



**THE EFFECT OF STORAGE TANK MATERIAL AND  
CONDITION ON BIODIESEL BLEND B10 STABILITY**

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**MASTER OF SCIENCE IN MECHANICAL ENGINEERING**

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**Faculty of Mechanical Technology and Engineering**

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**A thesis submitted  
in fulfilment of the requirements for the degree of Master of Science  
in Mechanical Engineering**

**Faculty of Mechanical Technology and Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2024**

## DECLARATION

I declare that this thesis entitled “The Effect of Storage Material and Storage Condition on Biodiesel Blend B10 Stability” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

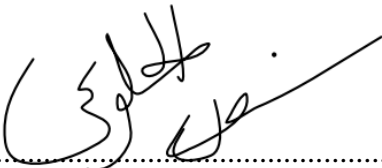
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## APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature :  .....

Supervisor Name : DR. NURUL HILWA BINTI MOHD ZINI .....

Date : 10 MAY 2024 .....

## **DEDICATION**

To my beloved parents and siblings

## ABSTRACT

Biodiesel is made from organic materials such as animal fat, plant lipids and waste cooking oil; it is widely used in many applications such as in diesel engine. This is because biodiesel reduces the emissions of carcinogenic compounds compared to petrodiesel. However, the storage stability of biodiesel can be affected by storage tank materials and storage conditions such as extended storage period and different storage environment. On a related note, manual biodiesel storage monitoring system increases risk of human errors, operational cost and expensive. Therefore, this study aimed to investigate the effect of storage material and storage condition, and also foam insulation on biodiesel stability. This study also analysed the potential of IoT technique as a new method to monitor biodiesel stability. Two setups were considered for B10 fuel: a pilot test without storage insulation and an actual test with storage insulation. The pilot test was conducted using three biodiesel storage tank materials with various shapes: stainless steel, high-density polyethylene (HDPE) and glass. The actual test used HDPE and glass for storage material which were insulated with 3D printed foam, together with rockwool as comparison; B10 fuel in the glass storage tank was remotely monitored using IoT. Both setups were monitored in enclosed space (indoor temperature) and outdoor (sun exposure). Based on the pilot test data collected, the results indicated that fuel samples barely degraded in indoor conditions. Properties of fuel in stainless steel tank stored outdoor for 90 days increased by 1.57%, 0.88%, 54.92% and 47.46% in density, kinematic viscosity, water content, and acid value, respectively. Meanwhile, the fuel samples stored outdoor in clear glass tanks showed dramatic increases in density, kinematic viscosity, water content and acid value by 4.35%, 11.23%, 95.08% and 95.41%, respectively, within 90 days of storage. However, the flashpoint decreased by 5.26% with increasing storage duration. Besides that, 3D printed foam as insulation for storage tanks was crucial as the degradation rate dropped for all biodiesel properties when compared to pilot test data. Fuel samples stored in the glass tank with foam insulation increased steadily by 1.69%, 4.67%, 68.85%, and 63.22% for density, kinematic viscosity, water content, and acid value, respectively, after 90 days storage. Furthermore, shapes of storage tank did not have an impact on experimental investigations. CFD simulation was conducted on storage tank insulations which managed to reduce temperature distribution of outdoor exposure (31.3°C) within the insulator before reaching storage tank wall for rockwool (28.8°C) and printed foam (29.7°C). Moreover, RSI value obtained for rockwool and printed which were 1.55 and 1.2, respectively. Meanwhile, IoT monitoring system recorded pH values in the range of 7.02 to 7.22 for indoor glass storage tank; these pH values were also manually validated using pH strips. However, pH values of the outdoor fuel samples dropped from pH 7 to pH 5 indicating increases in acid value within 90 days. From this study, it has been shown that biodiesel stability can be affected by storage material and storage condition; storage tanks made from stainless steel managed to reduce biodiesel degradation and is recommended as a storage tank material for B10, while higher storage temperature and longer storage duration result in biodiesel degradation. Foam insulation is shown to be an effective way to slow down biodiesel degradation. IoT technique is also demonstrated as a reliable new method to monitor biodiesel stability.

