Variation in particle emissions among biodiesels with controlled physicochemical properties

Md. Mostafizur Rahman, .M. Pourkhesalian, S. Stevanovic, H. Wang, B. Miljevic, Z. Ristovski

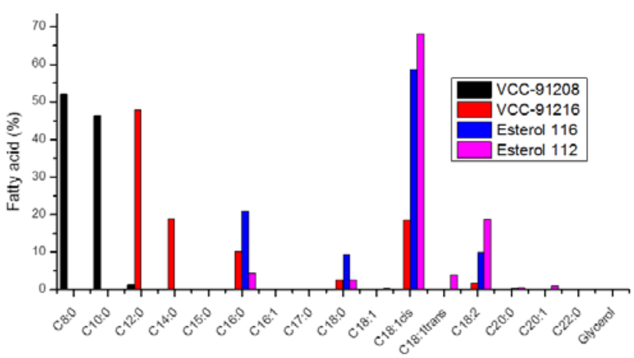
School of Chemistry Physics and Mechanical Eng. Queensland University of Technology,
Brisbane, QLD-4000, Australia

Introduction

Biodiesel is a mixture of wide variety of fatty acid esters. Its physicochemical properties depend on molecular structure of fatty acid ester. Biodiesel can be produced from variety of sources i.e. different vegetable oils, animal fats, municipal and industrial waste and even from insects[1]. Wide varieties in fatty acid profile usually exist among those feedstocks, even sometimes within the same feedstock. Hence, physical properties and chemical composition of biodiesel varies among different feedstocks which have noticeable influence on engine performance and emission [2, 3]. Therefore, it is necessary to find the optimum biodiesel properties in regards to engine performance end emissions before its widespread application. The aim of this study is to investigate the effect of biodiesel physical properties and chemical composition on particle emissions alongside with engine performance.

Methodology

Four biodiesels with different physicochemical properties and an ultra low sulfur diesel (sulfur content < 6ppm) were used at B100, B50 and B20 blends, in a common rail turbocharged diesel engine.Figure-1shows the fatty acid profile of used biodiesels, where table shows some important properties. $PM_{2.5}$ emissions was measured by a TSI DustTrak(Model 8530). Particle number and size distribution was measured by scanning mobility particle sizer (SMPS) consists of TSI 3080 electrostatic classifier (EC) and TSI 3025 butanol base condensation particle counter (CPC).



Fuel type/Properties	VCC-91208	VCC-91216	Esterol 116	Esterol 112	Diese
Oxygen content (wt%)	18.72	13.25	10.74	10.83	
Density(kg/l)	0.877	0.871	0.873	0.879	0.8482
Viscosity (mm²/sec)	1.95	4.37	4.95	5.29	3.148
Surface tension (mN/m)	26.184	28.41	29.9	29.966	20
Cetane value	62.96	65.57	61.06	53.65	48.5
Iodine value	1 max	8	65	105	
Saponication value	330	233	195	185	
Acid value	0.9	0.4	0.8	0.4	<0.05
Boiling point (°C)	190	>150	165.6	>150	
Gross Calorific value(MJ/kg)	35.335	37.585	38.409	39.825	44.365
Sulfur content(mg/kg)	--	--	--	--	2.5

Figure 1: Fatty acid profile of used biodiesel

Results

Regardless of the variations in physical properties and chemical composition, all four used biodiesels reduced particle emissions than petroleum diesel. Noticeable variation in particle emissions also observed among four biodiesels and their blends. Biodiesel with shorter carbon chain length and higher degree of saturation reduced particle emissions significantly (figure 3). Highest 98% reduction in PM and 90% reduction PN was observed for the fuel with the shortest carbon chain length (VCC-91208). Carbon chain length of Esterol-112 was similar with Esterol-116, but had higher degree of unsaturation, and found less particle emissions than Esterol-116. In addition, viscosity and surface tension were also higher. Therefore, this slight reduction in PM emissions from Esterol-112 might be attributed from its high iodine or comparatively low cetane value.

