UNIVERSITI PUTRA MALAYSIA

EFFECTS OF XYLANO-PECTINOLYTIC ENZYMES BY Bacillus subtilis ADI1 ON BIOBLEACHING OF KENAF (Hibiscus cannabinus L.) PULP

MUHAMMAD HARIADI NAWAWI

FBSB 2016 32

EFFECTS OF XYLANO-PECTINOLYTIC ENZYMES BY *Bacillus subtilis* ADI1 ON BIOBLEACHING OF KENAF (*Hibiscus cannabinus* L.) PULP

By

MUHAMMAD HARIADI NAWAWI

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

June 2016

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

EFFECTS OF XYLANO-PECTINOLYTIC ENZYMES BY *Bacillus subtilis* ADI1 ON BIOBLEACHING OF KENAF (*Hibiscus cannabinus* L.) PULP

By

MUHAMMAD HARIADI NAWAWI

June 2016

Chairman : Wan Zuhainis Saad, PhD
Faculty : Biotechnology and Biomolecular Sciences

Kenaf (*Hibiscus cannabinus*) is an annual non-wood plant which has shown great potential as an alternative source of papermaking fibre. In the pulp and paper industry, due to growing public concern about the environment, technological changes in the bleaching processes have been rising. The use of chemical additives during bleaching process to improve the brightness of paper causes the effluent to contain some chlorinated organic compounds that have shown mutagenic activity. The use of combined xylanase and pectinase in pulp bleaching may assist in enhancing the brightness of paper and could reduce harmful pectins produced in the effluent and thus rendering a more eco-friendly papermaking process as well as improvements in the paper quality. The aim of this research was to study the production of xylano-pectinolytic enzymes from a bacterial isolate *Bacillus subtilis* ADI1 and to examine the effectiveness of using xylano-pectinolytic enzymes on kenaf pulp in biobleaching. The characteristics of enzymes being sought in papermaking are higher production, higher optimal pH and temperature, good stabilities under these conditions and finally a low associated cellulase production. *Bacillus subtilis* ADI1, as the potentially high extracellular xylanase and pectinase producer, was isolated from composting and rotting area around UPM Serdang, Malaysia (Biorefinery Complex, UPM, Selangor). The effects of pH, temperature, inoculum concentration, agitation speed and concentration of rice bran on xylanase and pectinase production were studied. Optimum pH and temperature for xylano-pectinolytic enzymes production by *Bacillus subtilis* ADI1 was at pH 8 and 50°C. Highest xylanase and pectinase production was from 3% (v/v) inoculum concentration and agitation speed of 200 rpm. Maximum xylanase and pectinase production was obtained from 3% (w/v) of rice bran while higher and lower concentration of rice bran resulted in poor enzyme production. *Bacillus subtilis* ADI1 is an alkalophilic thermotolerant bacteria which under optimal cultural conditions, can produce 5.25 times more xylanase and 1.6 times more pectinase than prior to optimisation study (non-optimized condition). Meanwhile, the xylano-pectinolytic enzymes stabilities were studied at optimal pH and temperature for enzyme activities. Xylano-pectinolytic enzymes of *Bacillus subtilis* ADI1 resulted in the optimum

conditions of pH 8 and temperature 50°C. The enzymes showed considerable thermostability (stable up to 2 to 3 hours at 40°C) and pH stability (stable up to 3 hours at pH 8). Thus, xylano-pectinolytic enzymes of *Bacillus subtilis* ADI1 are suitable for application in biobleaching of pulp. Optimal enzymatic processes were studied, the xylanase-pectinase doses required in biobleaching pretreatment were 15 and 7.5 U/g of oven dried pulp, and the effective retention time needed for pretreatment was 180 min. The optimised enzymatic processes significantly improved the pulp properties and showed that the ISO brightness increased from 71.14% (untreated) to 84.18% (treated) and reduced the chlorine consumption by 15.5% reduction. In conclusion, xylano-pectinolytic enzymes from *Bacillus subtilis* ADI1 showed interesting biotechnological characteristics that are suitable for application in pulp and paper industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan Ijazah Sarjana Sains

KESAN ENZIM XYLANO-PEKTINOLITIK OLEH *Bacillus subtilis* ADI1 PADA BIOLUNTUR PULPA KENAF (*Hibiscus cannabinus* L.)

Oleh

MUHAMMAD HARIADI NAWAWI

Jun 2016

Pengerusi : Wan Zuhainis Saad, PhD
Fakulti : Bioteknologi dan Sains Biomolekular

Kenaf (*Hibiscus cannabinus*) merupakan tumbuhan bukan kayu tahunan yang telah menunjukkan potensi yang besar sebagai sumber alternatif gentian pembuatan kertas. Dalam industri pulpa dan kertas, timbul kebimbangan di kalangan orang ramai mengenai alam sekitar yang kini membawa kepada perubahan dan perkembangan teknologi dalam proses pelunturan. Penggunaan bahan kimia semasa proses pelunturan untuk meningkatkan kecerahan kertas menyebabkan efluen mengandungi beberapa sebatian organik berklorin yang telah menunjukkan aktiviti mutagen. Penggunaan kombinasi xylanase dan pektinase dalam pelunturan pulpa boleh membantu dalam meningkatkan kecerahan kertas dan boleh mengurangkan pektin-pektin berbahaya yang terhasil di dalam pengeluaran efluen dan dengan itu menjadikan proses pembuatan kertas menjadi lebih mesra alam dan meningkatkan kualiti pengeluaran kertas. Tujuan penyelidikan ini adalah untuk mengkaji pengeluaran enzim xylano-pektinolitik daripada isolat bakteria am *Bacillus subtilis* ADI1 dan untuk memeriksa keberkesanan bioluntur menggunakan enzim xylano-pektinolitik pada pulpa kenaf, kerana kenaf (*hibiscus cannabinus*) memainkan peranan utama dalam industri "hijau", dengan seratnya menghasilkan pulpa yang sangat baik membuatkan kilang kenaf menjadi terkemuka bagi industri kertas. Sifat-sifat enzim yang dicari dalam pembuatan kertas adalah: pengeluaran enzim yang lebih tinggi, pH dan suhu optima yang lebih tinggi, kestabilitian enzim yang baik di bawah syarat-syarat ini dan akhirnya pengeluaran selulase yang rendah. Oleh itu, enzim dari bakteria yang akan disasarkan dalam kajian ini. *Bacillus subtilis* ADI1 telah diasingkan sebagai xylanase luar sel yang berpotensi tinggi dan pengeluar pektinase yang dikumpul dari kawasan kompos dan reput di sekitar UPM Serdang, Malaysia (Kompleks kilang biopenapisan, UPM, Selangor), jelas mempunyai daya katabolit terhadap xylan dan pektin alam semula jadi. Kesan pH, suhu, kepekatan inokulum, kelajuan goncangan dan kepekatan dedak beras untuk xylanase dan pektinase untuk pengeluaran optimum telah dikaji. pH optimum untuk pengeluaran enzim xylano-pektinolitik oleh *Bacillus subtilis* ADI1 adalah pada pH 8 dan mencapai suhu optimum pada 50°C. Pengeluaran tertinggi xylanase dan pektinase berlaku pada kepekatan inokulum 3% (v/v) dan pengeluaran enzim tertinggi berlaku pada goncangan 200 rpm.

Perbezaan kepekatan dedak beras menunjukkan pengeluaran maksimum xylanase dan pektinase adalah pada 3% (w/v) manakala kepekatan yang lebih tinggi dan lebih rendah menyebabkan pengeluaran enzim berkurangan. *Bacillus subtilis* ADI1 adalah bakteria tahan haba alkalofilik yang di bawah keadaan optimum seperti yang dinyatakan sebelum ini, boleh menghasilkan 5.25 kali lebih xylanase dan 1.6 kali lebih pektinase daripada basal medium (bukan kondisi optimal). Sementara itu, kestabilan enzim xylano-pektinolitik turut dikaji dan merangkumi kesan suhu, pH dan juga kestabilan pada keadaan optimum. Enzim xylano-pektinolitik milik *Bacillus subtilis* ADI1 menghasilkan suhu yang tinggi dan nilai pH yang bersamaan dengan keadaan optimum untuk pH (pH 8) dan suhu (50°C). Enzim menunjukkan kestabilanthermo yang baik (stabil selama 2 hingga 3 jam pada suhu 40°C) dan kestabilan pH (selama 3 jam). Oleh itu, ini menjadikan enzim xylano-pektinolitik *Bacillus subtilis* ADI1 adalah sesuai untuk digunakan di dalam proses bio-luntur pulpa.. Proses enzim yang optimum telah dikaji menyebabkan dos xylanase-pektinase yang diperlukan dalam rawatan awal bioluntur adalah 15 dan 7.5 U/g pulpa kering ketuhar, dan masa tahanan yang berkesan diperlukan untuk rawatan awal adalah 180 min. Proses-proses enzim dioptimum bagi memberikan peningkatan yang ketara dalam sifat-sifat pulpa dan menunjukkan peningkatan kecerahan ISO dari 71.14% (tidak dirawat) kepada 84.18% (telah dirawat) dan menyebabkan kurang penggunaan klorin berkurangan sebanyak 15.5%. Oleh itu, *Bacillus subtilis* ADI1 dan enzim xylano-pektinolytik yang telah mempunyai sifat-sifat bioteknologi yang dikehendaki kelihatan sesuai untuk kegunaan industri pulpa dan kertas.

ACKNOWLEDGEMENT

The author wishes to express his deepest appreciation to all the people who have inspired, advised and assisted him during this study. Special recognition and sincere appreciation are extended to his supervisors; Dr. Wan Zuhainis Saad, Assoc. Prof Dr. Rosfarizan Mohamad, and Professor Dr. Paridah Md. Tahir, for their guidance, encouragement and constructive criticism throughout the study.

He would like to express his utmost thanks to the staff of the Mycology Laboratory in the Faculty of Biotechnology and Biomolecular Sciences; Laboratory in Pulp and Paper Technology in Faculty of Forestry and Institute of Tropical Forest and Forest Product (INTROP) 3; Microscopy Units, Institute of Biosciences, Universiti Putra Malaysia; Laboratory of Wood Chemistry Division of Forest Research Institute of Malaysia (FRIM), for their assistance in facilitating him and giving him full cooperation such as using laboratory facilities and equipment during his study.

He would also like to take this opportunity to thank his valuable coursemates and friends for their help, encouragement and comment. Finally and most importantly, he would like to thank his family members for their encouragement and continuous full support throughout the course of his study. All his achievements would not be possible without them.

I certify that a Thesis Examination Committee has met on 16 June 2016 to conduct the final examination of Muhammad Hariadi bin Mohd Nawawi on his thesis entitled "Effects of Xylano-Pectinolytic Enzymes by *Bacillus subtilis* ADI1 on Biobleaching of Kenaf (*Hibiscus cannabinus* L.) Pulp" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Janna Ong binti Abdullah, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Nor' Aini binti Abdul Rahman, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Internal Examiner)

Rosma Ahmad, PhD
Associate Professor
Universiti Sains Malaysia
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 August 2016

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Wan Zuhainis Binti Saad, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Rosfarizan Binti Mohamad, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Member)

Paridah Binti Md Tahir, PhD
Professor and Director
Institute of Tropical Forests and Forestry Products
Universiti Putra Malaysia
(Member)

_____
BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by Graduate Student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: Muhammad Hariadi bin Mohd Nawawi (GS 37235)

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature:	
Name of Chairman of Supervisory Committee:	Prof. Madya Dr. Wan Zuhanis Saad
Signature:	
Name of Member of Supervisory Committee:	Prof. Madya Dr. Rosfarizan Mohamad
Signature:	
Name of Member of Supervisory Committee:	Prof. Dr. Paridah Md. Tahir

TABLE OF CONTENTS

		Page
ABSTRACT		i
ABSTRAK		iii
ACKNOWLEDGEMENT		v
APPROVAL		vi
DECLARATION		viii
LIST OF TABLES		xiv
LIST OF FIGURES		xv
LIST OF ABBREVIATIONS		xvii
CHAPTER		
1	**INTRODUCTION**	1
2	**LITERATURE REVIEW**	3
2.1	Kenaf	4
2.1.1	History	4
2.1.2	Botanical Aspect on Kenaf	4
2.1.3	Physical Properties of Kenaf	4
2.1.4	Chemical Properties of Kenaf	5
2.1.4.1	Cellulose and its Composition in Kenaf	5
2.1.4.2	Xylan and its Composition in Kenaf	6
2.1.4.3	Pectin and its Composition in Kenaf	7
2.1.4.4	Lignin and its Composition in Kenaf	7
2.1.4.5	Extractives	8
2.2	Pulp And Paper Industry	8
2.2.1	Pulp and Paper Industry in Malaysia	9
2.3	Non-Wood As Raw Material For Pulp Paper	10
2.3.1	Fibre Morphology Non-Wood Plants in Papermaking	11
2.3.2	Kenaf in Papermaking	11
2.4	Biotechnology In Pulp & Paper Industry	12
2.4.1	Biobleaching in Pulp and Paper Industry	12
2.4.1.1	Xylanase & Its Performance in Bleaching	15
2.4.1.2	Pectinase & Its Performance in Bleaching	16
2.5	Enzymes Synthesis	18
2.5.1	Mode of Production for Enzymes Production	18
2.5.2	Rice Bran as Substrate for Enzymes Production	19

3 ISOLATION, SCREENING AND IDENTIFICATION OF XYLANO-PECTINOLYTIC BACTERIA FROM COMPOST 20
3.1 Introduction 20

3.2 Materials And Methods 20
3.2.1 Isolation of Bacteria from Compost Area 21
3.2.2 Primary Screening of Xylano-Pectinolytic Enzymes Producing Bacteria 21
3.2.3 Secondary Screening of Xylano-Pectinolytic Enzymes Producing Bacteria 21
3.2.4 Analytical Methods 22
3.2.4.1 Assays for Xylanase, Pectinase and Cellulase Enzymes 22
3.2.4.2 Determination of Soluble Protein 22
3.2.4.3 Determination of Reducing Sugar Content 22
3.2.5 Statistical Analysis 23
3.2.6 Microorganisms and Maintenance 23
3.2.7 Identification of Bacteria 23
3.2.7.1 Molecular Identification using 16S rDNA Sequencing 23