## **KESAN BAHAN DAN KEADAAN TANGKI SIMPANAN KE ATAS KESTABILAN CAMPURAN BIODIESEL B10**

### **ABSTRAK**

*Biodiesel diperbuat daripada bahan organik seperti lemak haiwan, lipid tumbuhan dan sisa minyak masak; ia digunakan dalam banyak aplikasi seperti dalam enjin diesel. Ini kerana biodiesel dapat mengurangkan pelepasan sebatian karsinogenik berbanding petrodiesel. Kestabilan penyimpanan biodiesel dipengaruhi oleh bahan tangki simpanan dan keadaan penyimpanan yang berbeza. Selain itu, sistem pemantauan biodiesel secara manual meningkatkan risiko kesilapan manusia, kos operasi dan mahal. Kajian ini bertujuan untuk mengkaji kesan bahan simpanan dan keadaan penyimpanan, dan juga tebatan busa terhadap kestabilan biodiesel. Kajian ini juga menganalisis potensi teknik IoT sebagai kaedah terbaru mengawasi kestabilan biodiesel. Dua persiapan eksperimen diambilkira untuk bahan api B10: ujian perintis tanpa penebat dan ujian sebenar dengan penebat. Ujian perintis dijalankan dengan tiga bahan tangki simpanan biodiesel dengan pelbagai bentuk: keluli tahan karat, polietilena berketumpatan tinggi (HDPE) dan kaca. Ujian sebenar menggunakan HDPE dan kaca untuk bahan simpanan yang ditebat dengan busa bercetak 3D, bersama-sama dengan rockwool sebagai perbandingan; bahan api B10 dalam tangki simpanan kaca dipantau dari atas talian menggunakan IoT. Kedua-dua bahan kajian dipantau dalam ruang tertutup (suhu) dan luar (pendedahan matahari). Keputusan ujian rintis menunjukkan bahawa keputusan sampel minyak hampir sama dalam ruang tertutup. Tangki keluli tahan karat yang disimpan di luar selama 90 hari meningkat sebanyak 1.57%, 0.88%, 54.92% dan 47.46% dalam ketumpatan, kelikatan kinematik, kandungan air dan nilai asid. Sampel yang disimpan di luar dalam tangki kaca jernih menunjukkan peningkatan mendadak dalam ketumpatan, kelikatan kinematik, kandungan air dan nilai asid sebanyak 4.35%, 11.23%, 95.08% dan 95.41%, dalam tempoh 90 hari penyimpanan. Titik kilat berkurangan sebanyak 5.26% dengan peningkatan tempoh penyimpanan. Busa bercetak 3D sebagai penebat untuk tangki simpanan adalah penting kerana kadar degradasi menurun untuk semua sifat biodiesel jika dibandingkan dengan data ujian perintis. Sampel bahan api yang disimpan dalam tangki kaca dengan penebat buih meningkat secara berterusan sebanyak 1.69%, 4.67%, 68.85%, dan 63.22% untuk ketumpatan, kelikatan kinematik, kandungan air dan nilai asid, masing-masing selepas penyimpanan 90 hari. Bentuk tangki simpanan tidak mempunyai kesan ke atas penyiasatan eksperimen. Simulasi CFD dilakukan pada penebat tangki simpanan dan ia berjaya mengurangkan taburan suhu pendedahan luar (31.3°C) dalam penebat sebelum mencapai dinding tangki simpanan untuk rockwool (28.8°C) dan busa bercetak (29.7°C). Nilai RSI diperolehi untuk rockwool dan busa ialah 1.55 dan 1.2. Sistem pemantauan IoT merekodkan nilai pH dalam julat 7.02 hingga 7.22; nilai pH ini juga telah disahkan secara manual menggunakan jalur pH. Nilai pH sampel minyak di luar menurun daripada pH 7 kepada pH 5 menunjukkan peningkatan dalam nilai asid dalam masa 90 hari. Kestabilan biodiesel dipengaruhi oleh bahan simpanan dan keadaan penyimpanan manakala suhu penyimpanan yang lebih tinggi dan tempoh penyimpanan yang lebih lama mengakibatkan degradasi biodiesel. Penebat busa berkesan untuk melambatkan degradasi biodiesel. Teknik IoT juga ditunjukkan sebagai kaedah baharu yang boleh dipercayai untuk memantau kestabilan biodiesel.*



