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An assessment of combustion, performance characteristics and emission control strategy by adding anti-oxidant additive in emulsified fuel

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ABSTRACT

In the current scenario, the global researchers are focused on multidimensional fossil fuel facts, namely, depletion of fuels, energy crises, and emission threats. Hence, this condition of biofuel has potential worldwide acceptance. This research work uses the novelty of biofuel and biofuel emulsion, for the fuelling of IC engines for experimental analysis. The main objective of this work is to reduce harmful engine emissions, namely, nitrogen oxide, carbon monoxide, hydrocarbon, and smoke. The new feedstock of novel biofuel was obtained by solvent extraction method and which is now called raw Borassus Flabellifer Oil (BFO). Raw oil directly introduced in IC engine showed enhanced emission threats during last decade. Fuel modification is an attractive solution to avoid this threat. Emulsion technique is considered as a propitious method for alternative fuel. BFO emulsion fuel was prepared by adding 5% water and 2% of span80 surfactant by volume. Using emission reduction agent called antioxidant L-ascorbic acid as an additive in BFO emulsion fuel for scavenging the nitrogen radicals. The test result was analyzed in terms of combustion, performance and emission characteristics on a single cylinder DI diesel engine with raw BFO, emulsified BFO and additive mixed emulsified BFO respectively. Reduced emission of nitrogen oxide, smoke, hydrocarbon, and carbon monoxide by the use of additive mixed emulsified BFO fuel was observed. This includes improved engine efficiency, heat release rate, peak pressure and energy consumption than raw BFO and emulsified BFO.

1. Introduction

Intensive investigation of alternative energy sources has been going on to identify a solution to the problem of increasing depletion of petroleum product, energy crisis, and environment issue. The condition demands an alternate source of energy for diesel engines. Biodiesel is currently used as an alternative fuel because of eco-friendliness and it can be easily extracted from renewable resources. Vegetable oils are also an alternative fuel for diesel engine. In addition, the biodiesel can be used to operate a diesel engine with little (or) no modification (Mahmudul et al., 2017; Hajjari et al., 2017; Patel and Sankhavara, 2016; Kumar et al., 2017). Biodiesel said to be a clean fuel has almost no aromatics and has about 10–11% oxygen (O_2) based on weight. The ignition quality of blended biodiesel is better compared with pure diesel due to its cetane number close to diesel fuel.

Since 1990, many researchers have taken up the work of exploration on alternate fuels owing to energy and environmental crisis. Fossil fuel, oil crops are the primary pillars for bio fuel production. Choice of the desirable feedstock for bio fuel production is important criteria a large number of feedstock crops have been projected, they are classified as edible and non-edible oil. In the current scenario, most of the researcher prefers to go with second-generation non-edible feedstock for bio fuel production because of food scarcity and considering an environment-friendly feature of non-edible oil (Miri et al., 2017; Abedin et al., 2014; Habibullah et al., 2014). In the present work, evaluation of the existing diesel engine has been done using Borassus flabellifer methyl ester. The Borassus flabellifer is a tall tree with a stout trunk. It is cultivated extensively in Asian and African continents. Nearly all the parts of the tree have medical use. The fruit of the tree has three to five nut portions, with a kind of fleshy, large and fibrous seed. The young seed contains a soft pulp with some juice. The tendered young seed gradually hardens and develops a fibrous kernel to help extraction of oil. The main

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Table 1
Physicochemical properties of test fuels.

Properties	Units	ASTM Standards	Diesel	BFO	BFO + Emulsion	BFO + Additive + Emulsion
Calorific value	MJ/kg	ASTM D5865	44.52	38.8	35.18	37.28
Kinematic viscosity 40 °C	cST	ASTM D445	3.9	35.7	5.12	5.74
Density	Kg/m^3	ASTM D 4052	820	880	750	789
Flash point	°C	ASTM D92	76	120	150	135
Latent heat of vaporization	(kJ/kg)	ASTM E2071	262	320	360	340
Auto ignition	°C	ASTM D2883	250	300	310	295
Cetane number	–	ASTM D 613	47	43	41	43.5

chemical constituents of fresh Borassus palm nuts are 0.08% ash, 0.18% protein, 0.26% fiber, 0.09% lipids, and 26.18% amylase contents as formed (Barminas et al., 2008). Usually, Palmyra seed is hard with an elliptical shape, nearly 5–7cm in diameter with color ranging from dark light brown.

The important properties of biodiesel such as high viscosity, low volatility, and poor cold flow properties have a significant effect on vaporization, fuel impingement on the walls and delay the start of ignition (Bueno et al., 2017; Sierra-Cantor and Guerrero-Fajardo, 2017). Particulate emission by using vegetable oils was found to be higher than that of diesel fuel. Hence, various techniques have been decreased to help reduction in nitrogen oxide and particulate emission some of those are Exhaust Gas Recirculation (EGR), retardation of fuel injection, air enrichment and emulsification (Khond and Kriplani, 2016; Hagos et al., 2017). Many researchers have found this technique emulsion as the most viable method for reducing NOx and Particulate Matter (PM).

