BIOSUGAR PRODUCTION FROM OIL PALM MESOCARP FIBER USING CRUDE LIGNOCELLULOSIC DEGRADING ENZYMES FROM *Rhizomucor pusillus* AK2

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Explicitly dedicated to my beloved parents and my entire family for their moral support and whom during my research engagements have been supportive and understanding despite missing me

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(*In the name of Allah, the most gracious and the most merciful*)

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ABSTRACT

The oil palm industry is undergoing global expansion as a result of the demand of oil palm. Consequently, similar expansion is occurring in amounts of lignocellulosic residues generated by the industries. The conversion of these residues to biosugar is limited by the uneconomical hydrolysis process and the high cost of lignocellulolytic enzymes. Thus, this study aimed at the production of enzymes for efficient degradation of oil palm mesocarp fiber (OPMF). The sum of 6 fungi isolates, AK1 to AK6, were isolated from OPMF, and screened for lignocellulolytic enzymes production on selective medium. Further screening of these isolates were carried out on untreated OPMF using solid state fermentation (SSF). Design-Expert software version 7.0, was used to operate the 2 level fractional factorial design and Central Composite Design (CCD) for the screening and optimization of significant factors affecting lignocelluose degrading enzymes production. The activity of crude enzyme, Viscozyme and Celluclast were evaluated based on the generation of biosugar from OPMF by determining the effects of pretreatments (2% (v/v) HNO_3, 2% (w/v) NaOH and 2% (w/v) 1-Butyl-3-methylimidazolium chloride), solid loading (1-4 % w/v) and enzyme cocktail (1:1 (v/v), crude enzyme and Viscozyme, crude enzyme and celluclast, viscozyme and celluclast, and 1:1:1 (v/v) crude enzyme, Viscozyme and Celluclast). Isolate AK2 exhibited potential for lignocellulase enzyme production based on the hydrolysis zones >1.5 mm on selective media and producing CMCase (25.4 U/g), FPase, (5.5 U/g), β-glucosidase (9.8 U/g), Xylanase (68.4 U/g) and MnP (4.9 U/g) at exceptional level. The isolate was thus identified by 18S RNA gene sequencing using a universal primer ITS1-F and ITS4-R as *Rhizomucor pusillus* AK2 (KY583064). From the 2 level fractional factorial design pH, temperature, inoculum size and moisture content are the significant factors affecting the production of lignocellulolytic enzymes. Xylanase was observed to be the highest activity in the lignocellulolytic enzymes cocktail (111.01 U/g). Therefore, CCD was carried out focussing on xylanase production. At the optimum condition, xylanase (128 U/g), was obtained at pH 4.98, temperature 40.27 °C, inoculum size at $10^{8.2}$ spores/g and moisture at 80.64% using CCD. The regression model of the ANOVA was found to be significant with $p<0.0001$ and R^2 of 0.9831.Biochemical characterization of the crude enzymes indicated that the enzyme was stable at pH of 4 to 6 and temperatures of 30 to 60 °C. Enzymatic saccharification was carried out with the crude enzymes comparative to Viscozyme and Celluclast. Maximum sugar production was obtained from celluclast-saccharified OPMF (1.2 g/L) using 1% (w/v) NaOH pretreated OPMF. Maximum reducing sugar generated from enzyme cocktail was 1.8 g/L obtained from 1% (w/v) NaOH pretreated OPMF which translates to polyoses; glucose (2.59 g/L), xylose (2.1 g/L) and arabinose (0.254 g/L) at 1:1:1 (v/v) crude enzyme, viscozyme and celluclast. The performance of the enzyme cocktail customized in this study is superior to that of the individual and cocktail of commercial enzyme. The study also indicates the potential of OPMF as both a substrate for biosugar and lignocellulase enzyme production from *R. pusillus* AK2.

ABSTRAK

Industri kelapa sawit sedang mengalami perkembangan global berikutan permintaan minyak sawit yang tinggi. Kesannya, berlaku peningkatan jumlah sisa tanaman sawit oleh industri, terutamanya residu lignoselulosik. Penukaran residu ini kepada biosugar adalah terbatas dari segi ekonomi disebabkan proses hidrolisis yang mahal serta kos enzim yang tinggi. Justeru, enzim lignoselluosa yang efisien perlu dihasilkan bagi tujuan pendegradan serat mesokarp kelapa sawit (OPMF). Sejumlah 6 pencilan kulat, AK1 hingga AK6, diasingkan dari OPMF, dan disaring untuk pengeluaran enzim pendegradan lignoselluosa menggunakan medium selektif. Penyaringan lanjut terhadap pencilan dilakukan terhadap OPMF yang tidak dirawat dengan menggunakan penapaian keadaan pepejal (SSF). Perisian Design-Expert versi 7.0 digunakan untuk mengendalikan reka bentuk faktorial pecahan 2 dan reka bentuk komposit sentral (CCD) untuk penyaringan dan pengoptimuman faktor-faktor penting yang mempengaruhi pengeluaran enzim pendegradan lignoselluosa. Aktiviti enzim mentah, Viscozyme dan Celluclast dinilai berdasarkan penjanaan biosugar dari OPMF dengan menentukan kesan prarawatan (2% (v/v) HNO3, 2% (w/v) NaOH dan 2% (w/v) 1-Butyl-3-methylimidazolium chloride), pembebanan pepejal (1-4% w/v) dan koktel enzim (1:1 (v/v), enzim mentah dan Viscozyme, enzim mentah dan Celluclast, Viscozyme dan Celluclast 1:1:1 (v/v) enzim mentah, Viscozyme dan Celluclast). Pencilan AK2 mempamerkan potensi pengeluaran enzim lignoselulase berdasarkan jangkauan zon hidrolisis >1.5 mm pada media selektif dan menghasilkan CMCase (25.4 U/g), FPase, (5.5 U/g), β-glucosidase (9.8 U/g), Xilanase (68.4 U/g) dan MnP (4.9 U/g) pada tahap yang terbaik. Pengecaman pencilan *Rhizomucor pusillus* AK2 (KY583064) dilakukan menerusi urutan gen RNA 18S yang mengguna pakai primer semesta ITS1-F dan ITS4-R. Menurut reka bentuk faktorial pecahan 2, faktor pH, suhu, saiz inokulum dan kandungan lembapan adalah faktor penting yang mempengaruhi enzim lignosellulase. Dikalangan koktel enzim lignosellulase, pengeluaran xilanase adalah tertinggi (111.01U/g). Oleh itu, CCD dilakukan bagi memfokuskan peningkatan pengeluaran xilanse. Pada kondisi optimum, xilanase (128U/g) dihasilkan pada pH 4.98, suhu 40.27°C, saiz inoculum $10^{8.2}$ spora/g dan kandungan lembapan 80.64%. Model regresi ANOVA didapati signifikan dengan $p < 0.0001$ dan R^2 dari 0.9831. Pencirian biokimia enzim mentah menunjukkan enzim stabil pada pH 4 hingga 6, dan suhu 30 hingga 60°C. Sakarifikasi enzim dilakukan menggunakan Viscozyme and Celluclast sebagai perbandingan kepada enzim mentah. Pengeluaran gula maksima (1.2g/L) diperoleh hasil sakarifikasi-Celluclast OPMF yang telah dirawat menggunakan 1% (w/v) NaOH. Prarawatan OPMF menggunakan 1% (w/v) NaOH juga menghasilkan gula penurun secara maksimum 1.8g/L dari koktail enzim, yang mengandungi poliosis; glukosa (2.59 g/L), xylose (2.1 g/L) dan arabinose (0.254 g/L) pada 1:1:1 (v/v) enzim mentah, Viscozyme dan Celluclast. Prestasi enzim koktail yang disesuaikan dalam kajian ini adalah lebih baik daripada enzim individu dan koktail komersil. Kajian juga menunjukkan potensi OPMF sebagai substrat untuk pengeluaran biosugar serta enzim lignosellulase dari *R. pusillus* AK2.

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LIST OF ABBREVIATIONS

2LFFD	-	Two level Fractional Factorial Design
ANOVA	-	Analysis of Variance
BGL	-	β-glucosidase
BLAST	-	Basic Local Alignment
BMIM[Cl]	-	1-Butyl-3-methylimidazolium chloride
BSA	-	Bovine Serum Albumin
$Cacl_2$	-	Calcium chloride
CCD	-	Central Composite Design
CMC	-	Carboxymethyl cellulose
CMCase	-	Carboxymethyl cellulase
DNA	-	Deoxyribonucleic acid
DNS	-	Dinitrosalicylic acid
$FeSO_4.7H_2O$	-	Iron (II) Sulfate Heptahydrate
FESEM	-	Field Emission Scanning Electron Microscope
FPase	-	Filter paper activity
FTIR	-	Fourier Transform Infra-Red
EDTA	-	Ethylenediaminetetraacetic Acid
EtBr	-	Ethidium bromide
mL	-	Millilitre
g	-	Gram
H_2SO_4	-	Sulphuric acid
HCL	-	Hydrochloric acid
H_2O_2	-	Hydrogen peroxide
HNO_3	-	Nitric acid
HPLC		High Performance Liquid Chromatography

IUPAC	-	International Union of Pure and Applied Chemistry
KH_2PO_4	-	Monopotassium phosphate
L	-	Liter
M	-	Molar
$MgSO_4.7H_2O$	-	Magnesium sulphate
min	-	Minute
mL	-	Milliliter
mm	-	Millimeter
MMT	-	Million metric tons
mM	-	Millimolar
MnP	-	Manganese Peroxidase
MW	-	Molecular weight
NaOH	-	Sodium hydroxide
nm	-	Nanometer
OPMF	-	Oil palm Mesocarp fiber
PDA	-	Potato Dextrose Agar
pNPG	-	p-nitrophenyl β-D-glucoside
PCR	-	Polymerase Chain Reaction
RID	-	Refractive Index Detector
RSM	-	Response Surface Methodology
SSF	-	Solid State Fermentation
U/g	-	Unit of enzyme per gram
U/mL	-	Unit of enzyme per millilitre
v/v	-	Volume per volume
w/t	-	Weight percent
w/v	-	Weight per volume
$ZnSO_4.7H_2O$	-	Zinc Sulfate Heptahydrate
°C	-	Degree Celsius
%	-	Percentage
µl	-	Microliter
µm	-	Micrometre

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Oil palm is one of the most economically and highly potential oil crops, a native of West Africa, belonging to the family of *Palmacea*, species of *Elaeis guineensis*. Due to the favourability of the weather towards this crop, its cultivation covers large hectares farm in Malaysia. The overall plantation area in 2007 was 4.17 million hectares, slightly increased to 4.48 million hectares in 2008 (Wahid and Chan, 2007) to 5.74 million hectares in 2016 (Malaysian Palm Oil Board, 2017).

