

TABLE OF CONTENTS

TITLE PAGE	i
APPROVAL PAGE	ii
PLAGIARISM FREE STATEMENT	iii
DEDICATION PAGE	iv
PREFACE	v
TABLE OF CONTENTS	vi
LIST OF FIGURES	viii
LIST OF TABLES	xii
LIST OF ABBREVIATIONS	xiv
LIST OF PUBLICATIONS	xv
SUMMARY	xvi
INTISARI	xviii
CHAPTER I INTRODUCTION	1
I.1 Background	1
I.2 Problem Formulation	3
I.3 Research Objectives	3
I.4 Research Benefits	4
I.5 Research Novelty	4
I.5.1 Characteristics of the developed catalyst material	6
I.5.2 Features of the catalyst types investigated	6
I.5.3 Principles of Green Chemistry	7
CHAPTER II LITERATURE REVIEW AND HYPOTHESIS FORMULATION	8
II.1 Literature Review	8
II.1.1 Biodiesel	8
II.1.2 Ethyl levulinate	9
II.1.3 Esterification of levulinic acid	10
II.1.4 Catalyst for the esterification reaction to form ethyl levulinate	12
II.1.5 Base catalysts	13
II.1.6 Magnetite (Fe ₃ O ₄)	15
II.1.7 Chitosan	18
II.1.8 Quaternary ammonium salts	20
II.1.9 Basic catalyst properties	24
II.1.10 Kinetics Study	26
II.2 Hypothesis Formulation	28
II.2.1 Hypothesis I	28
II.2.2 Hypothesis II	30
II.2.3 Hypothesis III	32
II.2.4 Hypothesis IV	33
II.2.4 Hypothesis V	34
II.2.5 Research design	35
CHAPTER III RESEARCH METHODOLOGY	40

III.1 Material and Instruments	40
III.1.1 Materials	40
III.1.2 Instruments	41
III.2 Research Procedures	41
III.2.1 Extraction of magnetic material (MM) from iron sand	41
III.2.2 Preparation of MM/chitosan	42
III.2.3 Preparation of MM/chitosan with GTMAC or BDMAC	42
III.2.4 Substitution of Cl^- in MM/Chi/GTMAC with F^- , Br^- , I^- , and OH^-	43
III.2.5 Characterization of precursors and prepared materials	43
III.2.6 Catalytic performance test of AL and EtOH esterification	44
III.2.7 Catalyst reusability test	46
CHAPTER IV RESULT AND DISCUSSION	47
IV.1 Extraction and Characterization of Magnetic Material (MM)	47
IV.2 Preparation and Characterization of MM/Chi/GTMAC	51
IV.3 Determination of Optimum Composition of MM/Chi/GTMAC	70
IV.4 Preparation and Characterization of MM/Chi/BDMAC	70
IV.5 Substitution of Cl^- in MM/Chi/GTMAC with F^- , Br^- , I^- , and OH^- and Their Characterization Results	79
IV.6 The Application of Materials as Catalysts for Esterification of LA and EtOH into EL	91
IV.6.1 Catalytic test of H_2SO_4 as homogeneous catalyst	92
IV.6.2 Catalytic test of GTMAC and BDMAC as homogeneous catalyst	93
IV.6.3 Catalytic activity test of MM/Chi/GTMAC	97
IV.6.4 Catalytic activity test of MM/Chi/BDMAC	103
IV.6.5 Catalytic activity test of MM/Chi/GTMAC substituted with F^- , Br^- , I^- , and OH^- anions	106
IV.7 The result of the catalyst reusability test	111
IV.7.1 Reusability test of MM/Chi/GTMAC	111
IV.7.2 Reusability test of MM/Chi/BDMAC	112
IV.7.3 Reusability test of MM/Chi/GTMAC catalyst substituted with F^- , Br^- , I^- , and OH^- anions	113
IV.8 Comparison of the Performance of the Catalysts Studied	114
CHAPTER V CONCLUSION AND SUGGESTION	117
VI.1 Conclusion	117
VI.2 Suggestion	118
REFERENCES	119
APPENDIX	135