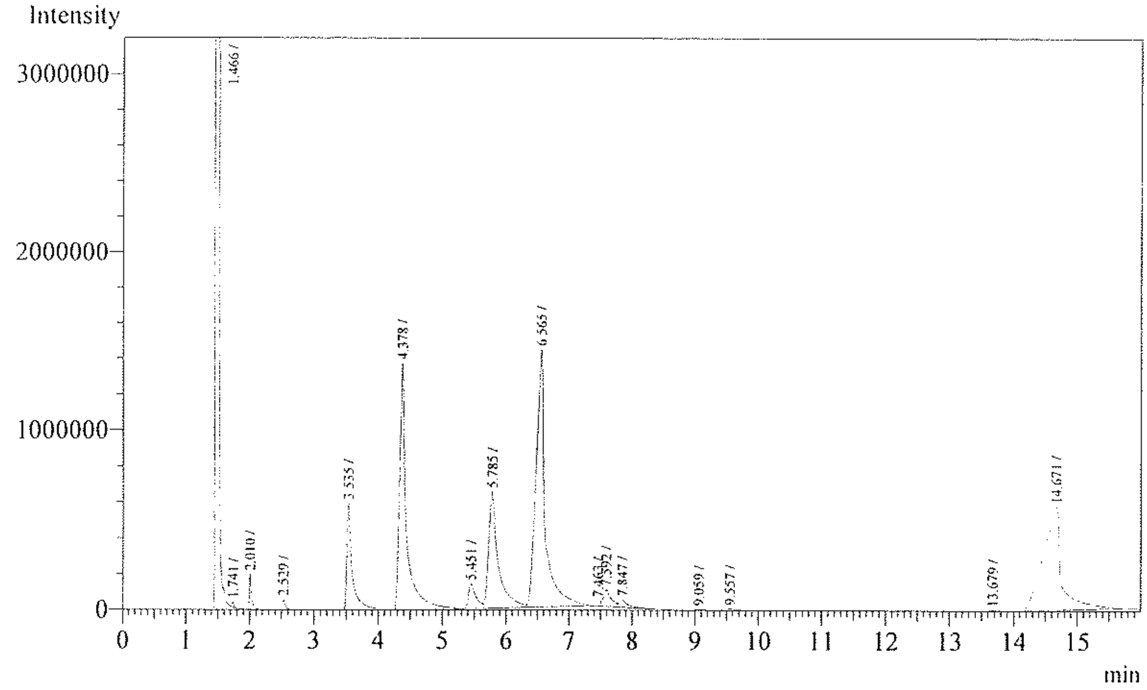
Data Name : D:\ACID\FA53.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	790948295	41192001	0.000		S		
2	1.739	36075	21513	0.000		T		
3	2.009	334169	145784	0.000				
4	2.527	143939	46250	0.000				
5	3.531	2488751	451276	0.000				
6	4.377	10336866	1451326	0.000				
7	5.442	824445	109665	0.000				
8	5.768	4615361	498088	0.000		V		
9	6.527	10376800	1099101	0.000				
10	7.448	110418	22041	0.000				
11	7.579	585350	69409	0.000		V		
12	7.838	272527	29726	0.000		V		
13	9.044	39200	4378	0.000				
14	9.546	92612	7506	0.000				
15	13.668	106024	6968	0.000				
16	14.580	8514325	444813	0.000				
Total		829825157	45599845					

Analysis Date & Time : 6/9/2554 11:10:25
User Name : Admin
Vial# : 8
Sample Name : 42
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

