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# Engine characterization study of hydrocarbon fuel derived through recycling of waste transformer oil

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ABSTRACT

This work intends to capitalize waste transformer oil (WTO) as a renewable source of fuel in a diesel engine, given the cost of fuel being used is reduced when using waste products. Previously, despite its higher viscosity, WTO is used as such or in blends with diesel in a diesel engine. However, in the current study, efforts are taken to chemically treat WTO so as to bring down its viscosity and make it conducive for diesel engine application. As such, WTO is pretreated with concentrated sulfuric acid and subjected to alkaline trans-esterification with an alcohol and alkali catalyst. Interestingly, the derived hydrocarbon fuel (HCF) discerned the presence of cyclo-hexenol and oxabycyclo-heptane as its major constituents, contrary to the exwastence of methyl esters as reported for other trans-esterified vegetable oils. Subsequently, HCF is utilized in a diesel engine by optimizing the combustion bowl geometry, considering that an engine modification is imperative to effectively operate high viscous fuel like derived HCF in a diesel engine. In this regard, three combustion bowl geometry shapes are preferred viz Piston 1 (shallow depth combustion chamber), Piston 2 (toroidal combustion chamber) and Piston 3 (hemispherical combustion chamber). In the pursuit of experimental investigation of B25 (HCF – 25% and diesel – 75%) and B100 (HCF – 100%), piston 2 showed enhanced engine performance and emission than the other two configurations. Notably, BTE for B25 with piston 2 is increased by 10.2%, while the emission such as HC, CO and smoke are reduced by 13.3%, 11.7% and 10.1%, respectively, than the conventional piston bowl geometry (piston 3) at the expense of increased $NO_X$ emission.



## 1. Introduction

In the past few decades, the choice of biodiesel as viable substitute for diesel in a diesel engine has been promulgated to be the probable solution for the problems of petroleum fuel depletion and catastrophic impact of pollutant emissions on environment [1,2]. Though researchers have identified wide variety of vegetable oil based fuels [3,4], the choice of feedstock is still being refined, traversing from first generation to third generation biofuels. Undeniably, availability of feedstock, effect of feedstock cost on the overall production cost of biodiesel and advancements in the production of biodiesel are recognized as potential reasons for the evolution for different categories of biodiesel [5]. Significantly, the cost of feedstock is being contended as one of the crucial factor as its price is reported to have been three times higher than conventional diesel and consequently, researchers have targeted using inedible feedstock, which are touted to be economical when compared to edible vegetable oils [6,7]. Going further, quite recently, few researchers have also resorted to avail waste oils as commensurate source of alternate renewable fuel in a diesel engine [8,9]. It is worthwhile to note here that these waste products, besides being inedible, are found to be economical and therefore, the notion to capitalize the renewable source of energy from waste products has to be given due attention.

Having emphasized the significance on the utilization of waste products as potential substitute for diesel, it is noteworthy to identify few of them. In this regard, Mani et al. [10] demonstrated the effective utilization of waste plastic oil, a renewable and biodegradable fuel produced by crackling process, in a diesel engine. Based on their study, reports on reduction in $NO_X$ (oxides of nitrogen), CO (carbon monoxide) and UHC (un-burnt hydrocarbon) emission and increase in BTE (brake thermal efficiency) are documented for waste plastic oil at a retarded injection timing of 14° CA (crank angle) BTDC (before top dead center). Similarly, Arpa et al. [11] identified that the engine

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**Table 1**
Thermal and physical properties of the blend fuels.

| Property | Measurement standards | Diesel | WTO | 25% HCF | 100% HCF |
|---|---|---|---|---|---|
| Kinematic viscosity at 40 °C (CSt) | ASTM D445 | 2.57 | 11.06 | 3.3 | 4.03 |
| Flash point (°C) | ASTM D92 | 75 | 144 | 89 | 93 |
| Fire point (°C) | ASTM D92 | 56 | 152 | 68 | 85 |
| Gross calorific value (kcal/kg) | ASTM D240 | 10,738 | 10,218 | 10,584 | 10,343 |
| Density at 15 °C (g/cc) | ASTM D1298 | 0.8072 | 0.8604 | 0.8234 | 0.8355 |
| Calculated cetane index | ASTM D976 | 50 | 52.7 | 51.5 | 52 |

lubrication oil is being discarded as waste and thus, initiated an attempt to utilize it as a fuel for diesel engine. In their venture, DLF (diesel like fuel) is produced from waste engine lubricating oil by pyrolytic distillation method and the measured properties of the produced DLF are found to be conducive for its use in a diesel engine. Subsequently, the experimental investigation revealed an increase in engine torque and BTE, while emissions such as CO and $NO_X$ are shown to be reduced. Besides the above reported waste products, vegetable oils, which are deemed to be discarded as waste, are effectively tapped as a source for producing biodiesel. In this regard, recently, Vedharaj et al. [12] asserted the utilization of kapok oil, extracted from waste kapok seeds through steam treatment process, in a diesel engine. In the pursuit of the experiential testing of kapok biodiesel in a coated diesel engine, B25 and B50 blend of kapok biodiesel are identified as the optimum blend in respect of engine performance and emission. In the same note, CNSL (cashew nut shell liquid), extracted from the waste cashew nut outer shells, has been seen as a sustainable source for producing biodiesel [13,14]. Notably, a recent study reports the production of CNSL biodiesel through double stage trans-esterification process [15] and in an attempt to effectively utilize it in a diesel engine, the engine components are coated and a 6% increase in BTE is pointed out for B25 blend of CNSL biodiesel.

