APPENDICES

APPENDIX A

Specifications of Thai biodiesel standards

A-1 Biodiesel standards for agricultural engines (Community biodiesel)

Property	Unit	Limits		Test Method
		Min	Max	
Density at 15 ^oC	kg/m^3	860	900	ASTM D 1298
Viscosity at 40 ^oC	cSt	1.9	8.0	ASTM D 445
Flash point	^oC	120	-	ASTM D 93
Sulphur	%wt	-	0.0015	ASTM D 2622
Cetane number	-	47	-	ASTM D 613
Sulphated ash	%wt	-	0.02	ASTM D 874
Water and sediment	%wt	-	0.2	ASTM D 2709
Copper Strip Corrosion	-	-	No.3	ASTM D 130
Acid value	mg KOH/g	-	0.50	ASTM D 664
Free glycerin	%wt	-	0.2	ASTM D 6584
Total glycerin	%wt	-	1.5	ASTM D 6584
Color			Purple	Test by eyes
Additive	To follow the permission of the Director General of the Department of Energy Busines			

Source: Department of Energy Business (2006)

APPENDIX B

PM and PAH determinations

C-1 Calculation of sampler calibration [30]

Sampling at Rajamangala University of Technology Lanna

Sampling condition

Sampling temperature: 318.2 K   Actual ambient pressure: 726.4 mmHg

The calibration was performed by MiniFlo calibration; serial number MNF 1500, which that of calibration equation was y= 5.6637x + 0.0048 and r^2 was 0.9998. Air sampler was calculated by using MiniVol Tools program version 2.0.

C-2 Calibration sheet

Q_{ind} (l/min)	ΔH inched of water	Q_{act} (l/min)	Q@std (l/min)	Q_{calc} (l/min)	Different (%)
6.50	1.53	7.115	6.734	6.732	-0.03
6.00	1.91	6.635	6.279	6.267	-0.20
5.50	2.25	6.105	5.778	5.801	0.41
5.00	2.65	5.626	5.324	5.336	0.22
4.50	3.13	5.814	4.906	4.871	-0.72
4.00	3.60	4.640	4.391	4.406	0.32

Where Q_{ind} = a rotameter indicated flow rate, l/min

ΔH = transfer standard pressure, inches of water

Q_{act} = actual flow rate, l/min

$Q_{@std}$ = standard correction flow rate, l/min

Q_{calc} is a calculated flow rate, l/min (from the linear regression)

Sample calibration equation was $Q_{@std} = 0.9305Q_{ind} + 0.6835$ or $y = 0.9305x + 0.6835$ and r^2 was 0.9994.

C-3 Calculation of PM concentration emission (mg/m^3)

To calculate the PM concentration (mg/m^3) for a sample taken with the MiniVol sampler, the volume of air that passed through the filter at experiment condition must be calculated [28].

1. Calculate the air flow rate at ambient conditions, Q_{act}, using Equation C1. The slope, m_{vol}, and intercept, b_{vol}, of the sampler calibration are obtained from the calibration sheet in Table C-1. For this sampler $m_{vol} = 0.9305$ and $b_{vol} = 0.6835$.

$$Q_{act} = (m_{vol}Q_{ind} + V_{vol}) \times \sqrt{\frac{P_{std}}{P_{act}} \times \frac{T_{act}}{T_{std}}} \qquad \text{(C1)}$$

Where Q_{act} = actual flow rate at ambient condition (L/min)

Q_{ind} = rotameter indicated flow rate (L/min)

m_{vol} = slope of sampler flow rate calibration relationship, 0.9305

b_{vol} = intercept of sampler flow rate calibration relationship, 0.6835

P_{std} = standard pressure, 760 mmHg

P_{act} = actual ambient pressure (mmHg)

T_{std} = standard temperature, 298 K

T_{act} = actual ambient temperature (K)

2. Calculate the volume of exhaust that passed through the filter during the sampling period at actual ambient conditions, V_{act} (m^3) using equation below (C2).

$$V_{act} = \frac{60_{min/hr} \times Q_{act(L/min)} \times t_{hr}}{1000_{(L/m^3)}} \quad \text{(C2)}$$

Where t_{hr} = sampling period, hr

3. Calculate the concentration of PM, divide the net mass gain of the filter by the volume of exhaust that passed through the filter, using equation below (C3).

