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Balanites Aegyptiaca 씨기름으로부터 바이오디젤의 생산과 생분해성 연구

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Production and Biodegradability of Biodiesel from *Balanites Aegyptiaca* Seed Oil

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요 약. *Balanites Aegyptiaca* 씨기름으로부터 바이오 디젤유를 생산하고 기름 품질 및 생분해성을 조사하였다. 비중, 밀도와 인화점은 각기 0.897, 0.89 g/cm^3 and 163 °C이었다. 이 바이오 디젤유는 D_2 디젤유(27.02%, 27.33%)에 비해 월등하게 82.58%, 86.98% 생분해 되었다.

주제어: *Balanites aegyptiaca*, 바이오 디젤유, 생분해성, 환경영향 평가

ABSTRACT. Seed oil of *Balanites aegyptica* was transesterified to produce biodiesel and its quality and biodegradability assessed. The specific gravity (SG), density and flash point of the methyl esters were found to be 0.897, 0.89 g/cm^3 and 163 °C respectively. Biodegradability of the biodiesel assessed by the standard CO_2 evolution method using two different inoculums revealed that the *Balanites aegyptica* biodiesel was readily biodegradable in both inoculums (82.58% and 86.98%), compared with the D_2 diesel which was partially biodegradable (27.02% and 27.33%). These suggest that *Balanites aegyptiaca* seed oil is a potential source of environmentally friendly biodiesel.

Keywords: *Balanites aegyptiaca*, Biodegradation, Environment, Inoculums, Desert Date

INTRODUCTION

The limited (and fast diminishing) resources of fossil fuel, increasing price of crude oil, and environmental concern have been the diverse reasons for exploring the use of vegetable oil as an alternative fuel. However, the direct use of vegetable oil has not been satisfactory because of its viscous nature and poor ignition property. However, methyl/ethyl esters of fatty acid produced from such oils have proved promising alternative now called biodiesel.[1]

The transportation of petroleum across the world is frequent. Consequently the potential for oil spill which constitutes a major source of ecosystem contamination is enormous.[2] Therefore as biodiesels are becoming commercialized, their fate in the environment is also an area of concern. Among these concerns, water quality and soil fertility are the most important issues for the ecosystem.[3] Therefore, it is imperative to examine the biodegradability of biodiesel fuel and their biodegradation rate in natural environment so as to have an idea of how persistent they would be when discharged into the environment. Comparative study between the biodegradability of biodiesel from rape seed oil and that of conventional diesel was undertaken and it was discovered that after 28 days 95% the rape seed biodiesel was biodegraded while only 40% of the petro-diesel was degraded.[4]

Balanites aegyptiaca is a dicotyledonous flowering plant that is popularly known as “Desert date” in English. It is a widely grown desert tree with a multitude of uses. It is found throughout the Sudano Sahelian region and in other arid areas of Africa, the Middle East, India and Burma. It is one of the most drought resistant tree species in the arid regions.[5] It is highly resistant to stress such as sandstorms and heat waves and grow extensively even when neglected.[6] In Nigeria, Balanites are found mostly in the northern and western part of the country.[7] The fruit pulp though bitter is edible. Pounded fruits make a refreshing drink which becomes alcoholic if left to ferment.[8]

This paper is aimed at extracting the oil of *Balanites* *aegyptiaca*, converting the oil to biodiesel and evaluating the fuel quality and biodegradability of the biodiesel.

EXPERIMENTALS

Materials

Balanites aegyptiaca seeds were purchased from Wunti market, Bauchi metropolis of Bauchi State, Nigeria. The fruit shells were cracked open and the cotyledons removed. They were crushed using a mortar and pestle, shade dried and kept for subsequent experiments. The reagents used were of Analar grade from BDH Chemicals Limited and Sigma-Aldrich Laboratore Chemikaleien Gmbh, Germany. Petro-diesel (D_2) used as a control was obtained from a local fuel station.

Methods

Oil Extraction: The ground seed (50 g) was soxhlet extracted with petroleum ether for a period of 8 hours. The extract was filtered to remove impurities and the solvent recovered using a rotary evaporator leaving behind the vegetable oil. The extracted oil was further evaporated in an oven at 105 °C to remove any traces of moisture and solvent. Oil quality parameters of the extracted oil such as moisture content, iodine value (IV), peroxide value (PV) and acid value were determined based on the AOAC methods.[9]

Preparation of Fatty Acid Methyl Esther (Biodiesel)

0.175 g of sodium hydroxide was weighed into a 150 ml conical flask; 10 ml of methanol was added slowly with continuous stirring, until the sodium hydroxide dissolved completely forming a sodium methoxide solution. The sodium methoxide was added to 50 ml of *Balanites aegyptiaca* seed oil contained in a 150 ml conical flask and the mixture heated to a temperature of 50 °C with a slow but continuous stirring for about an hour. Care was taken not to stir vigorously in order to avoid emulsification. The mixture was then transferred into a separating funnel and allowed to stand for an hour. Two separate layers were formed; the lower layer (glycerin) was run down the tap leaving the upper layer (Biodiesel). Warm distilled water (30 ml) was added to the crude product (biodiesel), swirled slowly and allowed to stand for an hour. The lower water layer was runoff and the washing process repeated with cold distilled water until a clear product was obtained. The clear product was then passed through a funnel that was plugged with cotton wool and sprayed with anhydrous magnesium sulfate on top in order to absorb any traces of water present and the final product was collected in a conical flask.