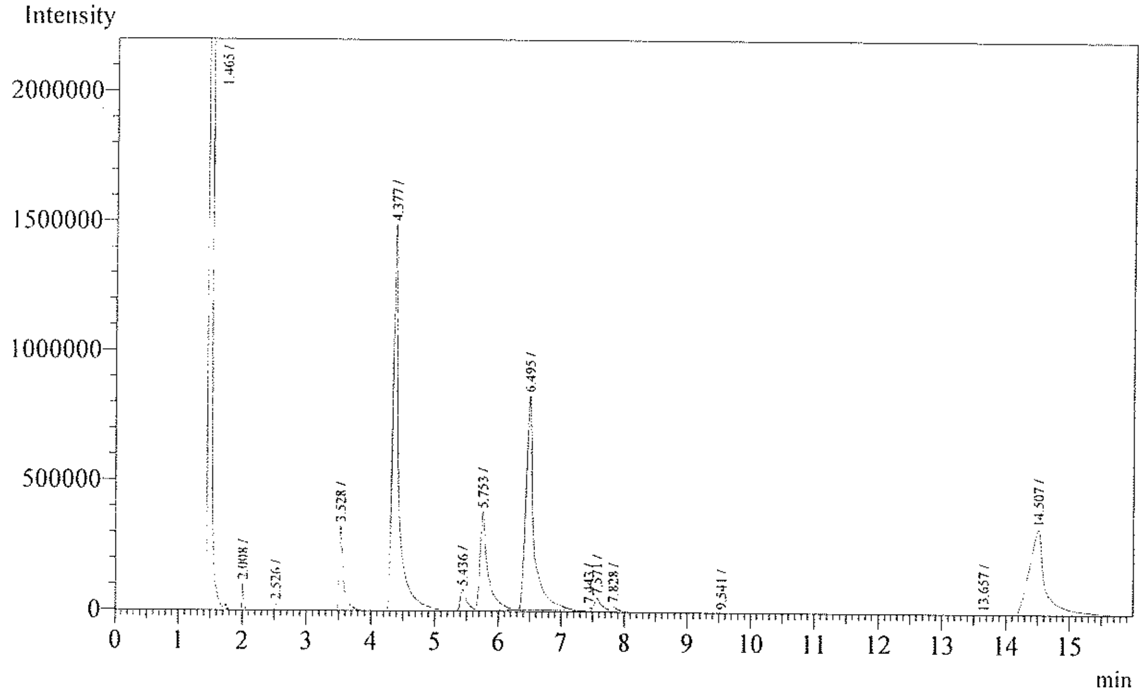
Data Name : D:\ACID\FA54.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	768697516	20711513	0.000		S		
2	1.741	49987	28853	0.000		T		
3	2.010	477823	197406	0.000				
4	2.529	207978	62254	0.000				
5	3.535	3506784	597570	0.000				
6	4.378	10441169	1369744	0.000				
7	5.451	1148499	138460	0.000				
8	5.785	6782861	649234	0.000		V		
9	6.565	14903668	1433782	0.000		V		
10	7.463	143374	29476	0.000				
11	7.592	802464	94193	0.000		V		
12	7.847	381066	40974	0.000		V		
13	9.059	55262	5959	0.000				
14	9.557	123845	10331	0.000				
15	13.679	134809	8583	0.000				
16	14.671	11961321	577093	0.000				
Total		819818426	25955425					

Analysis Date & Time : 6/9/2554 11:28:01
User Name : Admin
Vial# : 9
Sample Name : 43
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

