



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكرو فيلم

بسم الله الرحمن الرحيم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم



شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



MONA MAGHRABY



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



MONA MAGHRABY

**PHOTOBIOSTIMULATION OF GREEN ALGAE
Chlorella sorokiniana USING RED LASER
RADIATION FOR BIODIESEL PRODUCTION**

By

MARYAM ELSAYED MUHAMMED FARIED

B.Sc. Agric. Engineering, Fac. Agric., Cairo Univ., 2014

THESIS

Submitted in Partial Fulfillment of Requirements for the Degree of

MASTER OF SCIENCE

In

**Agricultural Sciences
(Agricultural Engineering)**

**Department of Agricultural Engineering
Faculty of Agriculture
Cairo University
EGYPT**

2020

SUPERVISION SHEET

**PHOTOBIOSTIMULATION OF GREEN ALGAE
Chlorella sorokiniana USING RED LASER
RADIATION FOR BIODIESEL PRODUCTION**

**M.Sc. Thesis
In Agric. Sci. (Agricultural Engineering)**

By

**MARYAM ELSAYED MUHAMMED FARIED
B.Sc. Agricultural Engineering, Fac. of. Agric., Cairo Univ., 2014**

SUPERVISION COMMITTEE

**Dr. MOHAMED SAMER MOHSEN FOUAD MOHAMED
Professor of Agricultural Engineering, Fac. Agric., Cairo University**

**Dr. RANIA SABER YOUSEF
Assist. Prof. of Biochemistry, Fac. Agric., Cairo University**

**Dr. ESSAM MOHAMED ABDELALIM ABDELSALAM
Assist. Prof. of Laser Applications in Metrology, Photochemistry
and Agriculture, National Institute of Laser Enhanced Science (NILES), Cairo
University.**

Name of Candidate: Maryam Elsayed Muhammed Faried **Degree:** M.Sc.
Title of Thesis: Photobiostimulation of green algae *Chlorella sorokiniana*
using red laser radiation for biodiesel production.

Supervisors: Dr. Mohamed Samer Mohsen Fouad Mohamed
Dr. Rania Saber Yousef
Dr. Essam Mohamed Abdelalim Abdelsalam

Department: Agricultural Engineering

Approval: 14 / 9/ 2020

ABSTRACT

At present, energy dependence on petrol fuels has been identified as a future challenge owing to the expected depletion of fossil fuel reserves and fast increasing consumption over recent years and thus could be said the increasing need for sustainable energy calls for the development of renewable and cost-effective alternative energy sources to reduce the use of fossil fuels. The ability of microalgae to produce high amount of lipid with fast growth rate made it superior biodiesel producers. Daily and diurnal cyclic changes in weather conditions, dramatic fluctuations of light intensity, limited capabilities of harvesting light and self-shading of microalgae are the most important problems. The objective of this study was to increase biodiesel production from green microalgal *Chlorella sorokiniana* biomass using Gas laser, (Red He-Ne laser 632.8 nm). The present study investigated the effect of monochromatic Light Emitting Diodes (LEDs) and He-Ne laser on the growth of the green microalgae *Chlorella sorokiniana*. The irradiation of microalgal cell with laser source was hypothesized to enhance the accumulated of lipid, which increases the biodiesel production. The photobiostimulating effects of laser irradiation on biodiesel was investigated by irradiating the microalgal biomass two hours with 632.8 nm He-Ne red laser source compared with two hours white light as a control. The results showed that under He-Ne red laser irradiation the oil content was three times the white light as a control which yielded 1.2 g Oil L⁻¹ Microalgae, 0.4 g Oil L⁻¹ Microalgae. Also, the results showed that under He-Ne red laser irradiation the yield of biodiesel was three times the white light as a control which yielded 0.06 g Biodiesel L⁻¹ Microalgae, 0.02 g Biodiesel L⁻¹ Microalgae respectively. Both of He-Ne red laser and blue LED were the best in terms of increasing the total lipid and yield of biodiesel which yielded 1.2 g Oil L⁻¹ Microalgae, 0.6 g Oil L⁻¹ Microalgae respectively and 0.06 g Biodiesel L⁻¹ Microalgae, 0.04 g Biodiesel L⁻¹ Microalgae respectively. The total lipid and yield of biodiesel from microalgae significantly increased under He-Ne red laser, blue LED, green LED, white light and red LED respectively.

Keywords: Microalgae, Biodiesel, Laser, Light Emitting Diodes, Irradiation, Photobiostimulation, Renewable energy.

DEDICATION

This thesis is dedicated to my mother, father's soul, brothers (Abduallah and Abdurahman), sisters (Rana and Maha), as well as my nephews (Lulia and Slim). My thanks also go out to my uncles and my best friend (Fatma).

ACKNOWLEDGEMENT

First and foremost, I feel always indebted to Allah beneficent and Merciful the most. This study was carried out at the faculty of Agriculture, Cairo University, Giza, Egypt.

*I would like to acknowledge the **Science and Technology Development Fund (STDF)** of Egypt for funding this paper (research project no. 26272).*

*I would like to express the deepest appreciation to my committee chair, **Prof. Dr. MOHAMED SAMER**, professor of Agricultural Engineering, Faculty of Agriculture, Cairo University, who has the attitude and the substance of a genius: he continually and convincingly conveyed a spirit of adventure in regard to research and scholarship and an excitant in regard to teaching. Without his guidance and persistent help this dissertation would not have been possible. Special thanks for his creative ideas and development of the hypothesis of this study.*

*Deepest and sincere thanks to assistant professor **Dr. RANIA SABER YOUSEF**, Department of Biochemistry, Faculty of Agriculture, Cairo University.*

*I would like to thank my committee member, **Dr. ESSAM MOHAMED ABDELALIM**, assistant professor of Laser Application in Metrology, Photochemistry and Agriculture National Institute of Laser Enhanced Science (NILES), Cairo University, for his continuous advice, friendly attitude and help during this work,*

***All my grateful to Dr. ABDALLAH SOBHY ALI**, Department of microbiology, faculty of Agriculture, Cairo University, who I had the pleasure to work him. Special thanks for his expertness an (Know how).*

*Immeasurable appreciation and deepest gratitude for help and support are extended to the following persons who in one way or another have contributed in making this study possible: **Dr. MOHAMED MOSELHY**, assistant professor of microbiology, faculty of Agriculture, Cairo University, **Dr. RASHA HUSIEN AHMED**, assistant professor of microbiology, faculty of Agriculture, Cairo University and **Dr. DIAA ATTIA MARREZ**, Marine Toxins Laboratory, Food Toxicology and Contaminants Department, National Research Centre, Dokki, Cairo, Egypt.*

*I would like to thank all members of **Research Park** especially all members of Analytical Chemistry, Water and Soil laboratories.*

I would like to take this opportunity to thank my mother and father, who have raised me to be the person I am now. you have been with me every step of the way, through good times and bad. Thank you for all unconditional love, guidance and support that you have given me, helping me to succeed and instilling in the me the confidence that I can capable of doing anything I put my mind to. Thank you for everything. Also, this work is a gift to my beloved father's soul, may God have mercy on him. I had promised to make my father proud by the achievement of this momenta academic goal and I hope that I have fulfilled that promise. I wished that he could still be alive today to share with me the celebration of my succeed. Finally, there aren't words to express my gratitude to my unknown soldier (Abdurahman) for his support, sympathy, helping and encouragement he had continually offered throughout my postgraduate studies.

LIST OF ABBRIVIATIONS

Acetyl-CoA	Acetyl Coenzyme
ACP	Acetyl Carrier Protein
AD	Anaerobic Digestion
ATB	Adenosine Triphosphate
ASTM	American Society for Testing and Materials
BDF	Biodiesel Fuel
BP	British Petroleum
CN	Cetane Number
CPR	Closed Pond Photobioreactor
DAG	Diacylglycerol
DCW	Dry Cell Weight
DHA	Docosahexaenoic Acid
DGAT	Diacylglycerol Acyltransferase
DW	Dry Weight
EDTA	Ethylenediaminetetraacetic acid
EPA	Eicosapentaenoic Acid
ER	Endoplasmic Reticulum
EROEI	Energy Return on Energy Investment
EN	European Standards
FAME	Fatty Acid Methyl Ester
FAS	Fatty Acid Synthase
FFA	Free Fatty Acids
FW	Fresh Weight
GC-MS	Gas Chromatography-Mass Spectrometry
G3P	Glycerol-3-Phosphate
GPAT	Glycerol-3-Phosphate Acyltransferase
GHGs	Greenhouse Gases
HFI	High Fluctuating Intensity
HRT	Hydraulic Retention Time
HLT	Hydrothermal Liquefaction Technology
HTP	Hydrothermal hydrolysis Pretreatment
LCA	Life Cycle Analysis
LCL	Lower Control Limit
LDPE	Low-Density Polyethylene
LEDs	Light Emitting Diodes
LPA	Lysophosphatidic acid

LPAT	Lysophosphatidic Acid Acyltransferase
NMR	Nuclear Magnetic Resonance
Ops	Open Ponds
PA	Phosphatidic Acid
PAP	Phosphatidic Acid Phosphatase
PAR	Photosynthetically Active Radiation
PBRs	Photobioreactors
PCA	Principle Component Analysis
PCs	Principal Components
PGA	Phosphoglycerate
PDH	Pyruvate Dehydrogenase
STP	Standard Temperature and Pressure
SCMA	Supercritical Methyl Acetate
TGAs	Triacylglycerol Triacylglycerols
UCL	Upper Control Limit
WLE	Wet Lipid Extraction

CONTENTS

	Page
INTRODUCTION.....	1
REVIEW OF LITERATURE.....	7
1. Background.....	7
2. Microalgae.....	10
3. Optimal bioenvironmental conditions.....	10
4. Process design of algal biodiesel production.....	13
5. Oil.....	17
a. Physicochemical properties of lipids.....	17
b. Transesterification.....	17
c. Biodiesel fuel properties.....	19
6. Full-scale <i>PBRs</i>.....	21
a. Current <i>PBR</i> designs.....	21
7. Algae cultivation systems.....	22
a. Raceway ponds.....	22
b. Photobioreactors.....	24
8. Current technological option of microalgae feedstock production.....	27
9. Main pros and cons of <i>PBRs</i>.....	27
10. Lab-scale <i>PBRs</i>.....	29
a. Design of <i>PBRs</i>	29
b. Experimental set-up for microalgae growth under various CO ₂ partial pressures.....	30
11. Process of microalgal biodiesel production.....	31
a. Biodiesel Production.....	31
b. Harvesting of algal biomass.....	33
12. Microalgae biodiesel value chain stages.....	35
a. Algal biodiesel production system.....	35
13. Bioengineering aspects.....	36
a. Biosynthesis of lipid in microalgae.....	36
b. Cell disruption.....	39
c. Biomass and lipid productivities of <i>Desmodesmus sp. F2</i> in semi-continuous cultivations.....	40
14. Life Cycle Analysis.....	42
15. Applications of microalgae.....	44
a. Biofuel production.....	44

b. Climate protection: greenhouse gas mitigation and algal biomass production for biofuel.....	45
c. Growth and lipid accumulation properties.....	45
d. Biodiesel specifications.....	46
e. Lipid content and lipid productivity.....	46
f. Conversion of microalgal biomass to biofuels.....	48
g. Preparation of organic fertilizer.....	48
h. Metal ions concentrations.....	49
i. The amounts of fatty acid methyl ester (<i>FAME</i>) in some isolates.....	49
j. Production process conditions.....	50
k. Prices of fossil fuels and microalgae fuels.....	51
l. <i>LCA</i> framework.....	51
m. Modeling photosynthesis in well-mixed dense cultures.....	52
n. Biogas production from algae.....	53
16. Biodiesel production using flue gases.....	54
17. Recent advancements.....	55
MATERIAL AND METHODS.....	59
1. Experimental setup.....	59
a. Design of <i>PBRs</i>	59
b. Photobiostimulation.....	61
c. Microalgae and culture media.....	63
2. Experimental design.....	64
a. Preliminary experiment.....	64
b. Main experiment.....	64
3. Measurements.....	68
a. Light intensity.....	68
4. Calculations.....	68
a. Growth rate.....	68
5. Analytical methods for main experiment.....	68
a. Oil extraction.....	69
b. peroxide value.....	69
c. Acid value.....	69
d. Transesterification.....	69
6. Statistical analysis.....	69
a. Preliminary experiment.....	70
b. Main experiment.....	70

RESULTS AND DISCUSSION	71
1. Results	71
a. Preliminary results of microalgal irradiation.....	71
b. Main experiment results.....	74
c. Growth rate.....	76
d. Analytical methods for main experiment.....	78
e. Statistical analysis.....	81
f. Energy balance assessment and costs analysis.....	96
2. Discussion	98
a. Photobiostimulation.....	98
SUMMARY	103
RECOMMENDATIONS	106
REFERENCES	107
ARABIC SUMMARY	i

LIST OF TABLES

No.	Title	Page
1	Oil yield of microalgae compared with different crops.....	3
2	Production process conditions.....	14
3	Total lipid properties of <i>Botryococcus</i>	17
4	Fatty acid profile of <i>Botryococcus</i> biodiesel.....	18
5	Main pros and cons of tubular, column and flat plate <i>PBRs</i>	28
6	Comparison of biomass level, lipid content and lipid productivity of <i>Desmodesmus</i> sp. F2 with those of other microalgal species reported in the literature.....	41
7	Biodiesel specifications for various countries.....	47
8	Characteristics of organic fertilizer medium.....	49
9	Production process conditions.....	50
10	Prices and heating values of fossil fuels and microalgae fuels.....	51
11	Specifications of <i>LED</i>	62
12	Specifications of Helium-Neon lasers.....	63
13	<i>DW</i> of microalgal biomass after irradiation of microalgae using <i>LEDs</i> for two hours.....	71
14	Mean performance of microalgal biomass weight influenced by different irradiation with monochromatic <i>LEDs</i> sources for two hours.....	73
15	Weights of microalgal Biomass after irradiation by <i>LEDs</i>	74
16	Weights of microalgal biomass after irradiation by red <i>LED</i> and red laser.....	76
17	Growth rate of microalgae after irradiation using <i>LEDs</i> and He-Ne laser.....	77
18	Total lipid extracted from microalgae biomass.....	78
19	Physicochemical properties of microalgae oil.....	79
20	The yield of biodiesel production.....	80
21	Descriptive statistics and Fisher test results for <i>DW</i> of biomass.....	85
22	Descriptive statistics and Fisher test results for total lipid (g L ⁻¹)	88

23	Descriptive statistics and Fisher test results for yield of biodiesel (g).....	91
24	Descriptive statistics and Fisher test results for peroxide value.....	93
25	Descriptive statistics and Fisher test results for acid value.....	95
26	Energy balance assessment and cost analysis for an algal biodiesel production plant of 1 ha that cultivates 235 m ³ of algae per year.....	97