UNIVERSITI MALAYSIA SARAWAK
UNIMAS

Faculty of Engineering

INFLUENCE OF PROPANOL AS ADDITIVE WITH DIESEL KARANJA BIODIESEL BLEND FUEL FOR DIESEL ENGINE

Suraya binti Zulkefli

Bachelor of Engineering with Honours
(Mechanical and Manufacturing Engineering)
2018/2019

UNIVERSITI MALAYSIA SARAWAK

Grade: ___________

Please tick (√)

Final Year Project Report ☑

Masters ☐

PhD ☐

DECLARATION OF ORIGINAL WORK

This declaration is made on the ....21.....day of....JUNE.....2019.

Student's Declaration:

I **SURAYA BINTI ZULKEFLI, 50975** from **FACULTY OF ENGINEERING** hereby declare that the work entitled **INFLUENCE OF PROPANOL AS ADDITIVE WITH DIESEL KARANJA BIODIESEL BLEND FUEL FOR DIESEL ENGINE** is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

21.6.19
Date submitted

Suraya binti Zulkefli (50975)

Supervisor's Declaration:

I **ASSOC PROF DR ABU SALEH AHMED** hereby certifies that the work entitled **INFLUENCE OF PROPANOL AS ADDITIVE WITH DIESEL KARANJA BIODIESEL BLEND FUEL FOR DIESEL ENGINE** was prepared by the above named student, and was submitted to the "FACULTY" as a * partial/full fulfillment for the conferment of **BACHELOR DEGREE (Hons) OF MECHANICAL AND MANUFACTURING ENGINEERING**, and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: ____________________ Date: 21/6/2019

Assoc Prof Dr Abu Saleh Ahmed

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirmed with free consent and willingness declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature ____ 21.6.19
(Date)

Supervisor signature: ____ 21/6/2019
(Date)

Current Address:

3B-1-1 Sri Lojing, Jalan 4/27E, Seksyen 10, Wangsa Maju, 53300 Kuala Lumpur

Notes: * If the Project/Thesis is CONFIDENTIAL or RESTRICTED, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

INFLUENCE OF PROPANOL AS ADDITIVE WITH DIESEL KARANJA BIODIESEL BLEND FUEL FOR DIESEL ENGINE

SURAYA BINTI ZULKEFLI

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering with Honours
(Mechanical and Manufacturing Engineering)

Faculty of Engineering
Universiti Malaysia Sarawak

2018/2019

Wholeheartedly dedicated to all who have guided and given me inspiration throughout this journey of knowledge.

ACKNOWLEDGEMENT

First and foremost, I would like to thank Almighty God for giving me the knowledge and strength to persevere and complete this research study successfully. This achievement would not have been possible without His blessings. Aside from Him is my beloved parents and family who have been supporting me morally and financially since day one of my study. Also, I would like to dedicate my heartfelt and sincere gratitude to Assoc. Prof Dr Abu Saleh Ahmed for extending the cooperation and guidance throughout the study. With his support and advices, this final year project has been satisfactorily completed. Thank you to the all lecturers, staff and technicians of Department of Mechanical and Manufacturing Engineering, Universiti Malaysia Sarawak for their assistance and for sharing useful theoretical and practical knowledges, over the past four years of my study. Last but not least, I am thankful for all my friends who have been supporting and helping me in many ways to complete this final year project.

ABSTRACT

A research study was conducted with the objective to produce biodiesel from non-edible oil of karanja (pongamia pinnata) and to evaluate the performance characteristics and efficiency for different types of fuel; diesel, diesel-karanja biodiesel and diesel-karanja biodiesel with additive when operate on a diesel engine. The presence of free fatty acid in the crude Karanja oil was more than 4%, hence it undergoes a two-step transesterification process. The process involves pre-treatment of crude Karanja oil by acid catalyzed transesterification and followed by based catalyzed transesterification process with methanol as reactant in the presence of H_2SO_4 and NaOH as the catalyst respectively. The maximum yield of biodiesel was found out to be 79.8% with a 9:1 ratio of methanol to oil. Apart from that, the test fuels characterization was conducted using Fourier Transform Infrared Spectroscopy (FT-IR) and bomb calorimeter. Based on the analyses performed, B10, B10P5 and B10P10 have a calorific value of 43.5668 MJ/kg, 43.4332 MJ/kg and 42.7761 MJ/kg respectively. The FTIR results indicate that both diesel and Karanja biodiesel have the same functional group of C-H (hydrocarbons). Moreover, diesel engine performance test were conducted at the speed range of 1500 rpm to 2000 rpm for four types of fuel blends to indicate its brake horse power, brake specific fuel consumption and mechanical efficiency.

ABSTRAK

Satu kajian penyelidikan telah dijalankan dengan objektif untuk menghasilkan biodiesel dari minyak karanja (pongamia pinnata) dan untuk menilai ciri-ciri prestasi dan kecekapan untuk pelbagai jenis minyak; diesel, diesel-karanja biodiesel dan diesel-karanja biodiesel dengan aditif apabila beroperasi pada enjin diesel. Kehadiran asid lemak bebas dalam minyak mentah karanja melebihi 4%, oleh itu ia menjalani proses transesterifikasi dua langkah. Proses ini melibatkan pra-rawatan minyak mentah karanja oleh transesterifikasi berasaskan katalis asid dan diikuti dengan proses transesterifikasi berasaskan katalis alkali dengan metanol sebagai reaktan dengan kehadiran H_2SO_4 dan NaOH sebagai pemangkin bagi kedua-dua proses. Hasil maksimum biodiesel didapati sebanyak 79.8% dengan nisbah 9: 1 metanol kepada minyak. Selain itu, pencirian minyak dilakukan menggunakan Fourier Infrared Spectroscopy (FT-IR) dan calorimeter bom. Berdasarkan analisa yang dilakukan, B10, B10P5 dan B10P10 masing-masing mempunyai nilai kalori 43.5668 MJ/kg, 43.4332 MJ/kg dan 42.7761 MJ/kg. Keputusan FTIR menunjukkan bahawa diesel dan Karanja biodiesel mempunyai kumpulan fungsi yang sama iaitu C-H (hidrokarbon). Selain itu, ujian prestasi enjin diesel telah dijalankan pada jarak laju 1500 rpm hingga 2000 rpm bagi empat jenis campuran bahan api untuk menunjukkan daya kuda brek, penggunaan bahan bakar khusus brek dan kecekapan mekanikal.

TABLE OF CONTENTS

		Page
Acknowledgement		i
Abstract		ii
Abstrak		iii
Table of Contents		iv
List of Tables		vii
List of Figures		viii
List of Abbreviations		x

Chapter 1 INTRODUCTION

1.1 Research Background 1

1.2 Biodiesel from Non-edible Oil 3

1.3 Problem Statement 4

1.4 Research Questions 5

1.5 Objectives of Study 5

Chapter 2 LITERATURE REVIEW

2.1 History of Karanja 6

2.2 Applications of Karanja 7

2.3 Extraction of Crude Karanja Oil 9

2.3.1 Mechanical Expeller 10

2.3.2 Solvent Extraction 10

2.4 Methods to Produce Karanja Biodiesel 12

2.4.1 Micro-emulsification 12

2.4.2 Pyrolysis 13

2.4.3 Dilution 14

2.4.4 Transesterification 14

2.4.4.1 Catalytic Transesterfication 15

2.4.4.2 Supercritical Alcohol Transesterification 16

	2.5	Variables that Influence the Biodiesel Production	17
		2.5.1 Reaction Temperature	17
		2.5.2 Catalyst	17
		2.5.3 Molar Ratio of Alcohol to Oil	18
		2.5.4 Mixing Intensity	18
		2.5.5 Purity of Reactants	19
	2.6	Properties of Biodiesel	19
	2.7	Performance and Emission of Karanja Biodiesel	21
		2.7.1 Brake Specific Energy Consumption (BSEC)	22
		2.7.2 Brake Thermal Efficiency (BTE)	22
		2.7.3 Mechanical Efficiency	23
		2.7.4 Emission of Carbon Monoxide (CO)	24
		2.7.5 Emission of Nitric Oxide (NO_x)	24
	2.8	Alcohol as Additive to Biodiesel	25
		2.8.1 Propanol as Additive	26
Chapter 3	**METHODOLOGY**		
	3.1	Introduction	28
	3.2	Material	28
	3.3	Method	30
		3.3.1 Production of Crude Karanja Oil (CKO)	30
		3.3.2 Measurement of Free Fatty Acid (FFA) Content in CKO	31
		3.3.3 Production of Karanja Biodiesel	33
		3.3.3.1 Acid Catalyzed Transesterification	33
		3.3.3.2 Base Catalyzed Transesterification	35
		3.3.3.3 Washing and Purification of Biodiesel	36
		3.3.3.4 Blending of Biodiesel	36
	3.4	Flow chart of Karanja Biodiesel Production	37
	3.5	Characterization of Karanja Biodiesel	38
		3.5.1 Bomb Calorimeter Test	38
		3.5.2 Fourier Transform Infrared Spectroscopy (FT-IR)	39

	3.6	Engine Performance Testing	39
Chapter 4	**RESULT AND DISCUSSION**		
	4.1	Introduction	41
	4.2	Production of Karanja Biodiesel	41
		4.2.1 Free Fatty Acid (FFA) Measurement	41
		4.2.2 Acid Catalyzed Transesterification	42
		4.2.3 Base Catalyzed Transesterification	44
	4.3	Biodiesel Characterization	45
		4.3.1 Bomb Calorimeter Analysis	45
		4.3.2 Fourier Transform Infrared Spectroscopy (FT-IR) Analysis	46
	4.4	Engine Performance Result	48
		4.4.1 Brake Horse Power (BHP)	49
		4.4.2 Brake Specific Fuel Consumption (BSFC)	50
		4.4.3 Mechanical Efficiency	51
Chapter 5	**CONCLUSION AND RECOMMENDATIONS**		
	5.1	Conclusion	54
	5.2	Recommendations	55
REFERENCE			56

LIST OF TABLES

Table		Page
2.1	Percentage yield of crude karanja oil	9
2.2	Characteristics of fatty acids in CKO	10
2.3	Classification of pyrolysis methods	13
2.4	Properties of different types of biodiesel	19
2.5	Properties of vegetable oil with different additives	26
3.1	Mass of methanol and H_2SO_4 needed for different alcohol to oil molar ratio	34
4.1	Measurement of crude karanja oil	42
4.2	FFA measurement of pre-treated karanja oil	43
4.3	Percentage of biodiesel yielding for different methanol to oil molar ratio	44
4.4	Calorific value of different types of test fuels	45
4.5	FT-IR results for conventional diesel and karanja biodiesel	47
4.6	Brake horse power for variation of speeds	49
4.7	Brake specific fuel consumption for variation of speeds	50
4.8	Mechanical efficiency for variation of speeds	52