Ogunkoya et al. (2015) pointed out that fuel microexplosion and puffing are the important process in the emulsion to break down fuel into fine droplets on account of water and oil have different boiling point temperature, which results in a fast rate of evaporation of water compared with oil in a combustion chamber. Tests had been conducted with cooking oil emulsion in a direct injection natural aspired diesel engine. WCO emulsion showed a substantial reduction in NO_x, smoke, HC and CO emission and cylinder peak pressure while ignition delay was increased compared to neat WCO (Kumar and Jaikumar, 2014a) has reviewed the effect of ethanol–biodiesel–water microemulsions fuel, the observations have led (Qi et al., 2017) to the conclusion that microemulsion fuel tends to increase HC and CO at low and middle loads but higher load emission results in the opposite trend. Water emulsion fuel could decrease NO_x emission at all load conditions (Elsanusi et al., 2017). Tan et al. (2017) found a significant reduction in CO_2 and CO emission of the entire emulsion blend at low and middle speeds, there was a gradual increase in carbon while increasing the engine speed. The reduction in nitrogen oxide emission was about 30% at middle load conditions.

Ithnin et al. (2015) reported that NOx and PM were found lower for all emulsion diesel blend. E20 (20% water + 80%diesel) blend is the best in the reduction of NOx and PM; it reduces by 41% and 35% correspondingly. At lower load, reduction in CO and CO_2 emission could be more than diesel fuel. E20 blend shows increase in cylinder pressure and heat release rate of the engine. Kumar and Jaikumar, 2014b found reduction in smoke, CO and HC emission with dual fuel operation, hydrogen injected as pilot fuel with waste cooking oil increased ignition delay and premixed combustion, resulting in superior performance at high power output. The emission of NO_X, CO, HC and PM reduction has been a matter of good concern for the automobile industry. In this regard, a number of techniques could be taken up for reduction of exhaust emission. A notable method is mixing of antioxidant additive with biodiesel, the experimental investigation has been reported with different type of antioxidant additives, namely, BHA (butyl ate hydro-oxyganisole), BHT (Butylated hydro-oxy-tolence) and 1, 4 dioxane with biodiesel for reducing NO_x emission but increased CO emission (Ramalingam et al., 2016a).

Sathiyamoorthi et al. (2017) have seen the behavior of compression ignition engine using a combination of Exhaust Gas Recirculation (EGR) and Di Ethyl Ester (DEE) added with 20% of nano emulsified lemongrass oil. Their conclusion was a minimal in oxides of nitrogen emissions by 30.71% and smoke emission by 11.2%. They also found increase in cylinder pressure and heat release rate with Di Ethyl Ester (DEE) of 20% of emulsified lemongrass oil (LGO) about 2.4% and 10.8% respectively on account of prolong ignition lag caused by exhaust gas dilution. Synthetic antioxidant and natural antioxidant with B20 sapota oil methyl ester blend showed reduction in the emission except nitrogen oxide (Ramalingam et al., 2016b).

Literature shows a major reduction in engine emission with added additives in emulsion fuel. The current research work has been motivated to evaluate the effect of the L-ascorbic acid as an additive in Borassus flabellifer oil emulsion. The observation leads to the conclusion optimum level of water content added to raw Borassus flabellifer oil by 5% and optimum level of dosage added with Borassus flabellifer emulsion by 5 ml To study the influence L-ascorbic acid as additive in Borassus flabellifer oil emulsion of engine performance, emission and combustion behavior. A comparative test made on single cylinder direction injection diesel engine for diesel, raw Borassus flabellifer oil, emulsified Borassus flabellifer oil and additive mixed emulsified Borassus flabellifer. All the physiochemical properties are tested and the property of these fuels meets ASTM standards. The properties of test fuels are shown in Table 1.

2. Materials and methods

2.1. Botanical biography of Borassus flabellifer

Borassus flabellifer oil is obtained from Borassus flabellifer seed kernel. The species of Borassus flabellifer is seen in larger quantities in the tropical areas. The Palmyra is a tall tree growing up to 30–40 m height; it reaches to full growth in 25–35 years. Worldwide Palmyra production is about 140 million with over 7 million in India. The young Palmyra seeds are called ice apple or Palmyra fruit seed commonly known as “Nungu” which is used during summer to reduce body heat. All over the world 100 million Palmyra fruits are gathered annually but 5 to 10 millions of fruits are only consumed, the rest is dried. The dried Palmyra seed kernel is extracted by a process manually or mechanically.

2.2. Borassus flabellifer oil extraction

Extraction of oil is commonly named as mechanical extraction, solvent extraction and enzymatic extraction. Mechanical extraction and solvent extraction are considered cheap and most of the researchers prefer these techniques for extraction, the oil yield mainly depends on the technique used for extraction as shown in Fig. 1. In our research work, the solvent extraction process is carried out in a soxhlet apparatus using N-Hexane as a solvent to extract BFO. (Fornasari et al., 2017).

The crushed Borassus flabellifer seed was first dried in an oven at a temperature of 110 °C. The solid samples of 100 g crushed seeds are placed in a thimble inside the soxhlet apparatus. N-hexane solvent was