Where would our biodiesel stand in our technology?

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Abstract. Biodiesel market may be jeopardizing as compared to years before due to the change of fuel usage policies in few countries around the world. Despite that, naturally, there are still many diversified feedstocks available feasible for the production of biodiesel. Less environmental impacts by biodiesel can be approached by the use of biodiesel blends. Other possible feedstocks for the production of biodiesel with possible technological advancement are discussed aligned with the industrial revolutionary market scenario. For environmental sustainability, as Asian perspective, since palm oil as one of the biggest vegetable productions in the world, dominating the production of biodiesel and visioning the integration of IR 4.0 would be the sustaining future stand for global perspective.

1. Introduction

Where would diesel of biodiesel be in the next 10 years? In general, the diesel as petrol diesel, biodiesel and biodiesel blend have been of comparable use around the world since it was first introduced. In the early history of diesel, petrol diesel was extracted from petroleum source the crude oil. The higher carbon 14 to 20 (C_{14}-C_{20}) can be extracted at the temperature of 270°C in a fractionating column as seen in the figure 1a. The complex method of separating the lighter (smaller molecules) and heavier hydrocarbons (heavier molecules) conventionally is based on different boiling points or volatilities. The refinery gas, petrol, naphtha, kerosene, diesel, lubricating oil, fuel oil and residue like bitumen, are found to be useful in the production of primary and secondary petroleum products.

How is biodiesel produced? Conventionally, transesterification produces biodiesel from renewable oil like vegetable oil as the saturated long chains of fatty acids. The glycerin removal occurs from oil as separated from triglycerides. With mild temperature of 50 to 80°C, in the presence of alcohol, alkaline catalyst, 3 mono alkyl esters with glycerin are derived namely the so-called biodiesel [1] and [2].

For a technological commercial production, according to [3], biodiesel can be produced through these steps. In the flowsheet as shown by figure 1b, there are (1) the pretreatment of the vegetable oil, comprising of mixing and filtering and (2) the refining of plant oil, through degumming, neutralization and centrifugation. Impurities are removed. Then, (3) the transesterifications reaction to biodiesel and finally, (4) the ester washing and distillation of biodiesel towards as the purest biodiesel product.

Would biodiesel be still sustainable in the future and what is the future stand to the use of biodiesel or biodiesel blends? Due to the change of fuel usage policies around the world, biodiesel market maybe jeopardizing as compared to years before. With vegetable oils as the main raw materials, naturally, there are still many other diversified feedstocks available feasible for a sustainable production of biodiesel.

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2. Biodiesel materials and methods
2.1. Biodiesel from vegetable oil
A portion of this biodiesel, can be blended with petrol diesel, to produce biodiesel blends, a clean burning alternative fuel, with the abbreviation of BX. For example, B10 means, 10% of biodiesel plus 90% of petrol diesel. It can be used in a diesel compression ignition engine with little or no modifications.

Historically, it started with in 1851, when Sir Samuel M Kier, discovered fractional distillation to produce carbon oil from crude oil. Two (2) years later, Sir Duffy and Sir Patrick, introduced transesterifications of triglycerides. From the year of 1893 to 1911, Sir Rudolph Diesel demonstrated his workable diesel compression ignition engine and made a declaration on the use of vegetable oil to the public. Unfortunately, in the 1920s, this diesel from vegetable oil was replaced by petrol diesel, by engine manufacturers. In 1980s, this so-called biodiesel, re-emerged as renewable fuel in Europe. At present, biodiesel is commercially produced for consumer use throughout the world.

2.1.1. Biodiesel blends. The types of biodiesel blends used available, ranges from B100 to B2. Most of the leading countries use B5 and B7. As for Malaysia, Envo Diesel/B5 was introduced in 2014 [4]. At present, B10 is planned to be introduced by the 1st of January 2019 [5]. Not recently, the use of B5 is reported to be used by the countries like Canada, Malaysia, Brazil, Netherlands, Poland China, Germany, Spain. Whilst, for B7, Argentina, Netherlands, Germany, France, Malaysia, are reported in usage.

2.1.2. Biodiesel standards. Table 1 shows the most commonly used biodiesel standards for respective biodiesel blends. As abbreviated: EN is from Europe and ASTM is from USA. EN14214, is applicable for all blends as shown. The biodiesel emission regulations range from Euro 1 (in 1991) to the most recently introduced which is Euro 6 in 2014. As for example, as shown in figure 2, Euro 5 releases of 180 mg/km diesel nitrogen oxide (NOx) to that of 80 mg/km diesel NOx, for Euro 6. Note that the regulations imposed on the emission of carbon monoxide (CO), NOx and particulate matter (PM) are becoming more stringent.

Ideally biodiesel, needs to have higher flash point, for safe use, and higher cetane number for higher combustion efficiency. The flash point is the temperature at which the fuel can ignite when being exposed to heat source. Cetane number is defined as the indicator of the combustion speed of diesel fuel and compression needed for ignition. As seen here, from Table 2, biodiesel from waste cooking oil successfully fulfils the specifications as stated by EN and ASTM standards.
Table 1. Biodiesel standard [6].

| Biodiesel Blend | Europe                  | USA                  |
|-----------------|-------------------------|----------------------|
| B2 to B5        | EN 14214                | ASTM D975            |
| B6 to B20       | EN 14214                | ASTM D7467           |
| B20 to B30      | EN 16709, EN 14214      | ASTM D 6751          |
| B30 to B100     | EN 14214                | ASTM D 6751          |

Figure 2. Reduction trend of petrol and diesel nitrogen oxides (NO\textsubscript{x}) and diesel particulate matter (PM) as by different diesel emission regulation types from Euro 0 to Euro 6.

Table 2. Standards and specifications of biodiesel [2]

| Properties                        | ASTM D6751 | EN14214 | Petro Diesel | Biodiesel (Waste Cooking Oil) |
|-----------------------------------|------------|---------|--------------|------------------------------|
| Flash Point, min (°C)            | 100-170    | ≥120    | 67-85        | 196                          |
| Pour point (°C)                  | -3 to -12  | -       | -19 to -13   | -11                          |
| Kinematic viscosity (40°C) (mm\textsuperscript{2}/s) | 1.9-6.0    | -       | 1.9-4.1      | 5.3                          |
| Density (15°C) (kg/m\textsuperscript{3}) | 820-900    | 860-900 | 75-840       | 897                          |
| Cetane number, min               | 47         | 51      | 40-46        | 54                           |
| Ash content (%)                  | 0.02       | -       | 0.008-0.010  | 0.004                        |
| Carbon residue (%)               | -          | -       | 0.35-0.40    | 0.33                         |
| Sulphur content (%)              | 0.05% (m/m)| 10 mg/kg| 0.35-0.55    | 0.06                         |
| Water content (%)                | 0.03 (v/v) | 500 (mg/kg) | 0.02-0.05 | 0.04                           |

2.1.3. Biodiesel feedstock from plant oil and 1\textsuperscript{st} generation: food crops. These are some of the examples of oil feedstocks from plants, like soybean oil, corn oil, rapeseed oil, palm oil (PO),
cottonseed oil and Jatropha. They are considered as the first-generation types of food crops in the production of biodiesel. There are also various feasible sources of feedstocks for the production of biodiesel.

2.2. Emission characteristics and sustainability compliance
[7] reported on the emission characteristics that were not only on feedstock from plant oil, but also include the used cooking oil (UCO), animal fats (AF) and microalgae (MA). It is mentioned that, diesel has the highest CO and PM emission percentage (%). Whilst palm oil shows the lowest emission % for CO and NOx. With biodiesel from microalgae, animal fat, and Jatropha, the carbon dioxide (CO₂) emission % is comparably the same with that of diesel. Therefore, the need to further increase the reductions of CO, CO₂, NOx and PM by biodiesel is highly needed for sustainability compliance.

2.2.1. Advantages of biodiesel: Sustainable energy source. There are many published advantages about biodiesel, the sustainable energy source [2]. Those advantages are like, it has low greenhouse emission, low in ash content, lower sulfur content, and low in carbon residue. It is non-toxic, renewable, safe to handle, higher biodegradability, which degrades quickly in the environment. Most importantly, it is compatible to existing diesel engine without extensive engine modifications.

3. Diversifying dominating feedstock: Leading biodiesel producers worldwide 2017 (billion liters)
Referring to figure 3 [8], United States of America leads in the production in 2017 of approximately 6 billion liters (BL) of biodiesel, followed by Brazil of 4.3 billion liters and Germany of 3.5 billion liters, contributing to the leading biodiesel producers worldwide. Malaysia only produces about 0.4 billion liters of biodiesel in 2017, in comparison to other palm users of 1.3 BL of that for Thailand, 2.5 BL for Indonesia, 0.6 BL for Columbia, and 1.3 BL for Spain. According to [8], diverse types of plants as mentioned earlier like corn, soybean, rapeseed, tallow, palm, cottonseed and Jatropha leads the dominating feedstock diversifications. Besides that, there are other kinds of feedstocks which are also used for example used cooking oil (UCO) by India and Netherland, waste cooking oil (WCO) by China and used cooking oil methyl ester (UCOME) by Germany.

Figure 3. Diversifying dominating feedstocks for leading biodiesel producers worldwide in 2017 in billion liters [8]
3.1.1. Germany feedstock. According to German’s office for agriculture and food, in Germany, in 2017, there is an increasing trend of the use of used cooking oil methyl ester, besides rapeseed, for biodiesel feedstock [9].