Recently, WTO (waste transformer oil) is noted to be disregarded as waste product, despite having immense attributes as a fuel [16,17]. Strikingly, when these WTO are discarded into the atmosphere, it is more likely to contaminate the land and pollute the environment, as used transformer oils are reported to have many contaminants. Comprehending the apprehensive effect of WTO on environment, Behera et al. [18], in their recent study, have refined and operated it in a diesel engine. Notably, the authors, based on the compositional analysis of WTO, have categorized the presence of essential hydrocarbons with the additional element of oxygen in their molecular structure. However, the kinematic viscosity of WTO is noted to be 5.4 times higher than diesel, which is believed to deter the direct use of it in a diesel engine. In-order to avert this, the authors have decided to avail the contemporary method of blending it with diesel and the experimental study confirmed 60% blending of WTO with diesel as optimum in respect of better engine characteristics.

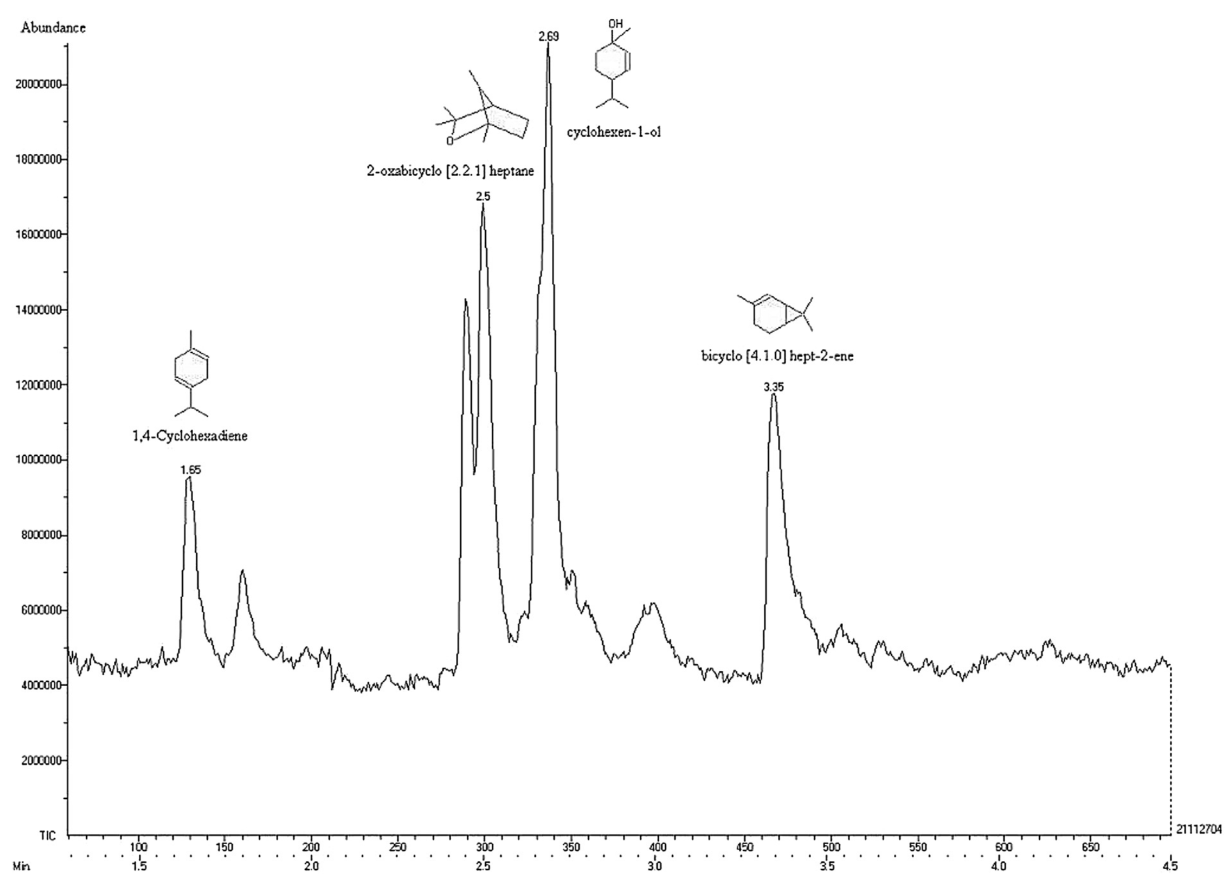


**Fig. 1.** GC–MS spectrum of the produced HCF.