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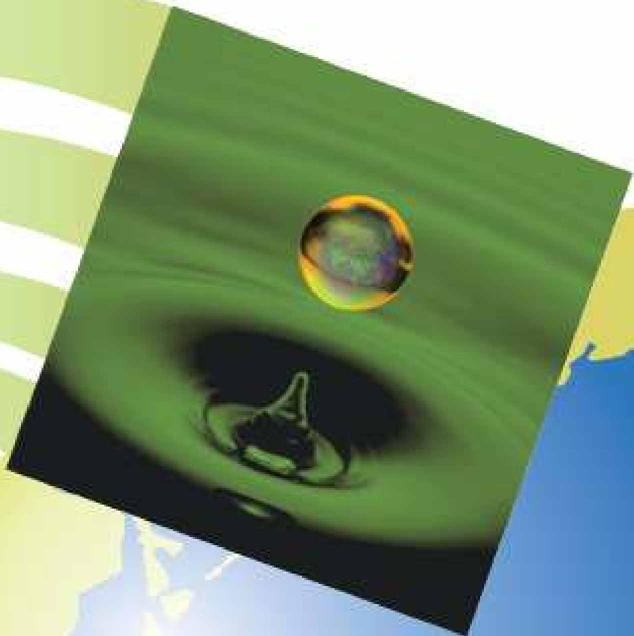
Establishment of the Guidelines for the Development of Biodiesel Standards in the APEC Region



APEC 21st Century Renewable Energy Development Initiative (Collaborative IX)

Thailand Institute of Scientific and Technological Research

กระทรวงพลังงาน MINISTRY OF ENERGY

ITRI Industrial Technology Research Institute

Bureau of Energy Ministry of Economic Affairs

April 2009

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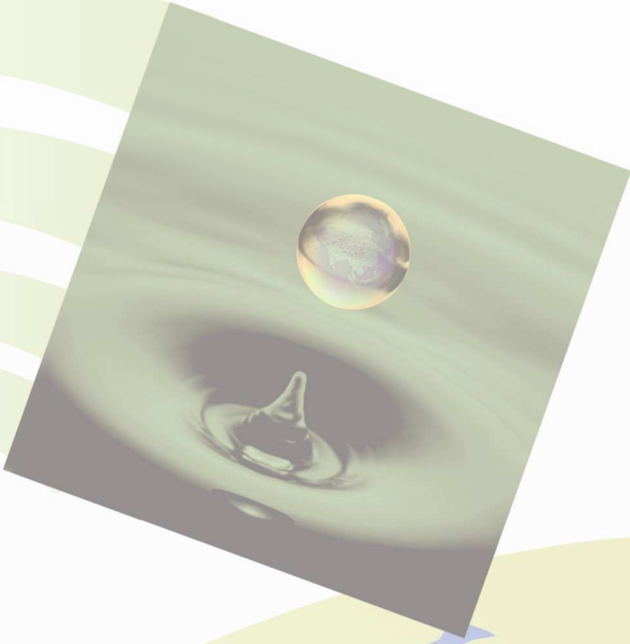
(EWG 02/2007A)



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APEC Project
Establishment of the Guidelines for the Development of
Biodiesel Standards in the APEC Region

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ISBN: 978-981-08-3179-0
[APEC#209-RE-03.1]

FOREWORD

While the global community is abuzz about energy and environment concerns from the crisis of climate change arising from the increasing of millions of vehicles and the surging of oil prices, many countries have taken actions in order to solve these problems by gearing towards more sustainable energy with positive impacts on the environment. Among the options, biodiesel has been identified as an option that can play a significant role in reducing consumption of imported petroleum and for environment benefits.

Considering the substantial increase of biodiesel production in the APEC region, biodiesel standards, which are slightly different in different parts of the world, have become an important topic for discussion in international markets.

This report was prepared as a product of a joint partnership of Australia, New Zealand, Chinese Taipei, the US, and Thailand and funded by the APEC Central Fund in an attempt to provide a revision of current biodiesel standards, potential feedstock, biodiesel application, lesson learned on the engines, vehicles and emission, related works on biodiesel fuel standards, as well as opportunities, gaps, and barriers. It is hoped that the information gained from the key eminent experts presented in this report will be a valuable contribution to development of the guideline for biodiesel production standards in the APEC region and help addressing market barriers and restore consumer confidence in the biodiesel industry among the APEC economies.

I wish to express my sincere appreciation to the APEC Secretariat for the support and proper guidance in financial and project implementing matters. Our special thanks are due to Dr. Cary Bloyd, Chairman of APEC Expert Group on New and Renewable Energy Technology (EGNRET). We owed a special debt of gratitude for his critical advice from his profound knowledge associated with the on-going work in the APEC biofuels projects. To Dr. Hom Ti Lee, Senior Researcher, Energy & Environment Research Labs, Industrial Technology Research Institute (ITRI), Chinese Taipei and his staff for cooperating and hosting the 2nd workshop on biodiesel standards development in Taipei. We are grateful to all participants attending in both workshops for sharing their valuable information, which contributes beautifully to this report.

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EXECUTIVE SUMMARY

Nowadays, oil price, the shortage of fossil fuel, and environmental problems are critical issues that are of concern to the global and domestic communities. While emissions from fossil fuel damages our environment and generates greenhouse effects, biodiesel is considered as clean and renewable energy. It is produced from vegetable oils; animal fats or recycled cooking grease. In pure form or blended biodiesel with petroleum diesel can be used as a transport fuel with suitable diesel engines. This means it can reduce fossil fuel consumption and emissions, so biodiesel has gained much attention by many countries. Biodiesel quality and standard are promoted accordingly for sustainable development.

The project on "Establishment of the guidelines for the development of biodiesel standards in the APEC region" was an effort of Thailand in close collaboration with Australia, New Zealand, Chinese Taipei, and the US as the project partners to promote neutral standards of biodiesel produced in the APEC region. It was initiated to support the Message from the APEC Energy Minister's Meeting in Republic of Korea in October 2005, which stressed the needs to respond to the impact of high oil prices and oil dependency.

Biodiesel standards in the APEC region are mostly based on European (EN 14214) and US (ASTM D 6751) standards. However, some parameters in these standards do not cover some of APEC feedstocks. The EN 14214 is based on biodiesel produced from rapeseed and combination of oils that together provide similar characteristics to rapeseed oil, including sunflower and soybean oil, while the US biodiesel standard was developed to address biodiesel produced predominantly from soybean and waste cooking oils.

The purpose of this project is thus to provide useful information for the establishment of the guidelines for the development of biodiesel standards in the APEC region. The report will also build overall capacity to expand the knowledge and awareness of APEC economies

and enhance the trade of biodiesel among APEC member economies in order to offer the possibility for a sustainable energy source with a neutral effect on greenhouse gas emission.

This report firstly presents information on the project background and activities. Then, the current status of biodiesel standards including US ASTM (D 6751), European biodiesel standard (EN 14214), are reviewed to provide an overview on how these standards are being referenced in the international markets, particularly in the APEC economies. The report also reviews biodiesel potential feedstocks in terms of their natural characteristics and lesson learned on the impact of biodiesel on the diesel engines and vehicle as well as their emissions. Related works on biodiesel fuel standard are also presented. Final section of the report presents the result of the workshops on the opportunities, gaps, barriers and lessons learned from using biodiesel as fuels with engine and automobile manufacturers in order to adopt biodiesel specification and its blends.

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ACRONYMS

ABNT	Associacao Brasileira de Normas Tecninas (Brazilian Standards)
ACEA	European Automobile Manufacturers Association
APCC	Asian and Pacific Coconut Community
APEC	Asia-Pacific Economic Cooperation
ASEAN	The Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
BAYNOX	20% 2,6-di- tert-butyl-4-methylphenol (Brand of Bayer AG, Leverkusen, Germany)
Baynox plus	Brand of Lanxess Deutschland GmbH
BDF	Biodiesel Fuel
BF320	Brand of Kemin
BHA	3-tert-Butyl-4-hydroxyanisole
BHT	2,6-Di-tert-butyl-4-methyl-phenol
BioExtend 30 HP	Brand of Eastman Chemical Deutschland GmbH
BioStable ™ 403E	Brand of Innospec Ltd.
BQ9000	Quality Management System of biodiesel
BTL	Biomass to Liquid
Bxxx	Biodiesel where XXX is the percentage of biodiesel in the blend
CA	California
CEN	European Committee for Standardization
CFPP	Cold Filter Plugging Point
Chimec CH 4636	Brand of Chimec SpA
Chimec R 876 HFP	Brand of Chimec SpA
CME	Coconut Methyl Ester
CNS	Chinese National Standards
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Cont.	Continue
Corp.	Corporation
cSt	CentiStoke
DIESOLIFT BD-3	Brand of International Fuel Technology
DRCOME	Distilled Recycled Cooking Oil Methyl Ester
DTBHQ	2,5-Di- tert-butyl-hydroquinone (Brand of AECI-Aroma and Fine Chemicals_Richards Bay, South Africa)
EAS	East Asia Summit
EGNRET	Expert Group on New and Renewable Energy Technology

ACRONYMS_(Cont.)