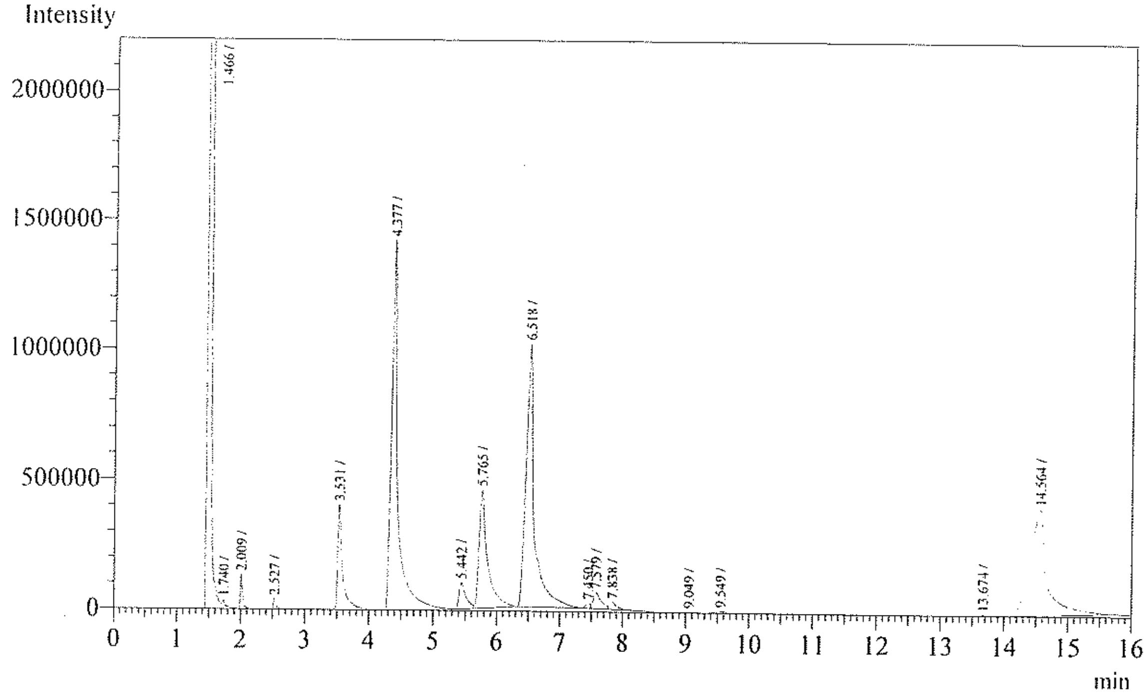
Data Name : D:\ACID\FA55.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	795886703	43410643	0.000		S		
2	2.008	246268	107786	0.000				
3	2.526	109626✓	34963	0.000				
4	3.528	1833682	334547	0.000				
5	4.377	10368769	1494974	0.000				
6	5.436	605938	83863	0.000				
7	5.753	3369561	380701	0.000		V		
8	6.495	7613552	824179	0.000				
9	7.443	79508✓	16438	0.000				
10	7.571	430582	50754	0.000		V		
11	7.828	203696x	21965	0.000		V		
12	9.541	72549✓	5916	0.000				
13	13.657	77841✓	5245	0.000				
14	14.507	6270794	332978	0.000				
Total		827169069	47104952					

Analysis Date & Time : 6/9/2554 11:45:37
User Name : Admin
Vial# : 10
Sample Name : 44
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

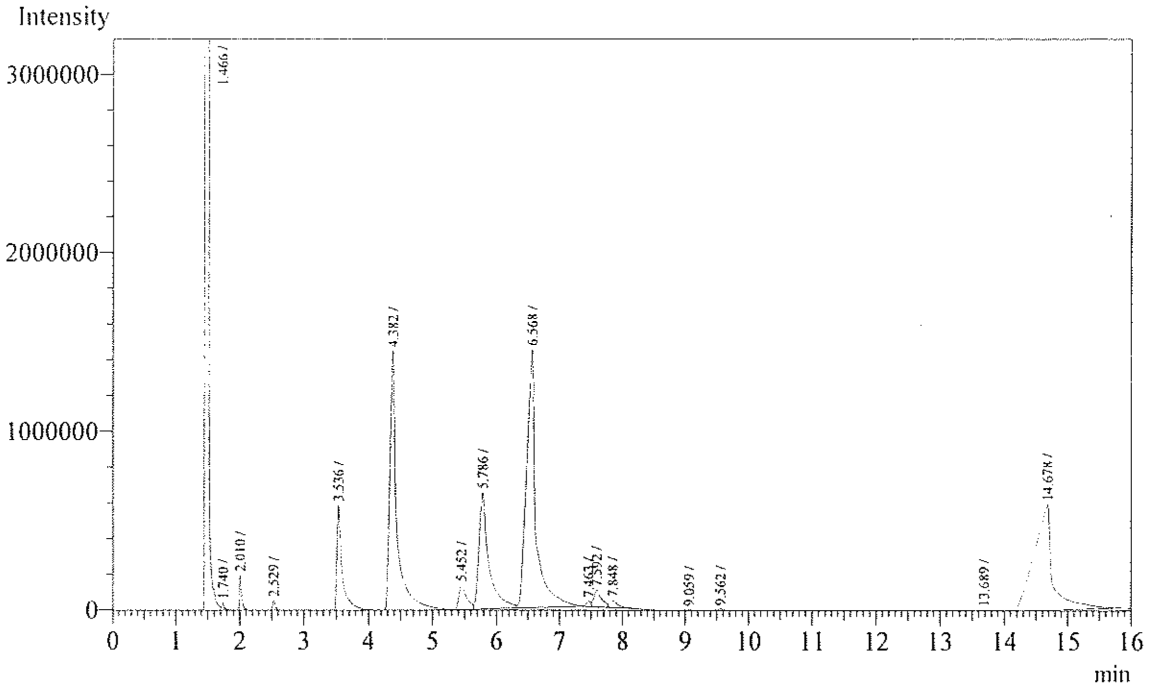
Data Name : D:\ACID\FA56.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	789316227	40054253	0.000		S		
2	1.740	30986	18732	0.000		T		
3	2.009	314159	132111	0.000				
4	2.527	140048	42683	0.000				
5	3.531	2310443	409413	0.000				
6	4.377	10303929	1425020	0.000				
7	5.442	752237	100839	0.000				
8	5.765	4235808	455605	0.000		V		
9	6.518	9564911	1011023	0.000				
10	7.450	100016	20257	0.000				
11	7.579	536576	62456	0.000		V		
12	7.838	256086	27239	0.000		V		
13	9.049	38492	4150	0.000				
14	9.549	84640	7040	0.000				
15	13.674	91856	6216	0.000				
16	14.564	7881623	409861	0.000				
Total		825958037	44186898					