LIST OF FIGURES

Figure		Page
2.1	Karanja pods	7
2.2	Karanja seeds	8
2.3	Schematic diagram of soxhlet apparatus	11
2.4	Chemical reaction for transesterfication of triglycerides	15
2.5	Graph of brake specific energy consumption versus load	22
2.6	Graph of brake thermal efficiency versus load	23
2.7	Graph of mechanical efficiency versus load	23
2.8	Graph of carbon monoxide emission versus load	24
2.9	Graph of nitric oxide emission versus load	25
3.1	Ripe karanja seeds	29
3.2	Unripe karanja seeds	29
3.3	Damaged karanja seeds	29
3.4	Step by step process to produce KCO	30
3.5	Apparatus set-up for titration process	31
3.6	KCO mixture after titration process	32
3.7	Process of mixing and separation for acid catalyzed transesterification	34
3.8	Process of mixing and separation for base catalyzed transesterification	35
3.9	Diesel-karanja biodiesel blend fuel	36
3.10	Step by step process to produce karanja biodiesel	37
3.11	Bomb calorimeter machine	38
3.12	Fourier transform infrared spectroscopy (FT-IR) machine	39
3.13	Diesel engine test machine	40
4.1	Graph of FFA content against different methanol to oil molar ratio	43
4.2	Graph of biodiesel yielding against methanol to oil molar ratio	44
4.3	Infrared spectrum of conventional diesel	46
4.4	Infrared spectrum of karanja biodiesel	47

4.5	Graph of brake horse power versus engine speed for the test fuels	50
4.6	Graph of brake specific fuel consumption versus engine speed for the test fuels	51
4.7	Graph of mechanical efficiency versus engine speed for the test fuels	53

LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing Materials
B0	-	100% Diesel
B10	-	90% Diesel, 10% Biodiesel
B10P5	-	85% Diesel, 10% Biodiesel, 5% Propanol
B10P10	-	80% Diesel, 10% Biodiesel, 10% Propanol
B100	-	100% Biodiesel
BHP	-	Brake Horse Power
BSEC	-	Brake Specific Energy Consumption
BSFC	-	Brake Specific Fuel Consumption
BTE	-	Brake Thermal Efficiency
C_2H_5OH	-	Ethanol
C_6H_{14}	-	Hexane
CH_3OH	-	Methanol
CI	-	Compression Ignition
CO	-	Carbon Monoxide
EN	-	European Standards
FAME	-	Fatty Acid Methyl Esters
FFA	-	Free Fatty Acid
FTIR	-	Fourier Transform Infrared Spectroscopy
H_2SO_4	-	Sulfuric Acid
IHP	-	Indicated Horse Power
IUPAC	-	International Union of Pure and Applied Chemistry
ISO	-	International Standardization for Organization
KCO	-	Karanja Crude Oil
KME	-	Karanja Methyl Ester
KOH	-	Potassium Hydroxide
ME	-	Mechanical Efficiency
NaOH	-	Sodium Hydroxide
NFTS	-	Nitrogen Fixing Trees
NO_x	-	Nitric Oxide

WVO	-	Waste Vegetable Oil

CHAPTER 1

INTRODUCTION

1.1 Research Background

The number of automobile has increased tremendously in recent days and as a result, demand for fuel product is getting higher which results in the increment of fuel price. Therefore, alternative fuel or known as non-conventional fuel has been developed as a substitute to conventional fuel. Biodiesel, ethanol, natural gas, propane, electricity and hydrogen are some of the well-known alternative fuels and these types of fuel are said to produce less vehicle emissions like greenhouse gases and nitrogen oxides. It is known that fossil fuels are the main contributor to air pollution, hence the purpose of implementing alternative fuels is to reduce damage to the environment. The supply of alternative fuels is unlimited as they are renewable and they can be produced at anytime.

Biodiesel is a substitute for diesel fuel which is known to be renewable and biodegradable and it is usually blended together with conventional diesel. Biodiesel is obtained by chemical process called transesterification whereby animal fats and vegetable oils are converted into fatty acid methyl esters (FAME). According to American Society for Testing Materials (ASTM), a mixture of long-chain monoalkylic esters from fatty acids obtained from renewable resources is what biodiesel is. Diesel engine was invented by Rudolph Diesel and it has been an idea to use vegetable oil as fuel since the birth of it as he has been experimenting with fuels from powdered coal to peanut oil (Rathore & Ramchandani, 2016).

Most biodiesel produced at present is from waste vegetable oil (WVO), however the oils need to undergo a process called titration test which includes filtering to remove debris. In addition, these waste oils are usually being used and heated multiple times which leads to presence of fatty acids. Therefore, sodium hydroxide or potassium hydroxide is needed to make the acid neutralize.

A broad variety of resources are being used to produce biodiesel. These days, fuel is getting expensive and inflation is hitting new highs across every country across the world. In fact, this is the main reason that makes people and also industries search for less expensive and reliable substitutes for everything in this world. Biodiesel made from waste vegetable oil is a new way to overcome this issue and also to preserve energy. WVO comes from variety of sources including domestic, commercial and industrial. Waste vegetable oil may cause problems if they are disposed incorrectly, therefore it needs to be properly managed to overcome this issue. The production cost of biodiesel is reduced to about 60-70% when cooking oil is used as a feedstock. Since cost is the main concern to biodiesel production, the use of non-edible vegetable oils is said to be a viable feedstock for biodiesel production as it is easy to find and produce.

As aforementioned, biodiesel is biodegradable and renewable, thus it is a product of immense interest for its environmental characteristics. Produced domestically with natural resources, biodiesel's use contributes to economy and simultaneously decreases the dependence on crude oils and imported fuels. Biodiesel has many benefits for the environment. The main advantage is that biodiesel produces no net output of carbon in the form of carbon dioxide, which it is described as 'carbon neutral'. Apart from saving the environment, biodiesel is also good for engine as it has added lubricant which engines have been shown to experience less wear and tear when used on a regular basis. In a nutshell, biodiesel is a great alternative for a safer earth and it is easily available nationwide.

These days, developed countries are looking forward to the utilization of biodiesel. For instance, palm has been utilized as the raw material for the production of biodiesel in Malaysia (Subno & Mugdho, n.d.). Apart from that, India is known to be the world's largest edible oil importer since the demand for edible oil is now accelerating due to its growing population and increasing rate of consumption. Biodiesel has now becoming one of the fastest growing alternative fuels in the world due its clean emission. However, due to minimal subsidy, the price of biodiesel is competitive with petroleum diesel. Production of biodiesel gives benefits to the world in the 21st century as the process of creating it is in sustainable manner allows a clean and cost-effective fuel to be produced.

1.2 Biodiesel from Non-edible Oil

Due to the price increment of crude oil, limited resources of fossil fuels and environmental issues, there has been a focus on non-edible vegetable oils to become an alternative to petroleum fuels (Bobade SN & Khyade VB, 2012). Non-edible oils are not suitable for human consumption as they contain unsaponifiable and toxic components (Naik et al., 2008). Vegetable oil usually has low vapour pressures, long molecule chains, high viscosities and high flash points. Thus, they are not a suitable substitute for diesel fuel in engines, boilers or cogeneration systems due to their inappropriate physical properties. However, some of the methods namely dilution, micro emulsion, pyrolysis and esterification may reduce the viscosity of vegetable oil (Rathore & Ramchandani, 2016).

The effect of vegetable usage in diesel on the performance and emission characteristic of constant speed of Compression Ignition (CI) engines has been experimented by researchers and engineers (Rathore & Ramchandani, 2016). Biodiesel has long chain structure hence it has low volatility and high viscosity which create problem in CI engine applications such as excessive pumping power, improper combustion and poor atomization of fuel particles.

There are many types of non-edible oil that are available around world such as karanja, jatropha, mahua, neem and tobacco seed oil. One of the examples of non-edible oil is Pongamia oil which is oil extracted from Pongamia pinnata or known as karanja. Karanja tree is a medium sized evergreen tree which is commonly found in Indian subcontinent and south-east Asia. It also grows in humid tropical regions and other parts of the country such as Australia, New Zealand, China and United States of America. The oil from this tree is blended with diesel fuel in many different proportions such as 10%, 20%, 30% etc. The properties of karanja oil differs slightly from diesel as their kinematic viscosity, flash, solidifying and ignition point are very high (G. Singh & Moses, 2015).

