CHAPTER 4

DISCUSSION

4.1 Fuel properties impact on toxic and green house gases emissions

The biodiesel properties including kinematic viscosity density, flash point cloud point, pour point, heating value or even cetane number were described in others studies [46-50] cited in Table 4.1. Most biodiesels reported in literatures were derived from palm oil, animal fat, crude palm oil, waste cooking oil and mahua biodiesel. It can be seen that their properties were close to those of CBF samples in this study. Although the cetane number (CN) was not determined in this study, Phalakornkule *et al.* reported that Thai biodiesel which was produced from community biodiesel scale plant demonstrated quite high value of CN [49]. It was also suggested that the use of fuel with high CN could lead to smoother running of the engine with less noise. The biodiesel properties including kinematic viscosity, density, flash point, could point, pour point, heating value or even cetane number were described in others. The valuation of some Thai biodiesel community standard for agricultural engines and methyl ester standards are shown in Table 4.2. Thai biodiesel properties including kinematic viscosity, density, cloud point, pour point are accepted for agricultural diesel engines but for methyl ester standard found PTT B5 and SAN are not accepted because kinematic viscosity value were not in the range, Methyl ester standards (2007), viscosity range is 3.5-5.0 mm^2/s^2.

The CBFs samples of high speed diesel engine showed higher density, flash point, could point than CBFs samples of agricultural diesel engine but lower pour point. The densities were observed to increase linearly with the increasing concentration of biodiesel and in the blends. The higher densities of palm oil, used palm oil and used mixes oil as compared to diesel may be attributed to the higher molecular weights of triglyceride molecules present in them. Slightly higher densities of pure biodiesel as compared to diesel make their energy content on volume basis somewhat closer to diesel than the energy content on a mass basis. Viscosity of CBFs are higher than CDFs, it might be affect on combustion system or even exhaust emission. The flash point of all CBFs higher than CDFs, Thus overall flammability hazard of both in agricultural diesel engine and high speed diesel engine is much less than of conventional diesel. The high values of cloud point and pour point may lead to the poor performance of the engine under cold condition when operating on the engine. The heating value is reported that lower heating of biodiesel found it higher fuel consumption rate than diesel [47 and 51].

Fuel properties may also have an effect on emissions from diesel engine. Fuel density, for instance, may affect the mass of fuel injected into the combustion chamber and thus, the air-fuel ratio. This was because fuel injection pumped fuel by volume not by mass, and a denser fuel contains a greater mass in the same volume. Fuel viscosity could also affect the fuel injection characteristics. The fuel with high viscosity caused poor fuel atomization during the spraying, increased the engine deposits, and needed more energy to pump the fuel into the combustion chamber [27]. Thus higher mass of fuel consumption may emit more emissions, as mentioned in the investigation of Canakci *et al.* and Labeckas *et al.* that the density, the viscosity and the carbon content were the great important properties affecting toxic and green house gases emission [64, 66]. However, in the case of CBFs in this study which are generally higher in density and viscosity, showed the reduction of toxic and green house gases emission, compared to CDF. Even toxic and green house gases emission in high speed diesel engine less reduction not same as agricultural diesel engine.

Ageing properties and storage condition could influence the biodiesel quality [27, 72]. It was due to nature of biodiesel that makes it more susceptible to oxidation or auto oxidation during long-term storage. The auto oxidation process takes place during the storage of fatty acid methyl esters. In the primary stage of oxidation process peroxides and hydroperoxides are formed. Further reactions of the unstable hydroperoxide species with another fatty acid chain may form high molecular weight materials, such as dimer or trimer acids, polymerization products and cyclic acids. Storage conditions of biodiesel with sunlight and occasional shaking in presence of air could enhance the oxidation occurrences [70 and 71]. These could lead to the increasing of the toxic and green house emission profile as was mentioned in Karavalakis *et al*. [74]. In this study, it could be observed that SAN, SAM, CPO and OUL which had stored for more than 1 year, were rather higher in fuel consumption, lesser in energy generated, and extremely emitted toxic and green house emission. However, there was no information about ageing or storage time of community biodiesel in Thailand that affected to the engine performance or emissions. Besides, this subject was not noticed in the specification of biodiesel standards for agricultural diesel engines. Hence, further studies should be carried out to investigate the effects of ageing properties and storage condition on the engine performance and the emissions of hazardous air pollutants.

Moreover, numerous studies suggested that the effect of biodiesel source material also influenced to the levels of toxic and green house gases emissions. It could be found that unsaturated and polyunsaturated fatty esters were susceptible to the reactions involved in some gases formation [68 and 64]. Furthermore, there was mentioned that the composition of biodiesel such as oxygen content or fatty acid content may influence to the level of NO_X emissions from biodiesel combustion [19-26, 59, 78].

The feed stocks of CBFs were derived from the used palm oil and mixed used oil. The used palm oil was obtained from the food industry, which was located nearby the community, while the latter was obtained from local markets, restaurant or household. The mixed used oil might be comprised with vegetable oil, pork tallow or grease yellow oil and so on that could lead to the exhaust emissions among various CBF samples. Nonetheless, those parameters were not determined in this study, many reasons as described above are reasonable to assume that the quality of biodiesel due to its origin feedstock might affect the toxic and green house gases concentration emissions in the exhaust of tested fuels. The vehicle emission standards and air quality standards in Thailand were presented in Table 4.3. It can be seen variation of toxic and green house gases from vehicle emission and air quality compare to this study.

Table 4.1 The comparison of biodiesel properties in others studies

Author	Kinematic Viscosity (cSt) at 40°C	Density (kg/m^3) at 15 °C	Flash point (°C)	Cloud point (°C)	Pour point (°C)	Heating value (MJ/kg)	Cetane number
Lin *et al.*, 2006b [46]	4.3	874	176	NA	15.0	39.8	63
Pianthong *et al.*, 2005 [47]	5.7	864	124	9	8.0	37.2	61
Wattanavicchien *et al.*, 2007 [48]	4.5	860	193	NA	6.0	39.5	49
Phalakornkule *et al.*, 2009 [49]	4.47	877	163	NA	NA	NA	74
Raheman *et al.*, 2007 [50]	3.9	880	203	NA	6.0	36.8	NA
This study	**3.1-5.5**	**827-888**	**56-176**	**6.0-19.0**	**-6.3-13.0**	**36.34-49.76**	**-**

NA, not available

Table 4.2 The evaluation of some biodiesel community standard for agricultural engines and methyl ester standards.

No.	**Symbol**	**Viscosity (cSt) at 40 ^oC**	**Density (kg/m^3) at 15 ^oC**	**Cloud point (^oC)**	**Pour point (^oC)**	**Agricultural Engines Standards[1/]**	**Methyl Ester Standards[2/]**
9	DIE100	NA	827	7.0 ± 1.0	-7.7 ± 1.0	Diesel[3/]	Diesel[3/]
4	DIE	3.103± 0.0	829	10.0 ± 0.0	4.0 ± 0.0	Diesel	Diesel
5	PTT B5	3.243± 0.0	832	10.0 ± 0.0	3.0 ± 0.0	accepted	not accepted
10	PTT B3	NA	840	6.0 ± 1.0	-6.3 ± 1.0	accepted	accepted
1	UMO	4.672 ± 0.0	875	16.0 ± 0.0	13.0 ± 0.0	accepted	accepted
2	SAM	5.026 ± 0.0	877	19.0 ± 0.0	10.0 ± 0.0	accepted	accepted
3	SAN	5.580 ± 0.0	888	12.0 ± 0.0	10.0 ± 0.0	accepted	not accepted
7	UPO	NA	888	17.0 ± 1.0	6.7 ± 1.0	accepted	accepted
8	CPO	NA	888	19.0 ± 1.0	6.7 ± 1.0	accepted	accepted
6	UOL	NA	888	14.0 ± 1.0	4.7 ± 1.0	accepted	accepted

Fuel tested at Chemistry Engineering laboratory, Burapha University, Chonburi province followed by ASTM method

[1]TBS: Thai biodiesel standards for horizontal single-cylinder, four strokes and water-cooled system agricultural engines (2006), viscosity range is 1.9-8.0- mm^2/s^2 and density range is 860-900 kg/m^3

[2]MES: Methyl ester standards (2007), viscosity range is 3.5-5.0 mm^2/s^2 and density range is 860-900 kg/m^3

[3] TDS: Thai diesel standards notification from Department of Energy Business (2007),
Kinematic viscosity range for B2 is 1.8-4.1 mm^2/s and pour point for B2, maximum is 10

Table 4.3 Vehicle emission standards and air quality standards in Thailand

Parameter	**HC**	**CO**	**Smoke**	**NO**	**NO_2**	**PM10**	**PM2.5**
Motorcycle	<1,000 ppm	2.5% by volume	-	-	-	-	-
Tricycle	<10,000 ppm	4.5% by volume	-	-	-	-	-
Vehicle (gasoline engine)	<100 ppm	0.5% by volume	-	-	-	-	-
Vehicle (diesel engine)	-	-	4.5% by volume	-			
Air quality standard 1 hrs.	-	<30 ppm, (34.2 mg/ m^3)			<0.17 ppm, (0.32 mg/ m^3)		
Air quality standard 8 hrs.	-	<9 ppm, (10.26 mg/ m^3)			-		
Air quality standard 24 hrs.	-	-	-	-	-	0.12 (mg/ m^3)	0.05 (mg/ m^3)
Air quality standard (Annual)	-				<0.03 ppm, (0.057 mg/ m^3)	0.05 (mg/ m^3)	0.025 (mg/ m^3)

Source: Pollutant Control Department (PCD) [52]

4.2 Toxic and green house gases emissions in exhausts of various tested fuels and their toxicity

The use of biodiesel as an alternative fuel in diesel engine results in a substantial reduction of unburned HC, carbon monoxide (CO) and particulate matter (PM) compared to diesel fuel. Addition, in the United Stated, diesel engine are regulated for smoke opacity, total nitrogen oxide (NO_X), total suspended particulate (TSP) less than 10µm or 2.5µm (PM-10 or PM2.5), carbon monoxide(CO), and total hydrocarbon according to test procedures defined by the Environmental Protection Agency (EPA) in the Code of Federal Regulations. Since the magnitude of diesel emission depends on fuel composition, emission certification testing is conducted with “certification diesel fuel” that represents the U.S. national average. Other emissions from diesel engine such as VOC, aldehydes and polyaromatic hydrocarbons (PAH) may be regulated in the future in an attempt to control ambient level of air toxic.[68].

The biodiesel exhaust emission has been extensively characterized under field and laboratory conditions. Biodiesel reduces emission of CO and CO_2 on a net lifecycle and contain fewer aromatic hydrocarbons. Biodiesel can also reduce the tailpipe emission of gases and particulate matter. Tailpipe emissions are complex function of many influential variables, including vehicle characteristics, vehicle activities patterns, ambient conditions, fuel properties. Overall, key factors that influence are fuel properties, vehicle weight, speed and acceleration and operating mode. In designing a field study for measurement of toxic and green house gases in this study, consideration was given recommendation from mechanical engineering technical.

Several commonly used method for measuring vehicle or engine include engine dynamometer, chassis dynamometer, tunnel studies, remote sensing, on board measurement, on road measurement and directly analysis in laboratory. High speed diesel engine (ISUZU 4JB1) and agricultural diesel engine (YANMAR TF75-LM) were choose to studies the engine performance and exhaust emission, additionally the local community used biodiesel on both of them. Detection of toxic and green house gases in the fuel exhaust from agricultural diesel engine and high speed diesel engine fueled with various CBFs and CDFs showed the variation of toxic and green house gases profile, toxic and green house gases was predominantly found in almost of exhaust. NO, NO_X and CO were slightly high for both agricultural diesel engine and high speed diesel engine tested, although a review of available agricultural diesel engine test data for a variety of diesel engines indicates that there is a reduction in the regulated emission rate of PM, CO, and HC, soot, smoke and an increase in the emission rate of NO_X, Nearby some literatures found to be slightly lower. Since founding some community used biodiesel with high speed diesel engine and lack of information data in engine performance and exhaust emission for community biodiesel, Therefore the investigation will be confirm to a suitable for community biodiesel.

The reduction of toxic and green house gases was quite low for each fuel in CO emission at the full load condition. The higher combustion temperature at higher engine load contributes to the general decreasing trend. With the addition of biodiesel, CO emission also decreases. It is possible that the oxygen contained in the fuel enhances complete combustion in the cylinder and decrease CO emission, while emission of NO_X appear increase from biodiesel [53, 54, 58, 66, 67]. NO_X increases with the increase concentration of biodiesel in pure biodiesel or in the mixture of biodiesel and petro diesel. This increase in NO_X may be due to the high temperature generated in the fairly complete combustion process on account of adequate presence of oxygen in the fuel [54, 57, 61, 62, 64, 65, 78]. This increase in NO_X may be neutralized by efficient use of NO_X control technologies, which fits better with almost nil biodiesel than conventional diesel containing sulfur. The levels toxic and green house gases emissions in the exhausts from agricultural diesel engine were found the significant difference in group by the using various CBFs, there no significantly difference between CBFs and CBD (except NO and NO_X was significant $p<0.05$). This relatively higher NO_X emission in this study and found the fuel temperature are much than conventional diesel.