Analysis Date & Time : 6/9/2554 12:03:18
User Name : Admin
Vial# : 11
Sample Name : 45
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

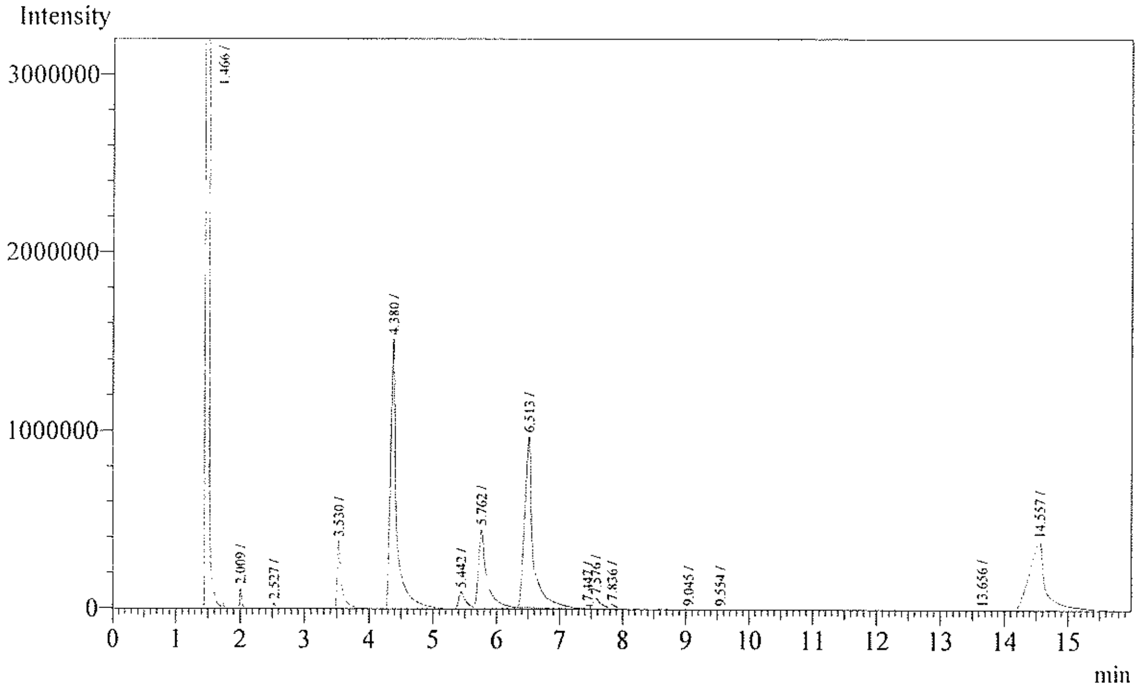
Data Name : D:\ACID\FA57.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	763853011	20646933	0.000		S		
2	1.740	50081	28909	0.000		T		
3	2.010	490371	199519	0.000				
4	2.529	212926	62743	0.000				
5	3.536	3588967	595082	0.000				
6	4.382	11347553	1449879	0.000				
7	5.452	1160682	137917	0.000				
8	5.786	6908780	652120	0.000		V		
9	6.568	15223278	1443329	0.000		V		
10	7.463	146683	30550	0.000				
11	7.592	820469	95503	0.000		V		
12	7.848	395141	42192	0.000		V		
13	9.059	55537	5899	0.000				
14	9.562	125248	10243	0.000				
15	13.689	137681	8434	0.000				
16	14.678	12280562	590989	0.000				
Total		816796970	26000241					

Analysis Date & Time : 6/9/2554 12:20:57
User Name : Admin
Vial# : 12
Sample Name : 46
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

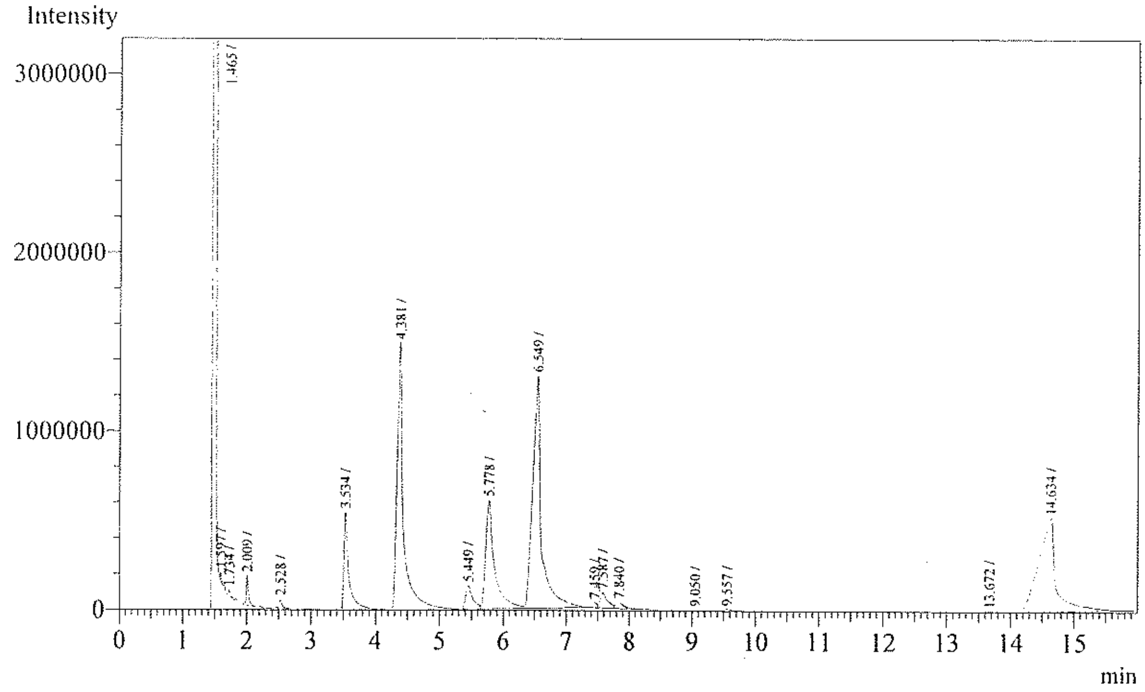
Data Name : D:\ACID\FA58.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	798416082	42383676	0.000		S		
2	2.009	274369	118404	0.000		T		
3	2.527	131936	39726	0.000		V		
4	3.530	2119086	391360	0.000				
5	4.380	10785679	1523203	0.000				
6	5.442	727624	97987	0.000				
7	5.762	4057257	448855	0.000		V		
8	6.513	9071327	966019	0.000				
9	7.447	92972	19296	0.000				
10	7.576	508044	59016	0.000		V		
11	7.836	240617	25726	0.000		V		
12	9.045	36304	3903	0.000				
13	9.554	83394	6826	0.000				
14	13.656	93446	6225	0.000				
15	14.557	7500292	394312	0.000				
Total		834138429	46484534					

