

**DESALINATION OF CRUDE GLYCEROL OBTAINED FROM BIODIESEL  
PRODUCTION BY ELECTRODEIONIZATION**

Danupol Ngamsitthisak

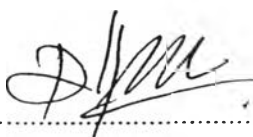
A Thesis Submitted in Partial Fulfilment of the Requirements  
for the Degree of Master of Science  
The Petroleum and Petrochemical College, Chulalongkorn University  
in Academic Partnership with  
The University of Michigan, The University of Oklahoma,  
Case Western Reserve University, and Institut Français du Pétrole  
2014

128369725

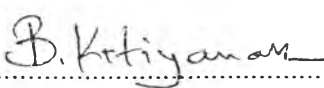
**Thesis Title:** Desalination of Crude Glycerol Obtained from Biodiesel  
Production by Electrodeionization  
**By:** Danupol Ngamsitthisak  
**Program:** Petroleum Technology  
**Thesis Advisors:** Asst. Prof. Boonyarach Kitiyanan  
Prof. Robert M. Ziff

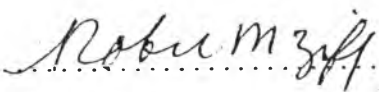
---

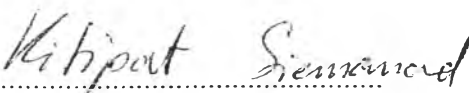
Accepted by The Petroleum and Petrochemical College, Chulalongkorn  
University, in partial fulfilment of the requirements for the Degree of Master of  
Science.


  
..... College Dean  
(Asst. Prof. Pomthong Malakul)

**Thesis Committee:**

  
.....  
(Asst. Prof. Boonyarach Kitiyanan)

  
.....  
(Prof. Robert M. Ziff)

  
.....  
(Asst. Prof. Kitipat Siemanond)

  
.....  
(Asst. Prof. Pailin Ngaotranwiwat)

## ABSTRACT

5573005063: Petroleum Technology Program

Danupol Ngamsitthisak: Desalination of Crude Glycerol Obtained from Biodiesel Production by Electrodeionization.

Thesis Advisors: Asst. Prof. Boonyarach Kitiyanan, and Prof. Robert M. Ziff 47 pp.

Keywords: Desalination/ Electrodeionization/ Glycerol purification

Crude glycerol, which is a by-product from transesterification of vegetable oil in biodiesel production was first filtered through ultrafiltration filters to remove any particles, organic impurities, or matter organic non-glycerol (MONG). Subsequently, the crude glycerol was fed to an electrodeionization (EDI) module that used a combination of electricity and ion-exchange resin for desalination in order to prevent reboiler fouling and reduce the energy requirement of glycerol purification by distillation. Furthermore, the effect of water content on inorganic salts removal and power consumption of EDI were studied. The salt removal capability was proportional to the water content, and EDI energy efficiency was significantly increased when the salt concentration decreased. Moreover, the water content also affected the dissolution of organic impurities, which favorably affected the removal of these impurities by the ultrafiltration membrane. All experiments were carried out at room temperature.

## บทคัดย่อ

คุณูปการนามสิทธิศักดิ์ : การลดปริมาณเกลือในกลีเซอรอลที่ได้จากกระบวนการผลิต ไบโอดีเซลโดยวิธีอิเล็กโทรดีไอออไนเซชัน (Desalination of Crude Glycerol Obtained from Biodiesel Production by Electrodeionization) อ. ที่ปรึกษา : ผศ. ดร. บุญยรัชต์ กิตยานันท์ และ Prof. Robert M. Ziff 47 หน้า

กลีเซอรอลซึ่งเป็นผลพลอยได้จากปฏิกิริยาทรานส์เอสเทอร์ฟิเคชันของน้ำมันพืชในกระบวนการผลิตไบโอดีเซล การทดลองทั้งหมดกระทำที่อุณหภูมิห้อง โดยขั้นตอนแรกจะถูกกรองด้วยไส้กรองอัลตราฟิวเตรชันเพื่อกำจัดอนุภาคและสารอินทรีย์เจือปนต่าง ๆ หรือ สารอินทรีย์ จากนั้นกลีเซอรอลจะถูกป้อนเข้าสู่เครื่องอิเล็กโทรดีไอออไนเซชัน (อีดีไอ) ที่อาศัยการผสมการทำงานของสนามไฟฟ้าและเรซิน แลกเปลี่ยนไอออนสำหรับการขจัดเกลือออกจากสารละลาย เพื่อที่จะป้องกันการเกิดตะกรันในรีบอยเลอร์และลดพลังงานที่ต้องใช้เพื่อทำกลีเซอรอลบริสุทธิ์ของหอกลับ นอกจากนี้ ยังได้ทำการศึกษาผลกระทบของปริมาณน้ำในกลีเซอรอลต่อความสามารถในการขจัดเกลือและการใช้พลังงานของเครื่องอีดีไอ พบว่า ปริมาณเกลือที่สามารถขจัดได้แปรผันตรงกับปริมาณน้ำ และประสิทธิภาพเชิงพลังงานของเครื่องอีดีไอสูงขึ้นอย่างมีนัยสำคัญเมื่อความเข้มข้นของเกลือลดลง อีกทั้งปริมาณน้ำในกลีเซอรอลที่เพิ่มขึ้นยังส่งผลต่อความสามารถในการละลายของสิ่งเจือปนอินทรีย์ ซึ่งส่งผลต่อการกรองด้วยไส้กรองอัลตราฟิวเตรชันอีกด้วย

## ACKNOWLEDGEMENTS

This thesis work is funded by The Petroleum and Petrochemical College, and by The Center of Excellence on Petrochemical and Materials Technology, Thailand.

It was impossible that this thesis would have been succeeded without assistance of various people. So, I would like to express my appreciation and grateful thanks to all those who gave me the possibility to complete this thesis

First of all, I would like to sincerely thank my advisor, Asst. Prof. Boonyarach Kitiyanan for giving me the suggestions, recommendations, assistance, encouragement and a great opportunity to do this challenging thesis, this work would have been impossible to accomplish without his support.

I would like to thank the Thai Oleochemicals's staff for provide me the crude glycerol, necessary instruments, lab test and residential support along the experiment.

I would also like to express my appreciation to Asst. Prof. Kitipat Siemanond and Asst. Prof. Pailin Ngaotrakanwiwat for being my thesis committee.

Finally, I would like to thank to my family for their love and encouragement, and parents for residential and financial support me throughout my whole study.

## TABLE OF CONTENTS

	<b>PAGE</b>
Title Page	i
Abstract (in English)	iii
Abstract (in Thai)	iv
Acknowledgements	v
Table of Contents	vi
List of Tables	viii
List of Figures	ix
 <b>CHAPTER</b>	
<b>I INTRODUCTION</b>	<b>1</b>
<b>II LITERATURE REVIEW</b>	<b>3</b>
2.1 Glycerol	3
2.2 Ultrafiltration	4
2.3 Desalination Technologies	5
2.3.1 Distillation	5
2.3.2 Reverse Osmosis	6
2.3.3 Ion Exchange Resin	8
2.3.4 Electrodialysis	11
2.3.5 Electrodeionization	14
2.4 The Transport Number and Membrane Permselectivity	16
<b>III EXPERIMENTAL</b>	<b>18</b>
3.1 Chemical	18
3.2 Apparatus	18
3.3 Methodology	20
3.4 Measurement	22

<b>CHAPTER</b>	<b>PAGE</b>
3.5 Simulation	22
3.5.1 EDI Simulation	23
3.5.2 Distillation Simulation	24
<b>IV RESULTS AND DISCUSSION</b>	<b>25</b>
4.1 Ultrafiltration Performance	25
4.2 Electrodeionization Performance	27
4.2.1 Salt Distribution in Each Stream in Different Water Content	27
4.2.2 Effect of Salt Concentration to the %Desalination of Glycerol Solution	28
4.2.3 Effect of Water Concentration to the Salt Removal	29
4.2.4 Effect of Water Concentration to the Power Consumption	30
4.3 Economic Evaluation	32
<b>V CONCLUSIONS AND RECOMMENDATIONS</b>	<b>33</b>
<b>REFERENCES</b>	<b>34</b>
<b>APPENDICES</b>	<b>36</b>
<b>Appendix A</b> Experimental Data and Salt Ions Balance in Each Stream	36
<b>Appendix B</b> Simulation Data of Distillation Treatment	38
<b>Appendix C</b> Simulation Data of EDI Treatment	41
<b>CURRICULUM VITAE</b>	<b>47</b>

## LIST OF TABLES

<b>TABLE</b>	<b>PAGE</b>	
4.1	Turbidity value of each sample	26
4.2	Salt removal after 5 cycles, total power consumption and calculated power consumption to achieve 10000ppm salt removal with EDI in different water concentration	31
4.3	The energy cost comparison between the conventional distillation and EDI	32
A1	Experimental data at 30% water concentration	36
A2	Experimental data at 40% water concentration	36
A3	Experimental data at 50% water concentration	36
A4	Experimental data at 60% water concentration	37
A5	Experimental data at 70% water concentration	37
A6	Experimental data of turbidity	37
B1	Simulation data of water removal unit	38
B2	Simulation data of water removal unit (cont.)	39
B3	Simulation data of glycerol purification unit	40
B4	Simulation data of glycerol purification unit (cont.)	41
C1	Simulation data of water removal unit 1	42
C2	Simulation data of water removal unit 1 (cont.)	43
C3	Simulation data of glycerol purification unit	43
C4	Simulation data of glycerol purification unit (cont.)	44
C5	Simulation data of water removal unit 2	45
C6	Simulation data of water removal unit 2	46



## LIST OF FIGURES

FIGURE	PAGE
2.1 Glycerol produced from hydrolysis of triglycerides.	3
2.2 Glycerol from biodiesel production via transesterification.	4
2.3 Comparison of each membrane separation capability.	5
2.4 Diagram of a typical industrial distillation tower.	6
2.5 Reverse osmosis process.	7
2.6 Expanded view of polystyrene bead.	9
2.7 Ion exchange resin principle.	10
2.8 Electrodialysis diagram.	11
2.9 Electrodeionization module.	15
3.1 Schematic diagram of the EDI process.	18
3.2 The drawing of EDI support aluminium frame.	19
3.3 Procedure flow diagram.	21
3.4 Apparatus set-up and EDI module.	21
3.5 Process flow diagram of glycerol purification by EDI	23
3.6 Process flow diagram of glycerol purification by conventional distillation	24
4.1 Appearance comparison in each state; (1) Crude glycerol, (2) Crude glycerol diluted to 70% of water, (3) Crude glycerol after treated by UF, (4) Deionized water for reference.	25
4.2 The conductivity changes of each stream in different water content.	27
4.3 Effect of salt concentration to the %desalination in 50% water concentration at the current of 1.6A.	28
4.4 The mechanism of ion exchange of the membrane in the EDI module.	29

<b>FIGURE</b>		<b>PAGE</b>
4.5	Change of the conductivity along the experiment of different water concentration.	29
4.6	Comparison of power consumption to the turbidity at different water concentration.	30