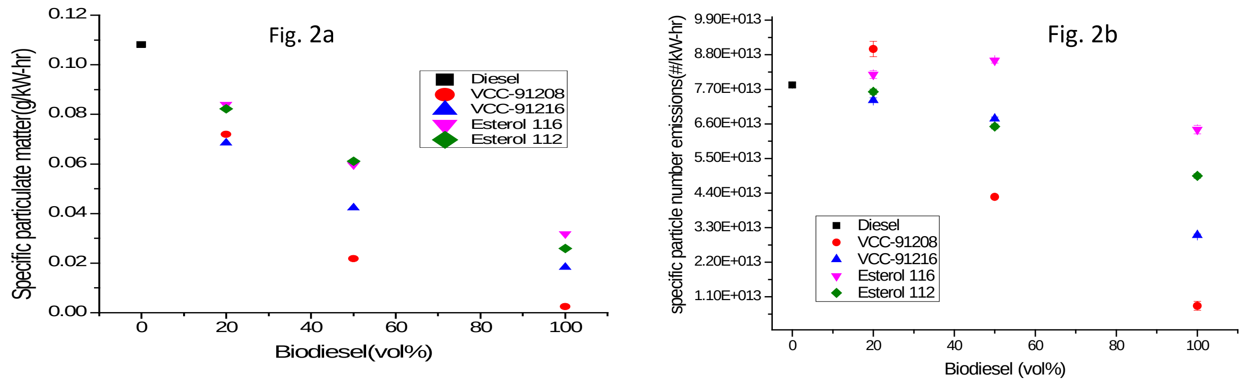


Figure 2: Specific PM and PN emissions from different tested fuels

Particle size and nanoparticles

Particle size and size distribution also varied among biodiesels tested. Biodiesel emitted less PM and PN, also provided smaller particle median size (Fig. 3a), which indicates that coagulation plays a role in overall particle size (see Fig 3b). The emissions of nanoparticles (<50nm) from biodiesels were lower than for the reference diesel fuel, with Esterol-112 emitting the highest number of nanoparticles compared to the rest of three biodiesels. As Esterol-112 had the highest degree of unsaturation this is an indicator that the degree of unsaturation could have a role in the increased emission of nanoparticles.

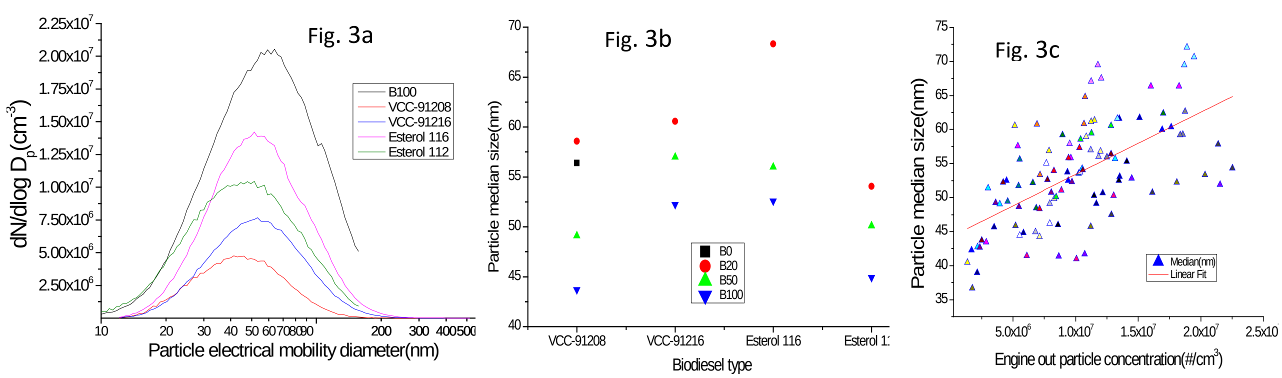


Figure 3: Particle size and size distribution from tested fuels

Effect of fuel properties on particle emissions

Particle emissions increased with the increase of fuel viscosity and surface tension but only within specific blend (Fig. 4a and 4b). For higher blend percentages (B50 and B100) there was a linear relationship between surface tension, viscosity and PM emission. A more consistent relationship was observed between fuel oxygen content and PM emission (4c). This relationship did not depend on the blend percentage. This is a clear indication that fuel chemical composition is more important than its physical properties in terms of engine exhaust particle emissions.

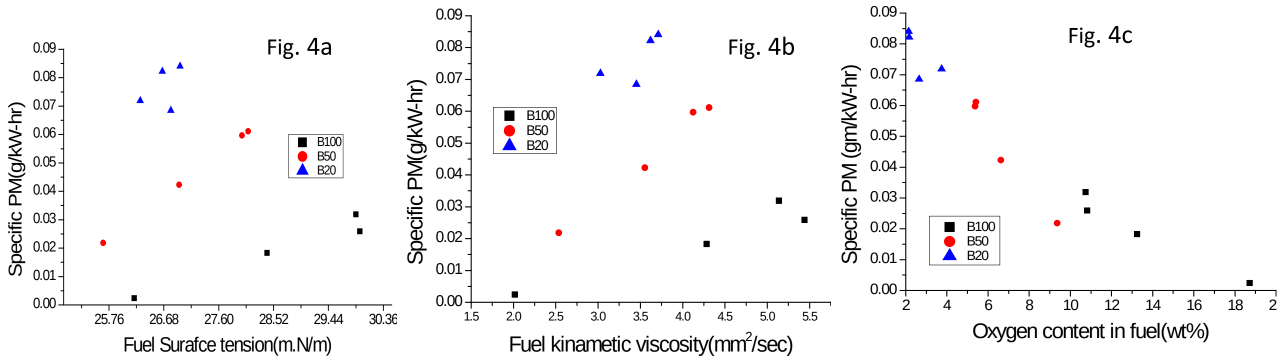


Figure 4: PM emissions with tested fuel surface tension, viscosity and Oxygen content

Conclusions

- Biodiesel with shorter carbon chain length and higher degree of saturation have more potential to decrease engine exhaust particle emissions.
- Coagulation influences overall engine exhaust particle size.
- Higher degree of unsaturation in biodiesel enhances nanoparticle emissions.
- Chemical composition of biodiesel is more important than its physical properties in regards to particle emissions.

Refrences

1. Salvi, B.L. and N.L. Panwar, *Biodiesel resources and production technologies – A review.* Renewable and Sustainable Energy Reviews, 2012. **16**(6): p. 3680-3689.
2. Hoekman, S.K., et al., *Review of biodiesel composition, properties, and specifications.* Renewable and Sustainable Energy Reviews, 2012. **16**(1): p. 143-169.
3. Mccormick, R.L., et al., *Impact of biodiesel source material and chemical structure on emissions and criteria pollutants from a heavy duty engine.* Environ. Sci. Technol., 2001. **35**(9): p. 1742-1747.

Variation in particle emissions among biodiesels with controlled physicochemical properties

Queensland University of Technology

Md. Mostafizur Rahman, .M. Pourkhesalian, S. Stevanovic, H. Wang, B. Miljevic, Z. Ristovski

School of Chemistry Physics and Mechanical Eng. Queensland University of Technology, Brisbane, QLD-4000, Australia

Email:mdmostafizur.rahman@qut.edu.au

ETH2013

17th ETH Conference on Combustion Generated Nanoparticles

Introduction

Biodiesel can be produced from variety of feedstocks and physicochemical properties of biodiesel also vary among those different feedstocks. Therefore it is necessary to find the optimum biodiesel properties in regards to engine performance end emissions before its widespread application.

Objectives

To investigate the influence of biodiesel physicochemical properties on engine exhaust particle emissions

Materials and methods

Four biodiesels with different physicochemical properties and an ultra low sulfur diesel (sulfur content < 6ppm) were used at B100, B50 and B20 blends, in a common rail turbocharged diesel engine. Figure 1 shows the fatty acid profile of used biodiesels, where the table shows some important physicochemical properties.

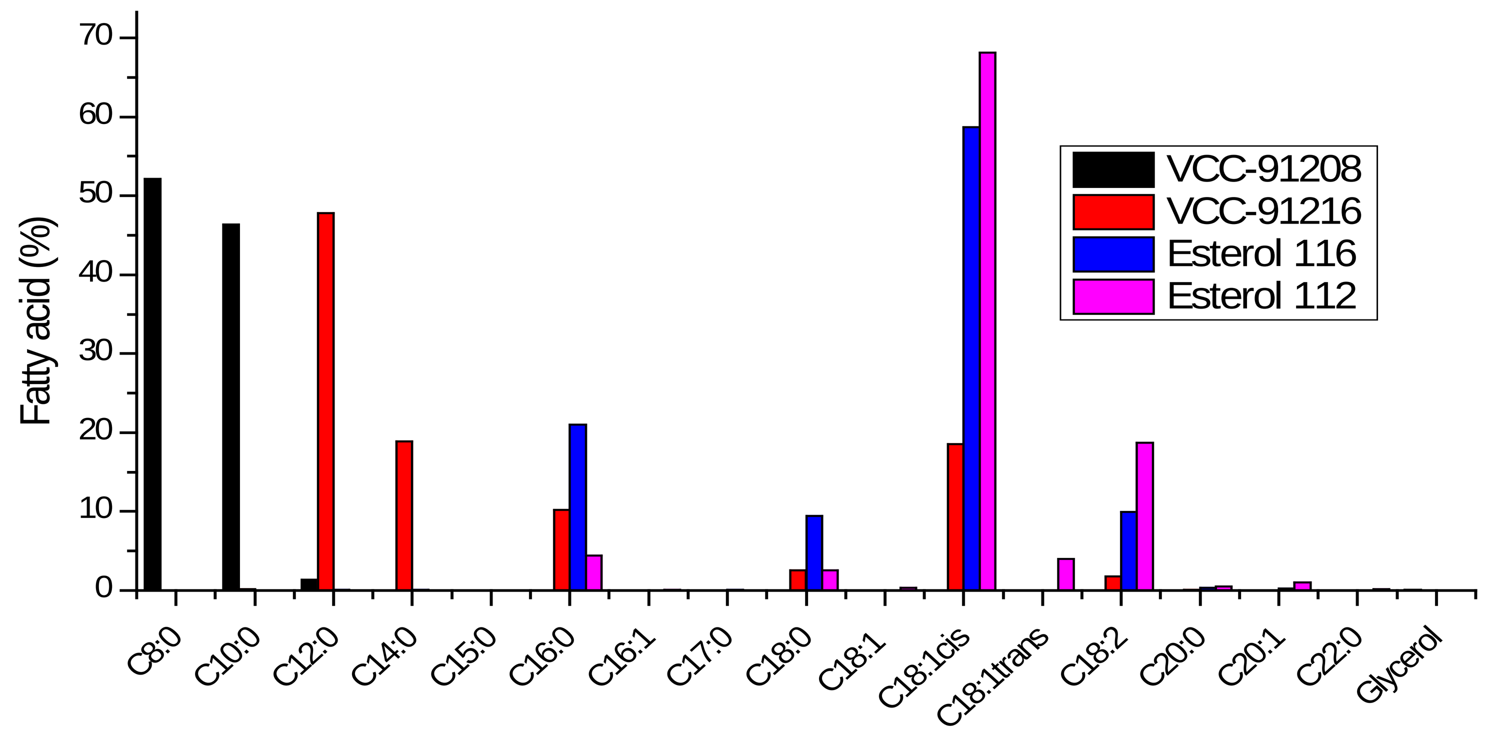


Figure 1: Fatty acid profile of used biodiesels

Fuel type/Properties	VCC-91208	VCC-91216	Esterol 116	Esterol 112	Diesel
Oxygen content (wt%)	18.72	13.25	10.74	10.83	
Density(kg/l)	0.877	0.871	0.873	0.879	0.8482
Viscosity (mm^2/sec)	1.95	4.37	4.95	5.29	3.148
Surface tension (mN/m)	26.184	28.41	29.9	29.966	20
Cetane value	62.96	65.57	61.06	53.65	48.5
Iodine value	1 max	8	65	105	
Saponication value	330	233	195	185	
Acid value	0.9	0.4	0.8	0.4	<0.05
Boiling point (^{0}C)	190	>150	165.6	>150	
Gross Calorific value(MJ/kg)	35.335	37.585	38.409	39.825	44.365
Sulfur content(mg/kg)	--	--	--	--	2.5