Analysis Date & Time : 6/9/2554 12:38:36
User Name : Admin
Vial# : 13
Sample Name : 47
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

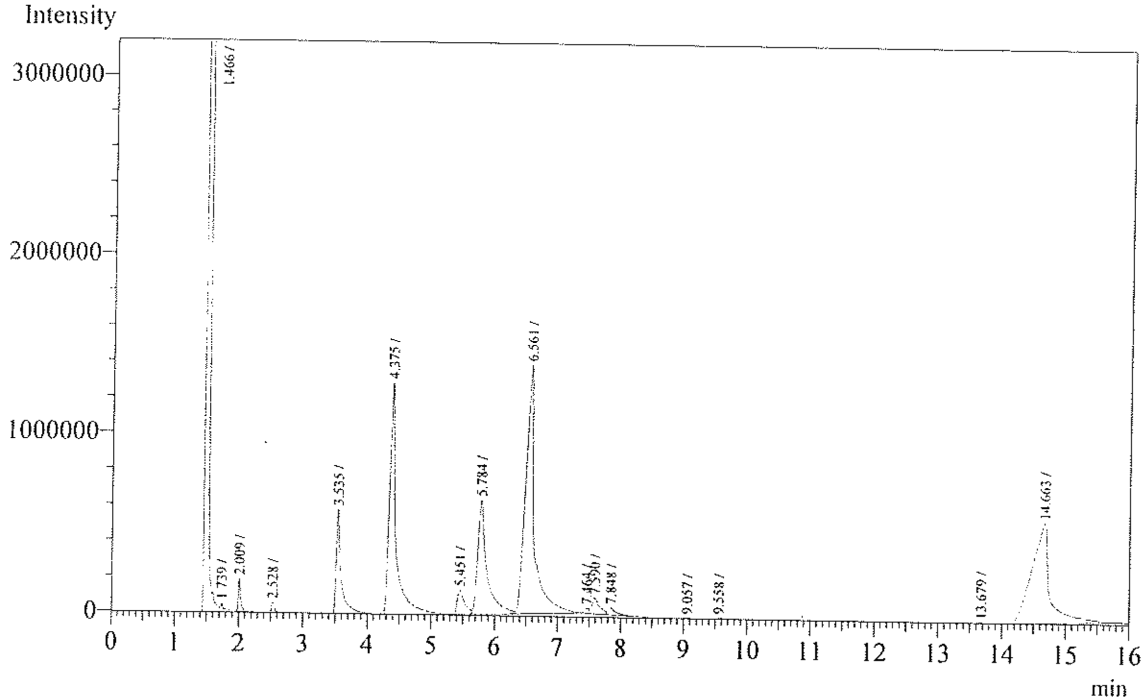
Data Name : D:\ACID\FA59.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.465	781332953	31507476	0.000		S		
2	1.597	63498	45076	0.000		T		
3	1.734	78893	36212	0.000		T		
4	2.009	382221	164287	0.000		T		
5	2.528	170346	54141	0.000		V		
6	3.534	2917476	544146	0.000				
7	4.381	10590595	1493813	0.000				
8	5.449	1021234	131677	0.000				
9	5.778	5838915	608115	0.000		V		
10	6.549	12705167	1299844	0.000		V		
11	7.459	132649	27872	0.000				
12	7.587	701707	84283	0.000		V		
13	7.840	329185	35919	0.000		V		
14	9.050	46444	5408	0.000				
15	9.557	115235	9459	0.000				
16	13.672	126565	8247	0.000				
17	14.634	10259996	521164	0.000				
Total		826813079	36577139					

Analysis Date & Time : 6/9/2554 12:56:19
User Name : Admin
Vial# : 14
Sample Name : 48
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

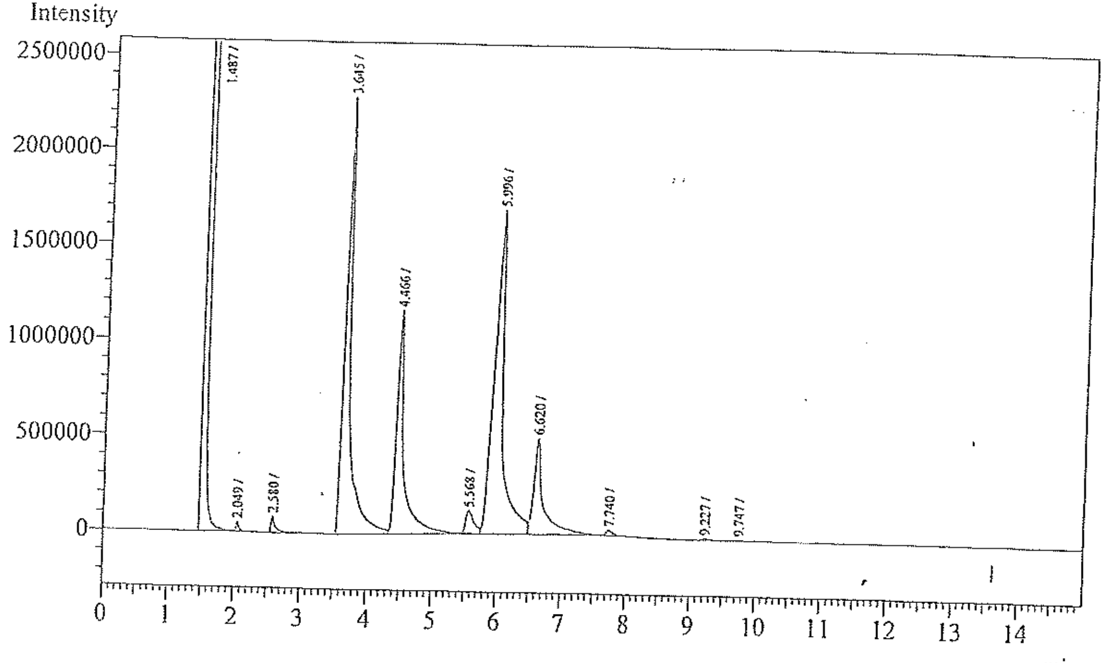
Data Name : D:\ACID\FA60.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.466	780879407	32533598	0.000		S		
2	1.739	58021	29681	0.000		T		
3	2.009	429517	182166	0.000		T		
4	2.528	194836	59310	0.000		V		
5	3.535	3327910	586492	0.000				
6	4.375	9551179	1290424	0.000				
7	5.451	1099838	136932	0.000				
8	5.784	6481657	637773	0.000		V		
9	6.561	14177148	1382412	0.000		V		
10	7.464	139537	28991	0.000				
11	7.590	761000	89640	0.000		V		
12	7.848	353315	39247	0.000		V		
13	9.057	52387	5751	0.000				
14	9.558	117812	9769	0.000				
15	13.679	133060	8617	0.000				
16	14.663	11386182	559960	0.000				
Total		829142806	37580763					

Analysis Date & Time :12/9/25549:37:34
User Name : Admin
Vial# : 4
Sample Name :
Sample ID : UNK-0001
Sample Type : Unknown
Injection Volume : 1.00
ISTD Amount :

Data Name : D:\ACID\FA37.gcd
Method Name : D:\ACID\FATTY ACID-2.gcm



Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	1.487	813995239	53050852	0.000		S		
2	2.049	151935	49711	0.000				
3	2.580	378563	86352	0.000				
4	3.645	15834470	2288758	0.000				
5	4.466	9629643	1164353	0.000		V		
6	5.568	1073723	120774	0.000				
7	5.996	17992196	1692775	0.000		V		
8	6.620	5305735	502461	0.000		V		
9	7.740	222917	28183	0.000				
10	9.227	68180	7247	0.000				
11	9.747	68857	5778	0.000				
Total		864721458	58997244					

BIOGRAPHY

Mister Pongsakorn Suklom was born in Chiang Rai province on December 3, 1979, He graduated from Rajabhat Institute Chaing Rai and received Bachelor degree in Chemical Science in 2002. In 2008 He entered the Graduate School of Chulalongkorn University to continue his study of Chemical Engineering.