3.1.2. Brazilian feedstock. Whilst, in Brazil, soybean is still a dominating feedstock. As reported by GAIN 2017 for Brazil, however, other feedstocks like tallow and cottonseeds are also explored [10].

3.1.3. Spain feedstock. In Spain, palm oil dominates as the feedstock usage from the year of 2013 to the year of 2017. According to [11], in the year of 2015, there was an abrupt percentage increase of recycled oil. For the production of biodiesel. Additionally, sunflower, rapeseed and soybean are increasingly used in 2017 [11].

3.1.4. China feedstock based on geographical regions. Let us now look at China from Asia. It is shown that, a diverse feedstock use for biodiesel is based on geographical regions [12]. For example, cottonseed is planted at Northwest China, whilst, Jatropha and rapeseed are mainly at the South Central of China. Other than these plant sources, China also uses microalgae and waste cooking oil for the production of biodiesel which are concentrated at the East and North East China.

3.1.5. Malaysia feedstock as biodiesel supply and demand. There is an abundant supply of palm oil tree in Malaysia, therefore, the biodiesel feedstock mainly comes from palm. According to [13] of the year 2017, the production and consumption of biodiesel increased by 470 million liters and 360 million liters, respectively. However, the export of biodiesel decreased and there were no imports of biodiesel that year.

3.2. Estimated kg of oil per unit hectare and price per tonne
According to figure 4 [2], the estimated kg of oil per unit hectare is shown for oil tree, rapeseed, peanut, sunflower and soybean. Palm has the highest estimated kg of oil per hectare in comparison to other feedstocks, followed by coconut oil tree, rapeseed, peanut, sunflower and soybean. Additionally, the price of palm in USD per tonne is also reported to be the lowest followed by sunflower, soybean, rapeseed, coconut and peanut.

![Figure 4](image_url)

**Figure 4.** The estimated kilogram (kg) of oil per unit hectare and price per unit tonne [2]
3.3. Most probable future dominating feedstocks
The most probable future dominating feedstocks can be camellina, castor algae in Brazil and Africa, Jatropha in Africa, animal fat and used cooking oil. Interestingly, apart from biodiesel, it is reported in 2017 that coffee wastes producing B20 blends will be run on double decker busses in London [14]. Therefore, the prospect of using diversified feedstocks for the production of biodiesel is still relevant. However, palm oil in Asia will still be dominating feedstocks due to the sustaining growth via palm plantations.

3.3.1. Product/waste of each fresh fruit bunch. Positively, palm product/waste can be alternatively used as alternative fuel in Malaysia. According to Index Mundi [15] as reported in the year of 2018, shows that Malaysia is still the second largest producer of palm oil after Indonesia. For each of fresh fruit bunch, 21% of palm oil can be extracted. Other than that, are from empty fruit bunch (EFB) (23%), palm oil methyl ester (POME) (28%), fibre (15%), palm kernel (7%), and shell (6%).

3.3.2. Palm oil and biodiesel. Historically, palm was originated from West Africa. Through this time until now, palm has become the biggest plantation estates replacing rubber trees. The largest palm plantations in Malaysia is Sime Darby Plantation. In 1980, the established Malaysian Palm Oil Board MPOB actively ventured biodiesel research. Test runs were conducted for 5 year from 1990 to 1995, on neat palm biodiesel and blends were conducted by MPOB Cycle and Carriage, on 30 Mercedez Benz buses [2].

4. Future technological expectation via life cycle and revolution
According to the world commission on environment and development, sustainable development is defined as when it meets the needs of the present without compromising the ability of future generations to meet their own needs’. CO₂ and biodiesel complete sustainable life cycle. The emitted CO₂ is absorbed by plant, and later to be used as biodiesel. With that, sustainability activities occur and the life cycle continues.

The Canadian lifecycle using rapeseed as feedstock for the production of biodiesel resulted in a great reduction of nearly 4.4 Million tonne of CO₂ equivalent, nearly 90% of the green house emission reduction in 2017 [16]. This highly supports sustainability policies relating to alternative fuel for future market.

4.1. Possible IR 4.0 integration: Home based standard compliance biodiesel production
Imagine that one day an augmented reality concept on home based standard compliance aiding towards own home production of biodiesel. Sensors, automations and real time monitoring are embedded with augmented reality. This maybe expected to sustain alternative and sustainable supply of fuel for the future from the backyard. Further discussions on best strategies must be looked into.

5. Conclusion
In 1911 World’s Fair in Paris, Dr. Rudolf Diesel once declared that ‘The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries which uses it’. In a Biodiesel Sustainability webpage, the scientist to biodiesel declaration, which sounds like “Biodiesel from a variety of feedstocks can meet contemporary needs for environmental stewardship, economic prosperity, and quality of life without compromising the ability of future generations to meet these needs for themselves.”

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