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Processing of Non-Edible Vegetable Oils in Biofuel Production Using Acidic Catalysts

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Abstract

In this study, Egyptian Jatropha and Castor oils were obtained and transformed into their corresponding biofuels by catalytic cracking using heterogeneous catalysts (Alumina and Montmorillonite-HCL) with different ratios (0.2%, 0.4%, 0.6%, 0.8% & 1%). The conditions of biofuel production were studied including: catalyst type, catalyst ratio (%), conversion time and temperature. The specifications of the obtained products were comparable to American Society for Testing and Materials (ASTM) Standards. The suitable blends between the obtained biofuels and gas oil fuel were described. The specifications of the prepared biofuel blends were comparable to fuel properties of petroleum diesel according to American Society for Testing and Materials (ASTM) Standards.

Keywords: Jatropha oil; Castor oil; Catalytic cracking; Biofuel; Fuel properties

Introduction

There is no doubt that petroleum plays an important role in our life, from it we get a lot of products needed in our life. Fuels, lubricants, sources of heat and power generation, and raw materials in the petrochemical industries are derived from petroleum. It is known that petroleum is a nonrenewable source of energy as petroleum production all over the world will not exceed the period of 30 years, and so it will disappear in one day of our future, so it is a must to find other sources of energy in order to continue our life with ease. Scientists are now searching for new sources to replace petroleum. It is known also that the fuels from petroleum origin have a hazardous effect on environment; biofuels are suggested to be the safest fuels to environment that can be used. A sustainable alternative fuel can be described as one without negative environmental, economic, and social impacts. In addition to having lower life cycle green house gas (GHG) emissions, sustainable biofuels should not compete with food or fresh water resources or contribute to deforestation, while providing socioeconomic value to local communities where plant stocks are grown. Oil-based energy crops that can meet these sustainability criteria include jatropha and castor oil. The choice of jatropha seed oil is favorable as it is non-edible oil, so there will be no competition with food crops. Biodiesel is a clean energy source rather than conventional petroleum diesel. Spreading the biodiesel in a commercial scale in several countries is escorted by a development in the standards to ensure good biofuel quality. The biodiesel is characterized by determining its physical and fuel properties including density, viscosity, iodine value, acid value, cloud point, pour point and volatility according to ASTM standards. Biodiesel is preferable than petroleum diesel due to several characteristics including: ease of transport, renewable, effective in combustion process, low aromatic and sulfur content, high cetane number, and biodegradable [1,2]. Biodiesel has higher parameters compared to petroleum diesel including: viscosity, cloud point, pour point, nitrogen oxide emission, and engine wear; and lower parameters such as: energy content, engine speed, and engine compatibility [3]. Regarding the safety point of view, biodiesel has safety profits than petroleum diesel as it is lower combustible and higher flash point [4]. These biodiesels can be mixed with petroleum diesel in any proportion or directly used in diesel engine without modification [5]. The high cost of biodiesel is the major barrier to its commercialization, and 80 % of the total cost of biodiesel production is the cost of the raw materials [6,7]. Biofuels are obtained by cracking of different vegetable oils including: Alcea pallid oil, woody oils, soybean oil, palm oil, cotton seeds oil, Jatropha oil, and waste cooking oils [8-14]. Cracking of vegetable oils performed either thermally without using any type of catalyst [15], or by using alkaline catalysts [16], metal oxides [17], zeolite [18-20]. Owing to economic reasons, the use of low cost raw material such as: Egyptian castor oil (ECO) planted in Upper Egypt in Al-Alaki valley and irrigated using industrial and pretreated wastewater, is being considered for biodiesel production. Castor oil is planted in Upper Egypt and is widely distributed in the southern and southwestern regions with a total area of about 2,000,000 ha, and the annual seeds production is above 250,700 tons [21]. The yield of the castor oil seed is about 40-60 %. In addition, the castor trees are gaining importance due to its low maintenance and fewer crop husbandry management practices required [21]. This paper aimed to evaluate the biodiesel that is produced from catalytic cracking of Egyptian castor and jatropha oils using ASTM standards, and compare its fuel properties with petroleum diesel.

Materials and Methods

Materials

Jatropha & Castor oils were extracted from Jatropha & Castor seeds via hydraulic pressing; Alumina & Montmorillonite-HCL catalysts were purchased from (Sigma-Aldrich, Germany).

Methods

Extraction of Jatropha and Castor Oils: Dry Jatropha and Castor seeds (500 g) were crushed individually using a hydraulic press until the oil was extracted. The oil was centrifuged to remove any solid contaminants and water, and used without further purification or treatment.

Catalytic Cracking of Jatropha and Castor Oil into Biodiesel: Catalytic cracking procedures were performed as follows: 150 mL of Jatropha & Castor oils were charged individually in 500 mL two necked flask and (Alumina & Montmorillonite-HCL) catalysts were added individually at different ratios of (0.2%, 0.4%, 0.6%, 0.8% & 1%) by weight relative to oil. The mixture was mixed and allowed to thermal agitation for 4 h at 250 ^{o}C. The reaction products were collected by a condenser and their volumes were determined. The obtained biofuels from the two oils were settled in a separating funnel to separate the produced water and then centrifuged to remove any contaminated or dispersed water. The reaction was completed and the products were: 75% biofuel, 15% water, 3% solids, and the rest were vapors. There are several parameters which affect the conversion reaction of Jatropha & Castor oils into biodiesels including: the catalyst ratio (%), conversion time and temperature. These parameters were studied to attain the optimized conversion reaction conditions.

Oil Characterization: The fatty acid composition of the obtained Jatropha & Castor oils was determined using GC-Chromatographic analysis using GC-7890A instrument equipped with DB-23 column, 60 mm x 0.25 mm, i.d. of 0.25 μm. The characteristic properties of jatropha and castor oils were determined including the following: iodine value, acid value, kinematic viscosity at 40°C, density, cloud point, pour point, oxidation stability, and sulphur content.

Biofuel Specification: The characteristic specifications of the obtained biofuels such as: density, flash point, pour point, cloud point, kinematic viscosity at 40 °C, water content, total sulphur, copper corrosion strip, carbon residue & ash content were also determined according to ASTM specifications [22-30]. The suitable blends between the obtained biofuels and fuel were described.

Results and Discussion

The Characteristic Properties of Jatropha and Castor Oils

The fatty acid profiles and the properties of Jatropha and Castor oils were listed in Table 1.

Property	Castor oil	Jatropha oil
Fatty acid composition (wt %):		
Palmitic acid (C16:0)	1	15.2
Palmitoleic acid (C16:1)	-----	0.7
Stearic acid (C18:0)	-----	6.8
Oleic acid (C18:1)	3	44.6
Linoleic acid (C18:2)	5	32.2
Linolenic acid (C18:3)	1	-----
Arachidic acid (C20:0)	-----	0.2
Ricinoleic acid (C18:1, OH)	89	-----
Acid value, (mg KOH/g)	3	3.8
Kinematic Viscosity @ 40 °C, (mm2/s)	43	37
Density, (g/cm3) at 15 °C	0.959	0.91
Cloud point, (°C)	8	8
Pour point, (°C)	3	3
Oxidation stability, (h)	5.5	2.56
Iodine value, gI2/100 g oil	80.5	104.46
Sulphur content %	0	0

Table 1: The fatty acid profiles and properties of Jatropha and Castor oils.

Properties of the Obtained Biofuel

The characteristic specifications of the obtained biofuels were determined according to (ASTM) specifications. The measured characteristics such as: density, flash point, pour point, cloud point, kinematic viscosity at 40°C, water content, total sulphur, copper corrosion strip, carbon residue & ash content were listed in Tables 2-5.