EMA	Engine Manufacturers Association
EN	European Biodiesel Standard
ERIA	Economic Research Institute for ASEAN and EAST Asia
EU	European Union
EWG	Energy Working Group
FA	Fatty Acid
FAME	Fatty Acid Methyl Esters
FAEE	Fatty Acid Ethyl Esters
g/ml	gram per mililitre
GB/T	Guobiao/tuiji (National Standards of the People's Republic of China/Recommended)
HC	Hydrocarbon
HDRD	Hydrogenation-derived Renewable Diesel
Inc.	Incorporation
IONOL BF200	Brand of Raschig GmbH
Ionox 220	4,4'- methylene-bis-(2,6-di-tert-butylphenol) (Brand of Degussa Sant Celoni, S.A., Spain)
IRGASTAB BD 100	Brand of Ciba Corporation
IRGASTAB BD 50	Brand of Ciba Corporation
ISO	International Organization for Standardization
ISO/TC 28	International Organization for Standardization: Technical Committee 28
ITRI	Industrial Technology Research Institute (Chinese Taipei)
JAMA	Japan Automobile Manufacturers Association, Inc.
JASO	Japanese Automotive Standards Organization
JIS	Japanese Industrial Standards
JWG	Joint Working group
Kerobit 3627	Brand of BASF SE
Kerobit TP 26	2,6-di-tert-butylphenol (Brand of BASF SE)
kg	kilogram
kg/m^3	kilogram per cubic meter
km	kilometer
max	maximum
mg KOH/g	milligrams of Potassium Hydroxide per gram
mg/kg	milligram per kilogram
min	minimum

ACRONYMS_(Cont.)

mm^2/ml	square millimeter per milliliter
mm^2/s	square millimeter per second
NO_x	Nitrogen Oxides
°C	Degree Celcius
OEM	Original Equipment Manufacturer
PG	n-Propyl gallate
PME	Palm Methyl Ester
PNS	Philippine National Standard
ppm	parts per million
PY	Pyrogallol
R120	Brand of Infineum UK Ltd
R130	Brand of Infineum UK Ltd
RCOME	Recycled Cooking Oil Methyl Ester
RME	Rapeseed Methyl Ester
RSB	Roundtable on Sustainable Biofuels
SBME	Soybean Methyl Ester
SME	Sunflower Methyl Ester
SNI	Standar National Indonesia (Indonesia National Standard)
TBHQ	tert Butyl hydroquinone
TC	Technical Committee
TISTR	Thailand Institute of Scientific and Technological Research
UFO	Used Frying Oil
ULSD	Ultra Low Sulfur Diesel
US	United States of America
USDA	United States Department of Agriculture
Vulkanox BKF	2,2'-methylene-bis-(4-methyl-6-tert-butylphenol) (Brand of Bayer AG, Leverkusen, Germany)
Vulkanox ZKF	2,2'-methylene-bis-(4-methyl-6-cyclohexylphenol) (Brand of Bayer AG, Leverkusen, Germany)
WG	Working Group
WWFC	World Wide Fuel Charter
%vol	Percent by volume
%wt	Percent by weight

1. INTRODUCTION

Background

World populations continue to increase every year means that the world energy demand continues to increase in the same way. Most energy resources are non-renewable energy e.g. petroleum. Nowadays, oil price, the shortage of fossil fuel, and environmental problems are the global issues that have been widely concerned. Biodiesel, as a source of renewable energy, is an attractive option to solve this crisis for many countries to improve energy security supply and reduces the impacts of oil dependency.

Biodiesel can be produced from various kinds of vegetable oils and animal fats. Straight oil, however, can not be used directly as fuel in conventional diesel engine. It has to be chemically converted to biodiesel through transesterification reaction. In the transesterification or conventional biodiesel process, the oils are reacted with the methanol in the presence of sodium hydroxide or potassium hydroxide as catalyst as reaction shown in Figure 1.

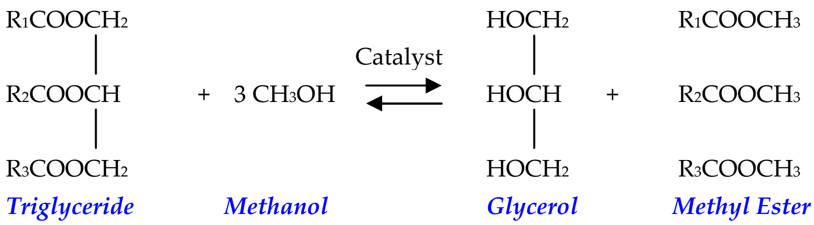


Figure 1. Transesterification reaction

Current biodiesel is produced based upon differential standard. European standard (EN 14214) and US standard (ASTM D 6751) are widely used as reference standards. The EN 14214 is based on biodiesel produced from rapeseed and combination of oils that together provide similar characteristics to rapeseed oil, while the US

ASTM D 6751 biodiesel standard was developed to address biodiesel produced predominantly from soybean and waste cooking oils. The quality of biodiesel produced depends on several factors such as climate, feedstock, and vehicle type. The difference in those factors may require slightly different biodiesel specification to fulfill market acceptance.

The project on "Establishment of the Guidelines for the Development of Biodiesel Standards in the APEC Region" was an effort of Thailand in close collaboration with Australia, New Zealand, Chinese Taipei, and the US as the project partners to promote neutral standards of biodiesel produced in the APEC region. It was initiated to support the Message from the APEC Energy Minister's Meeting in Republic of Korea in October 2005, which stressed the need to respond to the impact of high oil price and oil dependency. The main purpose of this project was to build up the capacity to expand the knowledge and awareness of APEC economies in the establishment of the guidelines for development of biodiesel standards.

Project Activities

- Hart Energy Consulting was selected to prepare a position paper for the project. It covered the current biodiesel standards, potential feedstocks, lessons learned on the affects of biodiesel on diesel engines and the investigation of the additives necessary for biodiesel. The study report can be accessed at:
  www.apec.org/apec/publications/all_publications/energy_working_group.html
- The implementation of the two related workshops have been an integral part of the project. Two workshops brought together representatives from energy sector among APEC economies including key eminent experts and stakeholders from governmental agencies, petroleum companies, automakers, biodiesel producers, and environmental protection officers. Participants of the two workshops were listed in Appendix A.

The two workshops were designed to review the current status of biodiesel standards applied in both of the APEC economies and non-APEC economies as well as potential feedstock and evaluate their natural characteristics that may affect the quality of biodiesel. Many issues were raised in the presentations from the participating speakers and the roundtable discussion. It also investigated the opportunities, gaps, barriers and lesson learnt from using biodiesel as sustainable energy source in the APEC region.

The two workshops were held as follows:

- The 1st APEC workshop was held on 25 – 26 October 2007 in Thailand with 90 participants from 15 APEC and non-APEC Economies.

- The 2nd APEC workshop was held on 16 – 17 July 2008 in Chinese Taipei with 76 participants from 11 APEC and non-APEC Economies.

The pictures from the APEC workshops are shown in Figure 2:

The 1st APEC workshop

The 2nd APEC workshop

Figure 2. The APEC Workshops

2. CURRENT BIODIESEL STANDARDS

The Biodiesel Standards in the APEC region are mostly referenced by EN 14214 and US ASTM (D-6751). European biodiesel specification (EN 14214) is an international standard for biodiesel, which was approved by CEN (European Committee for Standardization). It was set up to control biodiesel quality within the EU and has been used as a guideline for many countries. This standard is mostly based on biodiesel produced from rapeseed and combination of oils that together provides similar characteristics to rapeseed oil. ASTM D-6751 is the standard that covers pure biodiesel (B100), for blending level up to 20% by volume in the US. It was setting up by the American Society for Testing and Materials (ASTM), which is a standard development organization. As this standard was designed for neutral process and feedstock such as soybean that different from EN 14214 specification, some properties of ASTM D-6751 are slightly different from the European specification.

However, feedstock for biodiesel production in European countries (rapeseed oil) and US (soybean oil, used cooking oil) are completely different from those used in the APEC economies (palm oil, jathopha oil, coconut oil). Considerable efforts are being devoted to set up standards and harmonization for biodiesel production in APEC. For better understanding of all issues involved, the current status of biodiesel and biodiesel specification in both APEC economies and non-APEC Economies such as India were reviewed.

The Biodiesel specification of EU, US, APEC and non-APEC economies show in Table 1.

