PRODUCTION OF BIODIESEL FROM NON EDIBLE VEGETABLE OIL

By

Abdallah Sayed Ahmed Ali El-Gharbawy

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
Chemical Engineering

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Title of Thesis:
PRODUCTION OF BIODIESEL FROM NON-EDIBLE VEGETABLE OIL

Key Words:
Biodiesel, Transesterification, Used cooking oil.

Summary:
The depletion of fossil fuel forces the world to look for alternative ways for energy production. The most important alternative method is biofuels production. Biofuels are a type of fuel produced from natural resources such as agriculture, agriculture wastes, used cooking oil and biological creatures. Production of biodiesel from non edible vegetable oils is done through a chemical reaction called transesterification reaction. The oil used in this work is waste cooking oil which cannot be recycled or valid to human use. Transesterification is a chemical reaction at which the organic group (alkyl) of an alcohol is substituted with the organic group of a triglyceride producing fatty acid alkyl ester and glycerol. Transesterification reaction is catalyzed by addition of a base catalyst

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TABLE OF CONTENTS

TABLE OF CONTENTS ..... **II**
LIST OF TABLES ..... **V**
LIST OF FIGURES ..... **VII**
ABSTRACT ..... **X**
CHAPTER 1: INTRODUCTION **1**

CHAPTER 2: LITERATURE VIEW **3**
2.1. INTRODUCTION 3
2.2. RELATED WORK 3
2.2.1. Biodiesel Feedstocks 3
2.2.1.1. Edible Oil 4
2.2.1.2. Non Edible Oil 5
2.2.2. Transesterification Methods 7
2.2.3. Transesterification Steps 12
2.2.3.1. Removal Of Solid particles Impurities 12
2.2.3.2. Water Drying 12
2.2.3.3. Treating High FFA Waste Vegetable Oil 13
2.2.3.4. Transesterification Reaction 14
2.2.3.5. Biodiesel Purification 14
2.2.3.6. Water Washing 15
2.2.4. Factors Affecting Biodiesel Production 16
2.2.4.1. Reaction Temperature 16
2.2.4.2. Molar Ratio 16
2.2.4.3. Type Of Catalyst 16
2.2.4.4. Catalyst Concentration 17
2.2.4.5. Mixing Rate 17
2.2.4.6. Reaction Time 17
2.3. SUMMARY 18
2.3.1. Steps Of Biodiesel Production 18
2.3.2. Types Of Transesterification 18
2.3.3. Alcohols Used In Transesterification Process 20

CHAPTER 3: MATERIALS AND EXPERIMENT **21**
3.1. MATERIAL AND METHODS 21
3.1.1. Research Methodology 21
3.1.2. Materials Used In Experiments 21
3.1.3. Equipments Used In Experiments 22

3.1.4. Methods Of Biodiesel Production 23
3.1.4.1. Feedstock Pre-Treatment 23
3.1.4.2. Measuring Free Fatty Acid 23
3.1.4.3. Removal Of Solid Particles Impurities 23
3.1.4.4. Water Removal 23
3.1.4.5. Preparation Of Alcohol And Catalyst 24
3.1.4.6. Alkaline Transesterification Process 24
3.1.4.7. Biodiesel Purification 24
3.1.4.8. Water Washing 24
3.1.4.9. Drying of Produced Biodiesel 24
3.1.5. Determination Of Biodiesel Properties 25
3.1.5.1. Acid Value 25
3.1.5.2. Density 25
3.1.5.3. API Gravity 26
3.1.5.4. Aniline Point 26
3.1.5.5. Cetane Number 26
3.1.5.6. Cloud Point And Pour Point 27
3.1.5.7. Flash Point 27
3.2. EXPERIMENTS 28
3.2.1. Experimental Design 29

CHAPTER 4: RESULTS AND DISCUSSION 31
4.1. YIELD OF EXPERIMENT 31
4.2. LINEAR REGRESSION ANALYSIS 31
4.3. MULTIPLE REGRESSION ANALYSIS 40
4.3.1. Interactive Effect On Final Biodiesel 45
4.4. OPTIMUM CONDITIONS 48
4.5. BIODIESEL STANDARD PROPERTIES 50
4.6. PROPERTIES OF PRODUCED BIODIESEL 51
4.7. PRODUCED BIODIESEL COMPONENTS 54

CHAPTER 5: COST ANALYSIS 55
5.1. TYPES OF COST ESTIMATION 55
5.1.1. Analogous Estimation 55
5.1.2. Parametric Estimation 55
5.1.3. Three-Point Estimation 55
5.2. DESIGN OF COST ANALYSIS 56
5.2.1. Capital Expenditure (CAPEX) 56
5.2.1.1. Purchased Equipment Cost (PEC) 56
5.2.1.2. Other CAPEX 60

5.2.2. Operating Costs (OPEX) 64
5.2.2.1. Fixed Costs 64
5.2.2.2. Variable Costs 64
5.3. COST ANALYSIS BASIS 65
5.3.1. Technical Assumptions 65
5.3.2. Economic Assumptions 65
5.3.3. Operating Assumptions 65

CONCLUSION **77**

REFERENCES **79**

LIST OF TABLES

T able 2.1:	Comparison between methanol and ethanol in acid catalyzed transesterification	……	8
Table 2.2:	Comparison between catalytic and supercritical alcohol transesterification	……	12
Table 2.3:	Comparison between methanol and ethanol in transesterification reaction	……	20
Table 3.1:	Methanol weight (g)	……	28
Table 3.2:	Experiment setup	……	30
Table 4.1:	Feedstock specifications	……	31
Table 4.2:	Experimental and predicted results of linear regression	……	32
Table 4.3:	Analysis of variance of the linear regression model	……	34
Table 4.4:	Experimental and predicted results of multiple regression	……	43
Table 4.5:	Analysis of variance of the multiple regression model	……	44
Table 4.6:	Optimum Conditions from experimental design	……	48
Table 4.7:	The results at Optimum conditions from experimental design	……	48
Table 4.8:	Optimum runs	……	49
Table 4.9:	Biodiesel ASTM standard specifications	……	50
Table 4.10:	Produced biodiesel specifications	……	51
Table 4.11:	Produced Biodiesel components	……	54
Table 5.1:	Purchased equipment cost	……	59
Table 5.2:	Total capital cost	……	62
Table 5.3:	Biodiesel project technical and economic assumptions	……	67
Table 5.4:	Biodiesel operating assumptions	……	68
Table 5.5:	Biodiesel labors assumptions	……	68
Table 5.6:	Expected feedstocks and product price till 2037	……	69
Table 5.7	Expected utilities prices till 2037	……	70

Table 5.8:	Expected operating cost till 2037	……	71
Table 5.9:	Revenue of biodiesel project till 2037	……	73
Table 5.10:	Income statement	……	74
Table 5.11:	An estimation for production of 1 litre biodiesel	……	76

LIST OF FIGURES

Figure 2.1:	UK Biodiesel feedstock production	……	4
Figure 2.2:	Palm seeds and palm oil	……	4
Figure 2.3:	Soybean oil	……	5
Figure 2.4:	Rape seeds	……	5
Figure 2.5:	Jatropha oil and Jatropha seeds	……	6
Figure 2.6:	Used cooking oil	……	7
Figure 2.7:	Mechanism of base catalyst transesterification reaction	……	10
Figure 2.8:	Biodiesel and glycerol layers	……	15
Figure 2.9:	Water washing, the upper layer is biodiesel, the lower layer is distilled water	……	15
Figure 3.1:	Equipment connection	……	22
Figure 4.1:	Box graph showing the analysis of experiments with different factors on transesterification process	……	33
Figure 4.2:	Box graph showing the relation between produced and predicted yields with experiments on the transesterification process	……	34
Figure 4.3:	Box graph showing the relation between M:O ration and yield	……	36
Figure 4.4:	Box graph showing the relation between catalyst concentration and yield	……	37
Figure 4.5:	Box graph showing the relation between reaction temperature and yield	……	38
Figure 4.6:	Box graph showing the relation between reaction time and yield	……	39
Figure 4.7:	Box graph showing the relation between mixing rate and yield	……	40
Figure 4.8:	The RSM plots	……	47
Figure 5.1:	Batched stirred reactor	……	57
Figure 5.2:	Vapor-liquid separator	……	57

Figure 5.3:	Mixer	……	58
Figure 5.4:	Heat exchanger	……	58
Figure 5.5:	Alkali-catalyzed transesterification of WCO-process	……	63
Figure 5.6:	Total revenue versus total OPEX	……	75
Figure 5.7:	Biodiesel production cost and petro-diesel price	……	75
Figure 5.8:	Net income after taxes versus depreciation	……	76

ABBREVIATION

ASTM	American Standard Test Method
RCCD	Rotatable Central Composite Design
CAPEX	Capital Expenditure
OPEX	Operational Expenditure
PEC	Purchased Equipment Cost
FFA	Free Fatty Acid
WCO	Waste Cooking Oil
M:O	Methanol to Oil ratio
FAME	Fatty Acid Methyl Ester
GC	Gas Chromatograph
FID	Flame Ionization Detector
KTA	Kilo Tons per Annum
RSM	Response surface methodology
CV	Calorific Value

ABSTRACT

The depletion of fossil fuel forces the world to look for alternative ways for energy production. The most important alternative method is biofuels production. Biofuels are a type of fuel produced from natural resources such as agriculture, agriculture wastes, used cooking oil and biological organisms. Production of biodiesel from non edible vegetable oils is done through a chemical reaction called transesterification reaction. The feedstock used in this work was non edible waste cooking oil which cannot be recycled or valid to human use. Transesterification is a chemical reaction at which the organic group (alkyl) of an alcohol is substituted with the organic group of a triglyceride producing fatty acid alkyl ester (FAME) and glycerol. Transesterification reaction was catalyzed by addition a base catalyst. The conversion of triglycerides to alkyl esters (biodiesel) depends up on certain parameters that affect the biodiesel production process such as catalyst concentration, methanol to waste cooking oil ratio, temperature, mixing rate and reaction time.

The first part of this work is concerning with studying the effect of each reaction parameters on biodiesel yield and its specifications, specifying the optimum operating conditions for alkaline transesterification reaction through application of linear regression analysis and multiple regression analysis which are used to predict the responses change when one of variable is varied. The statistical software Design Expert 6.0.7 (Stat-Ease Inc., Minneapolis, USA) was used for design of experiments, regression and graphical analyses of the data obtained. The triglycerides conversion to biodiesel reaches to 99.2%. The high conversion obtained was based on the following conditions: methanol to oil molar ratio of 7.54:1, catalyst concentration of 0.875% , 1.17 hr of reaction time, temperature of 52 °C, mixing rate 266 rpm. The produced biodiesel quality is agreeing with the American standard testing method (ASTM), all properties such as cetane number, acid number, flash point, pour point, cloud point and aniline point are in the standard range. The calorific value of the produced biodiesel is 39.6 MJ/kg which is higher than the standard biodiesel calorific value by 6 %. The properties of produced biodiesel qualifies its utilization in vehicles instead of petro-diesel especially that the biodiesel is free of any sulfur.

The second part of work related to technical feasibility study for biodiesel plant build up using the alkaline transesterification process for more than 100,000 ton of used cooking oil. Apply the financial model template to analyze the economic effect. MICROSOFT EXCEL PROGRAM is one of the mathematical programs that used in establishing projects financial model. The main advantage of using this program is its availability and simplicity that enable any researcher to check the profitability of his ideas regarding any project and also optimize the project to get the optimum project configuration. The project will achieve a good income around 4 million US $ every year and the total net income during the life cycle of project is 72.5 million US $. The technical feasibility study concludes that the production cost of one litre biodiesel from used cooking oil is 0.515 $ while the global price of petro-diesel is 0.678 $/ litre and global biodiesel current price is 1 $/litre.

Keywords: Biodiesel, Transesterification, Used cooking oil.

CHAPTER 1: INTRODUCTION

Biodiesel is a fatty acid alkyl ester which produced from biological sources such as vegetable oil, animal fats wastes and algae. Biodiesel produced from renewable resources is considered the most important biofuel. Production of biodiesel from non edible vegetable oil hits a lot of benefits. It is economical as biodiesel production from waste cooking oil is lower in cost than production of petro-diesel from high cost crude oil in addition biodiesel plants does not cost money like refining plants. It is renewable as biodiesel is produced from renewable resources such as used cooking oil or biological organisms while petro-diesel made from finite sources. Production of biodiesel is simple process does not need a license or a complicated technology. Biodiesel is better for environment as it does not contain sulfur. Biodiesel which its specification achieves the international standard limits can be used directly or it can be blended with conventional diesel in diesel engine as the calorific value of petro-diesel is higher than for biodiesel.

The feedstocks of biodiesel varies between edible oil such as the oil of sunflower, soybean and coconut or non-edible oil such as the oil of Jatropha, jojoba and used cooking oil. Biodiesel is produced from vegetable oil through transesterification reaction.
There are four types of the transesterification processes, acid-catalyzed transesterification, alkaline catalyzed transesterification, enzyme catalyzed transesterification and non catalyzed supercritical methanol. The alkaline catalyzed transesterification method was used in this work as it is the fastest reaction, higher yield, mild reaction condition, low cost, less corrosive, less toxicity.

Alkaline catalyzed transesterification steps are three major steps: the first step is feedstock treatment which includes measuring feedstock free fatty acid, removal of insoluble impurities and water removal. The second step is the alkaline transesterification process which includes addition of alcohol and catalyst to the oil at specified temperature and mixing rate for certain time. The final step of transesterification process is biodiesel treatment which includes biodiesel purification, water washing, and water removal from produced biodiesel. There is many factors affecting biodiesel production, these factors are: methanol to oil ratio, catalyst concentration, temperature, time and mixing rate. The effect of each factor on the final yield is studied in this work through using rotatable central composite design (RCCD) as it allows usage of few numbers of experiments to cover wide range of variables. Linear regression method and multiple regression method were used to analyze the results. Multiple regression method is more accurate as it studies the interactive between factors and quadratic effects of factor while linear regression studies only one factor effect. Specifications of produced biodiesel are standard range and it can be blended with diesel engine.

Cost estimation is a prediction of cost and budget required to build up and operate a plant. The preliminary cost estimation in this work depends on the optimum condition obtained from the experimental work and parametric estimation way which includes a relationship between relevant historical data and other variables. The cost estimation model applied on a plant with capacity