The seeds from karanja tree can be use to produce biodiesel. Karanja tree has a potential for high oil seed production since it is known to be a fast-growing tree and drought resistant. The seeds produce a significant amount of oil content since the plant is one of the few nitrogen fixing trees (NFTS). The tree serves a lot of benefits and every part of the tree has their own uses. Although all parts of the plants are toxic, however the fruits and sprouts along with the seeds can be implemented in many traditional remedies. Back in the day, this plant has been used as a source of traditional medicines, animal fodder, green manure, waterpaint binder and fuel in India and recently, it has been identified as a viable source of oil for the biofuel industry that is growing rapidly.

1.3 Problem Statement

Substituting alternative fuel to conventional fuel serves a lot of purpose towards creating sustainable solutions to our energy needs. Depletion of fossil fuels is one of the reasons why people are searching for an alternative to a low carbon source of energy and fuel. Fossil fuel has a major contribution to the world due to its high reliability, adaptability, combustion efficiency and cost effectiveness. However, continuous consumption of fossil fuels may increase the global climate and risking human health. Also, fossil fuels are not considered as sustainable energy as the source are limited and on the verge on reaching their peak production. The application of biodiesel lowers down the emission of carbon dioxide and air quality. The performance of biodiesel corresponds to the amount of biodiesel in the blend.

Recently, biodiesel is known to be the best alternative to diesel fuel as it offers various benefits to developing countries by reducing greenhouse gas emissions. Furthermore, biodiesel actually contributes to the debate of food versus fuel. The price of edible oil is much more expensive, thus the utilization of non-edible oil would be more sustainable for biodiesel production. Apart from that, this results in the increment of food price. The production of biodiesel has increased over the last decade which is nearly 60 percent since 2008 in Europe. About 4 percent of the world's agricultural land is used for producing biodiesel and consequently results in deforestation and soil erosion. These are the cause contributing to the rise of issue on fuel versus food debate.

On the other hand, the most common issue faced by marketers and end users are operability problems, stability problems and process controls which often correlates with the production of biodiesel. Biodiesel typically has high density, viscosity, flash point and calorific value which are not appropriate for direct engine application. Thus, for biodiesel blends to meet the requirement of international fuel standards, fuel blending with additives has now becoming a strategy to enhance its properties. According to some research, it is observed that the operability of biodiesel blends is improved by fuel additives since problems such as oxidation and thermal degradation did not occur.

1.4 Research Questions

Based on the aforementioned problem statement, this research has been conducted to answer the question stated below:

1. What is the most suitable process to produce biodiesel?
2. What is the influence of adding additives to the diesel-karanja biodiesel blend fuel?
3. How does the amount of additive in the diesel-karanja biodiesel blend fuel affects the performance and efficiency of diesel engine?

1.5 Objectives of Study

The objectives of this research study are:

1. To produce karanja biodiesel from non-edible oil of karanja (pongamia pinnata) by using transesterification process.
2. To analyse the properties of karanja biodiesel and diesel-karanja biodiesel blended with propanol using bomb calorimeter and fourier transform infrared spectroscopy (FT-IR).
3. To evaluate the performance and efficiency of diesel-karanja biodiesel blended with propanol at different blending ratio for diesel engine.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Karanja

Karanja or commonly known as Pongamia Pinnata is a fast growing evergreen tree and a species of family Leguminasae which is adaptable to tropical and subtropical areas including part of India, Malaysia, Thailand, Vietnam, Japan, China and Australia (Mane, 2013). Halder et al. (2014) also mentioned that karanja was introduced into Hawaii by Hillebrand in the 1960s. Today, there are still some karanja trees growing in states, but this could not compare to the countless amount of karanja trees growing in other tropical and subtropical countries (Bedard, E., 2007). Karanja tree produce non-edible oil from its seed which is called as karanja oil and it can also be referred as pongam oil or honge oil. According to Mane (2013), karanja tree grows as a medium sized plant which reaches 15 to 25 meters in height and spreads canopy for casting moderate shade.

Karanja tree grows naturally through the dry land of India and it is widely known in that country, hence the trees are cultivated commercially by the large population of rural poor in India. To prove this statement, Halder et al. (2014) points out that 180 kg of seeds can be collected by a person in 8 hours of a day. One of the characteristics of karanja tree is that it can grow in various conditions such as in salty, sandy and stony soils. On the other hand, it can also tolerate drought bearing temperature that is up to 50°C and these trees survive with little amount of water. Karanja tree has a plant life of 80-100 years and it requires no pesticides to control various pests and disease carriers. Also, an average rainfall of 500 to 2500 mm is needed for plantations and growing process.

One important role of karanja tree is that it stops soil erosion, and for this reason vast amount of this trees are planted along the highways, roads and canals (Karikalan & Chandrasekaran, 2015). These trees are also being planted along the street however it is not appropriate for areas where many children are present as they contain poisonous pods that litter the ground. According to Halder et al. (2014), the growth and development of plant needs three irrigations per year. Moreover, karanja tree has pea-shaped flowers that are range from white to pink to purple, and the elliptical pods that consists a single seed inside it which can be extracted into oil to produce biodiesel. A study has shown that one tree may contain 8-24 kg of kernels which yields 30-40% of oil. The typical composition of air dried kernel contains 19% moisture and 27.5% oil (Halder et al., 2014).

2.2 Applications of Karanja

Every part of the plant have their own benefits and can be applied in many applications, however some of it are toxic to humans. Parts of karanja tree such as seeds, wood, root and bark, flowers and leaves and de oiled cake can be used in many applications such as in producing crude oil, medicine, karanja wood, feed supplement.

Karanja seeds are contained inside an oval shaped seedpods, which is around 1.5 inch long and brown in colour, and it can be found on the ground where karanja trees are planted. A fact which should be considered is the seedpods are poisonous and as a result, the product made from the seed is non-edible. Karanja seeds are utilized to produce karanja crude oil through solvent extraction or mechanical expeller method. The seeds are mainly used as feedstock for the production of biodiesel.

Figure 2.1: Karanja pods (Bedard, 2007)

Figure 2.2: Karanja seeds (Bedard, 2007)

According to Halder et al. (2014), the characteristic of karanja oil is thick, non-edible, has an unpleasant smell, yellow or reddish brown in colour and has a calorific value of 40.756 MJ/kg. Furthermore, karanja crude oil can be implemented in many applications namely in soap and candle making, lubricant, and also in body oils such as shampoos and lotions (Halder et al., 2014). Karanja oil also can be used as a medicine in the treatment of rheumatism and in skin diseases.

Parts of karanja tree such as leaves, flowers, fruits, roots or bark has medicinal value in which they can be used in treating many diseases. The leaves can be used to relieve diarrhea, wounds, inflammations and many more whereas the roots and bark can be used in curing coughs, colds, and as an oral hygiene. In addition, the root juice can be used to clean ulcers (Mane, 2013). Apart from that, flowers from karanja tree can be used in treating bleeding haemorrhoids whereas the fruits help with the treatment of abdominal tumor.

The wood of karanja tree can be used as fuel especially in rural areas in Bangladesh. It has a calorific value of 19.32 MJ/kg and varies from white to yellowish grey colour (Halder et al., 2014). The wood medium to coarse texture, susceptible to insect attack and tends to split during sowing, therefore it is only being implemented for cabinet making, cart wheels, stove top fuels and tool handles.

The by-product of karanja is de oiled cake which is produced after the oil extraction. It can be used as a feed supplement for cattle, sheep and poultry as it contains up to 30% protein (Rathore & Ramchandani, 2016). Karanja leaves are also suitable as a potential animal feed supplement where it consists of nutritive value of nitrogen-fixing trees. In