Table 1. The comparison of biodiesel specification of EU, US, APEC and non-APEC economies

Items	EU[1/]	US[1/]	China[1/]	Chinese Taipei[2/]	Indonesia[3/]	Japan[4/]	Korea[5/]	Philippines[6/]	Malaysia[7/]	Thailand[8/]	India[9/]
	EN 14214: 2003	ASTM D6751-07b	GB/T 20828-2007	CNS 15072	SNI 04-7182-2006	JASO M360	Fuel Spec (B100)	DPNS/DOE QS 002:2007	Spec of Palm Methyl Esters	B100-FAME	IS 15607:2005
Methyl ester content (wt%)	>96.5	-	-	>96.5	>96.5	>96.5	>96.5	-	>96.5	>96.5	>96.5
Density at 15°C (kg/m^3)	860-900	-	820-900 (20°C)	860-900	850-890 (40°C)	860-900	860-900	860-900	860-900	860-900	860-900
Viscosity at 40°C (cSt)	3.5-5.0	1.9-6.0	1.9-6.0 (20°C)	3.5-5.0	2.3-6.0	3.5-5.0	1.9-5.0	2.0-4.5	3.5-5.0	3.5-5.0	2.5-6.0
Flash point (°C)	>120	>93	>130	120	>100	>120	>120	>100	>120	>120	120
Sulfur content (ppm)	<10	<15	<50	<10	<100	<10	<10	<0.05	<10	<10	<0.005
Carbon residue on 100% distillation residue (wt%)	-	<0.05	-	-	<0.05	-	-	<0.05	<0.05	-	<0.05
Cetane number	>51	>47	>49	>51	>51	>51	-	>51	>51	>51	>51
Sulfated ash (wt%)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.01	<0.02	<0.02	<0.02	<0.02

Table 1. (Cont.)

Items	EU[1/]	US[1/]	China[1/]	Chinese Taipei[2/]	Indonesia[3/]	Japan[4/]	Korea[5/]	Philippines[6/]	Malaysia[7/]	Thailand[8/]	India[9/]
	EN 14214: 2003	ASTM D6751-07b	GB/T 20828-2007	CNS 15072	SNI 04-7182-2006	JASO M360	Fuel spec (B100)	DPNS/DOE QS 002:2007	Spec of Palm methyl esters	B100-FAME	IS 15607:2005
Water and sediment, (vol%)	-	<0.05	-	-	<0.05	-	<0.05	<0.05	<0.05	-	-
Total contamination (ppm)	<24	-	-	<24	-	<24	-	-	<24	<24	<24
Copper corrosion 3 hours at 50^{o}C (rating)	Class 1	No. 3	Class 1	No.1	Class 3	Class 1	Class 1	No. 1	Class 1	No.1	Class 1
Oxidation stability at 110^{o}C (hours)	>6	>3	>6	>6	-	By mutual agreement	>6	>6	>6	>6	>6
Acid value (mg KOH/g)	<0.5	<0.5	<0.8	<0.5	<0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Iodine value (g Iodine/100 g)	<120	-	-	<120	<115	<120	-	-	<110	<120	Report
Methyl linolenate (wt%)	<12	-	-	<12	-	<12	-	-	<12	<12	-

Table 1. (Cont.)

Items	EU[1/]	US[1/]	China[1/]	Chinese Taipei[2/]	Indonesia[3/]	Japan[4/]	Korea[5/]	Philippines[6/]	Malaysia[7/]	Thailand[8/]	India[9/]
	EN 14214: 2003	ASTM D6751-07b	GB/T 20828-2007	CNS 15072	SNI 04-7182-2006	JASO M360	Fuel spec (B100)	DPNS/DOE QS 002:2007	Spec of Palm methyl esters	B100-FAME	IS 15607:2005
Methanol content (wt%)	<0.2	<0.2 (*)	-	<0.2	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Monoglyceride content (wt%)	<0.8	-	-	<0.8	-	<0.8	-	<0.8	<0.8	<0.8	-
Diglyceride content (wt%)	<0.2	-	-	<0.2	-	<0.2	-	<0.2	<0.2	<0.2	-
Triglyceride content (wt%)	<0.2	-	-	<0.2	-	<0.2	-	<0.2	<0.2	<0.2	-
Free glycerol content (wt%)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-	<0.02	<0.02	<0.02	<0.02
Total glycerol content (wt%)	<0.25	<0.24	<0.24	<0.25	<0.24	<0.25	<0.25	<0.24	<0.25	<0.25	<0.25
Alkali, Na+K (ppm)	<5	<5	-	<5	-	<5	<5	<5	<5	<5	Report
Metals, Ca+Mg (ppm)	<5	<5	-	<5	-	<5	<5	<5	<5	<5	Report
Phosphorous content (ppm)	<10	<10	-	<10	<10	<10	<10	<10	<10	<10	<10

(*) 130°C of flashpoint is available instead of measuring methanol content

3. POTENTIAL FEEDSTOCKS

Biodiesel can be produced from various feedstock such as vegetable oils and animal fats. Each country uses different feedstock depending on their availability and cost. As biodiesel properties depend on the natural characteristic of the feedstock used as raw materials, biodiesel from different countries have different characteristics accordingly. The world oilseeds production in 2006/2007 shows in Table 2.

Table 2. World oilseeds production in 2006/2007

Unit : million metric tons

Country	**Oilseed**						**Oil**
	Soy bean	Rape seed	Sun flower	Peanut	Palm Kernel	Copra	Palm
US	87.00		0.97	1.57			
Brazil	59.00						
Argentina	48.80		3.50				
China	15.97		1.50	12.89			
India	7.69	5.80	1.29	5.39			
Canada	3.46	9.00					
Germany		5.34					
France		4.12	1.39				
UK		1.89					
Poland		1.65					
Russian			6.75				
Ukraine			5.30				
Philippines						2.20	
Indonesia				1.20	4.45	1.44	16.60
Malaysia					3.94		15.29
Thailand							1.17
Others	15.63	17.36	9.11	9.62	1.80	1.62	4.29
World production	**237.55**	**45.16**	**29.81**	**30.67**	**10.19**	**5.26**	**37.35**

Source: http://www.fas.usda.gov/wap/circular/2009/09-01/productionfull01-09.pdf[10/]

Table 3 shows the current potential feedstock for biodiesel production in each country.

Table 3. Potential feedstock for biodiesel production in each country

Country	Potential Feedstock for biodiesel production
Europe	Rapeseed oil, sunflower oil, soybean oil
Australia	Tallow, used cooking oil
Canada	Yellow grease and tallow, canola, mustard, flax, soybean oil
China	Rapeseed oil, used cooking oil, jatropha oil
Chinese Taipei	Used cooking oil, soybean oil, sunflower oil
India	Jatropha oil, rapeseed oil
Japan	Used cooking oil
Indonesia	Palm oil, jatropha oil
Korea	Soybean oil, used cooking oil, palm oil
Philippines	Coconut oil, jatropha oil
Malaysia	Palm oil
New Zealand	Used cooking oil, tallow
Singapore	Palm oil
Thailand	Palm oil, used cooking oil, jatropha oil
US	Soybean oil, sunflower oil, tallow and yellow grease

Biodiesel's quality depends on type of feedstock and their fatty acid composition. Carbon chain length and double bonds of oils affect the oils characteristic such as liquid/solid status of oil in room temperature. Fatty acid compositions of vegetable oils from various types of feedstock are shown in Table 4.

Table 4. Fatty acid composition of vegetable oils [11/]

Feed stock	Fatty acid composition								
	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3
Rapeseed	-	-	-	-	2.0 - 6.0	4.0 - 6.0	52.0 - 65.0	18.0 - 25.0	10.0 - 11.0
Soybean	-	-	-	-	10.0 - 12.0	3.0 - 5.0	18.0 - 26.0	49.0 - 57.0	6.0 - 9.0
Palm	-	-	-	-	40.0 - 47.0	3.0 - 6.0	36.0 - 44.0	6.0 - 12.0	-
Coconut	4.6 - 10.0	5.0 - 10.0	44.0 - 53.0	13.0 - 20.6	7.5 - 10.5	1.0 - 3.5	5.0 - 8.0	1.0 - 2.6	-
Sunflower	-	-	-	-	5.0 - 7.0	3.0 - 6.0	14.0 - 40.0	48.0 - 74.0	-

Natural characteristics of potential feedstock are described as follows:

Rapeseed Oil

Rapeseed, known as *Brassica napus*, has been a principal feedstock for biodiesel production in the EU since 2000. Main rapeseed producers include EU, China, and Canada. Rapeseed is mainly cultivated for animal feeds and rapeseed oil is for human consumption. Its seed has oil content about 38 – 44%. Rapeseed Methyl Ester (RME) has approximately iodine value about 97 g Iodine/100 g which iodine value of rapeseed oil before conversion approximately 94 – 120 g Iodine/100 g. Main composition of rapeseed oil is erucic acid, which is mildly toxic to humans in large doses. For lower levels of erucic acid than traditional, Canada bred *Brassica napus* and *Brassica rapa (campestris)* to became new hybrid called “canola”, which contains about 40% oil content. Currently, Canada is the world top producer of rapeseed.

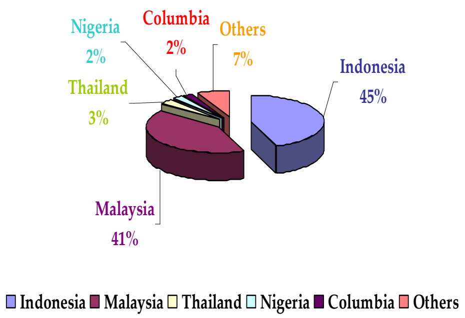
Soybean oil

Soybean is an annual plant, which is predominantly produced in the US which produces approximately 37% of the world’s soybean production. In 2006/2007, the US produced soybean at about 87 million metric ton. Although biodiesel from soybean oil shows good cold flow properties, it shows slightly poor oxidation stability and low cetane numbers. It should be blended with other feedstocks biodiesel to meet the cetane properties requirement[12/].