$$[PM]_{act} = \frac{M_{PM}}{V_{act}} \quad \text{(C3)}$$

Where $[PM]_{act}$ = PM concentration (mg/m^3)

M_{PM} = Mass of particulate matter collected on the filter (mg)

Sample calculation of PM concentration

Sample no. CD(B2)-1

1. To calculated the sampler flow rate at ambient condition, Q_{act} (l/min)

$$Q_{act} = (0.9305 \times 5.0 + 0.6835) \times \sqrt{\frac{760}{726.4} \times \frac{318.2}{298}}$$

= 5.6 L/min

2. To calculated volume of air, V_{act} (m^3) in 5 minute

$$V_{act} = \frac{5.6_{L/min} \times 5_{min}}{1000_{L/m^3}}$$

= 0.028 m^3

3. To calculated PM concentration (mg/m^3)

Pre-exposure weight = 65.594 mg

Post-exposure weight = 65.732 mg

$$[\mathrm{PM}]_{\mathrm{std}} = \frac{65.732 - 65.594}{0.028}$$

$$= 4.92\ \mathrm{mg/\ m^3}$$

C-4 Calculation of PAH concentration emission (μg/m^3)

To calculate the 1-NP concentration (μg/m^3) in exhaust particles from agricultural diesel engine, calibration curves of 1-NP standards was obtained from the raw data in the investigation of Ohno *et al.* [23]. =1-NP concentration in extract solution (x, μg/mL) was calculated from linear regression of those. Calculate 1-NP concentration in the actual volume of collected exhaust (x´, μg/m^3) using equation below

$$x' = \frac{X_{\mu g/mL} \times V_{extract(mL)}}{V_{act(m^3)}}$$

Whereas $V_{extract}$ = extract volume (mL)

APPENDIX C

1-NP emission data of various tested fuels (μg/m^3)

Replication		CD(B5)	CBU (CB50)	CBS (CB50)	CBU (CB100)	CBS (CB100)	CD(B2)
1		103.27	142.41	32.36	81.49	128.03	245.88
2		95.65	58.26	20.93	97.73	106.99	177.86
3		141.40	68.13	81.45	87.02	101.30	200.95
Mean		113.44	89.60	44.91	88.75	112.11	208.23
SD		24.51	46.00	32.15	8.26	14.08	34.59
CV (%)		21.61	51.34	71.59	9.30	12.56	16.61
95% Confidence Interval for Mean	Lower Bound	52.16	-25.40	-35.47	68.11	76.91	121.76
	Upper Bound	174.72	204.60	125.30	109.39	147.31	294.70
p*-value					0.01		

NA; data not available

*Significant difference p<0.05 between groups

APPENDIX D

Engine performance determination

E-1 Calculation of brake specific fuel consumption (BSFC) and thermal efficiency

To calculate the brake specific fuel consumption (BSFC) and thermal efficiency of agricultural diesel engine which is fueled with test fuel, the brake power output of the engine must be calculated.

1. Calculation the brake power (BP, kW) of engine which is equal to the force it exerts multiplied by its velocity using equation D1 and D2. In rotational systems, power is related to the torque (τ) and angular velocity (ω). The magnitude of torque depends on the force (F) applied and the length of the lever arm connecting the axis to the point of force application (r) which the length of the lever arm vector of test [52].

$$\mathrm{BP} = \tau \times \omega \qquad \text{(D1)}$$

or

$$\mathrm{BP} = \tau \times \frac{2\pi\,\mathrm{N}}{60} \qquad \text{(D2)}$$

Where $\tau\,(\mathrm{Nm}) = \mathrm{r} \times \mathrm{F}$; r is the lever arm vector of test engine which is 0.24 meter and F is the magnitude of the force applied which obtained from load applied.

N = engine speed (rpm)

2. Calculation the BSFC (kg/kWh) of fuel efficiency within a shaft reciprocating using equation 3 and thermal efficiency using equation D3.

$$\mathrm{BSFC} = \frac{\mathrm{mf}}{\mathrm{BP}} \qquad \text{(D3)}$$

Where mf = fuel consumption (kg/h) and BP is brake power as is defined above.