High speed diesel engine test with results reported community biodiesel higher concentration than conventional diesel except for NO_X in UPO and PTTB5 and found to be significant different higher emission in CO_2, NO_2 and NO_X, the levels toxic and green house gases emissions in the exhausts from high speed diesel engine were found the significant difference in group by the using various CBFs, there no significantly difference between CBFs and CDFs (except CO, NO_2 and NO_X was significant $p<0.05$). The sharp reduction of toxic and green house gases emission was observed in all CBFs, reduction emission in community biodiesel when compared to conventional diesel of tested with agricultural diesel engine, In the case of high speed diesel engine shown slightly higher in community biodiesel fuel than conventional diesel fuel. At present, there may reasonable to assume that toxic and green house gases, could be reduced or found the less amounts than emissions from conventional biodiesel. Therefore, it reflected that the substitution of community biodiesel in agricultural diesel engine could reduce their toxicity effects on environmental and human exposure.

But these founding, might be community biodiesel fuel is unsuitable for high speed diesel engine when we concerned about the emissions of toxic and green houses gases. These results indicated that the use of community biodiesel in agricultural diesel engine could reduce toxic and green house gases emitted to the environment, compared to the use of conventional diesel, while community biodiesel is unsuitable for high speed diesel engine.

Pollution from engine comes from by-products of this combustion process (exhaust) and from evaporation of the fuel itself. It was as indicated that using biodiesel was more effective for reducing toxic and green house gases and the potential hazard of in exhaust emission, can reduce harmful effect on human and the environment. The effect of toxic and green house gases some others reports speculated that the respiratory and histopathological changes of the lung were associated with NO_X and CO. Although some uncertainty exists in their analysis, the lesions that were observed are typical of these toxicants. It is well known that CO has marked effects on hematological and cardiac indices [33]. Nitrogen oxides are known to adversely affect the respiratory tract [33]. Moreover, was as indicated that under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NO_X. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone. They also contribute to the formation of acid rain. About 30 percent of NO_X emissions are from cars and trucks.

CO is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to CO_2. Exposure to carbon monoxide reduces the flow of oxygen in the bloodstream and is particularly dangerous to persons with heart [33]. Greenhouse gas emissions are primarily carbon dioxide (CO_2), which is a product of fuel combustion. CO_2 does not directly impair human health, but it is a "greenhouse gas" that traps the earth's heat and contributes to the potential for global warming. About 26 percent of anthropogenic greenhouse gas emissions are from cars and trucks. Furthermore, diesel engine combustion process which, besides, generated various pollutant gases, particulate matter or some PAHs, and n-PAHs direct cause of carcinogenic and mutagenic which have affect on human health and animal living. Nevertheless, there is the lack of evident information concerning the toxicity of emission from the use of community biodiesel. The n-PAHs emitted from the use of Thai community biodiesel had not been addressed. Further research requires the analysis of PAHs and n-PAHs emissions and their toxicity from the use of Thai community biodiesel in some an agricultural diesel engine, in a vehicular diesel engine and on human biomarker or animal living (some insect or bee etc.) [75].

Many investigations are shown the similar tendency for agricultural diesel engine [29, 30, 41, 61 and 62], which are complied into Table 3.10. Toxic and green house gases emissions in all investigations showed the lower gases emission from agricultural, the investigations of Chiburi *et al*., particularly. It can be seen that CO, NO_2 and NO_X emissions in exhaust of diesel engine varied in a large scope ranging within 0.55-7.66ppm. While CO, NO_2 and NO_X emissions from this study were ranged from 26.1 to 151.3.

It could be observed that the CO, NO_2 and NO_X emitted from the use of various CBFs in IDI agricultural diesel engine were extremely higher than those investigations. The results of Chaisuwan *et al*., which were performed in agricultural diesel engine, Kubota ET70, IDI, four-stroke, a single cylinder were less NO_2 and NO_X which is waste cooking oil compared to petroleum diesel. Moreover, Jindal *et al*., found Jatropha methyl ester biodiesel fueled with small agricultural diesel engine, TV1, four-stroke, a single cylinder, DI was lower NO_X emission than diesel fuel (178 and 237ppm) ,respectively. Result of Chetiyanukornkul *et al.*, showed CO, CO_2, NO, NO_2 and NO_X emission of used palm oil (B100) were ranged from 2.0 to 151.3 and reduction emission 49.18, 44.4, 48.41 +6.77 and 46.46%, respectively. Founding of CO and NO_X decreased 15% and 38.5%, respectively by Oner *et al.*, The emission and reduction of exhaust gases was decrease in agricultural diesel engine biodiesel fueled with biodiesel. In the case of NO_X an increased in the emissions with biodiesel compared to diesel fuel, some reported was decreased when fueled with biodiesel, they mentioned that NO_X was increased due to high oxygen content of biodiesel, high temperature in combustion chamber and depended on different of fuels or engine operating. It was reasonable to assume that the different tested engine or different sampling method could lead to the variation of toxic and green house gases emissions. Several literatures are also shown the similar tendency for high speed diesel engine [63, 64, 65 and 66], which are complied into Table 3.12. Toxic and green house gases emissions in all investigations showed the lower gases emission from high speed diesel engine and recently in many countries was used biodiesel or biodiesel blend with diesel fuel running on high speed diesel engine, car, truck or even heavy duty engine.

In this study toxic and green house gases emission in high speed diesel engine compose of CO_2, CO, NO, NO_2 and NO_X varied in a large scope ranging within 3.7 to 396.6 ppm, respectively. Emission of community biodiesel a slightly higher than conventional, however there were no significant different. While in the others literature found different results. In the investigations of Khuttiyawan *et al*., tested an automotive diesel engine (Indirect injection: IDI.), TOYOTA2L-Turbo was fuelled with diesel and blends of degummed-deacidified palm oil in diesel at proportions of 20% by volume. The long-term engine test was run for each fuel blends considered on the engine dynamometer by content speed test method, the engines are alliteratively run on the generator for 200 hr of each period. Exhaust gases emission results indicated that, at the full load condition and decreased of CO emission were ranged from 42 to 130 ppm, increased of NO_X emission were ranged from 292 to 469 ppm, those emission of their investigation were similar ranged in this study, also they mentioned that NO_X exhaust emission much higher when operated engine at full load and lower emission in low load. The results of Canakci et al., which were performed in A John Deere 4276T, four-stroke, four-cylinder, DI, turbocharged diesel engine. The neat biodiesel of yellow grease oil, soybean oil and their 20% blends with diesel and compared to diesel, both biodiesel provided significant reduction in CO 17.8%, 18.2%, 7.0 and 7.5%, respectively. The NO_X emission were increased 11.6%, 13.1%, 1.1% and 1.5% respectively relative to diesel and they noted that the total NO_X emission, as a sum of both harmful pollutants, NO and NO_X, depend actually on the bio fuel feedstock, its chemical structure, oxidation rate, thermal stability and iodine number, i.e. the presence of double bonds, cetane number, its volatility, flammability and other properties or may be associated with the oxygen content of the methyl esters, since the fuel oxygen may provide additional oxygen for NO_X formation. However, the equivalence ratios for the methyl ester fuels were very similar diesel fuel. The impact of the fuel's physical properties on the engine's injection timing, In the investigations of Dorado *et al*., fuel tests were performed with diesel engine Perkins AD 3-152, three cylinder, four-stroke, direct injection. Emission were characterized with neat biodiesel from used olive oil and convention diesel fuel revealed that the used of biodiesel resulted in lower emission of CO up to 58.9%, CO_2 8.6% and biodiesel presented a slight increase NO 37.5% and CO_2 81%. Moreover, Labeckas *et al.,* investigated the effect of rapeseed oil methyl ester (RME), their blends with diesel in the following proportion by volume B5, B10, B20 and B35 on diesel engine D-243, four-stroke, four-cylinder, water cooled, direct injection performance and exhaust emission, the maximum NO_X emission increase proportionally with the mass percent of oxygen in the biodiesel and engine speed, reaching the highest values at the speed of 2000 rpm, the highest being 2132 ppm value for the B35 blend and 2107 ppm for RME, at the rated speed, the total NO_X emission for all fuels are slightly lower, ranging from 1885 (diesel) to 2051 (B35), the CO emission and visible smoke emerging from the biodiesel over all load and speed range are lower by up to 51.6% and 13.5% to 60.3%, respectively.

The CO_2 emission, along with the fuel consumption and gases temperature, are slightly higher for the B20 and B35 blends and neat RME. The emission of THC for all fuels is low, 5-21 ppm, showing slightly milder values for RME and its blends with diesel fuel. It could be observed that the total toxic and green house gases emitted from the use of various CBFs in IDI and DI in agricultural diesel engine were extremely less than IDI and DI in those investigations.

Thus it could be revealed that the smaller engine may emit lower emissions than the bigger one. Although characteristics of that tested engine were similar to the tested engine in this study, the toxic and green house gases emission of biodiesel and blended biodiesel fuel tests was higher than agricultural and the neat community biodiesel was higher than conventional diesel tested. It was reasonable to assume that the different tested engine or different sampling method could lead to the variation of toxic and green house gases emissions.

Table 4.4 Comparison of toxic and green house gases emission from agricultural diesel engine in others studies

Authors	Engine specification	Fuel	Gases Emission Range					Reduction (%)				
			CO(ppm)	CO_2 (%)	NO(ppm)	NO_2(ppm)	NO_X(ppm)	CO	CO_2	NO	NO_2	NO_X
Chaiburi *et al*., 2009 [41]	Agricultural diesel engine, Kubota RT80,IDI, 465cc	D100	0.66	-	50.88	11.63	62.55	-	-	-	-	-
		B100	0.55	-	65.00	12.85	77.66	17*	-	+27.75*	+10.49*	+24.15*
Chaisuwan *et al*., [61]	Agricultural diesel engine, Kubota ET70,IDI, 401cc	D100	-	-	-	-	-	-	-	-	-	-
		B100	-	-	-	-	-	-	-	-	more	more
Jindal S. 2010 [29]	TV1, 4-stroke,DI, Rated power3.5kW @ 1,500rpm,	D100	-	-	-	-	237	-	-	-	-	-
		B100	-	-	-	-	178	-	-	-	-	25*
Chetiyanu kornkul *et al*., [30]	Yanmar, TF-75 LM 4-stroke,IDI	D100	49.0	3.6	145.4	5.9	151.3	-	-	-	-	-
		B100	24.9	2.0	75.0	6.3	81.0	49.18	44.4	48.41	+6.77	46.46
Oner et al., 2009 [62]	Rainbow-LA186,DI,4-stroke, one cylinder	D100	-	-	-	-	-	-	-	-	-	-
		B100	-	-	-	-	-	15.0	-	-	-	38.5

*Toxic and green house gases emission reduction calculated from the data provided by researchers (-) is less emission, (+) more emission

Table 4.5 Comparison of toxic and green house gases emission from high speed diesel engine in others studies

Authors	Engine specification	Fuel	Gases Emission					Reduction (%)				
			CO(ppm)	CO_2(%)	NO(ppm)	NO_2(ppm)	NO_X(ppm)	CO	CO_2	NO	NO_2	NO_X
Khuttiyawan *et al*., [63]	2LTurboToyota,IDI,4stroke, Max torque 215N.m.@2400 rpm, Rated power69 kW @ 4,000 rpm,	D100 B100	- 42-130	- -	- -	- -	- 292-469	- less	- -	- -	- -	- less
Canakci *et al*., [64]	John Deere 4276T, DI,4stroke, 4-cylinder,peak torque 305.0N.m.@1300 rpm, max power69 kW @ 2,100	D100 B100 B20	- - -	- - -	- - -	- - -	- - -	- 17.8 to 8.2 7.0 To 7.5	- 1.2 to 1.8 0.04 To 0.06	- - -	- - -	- +11.6 to +13.1 +1.1 To +1.5
Dorado et al., [65	Perkins AD 3-152, DI, 4-stroke, max toque 162.8kW @ 1,300rpm, max power 34kW @2,250rpm,	D100 B100	- -	- -	- -	- -	- -	- 58.9	- 8.6	- +37.5	- +81	
Labeckas et al., [66]	Diesel engine D-423, DI, 4-stroke, 4-cylinder	D100 B100 B5 B10 B20 B35	1150 811 633 695 580 811	- -	1823-1925 1924-2066	49-60 28-36	1983 2132	- 51.6	-	- -	- 8.8	- -

*Toxic and green house gases emission reduction calculated from the data provided by researchers (-) is less emission, (+) more emissions

4.3 Correlation with other pollutant gases emissions and PAHs in community biodiesel fuel exhausts

The pollutant gas emissions from using various CBF and CDF, which had been stated in previous study [30], are presented in percentage change of each pollutant gas emissions of 10 CBF samples, compared to those of CBD as depicted in Figure 4.1. It showed the reductions of NO, NO_x and SO_2 in all CBFs, despite NO_2 which increasing less than 30% of base CBD. Whereas CO and CO_2 of almost CBF samples were found lower than those of CBD. The occurrences of these gases were typical produced in combustion process of diesel engine. In this study was not specially observed SO_2 in the all tested.

Additionally the reductions of particulate matter in community biodiesel, meanwhile reduction of almost PAHs were observed, the distribution of fifteen PAH profiles in the exhausts from using community biodiesel could still be found. This evidence leads to the formation of PAH derivatives such as nitrate PAHs (nitro-PAHs) and oxygenated PAHs (oxy-PAHs) which some species are toxic, mutagenic and even carcinogenic to human body. A number of authors found the reduction of nitro-PAHs and oxy-PAHs emissions in diesel engine exhaust from combustion processes of biodiesel fuel compared to those in petroleum diesel exhausts [8, 60, 70-75]. This evidence may be beneficial for reduction of the toxic substances and, additionally, for health risks. As results of Maliwan et al., the 15 PAHs compounds can be detected in the exact of exhaust of from agricultural diesel engine and percentage of PAHs composition in tested fuel exhaust are shown in Figure 4.2 and they found reduction of total PAHs emission of all CBFs compared with CBD exhaust samples were up to 50%[77].

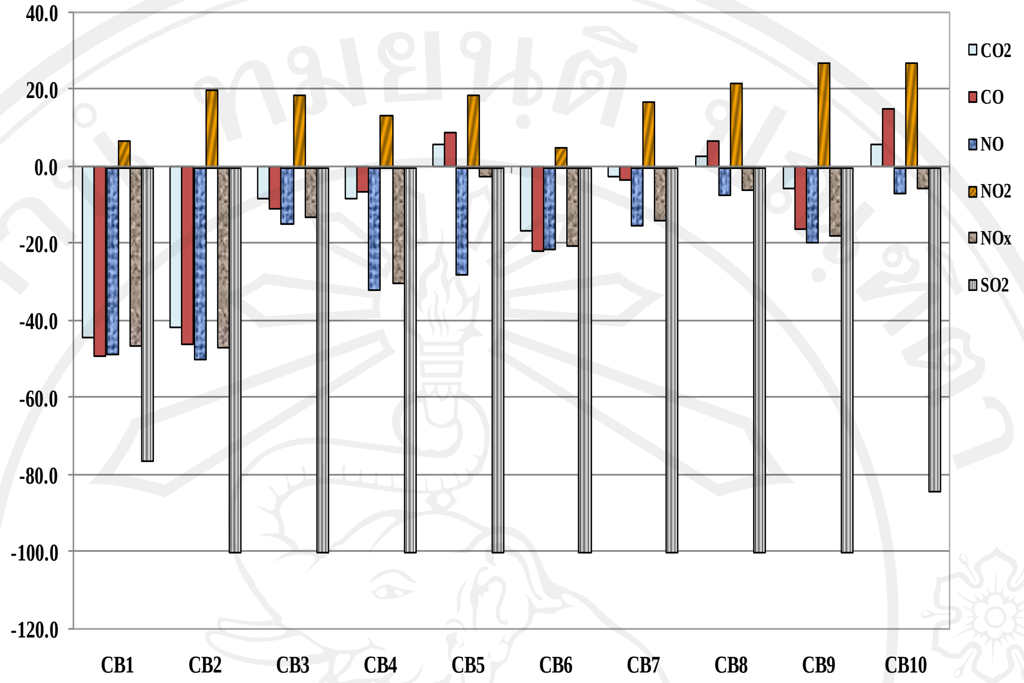

Figure 4.1 Percentage reductions of pollutant gases from the use of various CBFs, in comparison with CBD [30]

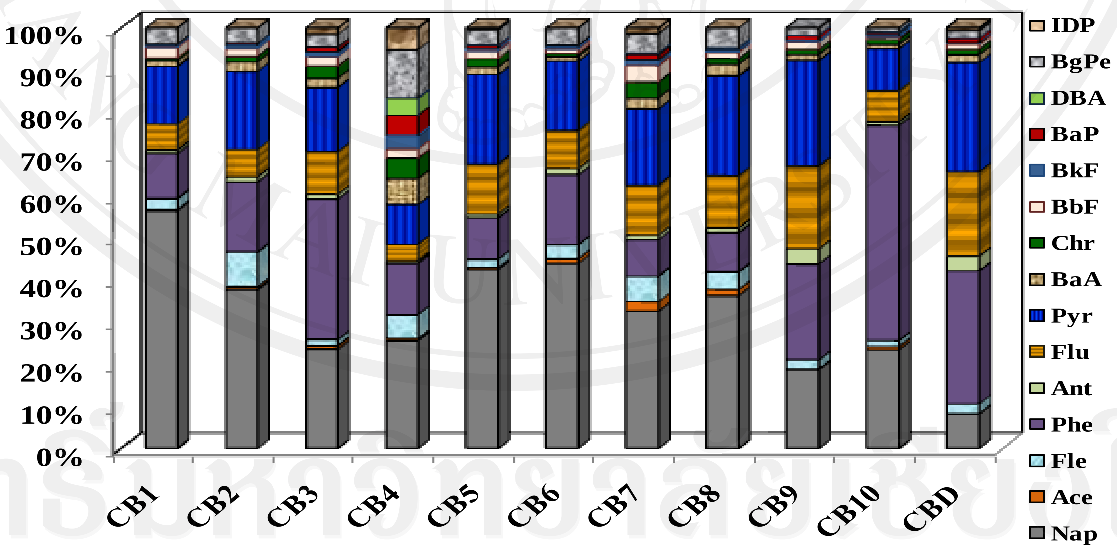

Figure 4.2 Percentage of 15 PAHs composition in various tested fuel exhausts [77]

4.4 Comparison of engine performance and exhaust emission in low speed and high speed diesel engine

The uses of community biodiesel on agricultural diesel engine and high speed diesel engine were found higher for fuel consumption and quite lower in thermal efficiency when compared to that of CDF. According to the results were found in many studies [9, 15, 16, 62, 64, 69, 72, 79]. Basha *et al.* reported that the BSFC of rapeseed biodiesel was 10.9% higher than that of petroleum diesel owing to a lower heating value of ester than petroleum diesel and thus more fatty acid methyl ester-based fuel which is required for the maintenance of a constant power output [9]. Likewise, Lin *et al.* found that BSFC value from using palm-biodiesel on diesel generator under 75% of total torque load was 5.35% higher than that of petroleum diesel. They mentioned that this evident was due to the low heating value of biodiesel that led to high fuel consumption [15]. The investigation of palm-biodiesel tested in heavy-duty diesel engines by Lin *et al.* also reported that the BSFC of biodiesel was 2.81% higher than that of petroleum diesel [16]. As results of Di *et al.*, the brake specific fuel consumption for biodiesel (Waste cooking oil) methyl ester was increased when compared to diesel fuel. Also, they mentioned that the increase in BSFC is mainly associated with the lower heat value of biodiesel [79].

The investigation of yellow grease biodiesel and soybean oil tested in John Deere 4276T diesel engines by Canakci *et al.* also reported that the BSFC of biodiesel was 14% higher than that of petroleum diesel [64]. Moreover, the investigation of Oner *et al.* also found the BSFC and the thermal efficiency of tallow methyl ester was 15% higher and 12.7% lower than those of petroleum diesel, respectively. This was due to the higher in viscosity, density and lower in heating value of this biodiesel

[62]. As results of Puhan *et al.*, the brake thermal efficiency for Mahua (Madhuca Indica seed oil) methyl ester was lower than diesel fuel. Also, they mentioned that the brake thermal efficiency of an engine depended on its heating value and its specific gravity [72]. Furthermore, as investigation of Meng *et al.* reported the lower heating value of waste cooking oil methyl ester compared to diesel fuel. The existence of oxygen content in the biodiesel resulted in better combustion [69].

The properties of all CBFs in this study were also higher in viscosity, density and lower in heating value similar to the above investigations. Although the viscosity was not analyzed all CBFs in high speed diesel engine. The higher viscosity led to the decrease of atomization, fuel vaporization and combustion. The higher density of biodiesel could lead to more fuel flow rate for the same displacement at the same injection pressure and also because of lower heating value of biodiesel. It could be stated that, in the case of community biodiesel, fuel consumption was increased owing to higher density and lower heating value and, as a consequent, thermal efficiency was decreased.

Considering the levels of toxic and green house gases emissions could be found that the uses of CBFs compare to CDF could reduce toxic and green house gases emission whereas the tested engine consume more fuel and release less thermal efficiency with mean increasing of approximately 31% and mean diminishing of approximately 13%. It should be noted that the use of community biodiesel positively influences the toxic and green house gases composition in the exhaust of agricultural diesel engine, although high speed in this study, it was found much toxic and green house gases composition in the exhaust, however fuel consumption of CBF and thermal efficiency was similar results with others. The tested engine consumes more fuel and release less thermal efficiency with mean increasing of approximately 37% and mean diminishing of approximately 18%.