Palm oil

Palm oil is a potential feedstock for biodiesel production in the APEC region. When compared with other oilseeds, it is considered as the most economic feedstock because of its high yield.

The world palm oil production has increased rapidly from 37.35 million tons in 2006/2007 and projected to 43.22 million tons in 2008/2009. Indonesia and Malaysia are the world palm oil major producers. In 2006/2007 palm oil production in Indonesia and Malaysia were 16.60 million tons and 15.29 million tones which were about 44.4% and 40.9% of the world palm oil production, respectively as shown in Figure 3.



Country	%	tonsx10^6
Indonesia	44.4	16.60
Malaysia	40.9	15.29
Thailand	3.1	1.17
Nigeria	2.2	0.81
Columbia	2.1	0.77
Others	7.3	2.71
World	100	37.35

Figure 3. The world palm oil production in 2006/2007[13/]

Palm oil based biodiesel has high cetane number and high oxidation stability. However, it shows poor cold-flow properties. It is usually blended with other biodiesel when used in cold weather[14/]

Coconut Oil

Coconut is known as *Cocos nucifera Linn*. It has about 70% oil content. Coconut oil contains high saturated and short-chain fatty acids. This leads to better fuel performance in ignition quality and oxidation stability. Coconut oil biodiesel can reduce serious air pollutants such as black smoke and toxic air and lower emission of nitrous oxide and sulfur oxide[15/].

Biodiesel characteristics of various feedstock are shown in Table 5.

Table 5. Biodiesel characteristics of various feedstock

Feed stock	Details	Strong point	Weak point
Rapeseed Oil	▪ Excellent raw material for biodiesel production	▪ CFPP of -10°C to 12°C can be achieved ▪ Has good oxidation stability with low antioxidant additive treats	-
Soybean Oil	▪ Relatively high degree of unsaturation and high proportion of polyunsaturated fatty acid	▪ Good cold flow properties	▪ Relatively poor oxidation stability
Palm Oil	▪ Saturated and unsaturated fatty acids are in nearly equal amount	▪ Give good oxidative stability	▪ Poor cold flow properties
	▪ Contain tocopherols and tocotrienols	▪ Prevent oxidation and long shelf life	-
	▪ High melting point (about 36°C)	▪ It becomes solid in temperate climates and semi-solid in tropical climates	▪ It is not possible to make palm-based biodiesel that meets the CFPP specified in European winter diesel specifications

Table 5._(Cont.)

Feed stock	Details	Strong point	Weak point
Palm Oil (Cont.)	▪ Palm oil biodiesel has high cetane levels	▪ High cetane gives excellent driving characteristics and makes palm-based biodiesel prized as a fuel additive	-
Coconut Oil	▪ High degree of saturation, with shorter than C14 molecule	▪ Good oxidation stability	▪ Biodiesel with low CFPP of -5°C
Sunflower Oil	▪ High, Unsaturated triglyceride oils	-	▪ Significant performance problems including formation of deposits and thickening

Normally biofuels are produced mainly from food crops which are rapeseed oil, soybean oil, palm oils and coconut oil. Recently, people are alerted on world food crisis and food security, these concerns have led to new approach of producing biodiesel from non-food feedstock such as waste cooking oil, jatropha oil, and algae for sustainable production.

Waste Cooking Oil

Waste cooking oil is an alternative feedstock for biofuel that help reduces biodiesel cost. However, it requires chemical treatment for cleaning before processing. The quality of oil depends on such various factors as type of oil used, cooking practices, and storage method. Waste cooking oil biodiesel is good for blending with other biodiesel when use in cold weather because it has higher CFPP than other biodiesel feedstock[16/].

Jatropha Oil

Jatropha, known as *Jatropha curcas Linn.*, is resistant to drought and pests. It can be grown in arid conditions and marginal land. Jatropha seeds and oil are mildly toxic. Its seeds have a high yield of oil. It contains oil about 33.5% of seed by weight. Its oil can be used to produce biodiesel and combusted as fuel. It is a non-food feedstock, so it can reduce competition between food and fuel. In Asia Pacific area, jatropha plantations are being created in India, China, Myanmar, and Philippines.

Algae

Several attempts have been made on using non-food biomass like algae for biofuel production. Algae have faster growing rates than crops. Algae can grow in polluted water and in marginal lands like desert. In addition, CO_2 emission from power plant can be the nutrient for algae cultivation. These issues push algae to be the potential future feedstock for biofuel production. However, problems challenging to the efficient of producing algae as future feedstock are the finding algal strain with a high oil content and faster growth rate together with the designing of cost-effective cultivation system. Currently numerous research works have been conducted for efficient algal fuel production in university and in private sector in many countries. A list of algal fuel producers shows in Table 6.

Table 6. List of algal fuel producers[17/]

Country	Algal fuel producers
Australia	▪ Biomax
Canada	▪ Algae Fuel System, Saskatoon, Canada ▪ International Energy, Inc.
New Zealand	▪ Aquaflow Bionomic Corporation
Spain	▪ AlgaeLink, in Cadiz ▪ Bio Fuel Systems
The Netherlands	▪ AlgaeLink
US	▪ Algae Floating Systems, Inc. ▪ AlgaeFuel, based in Berkeley, California ▪ Algae Fuel System, Ukiah, CA ▪ Algaewheel, based in Indianapolis, Indiana ▪ AlgalOilDiesel, LLP, based in Corvallis, Oregon ▪ Applied Research Associates, Inc., Albuquerque, New Mexico and in Panama City, Florida ▪ Aquatic Energy ▪ Algoil Industries, Inc. ▪ Aurora BioFuels ▪ Blue Marble Energy ▪ Cellana (Shell and HR BioPetroleum) ▪ Chevron Corporation (in collaboration with US-DOE NREL) ▪ Diversified Energy Corporation. ▪ Global Green Solutions ▪ GreenerBioEnergy ▪ GreenFuel Technologies Corporation ▪ Imperium Renewables former Seattle Biodiesel, LLC ▪ Inventure Chemical ▪ Kai BioEnergy Corp. ▪ Live Fuels, Inc. ▪ OriginOil, Los Angeles, CA ▪ PetroSun and Algae BioFuels Inc., Scottsdale, Arizona ▪ Sapphire Energy ▪ Solazyme, Inc. ▪ Solix Biofuels, Boulder, Colorado ▪ Vertigro, El Paso, Texas ▪ Virgin Green Fund

4. LESSON LEARNED ON THE ENGINES, VEHICLES AND EMISSION

While biodiesel has been substantially used for the sake of sustainable energy and environment, there are some concerns on the effect of the use of biodiesel on the engine and its emissions in several countries.

Canada has set up the Climate Change Central (Alberta) Project for demonstrating of blending and distribution within Canada and demonstrating of cold weather operability of biodiesel within Class 8 highway fleet. The tests had been conducted during 1 June 2007 to 31 August 2008. The interim observations showed that no blending issues as well as operation and maintenance issues with the truck fleet were reported.

Chinese Taipei has set up the Green Bus Programs for testing the use of biodiesel on engine since 2007. The biodiesel used for the investigation were produced from soybean and recycled cooking oil and blended with petrol diesel fuel. The city buses were fueled by B2 and B5. The result showed that no malfunction on the fuel pump, filter and injector were observed. For fuel tank corrosion test, there were no significant difference on the use of B2 and B5 compared to diesel fuel. Moreover, under the Green Country Program, B1 has been sold in 297 gas stations. There were no reports on any serious complaint on engine performances and emission issues except slightly lower power loss concerns.

The researchers from Gumma University in Japan studied the effect of biodiesel fuel from esterification of palm oil on direct injection diesel engine performance. They have witnessed that the biodiesel fuel blend ratio had an effect to particulate matter but it didn't effect on the heat release rate and exhaust gas composition.

From OEM side, the Japanese laboratory test was concerned on the effect of oxidative stability on fuel tank corrosion. JAMA suggested that the oxidation stability of 10 hours be necessary to prevent metal tank corrosion. The test with biodiesel of 6 hours oxidation stability, corrosion was observed in metal fuel tank. In addition, the injector deposit problems occurred. With this regard, JAMA has proposed the oxidation stability of 10 hours instead of 6 hours according to EN standard.

In Korea, the field tests on passenger cars with B5 and B20 fuel and on locomotive cars with B20 fuel were conducted. For passenger cars tested with B5 fuel, there were no troubles found in the first year. However, some running troubles and fuel filter plugging were observed in the second year. For passenger cars, the plugging problem was quite serious when tested with B20. It required changing the fuel filters regularly to solve the problem. For locomotive engines tested with B20, the performances of fuel injector and pump passed the permissible range.

In US, there was cooperation between the researchers of West Virginia University and National Renewable Energy Laboratory to investigate the effect of biodiesel from soya methyl ester on heavy trucks. The test was conducted with B35 fuelling in unmodified diesel engine. It was found that by using B35 as fuel, the emission in terms of CO and HC was lower than by using diesel fuel. The engine performance test with B35 had no significant problems found during the test.