3. Calculation the thermal efficiency (TE, %) which is the efficiency and completeness of combustion of the fuel usually perform as the ratio of the output or work done by the working substance in the cylinder in a given time to the input or heat energy of the fuel supplied during the same time [53], however; this study use the equation E4 which is the inverse of BSFC and heating value as below.

$$\mathrm{TE} = \frac{3{,}600}{\mathrm{BSFC} \times \mathrm{HHV}} \times 100 \qquad \text{(D4)}$$

Sample calculation of BSFC and TE

Fuel sample: CD(B5)-1

Load = 5.1 kg, r = 0.24 m and Speed (N) = 1,802 rpm

1. To calculated the BP (kW) which that of calculated Torque was 12 Nm

$$\mathrm{BP} = 12 \times \frac{2\pi \times 1{,}802}{60}$$

$$= 2.3 \text{ kW}$$

2. To calculated the BSFC (kg/kWh) which that of fuel flow rate was 0.836 kg/h

$$\mathrm{BSFC} = \frac{0.836}{2.3}$$

= 0.36 kg/kWh

3. To calculated the TE (kg/kWh) which that of heating value was 42,130 kJ/kg fuel flow rate was 0.873 kg/h

$$\mathrm{TE} = \frac{3{,}600}{0.36 \times 42{,}130} \times 100$$

= 24%

E-2 Engine performance data of tested fuel

Tested fuel	Load (kg)	Speed (rpm)	Torque (Nm)	Brake power (kW)	Fuel flow rate (kg/h)	Brake specific fuel consumption (kg/kWh)	Thermal efficiency (%)
CD(B5)	5.2	1,802	12	2.3	0.836	0.36	24
	5.1	1,801	12	2.3	0.818	0.36	24
	5.4	1,802	13	2.5	0.794	0.32	27
CBU	5.4	1,802	13	2.5	0.888	0.36	25
(CB50)	5.4	1,803	13	2.5	0.889	0.36	25
	5.5	1,803	13	2.5	0.882	0.36	25
CBS	5.6	1,806	13	2.5	0.895	0.36	25
(CB50)	5.7	1,804	14	2.6	0.878	0.34	24
	5.7	1,802	14	2.6	0.878	0.34	24
CBU	5.6	1,803	13	2.5	0.850	0.34	24
(CB100)	5.5	1,803	13	2.5	0.852	0.34	24
	5.5	1,805	13	2.5	0.854	0.34	24

E-2 Engine performance data of test fuel (Continued)

Tested fuel	Load (kg)	Speed (rpm)	Torque (Nm)	Brake power (kW)	Fuel flow rate (kg/h)	Brake specific fuel consumption (kg/kWh)	Thermal efficiency (%)
CBS	5.3	1,802	13	2.5	0.869	0.35	24
(CB100)	5.0	1,798	12	2.3	0.857	0.37	23
	5.1	1,807	12	2.3	0.852	0.37	23
CD(B2)	5.6	1,801	13	2.5	0.756	0.30	27
	5.4	1,802	13	2.5	0.789	0.31	26
	5.2	1,801	12	2.3	0.805	0.35	24

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List of Conferences

1. Nattapoom Nunto, Thaneeya Chetiyanukornkul, Akira Toriba, Takayuki Kameda, Ning Tang and Kazuichi Hayakawa. Emissions of Polycyclic Aromatic Hydrocarbons and 1-Nitropyrene from an Agricultural Diesel Engine with Community-scale Biodiesel, Thailand . Water and Environment Technology Conference, June 25-26, 2010 at Yokohama National University, Yokohama, Japan.
2. Nattapoom Nunto and Akira Toriba. Emissions of Polycyclic Aromatic Hydrocarbons and 1-Nitropyrene from an Agricultural Diesel Engine with Community-scale Biodiesel, Thailand . Invitation Project of Undergraduate and Postgraduate Students of Environment-related Subjects, Implemented by JASSO, September 25, 2010 at Kanazawa University, Ishikawa, Japan .

3. Nattapoom Nunto, Thaneeya Chetiyanukornkul, Akira Toriba, Takayuki Kameda, Ning Tang and Kazuichi Hayakawa. Polycyclic Aromatic Hydrocarbons and 1-Nitropyrene Emissions from Biodiesel Combustion Process. Center of Excellence on Environmental Health, Toxicology and Management of Chemicals Conference, August 21, 2011 at Convention Center, Chulabhorn Research Institute, Bangkok, Thailand.