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## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vi</b>
<b>LIST OF FIGURES</b>	<b>viii</b>
<b>LIST OF APPENDICES</b>	<b>xii</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xiii</b>
<b>LIST OF PUBLICATIONS</b>	<b>xiv</b>
<b>LIST OF SYMBOLS</b>	<b>xv</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Problem statement	3
1.3 Objective	4
1.4 Project scopes	5
1.5 Summary	5
<b>2. LITERATURE REVIEW</b>	<b>7</b>
2.1 Background	7
2.2 Biodiesel stability characterization	11
2.2.1 Density	14
2.2.2 Kinematic viscosity	16
2.2.3 Acid value	18
2.2.4 Water content	23
2.2.5 Flashpoint	25
2.2.6 Corrosion and degradation	27
2.3 Biodiesel storage insulation	29
2.4 Biodiesel monitoring system	31
2.5 Summary of past research	37
<b>3. METHODOLOGY</b>	<b>39</b>
3.1 Introduction	39
3.2 Research flow chart	40
3.3 Experimental setup	41
3.3.1 Pilot test setup	41
3.3.2 Actual test setup	42
3.3.2.1 3D printed foam as insulation	43
3.3.2.2 Internet of Things (IoT)	50
<b>4. RESULTS AND DISCUSSION</b>	<b>61</b>
4.1 Introduction	61
4.2 Pilot test experimental observation	61
4.2.1 Outdoor temperature and humidity	61
4.2.2 Biodiesel appearance observation	62

4.2.3	Evaluation of biodiesel properties	65
4.2.3.1	Kinematic viscosity experimental data	65
4.2.3.2	Density experimental data	68
4.2.3.3	Water content experimental data	71
4.2.3.4	Acid value experimental data	74
4.2.3.5	Flashpoint experimental data	77
4.3	Actual test experimental observation	80
4.3.1	Outdoor temperature and humidity	80
4.3.2	Biodiesel appearance observation after insulation application	81
4.3.3	Evaluation of biodiesel properties	83
4.3.3.1	Kinematic viscosity observation with insulation	83
4.3.3.2	Density experimental observation with insulation	85
4.3.3.3	Water content experimental observation with insulation	87
4.3.3.4	Acid value experimental observation with insulation	88
4.3.3.5	Flashpoint experimental observation with insulation	89
4.3.4	CFD simulated temperature distribution contours	91
4.3.5	Internet of Things (IoT) results with manual validation of pH	93
4.4	Observations between pilot and actual test investigations	96
4.4.1	Biodiesel appearance after 90 days with and without insulation	96
4.4.2	Experimental investigation comparison for outdoor storage conditions	96
4.5	Summary	107
<b>5.</b>	<b>CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH</b>	<b>109</b>
5.1	Conclusions	109
5.2	Recommendation	112
	<b>REFERENCES</b>	<b>114</b>
	<b>APPENDICES</b>	<b>131</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Biodiesel preparation methods (Atabani et al., 2012; Sani et al., 2012; Sommani et al., 2013; Adewale et al., 2015; Avhad and Marchetti, 2015; Charusiri and Vitidsant, 2017)	8
2.2	Biodiesel properties (Loterio et al., 2005; Demirbas, 2009; Atabani et al., 2012; Alhassan et al., 2013; Ang et al., 2014; Arquitectura et al., 2015; Mahmudul et al., 2017)	10
2.3	Biodiesel and petrodiesel comparison (Demirbas, 2009)	10
2.4	Summary on past biodiesel storage tank experimental investigations	12
2.5	Advantages and disadvantages of foamed plastic	30
3.1	Fuel properties analysis method	41
3.2	Insulation material properties	49
3.3	Mesh independency test	49
4.1	Initial and final properties of outdoor biodiesel B10 stored in cylindrical storages made from various materials after 90 days of storage duration	102
4.2	Initial and final properties of indoor biodiesel B10 stored in cylindrical storages made from various materials after 90 days of storage duration	102
4.3	Percentage change properties of biodiesel B10 after observation for 90 days in indoor and outdoor condition	103
4.4	Initial and final properties of outdoor biodiesel B10 stored in storages made from various materials with various shapes after 180 days of storage duration	103
4.5	Initial and final properties of indoor biodiesel B10 stored in cylindrical storages made from various materials after 180 days of storage duration	104

4.6	Percentage change properties of biodiesel B10 after observation for 180 days in indoor and outdoor condition	104
4.7	Initial and final properties of outdoor biodiesel B10 stored in storages made from various materials with various shapes after 180 days of storage duration	105
4.8	Initial and final properties of indoor biodiesel B10 stored in insulated storage tank after 90 days of storage duration	105
4.9	Percentage change properties of biodiesel B10 stored in insulated HDPE storage tank after 90 days of storage duration	106
4.10	Percentage change properties of biodiesel B10 stored in insulated glass storage tank after 90 days of storage duration	106

## LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Comparison of density versus hours for various biodiesel blends and storage tank materials: (a) indoor and (b) outdoor	15
2.2	Comparison of kinematic viscosity versus hours for various biodiesel blends and storage tank materials: (a) indoor and (b) outdoor	18
2.3	Comparison of acid value versus hours for various biodiesel blends and storage tank materials: (a) indoor and (b) outdoor	21
2.4	Comparison of water content versus hours for various biodiesel blends and storage tank materials: (a) indoor and (b) outdoor	24
2.5	Comparison of flashpoint versus hours at various biodiesel blends and storage tank materials: (a) indoor and (b) outdoor	26
2.6	The difference between isotropic and anisotropic foam structure (Damiati et al., 2018)	30
2.7	Process flow diagram of the proposed work (Suleiman and Reza, 2019)	33
2.8	The biodiesel remote monitoring system structure (Zu et al., 2015)	35
3.1	Flowchart of project flow	40
3.2	Pilot test setup: (a) illustrated setup, (b) outdoor storage and (c) indoor storage	42
3.3	Actual test setup with insulation and IoT system: (a) illustrated setup, (b) outdoor storage, and (c) indoor storage	43
3.4	Import file	45
3.5	Blender workbench	45
3.6	Units setting	46
3.7	Scale setting	46
3.8	Dimension of foam (a) height and (b) length and width	47

3.9	Random pore size	47
3.10	Insulated storage tanks: (a) 3d printed foam and (b) rockwool	48
3.11	Computational domain for insulated storage tank	49
3.12	Node versus storage tank wall temperature (°C)	50
3.13	Internet of Things (IoT) setup: (a) IoT components and (b) IoT sensor placement in and out of storage tank	51
3.14	ESP32 devkit pinouts (Suleiman and Reza, 2019)	52
3.15	PH electrode parts (E-gizmo mechatronics central, 2017)	53
3.16	DS18B20 sensor probe (Dallas semiconductor, 2008)	54
3.17	DS18B20 circuit diagram (Dallas semiconductor, 2008)	54
3.18	HM1500LF sensor (Measurement specialities, 2008)	55
3.19	MPX5010DP sensor (Motorola semiconductor, 2009)	56
3.20	Primary procedure	57
3.21	Network connection troubleshoot	57
3.22	Sensor coding configurations	57
3.23	Upload data to web-domain	58
3.24	Configuration if no internet access	58
3.25	Overall dashboard	59
3.26	Simplified workflow of IoT	59
3.27	Separate windows for each parameter: (a) temperature (outer), (b) temperature (inner), (c) humidity (d) pressure and (e) pH	60
4.1	Outdoor environment data on: (a) temperature and (b) humidity	62
4.2	Colour changes in biodiesel: (a) initial, (b) indoor after 180 days, and (c) outdoor after 30, 60, 90, and 180 days	64
4.3	Current work kinematic viscosity versus storage period	66
4.4	Current work kinematic viscosity versus storage period with error bars: (a) stainless steel, (b) HDPE and (c) glass	66
4.5	Comparison between current and past work on kinematic viscosity versus storage period: (a) indoor and (b) outdoor	67
4.6	Current work density versus storage period	69
4.7	Current work density versus storage period with error bars: (a) stainless steel, (b) HDPE and (c) glass	69
4.8	Comparison between current and past work on density versus storage period: (a) indoor and (b) outdoor	70
4.9	Current work water content versus storage period	72