The studies on the effect of biodiesel on diesel engine and their emission had been conducted during July 1984 – May 1985 in Malaysia. Preliminary field trials were set up to investigate the effect of palm oil biodiesel (B100) on taxi's engine. During 1986 – 1994, exhaustive engine field trials were set up for testing the effect of palm oil biodiesel B50 and B100 on several types of engine. All of the above, it was found that biodiesel could reduce HC, CO, CO_2, particular matter and smoke emissions except for No_x. Biodiesel was good performance for the engines.

Testing on the effect of the use of biodiesel on engines/vehicles and their emission presents in the Table 7.

Table 7. Lesson learned from the use of biodiesel on the engine and vehicle

Country	Fuel Type	Engine/Vehicle	Conditions	Lesson Learned on Engine and Emission
Canada[18/]	25 RME, 30 HDRD, and 20 ULSD B2, B5 (B5 is 75% Canola and 25% tallow ME)	**Blending and Distribution Test & Cold weather Operability of biodiesel Test** Class 8 high way fleet	▪ B2 used in winter ▪ B5 used from spring though to fall ▪ Cardlocks test locations were established in Edmonton, Lloydminister, and Calgary ▪ Yard tank test location was established in Edmonton	▪ No blending issues were reported ▪ No operational issues with the truck fleet were reported ▪ No maintenance issues with the truck fleet were reported
Chinese Taipei[2/]	B2, B5 (produced from soybean and recycled cooking oil)	**Mechanical fuel system Rig Test** Mechanical fuel injection system consists of fuel pump, filter and injector of 3.5 T truck	▪ 480 hr daily plus 120 hr max torque/ power ▪ Oil change per 120 hr ▪ Spray characteristics, open pressure and leakage and fuel flux were monitored	▪ Change of open pressure/fuel flux <3% ▪ No malfunction observed
	B0, B2, B5 (produced from soybean and recycled cooking oils, no extra acid added)	**Fuel tank corrosion Rig Test** 70 L galvanized steel sheet tank (SECE 40/40) with coating of epoxy-phenolic on the outside surface	▪ Tank bathed in hot water ▪ 2000 hr daily pattern ▪ Tank corrosion, change of water content and total acid in tested fuels were monitored	▪ Minor corrosion observed on inside surfaces ▪ Notable corrosion observed on outside surfaces ▪ No significant difference between B0/B2/B5 cases

Table 7._(Cont.)

Country	Fuel Type	Engine/Vehicle	Conditions	Lesson Learned on Engine and Emission
Japan[19/]	Blend biodiesel fuel	**Marketing experience**	**Real Condition** ▪ Biodiesel was higher concentration of FAME ▪ Impurities of Biodiesel ▪ Biodiesel performance at cold temperature	▪ Fuel tank corrosion because of the lack of oxidation stability in FAME ▪ Degradation of rubbers and plastics were occurred ▪ Forming carbonic acid (adhesive material) was produced and stickled inside filter plugging engine that made pump failure and filter plugging engine stop ▪ Sludge or deposit formation in pump and injectors ▪ Exhaust emission was produced ▪ Cold temperature caused hardly starting
Japan[1/, 20/]	Commercial diesel fuel blended 5% FAME	**Effect of Oxidative Stability on Fuel Tank Corrosion (JAMA)** Metal fuel tank	▪ 2000 hr test with 8 hr at 60°C and 16 hr at normal temperature	▪ Corrosion was observed in fuel tank when using biodiesel with 6 hr. oxidation stability
	Commercial diesel fuel blended 5% FAME with 400 ppm of antioxidant			▪ No corrosion was observed in fuel tank when using biodiesel of 10 hrs. oxidation stability which was improved by adding antioxidant
	B5, B10, B20 (produced from palm oil and blended with diesel fuel) compare with diesel fuel	**Direct Injection Diesel Engine Test** Single-cylinder general-purpose engine was used for testing	▪ Excess air ratio was changed from 1.85 to 3.0	**Engine Performance:** Changing of the blended ratio didn't change the combustion characteristic **Emission:** The amount of particulate matter of B20 more than B 5 and B10

Table 7._(Cont.)

Country	Fuel Type	Engine/Vehicle	Conditions	Lesson Learned on Engine and Emission
Korea[21/]	B5, B20 (produced from canola oil, waste fat)	**Field Tests on Passenger Cars** SANTAFE, SOENTO (Hyundai Inc), REXTON (Ssangyong Inc.)	▪ 60,000 km running for each car ▪ Emission tests every 10,000 km ▪ Check on fuel injection system	**Effecting of B5** ▪ No troubles were found in the first year ▪ Some running troubles were observed in the second year tests ▪ The troubles had been mainly due to fuel filter plugging and removed with the micro filtration of biodiesel
				Effecting of B20 ▪ Troubles were observed even with biodiesel prepared by microfiltration ▪ Monoglycerides were mainly responsible for the troubles ▪ Regular change of the fuel filters is needed to get rid of the troubles
	B20 (produced from canola oil, waste fat)	**Field tests on locomotive** Diesel engine: KTA-19L (Cummings Inc., US)	▪ Running tests for 8 months (October 2006 – May 2007) ▪ After the test, performances of fuel injector and pump have been evaluated by Korea Branch of Cummings Inc.	▪ **Performance of Fuel Pump:** Flow rate and pressure are within the permissible range ▪ **Evaluation of Fuel Injector:** Leakage tests on fuel injector with B20 were passed

Table 7._(Cont.)

Country	Fuel Type	Engine/Vehicle	Conditions	Lesson Learned on Engine and Emission
USA[22/]	B35 (Soya methyl ester) compared with No.2 diesel	**Engine Performance & Emission Tests** Nine heavy trucks with two different types of engines (six trucks were equipped with Cummins 855 engine made in the late 1980s and three trucks were equipped with DDC series 60 engine made in the 1990s) without engine modifications	▪ West Virginia University (WVU) uses their Transportable Heavy Duty Chassis Dynamometer Emissions Testing Laboratory and their conditions for testing engine performance & emission tests	▪ **Engine Performance:** The performance of all vehicles that fueled with biodiesel blends was good. They didn't have fuel-related problem during tests. The fuel economy of them showed that no significant difference between biodiesel blends and diesel. ▪ **Emission Analysis:** B35 and no.2 diesel have similar CO, NO_x and HC emission trends. ❖ The CO and HC emissions level of B35 fueled is lower than no.2 diesel ❖ The NO_x emission of B35 is a bit higher than no.2 diesel\
Malaysia[23/]	B10, B20, B50 (produced from palm oil)	**Stationary Engine Test** Yanmar L70AE-DETMYC	▪ Vary level of engine speed, engine load, and engine break mean effective pressure	▪ **Engine Performance:** Biodiesel and no.2 diesel fuel have similar in terms of thermal efficiency ▪ **Emission Analysis:** All biodiesel blends can reduce CO_2, CO, HC, particular matter and smoke emissions except for NO_x emission

5. NECESSARY ADDITIVES

Biodiesel is considered to have several advantages over fossil fuel such as reducing exhaust emissions, especially soot and carbon monoxide. However, biodiesel possesses poor inherent, cold-flow properties, and oxidation stability when compared to diesel fuel.

Several approaches have been taken to resolve these barriers. The cold-flow properties depend on the type of feedstock used. The higher unsaturated fatty acids, the better cold-flow properties are. The common approach is to select the suitable feedstock for the climate requirement or to use the cold-flow improvers. The other approach to improve the cold-flow properties is through winterization process in which the high melting saturated esters are removed. The lower saturated fatty acids remaining leads to the improvement of the cold-flow properties. By this mean, however, it may effect to its oxidation stability.

Biodiesel is more sensitive to oxidative degradation than petrodiesel. Oxidation stability is a measure of the stability or the shelf life of fuel during storage. The European standard (EN 14214) specifies minimum oxidation stability of 6 hours at 110^{o}C based on the EN 14112 specification or Rancimat test. Oxidation stability of biodiesel depends on the feedstock, processing conditions, contaminants, and storage conditions. The storage conditions include duration, temperature, exposure to air and light, and presence of metals and impurities.

The fatty acid composition of feedstock will directly affects the biodiesel stability. Biodiesel having higher amounts of polyunsaturated fatty acids is less stable than the one having lower amounts of polyunsaturated fatty acids. Figure 4 shows fatty acid profile of various types of biodiesel feedstock. Figure 4 presents that soybean oil containing higher amounts of polyunsaturated is less stable than palm oil which containing lower amounts of polyunsaturated fatty acids.