Table : Important Physicochemical properties of used fuels

Results

Biodiesel with shorter carbon chain length and higher degree of saturation reduced particle emissions significantly (Figure 2). Highest 98% reduction in PM and 90% reduction PN was observed for the fuel with the shortest carbon chain length (VCC-91208). PM emissions increased with the increase of biodiesel carbon chain length and degree of unsaturation. However, for the same carbon chain length completely unsaturated biodiesel(Esterol112) emitted less particle than partly unsaturated one(Esterol116).

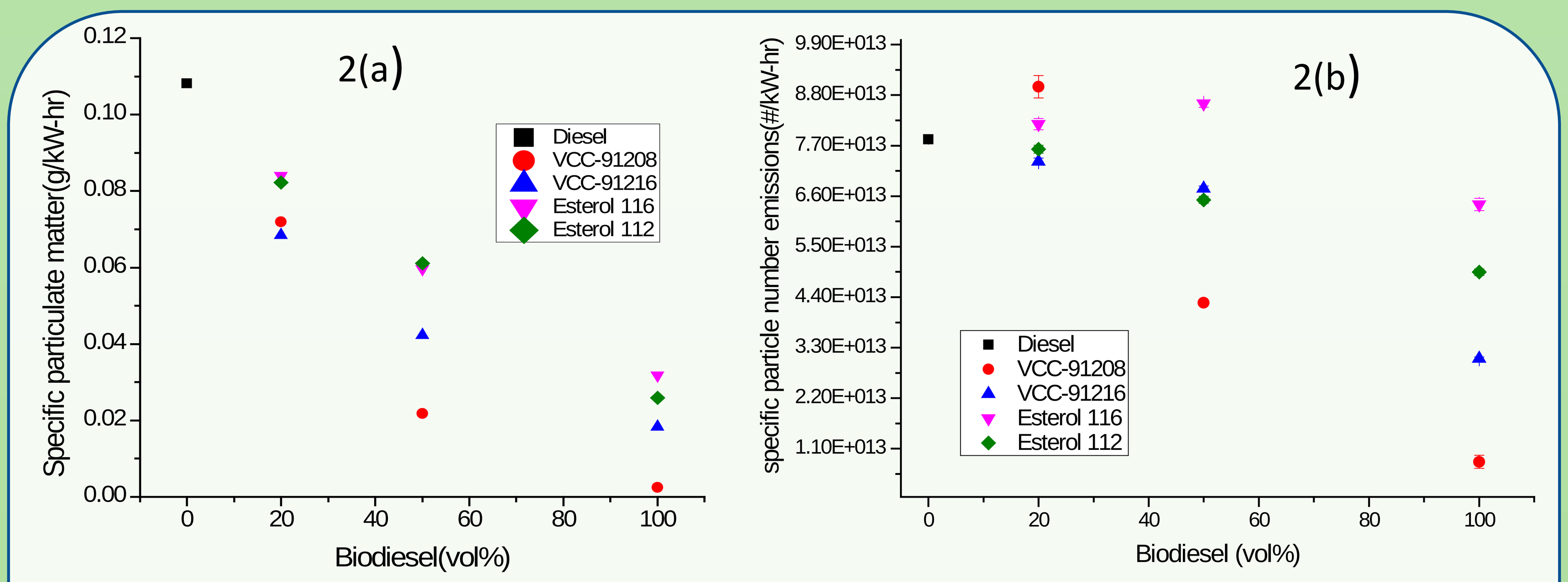


Figure 2: Specific PM and PN emissions from tested fuels

Particle size and nanoparticles

Particle size and size distribution also varied among biodiesels tested. Biodiesel emitted less PM and PN, also provided smaller particle median size(Fig. 3a), which indicates that coagulation plays a role in overall particle size (see Fig 3b). The emissions of nanoparticles (<50nm) from biodiesels were lower than for the reference diesel fuel, with Esterol-112 emitting the highest number of nanoparticles compared to the rest of three biodiesels. As Esterol-112 had the highest degree of unsaturation this is an indicator that the degree of unsaturation could have a role in the increased emission of nanoparticles.

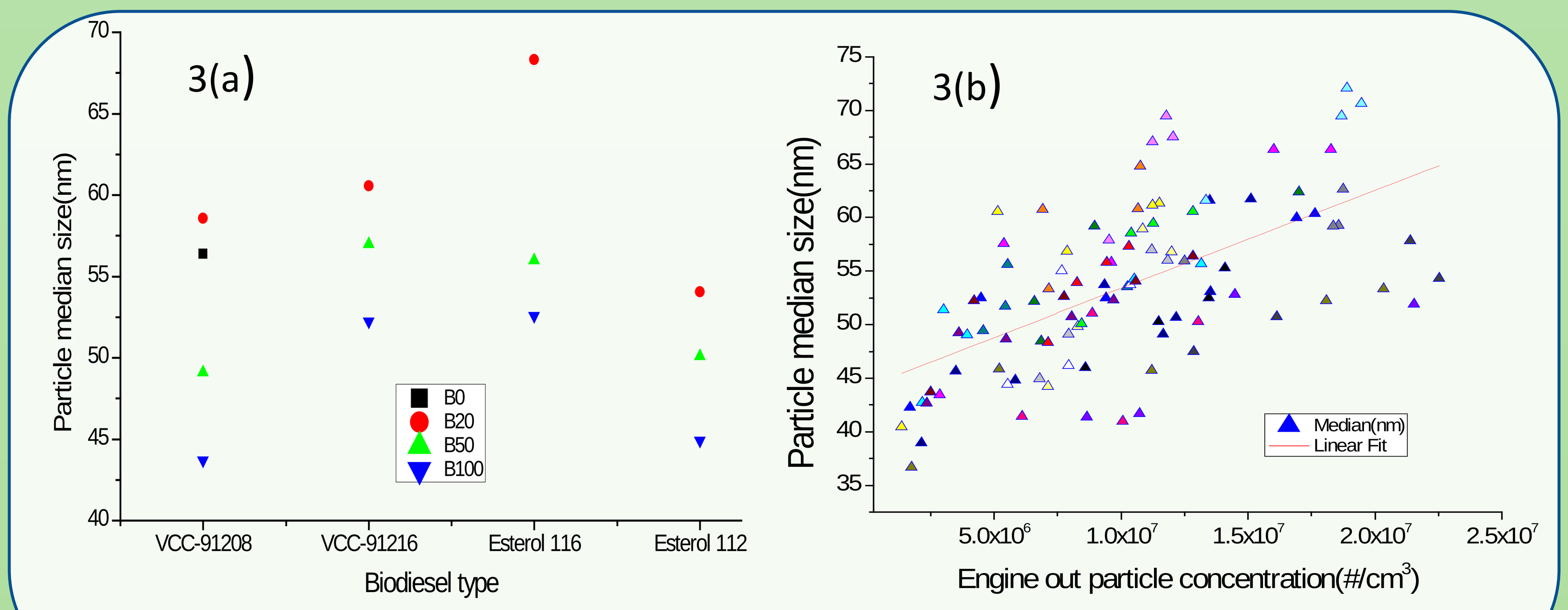


Figure 3: Particle median size from tested fuels

Effect of fuel properties on particle emissions

Particle emissions increased with the increase of fuel viscosity and surface tension but only within specific blend (Fig. 4a and 4b). For higher blend percentages (B50 and B100) there was a linear relationship between surface tension, viscosity and PM emission. A more consistent relationship was observed between fuel oxygen content and PM emission (4c). This relationship did not depend on the blend percentage. This is a clear indication that fuel chemical composition is more important than its physical properties in terms of engine exhaust particle emissions.

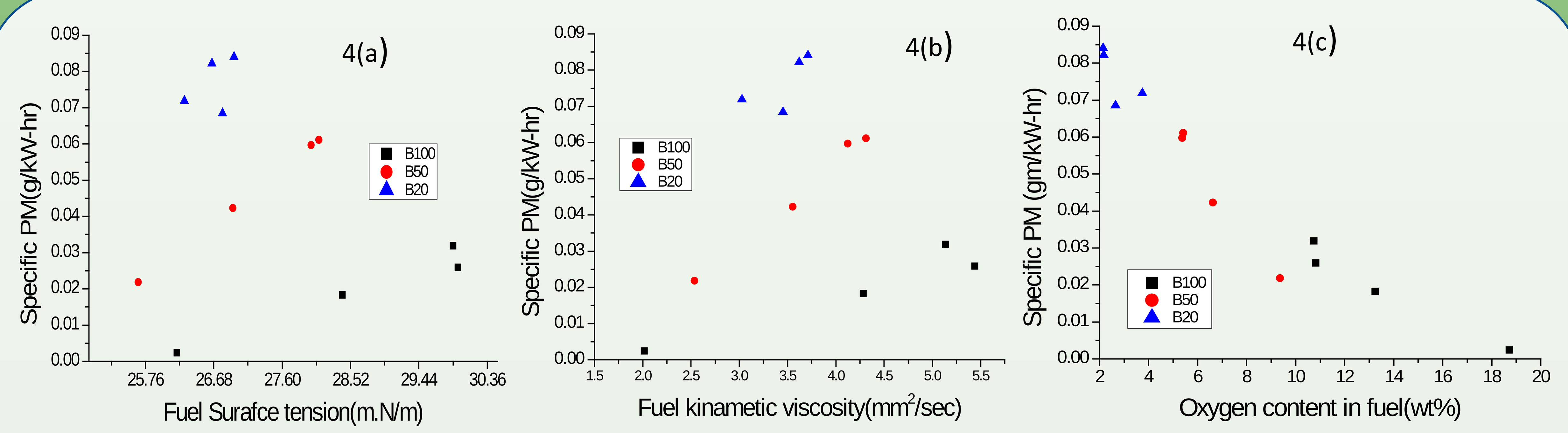


Figure 4: PM emissions with tested fuel surface tension, viscosity and oxygen content

Conclusions

- Biodiesel with shorter carbon chain length and higher degree of saturation have more potential to decrease engine exhaust particle emissions.
- Coagulation influences overall engine exhaust particle size.
- Higher degree of unsaturation in biodiesel enhances nanoparticle emissions.
- Chemical composition of biodiesel is more important than its physical properties in regards to particle emissions.

Queensland University of Technology

Variation in particle emissions among biodiesels with controlled physicochemical properties

Md. Mostafizur Rahman, .M. Pourkhesalian, S. Stevanovic, H. Wang, B. Miljevic, Z. Ristovski
School of Chemistry Physics and Mechanical Eng. Queensland University of Technology, Brisbane, QLD-4000, Australia
Email:mdmostafizur.rahman@qut.edu.au

ETH2013
17th ETH Conference on Combustion Generated Nanoparticles

Introduction

Biodiesel can be produced from variety of feedstocks and physicochemical properties of biodiesel also vary among those different feedstocks. Therefore it is necessary to find the optimum biodiesel properties in regards to engine performance end emissions before its widespread application.

Objectives

To investigate the influence of biodiesel physicochemical properties on engine exhaust particle emissions

Materials and methods

Four biodiesels with different physicochemical properties and an ultra low sulfur diesel (sulfur content < 6ppm) were used at B100, B50 and B20 blends, in a common rail turbocharged diesel engine. Figure 1 shows the fatty acid profile of used biodiesels, where the table shows some important physicochemical properties.

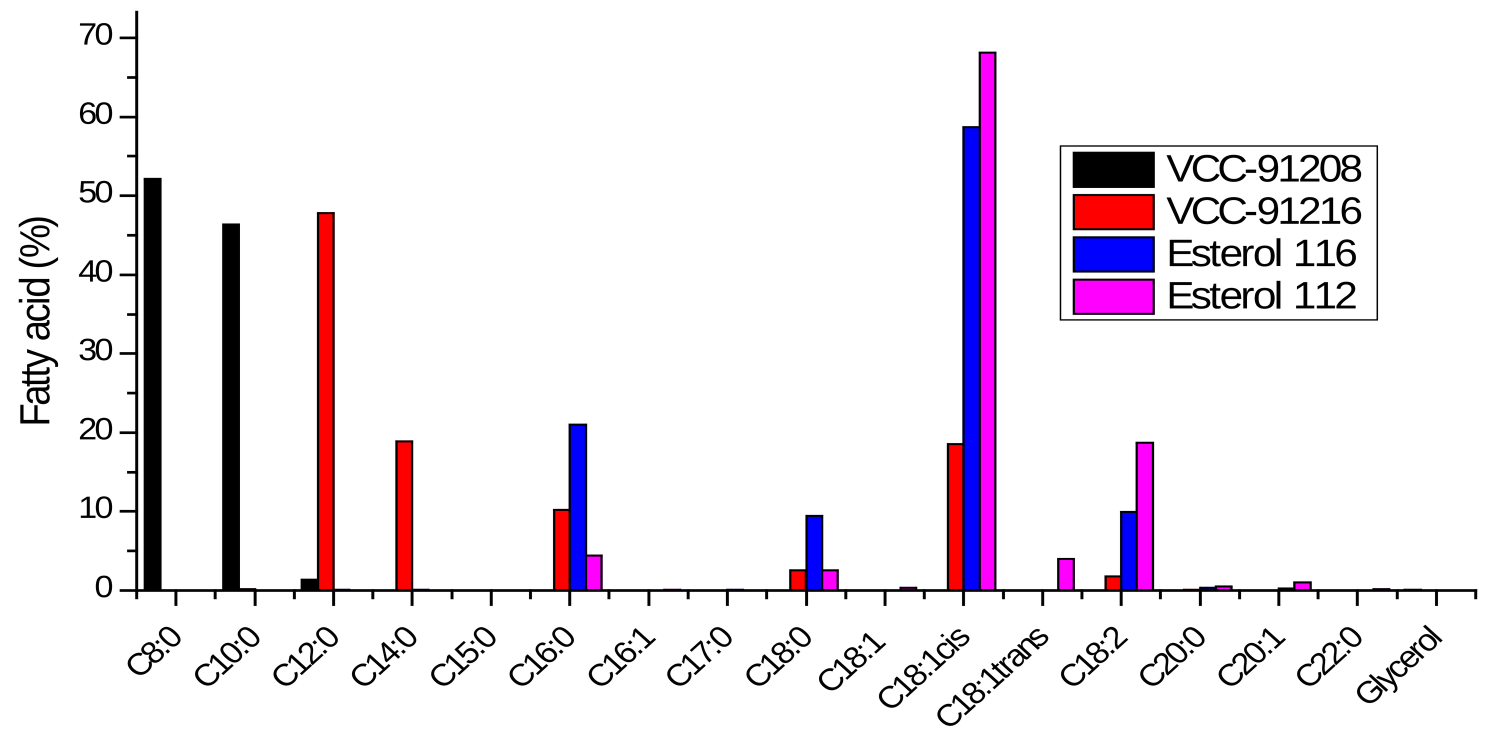


Figure 1: Fatty acid profile of used biodiesels

Fuel type/Properties	VCC-91208	VCC-91216	Esterol 116	Esterol 112	Diesel
Oxygen content (wt%)	18.72	13.25	10.74	10.83	
Density(kg/l)	0.877	0.871	0.873	0.879	0.8482
Viscosity (mm^2/sec)	1.95	4.37	4.95	5.29	3.148
Surface tension (mN/m)	26.184	28.41	29.9	29.966	20
Cetane value	62.96	65.57	61.06	53.65	48.5
Iodine value	1 max	8	65	105	
Saponication value	330	233	195	185	
Acid value	0.9	0.4	0.8	0.4	<0.05
Boiling point (^{0}C)	190	>150	165.6	>150	
Gross Calorific value(MJ/kg)	35.335	37.585	38.409	39.825	44.365
Sulfur content(mg/kg)	--	--	--	--	2.5