Properties	Biofuels results from catalytic cracking of Jatropha Oil with Alumina Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.)					Standard Test Methods
	0.20%	**0.40%**	**0.60%**	**0.80%**	**1%**	
Density @ 15^{0}C (gm/cm^3)	0.8989	0.8991	0.8991	0.8992	0.8992	ASTM D-4052
Flash Point (P.M.C.C) (^{0}C)	45	44	45	45	44	ASTM D-93
Pour Point (^{0}C)	-3	-6	-3	-6	-3	ASTM D-97
Cloud Point (^{0}C)	3	6	3	3	6	ASTM D-2500
Kinematic Viscosity @ 40^{0}C (CSt)	6.04	6.07	6.1	6.11	6.11	ASTM D-445
Water Content (% vol)	15	14	17	15	16	ASTM D-95
Total Sulphur (% wt)	0.01	0.01	0.02	0.02	0.02	ASTM D-4294
Copper Corrosion Strip @ 50^{0}C/3h	1A	1A	1A	1A	1A	ASTM D-130
Carbon Residue (%wt)	0.05	0.06	0.06	0.06	0.07	ASTM D-4530
Ash Content (% wt)	Nil	Nil	Nil	Nil	Nil	ASTM D-482

Table 2: Physical & Chemical Properties of Biofuels results from catalytic cracking of Jatropha Oil with Alumina Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.).

Properties	Biofuels results from catalytic cracking of Castor Oil with Alumina Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.)					Standard Test Methods
	0.20%	**0.40%**	**0.60%**	**0.80%**	**1%**	
Density @ 15⁰C (gm/cm³)	0.9211	0.9213	0.9213	0.9214	0.9216	ASTM D-4052
Flash Point (P.M.C.C) (⁰C)	45	46	44	45	45	ASTM D-93
Pour Point (⁰C)	-3	-3	-6	-3	-6	ASTM D-97
Cloud Point (⁰C)	6	3	6	3	3	ASTM D-2500
Kinematic Viscosity @ 40⁰C (CSt)	3.19	3.2	3.21	3.21	3.22	ASTM D-445
Water Content (% vol)	17	16	16	15	15	ASTM D-95
Total Sulphur (% wt)	0.02	0.01	0.01	0.02	0.01	ASTM D-4294
Copper Corrosion Strip @ 50⁰C/3h	1A	1A	1A	1A	1A	ASTM D-130
Carbon Residue (%wt)	0.06	0.05	0.05	0.07	0.06	ASTM D-4530
Ash Content (% wt)	Nil	Nil	Nil	Nil	Nil	ASTM D-482

Table 3: Physical & Chemical Properties of Biofuels results from catalytic cracking of Castor Oil with Alumina Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.).

Properties	Biofuels results from catalytic cracking of Jatropha Oil with Montmorillonite-HCL Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.)					Standard Test Methods
	0.20%	**0.40%**	**0.60%**	**0.80%**	**1%**	
Density @ 15⁰C (gm/cm³)	0.8988	0.899	0.899	0.8991	0.8991	ASTM D-4052
Flash Point (P.M.C.C) (⁰C)	42	44	43	45	43	ASTM D-93
Pour Point (⁰C)	-6	-3	-3	-3	-6	ASTM D-97
Cloud Point (⁰C)	3	3	6	6	3	ASTM D-2500
Kinematic Viscosity @ 40⁰C (CSt)	6.06	6.09	6.11	6.12	6.12	ASTM D-445
Water Content (% vol)	15	15	15	17	16	ASTM D-95
Total Sulphur (% wt)	0.01	0.01	0.02	0.02	0.01	ASTM D-4294
Copper Corrosion Strip @ 50⁰C/3h	1A	1A	1A	1A	1A	ASTM D-130
Carbon Residue (%wt)	0.06	0.06	0.06	0.06	0.06	ASTM D-4530
Ash Content (% wt)	Nil	Nil	Nil	Nil	Nil	ASTM D-482

Table 4: Physical & Chemical Properties of Biofuels results from catalytic cracking of Jatropha Oil with Montmorillonite-HCL Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.).

Properties	Biofuels results from catalytic cracking of Castor Oil with Montmorillonite-HCL Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.)					Standard Test Methods
	0.20%	**0.40%**	**0.60%**	**0.80%**	**1%**	
Density @ 15⁰C (gm/cm³)	0.921	0.9211	0.9212	0.9213	0.9213	ASTM D-4052
Flash Point (P.M.C.C) (⁰C)	45	45	46	45	44	ASTM D-93
Pour Point (⁰C)	-3	-6	-6	-3	-3	ASTM D-97
Cloud Point (⁰C)	3	6	3	6	3	ASTM D-2500
Kinematic Viscosity @ 40⁰C (CSt)	3.2	3.2	3.21	3.22	3.23	ASTM D-445
Water Content (% vol)	16	15	17	16	15	ASTM D-95
Total Sulphur (% wt)	0.01	0.01	0.01	0.02	0.01	ASTM D-4294
Copper Corrosion Strip @ 50⁰C/3h	1A	1A	1A	1A	1A	ASTM D-130
Carbon Residue (%wt)	0.05	0.06	0.05	0.07	0.06	ASTM D-4530
Ash Content (% wt)	Nil	Nil	Nil	Nil	Nil	ASTM D-482

Table 5: Physical & Chemical Properties of Biofuels results from catalytic cracking of Castor Oil with Montmorillonite-HCL Catalyst with different conc.s (0.2, 0.4, 0.6, 0.8, 1 % conc.).

The Suitable Blend between the Obtained Biofuel and Gas Oil Fuel

In this study, many blends were made between the prepared biofuel and gas oil fuel. The suitable blend between the obtained biofuel and gas oil fuel was (10% Biodiesel + 90% Gas Oil). The results of this biodiesel blend were in acceptable range compared to gas oil fuel according to the standard values of ASTM specifications Tables 6-9. The flash point of the obtained biofuel decreases than ASTM specifications (less than 52°C), when the blending ratio of the prepared biodiesel to petroleum diesel increases than 10%.

Property	Biofuel* B10 (10% Biodiesel + 90% Gas Oil)					Gas Oil	Specification Limits	Test Method
	0.20%	0.40%	0.60%	0.80%	1%			
Density @ 15⁰C (gm/cm^3)	0.8499	0.8504	0.8506	0.8507	0.8507	0.8394	Reported	ASTM D-4052
Flash point (P.M.C.C) (⁰C)	60	59	59	58	59	68	55 (min.)	ASTM D-93
Pour point (⁰C)	-6	-6	-6	-6	-6	-9	15 (max.)	ASTM D-97
Cloud point (⁰C)	3	3	3	3	3	3	Reported	ASTM D-2500
Kinematic viscosity at 40⁰C (CSt)	3.05	3.06	3.06	3.07	3.07	2.96	1.6 - 7	ASTM D-445
Distilled @ 350⁰C (% vol)	91	91	92	91	92	92	85 (min.)	ASTM D-86
Water and Sediment (% vol)	Nil	Nil	Nil	Nil	Nil	Nil	0.1 (max.)	ASTM D-2709
Total Sulphur (% wt)	0.11	0.11	0.12	0.12	0.12	0.12	1 (max.)	ASTM D-4294
Copper corrosion strip @ 50⁰C/3h	1A	1A	1A	1A	1A	1A	1 (max.)	ASTM D-130
Carbon Residue (% wt)	0.06	0.06	0.07	0.08	0.08	0.07	0.1 (max.)	ASTM D-4530
Ash content (% wt)	Nil	Nil	Nil	Nil	Nil	Nil	0.01 (max.)	ASTM D-482
Colour	2	2	2	2	2	2	4 (max.)	ASTM D-6045
Cetane index	51	50	50	51	51	55	46 (min.)	ASTM D-4737
Calorific Value (Mj/Kg)	43.1	43.1	43.1	43.2	43.1	43.2	Reported	ASTM D-4868
Aniline Point (⁰C)	70	70	71	70	70	71	Reported	ASTM D-611

Table 6: Physical & Chemical Properties of Biodiesel “B10” (10% Biofuel* + 90% Gas Oil).
*Biofuel: Jatropha Oil with Alumina Catalyst (0.2, 0.4, 0.6, 0.8, 1 % conc.)

Property	Biofuel* B10 (10% Biodiesel + 90% Gas Oil)					Gas Oil	Specification Limits	Test Method
	0.20%	0.40%	0.60%	0.80%	1%			
Density @ 15⁰C (gm/cm^3)	0.8533	0.8537	0.8538	0.8538	0.8539	0.8394	Reported	ASTM D-4052
Flash point (P.M.C.C) (⁰C)	60	61	59	60	61	68	55 (min.)	ASTM D-93
Pour point (⁰C)	-6	-6	-6	-6	-6	-9	15 (max.)	ASTM D-97
Cloud point (⁰C)	3	3	3	3	3	3	Reported	ASTM D-2500
Kinematic viscosity at 40 ⁰C (CSt)	3.21	3.23	3.24	3.24	3.27	2.96	1.6 - 7	ASTM D-445
Distilled @ 350⁰C (% vol)	92	91	91	91	91	92	85 (min.)	ASTM D-86
Water and Sediment (% vol)	Nil	Nil	Nil	Nil	Nil	Nil	0.1 (max.)	ASTM D-2709
Total Sulphur (% wt)	0.08	0.07	0.11	0.09	0.1	0.12	1 (max.)	ASTM D-4294
Copper corrosion strip @ 50⁰C/3h	1A	1A	1A	1A	1A	1A	1 (max.)	ASTM D-130
Carbon Residue (% wt)	0.07	0.08	0.07	0.06	0.07	0.07	0.1 (max.)	ASTM D-4530
Ash content (% wt)	Nil	Nil	Nil	Nil	Nil	Nil	0.01 (max.)	ASTM D-482
Colour	2	2	2	2	2	2	4 (max.)	ASTM D-6045
Cetane index	50	51	51	51	50	55	46 (min.)	ASTM D-4737
Calorific Value (Mj/Kg)	42.96	43.01	43.1	43.07	43.1	43.2	Reported	ASTM D-4868
Aniline Point (⁰C)	70	70	70	70	70	71	Reported	ASTM D-611

Table 7: Physical & Chemical Properties of Biodiesel “B10” (10% Biofuel* + 90% Gas Oil).
*Biofuel: Castor Oil with Alumina Catalyst (0.2, 0.4, 0.6, 0.8, 1 % conc.)

Property	Biofuel* B10 (10% Biodiesel + 90% Gas Oil)					Gas Oil	Specification Limits	Test Method
	0.20%	0.40%	0.60%	0.80%	1%			
Density @ 15⁰C (gm/cm³)	0.8519	0.8521	0.8522	0.8523	0.8525	0.8394	Reported	ASTM D-4052
Flash point (P.M.C.C) (⁰C)	56	55	57	58	56	68	55 (min.)	ASTM D-93
Pour point (⁰C)	-6	-6	-6	-6	-6	-9	15 (max.)	ASTM D-97
Cloud point (⁰C)	3	3	3	3	3	3	Reported	ASTM D-2500
Kinematic viscosity at 40⁰C (CSt)	3.02	3.03	3.03	3.04	3.05	2.96	1.6 - 7	ASTM D-445
Distilled @ 350⁰C (% vol)	91	91	92	92	92	92	85 (min.)	ASTM D-86
Water and Sediment (% vol)	Nil	Nil	Nil	Nil	Nil	Nil	0.1 (max.)	ASTM D-2709
Total Sulphur (% wt)	0.09	0.08	0.09	0.1	0.09	0.12	1 (max.)	ASTM D-4294
Copper corrosion strip @ 50⁰C/3h	1A	1A	1A	1A	1A	1A	1 (max.)	ASTM D-130
Carbon Residue (% wt)	0.08	0.07	0.07	0.07	0.07	0.07	0.1 (max.)	ASTM D-4530
Ash content (% wt)	Nil	Nil	Nil	Nil	Nil	Nil	0.01 (max.)	ASTM D-482
Colour	2	2	2	2	2	2	4 (max.)	ASTM D-6045
Cetane index	51	51	50	50	51	55	46 (min.)	ASTM D-4737
Calorific Value (Mj/Kg)	43.01	43.1	43.09	43.1	43.1	43.2	Reported	ASTM D-4868
Aniline Point (⁰C)	71	70	70	70	70	71	Reported	ASTM D-611

Table 8: Physical & Chemical Properties of Biodiesel “B10” (10% Biofuel* + 90% Gas Oil).
*Biofuel: Jatropha Oil with Montmorillonite-HCL Catalyst (0.2, 0.4, 0.6, 0.8, 1 % conc.)

Property	Biofuel* B10 (10% Biodiesel + 90% Gas Oil)					Gas Oil	Specification Limits	Test Method
	0.20%	0.40%	0.60%	0.80%	1%			
Density @ 15⁰C (gm/cm³)	0.8535	0.8538	0.8539	0.854	0.8541	0.8394	Reported	ASTM D-4052
Flash point (P.M.C.C) (⁰C)	60	61	61	61	60	68	55 (min.)	ASTM D-93
Pour point (⁰C)	-6	-6	-6	-6	-6	-9	15 (max.)	ASTM D-97
Cloud point (⁰C)	3	3	3	3	3	3	Reported	ASTM D-2500
Kinematic viscosity at 40⁰C (CSt)	3.23	3.24	3.26	3.28	3.28	2.96	1.6 - 7	ASTM D-445
Distilled @ 350⁰C (% vol)	91	92	92	91	92	92	85 (min.)	ASTM D-86
Water and Sediment (% vol)	Nil	Nil	Nil	Nil	Nil	Nil	0.1 (max.)	ASTM D-2709
Total Sulphur (% wt)	0.08	0.09	0.09	0.11	0.1	0.12	1 (max.)	ASTM D-4294
Copper corrosion strip @ 50⁰C/3h	1A	1A	1A	1A	1A	1A	1 (max.)	ASTM D-130
Carbon Residue (% wt)	0.06	0.06	0.06	0.07	0.07	0.07	0.1 (max.)	ASTM D-4530
Ash content (% wt)	Nil	Nil	Nil	Nil	Nil	Nil	0.01 (max.)	ASTM D-482
Colour	2	2	2	2	2	2	4 (max.)	ASTM D-6045
Cetane index	51	50	50	51	51	55	46 (min.)	ASTM D-4737
Calorific Value (Mj/Kg)	43.1	43.1	43.1	43.1	43.1	43.2	Reported	ASTM D-4868
Aniline Point (⁰C)	70	70	70	70	71	71	Reported	ASTM D-611

Table 9: Physical & Chemical Properties of Biodiesel “B10” (10% Biofuel* + 90% Gas Oil).
*Biofuel: Castor Oil with Montmorillonite-HCL Catalyst (0.2, 0.4, 0.6, 0.8, 1 % conc.)

Kinematic Viscosity at 40⁰C: Kinematic viscosity represents the flow characteristics and the tendency of fluids to deform with stress. Kinematic viscosity is expressed in centistokes (cSt). For gas oil, the kinematic viscosity at 40⁰C should be between (1.6 cSt – 7.0 cSt) in ASTM D-445 [24]. The obtained kinematic viscosity values of the prepared biodiesel blends were within the range of ASTM (3.07 cSt – 3.13 cSt).