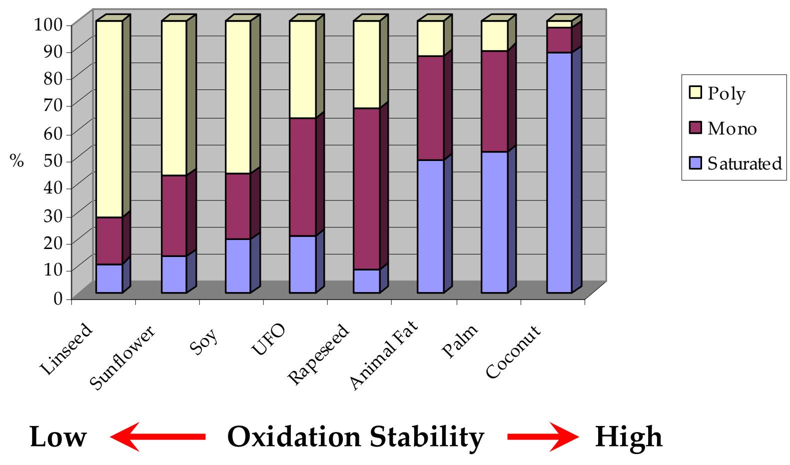


Figure 4. Fatty acid profile of various biodiesel feedstocks[24/]

Natural or synthetic antioxidant additives have been studied to improve the oxidation stability. Numerous attempts on searching efficient antioxidant additives for biodiesel have been conducted in governmental agencies, research institutes, and chemical companies.

Table 8 shows the effect of antioxidant additives on oxidation stability of biodiesel from various oils. The data shows that the biodiesel fuels produced from sunflower, soybean oil and the distilled biodiesel have induction period of lower than 6 hours. The synthetic antioxidants pyrogallol (PY), propylgallate (PG), TBHQ, and BHA could enhance the induction period tremendously[25/]. The effectiveness of antioxidant depends on the kind of feedstock used for biodiesel production. Beside the above mentioned antioxidants, other new synthetic antioxidants also been introduced for extending the shelf life of biodiesels from various feedstocks. Application of high amount of certain antioxidants might affect on other fuel properties. The studies of Baynox, DTBHQ, Vulkanox ZKF, Ionox 220, Vulkanox BKF as antioxidants in rapeseed oil methyl ester, distilled cooking oil methyl ester and tallow methyl ester showed adverse effect on other fuel properties as described below[26/] :

- With the use of 1,000 mg/kg antioxidant, it had no impact on other parameters which were the viscosity, density, CFPP, carbon residue and sulphated ash content, except acid value. When using Vulkanox ZKF as additive in the biodiesel of high acid value, acid values increased strongly outside the given limit of 0.5 mg KOH/g.
- With the use of 250 mg/kg antioxidant, it showed no impact of all parameters including acid value. All parameters were within the given limit even with the biodiesel of high acid value up to 0.42 mg KOH/g.

Table 8. The effect of antioxidant additives on oxidation stability of biodiesel from various oils

Antioxidant additives	Biodiesel from oils	Induction period With no additive (hrs.)	Additive amount (ppm)	Induction Period With additive (hrs.)	Reference
PY	undistilled RME (distilled RME)	9 (3.5)	250	22. (11.5)	Mittelbach (2003)[25/]
PG	undistilled RME (distilled RME)	9 (3.5)	250	17 (6.5)	Mittelbach (2003)[25/]
BHA	undistilled RME (distilled RME)	9 (3.5)	250	17 (10)	Mittelbach (2003)[25/]
PY	undistilled frying oil (distilled RME)	6 (4)	250	24 (18)	Mittelbach (2003)[25/]
PG	undistilled frying oil (distilled RME)	6 (4)	250	19 (12.5)	Mittelbach (2003)[25/]
BHA	undistilled frying oil (distilled RME)	6 (4)	250	9 (9)	Mittelbach (2003)[25/]
PY	undistilled SME (distilled RME)	3.5 (1.1)	250	11 (1.2)	Mittelbach (2003)[25/]
PG	undistilled SME (distilled RME)	3.5 (1.1)	250	7 (1.6)	Mittelbach (2003)[25/]
TBHQ	undistilled SME (distilled RME)	3.5 (1.1)	1,000	5.8 (6.4)	Mittelbach (2003)[25/]
Baynox	RME	4.60	250	7.0	Mittelbach (2004) [26/]
Vulkanox ZKF, Vulkanox BKF, Ionox 220, DTBHQ	RME	4.60	1,000	>7.4-9.4	Mittelbach (2004) [26/]
Baynox, DTBHQ, Vulkanox ZKF, Vulkanox BKF, Ionox 220	RCOME	7.50	250	>8.0-17.0	Mittelbach (2004) [26/]

Table 8._(Cont.)

Antioxidant additives	Biodiesel from oils	Induction period With no additive (hrs.)	Additive amount (ppm)	Induction Period With additive (hrs.)	Reference
Baynox, Vulkanox ZKF, Vulkanox BKF, Ionox 220, DTBHQ,	RCOME	7.50	1,000	>11.8-34.1	Mittelbach (2004) [26/]
Vulkanox BKF	DRCOME	2.00	250	8.0	Mittelbach (2004) [26/]
Baynox, DTBHQ, Vulkanox ZKF, Ionox 220, Vulkanox BKF	DRCOME	2.00	1,000	>11.0-26.5	Mittelbach (2004) [26/]
Kerobit® TP 26	Depending mainly on biodiesel quality		(Recommended 200-1,000 ppm)		BASF[27/]
Kerobit® 3627	Biodiesel from pure plant oil		(Recommended 100-500 ppm)		BASF[27/]
	RME	7.20	300	11.50	BASF[27/]
	SME	4.20	800	7.80	BASF[27/]
TBHQ, BHA	Distilled SBME	0.77	500	>6.0	Tang (2008)[28/]
PY	Distilled SBME	0.77	1,000	>6.0	Tang (2008)[28/]
VitaminE, BHA, TBHQ, PG	Used Frying Palm Oil Methyl Ester	3.42	100	>6.0	Loh (2006) [29/]
BHA, PG	Used Frying Palm Oil Methyl Ester	3.42	250	>6.0 and storage for 5 weeks	Loh (2006) [29/]

Table 8._(Cont.)

Antioxidant additives	Biodiesel from oils	Induction period With no additive (hrs.)	Additive amount (ppm)	InductionPeriod With additive (hrs.)	Reference
VitaminE, BHT, TBHQ	Used Frying Palm Oil Methyl Ester	3.42	500	>6.0 and storage for 5 weeks	Loh (2006) [29/]
None	Fresh Palm Oil Methy lEster	23.30	-	-	Loh (2006) [29/]
None	Palm Oil Methyl Ester From Spent Bleaching Earth	14.60	-	-	Loh (2006) [29/]
PY	Palm Oil Methyl Ester	10.80	50	21.8 and maintaining > 6 hrs for 7 weeks storage	Thanmongkhon (2008) [30/]
TBHQ	Palm Oil Methyl Ester	10.80	50	14.2 and maintaining > 6 hrs for 7 weeks storage	Thanmongkhon (2008) [30/]
Kerobit 3627	B10		Recommend highest addition 500 mg/kg	8	[31/]
Chimec CH 4636	B10		"	8	[31/]
Chimec R 876 HFP	B10		"	8	[31/]
IRGASTAB BD 100	B10		"	8	[31/]
IRGASTAB BD 50	B10		Recommend highest addition 500 mg/kg	8	[31/]
R120	B10		"	8	[31/]

Table 8._(Cont.)

Antioxidant additives	Biodiesel from oils	Induction period With no additive (hrs.)	Additive amount (ppm)	InductionPeriod With additive (hrs.)	Reference
R130	B10		"	8	31/
BioStable ™ 403E	B10		"	8	31/
DIESOLIFT BD-3	B10		"	8	31/
BF320	B10		"	8	31/
Baynox plus	B10		"	8	31/
BioExtend 30 HP	B10		"	8	31/
IONOL BF200	B10		"	8	31/
Vitamin E	Crude Palm Oil Methyl Ester		644	25.70	Yung (2006) 32/
α-Tocopherol	Distilled Palm Oil Methyl Esters	3.52	1000	6.17	Yung (2006) 32/
BHT	Distilled Palm Oil Methyl Esters	3.52	50	6.42	Yung (2006) 32/
TBHQ	Distilled Palm Oil Methyl Esters	3.52	50	8.85	Yung (2006) 32/

6. RELATED WORKS ON BIODIESEL FUEL STANDARDS

Related works on biodiesel fuel standards are actively progressing in international forums. Those projects are focusing on the alignment of biodiesel specifications and promoting the biodiesel for sustainable consumption and production.

6.1 Internationally Compatible Biodiesel Standards : Tripartite task force

Biodiesel Tripartite task force[33/] was an initiative of the three governments of Brazil, the European Commission, and the United Stated of America, which aimed to clarify and identify the existing biofuels standards in order to promote harmonization in the global biofuels markets and drives away the disadvantage of biofuels among the three regions. The resulting standard – classified biodiesel specification, which refer to individual parameters, their values, and related test methods, - is presented in the "White Paper on Internationally Compatible Biofuels Standards" as follows:

- *Category A*: similar (sulfated ash, alkali and alkaline earth metal content, free glycerol content, copper strip corrosion, methanol and ethanol content, acid number)

- *Category B*: significant differences between parameters and methods (total glycerol number, phosphorus content, carbon residue, ester content, distillation temperature, flash point, total contamination, water content and sediment)

- *Category C*: fundamental differences (sulfur content, cold climate operability, cetane number, oxidation stability, mono-, di-, tri-acylglycerides, density, kinematic viscosity, iodine number, linolenic acid content, polyunsaturated methyl ester)

It can be summarized that, to harmonize and align the standards of the three parties, the parameters in Category A indicated as *easily done* in alignment, while those in Category B and C are *feasible with some efforts* and *not feasible at present*, respectively. Biodiesel standards in Brazil and US are applicable to FAME and FAEE using for a blend stock of diesel fuel while that in EU are applicable to FAME in both of using directly as diesel fuel (or so-called B100) and using as a blend stock for diesel fuel. Some parameters are currently not aligned. Their non-alignment may have low impact when using in different regions and purposes. That is the use as fuel for heavy duty vehicles or for passenger cars. But these low impact parameters may need huge efforts to be aligned.

6.2 ERIA project: Working group for "Benchmarking of biodiesel fuel standardization for vehicles in East Asia"

Economic Research Institute for ASEAN and East Asia (ERIA) [1/] is an international organization that was established with an aim to promote the economic integration in East Asia. The project entitled "Benchmarking of Biodiesel Fuel Standardization for Vehicles in East Asia" was launched to benchmark biodiesel standard in Ease Asia region. Members of this working group from 12 countries in East Asia region jointly worked on the harmonization of biodiesel standards for East Asia region based on the EU standard. As the EU or EN 14214 standard was developed mainly on the properties of European feedstock, the ERIA has brought the properties of feedstock available in East Asia into their consideration.

In the process of developing benchmarking standard, the oxidation stability was raised up as a critical issue. It has a crucial impact on metal fuel tanks which popularly used for vehicles in Asia. The current oxidation stability of 6 hours is insufficient for preventing metal tank corrosion. It was recommended that oxidation stability should be 10 hours. Moreover, polyunsaturated FAME are easily oxidized and form sludge in fuel tank, the substances formed from the oxidation process cause seriously influence on engine performance. Thus, polyunsaturated FAME especially those produced from fish oil which consisting of more than 4 double bond should not be used.

The ERIA biodiesel fuel Standard was proposed and recognized at the Second EAS Energy Ministers Meeting on 7 August 2008 in Bangkok, Thailand. EAS-ERIA biodiesel fuel benchmark standard: 2008 shows in Table 9. It had been set up for B100 aiming for low level blending with diesel fuel.

Table 9. EAS-ERIA biodiesel fuel benchmark standard: 2008

Items	Units	EAS-ERIA Biodiesel Fuel Benchmark Standard: 2008
Ester content	mass%	96.5 min
Density	kg/m^3	860 - 900
Viscosity	mm^2/s	2.00 – 5.00
Flash point	^oC	100 min
Sulfur content	mass%	0.0010 max
Distillation, T90	^oC	-
Carbon residue (100%) or Carbon residue (10%)	mass%	0.05 max 0.3 max
Cetane number	- -	51.0 min
Sulfated ash	mass%	0.02 max
Water content	mg/kg	500 max
Total contamination	mg/kg	24 max
Copper corrosion	- -	Class-1
Oxidation stability	hrs.	10.0 min[1]
Acid value	mgKOH/g	0.50 max
Iodine value	g Iodine/100 g	Reported[2]
Methyl Linolenate	mass%	12.0 max
Polyunsaturated FAME (more than 4 double bonds)	mass%	N.D.[2]
Methanol content	mass%	0.20 max
Monoglyceride content	mass%	0.80 max
Diglyceride content	mass%	0.20 max
Triglyceride content	mass%	0.20 max
Free glycerol content	mass%	0.02 max
Total glycerol content	mass%	0.25 max
Na+K	mg/kg	5.0 max
Ca+Mg	mg/kg	5.0 max
Phosphorous content	mg/kg	10.0 max

[1] Need more data & discussion from 6 to 10 hours

[2] Need more data and further discussion

Source: ERIA (2008) ERIA Research Project Report 2007 No. 6-2
"Benchmarking of Biodiesel Fuel Standardization in East Asia"[1/]

6.3 World wide fuel charter (WWFC)

World wide fuel charter (WWFC)[34/] was created in 1998 among the four alliances including European Automobile manufacturers Association (ACEA), Alliance of Automobile Manufacturers, Engine Manufacturers Association (EMA), and Japan Automobile Manufacturers Association (JAMA). It was intended to promote understanding of the impact of fuel quality on engine, vehicle emissions, and performance as well as the harmonization of fuel quality worldwide that needed in different markets. The first edition of WWFC Biodiesel Guidelines, and Ethanol Guidelines were drafted and called for comments until 1 October 2008. The summary of specifications for B100 blendstock with test method is shown in Table 10.

Table 10. WWFC guidelines for B100 blendstock for using in B5 blends

Property	Value	Units	Test Methods
Ester content	96.5 min	% m/m	ISO: EN 14103 mod; EN 14078 Other: ABNT NBR 15342
Density	0.86 – 0.90	g/ml @ 15°C	ISO: EN 3675 ASTM: D4052 JIS: K 2249 Other: EN 12185 ABNT NBR 7148/14065
Kinematic Viscosity	2.0 – 5.0[1]	mm^2/s @ 40°C	ISO: EN 3104 ASTM: D445 JIS: K 2283 Other: ABNT NBR 10441
Flash Point	100 min	°C	ISO: 2719 ASTM: D93
Sulfur	10 max	ppm	ISO: EN 20846/20884 ASTM: D5453/D2622 JIS: K3541-1, -2, -6 or -7
Carbon Residue: Ramsbottom, on 100% distillation residue	0.05 max	% m/m	ASTM: D4530

Table 10._(Cont.)

Property	Value	Units	Test Methods
Cetane Number	51 min		ISO: 5165 ASTM: D613 JIS: K 2280
Sulfated Ash	0.005 max	% m/m	ISO: EN 3987 ASTM: D874 Other: ABNT NBR 984
Water	500 max	mg/kg (ppm)	ISO: EN 12937
Water and Sediment	0.05 max	% v/v	ASTM: D2709
Total Contamination	24 max	mg/kg	ISO: EN 12662 ASTM: D2276, D5452, D6217
Corrosion: Ferrous	Light rusting, max	Rating	ASTM: D665, Procedure A
Oxidation Stability: Induction Period	10 min	hr	ISO: EN 14112 or prEN 15751 as alternative
Total Acid Number	0.5 max	Mg KOH/g	ISO: EN 6618, EN 14104 ASTM: D664, D974 JIS: K 2501 Other: ABNT NBR 14448
Iodine Number	130 max [2]	g I_2/100 g	ISO: EN 14111 (for use on B100 only, not blends)
Linolenic acid methyl ester	12.0 max	% m/m	ISO: EN 14103 mod
Polyunsaturated acid methyl ester (≥4 double bonds)	1 max	% m/m	ISO: prEN 15799
Methanol	0.20 max	% m/m	ISO: EN 14110 JIS: K 2536 Other: ABNT NBR 15343
Glycerides			ISO: EN 14105
Mono-glyceride	0.80 max	% m/m	ISO: EN 14105 Other: ABNT NBR 15342
Di-glyceride	0.20 max	% m/m	ISO: EN 14105 Other: ABNT NBR 15342
Tri-glyceride	0.20 max	% m/m	ISO: EN 14105 Other: ABNT NBR 15342

Table 10._(Cont.)

Property	Value	Units	Test Methods
Glycerin (glycerol)			
Free glycerin	0.02 max	% m/m	ISO: EN 14105/14106 ASTM: D6584 Other: ABNT NBR 15341
Total glycerin	0.24 max	% m/m	ISO: EN 14105 ASTM: D6584 Other: ABNT NBR 15344
Alkali metals (Na+K)	5 max	ppm	ISO: EN 14108/14109, EN 14538
Alkaline metals (Ca+Mg)	5 max	ppm	ISO: EN 14538
Phosphorus	4 max	ppm	ISO: EN 14107 ASTM: D4951, D3231
Ash Content	0.001 max	% m/m	ISO: EN 6245 ASTM: D482 JIS: K 2272
Trace Metals	No addition		ASTM D7111

[1] For temperatures at or below –20°C, viscosity should be at or below 48 mm²/s to avoid potentially dangerous loads on the fuel injection pump drive system

[2] May unnecessarily preclude certain feedstocks

Source: WWFC (2008) "Proposal of the World Wide Fuel Charter (WWFC) Guidelines"[34/]

The comparison of US, EU, ERIA and WWFC biodiesel specification is shown in Table 11.