Table : Important Physicochemical properties of used fuels

Results

Biodiesel with shorter carbon chain length and higher degree of saturation reduced particle emissions significantly (Figure 2). Highest 98% reduction in PM and 90% reduction PN was observed for the fuel with the shortest carbon chain length (VCC-91208). PM emissions increased with the increase of biodiesel carbon chain length and degree of unsaturation. However, for the same carbon chain length completely unsaturated biodiesel(Esterol112) emitted less particle than partly unsaturated one(Esterol116).

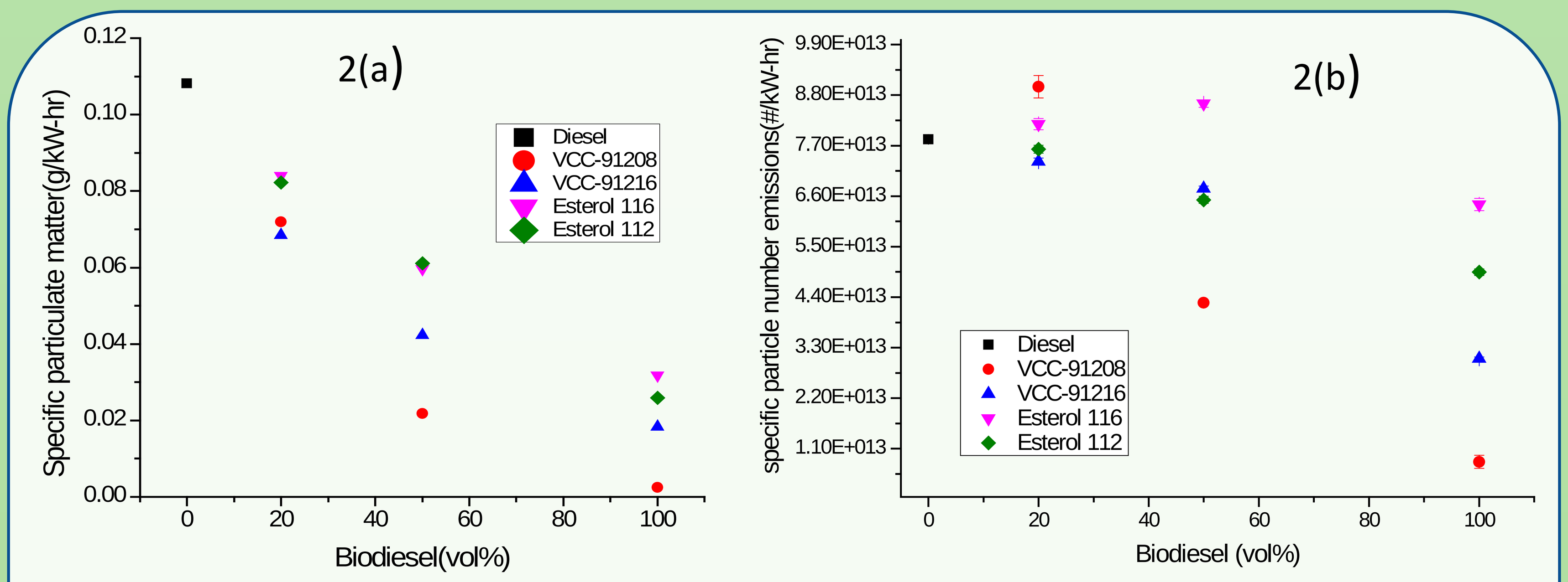


Figure 2: Specific PM and PN emissions from tested fuels

Particle size and nanoparticles

Particle size and size distribution also varied among biodiesels tested. Biodiesel emitted less PM and PN, also provided smaller particle median size(Fig. 3a), which indicates that coagulation plays a role in overall particle size (see Fig 3b). The emissions of nanoparticles (<50nm) from biodiesels were lower than for the reference diesel fuel, with Esterol-112 emitting the highest number of nanoparticles compared to the rest of three biodiesels. As Esterol-112 had the highest degree of unsaturation this is an indicator that the degree of unsaturation could have a role in the increased emission of nanoparticles.

