Sudan University
of Science & Technology
College of Graduate Studies

Viability of Using Vegetable Oil as a Fuel in Internal Combustion Engines

قابلية الزيت النباتي للإستخدام كوقود في محركات الاحتراق الداخلي

A thesis submitted in fulfillment of the requirements for the degree of Ph.D. in Mechanical Engineering

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بسم الله الرحمن الرحيم

قال الله تعالى:

(اللَّهُ لَا إِلَهَ إِلَّا هُوَ الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَةٌ وَلَا نَوْمٌ لَهُ مَا فِي السَّمَاوَاتِ وَمَا فِي الْأَرْضِ مَنْ ذَا الَّذِي يَشْفَعُ عِنْدَهُ إِلَّا بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلَا يُحِيطُونَ بِشَيْءٍ مِنْ عِلْمِهِ إِلَّا بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالْأَرْضَ وَلَا يَئُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ).

صدق الله العظيم

البقرة الآية (255)

DEDICATION

It is of honor, dedication of this thesis,
To my parents,
To my teachers,
To my family.

ACKNOWLEDGEMENT

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ABSTRACT

The world has recently faced fossil fuel depletion and environmental degradation that triggers the research for using alternative modes. Bio-fuels appear to be one of the most reliable and recommended ones. Sudan potentiality of producing bio- fuels is highly promising and can be quite feasible since enough fertile land, water and suitable climate are available.

In this research production of sudanese peanut oil methanol ester was attempted and tested in a 4-stroke diesel engine for performance evaluation and compared with fossil fuel. Using transesterification process at volumetric ratio of 40oil: 12methanol: 1 NaOH, at a temperature of 60 ^{0}C and stirring for one hour time, a bio-diesel of better properties was produced. It was considered as an acceptable substitute for conventional diesel fuel. More over blends of straight vegetable oil (SVO) with benzene was attempted and tested in 4-stroke and 2-stroke petrol engines for performance evaluation and compared with fossil fuel. Using 40% SVO by volume in the blend for 4-stroke engine, and 50% by volume for 2-stroke engine as maximum limit, blends of good properties were produced and proved to be an acceptable substitute for conventional (carburetor) petrol fuel system. Without any need for engines systems modifications, engines performance was improved and exhaust emissions were highly reduced.

مستخلص

يواجه العالم اليوم مشكلتي تناقص مخزون الوقود الأحفوري واتساع استخدامه والتدهور البيئي مما ادى الى توجيه البحوث عالميا نحو الوقود الحيوي كافضل بديل لحل هذه المشكلة مستقبلا. للسودان امكانية كبيرة من اراضي زراعية، ومياه، وطاقات طبيعية وبشرية مما يمكنه من انتاج هذا الوقود والتنافس به في السوق العالمي محققا استراتيجية اقتصادية واجتماعية مقدرة.

في هذا البحث استخدم زيت الفول السوداني لانتاج الوقود الحيوي الميثانولي بمساعدة هيدروكسيد الصوديوم، وباستخدام نسبة حجمية 40 زيت : 12 ميثانول : 1 هيدروكسيد صوديوم واجراء خلط مستمر لمدة ساعة في درجة حرارة 60 درجة سيلزيوس، تحقق مستوى افضل لخواص وقود الديزل الحيوي مقارنة بخواص وقود الديزل التقليدي. وباختبار هذا الوقود في محركات ديزل بدون اي تعديل كان مستوى الاداء مشابها لأداء الوقود التقليدي وانبعاث غازات العادم منخفضا مما يؤكد تقليل تلوث البيئة.

أيضا بخلط هذا الزيت مع البنزين مباشرة لاستخدامه كوقود في محركات البنزين رباعية وثنائية الدورة وباستخدام نسب حجمية 40% زيت في الخليط للمحرك رباعي الأشواط و 50% للمحرك ثنائي الدورة كحد اقصى، انتجت خلائط ذات خواص جيدة كبديل مقبول للوقود التقليدي في محركات البنزين.تحقق هذا بدون أي تعديل في محرك البنزين التقليدي (منظومة الوقود بالكاربيوريتر) رباعي او ثنائي الأشواط ، كان مستوى الأداء مشابها لأداء الوقود التقليدي وانبعاث غازات العادم منخفضا جدا مما يؤكد تقليل تلوث البيئة.

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NOMENCLATURE

The following is a list of abbreviations and symbols used in this thesis:

A.B.E. Acetone, Butanol, Ethanol .	**IEA** International Energy Agency.
A/F ratio Air / fuel ratio	**I_{mep}(IMEP)** Indicated mean effective pressure
AP Academic Press.	**I_P (IP)** Indicated power
A_nP_t Aniline Point.	**IPA** Isopropyl Alcohol 99% .
API American Petrolium Institute.	**LTFT** Low Temperature Flow Test
AICS Austral.Invent.of Chemical Subst.	**NASA** National American Space Agency
ASTM American Soci.forTest.and Measurement.	**NBB** National Bio-diesel Board
atm.. Atmosphere.	**No of obs.** Number of observations
BSFC Brake specific fuel consumption	**n** Equivalence ratio.
BTL Biomass-to-liquid	**oct.No.** Otane number.
CCR Critical Compression Ratio.	**ppm** part per million
cet.No. Cetane number.	**PAH** Polycyclic Aromatic Hydrocarbons
C.I.E. Compression Ignition Engine.	**P_B (BP)** Brake power
CFPP Cold Filter Plugging	**RME** Rapeseed methyl ester
CPO Crude Palm Oil	**S.I.E** Spark Ignition Engine.
cst. Centi stoke.	**SRO** Semi-Refined Oil
DME Dimethyl ether (DME).	**Std.Dv** Standard dependent variable
df Degree of freedom.	**Std. err** standard error
DV Dependent Variable.	**SVO** Straight Vegetable Oil
EPA Environmental Protection Agency	**TAME** Tertiary- Amyl- Methyl –Ether
ETAE Ethyl-Tertiary-Amyl-Ether	**TDC** Top Dead Center
ETBE Ethyl-Tertiary-Butyl-Ether.	**Temp.** Temperature.
EU European Union	**t-value** t- test statistical method
FAME Fatty Acid Methyl Ester	**Veg. oil** Vegetable oil.
FFA Free Fatty Acid.	**WFO** Waste Frying Oil.
GHG Green House Gases.	**WW-II** second World War.
GTL Gas-to-liquid	**$\acute{\eta}_{th-\text{"A"}}$** Thermal efficiency (fuel A)
HDPE High-Density Polyethylene	**$\acute{\eta}_{th-\text{"B"}}$** Thermal efficiency (fuel B)
ice internal combustion engine	

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