Table 11. The comparison of US, EU, ERIA and WWFC biodiesel specification

Property	Units	US ASTM D6751-07b	EU EN14214: 2003	ERIA EAS-ERIA Biodiesel Fuel Benchmark Standard: 2008	WWFC (For B100 Blendstock for use in B5 Blends)
Ester content	mass%	-	96.5 min	96.5 min	96.5 min
Density	kg/m^3	-	860 - 900	860 - 900	860 – 900
Viscosity	mm^2/s	1.9 - 6.0	3.5 - 5.0	2.0 - 5.0	2.0 - 5.0 [1]
Flashpoint	°C	93 min	120 min	100 min	100 min
Sulfur content	mass%	0.0015 max	0.0010 max	0.0010 max	0.0010 max
Carbon residue (100%)	mass%	0.05 max	-	0.05 max	0.05 max
Cetane number	- -	47.0 min	51.0 min	51.0 min	51 min
Sulfated ash	mass%	0.02 max	0.02 max	0.02 max	0.005 max
Water content	mg/kg	-	500 max	500 max	500 max
Water and sediment	vol%	0.05 max	-	-	0.05 max
Total contamination	mg/kg	-	24 max	24 max	24 max
Copper corrosion	rating	No. 3	Class 1	Class 1	Light rusting, max
Oxidation stability	hrs.	3.0 min	6.0 min	10.0 min [2]	10 min
Acid value	mgKOH/g	0.50 max	0.50 max	0.50 max	0.5 max
Iodine value	g I_2/100 g	-	120 max	Reported [3]	130 max [4]
Methyl Linolenate	mass%	-	12.0 max	12.0 max	12.0 max
Polyunsaturated FAME	mass%	-	1 max	N.D. [3]	1 max
Methanol content	mass%	0.20 max [5]	0.20 max	0.20 max	0.20 max
Monoglyceride content	mass%	-	0.80 max	0.80 max	0.80 max
Diglyceride content	mass%	-	0.20 max	0.20 max	0.20 max
Triglyceride content	mass%	-	0.20 max	0.20 max	0.20 max
Free glycerol content	mass%	0.02 max	0.02 max	0.02 max	0.02 max
Total glycerol content	mass%	0.24 max	0.25 max	0.25 max	0.24 max
Na+K	mg/kg	5.0 max	5.0 max	5.0 max	5.0 max
Ca+Mg	mg/kg	5.0 max	5.0 max	5.0 max	5.0 max
Phosphorous content	mg/kg	10.0 max	10.0 max	10.0 max	4.0 max

[1] For temperatures at or below –20°C, viscosity should be at or below 48 mm^2/s to avoid potentially dangerous loads on the fuel injection pump drive system

[2] Need more data & discussion from 6 to 10 hours

[3] Need more data and further discussion

[4] May unnecessarily preclude certain feedstocks

[5] 130°C of flashpoint is available instead of measuring methanol content

6.4 ISO/TC 28 [35/]

ISO/TC 28 was set up by the "International Organization for Standardization: Technical Committee 28" as a reference for many different types of petroleum products and lubricants in US and international. The prime aim of ISO/TC 28 is to extend the scopes of existing standards and developing new standards to the acceptable level and fulfill the needs of the international community.

To the extend of Biofuel production quality, ISO TC28/SC7 is a new technical committee formed by ISO to deal with liquid biofuel. There are three working groups being proposed including TC28/SC7/WG1 on bioethanol, TC28/SC7/WG2 on biodiesel, and TC28/SC7/WG3 joint working group (JWG) with TC34/SC11 input/output quality for feedstock and fatty acid esters used in biodiesel.

6.5 Roundtable on sustainable biofuels (RSB) [36/]

Unlike the above mentioned biodiesel standards which deal with the technical fuel properties, the Roundtable on Sustainable Biofuels or RSB developed draft global standards for sustainable biofuels production and processing. The RSB aims to address the potential impacts as unintended consequences of the farmers and biodiesel producers' activities. The standard for global stakeholder feedback on "Version Zero" of its sustainability principles and criteria was proposed since August 13th 2008. It includes ***principles*** (general principles of sustainable production), and ***criteria*** (conditions to be achieve these principles). The "Version Zero" draft standard includes the following issues:

1. Legality
2. Consultation, planning, and monitoring
3. Greenhouse gas emissions
4. Human and labour rights
5. Rural and social development
6. Food security
7. Conservation
8. Soil
9. Water
10. Air
11. Economic efficiency, technology, and continuous improvement
12. Land right

7. OPPORTUNITIES, GAPS, BARRIERS AND LESSON LEARNED

At the second workshop, held on July 2008 in Chinese Taipei, the participants shared their experiences and ideas about barriers, needs and lesson learned of the use of biodiesel on the engine and the emissions in the roundtable discussion as shown in Table 12.

Table 12. Barriers, needs, and lesson learned of the use of biodiesel on the engine and the emissions

Description	Barriers	Needs	Lesson Learned
Standard	▪ Difficulty of setting up neutral specifications from various feedstock ▪ Non-neutral standard like EN standard is difficult to adaptation of feedstock ▪ Current specification isn't appropriate for new engine technology ▪ Lack of coordination among various discipline ▪ Using performance-base specification for meaningful results with reasonable limit based on science	▪ Standard should be designed for feedstock and process neutral and fit to use as specified blend ▪ Difference of oxidation stability should be considered. ▪ Quality enforcement once feedstock/process neutral standard is obtained (for producer, distributor and end users) e.g. BQ9000 ▪ Specify country acceptance on BDF specification	▪ Current testing method to measure ester content is not appropriate for PME & CME ▪ Mono-glyceride content limit is required for different biodiesel (for feedstock neutral) ▪ Maybe more appropriate to have many vegetable-oil standard than a single one for all

Table 12._(Cont.)

Description	Barriers	Needs	Lesson Learned
Feedstock	▪ Competition between food & fuel in the future ▪ Lack of verifiable sustainability information ▪ Difficulty of defining sustainable agricultural practice	▪ Sustainable feedstock is required (not compete with food) ▪ Sustainable issue for the future must be concerned, e.g. new feedstock, process ▪ FAEE in the future due to increasing methanol price in the future	▪ BDF maybe a temporary solution for diesel engine. How about BTL and other new generation fuel
Technical	▪ No technical support for adding the iodine value specification to WWFC standard ▪ Suitable choices for engine oil ▪ Maintain process-quality relationship ▪ Chemical process needs further improvement not optimized for Jatropha feedstock	▪ Technological support requires for different feedstock, process ▪ Handling about water contamination in humid countries after B100 processing ▪ Extensive technical evidence required for modification to existing standard ▪ Effects of various properties on engine ▪ Less sophisticated and less expensive test method ▪ Upper limit of the blend and recommendation for engine designers in the future (is it B100, B20 or others?)	▪ Technical development information must be shared ▪ Moisture content easily increases during transportation of fuel from refinery to gas station ▪ Different requirement for light vs. heavy duty vehicle ▪ Accessible testing methodology is the key for quality control

Table 12._(Cont.)

Description	Barriers	Needs	Lesson Learned
Technical (Cont.)		▪ True understanding of chemical property limit e.g. iodine value ▪ Urgently establish technological working group to make recommendation to EWG for micro-algae derived biodiesel commercialization ▪ A quickly test at gas station to protect end- users from false blending of community standard BDF	
Economic	▪ Different economy has different infrastructure, e.g. vehicle type & system	▪ Different economy requires common guideline on biodiesel usage ▪ Agreed testing method is required for cross-border trading ▪ Export market is required and fleet test data done in APEC must be reported to the rest of the world	▪ It's not a good idea to estimate quality management system equally important as setting an APEC standard due to various differences among economy

Table 12._(Cont.)

Description	Barriers	Needs	Lesson Learned
Political & Social	▪ Negative mindset from end-users ▪ Lack of financial support for sustainable development ▪ Hesitation to promote biofuel after new reports coming out. It needs further tests to confirm the results	▪ Reasonable standard is required to protect consumer while promoting biodiesel ▪ Accessible channel and cheap test lab sponsored by government ▪ Recommend the adoption of B5 as a method of facilitation the implementation of biodiesel trade in the APEC region	▪ Complicated value chain for BDF ▪ One incident doesn't imply for all bad experience on specific incident ▪ Industry can manage to comply with whatever standard set forth by government
Cooperation	▪ Difficulty of traceability/repeatability on data ▪ Common understanding of the real experience in trust equation from engine manufacture, fuel provider, government body	▪ Information exchange among the APEC members, e.g. successful implementation methodology, benchmark standard ▪ Collaborative work effort to save time, budget ▪ Coordination/cooperation on micro-algae research	▪ Information exchange is good ▪ Impossible to promote biodiesel without supports from all stakeholders ▪ Vehicle owner's feedback is value for proper consideration of vehicle safety

8. CONCLUSIONS

As a result of the project initiated by the APEC Energy Working Group's Expert Group on New and Renewable Energy Technologies under the APEC 21st Century Renewable Energy Development Initiative Collaborative IX, this project was undertaken to promote the development of standardization of biodiesel produced in the APEC region.

To responding the project objective, the current biodiesel standards, potential feedstocks, and lessons learned from the use of biodiesel were reviewed in this report in order to provide useful information for building up the capacity, and expanding the knowledge and awareness of the APEC economies in contribution to the establishment the guideline for development of biodiesel standard. Valuable ideas concerning the barriers, needs, and opportunities have been brought together from key eminent experts. Yet, the information gained from the workshops, particularly the oxidation stability requirement, for example, reflects one of the difficulties in setting up a neutral biodiesel standard in the APEC region. There is no unique solution to set up a biodiesel standard in this region since there are many critical factors such as climate, feedstock, and vehicle type. It was suggested to increase such cooperative activities as information exchange and technical support among governments, businesses, organizations, and individuals from the APEC member economies.

The report is therefore a contribution to a better understanding of the current status and the possible way forward for biodiesel standards in the APEC and as a beginning step for further discussions. It can be used as background for future cooperative projects in view of the trade impacts of biodiesel standards in the APEC region.

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10. APPENDICES

Appendix A. Participants

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