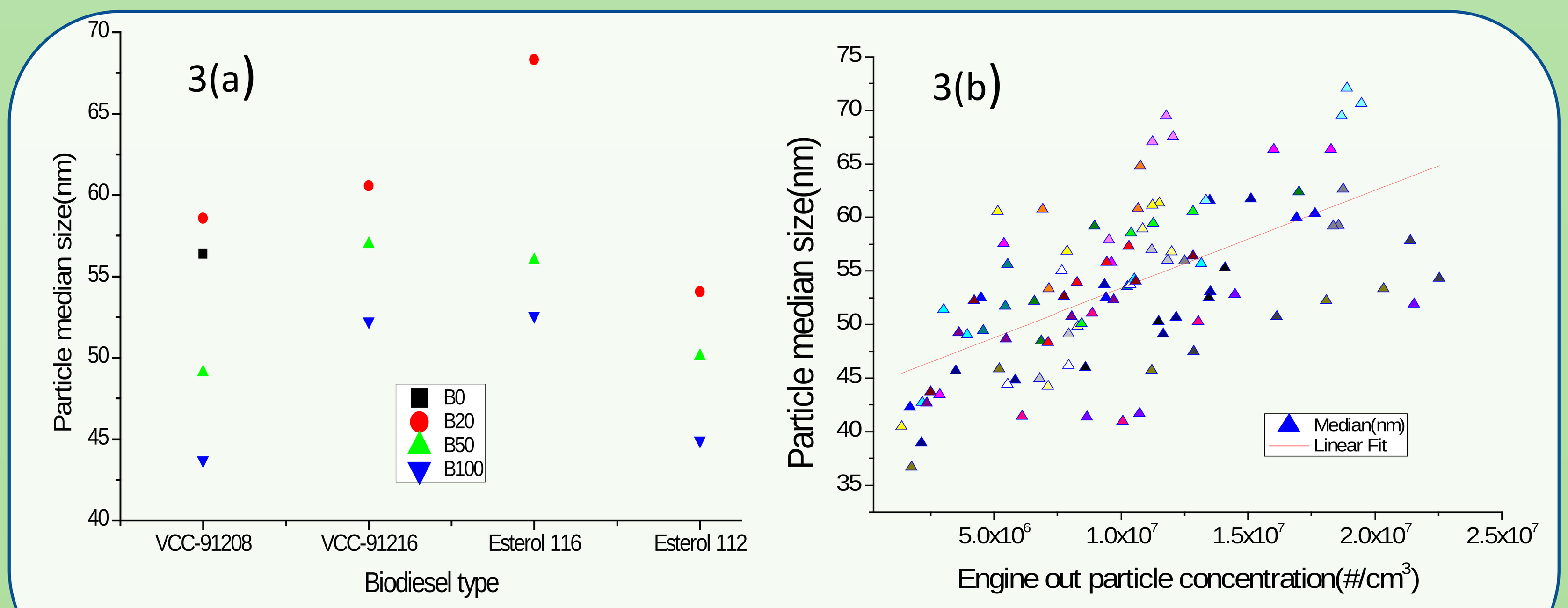


Figure 3: Particle median size from tested fuels

Effect of fuel properties on particle emissions

Particle emissions increased with the increase of fuel viscosity and surface tension but only within specific blend (Fig. 4a and 4b). For higher blend percentages (B50 and B100) there was a linear relationship between surface tension, viscosity and PM emission. A more consistent relationship was observed between fuel oxygen content and PM emission (4c). This relationship did not depend on the blend percentage. This is a clear indication that fuel chemical composition is more important than its physical properties in terms of engine exhaust particle emissions.

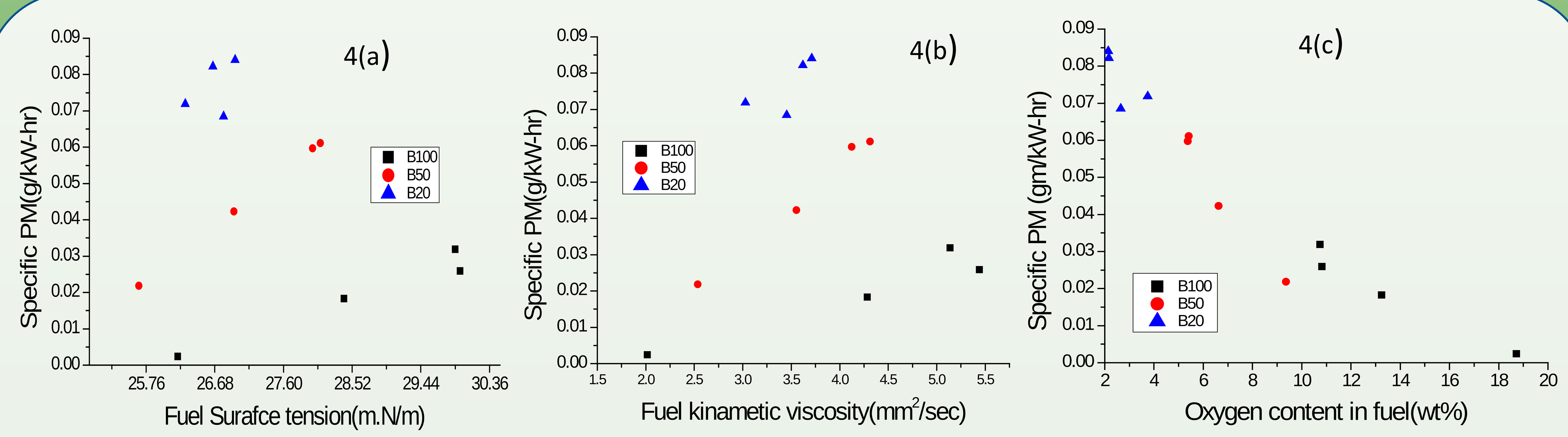


Figure 4: PM emissions with tested fuel surface tension, viscosity and oxygen content

Conclusions

- Biodiesel with shorter carbon chain length and higher degree of saturation have more potential to decrease engine exhaust particle emissions.
- Coagulation influences overall engine exhaust particle size.
- Higher degree of unsaturation in biodiesel enhances nanoparticle emissions.
- Chemical composition of biodiesel is more important than its physical properties in regards to particle emissions.