3.3 Results And Discussion 23
3.3.1 Isolation of Bacteria from Compost 23
3.3.2 Screening of Xylano-Pectinolytic Enzymes Producing Bacteria 25
3.3.3 Identification of Bacterial Culture using 16S rRNA Gene Sequence Analysis 30

3.4 Conclusions 31

4 OPTIMISATION OF CULTURAL CONDITIONS TO ENHANCE ENZYMES PRODUCTION AND PARTIAL CHARACTERISATION OF XYLANO-PECTINOLYTIC ENZYMES OF *BACILLUS SUBTILIS* ADI1 32
4.1 Introduction 32

4.2 Materials And Methods 33
4.2.1 The Selected Microorganism Used for Optimisation and Partial Characterisation Studies 33
4.2.2 Preparation of Culture Medium and Culture Cultivation for Optimisation and Partial Characterisation Studies 33
4.2.3 Production of Xylano-Pectinolytic Enzymes 33
4.2.4 Enzymes Assay for Xylanase, Pectinase and Cellulase Enzymes 34
4.2.5 Analytical Methods 34

4.2.6 Effect of Cultural Conditions on Xylanase and Pectinase Production by *Bacillus subtilis* ADI1 34
4.2.6.1 Effect of pH on Xylanase and Pectinase Production 34
4.2.6.2 Effect of Temperature on Xylanase and Pectinase Production 34
4.2.6.3 Effect of Inoculum Concentration on Xylanase and Pectinase Production 34
4.2.6.4 Effect of Agitation on Xylanase and Pectinase Production 35
4.2.6.5 Effect of Substrate Concentration on Xylanase and Pectinase Production 35
4.2.7 Partial Characterisation of Crude Xylano-Pectinolytic Enzymes 35
4.2.7.1 Effect of pH on Xylanase and Pectinase Activities and Stabilities 35
4.2.7.2 Effect of Temperature on Xylanase and Pectinase Activities and Stabilities 36
4.3 Results And Discussion 36
4.3.1 Effect of Cultural Conditions on Xylanase and Pectinase Production by *Bacillus subtilis* ADI1 36
4.3.1.1 Effect of pH on Xylanase and Pectinase Production 35
4.3.1.2 Effect of Temperature on Xylanase and Pectinase Production 38
4.3.1.3 Effect of Inoculum Concentration on Xylanase and Pectinase Production 39
4.3.1.4 Effect of Agitation on Xylanase and Pectinase Production 40
4.3.1.5 Effect of Substrate Concentrations on Xylanase and Pectinase Production 42
4.3.1.6 Comparison of Xylanase and Pectinase Production in the Optimised Cultural Conditions with Non-Optimised Conditions 43
4.3.2 Partial Characterisation of Crude Xylanases and Pectinases 44
4.3.2.1 Effect of Temperature on Activity and Stability of Crude Xylanase and Pectinase 44
4.3.2.2 Effect of pH on Activity and Stability of Crude Xylanase and Pectinase 47
4.4 Conclusion 50

5 EFFECT OF XYLANO-PECTINOLYTIC ENZYMES BY *BACILLUS SUBTILIS* ADI1 IN BIOBLEACHING ON KENAF PULP 51
5.1 Introduction 51

5.2 Material And Methods 52
5.2.1 Pulp Sample 52
5.2.2 Optimisation of Enzymatic Pretreatment Reaction Conditions 52
5.2.3 Evaluation of the Pulp-Free Filtrate and the Pulp Sample 52
5.2.4 Biobleaching and Chemical Bleaching of Kenaf Pulp 53
5.2.5 Analytical Studies of Physical Properties of Kenaf Pulp 53
5.2.6 Statistical Analysis 53

5.3 Results And Discussion 54
5.3.1 Optimisation of Enzymatic Pretreatment Processes 54
5.3.2 Biobleaching using Xylano-Pectinolytic Enzymes on Kenaf Pulp 56

5.4 Conclusion 57

6 GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS FOR FUTURE STUDIES 58
6.1 General Discussion 58
6.2 Conclusion 61
6.3 Recommendations For Further Studies 62

REFERENCES 63
APPENDICES 86
BIODATA OF STUDENT 94
PUBLICATION 95

LIST OF TABLES

Table		Page
3.1	Morphological characteristics of isolates	24
3.2	Primary screening of selected isolates on agar plate with clear zone diameter	26
3.3	Growth profile and enzymes production by EFB-11 from initial screening	28
5.1	Effect of different enzyme doses on pulp biobleaching	54
5.2	Effect of different retention time on pulp biobleaching	55
5.3	Physical properties of enzymatic pretreated kenaf pulp	56

LIST OF FIGURES

Figure		Page
2.1	a) Cell wall containing cellulose microfibrils, hemicellulose, pectin, lignin and soluble proteins. b) Cross section of cell wall. c) Layers of the cell wall	14
3.1	Colony morphology of EFB-11	24
3.2	Gram's stain of EFB-11 under light microscope	25
3.3	Zone of clearance around the well containing bacterial suspension on xylan agar	26
3.4	Phylogenetic tree of *Bacillus subtilis* ADI1 with other *Bacillus* sp.	30
4.1	Pattern of enzyme activity in basal medium with different pH values (pH 5 to 11). Enzymes activity was monitored after 72 hours	37
4.2	Pattern of pH change in basal media with different initial pH values (pH 5 – 11) during growth of *Bacillus subtilis* ADI1 at 72 hours	38
4.3	Effect of temperature on xylanase and pectinase production by *Bacillus subtilis* ADI1 after 72 hours	39
4.4	Effect of inoculum concentration on growth and xylanase and pectinase production after 72 hours	40
4.5	Effect of agitation on xylanase and pectinase production by *Bacillus subtilis* ADI1 after 72 hours	41
4.6	Effect of different levels of rice bran (RB) on xylanase and pectinase production after 72 hours	42
4.7	Xylanase and pectinase production in control and optimized cultural conditions by *Bacillus subtilis* ADI1 after 72 hours	44
4.8	Effect of temperature on crude (●) xylanase and (■) pectinase activity. The reaction was carried out for 10 minutes at various temperatures (25-90°C) using 0.01 M NaOH glycine buffer (pH 8) and enzyme activity was expressed as a percentage of highest activity (40°C)	45
4.9	Effect of temperature on the stability of xylanase. Thermal stability was determined by preincubating the crude enzymes for 24 hours at (●) 40°C, (■) 55°C, (▲) 60°C, (×) 65°C and (+) 70°C.	46

	The residual activities were monitored at 1-hour interval up to 5 hours under standard assay conditions	
4.10	Effect of temperature on the stability of pectinase. Thermal stability was determined by preincubating the crude enzymes for 24 hours at (●) 40°C, (■) 55°C, (▲) 60°C, (×) 65°C and (+) 70°C. The residual activities were monitored at 1-hour interval up to 5 hours under standard assay conditions	47
4.11	Effect of pH on (●) xylanase and (■) pectinase activity. The enzyme was buffered with 0.01M citrate buffer (CP) (pH5-6.5), 0.01M phosphate buffer (P) (pH 6-8), 0.01M Tris-HCl buffer (TH) (pH 7.5-8.5) and 0.01M glycine-NaOH buffer (GN) (pH 9-10) and incubated for 10 minutes	48
4.12	Effect of pH on stability of xylanase. Stability studies were performed by incubating crude enzyme solution for 24 hours at pH (●) 6.5 (citrate phosphate buffer), (■) 7.0 (phosphate buffer), (▲) 8.0 (phosphate buffer), (×) 8.0 (tris-HCl) and (+) 9.0 (glycine-NaOH)	49
4.13	Effect of pH on stability of pectinase. Stability studies were performed by incubating crude enzyme solution for 24 hours at hours at pH (●) 6.5 (citrate phosphate buffer), (■) 7.0 (phosphate buffer), (▲) 8.0 (phosphate buffer), (×) 8.0 (tris-HCl) and (+) 9.0 (glycine-NaOH)	49
5.2	Handsheets produced after bleaching process. A) untreated, B) treated with xylano-pectinolytic enzymes	57

LIST OF ABBREVIATIONS

°C	Degree celcius
AOX	Adsorbable organic halides
B. subtilis	*Bacillus subtilis*
CMC	Carboxymethylcellulose
DP	Degree of polymerization
ECF	Elemental chlorine free
g	Gravitational force
h	Hour
ha	Hectare
MARDI	Malaysian Agriculture Research and Development Institute
min	Minutes
ml	Millilitre
NA	Nutrient agar
OD	Optical density
OPEFB	Oil palm empty fruit bunch
PGA	Polygalacturonic Acid
psi	pounds per square inch (pressure)
rpm	Rotation per minute
SmF	Submerged fermentation
sp.	Species
SSF	Solid-state fermentation
TAPPI	Technical Association of the Pulp and Paper Industry
TCF	Total chlorine free
ton	Tonne
ton/ha	Tonne per hectare

CHAPTER 1

INTRODUCTION

The utilization of raw materials for pulp and paper production, such as non-wood plant fibers instead of wood fibers is rising in many developing and developed countries. From 1970 to the present time, the capacity of the non-wood plant fiber has increased two to three times compared to the capacity for producing wood pulp for papermaking (Dutt et al., 2009; Rowell et al., 1997). Due to the global demand for fibrous material, non-woods have become one of the important alternative sources for the 21st century, since there is a worldwide shortage of trees in many areas (Ashori and Bahreini, 2009).

Over the last decade, kenaf (*Hibiscus cannabinus L.)* a warm-season annual plant in the family of Malvaceae, which grows quickly, has attracted attention as a potential non-wood raw material for pulp and papermaking. In Malaysia's climate, kenaf managed to grow to height of 3.66-4.27 m for around five months, thus achieving yields of kenaf that vary from 2 ton/ha to 25 ton/ha (Mossello et al., 2010a; Paridah et al., 2009a; Fried 1999; Touzinsky, 1993) which is faster when compared to hardwood that requires several years to grow (Webber and Bledsoe, 2002; Kaldor et al., 1990). Kenaf can act as great alternative fibre crop in the pulp and paper industry since it can produce pulp and papers in comparable quality to those produced from wood (Ashori et al., 2006). Furthermore, kenaf is becoming a new important non-wood fibre crops for paper products because of the dwindling amount of virgin wood and forests cause these products to become more expensive (Monti and Alexopoulou, 2014).

In the pulp and paper industry, growing public concern about the environment is giving rise to technological changes in the bleaching processes. The effluent from the conventional bleaching process contains some chlorinated organic compounds that have shown mutagenic activity (Bajpai et al., 2006; Bajpai, 2005; Erikson and Kirk, 1985). During conventional pulp bleaching, chlorinated phenolic compounds are produced. These compounds are highly resistant to biodegradation, thus contributing to environmental pollution.

When Viikari et al. (1986) initially carried out the use of xylanases to depolymerize hemicelluloses from Kraft pulp prior to pulp bleaching, it showed a reduction of chemicals released. With increasing environmental awareness, ligninase and hemicellulase (xylanases) have been tested for biobleaching and resulted in low chlorine consumption as reported by Kaur et al. (2010). Instead of using xylanase to degrade xylan, pectin is also present in the pulp fibres which required pectinase to degrade pectin (Yang et al., 2008). The pectinases are effective in biobleaching of mixed hardwood and bamboo kraft pulps due to its ability to depolymerize polymers of galacturonic acid. This lowered the cationic demand of pectin solutions and the filtrate from peroxide bleaching (Dhiman et al., 2009; Ahlawat et al., 2007; Viikari et al., 2001; Reid and Ricard, 2000). Nowadays, xylanases are commonly used as a physical barrier to the access of bleaching chemicals since it can remove lignin-carbohydrate complex (Kapoor et al., 2008; Beg et

al., 2000a; Viikari et al., 1994). In addition, pectinase are known to depolymerize pectin (or polymers of galacturonic acid) that is present in xylan-pectin-lignin complexes on pulp fibres, subsequently reducing the requirement of peroxide bleaching and cationic demand of pectin solutions. Therefore, the use of xylanase and pectinase from microbes in combination in pulp bleaching may able to reduce harmful pectins produced in the effluent, thus rendering the papermaking process more eco-friendly and improving the quality of paper production.

No report has been published on the biobleaching of kenaf pulp by using concurrent xylanase and pectinase. To date, there is no report available regarding the simultaneous production of xylanase and pectinase in combination from the local Malaysian bacterial isolate for kenaf pulp biobleaching. One of the new and developing techniques is the replacement of chlorine-based bleaching stages with biobleaching using xylano-pectinolytic (ligninolytic) enzymes.

Therefore, the specific objectives of this study were:

a) to isolate, screen and identify xylanase and pectinase enzymes-producing bacteria from compost,
b) to determine the optimum cultural conditions for enhanced production of xylano-pectinolytic enzymes by the isolated bacteria, and
c) to investigate the effect of xylano-pectinolytic enzymes in pretreatment on the physical properties of the bleached kenaf pulp.

REFERENCES

Abdel-Aal, M. A., Nasser, R. A., Khan, P. R., & Mefarrej, H. A. (2015). Anatomical and physical characterisations of some lignocellulosic residues and their suitability for fibre production. *Journal of Environmental Biology*, *36*, 543–549.

Abdul Khalil, H. P. S., Yusra, A. F. I., Bhat, A. H., & Jawaid, M. (2010). Cell wall ultrastructure, anatomy, lignin distribution, and chemical composition of Malaysian cultivated kenaf fiber. *Industrial Crops and Products*, *31*(1), 113–121. doi:10.1016/j.indcrop.2009.09.008

Abott, T. P., Tijarks, L. W. & Bagby, M. O. (1987). *Kenaf lignin structure by correlation of CMR, FTIR and chemical analysis.* In *Proceeding of 1987 Tappi.*

Aehle, W. (Ed.). (2007). *Enzymes in industry: Production and applications* (3rd ed.). Germany: Wiley-VCH Verlag GmbH.

Ahlawat, S., Battan, B., Dhiman, S. S., Sharma, J., & Mandhan, R. P. (2007). Production of thermostable pectinase and xylanase for their potential application in bleaching of kraft pulp. *Journal of Industrial Microbiology & Biotechnology*, *34*(12), 763–770. http://doi.org/10.1007/s10295-007-0251-3.

Ahlawat, S., Dhiman, S. S., Battan, B., Mandhan, R. P., & Sharma, J. (2009). Pectinase production by *Bacillus subtilis* and its potential application in biopreparation of cotton and micropoly fabric. *Process Biochemistry*, *44*(5), 521–526. doi:10.1016/j.procbio.2009.01.003

Ahlawat, S., Mandhan, R. P., Dhiman, S. S., Kumar, R., & Sharma, J. (2008). Potential application of alkaline pectinase from *Bacillus subtilis* SS in pulp and paper industry. *Applied Biochemistry and Biotechnology*, *149*(3), 287–293. http://doi.org/10.1007/s12010-007-8096-9.

Ahmed, S., Riaz, S., & Jamil, A. (2009). Molecular cloning of fungal xylanases: An overview. *Applied Microbiology and Biotechnology*, *84*(1), 19–35. http://doi.org/10.1007/s00253-009-2079-4.

Akhavan Sepahy, A., Ghazi, S., & Akhavan Sepahy, M. (2011). Cost-Effective Production and Optimization of Alkaline Xylanase by Indigenous *Bacillus mojavensis* AG137 Fermented on Agricultural Waste. *Enzyme Research*, *2011*, 1–9. http://doi.org/10.4061/2011/593624.

AkzoNobel. (2015). *ECF and TCF bleaching - AkzoNobel Eka - we help make pulp bright and white*. Retrieved February 18, 2016, from AkzoNobel Eka, https://www.akzonobel.com/eka/services/pulp_bleach/ecf_tcf/

Ali Shah, F., Mahmood, Q., Maroof Shah, M., Pervez, A., & Ahmad Asad, S. (2014). Microbial ecology of anaerobic Digesters: The key players of Anaerobiosis. *The Scientific World Journal*, *2014*, 1–21. doi:10.1155/2014/183752

Ang, L. S., Leh, C. P., & Lee, C. C. (2010). Effects of alkaline pre-impregnation and pulping on Malaysia cultivated kenaf (Hibiscus cannabinus). *BioResources*, *5*(3), 1446–1462.

Anisa, S. K., & Girish, K. (2014). Pectinolytic activity of *Rhizopus* sp. and *Trichoderma viride*. *International Journal of Research in Pure and Applied Microbiology*, *4*(2), 28-31.

Annamalai, N., Thavasi, R., Jayalakshmi, S., & Balasubramanian, T. (2009). Thermostable and Alkaline Tolerant Xylanase Production by *Bacillus subtilis* isolated from Marine Environment. *Indian Journal of Biotechnology*, *8*, 291–297.

Anonymous. (2004). *Malaysia's paper and paper products industry working towards self-sufficiency*. Malaysia: Malaysian Timber Council.

Arase, A., Yomo, T., Urabe, I., Hata, Y., Katsube, Y., & Okada, H. (1993). Stabilization of xylanase by random mutagenesis. *FEBS Letters*, *316*(2), 123–127. http://doi.org/10.1016/0014-5793(93)81199-a.

Aravamuthan, R., Lechlitnerm J. & Lougen, G. (2002). High yield pulping of kenaf for corrugating medium. In *Proceeding of paper* presented at the TAPPI, Fall Technical Conference.

Arora, N., Banerjee, A. K., Mutyala, S., & Murty, U. S. (2009). Comparative characterization of commercially important xylanase enzymes. *Bioinformation*, *3*(10), 446–453.

Ashori, A., & Bahreini, Z. (2009). Evaluation of Calotropis gigantea as a promising raw material for fiber-reinforced composite. *Journal of Composite Materials*, *43*(11), 1297–1304. doi:10.1177/0021998308104526

Ashori, A., Harun, J., Raverty, W. D., & Yusoff, M. N. M. (2006). Chemical and morphological characteristics of Malaysian cultivated Kenaf (*Hibiscus cannabinus*) fiber. *Polymer-Plastics Technology and Engineering*, *45*(1), 131–134. doi:10.1080/03602550500373782.

Atchison, J. E., & McGovern, J. N. (1983). History of paper and the importance of non-wood plants fibres. In *Pulp and paper manufacturer* (3rd ed.). Kocurek M. J. & Stevens F. (eds). Atlanta GA: Tappi Press.

Auntsrup, K. (1974). In: Industrial aspects of biochemistry (B. Spencer, Ed.), Federation of European Biochemical Socities Symposium, pp 23, Elsevier, Amsterdam.

Azeri, C., Tamer, A.U., Oskay, M., (2010). Thermoactive cellulase free xylanase production from alkaliphilic *Bacillus* strains using various agro-residues and their potential in biobleaching of kraft pulp. *African Journal of Biotechnology*, *9*(1), 63–72.

Bajpai, P. (1999). Application of enzymes in the pulp and paper industry. *Biotechnology Progress*, *15*(2), 147–157. http://doi.org/10.1021/bp990013k.

Bajpai, P. (2005). *Environmentally benign approaches for pulp bleaching*. Amsterdam: Elsevier Science.

Bajpai, P. (2011). *Biotechnology for pulp and paper processing*. New York: Springer-Verlag New York.

Bajpai, P. (2012a). *Biotechnology for pulp and paper processing*. New York: Springer Science and Business Media.

Bajpai, P. (2012b). *Environmentally benign approaches for pulp bleaching* (2nd ed.). Netherlands: Elsevier Science & Technology.

Bajpai, P. (2015a). *Green Chemistry and Sustainability in Pulp and Paper Industry* (1st ed.). India: Springer.

Bajpai, P. (2015b). *Pulp and paper industry*. United States: Elsevier Science.

Bajpai, P. K., Anand, a, Sharma, N., Mishra, S. P., Bajpai, P. K., & Lachenal, D. (2006). Enzymes improve ecf bleaching of pulp. *Bioresources*, *1*(Pryke 1997), 34–44. http://doi.org/10.15376/biores.1.1.34-44

Bajpai, P., Anand, A., Sharma, N., Mishra, S. P., Bajpai, P. K., & Lachenal, D. (2006). Enzymes improve ECF bleaching of pulp. *BioResources*, *1*(1), 34–44.

Bajpai, P., Bajpai, P. K., & Kondo, R. (2012). *Biotechnology for environmental protection in the pulp and paper industry*. Berlin: Springer.

Bandikari, R., Poondla, V., & Obulam, V. S. R. (2014). Enhanced production of xylanase by solid state fermentation using *Trichoderma koeningi* isolate: Effect of pretreated agro-residues. *3 Biotech*, *4*(6), 655–664. doi:10.1007/s13205-014-0239-4

Bansal, N., Tewari, R., Gupta, J., Soni, R., & Soni, S. (2011). A novel strain of *Aspergillus niger* producing a cocktail of hydrolytic depolymerising enzymes for the production of second generation biofuels. *BioResources, 6*(1), 552-569. doi:10.15376/biores.6.1.552-569.

Barredo, J. L. (Ed.). (2005). *Microbial Enzymes and Biotransformations (Methods in Biotechnology)* (1st ed.). United States: Humana Press.

Basu, S., Ghosh, A., Bera, A., Saha, M. N., Chattopadhyay, D., & Chakrabarti, K. (2008). Thermodynamic characterization of a highly thermoactive extracellular pectate lyase from a new isolate *Bacillus pumilus* DKS1. *Bioresource Technology*, *99*(17), 8088–8094. http://doi.org/10.1016/j.biortech.2008.03.032

Battan, B., Sharma, J., Dhiman, S. S., & Kuhad, R. C. (2007). Enhanced production of cellulase-free thermostable xylanase by *Bacillus pumilus* ASH and its potential application in paper industry. *Enzyme and Microbial Technology*, *41*(6-7), 733–739. http://doi.org/10.1016/j.enzmictec.2007.06.006.

Beg, Q. K., Bhushan, B., Kapoor, M., & Hoondal, G. S. (2000a). Enhanced production of a thermostable xylanase from *Streptomyces sp.* QG-11-3 and its application in biobleaching of eucalyptus kraft pulp. *Enzyme and Microbial Technology*, *27*(7), 459–466. http://doi.org/10.1016/s0141-0229(00)00231-3.

Beg, Q. K., Bhushan, B., Kapoor, M., & Hoondal, G. S. (2000b). Production and characterization of thermostable xylanase and pectinase from *Streptomyces sp*. QG-11-3. *Journal of Industrial Microbiology and Biotechnology*, *24*(6), 396–402. http://doi.org/10.1038/sj.jim.7000010.

Beg, Q. K., Kapoor, M., Mahajan, L., & Hoondal, G. S. (2001). Microbial xylanases and their industrial applications: A review. *Applied Microbiology and Biotechnology*, *56*(3-4), 326–338. http://doi.org/10.1007/s002530100704.

Béguin, P., & Aubert, J.-P. (1994). The biological degradation of cellulose. *FEMS Microbiology Reviews*, *13*(1), 25–58. doi:10.1111/j.1574-6976.1994.tb00033.x

Berg, B., & Hofsten, A. V. (1976). The Ultrastructure of the fungus *Trichoderma viride* and investigation of its growth on cellulose. *Journal of Applied Bacteriology*, *41*(3), 395–399. doi:10.1111/j.1365-2672.1976.tb00651.x

Berg, B., & Petterson, G. (1977). Location and formation of Cellulases in *Trichoderma viride*. *Journal of Applied Bacteriology*, *42*(1), 65–75. doi:10.1111/j.1365-2672.1977.tb00670.x

Bert, N. (2002). Kenaf fibres. Presentation of the 5th annual conference of the America kenaf society. November 7-9, Memphis, TN.

Bhalla, A., Bischoff, K. M., & Sani, R. K. (2015). Highly Thermostable Xylanase production from A *Thermophilic Geobacillus* sp. Strain WSUCF1 utilizing Lignocellulosic Biomass. *Frontiers in Bioengineering and Biotechnology*, *3*, . doi:10.3389/fbioe.2015.00084

Bhushan, B., Kapoor, M., & Hoondal, G. S. (2000). Production and characterization of thermostable xylanase and pectinase from *Streptomyces sp.* QG-11-3. *Journal of Industrial Microbiology and Biotechnology*, *24*(6), 396. http://doi.org/10.1038/sj.jim.7000010.

Biermann, C. J. (1996). *Handbook of pulping and papermaking* (2nd ed.). San Diego, CA: Academic Press.

Birijlall, N., Manimaran, A., Santhosh Kumar, K., Permaul, K., & Singh, S. (2011). High level expression of a recombinant xylanase by *Pichia pastoris* NC38 in a 5L fermenter and its efficiency in biobleaching of bagasse pulp. *Bioresource Technology*, *102*(20), 9723–9729. doi:10.1016/j.biortech.2011.07.059

Botella, C., Diaz, A., de Ory, I., Webb, C., & Blandino, A. (2007). Xylanase and pectinase production by *Aspergillus awamori* on grape pomace in solid state fermentation. *Process Biochemistry*, *42*(1), 98–101. http://doi.org/10.1016/j.procbio.2006.06.025.

Bradford, M. (1976). A rapid and sensitive method for the Quantitation of Microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, *72*(1-2), 248–254. http://doi.org/10.1006/abio.1976.9999.

Bruhlmann, F., Kim, K. S., Zimmerman, W., & Fiechter, A. (1994). Pectinolytic enzymes from actinomycetes for the degumming of ramie bast fibres. *Applied Environmental Microbiology Letter*, *175*, 1-9.

Campilho, R. D. S. G. (2015). *Natural fiber composites* (1st ed.). United Kingdom: CRC Press.

Canel. E., Moo-Young, M. (1980). Solid state fermentation systems. *Process Biochemistry*, *15*, 24- 28.

Cao, J., Zheng, L., & Chen, S. (1992). Screening of pectinase producer from alkalophilic bacteria and study on its potential application in degumming of ramie. *Enzyme and Microbial Technology*, *14*(12), 1013–1016. http://doi.org/10.1016/0141-0229(92)90087-5.

Cappuccino, J. G., & Sherman, N. (2010). *Microbiology: A laboratory manual* (8th ed.). San Francisco: Pearson/Benjamin Cummings.

Chahal, P. S., Chahal, D. S., & Lê, G. B. B. (1996). Production of Cellulase in solid-state fermentation with *Trichoderma reesei* MCG 80 on wheat straw. *Seventeenth Symposium on Biotechnology for Fuels and Chemicals*, 433–442. http://doi.org/10.1007/978-1-4612-0223-3_40.

Chen, L., Columbus, E. P., Pote, J. W., Fuller, M. J., & Black, J. G. (1995). Kenaf bast and core separation. In *International Kenaf Association Conference Proceedings*. Texas, 8-10 March, pp 15-23.

Chhabilendra, R. (2009). *International jute commodity system* (1st ed.). New Delhi: Northern Book Centre.

Chia, C. H., Zakaria, S., Nguyen, K. L., & Abdullah, M. (2008). Utilisation of unbleached kenaf fibers for the preparation of magnetic paper. *Industrial Crops and Products*, *28*(3), 333–339. doi:10.1016/j.indcrop.2008.03.012.

Chivero, E. T., Mutukumira, A. N., Zvauya, R. (2001). Partial purification and characterization of a xylanase enzyme. *Food Chemistry*, *72*, 179–185.

Cho, S. S., & Samuel, P. (Eds.). (2009). *Fiber ingredients: Food applications and health benefits*. CRC Press.

Choudhury, B., Aggarwal, P., Gothwal, R. K., Mantri, R., Mohan, M. K., & Ghosh, P. (2006). Biobleaching of Nonwoody Pulps using Xylanase of *Bacillus brevis* BISR-062. *Applied Biochemistry and Biotechnology*, *128*(2), 159–170. http://doi.org/10.1385/abab:128:2:159.

Christopher, L. (Ed.). (2012). *Integrated forest biorefineries: Challenges and opportunities*. Cambridge: Royal Society of Chemistry.

Clark, J. A. (1985). Pulp technology and treatment for paper (2nd ed.). San Francisco, USA: Miller-Freeman.

Claye, S. S., Idouraine, A., & Weber, C. W. (1996). Extraction and fractionation of insoluble fiber from five fiber sources. *Food Chemistry*, *57*(2), 305–310. http://doi.org/10.1016/0308-8146(95)00250-2

Cunha, F. M., Esperança, M. N., Zangirolami, T. C., Badino, A. C., & Farinas, C. S. (2012). Sequential solid-state and submerged cultivation of *Aspergillus niger* on

sugarcane bagasse for the production of cellulase. *Bioresource Technology*, *112*, 270–274. doi:10.1016/j.biortech.2012.02.082.

Cunningham, R. L., Carr, M. E., & Bagby, M. O. (1986). Hemicellulose isolation from annual plants. In *Biotechnology and bioengineering symposium.* Tennessee, 13-16 May, pp 159.

Dahlberg, L., Holst, O., & Kristjansson, J. (1993). Thermostable xylanolytic enzymes from *Rhodothermus marinus* grown on xylan. *Applied Microbiology and Biotechnology*, *40*(1). http://doi.org/10.1007/bf00170430.

Dahlberg, L., Holst, O., Anker, L., Konraddsdottir, M., & Kristjansson, J. K. (1992). Thermostable xylanases from Icelandic hot springs. In J. Visser, G. Beldman, M. A. Kusters-van Someran, & A. G. J. Voragen, *Xylans and Xylanases* (pp. 459–462). Amsterdam: Elsevier Science Publishers.

Damiano, V.B., Bocchini, D.A., Gomes, E., Da Silva, R., (2003). Application of crude xylanase from *Bacillus licheniformis* 77-2 to the bleaching of eucalyptus kraft pulp. *World Journal of Microbiology Biotechnology, 19*, 139–144.

Danielle, B. P., Alexandre, C. M., Eleni, G., & Eleonora, C. C. (2009). Pectin and Pectinases: Production, Characterization and Industrial Application of Microbial Pectinolytic Enzymes. *The Open Biotechnology Journal*, *3*, 9–18.

David, J. S., Moreland, D. G., & Peter, L. B. (2005). *Enzymatic Bleaching of Wood Pulp*. Retrieved February 14, 2016, from New Zealand Institute of Chemistry, http://nzic.org.nz/ChemProcesses/forestry/index.html

Dhillon, A. (2000). A cellulase-poor, thermostable, alkalitolerant xylanase produced by *Bacillus circulans* AB 16 grown on rice straw and its application in biobleaching of eucalyptus pulp. *Bioresource Technology*, *73*(3), 273–277. http://doi.org/10.1016/s0960-8524(99)00116-9.

Dhiman, S. S, Sharma, J., Battan, B. (2008a). Industrial Applications and future prospects of Microbial Xylanases: A Review. *Bioresources*, *3*(4), 1377-1402.

Dhiman, S. S., Garg, G., Mahajan, R., Garg, N., Sharma, J. (2009). Single lay out and mixed lay out enzymatic processes for biobleaching of kraft pulp. *Bioresource Technology*, *100*, 4736–4741.

Dhiman, S. S., Sharma, J., & Battan, B. (2008b). Pretreatment processing of fabrics by alkalothermophilic xylanase from *Bacillus stearothermophilus* SDX. *Enzyme and Microbial Technology*, *43*(3), 262–269. http://doi.org/10.1016/j.enzmictec.2008.03.016.

Duarte, M. C. T., Pellegrino, A. C. A., Portugal, E. P., Ponezi, A. N., & Franco, T. T. (2000). Characterization of alkaline xylanases from *Bacillus pumilus*. *Brazilian Journal of Microbiology*, *31*(2), . doi:10.1590/s1517-83822000000200005

Dubeau, H., Chabal, D. S., & Ishaque, M. (1987) Xylanase of *Chatomium cellulolyticum*: its nature of production and hydrolytic potential. *Biotechnology Letters, 9*(4), 275-280.

Dutt, D, Upadhyaya, J. S., Tyagi, C. H. (2010). Studies on *Hibiscus cannabinus*, *Hibiscus sabdariffa* and *Cannabis sativa* pulp to be a substitute for softwood pulp-part1: AS-AQ delignification process. *BioResources, 5*(4), 2123-2136.

Dutt, D., Upadhyay, J. S., Singh, B & Tyagi, C. H. (2009) Studies on *Hibiscus cannabinus* and *Hibiscus sabdariffa* as an alternative pulp blend for softwood: An optimization of kraft delignification process. *Industrial Crops and Products, 29*, 16-26.

Edeerozey, A. M. M., Akil, H. M., Azhar, A. B., Ariffin, M. I. Z. (2007). Chemical modification of kenaf fibers. *Material Letters, 61*(10), 2023-2025.

Embaby, A. M., Masoud, A. A., Marey, H. S., Shaban, N. Z., & Ghonaim, T. M. (2014). Raw agro-industrial orange peel waste as a low cost effective inducer for alkaline polygalacturonase production from *Bacillus licheniformis* SHG10. *SpringerPlus*, *3*(1), 327. doi:10.1186/2193-1801-3-327

Erikson, K. E. & Kirk, T. K. (1985). Biopulping, biobleaching and treatment of kraft bleaching effluents with white rot fungi. In: Comprehensive Biotechnology, Vol. 4. Pp 271-294, Pergamon Press, New York.

Ersayin Yasinok, A., Biran, S., Kocabas, A., & Bakir, U. (2010). Xylanase from a soil isolate, *Bacillus pumilus*: Gene isolation, enzyme production, purification, characterization and one-step separation by aqueous-two-phase system. *World Journal of Microbiology and Biotechnology*, *26*(9), 1641–1652. http://doi.org/10.1007/s11274-010-0340-8.

Ertan (İnceoğlu), F., Balkan, B., & Yarkın, Z. (2014). Determination of the effects of initial glucose on the production of α-amylase from *Penicillium* sp. Under solid-state and submerged fermentation. *Biotechnology & Biotechnological Equipment*, *28*(1), 96–101. doi:10.1080/13102818.2014.901670

Falkowski, P. G., & Knoll, A. H. (Eds.). (2007). *Evolution of primary producers in the sea*. Amsterdam: Elsevier Academic Press.

FAO. (1998). *The outlook for pulp and paper to 2010.* Rome: FAO.

FAO. (2006). *Jute, kenaf, sisal, abaca, coir and allied fibres statistics.* Retrieved on 7 February 2016 from http://www.fao.org/fileadmin/templates/est/COMM_MARKETS_MONITORING/Jute_Hard_Fibres/Documents/JUTE_Statistical_bulletin_2013.pdf

Felsenstein, J. (1985). Confidence limits on phylogenies: An approach using the bootstrap. *Evolution*, *39*, 783-791.

Fernandez-Espinar, M. T., Ramon, D., Pinaga, F. & Valles, S. (1992). Xylanase production by *Aspergillus nidulans*. *FEMS Microbiology Letters, 91*(2), 91-96.

Firouzabadi, D. M., Tavasoli, A., & Mahdavi, S. (2008). Repalcing imported long fibre pulp with kenaf bast fibre soda pulp to improve quality of paper made form bagasse soda pulp. *Iranian Journal of Wood Paper Science Research, 23,* 157-168.

Fisher, G. (1994). Availability of kenaf fibres for the U.S. paper industry. In *TAPPI Proceedings*. Atlanta, pp 91-94.

Fladung, M. (2006). *Tree Transgenesis.* United States: Springer.

Fried, R. (1999). Kafus environmental industries: producing forestry products without trees. *Corporate Environmental Strategy 6*(4), 378-386.

Fritsche, E., Paschos, A., Beisel, H.-G., Böck, A., & Huber, R. (1999). Crystal structure of the hydrogenase maturating endopeptidase HYBD from *Escherichia coli*. *Journal of Molecular Biology*, *288*(5), 989–998. doi:10.1006/jmbi.1999.2719

Frost, G. M., Moss, D. A. (1987). In: *Biotechnology*. *Enzyme Technology*. Kennedy, J.F. (ed.) Vol. 7a Verlag Chemie, Weinheim. pp. 65-211.

Gaewchingduang, S., & Pengthemkeerati, P. (2010). Enhancing efficiency for reducing sugar from cassava bagasse by pretreatment. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, *4*(10), 477–480.

Galkiewicz, J. P., & Kellogg, C. A. (2008). Cross-kingdom amplification using Bacteria-specific primers: Complications for studies of coral microbial ecology. *Applied and Environmental Microbiology*, *74*(24), 7828–7831. http://doi.org/10.1128/AEM.01303-08

Gangwar, A. K., Prakash, N. T., & Prakash, R. (2014). Applicability of microbial Xylanases in paper pulp bleaching: A review. *BioResources*, *9*(2). doi:10.15376/biores.9.2.3733-3754

Gao, D., Haarmeyer, C., Balan, V., Whitehead, T. A., Dale, B. E., & Chundawat, S. P. (2014). Lignin triggers irreversible cellulase loss during pretreated lignocellulosic biomass saccharification. *Biotechnology for Biofuels*, *7*(1), 1-13. doi:10.1186/s13068-014-0175-x

Garg, A.P., Roberts, J.C., McCarthy, A.J. (1998). Bleach boosting effect of cellulase free xylanase of *Streptomyces thermoviolaceus* and its comparison with two commercial enzyme preparations on birchwood kraft pulp. *Enzyme and Microbiology Technology, 22*, 594–598.

Garg, G., Singh, A., Kaur, A., Singh, R., Kaur, J., & Mahajan, R. (2016). Microbial pectinases: An ecofriendly tool of nature for industries. *3 Biotech*, *6*(1), . doi:10.1007/s13205-016-0371-4

Gavrilescu, M., & Chisti, Y. (2005). Biotechnology—a sustainable alternative for chemical industry. *Biotechnology Advances*,*23*(7-8), 471–499. doi:10.1016/j.biotechadv.2005.03.004

Geok, L. P., Razak, C. N. A., Abd Rahman, R. N. Z., Basri, M., & Salleh, A. B. (2003). Isolation and screening of an extracellular organic solvent-tolerant protease producer. *Biochemical Engineering Journal*, *13*(1), 73–77. doi:10.1016/s1369-703x(02)00137-7

Ghazala, I., Sayari, N., Romdhane, M. B., Ellouz-Chaabouni, S., & Haddar, A. (2015). Assessment of pectinase production by *Bacillus mojavensis* I4 using an economical substrate and its potential application in oil sesame extraction. *Journal of Food Science and Technology*, *52*(12), 7710–7722. doi:10.1007/s13197-015-1964-3

Giacomo, C., & Roberto, O. (2014). *My library My History Books on Google Play Current Environmental Issues and Challenges* (1st ed.). Italy: Springer Science & Business.

Gomes, D.J., Gomes, J., & Steiner, W. (1994). Factors influencing the induction of endo-xylanase by *Thermoascus aurantiacus*. *Journal of Biotechnology, 33*, 87-94.

Gomes, I., Saha, R. K., Mohiuddin, G., Hoq, M. M. (1992). Isolation and characterization of a cellulase-free pectinolytic and hemicellulolytic thermophilic fungus. *World Journal of Microbiology Biotechnology, 8*(6), 589-592.

Goring, D. A. I., & Timell, W. E. (1962). The influence of extractives on pulping of wood. Pp. 367- 404. In Wise, L.E. ed., *Wood Extractives and Their Significance to the Pulp and Paper Industries*. New York: Academic Press.

Gowdhaman, D., Manaswini, V. S., Jayanthi, V., Dhanasri, M., Jeyalakshmi, G., Gunasekar, V., … Ponnusami, V. (2014). Xylanase production from *Bacillus aerophilus* KGJ2 and its application in xylooligosaccharides preparation. *International Journal of Biological Macromolecules*, *64*, 90–98. doi:10.1016/j.ijbiomac.2013.11.012

Gräsvik, J., Winestrand, S., Normark, M., Jönsson, L. J., & Mikkola, J.-P. (2014). Evaluation of four ionic liquids for pretreatment of lignocellulosic biomass. *BMC Biotechnology*, *14*(1), 34. doi:10.1186/1472-6750-14-34

Guljarani, M. L. (2013). *Advances in the dyeing and finishing of technical textiles* (1st ed.). United Kingdom: Woodhead Publishing.

Gummadi, S. N., & Panda, T. (2003). Purification and biochemical properties of microbial pectinases—a review. *Process Biochemistry*, *38*(7), 987–996. doi:10.1016/s0032-9592(02)00203-0

Gupta, U., & Kar, R. (2009). Xylanase production by a thermo-tolerant *Bacillus* species under solid-state and submerged fermentation. *Brazilian Archives of Biology and Technology*, *52*(6), 1363–1371. doi:10.1590/s1516-89132009000600007

Habibi, Y., Lucia, L. A., & Rojas, O. J. (2010). Cellulose Nanocrystals: Chemistry, self-assembly, and applications. *Chemical Reviews*, *110*(6), 3479–3500. doi:10.1021/cr900339w.

Haddar, A., Driss, D., Frikha, F., Ellouz-Chaabouni, S., & Nasri, M. (2012). Alkaline xylanases from *Bacillus mojavensis* A21: Production and generation of xylooligosaccharides. *International Journal of Biological Macromolecules*, *51*(4), 647–656. doi:10.1016/j.ijbiomac.2012.06.036

Hakeem, K. R., Jawaid, M., & Alothman, O. (2015). *Agricultural Biomass based potential materials*. United States: Springer International Publishing.

Halis, R. (2010). *Optimization of raft and biokraft pulping for kenaf v36*, PhD Thesis, Universiti Putra Malaysia.

Haltrich, D., Nidetzky, B., Kulke, K. D., Stenier, W., Zupancic, S. (1996). Production of fungal xylanase. *Bioresource Technology*, *58*, 137–161.

Hamidi, A. A., & Amin, M. (2014). *Wastewater Engineering: Advance Wastewater Treatment Systems* (1st ed.). Penang, Malaysia: IJSR Publication.

Han, J. S. (1998). Properties of nonwood fibers. In *Proceeding of the Korean society of wood science and technology annual meeting 1998*. Seoul, 24-25 April, pp 3-12.

Hardy Diagnostics. (2013). *Microbiology Culture Media and Laboratory Supplies*. Retrieved January 31, 2016, from http://hardydiagnostics.com/

Heitner, C., Dimmel, D., & Schmidt, J. (Eds.). (2010). *Lignin and Lignans: Advances in chemistry*. United States: CRC Press.

Henderson, A. J., Ollila, C. A., Kumar, A., Borresen, E. C., Raina, K., Agarwal, R., & Ryan, E. P. (2012). Chemopreventive properties of dietary rice bran: Current status and future prospects. *Advances in Nutrition: An International Review Journal*, *3*(5), 643–653. doi:10.3945/an.112.002303

Hillis, W. E. (Ed.). (2014). *Wood Extractives and their significance to the pulp and paper industries* (Revised ed.). United States: Academic Press.

Hölker, U., & Lenz, J. (2005). Solid-state fermentation — are there any biotechnological advantages?. *Current Opinion in Microbiology*, *8*(3), 301–306. doi:10.1016/j.mib.2005.04.006

Holker, U., Hofer, M., Lenz, J. (2004). Biotechnological advantages of laboratory-scale solid-state fermentation with fungi. *Applied Microbiology and Biotechnology*, *64*, 175-186.

Holliman, J. H. (2012). *Pathology* (3rd ed.). New York, NY: Springer US.

Hooi, L. H. (2015). Xylanase production by *Bacillus subtilis* using carbon source of inexpensive agricultural wastes in two different approaches of submerged fermentation (SmF) and solid state fermentation (SSF). *Journal of Food Processing & Technology*, *06*(04), 1–9. doi:10.4172/2157-7110.1000437

Hoondal, G. S., Tiwari, R.P., Tewari, R., Dahiya, N., Beg, Q. K. (2002). Microbial alkaline pectinases and their industrial applications: a review. *Applied Microbiology and Biotechnology*, *59*, 409-418.

Horikoshi, K. (1991) Isolation and classification of alkalophilic microorganisms. In: Microorganisms in alkaline environment. Pp.5-24, Kodansha Ltd. Tokyo, (Japan), VCH Weinheim, (Germany) and New York, USA.

Horn, S., Vaaje-Kolstad, G., Westereng, B., & Eijsink, V. G. (2012). Novel enzymes for the degradation of cellulose. *Biotechnology for Biofuels*, *5*(1), 45. doi:10.1186/1754-6834-5-45

Hossain, M. D., Hanafi, M. M., Jol, H., & Abdul Hamid, H. (2011). Growth, yield, and fiber morphology of kenaf (*Hibiscus cannabinus* L.) grown on sandy bris soil as influenced by different levels of carbon. *African Journal of Biotechnology*, *10*(50), 10087–10094. doi:10.5897/AJB11.1278

Hunsigi, G. (1989). Agricultural fibres for paper pulp. *Outlook on Agriculture, 18*(3), 96-103.

Hurter, A. M. (1988). Utilization of annual plants and agricultural residues for the production of pulp and paper. In *Proceeding of TAPPI Pulping Conference.* New Orleans, LA, USA. Book 1. P. 139-160.

Ilvessalo-Pfäffli, M.-S. (2009). *Fiber atlas: Identification of papermaking fibers*. Berlin: Springer-Verlag.

Inamine, E., Lago, B. D. & Demain, A. L. (1969). Regulation of mannosidase, an enzyme of streptomycin biosynthesis, In *Fermentation advances*. Pp.199-221 (Perlman, E. Ed.). New York: Academic Press.

Irfan, M., Asghar, U., Nadeem, M., Nelofer, R., & Syed, Q. (2015). Optimization of process parameters for xylanase production by *Bacillus* sp. In submerged fermentation. *Journal of Radiation Research and Applied Sciences*. doi:10.1016/j.jrras.2015.10.008

Isil, S., & Nilufer, A. (2005). Investigation of factors affecting xylanase activity from *Trichoderma harzianum* 1073 D3. *Brazilian Archives of Biology and Technology*, *48*(2), . doi:10.1590/s1516-89132005000200004

Iyer, P. V., & Ananthanarayan, L. (2008). Enzyme stability and stabilization—Aqueous and non-aqueous environment. *Process Biochemistry*, *43*(10), 1019–1032. doi:10.1016/j.procbio.2008.06.004

Ja'afaru, M. I. (2013). Screening of fungi isolated from environmental samples for Xylanase and Cellulase production. *ISRN Microbiology*, *2013*, 1–7. doi:10.1155/2013/283423

Jacob, N., Niladevi, K. N., Anisha, G. S., & Prema, P. (2008). Hydrolysis of pectin: An enzymatic approach and its application in banana fiber processing. *Microbiological Research*, *163*(5), 538–544. doi:10.1016/j.micres.2006.07.016

Jahan Latibari, A., Hossein, M., & Hossienpour, R. (2010). Application of alkaline sulfite pulping on corn stalks. *BioResources, 6*(1), 48-58. doi:10.15376/biores.6.1.48-58

Jalaluddin H. (2001). Fibre characteristics of kenaf and development of kenaf fibres reinforced plastic composite for industrial applications. In *Proceeding of the First Technical Review Meeting on the National Kenaf Research Project*, eds. C.C. Wong and M.D. Mat daham, p. 87-122. Serdang: Malaysian Agricultural Research and Development Institute.

Jecu, L. (2000). Solid state fermentation of agricultural wastes for endoglucanase production. *Industrial Crops and Products*, *11*(1), 1–5. http://doi.org/10.1016/s0926-6690(99)00022-9.

Jiang, Z. Q., Li, X. T., Yang, S. Q., Li, L. T., Li, Y., & Feng, W. Y. (2005). Biobleach boosting effect of recombinant xylanase B from the hyperthermophilic *Thermotoga maritima* on wheat straw pulp. *Applied Microbiology and Biotechnology*, *70*(1), 65–71. http://doi.org/10.1007/s00253-005-0036-4.

Jonathan, B. (2014). *Paper demand stacks up*. Retrieved February 14, 2016, from HSBC, http://www.hsbc.com/news-and-insight/2014/paper-demand-stacks-up

Judt, M. (1993). Non-wood plant fibres, will there be a come-back in paper-making?. *Industrial Crops and Products*, *2*(1), 51–57. doi:10.1016/0926-6690(93)90011-w

Jukes T.H. & Cantor C.R. (1969). Evolution of protein molecules. In Munro HN, editor, *Mammalian Protein Metabolism*, pp. 21-132. New York: Academic Press.

Kaldor, A. F., Karlgren, C. & Wewest, H. (1990). Kenaf: A fast growing fibre source for papermaking. *Tappi Journal*, *73*, 205-209.

Kalia, S. (2016). *Biodegradable green composites*. United States: John Wiley & Sons.

Kalia, S., Dufresne, A., Cherian, B. M., Kaith, B. S., Avérous, L., Njuguna, J., & Nassiopoulos, E. (2011). Cellulose-based bio- and Nanocomposites: A review. *International Journal of Polymer Science*, *2011*, 1–35. doi:10.1155/2011/837875

Kamble, R. D., & Jadhav, A. R. (2012). Isolation, Purification, and Characterization of Xylanase Produced by a New Species of *Bacillus* in Solid State Fermentation. *International Journal of Microbiology*, *2012*, 1–8. http://doi.org/10.1155/2012/683193.

Kantelinen, A., Hortling, B., Sundquist, J., Linko, M., & Viikari, L. (1993). Proposed mechanism of the enzymatic bleaching of kraft pulp with Xylanases. *Holzforschung*, *47*(4), 318–324. doi:10.1515/hfsg.1993.47.4.318

Kapoor, M., Nair, L. M., & Kuhad, R. C. (2008). Cost-effective xylanase production from free and immobilized *Bacillus pumilus* strain MK001 and its application in saccharification of *Prosopis juliflora*. *Biochemical Engineering Journal*, *38*(1), 88–97. http://doi.org/10.1016/j.bej.2007.06.009.

Kar, S., Gauri, S. S., Das, A., Jana, A., Maity, C., Mandal, A., Mohapatra, P. K. D., Pati, B. R., Mondal, K. C. (2013). Process optimization of xylanase production using cheap solid substrate by *Trichoderma reesei* SAF3 and study on the alteration of behavioral properties of enzyme obtained from SSF and SmF. *Bioprocess and Biosystems Engineering*, *36*(1), 57-68.

Karigar, C. S., & Rao, S. S. (2011). Role of microbial enzymes in the Bioremediation of pollutants: A review. *Enzyme Research*, *2011*, 1–11. doi:10.4061/2011/805187

Kasana, R. C., Salwan, R., Dhar, H., Dutt, S., & Gulati, A. (2008). A Rapid and Easy Method for the Detection of Microbial Cellulases on Agar Plates Using Gram's Iodine. *Current Microbiology*, *57*(5), 503–507. http://doi.org/10.1007/s00284-008-9276-8.

Kashyap, D. R., Chandra, S., Kaul, A., & Tewari, R. (2000). Production, purification and characterization of pectinase from a *Bacillus sp*. DT7. *World Journal of Microbiology and Biotechnology*, *16*(3), 277–282. http://doi.org/10.1023/a:1008902107929.

Kashyap, D. R., Vohra, P. K., Chopra, S., Tewari, R. (2001a) Applications of pectinases in the commercial sector: A Review. *Bioresource Technology*, *77*, 215-227.

Katri, S. P. (2001). Non-wood plants as raw material for pulp and paper. *Agricultural and Food Science*, *10*(Supplement), 101. Retrieved from http://ojs.tsv.fi/index.php/AFS/article/view/5707

Kaur, A., Mahajan, R., Singh, A., Garg, G., & Sharma, J. (2010). Application of cellulase-free xylano-pectinolytic enzymes from the same bacterial isolate in biobleaching of kraft pulp. *Bioresource Technology*, 9150-9155.

Kaur, H., Dutt, D., Tyagi, C. H. (2011). Production of novel alkali-thermo-tolerant cellulasepoor xylanases from *Coprinopsis cinerea* HK-1 NFCCI-2032. *BioResources*, *6*(2), 1376- 1391.

Kaushal, R., Sharma, N., & Dogra, V. (2015). Optimization of the production and molecular characterization of cellulase-free xylanase from an alkalophillic *Bacillus subtilis* SD8 isolated from paper mill effluent. *Applied Biochemistry and Microbiology*, *51*(5), 551–559. doi:10.1134/s0003683815050117

Kennedy, J. F., & Hasamudin, W. H. W. (1995). Cellulose: Structure, accessibility and reactivity. *Polymer International*, *36*(1), 101–101. doi:10.1002/pi.1995.210360114

Keskar, S. S. (1992). High activity xylanase from thermotolerent *Streptomyces* T7: cultural conditions and enzyme properties. *Biotechnology Letters*, *14*(6), 481-486.

Khakifirooz, A., Ravanbakhsh, F., Samariha, A., & Kiaei, M. (2012). Investigating the possibility of Chemi-mechanical pulping of Bagasse. *BioResources*, *8*(1), . doi:10.15376/biores.8.1.21-30

Khasin, A., Alchanati, I., Shoham, Y. (1993). Purification and characterisation of a thermostable xylanase from *Bacillus stearothermophilus* T-6. *Applied and Environmental Microbiology*, *59*, 1725-1730.

Kirikyali, N. (2015). Xylan degrading enzymes from fungal sources. *Journal of Proteomics & Enzymology*, *04*(01), 1–11. doi:10.4172/2470-1289.1000118

Kirk, T. K., & Chang, H.-M. (Eds.). (2013). *Biotechnology in pulp and paper manufacture: Applications and fundamental investigations: Proceedings of the fourth international conference on biotechnology in the pulp and paper industry* (Revised ed.). United States: Butterworth-Heinemann.

Knob, A., Beitel, S. M., Fortkamp, D., Terrasan, C. R. F., & Almeida, A. F. de (2013). Production, purification, and characterization of a major *Penicillium glabrum* Xylanase using brewer's spent grain as substrate. *BioMed Research International*, *2013*, 1–8. doi:10.1155/2013/728735

Ko, C.-H., Tsai, C.-H., Tu, J., Yang, B.-Y., Hsieh, D.-L., Jane, W.-N., & Shih, T.-L. (2011). Identification of *Paenibacillus* sp. 2S-6 and application of its xylanase on biobleaching. *International Biodeterioration & Biodegradation*, *65*(2), 334–339. doi:10.1016/j.ibiod.2010.12.006

Kohli, U., Nigam, P., Singh, D., Chaudhary, K. (2001). Thermostable, alkalophilic and cellulase free xylanase production by *Thermoactinomyces thalophilus* subgroup C. *Enzyme Microbiology Technology*, *28*, 606-610.

Komiyama, H., Kato, A., Aimi, H., Ogihara, J., & Shimizu, K. (2008). Chemical structure of kenaf xylan. *Carbohydrate Polymers*, *72*(4), 638–645. doi:10.1016/j.carbpol.2007.10.003

Kristjansson, M. M. & Kinsella, J. E. (1991). Protein and enzyme stability: structural thermodynamic and experimental aspects. *Advances in Food and Nutrition Research*, *35*, 237-316.

Kuhad, R. C., & Singh, A. (2007). *Lignocellulose biotechnology: Future prospects* (1st ed.). India: I K International Publishing House Pvt.

Kulkarni, N., Abhay, S., Rao, M. (1999). Molecular and biotechnological aspects of xylanases. *FEMS Microbiology Reviews*, *23*, 411–456.

Kumar, L., Kumar, D., Nagar, S., Gupta, R., Garg, N., Kuhad, R. C., & Gupta, V. K. (2013). Modulation of xylanase production from alkaliphilic *Bacillus pumilus* VLK-1 through process optimization and temperature shift operation. *3 Biotech*, *4*(4), 345–356. doi:10.1007/s13205-013-0160-2

Kumar, P., Barrett, D. M., Delwiche, M. J., & Stroeve, P. (2009). Methods for pretreatment of Lignocellulosic Biomass for efficient hydrolysis and Biofuel production. *Industrial & Engineering Chemistry Research*, *48*(8), 3713–3729. doi:10.1021/ie801542g

Kumar, S., Sharma, H. K., & Sarkar, B. C. (2011). Effect of substrate and fermentation conditions on pectinase and cellulase production by *Aspergillus niger* NCIM 548

in submerged (SmF) and solid state fermentation (SSF). *Food Science and Biotechnology*, *20*(5), 1289–1298. http://doi.org/10.1007/s10068-011-0178-3.

Kwon, H. W., Yoon, J. H., Kim, S. H., Hong, S. B., Cheon, Y., & Ko, S. J. (2007). Detection of Extracellular enzymes activities in various *Fusarium* spp. *Mycobiology*, *35*(3), 162. doi:10.4489/myco.2007.35.3.162

Lajoie, M., Bertrand, D., & El-Mabrouk, N. (2009). Inferring the evolutionary history of gene clusters from Phylogenetic and Gene Order data. *Molecular Biology and Evolution*, *27*(4), 761–772. doi:10.1093/molbev/msp271

Lee, J., Seo, E., Kweon, D., Park, K., & Jin, Y. (2009). Fermentation of rice bran and Defatted rice bran for butanol production using *Clostridium beijerinckii* NCIMB 8052. *Journal of Microbiology and Biotechnology*, *19*(5), 482–490. doi:10.4014/jmb.0804.275

Lethbridge, G., Bull, A.T. & Burns, R.G. (1978). Assay and properties of 1,3-B-glucanase in soil. *Soil Biology and Biochemistry, 10,* 389-391.

Letovsky, S. I. (2006). *Bioinformatics: Databases and systems*. Boston: Kluwer Academic Publishers.

Lichtenegger, H. C., Müller, M., Wimmer, R., & Fratzl, P. (2003). Microfibril angles inside and outside Crossfields of Norway spruce Tracheids. *Holzforschung*, *57*(1), . doi:10.1515/hf.2003.003

Lincoln, R.E. (1960). Control of stock culture preservation and inoculum build up in bacterial fermentation. *Journal of Biochemical and Microbiological Technology and Engineering*, *2*, 481-500.

Lopez, C., Blanco, A. & Pastor, F. I. J. (1998). Xylanase production by a new alkalitolerant isolate of *Bacillus*. *Biotechnology Letters*, *20*(3), 243-246.

López, G., & Estrada, P. (2014). Effect of temperature on Xylanase II from Trichoderma reesei QM 9414: A calorimetric, catalytic, and conformational study. *Enzyme Research*, *2014*, 1–16. doi:10.1155/2014/708676

Makoto, S., & Shinji, M. (2011). Characterization of enzymes associated with degradation of insoluble fibre of sotbean curd residue by *Bacillus subtilis*. In D. Krezhova (Ed.), *Recent Trends for Enhancing the Diversity and Quality of Soybean Products* (1st ed.) (pp. 523–536). Croatia: inTech.

Malherbe, A. R., Rose, S. H., Viljoen-Bloom, M., & van Zyl, W. H. (2014). Expression and evaluation of enzymes required for the hydrolysis of galactomannan. *Journal of Industrial Microbiology & Biotechnology*, *41*(8), 1201–1209. doi:10.1007/s10295-014-1459-7

Martínez-Trujillo, A., Aranda, J. S., Gómez-Sánchez, C., Trejo-Aguilar, B., & Aguilar-Osorio, G. (2009). Constitutive and inducible pectinolytic enzymes from *Aspergillus flavipes* FP-500 and their modulation by pH and carbon source. *Brazilian Journal of Microbiology*, *40*(1), 40–47. http://doi.org/10.1590/s1517-83822009000100006.

Martín-Sampedro, R., Rodríguez, A., Requejo, A., & Eugenio, M. E. (2012). Improvement of TCF bleaching of olive tree pruning residue pulp by addition of a laccase and/or xylanase pre-treatment. *BioResources*, *7*(2), 1488-1503. doi:10.15376/biores.7.2.1488-1503

McDougall, G. J., Morrison, I. M., Stewart, D., Weyers, J. D. B. and Hillman, J. R. (1993), Plant fibres: Botany, chemistry and processing for industrial use. *Journal of Science and Food Agricultural, 62*, 1–20. doi: 10.1002/jsfa.2740620102

Mei, Y., Chen, Y., Zhai, R., & Liu, Y. (2013). Cloning, purification and biochemical properties of a thermostable pectinase from *Bacillus halodurans* M29. *Journal of*

Molecular Catalysis B: Enzymatic, *94*, 77–81. http://doi.org/10.1016/j.molcatb.2013.05.004.

Mendoza, N. S., Caliwara, M. T. E., Unciano, N. M. (2006). A local isolate of non-cellulolytic, xylanolytic and pectinolytic thermophilic fungus *Thermomyces lanuginosus* C1a. *Philippine Journal of Science, 135*(2), 113-119.

Meyrath, J. & Suchanek, G. (1972). Inoculation techniques – effects due to quality and quantity of inoculum. In: Methods in Microbiology, Vol 7B, pp.159-209 (Norris, J.R. and Ribbons, D.W. Eds.), London: Academic Press.

Michelin, M., Ruiz, H. A., Silva, D. P., Ruzene, D. S., Teixeira, J. A., & Polizeli, M. L. T. M. (2014). Cellulose from Lignocellulosic waste. *Polysaccharides*. doi:10.1007/978-3-319-03751-6_52-1

Miller, G. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical Chemistry*, 426-428.

Mod, R. R., Conkerton, E. J., Ory, R. L., & Normand, F. L. (1978). Hemicellulose composition of dietary fiber of milled rice and rice bran. *Journal of Agricultural and Food Chemistry*, *26*(5), 1031–1035. doi:10.1021/jf60219a048

Mohieldin, S. D. (2004). Environmentally friendly pulping and bleaching of some Sudanese *Acacias* and *Eucalyptuses* (Doctoral dissertation). Retrieved from http://khartoumspace.uofk.edu/bitstream/handle/123456789/9315/Environmentally%20FriendlyPulpingAndBleaching.pdf

Monti, A., & Alexopoulou, E. (2014). *Kenaf: A multi-purpose crop for several industrial applications: New insights from the Biokenaf project*. London: Springer.

Moon, S. H., & Parulekar, S. J. (1991). A parametric study ot protease production in batch and fed-batch cultures of Bacillus firmus. *Biotechnology and Bioengineering*, *37*(5), 467–83. http://doi.org/10.1002/bit.260370509

Mossello, A. A., Harun, J., Shamsi, S. R. F., Resalati, H., Tahir, P. M., Ibrahim, R., & Mohmamed, A. Z. (2010d). A review of literatures related to Kenaf as a alternative for Pulpwoods. *Agricultural Journal*, *5*(3), 131–138. doi:10.3923/aj.2010.131.138

Mossello, A. A., Harun, J., Tahir, P. M., Resalati, H., Ibrahim, R., Shamsi, S. R. F., Mohamed, A. Z. (2010a). A review of literatures related of using Kenaf for pulp production (Beating, Fractionation, and Recycled Fiber). *Modern Applied Science*, *4*(9), 44-49.

Mossello, A. A., Harun, J., Tahir, P. M., Resalati, H., Ibrahim, R., Shamsi, S. R. F., Mohamed, A. Z. (2010b). New approach to use of kenaf for paper and paperboard production. *BioResource, 5*(4):2112-2122.

Mossello, A. A., Harun, J., Tahir, P. M., Resalati, H., Ibrahim, R., Shamsi, S. R. F., Mohamed, A. Z. (2010c). Evaluation of linerboard properties from Malaysian cultivated kenaf soda-anthraquinone pulps versus commercial pulps. *BioResources, 5*(3):1595-1604.

Murad, H. A., Azzaz, H. H., Kholif, A. M., Hanfy, M. A., & Gawad, M. H. A. (2012). Optimization of culture conditions affecting fungal cellulase production. *Research Journal of Microbiology*, *7*(1), 23–31. doi:10.3923/jm.2012.23.31

Nacos, M., Katapodis, P., Pappas, C., Daferera, D., Tarantilis, P., Christakopoulos, P., & Polissiou, M. (2006). Kenaf xylan – A source of biologically active acidic oligosaccharides. *Carbohydrate Polymers*, *66*(1), 126–134. doi:10.1016/j.carbpol.2006.02.032

Nagar, S., Gupta, V. K., Kumar, D., Kumar, L., Kuhad, R. C. (2010). Production and optimization of cellulase-free, alkali-stable xylanase by *Bacillus pumilus* SV-85S in submerged fermentation. *Journal of Industrial Microbiology & Biotechnology, 37*, 71-83.

Nagar, S., Mittal, A., & Gupta, V. K. (2012). A cost effective method for screening and isolation of xylan degrading bacteria using agro waste material. *Asian Journal of Biological Sciences*, *5*(8), 384–394. doi:10.3923/ajbs.2012.384.394

Nakamura, S., Nakai, R., Wakabayashi, K., Ishiguro, Y., Aono, R. & Horikoshi, K. (1994). Thermophilic alkaline xylanase from newly isolated alkaliphilic and thermophilic *Bacillus* sp. Strain TAR-1. *Bioscience, Biotechnology, and Biochemistry, 58*(1), 78-81.

Nakamura, S., Wakabayashi, K., Nakai, R., Aono, R. and Horikoshi, K. (1993). Production of alkaline xylanase by a newly isolated alkaliphilic *Bacillus* sp. strain 41M-1. *World Journal of Microbiology and Biotechnology, 9*, 221-224.

Namasivayam, E., Ravindar. D, J., K, M., jiji, A., & Kumar, M. (2011). Production of extracellular pectinase by *Bacillus Cereus* isolated from market solid waste. *Journal of Bioanalysis & Biomedicine*, *03*(03), . doi:10.4172/1948-593x.1000046

Nelson, G. H., Nieschlag, H. J. & Wolff, I. A. (1962). *A search for new fiber crops*, V. Pulping studies on kenaf. *TAPPI, 45*(10):780–786.

Nigam, P. S. (2013). Microbial enzymes with special characteristics for biotechnological applications. *Biomolecules*, *3*, 597–611. http://doi.org/10.3390/biom3030597

Ninawe, S., & Kuhad, R. C. (2005). Use of xylan-rich cost effective agro-residues in the production of xylanase by *Streptomyces cyaneus* SN32. *Journal of Applied Microbiology*, *99*(5), 1141–1148. doi:10.1111/j.1365-2672.2005.02711.x

NKTB. (2010). *Lembaga Kenaf & Tembakau Negara - Laporan Tahunan 2010*. Retrieved February 5, 2016, from Lembaga Kenaf dan Tembakau Negara, http://www.lktn.gov.my/index.php/my/penerbitan/laporan-tahunan/laporan-tahunan-2010#top.

NPCS Board of Consultants & Engineers (2008). *Handbook on pulp and paper processing* (1st ed.). India: Asia Pacific Business Press.

Octavio, L. C., & Francisco, V.-O. (2006). Xylanases. In G. G.-G. Ramon & T.-P. Irineo (Eds.), *Advances in Agricultural and Food Biotechnology* (1st ed.) (pp. 305–322). Kerala, India: Research Signpost.

Ohtani, Y., Mazumder, B. B., & Sameshima, K. (2001). Influence of the chemical composition of kenaf bast and core on the alkaline pulping response. *Journal of Wood Science*, *47*(1), 30–35. doi:10.1007/bf00776642

Oluwadare, A., Oluwafemi, S., & Ashimiyu Sotannde, O. (2007). The relationship between fibre characteristics and pulp-sheet properties of *Leucaena leucocephala* (Lam.) De Wit. *Middle-East Journal of Scientific Research*, *2*(2), 63–68.

Omojasola, P. F., & Jilani, O. P. (2008). Cellulase production by *Trichoderma longi*, *Aspergillus niger* and *Saccharomyces cerevisae* cultured on waste materials from orange. *Pakistan Journal of Biological Sciences*, *11*(20), 2382–2388. doi:10.3923/pjbs.2008.2382.2388

Paavilainen, L. (1997). *Non-wood Fibers Short Course*. Atlanta, GA: Tappi Press.

Paavilainen, L. (1998, June 1). European prospects for using nonwood fibers. *Pulp and Paper Magazine*. Retrieved from http://www.risiinfo.com/magazines/June/1998/PPI/pulp-

paper/magazine/international/june/1998/European-prospects-for-using-nonwood-fibers.html

Paavilainen, L., Paltakari, J., Cheng, Z. & Tuhkanen, T. (1996). Behaviour of special reed pulp on the paper machine. Proceedings of the 3rd International Non-wood Fibre Pulping and Papermaking Conference 1996. Beijing, China. P. 577-582.

Padya, A. (2009). *Exploiting Natural Resources*. Retrieved February 14, 2016, from The Stimson Center, http://www.stimson.org/images/uploads/research-pdfs/Exploiting_Natural_Resources-Full.pdf

Paice, M. G., Bernier, R. J., Jurasek, L. (1988). Viscosity enhancing bleaching of hardwood kraft pulp with xylanase from a cloned gene. *Biotechnology and Bioengineering, 32*, 235–239.

Paice, M. G., Gurnagul, N., Page, D. H., & Jurasek, L. (1992). Mechanism of hemicellulose-directed prebleaching of kraft pulps. *Enzyme and Microbial Technology*, *14*(4), 272–276. doi:10.1016/0141-0229(92)90150-m

Pande, H. (1998). *Non-wood fibre and global fibre supply*. Rome: Forestry Department (FAO Information Division).

Pang, C., Shanks, R. A., & Daver, F. (2015). Characterization of kenaf fiber composites prepared with tributyl citrate plasticized cellulose acetate. *Composites Part A: Applied Science and Manufacturing*, *70*, 52–58. doi:10.1016/j.compositesa.2014.12.003

Pang, H., Zhang, P., Duan, C. J., Mo, X. C., Tang, J. L., & Feng, J. X. (2009). Identification of cellulase genes from the metagenomes of compost soils and functional characterization of one novel endoglucanase. *Current Microbiology*, *58*(4), 404–408. http://doi.org/10.1007/s00284-008-9346-y

Paridah, M. T., Abdullah, L. C. and Norfayani, K. (2009a). *Kenaf biocomposite, derivatives and economics.* Kuala Lumpur: Pustaka Prinsip.

Paridah, M. T., Basher, A. B., SaifulAzry, S. & Ahmed, Z. (2011). Retting process of some bast plant fibres and its effect on fibre quality: a review. *BioResources, 4*, 5260-5281.

Paridah, M. T., Hafizah, A. W. N., Zaidon, A., Azmi, I., Nor, M. Y. M. & Yuziah, M. Y. N. (2009b). Bonding properties and performance of multi layered kenaf board. *Journal of Tropical Forest Science, 21*(2), 113-122.

Park, Y. S., Kang, S. W., Lee, J. S., Hong, S. I., Kim, S. W. (2002). Xylanase production in solid state fermentation by *Aspergillus niger* mutant using statistical experimental designs. *Applied Microbiology and Biotechnology, 58*, 761–766.

Pastor, F. I. J., Gallardo, O., Aparicio, J. S. & Diaz, P. (2007). Xylanases: molecular properties and applications. In *Industrial Enzyme Structure, Function and Applications*, ed. J. Polaine, & A. P. MacCabe, pp. 65-82. Netherlands: Springer.

Patil, S. R., Dayanand, A. (2006). Production of pectinase from deseeded sunflower head by *Aspergillus niger* in submerged and solid-state conditions. *Bioresource Technology, 97*, 2054- 2058.

Peng, L. C. (2002). *Influence of properties variables on totally chlorine free dissolving pulp from oil palm lignocellulosic as evaluated by response surface methodology*. PhD Thesis, Universiti Sains Malaysia, Malaysia. pp. 43–110.

Pereira, H., Santos, A., & Anjos, O. (2015). Fibre morphological characteristics of kraft Pulps of *Acacia melanoxylon* estimated by NIR-PLS-R models. *Materials*, *9*(1), 8. doi:10.3390/ma9010008

Pérez, J., Muñoz-Dorado, J., la Rubia, T. de, & Martínez, J. (2002). Biodegradation and biological treatments of cellulose, hemicellulose and lignin: An overview. *International Microbiology*, *5*(2), 53–63. doi:10.1007/s10123-002-0062-3.

Peter, F. S., Allan, W., & Stephen, J. H. (2014). *Principles of fermentation technology* (2nd ed.). United States: Elsevier.

Polaina, J., & MacCabe, A. P. (2007). *Industrial enzymes: Structure, function and applications*. Dordrecht: Springer-Verlag New York.

Polizeli, M. L. T. M., Rizzatti, A. C. S., Monti, R., Terenzi, H. F., Jorge, J. A., Amorim, D. S., (2005). Xylanases from fungi: properties and industrial applications. *Applied Microbiology and Biotechnology*, *67*, 577–591.

Pothiraj, C., Kanmani, P., & Balaji, P. (2006). Bioconversion of lignocellulose materials. *Mycobiology*, *34*(4), 159. doi:10.4489/myco.2006.34.4.159

Preiss, L., Hicks, D. B., Suzuki, S., Meier, T., & Krulwich, T. A. (2015). Alkaliphilic bacteria with impact on industrial applications, concepts of early life forms, and Bioenergetics of ATP synthesis. *Frontiers in Bioengineering and Biotechnology*, *3*, . doi:10.3389/fbioe.2015.00075

Qing, Q., & Wyman, C. E. (2011). Supplementation with xylanase and β-xylosidase to reduce xylo-oligomer and xylan inhibition of enzymatic hydrolysis of cellulose and pretreated corn stover. *Biotechnology for Biofuels*, *4*(1), 18. doi:10.1186/1754-6834-4-18

Rai, M., & Maria de Lourdes T. M. Polizeli (Eds.). (2013). *Fungal enzymes*. Boca Raton, FL: CRC Press.

Raj, A., Kumar, S., & Singh, S. K. (2013). A highly Thermostable xylanase from *Stenotrophomonas maltophilia*: Purification and partial characterization. *Enzyme Research*, *2013*, 1–8. doi:10.1155/2013/429305

Ralph, J., Hatfeld, R. D., Lu, F., Grabber, H. J., Jung, H. G., Han, J. S. & Ralph, S.A. (1995). Kenaf˝s amazing lignin. In: *Proceedings of the 8th International Symposium on Wood and Pulping Chemistry*. June 6–9, Helsinki, Finland, Vol.II. Gummerus Kirjapoino Oy: Jyvaskula; pp.125–128.

Reid, I. D., & Paice, M. G. (1992). Biological bleaching of kraft paper pulp. *Frontiers in Industrial Mycology*. doi:10.1007/978-1-4684-7112-0_8

Reid, J., Ricard, M. (2000). Pectinase in paper making: Solving retention problems in mechanical pulps bleached with hydrogen peroxide. *Enzyme and Microbial Technology, 26*, 115-123.

Reyes, P., Teixeira Mendonca, R., Rodriguez, J., Fardim, P., & Vega, B. (2013). Characterization of the hemicellulosic fraction obtained after pre-hydrolysis of *pinus radiata* wood chips with hot-water at different initial pH. *Journal of the Chilean Chemical Society*, *58*(1), 1614–1618. doi:10.4067/s0717-97072013000100024.

Robl, D., da Delabona, P., Mergel, C., Rojas, J., Costa, P. dos, Pimentel, I., … Padilla, G. (2013). The capability of endophytic fungi for production of hemicellulases and related enzymes. *BMC Biotechnology*, *13*(1), 94. doi:10.1186/1472-6750-13-94

Roda, J.-M., & Rathi, S. (2006). *Asia Pro Eco program: Feeding china's expanding demand for wood pulp: A diagnostic assessment of plantation development, fiber supply, and impacts on natural forests in china and in the south east Asia Region*. Jakarta, Indonesia: Center for International Forestry Research.

Rodriguez-Fernandez, D. E., Rodriguez-Leon, J. A., Carvalho, J. C., Sturm, W., Soccol, C. R. (2011). The behaviour of kinetic parameters in production of pectinase and

xylanase by solid state fermentation. *Bioresource Technology, 102*, 10657-10662.

Roussos, S., Soccol, C. R., Pandey, A., & Augur, C. (2013). *New horizons in biotechnology* (1st ed.). Dordrecht: Springer Netherlands.

Rowell, J. (1997). Chapter 5. Paper and Composites from Agro-based Resources. In *Chemical Composition of Fibers* (pp. 83–134).

Rowell, M.R. & Han, J.S. (1999) Changes in kenaf properties and chemistry as a function of growing time, In *Kenaf Properties, Processing and Products*; Missisippi State University, Agriculture & Bio Engineering. pp 34-41.

Rowell, R. M. (Ed.). (2012). *Handbook of wood chemistry and wood composites, Second edition* (2nd ed.). Boca Raton, FL: Taylor & Francis.

Rowell, R. M., & Stout, H. P. (2007). Jute and Kenaf. In M. Lewin (Ed.), *Handbook of Fiber Chemistry* (3rd ed.) (pp. 406–448). Boca Raton: Taylor & Francis.

Rowell, R. M., Han, J. S. & Rowell, J. S. (2000). Characterization and factors effecting fibre properties. In *Natural Polymer and Agrofibre Composites.* Elisabete, J. Alcides, L. L. & Matuso, H. C. (Eds). Brasil: Emrapa Instrumentacao Agropecuaria.

Rowell, R. M., Young, R. A., & Rowell, J. K. (1996). *Paper and composites from Agro-Based resources*. United States: CRC Press.

Ruiz-Dueñas, F. J., & Martínez, Á. T. (2009). Microbial degradation of lignin: How a bulky recalcitrant polymer is efficiently recycled in nature and how we can take advantage of this. *Microbial Biotechnology*, *2*(2), 164–177. doi:10.1111/j.1751-7915.2008.00078.x

Sa´-Pereira, P., Mesquita, A., Duarte, J. C., Barro, M. R. A., Costa-Ferreira, M. (2002). Rapid production of thermostable cellulase-free xylanase by a strain of *Bacillus subtilis* and its properties. *Enzyme Microbiology Technology, 30*, 924–933.

Saher, S., Piqueras, A., Hellin, E., & Olmos, E. (2005). Pectin methyl esterases and pectins in normal and hyperhydric shoots of carnation cultured in vitro. *Plant Physiology and Biochemistry*, *43*(2), 155–159. doi:10.1016/j.plaphy.2005.01.017.

Saitou, N., & Nei, M. (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution, 4*, 406-425.

Sakthiselvan, P., Naveena, B., & Partha, N. (2014). Molecular characterization of a xylanase-producing fungus isolated from fouled soil. *Brazilian Journal of Microbiology*, *45*(4), 1293–1302. doi:10.1590/s1517-83822014000400020

Salariato, D., Diorio, L. A., Mouso, N., Forchiassin, F. (2010). Extraction and characterization of polygalacturonase of *Fomes sclerodermeus* produced by solid-state fermentation. *Revista Argentina de Microbiologia, 42*, 57-62.

Saleh, M., Asa'ari, A. Z., Jasmani, L., Othman, M. S., Md Tahir, P., Harun, J., Hashim, N., Mohd Yusof, M. N., Singaram, Saffian, H. A. (2012). *Kenaf: a potential fibre for pulp and paper manufacture*. Kuala Lumpur: Malaysian Timber Industry Board.

Salit, M. S. (2014). Tropical natural Fibres and their properties. *Tropical Natural Fibre Composites*. doi:10.1007/978-981-287-155-8_2

Samain, E., Touzel, J. P., Brodel, B. & Debeire, P. (1992). Isolation of a thermophilic bacterium producing high levels of xylanase. In *Xylans and xylanases*. Progress in biotechnology, Vol. 7, (Visser, J., Beldman, G., Kusters-van Someren, M.A. and Voragen, A.G.J, Eds.) pp. 467-470. Amsterdam: Elsevier Science Publishers.

Sánchez, S., Chávez, A., Forero, A., García-Huante, Y., Romero, A., Sánchez, M., … Ruiz, B. (2010). Carbon source regulation of antibiotic production. *The Journal of Antibiotics*, *63*(8), 442–459. doi:10.1038/ja.2010.78

Sanghvi, G., Jivrajani, M., Patel, N., Jivrajani, H., Bhaskara, G. B., & Patel, S. (2014). Purification and characterization of Haloalkaline, organic solvent stable Xylanase from newly isolated Halophilic Bacterium-OKH. *International Scholarly Research Notices*, *2014*, 1–10. doi:10.1155/2014/198251

Sathyanarayana, N. G., Manoj, N., & Kumar, D. S. (2007). Structural and biochemical properties of Pectinases. *Industrial Enzymes*. doi:10.1007/1-4020-5377-0_7

Satyanarayana, T., Littlechild, J., & Kawarabayasi, Y. (2014). *Thermophilic microbes in environmental and industrial biotechnology: Biotechnology of Thermophiles* (2nd ed.). Netherlands: Springer.

Schaechter, M. (2014). *Encyclopedia of microbiology* (3rd ed.). Amsterdam: Elsevier/Academic Press.

Schofield, L. R. & Daniel, R. M. (1993). Purification and properties of a β-1-4-xylanase from a cellulolytic extreme thermophile expressed in *Escherichia coli*. *International Journal of Biochemistry, 25*(4), 609-617.

Segato, F., Damásio, A. R. L., de Lucas, R. C., Squina, F. M., & Prade, R. A. (2014). Genomics review of holocellulose deconstruction by Aspergilli. *Microbiology and Molecular Biology Reviews*, *78*(4), 588–613. doi:10.1128/mmbr.00019-14

Sen, S. & Satyanarayana, T. (1993). Optimization of alkaline protease production by thermophilic *Bacillus licheniformis* S-40. *Indian Journal of Microbiology*, *33*(1), 43-47.

Senior, D. J., & Hamilton, J. (1993). Xylanase treatment for the bleaching of softwood kraft pulps: the effect of chlorine dioxide substitution. *TAPPI Journal*, *76*(8), 200–206

Sepahy, A., Ghazi, S., & Sepahy, M. (2011). Cost-Effective Production and Optimization of Alkaline Xylanase by Indigenous *Bacillus mojavensis* AG137 Fermented on Agricultural Waste. *Enzyme Research*, 1-9.

Sethi, B. K., Jana, A., Nanda, P. K., Mohapatra, P. K. Das, & Sahoo, S. L. (2015). Thermostable acidic protease production in *Aspergillus terreus* NCFT 4269.10 using chickling vetch peels. *Journal of Taibah University for Science*. doi:10.1016/j.jtusci.2015.11.001

Sethi, B. K., Nanda, P. K., & Sahoo, S. (2016). Enhanced production of pectinase by *Aspergillus terreus* NCFT 4269.10 using banana peels as substrate. *3 Biotech*, *6*(1), . doi:10.1007/s13205-015-0353-y

Sethi, S., Datta, A., Gupta, B. L., & Gupta, S. (2013). Optimization of Cellulase production from bacteria isolated from soil. *ISRN Biotechnology*, *2013*, 1–7. doi:10.5402/2013/985685

Shah, A. R., Madamwar, D. (2005). Xylanase production by a newly isolated *Aspergillus foetidus* strain and its characterization. *Process Biochemistry*, *40*, 1763-1771.

Sharma, D. C., & Satyanarayana, T. (2012). Biotechnological potential of agro residues for economical production of thermoalkali-stable pectinase by *Bacillus pumilus* dcsr1 by solid-state fermentation and its efficacy in the treatment of ramie fibres. *Enzyme Research*, *2012*, 1–7. http://doi.org/10.1155/2012/281384.

Sharma, D. C., Satyanarayana, T., (2006). A marked enhancement in the production of a highly alkaline and thermostable pectinase by *Bacillus pumilus* dcsr1 in submerged fermentation by using statistical methods. *Bioresource Technology*, *97*(5), 727–733.

Sharma, H. S. S. (1987). Enzymatic degradation of residual non-cellulosic polysaccharides present on dew-retted flax fibres. *Applied Microbiology and Biotechnology*, *26*, 358-362.

Sharma, M., Kumar, A. (2013). Xylanases: An Overview. *British Biotechnology Journal*, *3*(1), 1-28.

Shen, D., Xiao, R., Gu, S., & Zhang, H. (2013). The overview of thermal decomposition of cellulose in lignocellulosic biomass. *Cellulose - Biomass Conversion*. doi:10.5772/51883

Shi, P., Du, Y., Yang, H., Huang, H., Zhang, X., Wang, Y., & Yao, B. (2015). Molecular characterization of a new alkaline-tolerant xylanase from *Humicola insolens* Y1. *BioMed Research International*, *2015*, 1–7. doi:10.1155/2015/149504

Shoham, Y., Schwartz, Z., Khasin, A., Gat, O., Zosim, Z. & Rosenberg, E. (1992). Delignification of wood pulp by a thermostable xylanase from *Bacillus sterothermophius* strain T-6. *Biodegradation*, *3*, 207-218.

Shulami, S., Shenker, O., Langut, Y., Lavid, N., Gat, O., Zaide, G., … Shoham, Y. (2014). Multiple regulatory mechanisms control the expression of the *Geobacillus stearothermophilus* gene for extracellular xylanase. *Journal of Biological Chemistry*, *289*(37), 25957–25975. doi:10.1074/jbc.m114.592873

Silva, L. A. O., Terrasan, C. R. F., & Carmona, E. C. (2015). Purification and characterization of xylanases from *Trichoderma inhamatum*. *Electronic Journal of Biotechnology*, *18*(4), 307–313. doi:10.1016/j.ejbt.2015.06.001

Singh, A., Kaur, A., Dua, A., & Mahajan, R. (2015). An efficient and improved methodology for the screening of industrially valuable xylano-pectino-cellulolytic microbes. *Enzyme Research*, *2015*, 1–7. http://doi.org/10.1155/2015/725281.

Sjostrom, E. (2014). *Wood chemistry: Fundamentals and applications*. United States: Academic Press.

Smook, G. A. (2003). *Handbook for pulp and paper Technologists* (3rd ed.). Vancouver: Angus Wilde Publications.

Soares M.M.C.N., da Silva, R., Gomes, E. (1999). Screening of bacterial strains for pectinolytic activity: characterization of the polygalacturonase produced by *Bacillus* sp. *Annual Review of Microbiology, 30*, 299-303.

Soriano, M., Diaz, P., & Pastor, F. I. J. (2005). Pectinolytic systems of two aerobic sporogenous bacterial strains with high activity on pectin. *Current Microbiology*, *50*(2), 114–118. http://doi.org/10.1007/s00284-004-4382-8.

Srinivasan, M.C. & Rele, M.V. (1995) Cellulase-free xylanases from microorganisms and their application to pulp and paper biotechnology: an overview. *Indian Journal of Microbiology*, *35*(2), 93-101.

Srivastava, S. K., Gopalkrishnan, K. S., & Ramachandran, K. B. (1987). The production of β-glucosidase in shake-flasks by *Aspergillus wentii*. *Journal of Fermentation Technology*, 65(1), 95–99. doi:10.1016/0385-6380(87)90071-9

Sticklen, M. B. (2008). Plant genetic engineering for biofuel production: Towards affordable cellulosic ethanol. *Nature Reviews Genetics*, *9*(6), 433–443. doi:10.1038/nrg2336

Sudeep, P. G., Absar, A., Mala, B. R. (2001). A novel thermostable xylanase from *Thermomonospora* sp: influence of additives on thermostability. *Bioresource Technology, 78*, 221-234.

Suess, H. U., & Seuss, H. U. (2010). *Pulp bleaching today*. New York: Walter de Gruyter & Co.

Sujani, S., & Seresinhe, R. T. (2015). Exogenous enzymes in Ruminant nutrition: A review. *Asian Journal of Animal Sciences*, *9*(3), 85–99. doi:10.3923/ajas.2015.85.99

Summerscales, J., Dissanayake, N. P. J., Virk, A. S., & Hall, W. (2010). A review of bast fibres and their composites. Part 1 – Fibres as reinforcements. *Composites Part A: Applied Science and Manufacturing*, *41*(10), 1329–1335. doi:10.1016/j.compositesa.2010.06.001.

Sunnotel, O., & Nigam, P. (2002). Pectinolytic activity of bacteria isolated from soil and two fungal strains during submerged fermentation. *World Journal of Microbiology and Biotechnology*, (18), 835–839.

Swain, M. R., & Ray, R. C. (2010). Production, characterization and application of a Thermostable Exo-polygalacturonase by *Bacillus subtilis* CM5. *Food Biotechnology*, *24*(1), 37–50. doi:10.1080/08905430903320958

Tamura, K., Dudley, J., Nei, M., Kumar, S. (2007). MEGA4: Molecular evolutionary genetics analysis (mega) software version 4.0. *Molecular Biology and Evolution, 24*, 1596-1599.

Tamura, K., Stecher G., Peterson, D., Filipski, A., & Kumar, S. (2013). MEGA6: Molecular evolutionary genetics analysis version 6.0. *Molecular Biology and Evolution, 30*, 2725-2729.

TAPPI. (1996). *Tappi Test Methods*. Atlanta, GA: TAPPI Press.

Techapun, C., Poosaran, N., Masanori, W., Sasaki, K. (2003). Thermostable and alkaline-tolerant microbial cellulose-free xylanases produced from agricultural wastes and the properties required for use in pulp bleaching bioprocesses: a review. *Process Biochemistry, 38*, 1327–1340.

Tewari, R., Tewari, R., & Hoondal, G. (2005). Microbial pectinases. *Methods in Biotechnology, Vol. 17: Microbial Enzymes and Biotransformations*, *17*, 191–208. Retrieved from http://agris.fao.org/agris-search/search/display.do?f=2003/NL/NL03008.xml;NL2003686266

Thakur, A., Pahwa, R., Singh, S., & Gupta, R. (2010). Production, purification, and characterization of Polygalacturonase from *Mucor circinelloides* ITCC 6025. *Enzyme Research*, *2010*, 1–7. doi:10.4061/2010/170549.

Thakur, V. V., Jain, R. K., & Mathur, R. M. (2012). Studies on xylanase and laccase enzymatic prebleaching to reduce chlorine-based chemicals during CEH and ECF bleaching. *BioResources*, *7*(2), 2220–2235. doi:10.15376/biores.7.2.2220-2235

Thermo. (2015). *Storing bacterial samples for optimal viability*. Retrieved February 10, 2016, from Thermo Scientific, http://www.thermoscientific.com/content/tfs/en/about-us/general-landing-page/storing-bacterial-samples-for-optimal -viability.html

The Star. (2015). *Boosting income in Malaysia*. Retrieved February 20, 2016, from The Star Online,

http://m.thestar.com.my/story.aspx?hl=Boosting+income+in+Malaysia+northern+states+to+RM48000+per+capita&sec=business&id=%7B8F57D16A-9CF9-4393-B0A2-258F9BC2B699%7D

Thomas, R., Singh, S.P., Subrahmanyam, S.V., (2007). A study on oxygen delignification of *Melocanna baccifera* (Muli bamboo) kraft pulp. *BioResources*, *2*(3), 430–441.

Thompson, J. D., Higgins, D. G., & Gibson, T. J. (1994). CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. *Nucleic Acids Research, 22*, 4673-4680.

Tishkov, V. I., Uglanova, S. V., Fedorchuk, V. V., & Savin, S. S. (2010). Influence of ion strength and ph on thermal stability of yeast formate dehydrogenase. *Acta Naturae*, *2*(2), 82–88.

Tork, S., Aly, M. M., Alakilli, S. Y., Al-Seeni, M. N. (2013). Production and characterization of thermostable xylanase from *Bacillus subtilis* XP10 isolated from marine water. *African Journal of Biotechnology, 12*(8), 780-790.

Touzinsky, G. F. (1993). Kenaf in secondary fibers and nonwood pulping, 3rd Ed. (F. Hamilton and B. Leopold, Tech. Eds.), Pulp and Paper Manufacture, Vol. 3, pp.106- 109, Joint Textbook Committee of the Paper Industry: Atlanta, GA, Montreal.

Unsworth, L. D., van der Oost, J., & Koutsopoulos, S. (2007). Hyperthermophilic enzymes − stability, activity and implementation strategies for high temperature applications. *FEBS Journal*, *274*(16), 4044–4056. doi:10.1111/j.1742-4658.2007.05954.x

Valls, C., & Roncero, M. B. (2009). Using both xylanase and laccase enzymes for pulp bleaching. *BioResource Technology*,*100*(6), 2032–2039. doi:10.1016/j.biortech.2008.10.009

Van Hoed, V., Depaemelaere, G., Ayala, J. V., Santiwattana, P., Verhe, R., & De Greyt, W. (2006). Influence of chemical refining on the major and minor components of rice brain oil. *Journal of the American Oil Chemists' Society*, *83*(4), 315–321. doi:10.1007/s11746-006-1206-y

Van-Thuoc, Hashim, S. O., Hatti-Kaul, R., & Mamo, G. (2012). Ectoine-mediated protection of enzyme from the effect of pH and temperature stress: A study using *Bacillus halodurans* xylanase as a model. *Applied Microbiology and Biotechnology*, *97*(14), 6271–6278. doi:10.1007/s00253-012-4528-8

Vermelho, A. B., Supuran, C. T., & Guisan, J. M. (2012). Microbial enzyme: Applications in industry and in bioremediation. *Enzyme Research*, *2012*, 1–2. doi:10.1155/2012/980681

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P., & Santas, R. (2004). Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production. *Industrial Crops and Products*, *19*(3), 245–254. doi:10.1016/j.indcrop.2003.10.006

Viikari, L., Kantelinen, A., Sundquist, J., & Linko, M. (1994). Xylanases in bleaching: From an idea to the industry. *FEMS Microbiology Reviews*, *13*(2-3), 335–350. http://doi.org/10.1111/j.1574-6976.1994.tb00053.x.

Viikari, L., Ranua, M., Kantelinen, A., Sundquist, J., Linko, M. (1986). Bleaching with enzymes. In *Proceedings of the 3rd international conference of biotechnology on pulp and paper industry*. Stockholm, 16–19 June, pp 67–69.

Viikari, L., Suurnäkki, A., Grönqvist, S., Raaska, L., & Ragauskas, A. (2009). Forest Products: Biotechnology in pulp and paper processing. *Encyclopedia of Microbiology (Third Edition)*. doi:10.1016/B978-012373944-5.00123-1

Viikari, L., Tenkanen, M., Suranakki, A., (2001). Biotechnology in the pulp and paper industry. *Journal. Biotechnology, 50*, 523-540.

Viikari, L., Viikari, L., & Lantto, R. (Eds.). (2002). *Biotechnology in the pulp and paper industry: 8th Icbppi meeting*. Netherlands: Elsevier Science & Technology.

Villar, J. C., Revilla, E., Gómez, N., Carbajo, J. M., & Simón, J. L. (2009). Improving the use of kenaf for kraft pulping by using mixtures of bast and core fibers. *Industrial Crops and Products*, *29*(2-3), 301–307. doi:10.1016/j.indcrop.2008.06.002.

Walsh, G. (2002). *Proteins: Biotechnology and biochemistry*. United States: Turtleback Books.

Walsh, G. (2014). Industrial enzymes: proteases and carbohydrates. In *Protein, Biochemistry and Biotechnology* (2nd ed.). United States: Wiley-Blackwell (an imprint of John Wiley & Sons Ltd).

Wang, N. S. (2009). *Glucose Assay by Dinitrosalicyclic Assay Method*. Retrieved June 12, 2016, from Department of Chemical & Biomolecular Engineering University of Maryland, http://www.eng.umd.edu/~nsw/ench485/lab4a.htm

Wang, S. L., Yen, Y. H., Shih, I. L., Chang, A. C., Chang, W. T., Wu, W. C., & Chai, Y. Der. (2003). Production of xylanases from rice bran by Streptomyces actuosus A-151. *Enzyme and Microbial Technology*, *33*(7), 917–925. http://doi.org/10.1016/S0141-0229(03)00246-1

Webber, C. L. & Bledsoe, V. K. (2002). Kenaf yield components and plant composition. In Janick, J. & Whipkey, A. (Eds), *Trends in new crops and new uses.* Alexandria, VA: ASHS Press.

Webber, C. L., Bhardwaj, H. L. & Bledsoe, V. K. (2002). Kenaf production: Fiber, feed, and seed. In Janick, J. & Whipkey, A. (Eds.), *Trends in new crops and new uses*. Alexandria, VA: ASHS Press.

Whitaker, J. R. (1991). Microbial pectolytic enzymes. In W. M. Fogarty & C. T. Kelly (Eds.), *Microbial Enzymes and Biotechnology* (1st ed.) (pp. 133–176). London: Elsevier Science.

Wong, K. K. Y., & Saddler, J. N. (1992). Trichoderma Xylanases, their properties and application. *Critical Reviews in Biotechnology*, *12*(5-6), 413–435. doi:10.3109/07388559209114234

Wood, I. M. (1981). The utilization of field crops and crop residues for paper pulp production. *Field Crop Abstract*, *34*, 557-568.

Xie, T., Chong, T., Li, W. & Long, Y. (1988). Sugar component in hemicellulose of cotton stalk and kenaf. *Cellulose Chemical Technology*, *22*, 399-403.

Yadav, R. D., Chaudhry, S., & Dhiman, S. S. (2010). Biopulping and its potential to reduce effluent loads from bleaching of hardwood kraft pulp. *BioResources*, *5*(1), 159–171.

Yang, V. W., Zhuang, Z., Elegir, G., Jeffries, T. W. (1995). Alkaline active xylanase produced by an alkaliphilic *Bacillus* sp isolated from kraft pulp. *Journal of Industrial Microbiology*, *5*, 434–441.

Yang, Z., Xu, S., Ma, X., Wang, S., (2008). Characterization and acetylation behaviour of bamboo pulp. *Wood Science Technology, 42*, 621-632.

Yu, H., & Yu, C. (2007). Study on microbe retting of kenaf fiber. *Enzyme and Microbial Technology*, *40*(7), 1806–1809. doi:10.1016/j.enzmictec.2007.02.018

Zeni, J., Cence, K., Grando, C. E., Tiggermann, L., Colet, R., Lerin, L. A., … Valduga, E. (2010). Screening of pectinase-producing microorganisms with polygalacturonase activity. *Applied Biochemistry and Biotechnology*, *163*(3), 383–392. doi:10.1007/s12010-010-9046-5

Zhang, C., Yao, J., Zhou, C., Mao, L., Zhang, G., & Ma, Y. (2013). The alkaline pectate lyase PEL168 of *Bacillus subtilis* heterologously expressed in Pichia pastoris is more stable and efficient for degumming ramie fiber. *BMC Biotechnology*, *13*(1), 26. doi:10.1186/1472-6750-13-26

Zhang, Y.-H. P., Himmel, M. E., & Mielenz, J. R. (2006). Outlook for cellulase improvement: Screening and selection strategies. *Biotechnology Advances*, *24*(5), 452–481. doi:10.1016/j.biotechadv.2006.03.003

Zhang, Z., Triplett, O. A., Nguyen, K. T., Melchior, W. B., Taylor, K., Jackson, L. S., & Tolleson, W. H. (2013). Thermal inactivation reaction rates for ricin are influenced by pH and carbohydrates. *Food and Chemical Toxicology*, *58*, 116–123. doi:10.1016/j.fct.2013.04.012

Zou, M., Guo, F., Li, X., Zhao, J., & Qu, Y. (2014). Enhancing production of alkaline polygalacturonate Lyase from *Bacillus subtilis* by fed-batch fermentation. *PLoS ONE*, *9*(3), e90392. doi:10.1371/journal.pone.0090392.

Zychlinska, A. W., Czkaj, J., Jedrychowska, B. and Zukowska, R. S. (1992). Production of xylanases by *Chaetomium globosum*. In: Xylans and xylanases. Prog. Biotechnol/ Vol.7, (Visser, J., Beldman, G., Kusters-van Someren, M.A. and Voragen, A.G.J., Eds.) pp. 493-496. Amsterdam: Elsevier Science Publishers.