

LIST OF CONTENTS

	Page
Acknowledgement	iii
Abstract (in English)	iv
(in Thai)	vi
List of contents	viii
List of illustrations	xii
List of tables	xv
Abbreviations and symbols	xvi
Chapter 1 Introduction	1
Chapter 2 Literature review	
2.1 Environmental problems from dyestuffs	4
2.2 Dye classification	6
2.2.1 Azo dye class	6
2.2.2 Anthraquinone dye class	8
2.2.3 Indigoid dye class	9
2.2.4 Phthalocyanine dye class	9
2.2.5 Aryl methane dye class	11
2.3 Dye contaminated wastewater treatments	11
2.3.1 Physical treatments	11
2.3.2 Chemical treatments	13
2.3.3 Physicochemical treatments	13

LIST OF CONTENTS (CONTINUED)

	Page
2.3.4 Biological treatments	13
2.3.4.1 Conventional treatments	13
2.3.4.2 Candidate microorganisms	14
2.3.4.3 Enzymatic treatments	14
2.3.5 Disadvantages	14
2.3.6 Alternative methods	15
2.4 White rot fungi	15
2.4.1 Characteristics and Ecology	16
2.4.2 Application in bioremediation	16
2.4.3 <i>Coriolus versicolor</i>	18
2.5 Ligninolytic enzymes	20
2.5.1 Laccase	20
2.5.2 Manganese peroxidase	21
2.5.3 Lignin peroxidase	24
2.5.4 Redox mediators	24
2.5.5 Manganese independent peroxidase	26
2.5.6 Associated enzymes	28
2.5.7 Applications	28
2.6 Decolorization by white rot fungi	28
2.6.1 Decolorization of dark effluents	28
2.6.2 Dye decolorization	31
2.6.3 Dye decolorization mechanisms	33
2.6.3.1 Biodegradation	33
2.6.3.2 Biosorption	34
2.7 Immobilized fungal bioreactor	37
2.7.1 Cell immobilization	37
2.7.2 Immobilized cell bioreactor	39
2.7.3 Packed bed bioreactor	39

LIST OF CONTENTS (CONTINUED)

	Page
2.8 Related research	41
 Chapter 3 Materials and Methods	
3.1 Materials and chemical reagents	43
3.1.1 Media and chemical reagents	43
3.1.2 Equipment	44
3.2 Methods	45
3.2.1 Batch decolorization	45
3.2.1.1 Effect of ammonium sources on dye decolorization	45
3.2.1.2 Effect of glucose concentration on dye decolorization	46
3.2.1.3 Effect of nitrogen concentration on dye decolorization	46
3.2.1.4 Effect of initial pH on dye decolorization	46
3.2.1.5 Effect of ambient temperature on dye decolorization	46
3.2.1.6 Monitoring of ligninolytic enzymes production during dye decolorization	47
3.2.2 Cell immobilization	48
3.2.2.1 Effect of polyurethane foam volume and incubation time on cell immobilization	48
3.2.2.2 Packed bed bioreactor design and configuration	48
3.2.3 Continuous decolorization	51
3.2.3.1 Warming-up time of bioreactor	51
3.2.3.2 Effect of hydraulic retention times on dye decolorization	51
3.2.3.3 Effect of polyurethane foam sizes on dye decolorization	51
3.2.3.4 Effect of dye concentration on dye decolorization	53
3.2.4 Decolorization of Batik wastewater	53

LIST OF CONTENTS (CONTINUED)

	Page
Chapter 4 Results and Discussion	
4.1 Effect of ammonium sources on dye decolorization	55
4.2 Effect of glucose concentration on dye decolorization	57
4.3 Effect of nitrogen concentration on dye decolorization	60
4.4 Effect of initial pH on dye decolorization	61
4.5 Effect of ambient temperature on dye decolorization	65
4.6 Monitoring of ligninolytic enzymes production during dye decolorization	67
4.7 Effect of polyurethane foam volume and incubation time on cell immobilization	69
4.8 Packed bed bioreactor design and configuration	71
4.9 Warming-up time of bioreactor	72
4.10 Effect of hydraulic retention times on dye decolorization	72
4.11 Effect of polyurethane foam sizes on dye decolorization	74
4.12 Effect of dye concentration on dye decolorization	80
4.13 Decolorization of Batik wastewater	83
Chapter 5 Conclusions	86
References	88
Appendixes	
Appendix A: Media	95
Appendix B: Ligninolytic enzymes assay	97
Appendix C: Standard curve of Orange II concentration	100
Appendix D: Morphology of <i>C. versicolor</i>	102
Appendix E: Some scene review of the experiments	103
Curriculum vitae	110

LIST OF ILLUSTRATIONS

	Page
Figure 2.1 Structure of benzidine, one member of aromatic amines	5
Figure 2.2 Structure of azo dyes	7
Figure 2.3 Structure of anthraquinone dyes	8
Figure 2.4 Structure of indigoid dyes	9
Figure 2.5 Structure of phthalocyanine dyes	10
Figure 2.6 Structure of arymethane dyes	12
Figure 2.7 White area of wood degraded by white rot fungi (<i>Coriolus versicolor</i>)	16
Figure 2.8 Catalytic cycle of laccase	23
Figure 2.9 Catalytic cycle of manganese peroxidases	23
Figure 2.10 Catalytic cycle of lignin peroxidases	24
Figure 2.11 3-Hydroxyanthranilic acid	26
Figure 2.12 Possible pathway of azo dye degradation	35
Figure 2.13 Possible pathway of indigo dye degradation	36
Figure 2.14 Upward flow packed bed bioreactor	40
Figure 2.15 1,2-naphthoquinone	42
Figure 3.1 Polyurethane foam preparation	49
Figure 3.2 Variation of polyurethane foam in 50 ml malt extract broth	49
Figure 3.3 Packed bed bioreactor design and configuration	50
Figure 3.4 Polyurethane foam preparation in different sizes	52
Figure 4.1 Decolorization of Orange II from various ammonium salts	56
Figure 4.2 pH change during decolorization from various ammonium salts	57
Figure 4.3 Final biomass from various ammonium salts	58
Figure 4.4 Decolorization of Orange II from various glucose concentration	59
Figure 4.5 Final biomass from various glucose concentration	60
Figure 4.6 Decolorization of Orange II from various nitrogen concentration	62
Figure 4.7 Final biomass from various nitrogen concentration	63
Figure 4.8 Decolorization of Orange II from various initial pH	63

LIST OF ILLUSTRATIONS (CONTINUED)

	Page
Figure 4.9 pH change during decolorization from various initial pH	64
Figure 4.10 Final biomass from various initial pH	65
Figure 4.11 Decolorization of Orange II from various ambient temperature	66
Figure 4.12 Final biomass from various ambient temperature	67
Figure 4.13 Ligninolytic enzymes production during Orange II decolorization	68
Figure 4.14 Immobilization of RC3 strain on various mass (g) of polyurethane foam	70
Figure 4.15 Colonization of RC3 strain on various polyurethane foam volume	71
Figure 4.16 Packed bed bioreactor used in this study	71
Figure 4.17 Decolorization in warming-up period	73
Figure 4.18 Continuous decolorization from various hydraulic retention time	74
Figure 4.19 Comparison of bed density in packed bed bioreactor	75
Figure 4.20 Decolorization and laccase production from various sizes of polyurethane foam	77
Figure 4.21 Change of effluent pH from various sizes of polyurethane foam	78
Figure 4.22 Continuous decolorization from various dye concentration	81
Figure 4.23 Laccase production from various dye concentration	81
Figure 4.24 Absolute dye removal from various dye concentration	82
Figure 4.25 Change of effluent pH from various dye concentration	82
Figure 4.26 Decolorization curve of Batik wastewater	83
Figure 4.27 Decolorization feature of Batik wastewater	84
Figure 6.1 Oxidative transformation of DMP	99
Figure 6.2 Oxidative transformation of veratryl alcohol	99
Figure 6.3 Standard curve of Orange II concentration	101
Figure 6.4 Morphology of <i>Coriolus versicolor</i>	102
Figure 6.5 Morphology of <i>Coriolus versicolor</i> RC3	102

LIST OF ILLUSTRATIONS (CONTINUED)

	Page
Figure 6.6 Batch decolorization study in effect of nitrogen concentration, each flasks showed a different decolorization rate	103
Figure 6.7 Preliminary study of continuous decolorization using packed bed bioreactor, a good decolorization efficiency could be achieved in room temperature	103
Figure 6.8 Color comparison between influent, 98% decolorization effluent and pure water from left to right	104
Figure 6.9 Foam in foam trapping column generated large amount in initial period of cultivation from protein rich broth remaining in immobilized polyurethane foam, the foam would be decreased and stabilized when continuous running time was increased	104
Figure 6.10 Immobilized RC3 strain on various size of PUF	105
Figure 6.11 Development in the reactor packed with 1.5 cm ³ PUF	106
Figure 6.12 Clogging pattern of 1 cm ³ PUF, packed PUF layer was lifted by applied air	107
Figure 6.13 Clogging pattern of 1.5 cm ³ PUF, glass bead layer was lifted by applied air	107
Figure 6.14 Clogging pattern of 2 cm ³ PUF, effluent port of the reactor was clogged by the mycelium as in red circle	108
Figure 6.15 High cell density obtained almost 2 weeks of cultivation, they could be put out from the reactor in stable shape	108
Figure 6.16 Comparison of color intensity of Orange II between 0, 20, 50 and 100 ppm from left to right	109
Figure 6.17 Textile wastewater from Batik industry in stabilization pond	109

LIST OF TABLES

	Page
Table 2.1 List of specified toxic and carcinogenic aromatic amines	5
Table 2.2 Environmental pollutants degraded by white rot fungi	17
Table 2.3 White rot fungi used in biodegradation or decolorization studies	19
Table 2.4 Various ligninolytic enzymes secreted by white rot fungi	22
Table 2.5 Some native and synthetic mediators in ligninolytic enzyme systems	27
Table 2.6 Potential application of ligninolytic enzymes	29
Table 2.7 Decolorization in various effluents by white rot fungi and their enzymes	30
Table 2.8 Dye decolorization by white rot fungi and their enzymes	31
Table 2.9 Porous materials used in cell immobilization	38
Table 3.1 Reaction mixtures of ligninolytic enzymes assay (μl)	47
Table 3.2 Flow parameters used in packed bed bioreactor	52
Table 3.3 Size and amount of polyurethane foam used in this experiment	52
Table 3.4 Dye loading rate in various dye concentration	53
Table 3.5 Treatments used in Batik wastewater decolorization study	54
Table 4.1 Comparison of treating efficiency in various HRT	74
Table 4.2 Comparison of efficiency in three different size of PUF	79
Table 6.1 Difference of medium composition used in each experiments	96
Table 6.2 Absorbances at 483 nm in various Orange II concentration	100

ABBREVIATIONS AND SYMBOLS

%	Percentage
ABTS	2,2'-Azinobis(3-ethylbenzthiazoline-6-sulfonate)
°C	Degree Celsius
cm	Centimeter
DMP	2,6-Dimethoxyphenol
DMQ	2,6-Dimethoxyquinone
g	Gram
g/l	Gram per litre
g/l/d	Gram per litre per day
HAA	3-Hydroxyanthranilic acid
HBT	1-Hydroxybenzotriazole
hr	Hour
HRT	Hydraulic retention time
kg	Kilogram
kg/m ³	Kilogram per cubicmeter
μl	Microlitre
LiP	Lignin peroxidase
M	Molar
MA	Malt extract agar
MB	Malt extract broth
mg	Milligram
min	Minute
MIP	Manganese independent peroxidase
ml	Millilitre
ml/hr	Millilitre per hour
ml/l	Millilitre per litre
mm	Milimeter
mM	Milimolar
MnP	Manganese peroxidase

ABBREVIATIONS AND SYMBOLS (CONTINUED)

mU/ml	Milliunit per millilitre
N	Normal
nm	Nanometer
ppm	Part per million
PUF	Polyurethane foam
RC3	Rukkachat park no. 3
rpm	Round per minute
VA	Veratryl alcohol
vvm	Volume of air per volume of working per minute
w/v	Weight by volume

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved