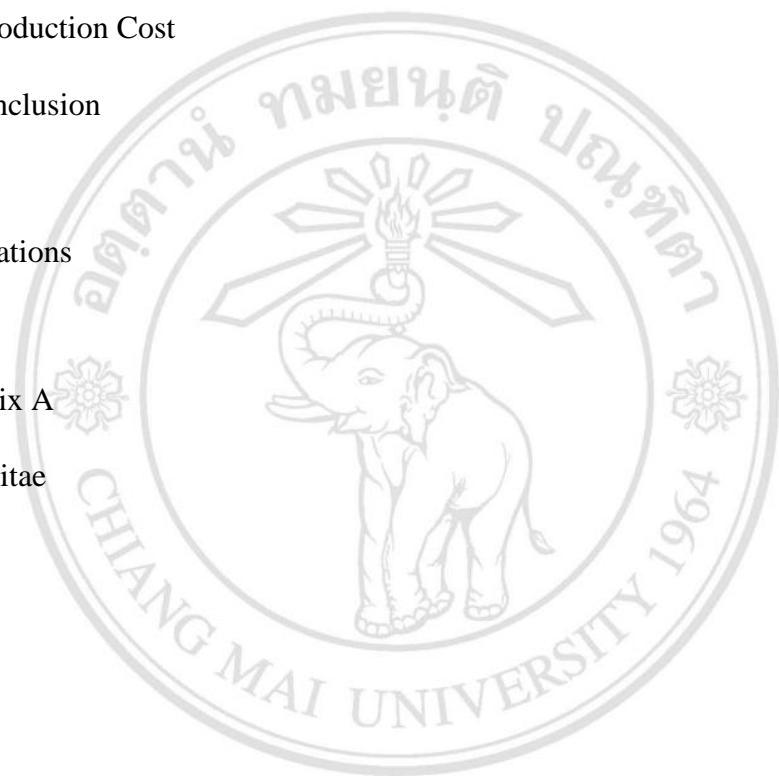


# CONTENTS

	Page
Acknowledgement	c
Abstract in Thai	d
Abstract in English	f
List of Tables	j
List of Figures	k
List of Abbreviations	m
Chapter 1 Introduction	1
1.1 Statement and Significance of the Problems	1
1.2 Objectives	2
1.3 Scope and Study	3
Chapter 2 Literature Reviews	4
2.1 Coffee and By-products of Coffee Industry	4
2.2 Pectin	8
2.3 Chlorogenic Acids	11
2.4 Carboxymethyl Cellulose	13
2.5 Chitosan	15
2.6 Bioplastics	16
2.7 Fresh Cut Carrot	19
Chapter 3 Research Design and Methods	21
3.1 Materials and Instruments	21
3.2 Process of Making Coffee Pulp Bioplastic	26
3.3 Research Design	30
3.4 Methods of Analysis	38

Chapter 4 Results and Discussion	52
4.1 Process Optimization for Pectin and Chlorogenic Acid Extraction	52
4.2 Process Optimization for CMC Synthesis	61
4.3 Optimization of Film Formulation	64
4.4 Film Studies	71
4.5 Coffee Pulp Bioplastic Active Properties	78
4.6 Production Cost	87
Chapter 5 Conclusion	88
References	91
List of Publications	105
Appendix	106
Appendix A	106
Curriculum Vitae	110



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
 Copyright© by Chiang Mai University  
 All rights reserved

## LIST OF TABLES

	Page
Table 2.1 Amount of by-products from coffee bean production	7
Table 2.2 Chemical composition of coffee by-products	7
Table 2.3 Optimal conditions for pectin extraction	10
Table 2.4 Optimum methods and conditions for chlorogenic acid extraction by water	12
Table 3.1 Experimental design for pectin and chlorogenic acid extraction	31
Table 3.2 Experimental design for CMC synthesis	33
Table 3.3 Product formulations in mixture design	34
Table 3.4 Composition of synthetic waste used for biodegradability testing	50
Table 4.1 Experimental results of pectin and chlorogenic acid extraction in different conditions	52
Table 4.2 Mathematical models of responses from pectin and chlorogenic acid extraction	53
Table 4.3 Experimental results of CMC synthesis in different NaOH concentration	61
Table 4.4 Mathematical models of responses from CMC synthesis	61
Table 4.5 Experiment results of various film formulations	64
Table 4.6 Mathematical models of responses from film formulation	65
Table 4.7 Corrected final film formulation	71
Table 4.8 Comparison between coffee pulp film with and without polyelectrolyte complex structure	72
Table 4.9 Biodegradability of coffee pulp bioplastic	81
Table 4.10 Weight loss and total plate count of fresh cut carrot with different packaging during 8 days of storage	82
Table 4.11 Color (L*a*b*) of fresh cut carrot with different packaging during 8 days of storage	82
Table 4.12 Production cost of a 14 x 22 cm <sup>2</sup> sheet of coffee pulp film (4.99 ± 0.15 g)	87

## LIST OF FIGURES

	Page
Figure 2.1 Constitution of coffee berry	5
Figure 2.2 Chemical structure of poly-D-galacturonic acid esterified with methoxyl group	9
Figure 2.3 Chemical structures of chlorogenic acids	11
Figure 2.4 Chemical structure of CMC	14
Figure 2.5 Polyelectrolyte complex structure	18
Figure 3.1 Process of making coffee pulp bioplastic	28
Figure 3.2 Standard curve of chlorogenic acid	40
Figure 3.3 Standard curve of total phenolic compounds in term of gallic acid equivalent	41
Figure 3.4 Standard curve antioxidant activity in term of gallic acid equivalent	47
Figure 4.1 Effect of extraction parameters on pectin yield (%): Effect of acid concentration and temperature (left); Effect of time and temperature (right)	54
Figure 4.2 Effect of extraction parameters on pectin DE (%): Effect of acid concentration and temperature (left); Effect of acid concentration and time (right)	56
Figure 4.3 Effect of extraction parameter on chlorogenic acid content (mg/100 mL): Effect of acid concentration and temperature (left); Effect of acid concentration and time (right)	57
Figure 4.4 Effect of extraction parameter on total phenolic compounds (mg gallic acid equivalent/mL): Effect of acid concentration and temperature (left); Effect of acid concentration and time (right)	59
Figure 4.5 Graphical optimization of extraction condition (× = optimum point)	60
Figure 4.6 Effect of NaOH concentrations on CMC yield	62

Figure 4.7	Effect of NaOH concentrations on DS	63
Figure 4.8	Desirability plot against various NaOH concentrations	64
Figure 4.9	Effect of film formulation on elongation at break	66
Figure 4.10	Effect of film formulation on tensile strength	68
Figure 4.11	Effect of film formulation on WVT ( $\text{g}\cdot\text{h}^{-1}\cdot\text{m}^2$ )	69
Figure 4.12	Graphical optimization of film formulation ( $\times$ = optimum point)	70
Figure 4.13	DSC thermograms of coffee pulps films	73
Figure 4.14	SEM micrographs of coffee pulp film without polyelectrolyte complex structure: Surface (top); Cross-section (bottom)	75
Figure 4.15	SEM micrographs of coffee pulp film surface with polyelectrolyte complex structure: 100x (top); 5,000x (bottom)	76
Figure 4.16	SEM micrographs of coffee pulp film crossed-sectioned with polyelectrolyte complex structure: 500x (top); 5,000x (bottom)	77
Figure 4.17	FT-IR spectrums of coffee pulp bioplastic	78
Figure 4.18	Antimicrobial property of coffee pulp bioplastic	80
Figure 4.19	Change in weight loss of fresh cut carrot with different packaging during 8 days of storage	83
Figure 4.20	Change in microbial load (total plate count) of fresh cut carrot with different packaging during 8 days of storage	84
Figure 4.21	Change in color of fresh cut carrot with different packaging during 8 days of storage: $L^*$ (top); $a^*$ and $b^*$ (bottom)	86
Figure A-1	Coffee pulp extract (left) and solid residue (right)	107
Figure A-2	Cellulose fiber (left) and CMC (right)	107
Figure A-3	Coffee pulp film during drying process (left) and final formulation of coffee pulp film (right)	108
Figure A-4	Biodegradability testing: Coffee pulp film (left); Control (right)	108
Figure A-5	Shelf life testing of fresh cut carrot: Coffee pulp film (left); Conventional packaging; polyvinylchloride cling film (right)	109

## LIST OF ABBREVIATIONS

AOAC	Association of Analytical Communities
ASTM	American Society for Testing and Materials
ATR	Attenuated Total Reflectance
CMC	Carboxymethyl Cellulose
DE	Degree of Esterification
DS	Degree of Substitution
DSC	Differential Scanning Calorimetry
FT-IR	Fourier Transform Infrared Spectroscopy
HDPE	High Density Polyethylene
HMP	High Methoxyl Pectin
LMP	Low Methoxyl Pectin
RH	Relative Humidity
SEM	Scanning Electron Microscope
WVT	Water Vapor Transmission

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved