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Review article

Review of scientific research regarding PPO, tallow and RVO as diesel engine fuel

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ABSTRACT

Pure Plant Oil (PPO) is extracted from the seeds of oil producing plants. It is often further processed to make bio-diesel in order to reduce the fuel's viscosity, thus making it suitable for direct use in diesel engines. This process adds to the fuel production energy consumption, increases the fuel cost and generates undesirable by-products. The viscosity of PPO can also be reduced by heating the fuel using heat from the engine with simple heat exchangers. This fuel may also be more suitable for smaller markets, e.g. the Irish market, whereby Irish bio-fuel producers would be able to supply "un-transesterified" fuel, maximising their profits, because of the lower production cost. The following paper describes benefits of PPO over bio-diesel fuel, it outlines the stark lack of literature regarding the optimisation of PPO fuelled diesel engines. Furthermore aspects such as the importance of fuel feedstock quality and storage are investigated in order to establish the current status of PPO, RVO and tallow in this regard on engine performance. It was found that while much literature exists regarding bio-diesel degradation and storage, very little was available regarding the un-transesterified fuel and the effects of this fuel's quality on engine performance and degradation.

Contents

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1. Introduction to the fuel

Pure Plant Oil (PPO) also known as straight vegetable oil (SVO) is the use of plant and vegetable oils without any modification to their chemical structure as a fuel in order to be combusted inside a diesel engine. This fuel type should not be confused with bio-diesel, which is a fuel derived from pure plant oils through a transesterification process that splits fatty acids from glycerine in order to reduce the PPO viscosity similar to that of mineral diesel. Even though PPO generally has a viscosity 10 times higher that that of mineral diesel, its viscosity can be reduced easily by heating it. There are some notable advantages to this method, the foremost of which, being the neglecting of the chemical processing required by bio-diesel production, which may furthermore be more favourable for the over all energy balance [1]. Moreover, PPO systems can use energy that would normally be lost from the combustion process in order to heat up the oil, which in turn reduces its viscosity via a simple heat exchanger.

In a Danish study [2] using, EMBIO, the Danish energy agency's model for economic and environmental assessment of bio-fuels, a conclusion was found that states rape-seed oil production and use, has a strongly positive energy and CO_2 balance and that rape-seed can be said to be genuinely CO_2 neutral.

They argue that the CO_2 reduction/capture from just the feedstock straw far surpass the CO_2 emissions by the cultivation processes. The low overall energy consumption in optimised production is a massive advantage for PPO over bio-diesel. The over all consumptions as reported by Jensen [3], states that the energy consumptions in order to produce the fuel, when compared to their output are; for fossil diesel 12%, for PPO 13%, and for bio-diesel 26%. Thus PPO is clearly overall a more energy efficient fuel than bio-diesel. No special precautions are needed for PPO and the fuel is harmless to humans, water and soil. In contrast, bio-diesel is made from an additional industrial process based on the poisonous methanol, so it requires some more energy to produce and it must be handled like fossil diesel. In the German system of water pollution classes [4], rapeseed oil is classified in the lowest class 0, whereas bio-diesel is in class 1, and fossil diesel is in class 2.

In particular PPO is much more suitable for the Irish and other small scale markets because the bio-fuel producers can maximise their profits and make their bio-fuel venture a more viable endeavour. Unprocessed rapeseed oil, recovered vegetable oil [RVO] and tallow can be used as fuel when some minor peripheral modifications are made to a diesel engine. This means that fuel processing costs and industry start-up costs are kept low. This approach would have particular relevance in Ireland and other small markets because this type of fuel production would require only a low capital investment, both the fuel and the by-product cake can be used locally, none of the undesirable liability [5] glycerine is produced and it is possible to start small production and expand later. In bio diesel production 10% raw oil is converted to a glycerine by-product, which contains 50–60% glycerine and 20–25% methanol. This glycerine is classified as a crude produce as it contains other compounds. Singhabhandhu and Tezuka studied the case of Japan [6] and concluded that without government subsidy, the production of glycerine as a product for the current demand, is not very profitable. They state that new markets for glycerine are key in order to increase its value as the glycerine market becomes even more flooded with this product from bio-diesel production. Other studies involving the possible cogeneration of bio-diesel and other chemicals has been studied by Vlysidis et al. [7] where a 60% profit enhancement over a 20 year plant lifetime was estimated by producing succinic acid as a by product. Also in order to make bio-diesel more cost effective, recently Endalew et al. [8] have tried to use a single step in order to achieve simultaneous esterification and transestrification of PPO using heterogeneous catalysts in order to simplify the bio-diesel production process. The authors show that this process could be quite difficult to achieve.

In terms of produce a rape methyl ester plant with a throughput of 36,000 tonnes per annum has an estimated capital cost of $18 million compared with approximately $3 million for an equivalent PPO plant [9]. Groups can grow rape seed on set-aside land or add the rapeseed with normal crops in crop rotations [10–12], crush the seeds and feed the cake to dairy cows or pigs and use the oil in local vehicles.

According to an Irish 2008 report on Energy in Transport by Sustainable Energy Ireland [13] the transport sector accounted for 41% of Ireland's final energy demand in 2005, consuming more than twice as much as industry. The share of diesel in transport energy increased from 34% to 48% over the period 1990–2008 while the share of petrol declined from 47% to 34%. There was a significant increase in the share of transport energy from bio-fuels since 2006, albeit from a low base. In absolute terms, bio-fuels in transport increased from 1 ktoe in 2005 [0.03% of road and rail energy use] to 56 ktoe in 2008 [1.2%]. According to an Irish 2006 report on Energy in Transport by Sustainable Energy Ireland [14], private cars were responsible for 24% of all transport fuel usage in 2005, fuel consumption by freight transport increased by 264% from 1990 to 2005. From 1990 to 2008, total CO_2 emissions increased by 53% [2.4% per annum on average]. Transport recorded the largest increase at 176% [5.8% per annum] over the period. Transport share of energy-related CO_2 emissions was 35% in 2008 [13]. The amount of bio-fuels that Ireland can produce will only ever be able to supply a small fraction of the demand and thus there is a very strong argument that PPO should be targeted to fuel the freight haulage industry, where the energy conversion would be most effective and easiest to make the simple engine modifications required.

The production, harvesting and processing of rape is carried out on a commercial basis in Ireland with as much as up to 6000 ha is grown every year. Typical Irish oilseed rape yields are in the range of 2.5 t/ha. (Spring sown) to 3.2 t/ha. (Winter sown) [15]. For Ireland to achieve a 2% substitution of road diesel, a production of about 35,000 t/annum of bio-fuel would be required [16]. A report by Sustainable Energy Ireland in 2004 [17] on a liquid bio-fuel strategy for Ireland suggested that there is a potential of growing 10–15 kilo hectares per annum of rape seed oil crops. They also suggest that the average yield for rape-seed crops is about 3 tones per hectare, which equates 1 tone per hectare of vegetable oil that can be utilised for fuel. They estimated that 19.8 kt of waste vegetable oil was collected in Ireland in 2003 and they estimate that 25.4 kt will be collected in 2020. The amount of tallow available for fuel is estimated to be 15 kt in 2010. Combined PPO, RVO and tallow could equate to over 30 kt of vegetable oil available for fuelling diesel engines in Ireland. This would almost equal the 2% substitution of road diesel, as outlined by [16] in a publication specific to Ireland.