Fuel Properties Test

The parameters tested include density, specific gravity and flash point. Determination of flash point was done by measuring 5 ml of biodiesel in to a 150 ml conical flask. The flask was heated slowly on a hot plate at a constant rate. The flash point was taken as the lowest temperature an applied test flame caused the vapor above the flask to make a pop sound. The same procedure was repeated using the D_2 diesel.

Biodegradability of Biodiesel

The carbon dioxide (CO_2) evolution method was used in this work, following the EPA standard method 560/6-82-003 for determining biodegradability of chemical substances.[10] A specially equipped 2 liter Erlenmeyer flask containing 100 ml of inoculum (prepared from diesel contaminated soil, activated sewage, raw domestic sewage water, 14 days before the experiment), 900 ml of deionized distilled water (DIW), 10 ml of test substrate, a reservoir holding 10 ml of barium hydroxide ($Ba(OH)_2$) solution suspended in the flask to trap any carbon dioxide produced by the test substrate. Another inoculum prepared using the TTC technique was used for comparative purpose.[3,10] The flask was sealed and incubated with shaking in the dark for a 28 day period. Periodically (within the 28 days), the 10 ml of $Ba(OH)_2$ and 10 ml of distilled water was removed and titrated with hydrochloric acid to the phenolphthalein end point to determine the CO_2 evolved. Each time the reservoir was refilled with fresh $Ba(OH)_2$. The sample was analyzed at time zero and four other times (weekly) within the 28 days period. The same procedure was carried out for the D_2 diesel and for the control without the test substrate and the percentage CO_2 evolved calculated as follows:

$$CO_2 = (T_f - C_f)/C \times 100$$

Where

T_f = ml of HCl required to titrate $Ba(OH)_2$ from the test flask

C_f = ml of HCl required to titrate $Ba(OH)_2$ from the control flask

C is a constant which is given as 16.67 for carbon substance

RESULTS AND DISCUSSION

Oil Quality Parameters of *Balanites aegyptiaca*

The oil quality parameters of *Balanites aegyptiaca* seed oil in comparison with that of rapeseed oil are shown on *Table* 1. The seed has a low moisture content of 8.73% which is close to that of rapeseed (7.5%). Low moisture content is an indication of a reasonable shelf life for the seed, because there is little or no water for the hydrolysis of the oil to take place.[11-14] The average oil content obtained from *Balanites aegyptiaca* seed was 37.2% (*Table* 1) which is slightly above that of rapeseed (36.2%).[15] This places *Balanites aegyptiaca* seed amongst the richest oil seeds. The Iodine value of 42.28% recorded for *Balanites aegyptiaca* indicate that the oil is a non drying type with a very low degree of unsaturation. Oils are classified in accordance with their iodine value as non-drying (I.V. less than 100), drying (I.V. 130 and above) and semi-drying oils (I.V. between 100 and 130). It is known that the more unsaturated, the higher the iodine value and the more prone the oil to rancidity by oxidation.[16] The low iodine value of the oil is highly advantageous because the oil would be stable to polymerization and/or oxidation.

The peroxide value of an oil or fat is used as a measurement of the extent to which rancidity reaction have occurred during storage. The peroxide value of *Balanites aegyptiaca* seed oil was 8.0 mewq/Kg which is lower than that of rapeseed (*Table* 1). For fresh vegetable oil, the peroxide value is known to be lower than 100 meq/Kg.[17] The lower value observed could be due to the freshness of the oil. This suggests that *Balanites aegyptiaca* seed oil may be less susceptible to oxidation and resistant to rot.

The saponification value of *Balanites aegyptiaca* seed oil was 143.64 meq/Kg which is lower than that of rapeseed (185 meq/Kg). For a vast majority of oils used in biodiesel production, their saponification values are within the range of 130 to 193 meq/Kg. This shows that the oil is suitable for use in biodiesel production. The acid number

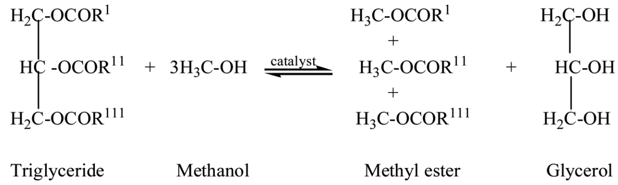

***Fig.* 1.** A scheme of transesterification process of triglyceride with methanol using a base catalyst.

is used to quantify the amount of acid present in a chemical substance. Acid value should not be more than 1.50 mgKOH/g since the FFA produced may corrode automotive parts. The acid value for *Balanites aegyptiaca* seed oil was found to be 0.995 mgKOH/g which is lower than that of rapeseed (2.0) and within the acceptable limit for biodiesel production.[17]

Production of Biodiesel (Transesterification)

Chemically, transestarification reaction is a typical substitution reaction. The process involves substituting the alkyl group of the esters with the alkyl group of the alcohol. In the case of fatty acid methyl esters (FAME) using *Balanites aegyptiaca* seed oil, the alkyl group on the triglyceride (oil) is substituted with the methyl group of the alcohol (*Fig*. 1). The base (NaOH) catalyst was dissolved in the alcohol to make it convenient for dispersing the solid catalyst into the oil. The methoxide produced ($NaOCH_3$) was then mixed with the oil and the substitution reaction proceeds in a series of steps. The percentage conversion of the *Balanites aegyptiaca* seed vegetable oil (BAVO) to fatty acid methyl esters (FAMES) was 40.68%.

Fuel Quality Parameters

Specific Gravity and Density: The specific gravity of the biodiesel was 0.897, which is similar to that of D_2 diesel (0.9) and that of BAVO (0.97). These are all within the

***Table* 1.** Oil Quality Parameters of *Balanites Aegyptiaca* in comparison with those of Rapeseed Oil[15].

Quality parameters	Balanites seed oil	Rape seed oil
Moisture content (%)	8.73	7.5
Oil Content (%)	37.2	36.5
Iodine value (I.V)(%)	42.28	94.20
Saponification value (S.V) (meq/Kg)	134.64	185
Acid vale (A.V) (%)	0.995_{max}	2.0_{max}
Free fatty acid Value (FFA) (%)	0.50_{max}	1.01_{max}
Peroxide value (P.V) (meq/Kg)	8.0	29.42
Smell	Pleasant	Pleasant smell of popcorn
Colour	Pale yellow	Pale yellow
Texture	Viscous	Viscous

***Table* 2.** Fuel Quality Parameters of *Balanites aegyptiaca* Vegetable Oil (BAVO), Fatty Acid Methyl Esters (FAME) and D_2 petro diesel in comparison with the ASTM standard[18]

Fuel Property	Fames	Bavo	D_2 Diesel	Astm Standard
Specific Gravity	0.897	0.97	0.90	0.82_{min}
Density (g/cm^3)	0.89	0.95	0.88	0.86
Flash point (°C)	163	176	134	100_{min}

***Table* 3.** Carbon dioxide (CO_2) evolution from biodiesel and D_2 diesel using two different inoculums

Day	Inoculum A		Inoculum B	
	Bames	D_2 Diesel	Bames	D_2 Diesel
0	0.00	0.00	0.00	0.00
7	52.19%	13.80%	45.0%	13.40%
14	54.19%	22.32%	62.39%	19.22%
21	79.18%	23.99%	74.39%	24.21%
28	82.58%	27.02%	86.98%	27.33%

ASTM standard.[18] The density of the *Balanites aegyptiaca* seed oil was found to be 0.95 g/cm^3, while that of the biodiesel and D2 diesel were found to be 0.89 g/cm^3 and 0.88 g/cm^3 respectively. These show that both biodiesels possess the required density for a good biodiesel.

Flash Point

The flash point is used in assesing the overall flammability of a material. Higher flash point indicate material that is less likely to ignite accidentally.[18,19] ASTM standard require a minimum value of 100 °C. The flash point of *Balanites aegyptiaca* methyl esters (BAMES) (163 °C) is lower than that of *Balanites aegyptiaca* vegetable oil (BAVO) (176 °C) but both of them are greater than that of D_2 diesel and are all within the ASTM standard (*Table* 2).[20] This indicates that FAME would be safe for use since it will not ignite easily.

Biodegradability Test

The cumulative percentage of CO_2 evolved from *Balanites aegyptiaca* methyl esters (biodiesel) and D_2 diesel within the 28 days period is shown on *Table* 3. The maximum percent CO_2 evolved within the 28 days period from BAME was 82.58% with inoculum A, while 86.98% CO_2 was evolved using inoculum B. This indicates that there is no significant difference in the biodegradability of the biodiesel irrespective of the two inoculum used. The maximum CO_2 evolved from the D_2 diesel was 27.02% with inoculum A and 27.33% with inoculum B. This is very much lower than that of the biodiesel. This show that the biodiesel fuel is “readily biodegradable” in both inoculums (82.58% and 86.98%) and that the D_2 diesel is only partially biodegradable (27.02% and 27.33%).

CONCLUSIONS

Balanites aegyptiaca is a rich source of vegetable oil. The fuel quality parameters of the *Balanites aegyptiaca* biodiesel such as the flash point and specific gravity are similar to those of D_2 diesel. *Balanites aegyptiaca* biodiesel is “readily biodegradable” compared with the D_2 diesel which is partially degradable. These suggest that *Balanites aegytiaca* seed oil is a potential source of environmentally friendly biodiesel.

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