4.10	Current work water content versus storage period with error bars: (a) stainless steel, (b) HDPE and (c) glass	72
4.11	Comparison between current and past work on water content versus storage period: (a) indoor and (b) outdoor	73
4.12	Current work acid value versus storage time	75
4.13	Current work acid value versus storage period with error bars: (a) stainless steel, (b) HDPE and (c) glass	75
4.14	Comparison between current and past work on acid value versus storage period: indoor and (b) outdoor	76
4.15	Current work flashpoint versus storage period	78
4.16	Current work flashpoint versus storage period with error bars: (a) stainless steel, (b) HDPE and (c) glass	78
4.17	Comparison between current and past work on flashpoint versus storage time: (a) indoor and (b) outdoor	79
4.18	Outdoor environmental data: (a) temperature and (b) humidity	80
4.19	Colour changes in biodiesel: (a) initial, (b) indoor after 90 days, and (c) outdoor after 30, 60, and 90 days	82
4.20	Insulation quality before and after 90 days: (a) Rockwool and (b) 3D printed foam	83
4.21	Kinematic viscosity for current work with insulation versus storage period	84
4.22	Kinematic viscosity for current work with insulation versus storage period with error bars; (a) HDPE and (b) glass	85
4.23	Density for current work with insulation versus storage period	86
4.24	Density for current work with insulation versus storage period with error bars; (a) HDPE and (b) glass	86
4.25	Water content for current work with insulation versus storage period	87
4.26	Water content for current work with insulation versus storage period with error bars; (a) HDPE and (b) glass	88
4.27	Acid value for current work with insulation versus storage period	89
4.28	Acid value for current work with insulation versus storage period with error bars; (a) HDPE and (b) glass	89



4.29	Flashpoint for current work with insulation versus storage period	90
4.30	Flashpoint for current work with insulation versus storage period with error bars; (a) HDPE and (b) glass	91
4.31	Temperature contour of insulated storage tank: (a) non-insulated (b) foam and (c) rockwool	92
4.32	IoT data recording: (a) Temperature, (b) Humidity and (c) Pressure	94
4.33	pH level reading (a) IoT and (b) manual validation with pH strip for indoor	95
4.34	Manual validation with pH strips for Outdoor: (a) 15 days and (b) 90 days	95
4.35	Colour changes in biodiesel after 90 days: (a) pilot test (non-insulated) and (b) actual test (insulated)	96
4.36	Comparison between pilot and actual test investigation for outdoor conditions for kinematic viscosity	97
4.37	Comparison between pilot and actual test investigation for outdoor conditions for density	98
4.38	Comparison between pilot and actual test investigation for outdoor conditions for water content	99
4.39	Comparison between pilot and actual test investigation for outdoor conditions for acid value	100
4.40	Comparison between pilot and actual test investigation for outdoor conditions for flashpoint	101

## LIST OF APPENDICES

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	Apparatus procedure	131

## LIST OF ABBREVIATIONS

3D	-	3-dimensional
AN	-	Acid number
ASTM	-	American Society for Testing and Materials
CO <sub>2</sub>	-	Carbon dioxide
EPA	-	Environmental Protection Agency
EPS	-	Expanded polystyrene
FA	-	Fatty acid
FAME	-	Fatty acid methyl ester
GHG	-	Greenhouse gas
HDPE	-	High-density polyethylene
IDE	-	Integrated development environment
IoT	-	Internet of Things
KOH	-	Sodium hydroxide
NaOH	-	Potassium hydroxide
OEM	-	Original equipment manufacturer
PU	-	Polyurethane
PV	-	Peroxide value
SoC	-	System on Chip
TBHQ	-	Tert-Butylhydroquinone
UF	-	Formaldehyde
UV	-	Ultraviolet
WCO	-	Waste cooking oil

## LIST OF PUBLICATIONS

1. Rao, N.S., Zini, N.H.M., Saadun, M.N.A., Anuar, F.S., 2023. Effect of Storage Tank Material on Biodiesel Stability under Different Environmental Conditions. *Jurnal Tribologi*, vol. 36, pp.32–42.
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## LIST OF SYMBOLS

$\rho$	-	Density
$V$	-	Volume
$M$	-	Mass
$C$	-	Concentration
%	-	Percent

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Initially, diesel engines were designed by Rudolf Diesel in the 1880s to run on various fuels such as kerosene and coal dust with a complex injection system. Then, he made a conventional diesel engine that used 100% peanut-based oil which gave him a breakthrough during Paris Exhibition in 1900 (Adipah, 2018). However, poor quality fuel spray was caused by the viscosity of the vegetable oil, and thus, engines were damaged as a result of this. Scientists then continuously conducted experiments to improve the quality of the vegetable oils, which are now commercially known as biodiesel (Ogunkunle and Ahmed, 2019).

A biodiesel blend is a mix of ethyl esters or methyl derived from various renewable sources such as vegetable oil, recycled cooking oil, and animal fat. These esters, known as oxygenated organic compounds, are compatible to be used in compression ignition engines due to their key properties comparable with existing diesel fuel. Biodiesel properties offer a carbon-neutral cycle due to its net-zero carbon impact on the environment (Nguyen et al., 2020). Biodiesel is considered carbon-neutral because the sources of biodiesels are from feedstocks, such as palm oil trees which absorb carbon dioxide (CO<sub>2</sub>) as they grew. CO<sub>2</sub> absorption by the raw materials balances the CO<sub>2</sub> formed during the making and burning of biodiesel (Mishra and Goswami, 2018).

Biofuel can be divided into two categories: (1) biodiesel and (2) bioethanol. Biodiesel is renewable and obtained from animals, plants, microorganisms, and organic wastes. The

organic materials for biodiesel are extracted from rapeseed, palm, soybean and sunflower meanwhile bioethanol is produced from sugar beet, potatoes, maize, and wheat. (Noraini et al., 2014). Biodiesel is widely used for numerous purposes such as transportation fuel, energy generation, cooking, lubrication and paint removal. This fuel causes less damage to the environment as it is non-toxic, biodegradable, grown locally, and has fewer greenhouse gas (GHG) emissions (Abed et al., 2019). On the other hand, petroleum diesel is high in toxic, clogs engines and expensive.

There are several processes involved to extract the biodiesel fuel, which are transesterification, pyrolysis, micro emulsification and blending (Rajalingam et al., 2016). In the transesterification process, crude methyl esters and glycerine are separated from the vegetable oil. Then, they are further refined, which turns methyl esters of biodiesel and glycerine into a variety of products such as soaps and shampoo. There are specific blends for biodiesel that will be made according to the usage. Some examples include B100 which contains 100% biodiesel and B20 that contains 80% petrodiesel with 20% biodiesel (Nair, 2015). Most of the current engines can run on B100 but modification needs to be done on the engines in the aspects of cold starting, engine timing, rubber seals and oil change to avoid future performance and maintenance complications. The rubber seal also has to be replaced as this fuel reacts with the seals and the timing of the diesel engines has to be tuned by two or three degrees by considering the number of cetane of the respective fuels to maintain the performance of the engine (Xue et al., 2011).

Biodiesel has a shelf life of around three years in stable storage conditions. Many researchers have tested the fuel with various storage materials in different surroundings to obtain the best storage tank for this fuel. In addition, the materials used were mild steel, stainless steel, plastic, glass and copper. (Bouaid et al., 2007; Hu et al., 2012; Pattamaprom et al., 2012; Shahabuddin et al., 2012; Komariah et al., 2017; Prasad et al., 2018; Komariah

et al., 2019). Oxidation, water level, bacteria contamination, kinematic viscosity, acid level, density, temperature and humidity level are the main factors that have to be monitored throughout the storage period (Shahabuddin et al., 2012; Komariah et al., 2017; Prasad et al., 2018). In this aspect, a country climate is also the main issue to be taken into account; for biodiesel storage, the extreme climate during transportation can affect biodiesel quality. For example, biodiesel fuel tends to freeze in an icy climate at around  $-1^{\circ}\text{C}$  and increases in viscosity during higher temperature storage compared to fossil fuels (M.A. Hazrat et.al., 2020). An ideal storage tank can maintain or increase the shelf life of biodiesel fuel without any problem.

## **1.2 Problem statement**

Biodiesel is derived from animal fat, vegetable oil and waste cooking oils (Datta et al., 2019). As it is biodegradable, biodiesel is susceptible to microbial contamination and oxidation. If it is not stored correctly, biodiesel can be exposed to atmospheric oxygen and moisture which can result in biodiesel to become unstable due to its chemical structure degrading over time. Apart from that, long term storage stability of biodiesel is not as good as conventional petrodiesel storage because of its degradable properties (Thompson et al., 2013). Properties such as water content, kinematic viscosity, density, and acid value tend to increase over longer storage time in most cases.

Oxidation is a process that will increase fuel acidity level and corrodes the fuel system. Therefore, the time taken for oxidation or degradation of biodiesel in the storage shall be prolonged or completely diminished if possible. However, current study shows that the oxidation process cannot be avoided (Erdmann et al., 2019). Other than that, higher water content in the biodiesel is observed during the pyrolysis process. This indirectly increases fuel degradation. Thus, a proper storage of biodiesel is very crucial to prevent fuel storage