Cetane Number: The cetane number (CN) defines as the ability of fuel to ignite quickly after being injected. Higher value of (CN) indicates better ignition quality of fuel. For gas oil, the cetane number should be (min. 40) in ASTM D-4737 [29]. The obtained cetane number values of the prepared biodiesel blend were within the range of ASTM (49 – 51). The higher value of cetane number of the produced biodiesel from jatropha and castor oils represents its high ability towards ignition in engines after injection.

Density: The density of the fuel represents the weight of one gram of it. The density is an important factor during the fuel processing and ignition, because the fuel represents an extra weight on the vesicle. Consequently, higher density of fuel will consume larger amount of fuel during the automotive work. For gas oil, the density value was (0.8394 g/cm^3) according to ASTM D-4052 [27]. The obtained density values of the prepared biodiesel blends were within the range of (0.8462–0.8472 g/cm^3), which is comparably slightly higher than the density of gas oil.

Pour Point: The pour point of the fuel represents the temperature at which the fuel becomes solid before it and liquid after it. Pour point is important characteristic during the transportation of the fuel at elevated low temperatures. In cold climate countries of low temperatures, high pour point fuels freeze. The pour point measurement is a standard test which applied to measure the flow properties of biodiesel during operating in cold weathers [31]. For gas oil, the pour point should be (max. 15°C) in ASTM D-97 [23]. The obtained pour point values of the prepared biodiesel blends were within the range of ASTM (-6^{o}C to -9^{o}C).

Cloud Point: The cloud point is defined as the temperature at which a cloud of wax crystals first appears in a liquid when it is cooled. In general, wax crystals occur in two phases: nucleation and growth of crystals. The cloud point of biodiesel occurs during the start of wax cluster formation involving higher molecular weight components to give visible crystals [32-34]. By continuous cooling of the sample, the agglomeration occurs. At this point, it involves the interaction between the high and low melting components to give bigger crystals. Low cloud points of the biofuels are important property due to the formation of regular clusters of the hydrocarbons lowers the fluidity of the biofuel which decreases its transportation through pipes and tubes. For gas oil, the cloud point should be (-3°C to 12°C) in ASTM D-2500 [26]. The obtained cloud point values of the prepared biodiesel blends were within the range of ASTM (3°C).

Flash Point: The flash point is the temperature at which the fuel becomes a mixture that will ignite when exposed to a spark or flame. Since biodiesel has high flash point, it is a safer fuel to transport and handle [33]. For gas oil, the flash point should be (min. 52°C) in ASTM D-93. The obtained flash point values of the prepared biodiesel blends were within the range of ASTM (55°C – 62°C).

Carbon Residue: For gas oil, the carbon percentage should be (max. 0.1 %) in ASTM D-4530 [28]. The obtained carbon percentage values of the prepared biodiesel blends were within the range of ASTM (0.06 % – 0.08%), which are very low values and did not cause any potential on the environment when ignited.

Ash Content: For gas oil, the ash percentage should be (max. 0.01 %) in ASTM D-482 [25]. The obtained ash percentage values of the prepared biodiesel blends were within the range of ASTM (Nil), which did not cause any potential on the environment when ignited.

Conclusions

From the results obtained in this study, the following conclusions can be recorded:

1. Castor and Jatropha oils were converted into biofuel using heterogeneous catalysts (Alumina & Montmorillonite-HCL) with different ratios (0.2%, 0.4%, 0.6%, 0.8% & 1%).
2. The specifications of the obtained products were comparable to ASTM specifications.
3. The suitable blend between the obtained biofuel and gas oil fuel was (10% Biodiesel + 90% Gas Oil).
4. The results of this biodiesel blend were in acceptable range compared to gas oil fuel according to the standard values of ASTM specifications.
5. When the blending ratio of the prepared biodiesel to petroleum diesel increases than 10%, the flash point of the obtained biofuel decreases than ASTM specifications (less than 52°C).

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