The waste generated in the processing mills are usually in the form of oil palm mesocarp fibre, empty fruit bunches (EFB), palm kernel shells (PKS) and palm oil mill effluent (POME). Evaluation on the annual generation of the biomass showed that, roughly, 77.24 million tons of biomass is yearly generated by oil palm mills. Out of which comprises 44.48 million tons of palm oil fronds, 6.93 million tons of empty fruit bunches, 13.97 million tons of trunk, 7.29 million tons of palm fibre and 4.21 million tons of shell, the increase in these higher values is even expected till 2020 (Ng *et al*.,

2012). Oil palm mesocarp fibre (OPMF) is a lignocellulose waste consisting of cellulose, hemicellulose and lignin. Fundamentally, cellulose and hemicellulose polymers are pools of sugars, which can be explored after degradation of lignin which is a tough compound physically sealing the sugar polymers. Thus, the degradation of cellulose and hemicellulose into monomers sugar requires enzyme complexes system that are hydrolytic and lignolytic in nature to catalyze in synergy.

To enable the accessibility of the enzymes to the fibres for degradation, various works suggested pretreatment using chemicals (Sun and Cheng, 2002; Auxenfans *et al*., 2017). However, such harsh treatments result in losses of sugars from cellulose and hemicellulose, and the lignin can be degraded into inhibitory products (Mussatto and Roberto, 2004). The size reduction process which is a form of physical pretreatment enables enzymatic conversion of biomass (Ang *et al*., 2015a). Besides physical process, biological treatment for lignin degradation is an oxidative process, involving three major enzymes, lignin peroxidases (LiP), manganese peroxidases (MnP) and laccases (Lac). LiP and MnP oxidize the substrate by two successive one-electron oxidation steps with cation radical formation as intermediate (Sánchez, 2009).

Cellulases and xylanases are two major hydrolytic enzymes responsible for degradation of lignocellulosic resources into biosugar. Cellulases include endoglucanase, exoglucanase and β-glucosidase that act synergistically to degrade cellulose to glucose. Xylanase is an enzyme that catalyses the hydrolysis of xylan backbone to produce pentose sugars as xylose and arabinose, and hexose sugar as mannose and galactose (Chávez *et al*., 2006). The glucose and xylose produce as a result of cellulases and xylanases action become available as substrate for producing biofuel.

The cost of enzyme production together with the raw material are the two leading contributors to the overall biosugar and biofuel cost such as bioethanol (Wingren *et al*.,

2003; Galbe and Zacchi, 2007). In the year 2010, the demands in industrial enzymes in the global market were valued at $3.6 billion; which grow at a compounded annual growth rate of 9.1% to reach $6 billion by 2016 (Dewan, 2012). World record on sugar, estimated in 2010 that the production of sugar was 159 7 million metric tons (MMT) below the need estimate of 161.7 MMT, and 178 MMT less than 181 MMT in 2017 (Licht, 2017). Global consumption continues to expand between 1.5 to 2%, driven largely by population growth (Nyberg, 2006). Since the key obstacle hindering biosugar and biofuel production from biomass is the general absence of low cost technology for lignocellulosic degrading enzyme production and the development of an economically viable hydrolysis process (Kuhad *et al*., 2016). Development of an economically viable lignocellulosic degrading enzyme for the hydrolysis process is a key solution to identifying competent strains that can degrade lignocellulosic biomass considering the vast majority of the fungal kingdom remains unexplored for industrial applications (Seppälä *et al*. (2017).

Filamentous fungi are good producers of extracellular lignocellulolytic enzymes and can be cultivated very easily (Adhyaru *et al*., 2015). Research findings have indicated that the fermentation method can markedly influence enzyme production (Elisashvili *et al*., 2001). Solid state fermentation has been ranked as the most suitable method for fungi cultivation and lignocellulolytic enzyme production, because SSF growth condition is similar to their natural niche (Pandey *et al*., 1999). The productions of lignocellulosic degrading enzymes in the form of cellulase, xylanase, ligninase from oil palm biomass such as oil palm trunk (Ang *et al*., 2015b) Palm kernel (Kheng and Omar, 2005), palm oil mill (Prasertsan *et al*., 1997), oil palm empty fruit bunch (Ottenheim *et al*., 2014) have been intensively studied. None of the available literature reported the production of lignocellulose degrading enzymes using treated or untreated mesocarp fibre. This is a clear indication that the biomass in question has been pint-sized in literature and requires exploration to unfold its biotechnological potentials. As a lignocellulose they may serve as an inducer for producing large titres of low cost enzymes that can be applied in producing biosugar at increased solid loading.

1.2 Statement of the problem

Global record on sugar forecast has shown that in 2010 the production of sugar was 159 MMT below the consumption value of 161.7 million metric tons (MMT) while in 2011 the production was 165.4 MMT against the consumption 162.7 MMT. In 2016 production was 174.7 below the consumption value of 180. The production in 2017 was 178 MMT below consumption 181 MMT in food and biofuel industries (Licht *et al*., 2017). This imbalance of consumption against the production is posing a threat in world sugar production that necessitates a drastic measure to upset the production and the consumption. Conversely, oil palm production has been on increase as a result of global demand, which caused a significant increase in the area of cultivation (Yacob, 2008). For that reason, it is believed that enormous sugar polymer rich lignocellulose biomass will consistently be generated in the mills.

Lignocellulosic wastes could be harnessed as potential raw materials for economic production of high added value products such as biosugar, biocatalysts, and biofuel that currently remains the subject of considerable attention (Iqbal and Kamal, 2012). The high cost of converting lignocellulose by enzymatic hydrolysis is a recurring problem that limits the production of biosugar and to subsequently bioethanol from a renewable biomass (Hess, 2008). Low hydrolysis rates remain the main obstacle in lignocellulosic biosugar production with enzymes, which could be improved through using more digestible feedstocks in combination with increases in lignocellulase activity. To fully realize the potential of sustainable biosugar production, there is a great need to identify novel organisms, enzymes and molecules with activities that can be harnessed for a range of breakdown and lignocellulosic conversion applications (Monciardini *et al*., 2014, Seppälä *et al*., 2017). Thus, the need for the exploration of a new type of fungus that can produce enzymes to convert lignocellulosic biomass to biosugar.

1.3 Research objectives

This study aims at finding a new source of biosugar and competent lignocellulosic degrading fungi for biosugar production. In order to achieve the mentioned objectives, the following need to be addressed:

I. To characterize the composition of lignin, cellulose and hemicellulose of oil palm mesocarp fibre (OPMF).
II. To isolate, screen and identify lignocellulosic degrading fungi from oil palm mesocarp fibre using 18S rDNA gene sequencing.
III. To screen the significant parameters influencing the production of lignocellulosic degrading enzymes using 2-Level fractional factorial design.
IV. To optimize the significant parameters influencing the production of lignocellulosic degrading enzymes by using Response Surface Methodology (RSM).
V. To compare the performance of crude lignocellulolytic degrading enzyme cocktail produced by *Rhizomucor pusillus* AK2 and commercial enzyme in saccharification of oil palm mesocarp fibre for biosugar production.

1.4 Scope of research

The research was conducted within the following limits:

I. The characterization of OPMF was conducted to determine the content of lignin, cellulose and hemicellulose.

II. The media used for the fungi isolation was Potato dextrose agar (PDA) agar. Qualitative screening to determine the potential lignocellulase enzymes producers was based on hydrolysis zones on Carboxymethyl cellulose (CMC) and Xylan agar plates. Quantitative screening was conducted based on CMCase, FPase, β-glucosidase, xylanase and manganese peroxidase activities via solid state fermentation of OPMF. Identification of the potential isolates based on 18S rRNA gene sequencing was based on universal primer ITS 1 (F) and ITS 4 (R).

III. The parameters screen for the 2-Level fractional factorial design was based on physiological factors, namely; pH, temperature, incubation days, inoculum size and moisture content. The available software used for the experiment was Design expert software (version 7.0).

IV. Optimization of significant factors was carried using Central composite design (CCD) of Response surface methodology (RSM) based on the data generated by Design expert software (version 7.0).

V. Evaluation of the crude lignocellulosic degrading enzyme cocktail produced by *Rhizomucor pusillus* enzyme was evaluated alongside two commercial enzymes celluclast and viscozyme based on the production of biosugar from OPMF.

1.5 Significance of study

Residues from oil palm mill such oil palm mesocarp fibre (OPMF) is a lignocellulose waste containing cellulose and hemicellulose. Fundamentally, cellulose and hemicellulose polymers are pools of fermenting sugars that can be used by various industries such as biofuel, pharmaceuticals and food and beverages. Enzymatic conversion of the OPMF to the biosugar does not inflict any pollution problem. OPMF seems to be a bioresource which can be entirely converted into biosugar, a concept of "waste to wealth approach". The growing interest on use of OPMF for bioconversion to

biosugar is justified as the substrate is of lower cost and renewable. The study gives insight into the better combination of parameters from the use of Central Composite Design (CCD) statistical optimization in achieving enzymes production, thus paving a way for reduced enzyme cost a major factor contributing to higher biosugar and biofuel cost. This study provides a better understanding of the synergy between cellulases and hemicellulases application via the saccharification of OPMF substrates, thereby enable effective biosugar production at elevated solid loading in enzymatic hydrolysis.

Furthermore, every palm oil processing company is aiming at avoiding unnecessary waste accumulation. The application of OPMF in fermentation and saccharification will improve the revenue of the palm oil mill industry. By and large contribute to the nation's economy in addition attaining environmental sustainability.

REFERENCES

Abdul Khalil, H.P.S., Siti Alwani, M., Ridzuan, R., Kamarudin, H. and Khairul, A. (2008). Chemical composition, morphological characteristics, and cell wall structure of Malaysian oil palm fibres. *Polymer-Plastics Technology and Engineering*. 47(3), 273-280.

Acevedo, F., Pizzul, L., Castillo, M.D.P., Rubilar, O., Lienqueo, M.E., Tortella, G. and Diez, M.C. (2011). A practical culture technique for enhanced production of manganese peroxidase by Anthracophyllum discolor Sp4. *Brazilian Archives of Biology and Technology*. 54(6), 1175-1186.

Acosta Aranda, J.A., Robledo, A., Montanéz-Sáen, C. J. and Cruz-Hernández, M. (2013). Industrial Interest Enzyme Production by *Rhizomucor pusillus*. *12th international symposium on the genetics of industrial microorganisms.* 23-28 June. Cancun, Mexico.

Adams, P.R. and Deploey, J.J. (1976). Amylase production by Mucor miehei and Mucor pusillus [Fungi]. *Mycologia*.

Adhyaru, D. N., Bhatt, N. S. and Modi, H. A. (2015). Optimization of upstream and downstream process parameters for cellulase-poor-thermo-solvent-stable xylanase production and extraction by Aspergillus tubingensis FDHN1. *Bioresources and Bioprocessing*. *2*(1), 1-14.

Agbor, V.B., Cicek, N., Sparling, R., Berlin, A. and Levin, D.B. (2011). Biomass pretreatment: fundamentals toward application. *Biotechnology advances*. 29(6), 675-685.

Aguilar, C.N., Aguilera-Carbo, A., Robledo, A., Ventura, J., Belmares, R., Martinez, D., Rodríguez-Herrera, R. and Contreras, J. (2008). Production of antioxidant

nutraceuticals by solid-state cultures of pomegranate (Punica granatum) peel and creosote bush (Larrea tridentata) leaves. *Food Technology and Biotechnology*. 46(2), 218-222.

Ahmed, S., Riaz, S. and Jamil, A. (2009). Molecular cloning of fungal xylanases: an overview. *Applied Microbiology and Biotechnology*. 84(1), 19-35.

Alam, M.Z., Mamun, A.A., Qudsieh, I.Y., Muyibi, S.A., Salleh, H.M. and Omar, N.M. (2009). Solid state bioconversion of oil palm empty fruit bunches for cellulase enzyme production using a rotary drum bioreactor. *Biochemical Engineering Journal*. 46(1), 61-64.

Alves, E. F., Bose, S. K., Francis, R. C., Colodette, J. L., Iakovlev, M. and Van Heiningen, A. (2010). Carbohydrate composition of eucalyptus, bagasse and bamboo by a combination of methods. *Carbohydrate Polymers*. 82(4), 1097-1101.

Alvira, P., Tomás-Pejó, E., Ballesteros, M.J. and Negro, M.J. (2010). Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis: a review. *Bioresource technology*. 101(13), 4851-4861.

Anderson, M.J. and Whitcomb, P.J. (2000). DOE simplified: practical tools for effective experimentation. *Portland, Or.: Productivity. xiii*.

Anderson, J.L., Ding, J., Welton, T. and Armstrong, D.W. (2002). Characterizing ionic liquids on the basis of multiple solvation interactions. *Journal of the American Chemical Society*. 124(47), 14247-14254.

Anderson, I.C., Campbell, C.D. and Prosser, J.I. (2003). Potential bias of fungal 18S rDNA and internal transcribed spacer polymerase chain reaction primers for estimating fungal biodiversity in soil. *Environmental Microbiology*. 5(1), 36-47.

Ang, S. K., Shaza, E. M., Adibah, Y., Suraini, A. A. and Madihah, M. S. (2013). Production of cellulases and xylanase by Aspergillus fumigatus SK1 using untreated oil palm trunk through solid state fermentation. *Process Biochemistry*. *48*(9), 1293-1302.

Ang, S. K., Yahya, A., Abd Aziz, S. and Md Salleh, M. (2015a). Isolation, Screening, and Identification of Potential Cellulolytic and Xylanolytic Producers for Biodegradation of Untreated Oil Palm Trunk and Its Application in

Saccharification of Lemongrass Leaves. *Preparative Biochemistry and Biotechnology*. *45*(3), 279-305.

Ang, S. K. and Abd-Aziz, S. (2015b). Potential Uses of Xylanase-Rich Lignocellulolytic Enzymes Cocktail for Oil Palm Trunk (OPT) Degradation and Lignocellulosic Ethanol Production. *Energy & Fuels*. 29(8), 5103-5116.

Antony, J. (2003). *Design of Experiments for Engineers and Scientists*. New York: Butterworth-Heinemann

Arora, D.S., Chander, M. and Gill, P.K. (2002). Involvement of lignin peroxidase, manganese peroxidase and laccase in degradation and selective ligninolysis of wheat straw. *International Biodeterioration & Biodegradation*. 50(2), 115-120.

Arulanandham, T.V. and Palaniswamy, M. (2014). Production of xylanase by Aspergillus nidulans isolated from litter soil using rice bran as substrate by solid state fermentation. *World journal of pharmacy and pharmaceutical sciences*. 3(7), 1805-1813.

Asgher, M., Wahab, A., Bilal, M. and Iqbal, H.M.N. (2016). Lignocellulose degradation and production of lignin modifying enzymes by Schizophyllum commune IBL-06 in solid-state fermentation. *Biocatalysis and Agricultural Biotechnology*. 6, 195-201.

Auxenfans, T., Husson, E. and Sarazin, C. (2017). Simultaneous pretreatment and enzymatic saccharification of (ligno) celluloses in aqueous-ionic liquid media: A compromise. *Biochemical Engineering Journal*. 117, 77-86.

Azad, K., Halim, M.A. and Hossain, F. (2013). Optimization of culture conditions for the production of xylanase by two thermophilic fungi under solid state fermentation. *Journal of the Asiatic Society of Bangladesh, Science*. 39(1), 43-51.

Azaliza, S. W., Madihah, M. S., Suraini, A. A., Osman, H. and Nor, M. M. (2009). Medium optimization for chitinase production from *Trichoderma virens* using central composite design. *Biotechnology and Bioprocess Engineering*. 14, 781-787.

Azin, M., Moravej, R. and Zareh, D. (2007). Production of xylanase by Trichoderma longibrachiatum on a mixture of wheat bran and wheat straw: Optimization of

culture condition by Taguchi method. *Enzyme and microbial technology*. 40 (4), 801-805.

Bælum, J., Henriksen, T., Hansen, H.C.B. and Jacobsen, C.S. (2006). Degradation of 4-chloro-2-methylphenoxyacetic acid in top-and subsoil is quantitatively linked to the class III tfdA gene. *Applied and environmental microbiology*. 72(2), 1476-1486.

Bailey, M.J., Biely, P. and Poutanen, K. (1992). Interlaboratory testing of methods for assay of xylanase activity. *Journal of biotechnology*. 23(3), 257-270.

Bakri, Y., Jacques, P. and Thonart, P. (2003). Xylanase production by Penicillium canescens 10–10c in solid-state fermentation. In *Biotechnology for Fuels and Chemicals* (pp. 737-748). Humana Press.

Bala, K., Chander, J., Handa, U., Punia, R.S., Raj, R. and Aggarwal, S. (2014). Isolation and identification of Rhizomucor pusillus from rhinofacial mucormycosis in a diabetic patient. *JMM Case Reports*. 1(3).

Balat, M. (2011). Production of bioethanol from lignocellulosic materials via the biochemical pathway: a review. *Energy conversion and management*. 52(2), 858-875.

Bansal, N., Tewari, R., Soni, R. and Soni, S.K. (2012). Production of cellulases from Aspergillus niger NS-2 in solid state fermentation on agricultural and kitchen waste residues. *Waste management*. 32(7), 1341-1346.

Başkan, K.S., Tütem, E., Akyüz, E., Özen, S. and Apak, R. (2016). Spectrophotometric total reducing sugars assay based on cupric reduction. *Talanta*. 147,162-168.

Behera, S.S. and Ray, R.C. (2016). Solid state fermentation for production of microbial cellulases: recent advances and improvement strategies. *International journal of biological macromolecules*. 86, 656-669.

Bezerra, M.A., Santelli, R.E., Oliveira, E.P., Villar, L.S. and Escaleira, L.A. (2008). Response surface methodology (RSM) as a tool for optimization in analytical chemistry. *Talanta*.76(5), 965-977.

Bhattacharya, S.S., Garlapati, V.K. and Banerjee, R. (2011). Optimization of laccase production using response surface methodology coupled with differential evolution. *New biotechnology*. 28(1), 31-39.

Bissoon, S., Christov, L. and Singh, S. (2002). Bleach boosting effects of purified xylanase from Thermomyces lanuginosus SSBP on bagasse pulp. *Process Biochemistry*. 37(6), 567-572.

Bourbonnais, R. and Paice, M.G. (1992). Demethylation and delignification of kraft pulp by Trametes versicolor laccase in the presence of 2, 2′-azinobis-(3-ethylbenzthiazoline-6-sulphonate). *Applied Microbiology and Biotechnology*. 36(6), 823-827.

Bouza, R. J., Gu, Z. and Evans, J. H. (2016). Screening conditions for acid pretreatment and enzymatic hydrolysis of empty fruit bunches. *Industrial Crops and Products*. 84, 67-71.

Box, G.E. and Behnken, D.W. (1960). Some new three level designs for the study of quantitative variables. *Technometrics*. 2(4), 455-475.

Brijwani, K., Oberoi, H.S. and Vadlani, P.V. (2010). Production of a cellulolytic enzyme system in mixed-culture solid-state fermentation of soybean hulls supplemented with wheat bran. *Process Biochemistry*. 45(1), 120-128.

Carvalheiro, F., Duarte, L.C. and Gírio, F.M. (2008). Hemicellulose biorefineries: a review on biomass pretreatments. *Journal of Scientific & Industrial Research*. 849-864.

Cassia Pereira, J., Paganini Marques, N., Rodrigues, A., Brito de Oliveira, T., Boscolo, M., Silva, R.D., Gomes, E. and Bocchini Martins, D.A. (2015). Thermophilic fungi as new sources for production of cellulases and xylanases with potential use in sugarcane bagasse saccharification. *Journal of applied microbiology*. 118(4), 928-939.

Chadha, B. S., Harmeet, G., Mandeep, M., Saini, H. S. and Singh, N. (2004). Phytase production by the thermophilic fungus Rhizomucor pusillus. *World Journal of Microbiology and Biotechnology*. 20(1), 105-109.

Chandra, R.P., Bura, R., Mabee, W.E., Berlin, D.A., Pan, X. and Saddler, J.N. (2007). Substrate pretreatment: The key to effective enzymatic hydrolysis of lignocellulosics?. In *Biofuels* (pp. 67-93). Springer Berlin Heidelberg.

Chandra, M., Kalra, A., Sharma, P.K., Kumar, H. and Sangwan, R.S. (2010). Optimization of cellulases production by Trichoderma citrinoviride on marc of

Artemisia annua and its application for bioconversion process. *Biomass and Bioenergy*. 34(5), 805-811.

Chang, V.S. and Holtzapple, M.T. (2000). Fundamental factors affecting biomass enzymatic reactivity. *Applied biochemistry and biotechnology*. 84(1), 5-37.

Chávez, R., Bull, P. and Eyzaguirre, J. (2006). The xylanolytic enzyme system from the genus Penicillium. *Journal of biotechnology*. 123(4), 413-433.

Chen, M., Zhao, J. and Xia, L. (2009). Comparison of four different chemical pretreatments of corn stover for enhancing enzymatic digestibility. *Biomass and Bioenergy*. 33(10), 1381-1385.

Chen, H. (2013). Modern solid state fermentation. *Netherlands: Springer*.

Chen, L., Li, J., Lu, M., Guo, X., Zhang, H. and Han, L. (2016). Integrated chemical and multi-scale structural analyses for the processes of acid pretreatment and enzymatic hydrolysis of corn stover. *Carbohydrate polymers*. 141, 1-9.

Christakopoulos, P., Macris, B.J. and Kekos, D. (1990). Exceptionally thermostable α- and β-galactosidase from *Aspergillus niger* separated in one step. *Process biochemistry*. 25(6), 210-212.

Chylenski, P., Forsberg, Z., Ståhlberg, J., Várnai, A., Lersch, M., Bengtsson, O., and Eijsink, V. G. (2017). Development of minimal enzyme cocktails for hydrolysis of sulfite-pulped lignocellulosic biomass. *Journal of Biotechnology*. 246, 16-23.

Coates, J. (2000). Interpretation of infrared spectra, a practical approach. *Encyclopedia of analytical chemistry*.

Coimbra, M.C., Duque, A., Saéz, F., Manzanares, P., Garcia-Cruz, C.H. and Ballesteros, M. (2016). Sugar production from wheat straw biomass by alkaline extrusion and enzymatic hydrolysis. *Renewable Energy*. *86*, 1060-1068.

Collins, T., Gerday, C. and Feller, G. (2005). Xylanases, xylanase families and extremophilic xylanases. *FEMS microbiology reviews*. 29(1), 3-23.

Costa, A.G., Pinheiro, G.C., Pinheiro, F.G.C., Dos Santos, A.B., Santaella, S.T. and Leitão, R.C. (2013). Pretreatment strategies to improve anaerobic biodegradability and methane production potential of the palm oil mesocarp fibre. *Chemical engineering journal*. 230, 158-165.

Dashtban, M., Schraft, H. and Qin, W. (2009). Fungal bioconversion of lignocellulosic residues; opportunities & perspectives. *International journal of biological sciences*. 5(6), 578.

Da Silva Delabona, P., Pirota, R.D.B., Codima, C.A., Tremacoldi, C.R., Rodrigues, A. and Farinas, C.S. (2012). Using Amazon forest fungi and agricultural residues as a strategy to produce cellulolytic enzymes. *Biomass and bioenergy*. 37, 243-250.

Da Silva Delabona, P., Pirota, R.D.P.B., Codima, C.A., Tremacoldi, C.R., Rodrigues, A. and Farinas, C.S. (2013). Effect of initial moisture content on two Amazon rainforest Aspergillus strains cultivated on agro-industrial residues: Biomass-degrading enzymes production and characterization. *Industrial Crops and Products*. 42, 236-242.

De Hoog, G.S. and Guarro, J. (1995). *Atlas of clinical fungi*. Centraalbureau voor Schimmelcultures.

De Souza-Cruz, P.B., Freer, J., Siika-Aho, M. and Ferraz, A. (2004). Extraction and determination of enzymes produced by Ceriporiopsis subvermispora during biopulping of Pinus taeda wood chips. *Enzyme and microbial technology*. 34(3), 228-234.

Dean, A.M. and Voss, D. (1999). *Design and analysis of experiments* (Vol. 1). New York: Springer.

Dekker, R.F.H. and Lindner, W.A. (1979). Bioutilization of lignocellulosic waste materials- A review. *South African Journal of Science*. 75, 65-71.

Del Pozo, M.V., Fernández-Arrojo, L., Gil-Martínez, J., Montesinos, A., Chernikova, T.N., Nechitaylo, T.Y., Waliszek, A., Tortajada, M., Rojas, A., Huws, S.A. and Golyshina, O.V. (2012). Microbial β-glucosidases from cow rumen metagenome enhance the saccharification of lignocellulose in combination with commercial cellulase cocktail. *Biotechnology for biofuels*. 5(1), 73.

Detroy, R.W. and St Julian, G. (1982). Biomass conversion: fermentation chemicals and fuels. *CRC Critical reviews in microbiology*. 10(3), 203-228.

Deswal, D., Khasa, Y.P. and Kuhad, R.C. (2011). Optimization of cellulase production by a brown rot fungus Fomitopsis sp. RCK2010 under solid state fermentation. *Bioresource technology*. 102(10), 6065-6072.

Dhillon, G.S., Oberoi, H.S., Kaur, S., Bansal, S. and Brar, S.K. (2011). Value-addition of agricultural wastes for augmented cellulase and xylanase production through solid-state tray fermentation employing mixed-culture of fungi. *Industrial Crops and Products*. 34(1), 1160-1167.

Di Blasi, C., Signorelli, G., Di Russo, C. and Rea, G. (1999). Product distribution from pyrolysis of wood and agricultural residues. *Industrial & Engineering Chemistry Research*. 38(6), 2216-2224.

Doğar, Ç., Gürses, A., Açıkyıldız, M. and Özkan, E. (2010). Thermodynamics and kinetic studies of biosorption of a basic dye from aqueous solution using green algae Ulothrix sp. *Colloids and Surfaces B: Biointerfaces*. 76(1), 279-285.

Elisashvili, V., Parlar, H., Kachlishvili, E., Chichua, D., Bakradze, M., Kokhreidze, N. and Kvesitadze, G. (2001). Ligninolytic activity of basidiomycetes grown under submerged and solid-state fermentation on plant raw material (sawdust of grapevine cuttings). *Advances in food sciences*. 23(3), 117-123.

Elisashvili, V., Kachlishvili, E., Tsiklauri, N., Metreveli, E., Khardziani, T. and Agathos, S.N. (2009). Lignocellulose-degrading enzyme production by white-rot Basidiomycetes isolated from the forests of Georgia. *World Journal of Microbiology and Biotechnology*. 25(2), 331-339.

El-Bakry, M., Abraham, J., Cerda, A., Barrena, R., Ponsá, S., Gea, T. and Sánchez, A. (2015). From wastes to high value added products: novel aspects of SSF in the production of enzymes. *Critical Reviews in Environmental Science and Technology*. 45(18),1999-2042.

Farinas, C.S., Loyo, M.M., Baraldo, A., Tardioli, P.W., Neto, V.B. and Couri, S. (2010). Finding stable cellulase and xylanase: evaluation of the synergistic effect of pH and temperature. *New Biotechnology*. 27(6), 810-815.

Farinas, C.S., Vitcosque, G.L., Fonseca, R.F., Neto, V.B. and Couri, S. (2011). Modeling the effects of solid state fermentation operating conditions on endoglucanase production using an instrumented bioreactor. *Industrial Crops and Products*. 34(1), 1186-1192.

Farinas, C.S. (2015). Developments in solid-state fermentation for the production of biomass-degrading enzymes for the bioenergy sector. *Renewable and Sustainable Energy Reviews*. *52*, 179-188.

Florencio, C., Couri, S. and Farinas, C.S. (2012). Correlation between agar plate screening and solid-state fermentation for the prediction of cellulase production by Trichoderma strains. *Enzyme research*. 2012.

Foyle, T., Jennings, L. and Mulcahy, P. (2007). Compositional analysis of lignocellulosic materials: Evaluation of methods used for sugar analysis of waste paper and straw. *Bioresource technology*. 98(16), 3026-3036.

Galbe, M. and Zacchi, G. (2007). Pretreatment of lignocellulosic materials for efficient bioethanol production. In *Biofuels* (pp. 41-65). Springer Berlin Heidelberg.

Gama, R., 2014. *A Lignocellulolytic Enzyme System for Fruit Waste Degradation: Commercial Enzyme Mixture Synergy and Bioreactor Design.* Doctoral dissertation, Rhodes University.

Gao, J., Weng, H., Zhu, D., Yuan, M., Guan, F. and Xi, Y. (2008). Production and characterization of cellulolytic enzymes from the thermoacidophilic fungal Aspergillus terreus M11 under solid-state cultivation of corn stover. *Bioresource Technology*. 99(16), 7623-7629.

Gao, D., Chundawat, S.P., Liu, T., Hermanson, S., Gowda, K., Brumm, P., Dale, B.E. and Balan, V. (2010). Strategy for identification of novel fungal and bacterial glycosyl hydrolase hybrid mixtures that can efficiently saccharify pretreated lignocellulosic biomass. *BioEnergy Research*. 3(1), 67-81.

Gao, D., Uppugundla, N., Chundawat, S.P., Yu, X., Hermanson, S., Gowda, K., Brumm, P., Mead, D., Balan, V. and Dale, B.E. (2011). Hemicellulases and auxiliary enzymes for improved conversion of lignocellulosic biomass to monosaccharides. *Biotechnology for biofuels*. 4(1), 5.

Garai, D. and Kumar, V. (2013). A Box–Behnken design approach for the production of xylanase by *Aspergillus candidus* under solid state fermentation and its application in saccharification of agro residues and *Parthenium hysterophorus* L. *Industrial Crops and Products.* 44, 352-363.

Garcia, N.F.L., Santos, F.R.D.S., Gonçalves, F.A., Paz, M.F.D., Fonseca, G.G. and Leite, R.S.R. (2015). Production of β-glucosidase on solid-state fermentation by Lichtheimia ramosa in agroindustrial residues: Characterization and catalytic properties of the enzymatic extract. *Electronic Journal of Biotechnology*. 18(4), 314-319.

Garcia-Nunez, J.A., Ramirez-Contreras, N.E., Rodriguez, D.T., Silva-Lora, E., Frear, C.S., Stockle, C. and Garcia-Perez, M. (2016). Evolution of palm oil mills into bio-refineries: literature review on current and potential uses of residual biomass and effluents. *Resources, Conservation and Recycling*. 110, 99-114.

Gardes, M. and Bruns, T.D. (1993). ITS primers with enhanced specificity for basidiomycetes-application to the identification of mycorrhizae and rusts. *Molecular ecology*. 2(2), 113-118.

Ghose, T.K. (1987). Measurement of cellulase activities. *Pure and applied Chemistry*. 59(2), 257-268.

Ghanem, N.B., Yusef, H.H. and Mahrouse, H.K. (2000). Production of Aspergillus terreus xylanase in solid-state cultures: application of the Plackett–Burman experimental design to evaluate nutritional requirements. *Bioresource Technology*. 73(2), 113-121.

Gilbert, H.J. and Hazlewood, G.P. (1993). Bacterial cellulases and xylanases. *Microbiology*. 139(2), 187-194.

Gomes, E., Aguiar, A.P., Carvalho, C.C., Bonfá, M.R.B., Silva, R.D. and Boscolo, M. (2009). Ligninases production by Basidiomycetes strains on lignocellulosic agricultural residues and their application in the decolorization of synthetic dyes. *Brazilian Journal of Microbiology*. 40(1), 31-39.

Goncalves, G.A., Takasugi, Y., Jia, L., Mori, Y., Noda, S., Tanaka, T., Ichinose, H. and Kamiya, N. (2015). Synergistic effect and application of xylanases as accessory enzymes to enhance the hydrolysis of pretreated bagasse. *Enzyme and microbial technology*. 72,16-24.

Gorin, P.A.J. and Spencer, J.F.T. (1968). Structural chemistry of fungal polysaccharides. *Advances in carbohydrate chemistry*. 23, 367-417.

Haaland, P.D., 1989. *Experimental design in biotechnology* (Vol. 105). CRC press.

Haltrich, D., Nidetzky, B., Kulbe, K. D., Steiner, W. and Župančič, S. (1996). Production of fungal xylanases. *Bioresource Technology*. 58(2), 137-161.

Hamelinck, C.N., Van Hooijdonk, G. and Faaij, A.P. (2005). Ethanol from lignocellulosic biomass: techno-economic performance in short-, middle-and long-term. *Biomass and bioenergy*. 28(4), 384-410.

Hammel, K.E. (1997). Fungal degradation of lignin. *Driven by nature: plant litter quality and decomposition. CAB International, Wallingford*, pp.33-46.

Han, X., Song, W., Liu, G., Li, Z., Yang, P. and Qu, Y. (2017). Improving cellulase productivity of Penicillium oxalicum RE-10 by repeated fed-batch fermentation strategy. *Bioresource technology*. 227, 155-163.

Hanif, A., Yasmeen, A. and Rajoka, M.I. (2004). Induction, production, repression, and de-repression of exoglucanase synthesis in Aspergillus niger. *Bioresource Technology*. 94(3), 311-319.

Hao, J.J., Tian, X.J., Song, F.Q., He, X.B., Zhang, Z.J. and Zhang, P. (2006). Involvement of lignocellulolytic enzymes in the decomposition of leaf litter in a subtropical forest. *Journal of Eukaryotic Microbiology*. 53(3), 193-198.

Hao, J., Song, F., Huang, F., Yang, C., Zhang, Z., Zheng, Y. and Tian, X. (2007). Production of laccase by a newly isolated deuteromycete fungus Pestalotiopsis sp. and its decolorization of azo dye. *Journal of industrial microbiology & biotechnology*. 34(3), 233.

Haykir, N.I. and Bakir, U. (2013). Ionic liquid pretreatment allows utilization of high substrate loadings in enzymatic hydrolysis of biomass to produce ethanol from cotton stalks. *Industrial crops and products*. 51, 408-414.

Henriksson, G., Akin, D. E., Slomczynski, D. and Eriksson, K. E. L. (1999). Production of highly efficient enzymes for flax retting by *Rhizomucor pusillus*. *Journal of Biotechnology*. 68(2), 115-123.

Hölker, U., Höfer, M. and Lenz, J. (2004). Biotechnological advantages of laboratory-scale solid-state fermentation with fungi. *Applied Microbiology and Biotechnology*. 64(2), 175-186.

Hoq, M. M. and Deckwer, W. D. (1995). Cellulase-free xylanase by thermophilic fungi: a comparison of xylanase production by two Thermomyces lanuginosus strains. *Applied microbiology and biotechnology*. 43(4), 604-609.

Howard, R.L., Abotsi, E.L.J.R., Van Rensburg, E.J. and Howard, S. (2003). Lignocellulose biotechnology: issues of bioconversion and enzyme production. *African Journal of biotechnology*. 2(12), 602-619.

Hu, J., Arantes, V. and Saddler, J.N. (2011). The enhancement of enzymatic hydrolysis of lignocellulosic substrates by the addition of accessory enzymes such as xylanase: is it an additive or synergistic effect? *Biotechnology for biofuels*. 4(1), 36.

Hu, J., Chandra, R., Arantes, V., Gourlay, K., van Dyk, J.S. and Saddler, J.N. (2015). The addition of accessory enzymes enhances the hydrolytic performance of cellulase enzymes at high solid loadings. *Bioresource technology*. 186, 149-153.

Huang, Y., Busk, P.K., Grell, M.N., Zhao, H. and Lange, L. (2014). Identification of a β-glucosidase from the Mucor circinelloides genome by peptide pattern recognition. *Enzyme and microbial technology*. 67, 47-52.

Iberahim, N.I., Jahim, J.M., Harun, S., Nor, M.T.M. and Hassan, O. (2013). Sodium hydroxide pretreatment and enzymatic hydrolysis of oil palm mesocarp fibre. *International Journal of Chemical Engineering and Applications*. 4(3), 101.

Igwe, J.C. and Onyegbado, C.C. (2007). A review of palm oil mill effluent (POME) water treatment. *Global Journal of Environmental Research*. 1(2), 54-62.

Ioelovich, M. and Morag, E. (2012). Study of enzymatic hydrolysis of mild pretreated lignocellulosic biomasses. *BioResources*. 7(1), 1040-1052.

Iqbal, H.M.N. and Kamal, S. (2012). Economical bioconversion of lignocellulosic materials to value-added products. *J. Biotechnol Biomater*. 2(5), 1-2.

Ito, K., Ogasawara, H., Sugimoto, T. and Ishikawa, T. (1992). Purification and properties of acid stable xylanases from Aspergillus kawachii. *Bioscience, biotechnology, and biochemistry*. 56(4), 547-550.

Jabasingh, S.A. and Nachiyar, C.V. (2011). Utilization of pretreated bagasse for the sustainable bioproduction of cellulase by *Aspergillus nidulans* MTCC344 using

response surface methodology. *Industrial Crops and Products*. 34(3), 1564-1571.

Jørgensen, H., Vibe-Pedersen, J., Larsen, J. and Felby, C. (2007). Liquefaction of lignocellulose at high-solids concentrations. *Biotechnology and bioengineering*. 96(5), 862-870.

Jung, D.U., Yoo, H.Y., Kim, S.B., Lee, J.H., Park, C. and Kim, S.W. (2015). Optimization of medium composition for enhanced cellulase production by mutant *Penicillium brasilianum* KUEB15 using statistical method. *Journal of Industrial and Engineering Chemistry*. 25, 145-150.

Juturu, V. and Wu, J.C. (2012). Microbial xylanases: engineering, production and industrial applications. *Biotechnology advances*. 30(6), 1219-1227.

Kamiya, N., Matsushita, Y., Hanaki, M., Nakashima, K., Narita, M., Goto, M. and Takahashi, H. (2008). Enzymatic in situ saccharification of cellulose in aqueous-ionic liquid media. *Biotechnology letters*. 30(6), 1037.

Kamra, P. and Satyanarayana, T. (2004). Xylanase production by the thermophilic mold *Humicola lanuginosa* in solid-state fermentation. *Applied biochemistry and biotechnology*. 119(2), 145.

Karmakar, M. and Ray, R.R. (2010). Extra cellular endoglucanase production by *Rhizopus oryzae* in solid and liquid state fermentation of agro wastes. *Asian Journal Biotechnology*. 2(1), 27-36.

Kassaye, S., Pant, K.K. and Jain, S. (2017). Hydrolysis of cellulosic bamboo biomass into reducing sugars via a combined alkaline solution and ionic liquid pretreament steps. *Renewable Energy*. 104, 177-184.

Keshwani, D.R. and Cheng, J.J. (2009). Switchgrass for bioethanol and other value-added applications: a review. *Bioresource Technology*. 100(4), 1515-1523.

Kheng, P.P. and Omar, I.C. (2005). Xylanase production by a local fungal isolate, *Aspergillus niger* USM AI 1 via solid state fermentation using palm kernel cake (PKC) as substrate. *Songklanakarin Journal of Science and Technology*. 27(2), 325-336.

Kim, I., Lee, B., Park, J.Y., Choi, S.A. and Han, J.I. (2014). Effect of nitric acid on pretreatment and fermentation for enhancing ethanol production of rice straw. *Carbohydrate polymers*. 99, 563-567.

Kim, I.J., Lee, H.J. and Kim, K.H. (2017). Pure enzyme cocktails tailored for the saccharification of sugarcane bagasse pretreated by using different methods. *Process Biochemistry*. 57, 167-174.

Kirk, T.K., Tien, M., Kersten, P.J., Mozuch, M.D. and Kalyanaraman, B. (1986). Ligninase of *Phanerochaete chrysosporium*. Mechanism of its degradation of the non-phenolic arylglycerol β-aryl ether substructure of lignin. *Biochemical Journal*. 236(1), 279-287.

Kjosbakken, J. and Colvin, J.R. (1973). Biosynthesis of cellulose by a particulate enzyme system from *Acetobacter xylinum*. *Biogenesis of plant cell wall polysaccharides*. 361-371.

Koba, Y. and Ishizaki, A. (1990). Chemical composition of palm fibre and its feasibility as cellulosic raw material for sugar production. *Agricultural and Biological chemistry*. 54(5), 1183-1187.

Kraber, S., Whitcomb, P. and Andersen, M. (2002). Handbook for experimenters. *Stat-Ease: Minneapolis, MN, Version,* 06.8

Krisch, J., Bencsik, O., Papp, T., Vágvölgyi, C. and Takó, M. (2012). Characterization of a β-glucosidase with transgalactosylation capacity from the zygomycete *Rhizomucor miehei*. *Bioresource technology*. 114, 555-560.

Kristensen, J.B., Felby, C. and Jørgensen, H. (2009). Yield-determining factors in high-solids enzymatic hydrolysis of lignocellulose. *Biotechnology for Biofuels*. 2(1), 11.

Kubicek, C.P. ed. (2012). *Fungi and lignocellulosic biomass*. John Wiley & Sons.

Kuhad, R. C., Deswal, D., Sharma, S., Bhattacharya, A., Jain, K. K., Kaur, A. and Karp, M. (2016). Revisiting cellulase production and redefining current strategies based on major challenges. *Renewable and Sustainable Energy Reviews*. 55, 249-272.

Kumar, R., Singh, S. and Singh, O. V. (2008). Bioconversion of lignocellulosic biomass: biochemical and molecular perspectives. *Journal of industrial microbiology & biotechnology*. 35(5), 377-39

Kumar, P., Barrett, D.M., Delwiche, M.J. and Stroeve, P. (2009a). Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial & engineering chemistry research*. 48(8), 3713-3729.

Kumar, A., Prasad, B. and Mishra, I.M. (2009b). Optimization of acrylonitrile removal by activated carbon-granular using response surface methodology. *The Canadian Journal of Chemical Engineering*. 87(4), 637-643.

Kumar, R., Mago, G., Balan, V. and Wyman, C.E. (2009c). Physical and chemical characterizations of corn stover and poplar solids resulting from leading pretreatment technologies. *Bioresource Technology*. 100(17), 3948-3962.

Kuo, C.H. and Lee, C.K. (2009). Enhancement of enzymatic saccharification of cellulose by cellulose dissolution pretreatments. *Carbohydrate Polymers*. 77(1), 41-46.

Lakshmi, G.S., Rao, C.S., Rao, R.S., Hobbs, P.J. and Prakasham, R.S. (2009). Enhanced production of xylanase by a newly isolated Aspergillus terreus under solid state fermentation using palm industrial waste: A statistical optimization. *Biochemical Engineering Journal*. 48(1), 51-57.

Lawson, J. (2010). *Design and Analysis of Experiments with SAS*. CRC Press.

Lee, S.H., Doherty, T.V., Linhardt, R.J. and Dordick, J.S. (2009). Ionic liquid-mediated selective extraction of lignin from wood leading to enhanced enzymatic cellulose hydrolysis. *Biotechnology and Bioengineering*. 102(5), 1368-1376.

Lenartovicz, V., Marques De Souza, C.G., Moreira, F.G. and Peralta, R.M. (2002). Temperature effect in the production of multiple xylanases by *Aspergillus fumigatus*. *Journal of basic microbiology*. 42(6), 388-395.

Levin, L., Herrmann, C. and Papinutti, V.L. (2008). Optimization of lignocellulolytic enzyme production by the white-rot fungus *Trametes trogii* in solid-state fermentation using response surface methodology. *Biochemical Engineering Journal*. 39(1), 207-214.

Li, S., Xu, S., Liu, S., Yang, C. and Lu, Q. (2004). Fast pyrolysis of biomass in free-fall reactor for hydrogen-rich gas. *Fuel Processing Technology*. 85(8), 1201-1211.

Li, Y., Cui, F., Liu, Z., Xu, Y. and Zhao, H. (2007). Improvement of xylanase production by *Penicillium oxalicum* ZH-30 using response surface methodology. *Enzyme and Microbial Technology*. 40(5), 1381-1388.

Licht, F. O. (2017). First estimate of the world sugar balance 2016/17. *International Sugar Journal: ISJ's World Sugar Outlook* 2015. 6-15.

Liers, C., Ullrich, R., Steffen, K.T., Hatakka, A. and Hofrichter, M. (2006). Mineralization of 14C-labelled synthetic lignin and extracellular enzyme activities of the wood-colonizing ascomycetes *Xylaria hypoxylon* and *Xylaria polymorpha*. *Applied microbiology and biotechnology*. 69(5), 573-579.

Lin, L., Yan, R., Liu, Y. and Jiang, W. (2010). In-depth investigation of enzymatic hydrolysis of biomass wastes based on three major components: cellulose, hemicellulose and lignin. *Bioresource Technology*. 101(21), 8217-8223.

Lin, C., Shen, Z. and Qin, W. (2017). Characterization of xylanase and cellulase produced by a newly isolated *Aspergillus fumigatus* N2 and its efficient saccharification of barley straw. *Applied biochemistry and Biotechnology*.182(2), 559-569.

Liu, H.L., Lan, Y.W. and Cheng, Y.C. (2004). Optimal production of sulphuric acid by *Thiobacillus thiooxidans* using response surface methodology. *Process Biochemistry*. 39(12), 1953-1961.

Liu, D., Zhang, R., Yang, X., Wu, H., Xu, D., Tang, Z. and Shen, Q. (2011). Thermostable cellulase production of *Aspergillus fumigatus* Z5 under solid-state fermentation and its application in degradation of agricultural wastes. *International Biodeterioration & Biodegradation*. 65(5), 717-725.

Liu, J., Ju, M., Wu, W., Liu, B., Zhan, L., Wu, M. and Tong, S. (2014). Lignocellulolytic enzyme production in solid-state fermentation of corn stalk with ammoniation pretreatment by Lentinus edodes L-8. *BioResources*. 9(1), 1430-1444.

Liu, Z.H. and Chen, H.Z. (2016). Periodic peristalsis enhancing the high solids enzymatic hydrolysis performance of steam exploded corn stover biomass. *Biomass and Bioenergy*. 93, 13-24.

Loh, S.K. and Choo, Y.M. (2013). Prospect, challenges and opportunities on biofuels in Malaysia. In *Advances in biofuels* (pp. 3-14). Springer US.

Lonsane, B.K., Ghildyal, N.P., Budiatman, S. and Ramakrishna, S.V. (1985). Engineering aspects of solid state fermentation. *Enzyme and Microbial Technology*. 7(6), 258-265.

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. (1951). Protein measurement with the Folin phenol reagent. *Journal of biological chemistry*. 193(1), 265-275.

Lynd, L.R., Weimer, P.J., Van Zyl, W.H. and Pretorius, I.S. (2002). Microbial cellulose utilization: fundamentals and biotechnology. *Microbiology and molecular biology reviews*. 66(3), 506-577.

Ma, C., Sun, Z., Chen, C., Zhang, L., Zhu, S. (2014). Simultaneous separation and determination of fructose, sorbitol, glucose and sucrose in fruits by HPLC–ELSD. *Food Chemistry*. 145, 784–788.

Maeda, R.N., Barcelos, C.A., Santa Anna, L.M.M. and Pereira, N. (2013). Cellulase production by Penicillium funiculosum and its application in the hydrolysis of sugar cane bagasse for second generation ethanol production by fed batch operation. *Journal of Biotechnology*. 163(1), 38-44.

Mahmood, R.T., Asad, M.J., Mehboob, N., Mushtaq, M., Gulfraz, M., Asgher, M., Minhas, N.M. and Hadri, S.H. (2013). Production, purification, and characterization of exoglucanase by *Aspergillus fumigatus*. *Applied biochemistry and biotechnology*. 170(4), 895-908.

Mahmud, N.A.N., Baharuddin, A.S., Bahrin, E.K., Sulaiman, A., Naim, M.N., Zakaria, R., Hassan, M.A., Nishida, H. and Shirai, Y. (2013). Enzymatic saccharification of oil palm mesocarp fibre (OPMF) treated with superheated steam. *BioResources*. 8(1), 1320-1331.

Malaysian Palm Oil Board (2017). Malaysian Oil Palm Industry Performance 2016 and Prospects for 2017. Available from: (accessed 19.111.2017).

http://www.mpob.gov.my/images/stories/pdf/2017/2017_Dr.KushairiPALMEROS2017.pdf

Mandels, M. and Reese, E.T. (1957). Induction of cellulase in *Trichoderma viride* as influenced by carbon sources and metals. *Journal of Bacteriology*. 73(2), 269.

Mandels, M. and Weber, J. (1969). The production of cellulases. *Advances in Chemistry Series.* 95**,** 391-414.

Martins, E.S., Silva, D., Da Silva, R. and Gomes, E. (2002). Solid state production of thermostable pectinases from thermophilic *Thermoascus aurantiacus*. *Process Biochemistry*. 37(9), 949-954.

Martins, D.A.B., do Prado, H.F.A., Leite, R.S.R., Ferreira, H., de Souza Moretti, M.M., da Silva, R. and Gomes, E. (2011). Agroindustrial wastes as substrates for microbial enzymes production and source of sugar for bioethanol production. In *Integrated Waste Management-Volume II*. InTech.

Martínez, A. T., Martínez, M. J., Gutiérrez, A. and Del Rio, J. C. (2005). Biodegradation of lignocellulosics: microbial, chemical, and enzymatic aspects of the fungal attack of lignin. *International Microbiology*. 8, 195-204.

McMillan, J.D. (1994). Pretreatment of lignocellulosic biomass.

Membrillo, I., Sánchez, C., Meneses, M., Favela, E. and Loera, O. (2011). Particle geometry affects differentially substrate composition and enzyme profiles by Pleurotus ostreatus growing on sugar cane bagasse. *Bioresource technology*. 102(2), 1581-1586.

Mendicuti Castro, L.P., Trejo-Aguilar, B.A. and Aguilar Osorio, G. (1997). Thermostable xylanases produced at 37 C and 45 C by a thermotolerant Aspergillus strain. *FEMS Microbiology letters*. 146(1), 97-102.

Menon, V. and Rao, M. (2012). Trends in bioconversion of lignocellulose: biofuels, platform chemicals & biorefinery concept. *Progress in Energy and Combustion Science*. 38(4), 522-550.

Mes-Hartree, M., Dale, B.E. and Craig, W.K. (1988). Comparison of steam and ammonia pretreatment for enzymatic hydrolysis of cellulose. *Applied Microbiology and Biotechnology*. 29(5), 462-468.

Merino, S.T. and Cherry, J. (2007). Progress and challenges in enzyme development for biomass utilization. In *Biofuels* (pp. 95-120). Springer Berlin Heidelberg.

Miller, G.L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Analytical chemistry*. 31(3), 426-428.

Mitchell, D.A., Krieger, N. and Beroviˇc, M. (2006). Solid-State fermentation bioreactors. *Springer, Heidelberg*, 19.

Monciardini, P., Iorio, M., Maffioli, S., Sosio, M., and Donadio, S. (2014). Discovering new bioactive molecules from microbial sources. *Microbial biotechnology*. 7(3), 209-220.

Moredo, N., Lorenzo, M., Domínguez, A., Moldes, D., Cameselle, C. and Sanroman, A. (2003). Enhanced ligninolytic enzyme production and degrading capability of *Phanerochaete chrysosporium* and Trametes versicolor. *World Journal of Microbiology and Biotechnology*. 19(7), 665-669.

Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y.Y., Holtzapple, M. and Ladisch, M. (2005). Features of promising technologies for pretreatment of lignocellulosic biomass. *Bioresource technology*. 96(6), 673-686.

Mussatto, S.I. and Roberto, I.C. (2004). Alternatives for detoxification of diluted-acid lignocellulosic hydrolyzates for use in fermentative processes: a review. *Bioresource technology*. 93(1), 1-10.

Ncube, T., Howard, R.L., Abotsi, E.K., van Rensburg, E.L.J. and Ncube, I. (2012). Jatropha curcas seed cake as substrate for production of xylanase and cellulase by *Aspergillus niger* FGSCA733 in solid-state fermentation. *Industrial Crops and Products*. 37(1), 118-123.

Negi, S. and Banerjee, R. (2009). Optimization of extraction and purification of glucoamylase produced by *Aspergillus awamori* in solid-state fermentation. *Biotechnology and Bioprocess Engineering*. 14(1), 60-66.

Nee'Nigam, P. (2009). Production of bioactive secondary metabolites. *Biotechnology for Agro-Industrial Residues Utilisation*.129-145.

Ng, F.Y., Yew, F.K., Basiron, Y. and Sundram, K. (2012). A renewable future driven with Malaysian palm oil-based green technology. *Journal of Oil Palm, Environment and Health (JOPEH). 2*.

Nitsos, C.K., Matis, K.A. and Triantafyllidis, K.S. (2013). Optimization of hydrothermal pretreatment of lignocellulosic biomass in the bioethanol production process. *ChemSusChem*. 6(1), 110-122.

Noratiqah, K., Madihah, M.S., Aisyah, B.S., Eva, M.S., Suraini, A.A. and Kamarulzaman, K. (2013). Statistical optimization of enzymatic degradation process for oil palm empty fruit bunch (OPEFB) in rotary drum bioreactor using crude cellulase produced from *Aspergillus niger* EFB1. *Biochemical engineering journal*. 75, 8-20.

Nordin, N.I.A.A., Ariffin, H., Andou, Y., Hassan, M.A., Shirai, Y., Nishida, H., Yunus, W.M.Z.W., Karuppuchamy, S. and Ibrahim, N.A. (2013). Modification of oil palm mesocarp fibre characteristics using superheated steam treatment. *Molecules*. 18(8), 9132-9146.

Nyberg, J. (2006). Competitive Commercial Agriculture in Sub–Saharan Africa (CCAA) Study.

O'Dwyer, M.H. (1934). The hemicelluloses of the wood of English oak: The composition and properties of hemicellulose A, isolated from samples of wood dried under various conditions. *Biochemical Journal*. 28(6), 2116.

Ofori-Boateng, C. and Lee, K.T. (2013). Sustainable utilization of oil palm wastes for bioactive phytochemicals for the benefit of the oil palm and nutraceutical industries. *Phytochemistry reviews*. 12(1), 173-190.

Okeke, B.C., Hall, R.W., Nanjundaswamy, A., Thomson, M.S., Deravi, Y., Sawyer, L. and Prescott, A. (2015). Selection and molecular characterization of cellulolytic–xylanolytic fungi from surface soil-biomass mixtures from Black Belt sites. *Microbiological research*. 175, 24-33.

Ottenheim, C., Verdejo, C., Zimmermann, W. and Wu, J.C. (2014). Hemicellulase production by *Aspergillus niger* DSM 26641 in hydrothermal palm oil empty fruit bunch hydrolysate and transcriptome analysis. *Journal of bioscience and bioengineering*. 118(6), 696-701.

Pal, M., Calvo, A.M., Terron, M.C. and Gonzalez, A.E. (1995). Solid-state fermentation of sugarcane bagasse with *Flammulina velutipes* and *Trametes versicolor*. *World Journal of Microbiology and Biotechnology*. 11(5), 541-545.

Pal, A. and Khanum, F. (2010). Production and extraction optimization of xylanase from *Aspergillus niger* DFR-5 through solid-state-fermentation. *Bioresource technology*. 101(19), 7563-7569.

Palamae, S., Dechatiwongse, P., Choorit, W., Chisti, Y. and Prasertsan, P. (2017). Cellulose and hemicellulose recovery from oil palm empty fruit bunch (EFB) fibres and production of sugars from the fibres. *Carbohydrate polymers*. 155, 491-497.

Palaniswamy, M., Pradeep, B. V., Sathya, R. and Angayarkanni, J. (2008). Isolation, identification and screening of potential xylanolytic enzyme from litter degrading fungi. *African Journal of Biotechnology*. 7.

Palmowski, L.M. and Müller, J.A., 2000. Influence of the size reduction of organic waste on their anaerobic digestion. *Water science and technology*. 41(3), 155-162.

Panagiotou, G., Kekos, D., Macris, B.J. and Christakopoulos, P. (2003). Production of cellulolytic and xylanolytic enzymes by Fusarium oxysporum grown on corn stover in solid state fermentation. *Industrial Crops and Products*. 18(1), 37-45.

Pandey, A. (1992). Recent process developments in solid-state fermentation. *Process Biochemistry*. 27(2), 109-117.

Pandey, A., Selvakumar, P., Soccol, C. R. and Nigam, P. (1999). Solid state fermentation for the production of industrial enzymes. *Current science*. 77(1), 149-162.

Pandey, K.K. (1999). A study of chemical structure of soft and hardwood and wood polymers by FTIR spectroscopy. *Journal of Applied Polymer Science*. 71(12), 1969-1975.

Pandey, A. (2003). Solid-state fermentation. *Biochemical Engineering Journal*. 13(2), 81-84.

Pandey, A.K., Edgard, G. and Negi, S. (2016). Optimization of concomitant production of cellulase and xylanase from *Rhizopus oryzae* SN5 through EVOP-factorial design technique and application in sorghum stover based bioethanol production. *Renewable Energy*. 98, 51-56.

Pastor, F.J., Gallardo, O., Sanz-Aparicio, J. and Díaz, P. (2007). Xylanases: molecular properties and applications. *Industrial enzymes*. 67, 65-82.

Patel, H., Chapla, D., Divecha, J. and Shah, A. (2015). Improved yield of α-L-arabinofuranosidase by newly isolated *Aspergillus niger* ADH-11 and synergistic effect of crude enzyme on saccharification of maize stover. *Bioresources and Bioprocessing*. 2(1), 11.

Patel, H., Divecha, J. and Shah, A. (2017). Microwave assisted alkali treated wheat straw as a substrate for co-production of (hemi) cellulolytic enzymes and development of balanced enzyme cocktail for its enhanced saccharification. *Journal of the Taiwan Institute of Chemical Engineers*. 71, 298-306.

Paul, J.S., Tiwari, K.L. and Jadhav, S.K. (2015). Long term preservation of commercial important fungi in glycerol at 4 C. *International Journal of Biological Chemistry*. 9(2), 79-85.

Paës, G., Berrin, J.G. and Beaugrand, J. (2012). GH11 xylanases: structure/function/properties relationships and applications. *Biotechnology advances*. 30(3), 564-592.

Pérez-Guerra, N., Torrado-Agrasar, A., López-Macias, C. and Pastrana, L. (2003). Main characteristics and applications of solid substrate fermentation. *Electronic Journal of Environmental, Agricultural and Food Chemistry*. 2(3).

Pilz, J. (2011). Statistical Design of Experiments (DOE). In *International Encyclopedia of Statistical Science* (pp. 1392-1396). Springer Berlin Heidelberg.

Pointing, S.B. (1999). Qualitative methods for the determination of lignocellulolytic enzyme production by tropical fungi. *Fungal diversity*.

Poku, K. (2002). *Small-scale palm oil processing in Africa* (Vol. 148). Food & Agriculture Org.

Polizeli, M.L.T.M., Rizzatti, A.C.S., Monti, R., Terenzi, H.F., Jorge, J.A. and Amorim, D.S. (2005). Xylanases from fungi: properties and industrial applications. *Applied microbiology and biotechnology*. 67(5), 577-591.

Prasertsan, P., Kittikul, A., Kunghae, A., Maneesri, J. and Oi, S. (1997). Optimization for xylanase and cellulase production from *Aspergillus niger* ATTC 6275 in

palm oil mill wastes and its application. *World Journal of Microbiology and Biotechnology*. 13(5), 555-559.

Qi, B., Chen, X., Shen, F., Su, Y. and Wan, Y. (2009). Optimization of enzymatic hydrolysis of wheat straw pretreated by alkaline peroxide using response surface methodology. *Industrial Engineering and Chemistry Resource*. 48, 7346-7353.

Quiroz-Castaneda, R.E., Pérez-Mejía, N., Martínez-Anaya, C., Acosta-Urdapilleta, L. and Folch-Mallol, J. (2011). Evaluation of different lignocellulosic substrates for the production of cellulases and xylanases by the basidiomycete fungi *Bjerkandera adusta* and *Pycnoporus sanguineus*. *Biodegradation*. 22(3), 565-572.

Raghavarao, K.S.M.S., Ranganathan, T.V. and Karanth, N.G. (2003). Some engineering aspects of solid-state fermentation. *Biochemical Engineering Journal*. 13(2), 127-135.

Raimbault, M. (1998). General and microbiological aspects of solid substrate fermentation. *Electronic Journal of Biotechnology*, 1(3), 26-27.

Ralph, J., Lundquist, K., Brunow, G., Lu, F., Kim, H., Schatz, P.F., Marita, J.M., Hatfield, R.D., Ralph, S.A., Christensen, J.H. and Boerjan, W. (2004). Lignins: natural polymers from oxidative coupling of 4-hydroxyphenyl-propanoids. *Phytochemistry Reviews*. 3(1-2), 29-60.

Ramani, G., Meera, B., Vanitha, C., Rao, M. and Gunasekaran, P. (2012). Production, purification, and characterization of a β-glucosidase of *Penicillium funiculosum* NCL1. *Applied biochemistry and biotechnology*. 167(5), 959-972.

Reddy, P. (2015). A critical review of ionic liquids for the pretreatment of lignocellulosic biomass. S Afr J Sci. 111(11/12).

Ren, H. (2006). Effect of cell wall degrading enzymes and chemicals on corn stover preservation and pretreatment during ensilage processing. Doctoral dissertation, Pennsylvania State University.

Rocky-Salimi, K. and Hamidi-Esfahani, Z. (2010). Evaluation of the effect of particle size, aeration rate and harvest time on the production of cellulase by *Trichoderma reesei* QM9414 using response surface methodology. *Food and bioproducts processing*. 88(1), 61-66.

Rodríguez Couto, S. (2008). Exploitation of biological wastes for the production of value-added products under solid-state fermentation conditions. *Biotechnology Journal*. 3(7), 859-870.

Rosgaard, L., Pedersen, S., Cherry, J.R., Harris, P. and Meyer, A.S. (2006). Efficiency of new fungal cellulase systems in boosting enzymatic degradation of barley straw lignocellulose. *Biotechnology progress*. 22(2), 493-498.

Saha, B.C. (2004). Lignocellulose biodegradation and applications in biotechnology.

Saini, A., Aggarwal, N.K., Sharma, A. and Yadav, A. (2015). Actinomycetes: a source of lignocellulolytic enzymes. *Enzyme research*. 2015.

Sánchez, C. (2009). Lignocellulosic residues: biodegradation and bioconversion by fungi. *Biotechnology advances*. 27(2), 185-194

Sarkar, N. and Aikat, K. (2012). Cellulase and Xylanase Production from Rice Straw by a Locally Isolated Fungus *Aspergillus fumigatus* NITDGPKA3 under Solid State Fermentation–Statistical Optimization by Response Surface Methodology. *Journal of Technology Innovations in Renewable Energy*. 1(1), 54-62.

Seppälä, S., Knop, D., Solomon, K. V., and O'Malley, M. A. (2017). The importance of sourcing enzymes from non-conventional fungi for metabolic engineering & biomass breakdown. *Metabolic engineering*.

Shah, A.R. and Madamwar, D. (2005). Xylanase production by a newly isolated *Aspergillus foetidus* strain and its characterization. *Process Biochemistry*. 40(5), 1763-1771.

Shafiei, M., Zilouei, H., Zamani, A., Taherzadeh, M.J. and Karimi, K. (2013). Enhancement of ethanol production from spruce wood chips by ionic liquid pretreatment. *Applied Energy*. 102, 163-169.

Shallom, D. and Shoham, Y. (2003). Microbial hemicellulases. *Current opinion in microbiology*. 6(3), 219-228.

Sherief, A.A., El-Tanash, A.B. and Atia, N. (2010). Cellulase production by *Aspergillus fumigatus* grown on mixed substrate of rice straw and wheat bran. *Research Journal of Microbiology*. 5(3), 199-211.

Shina, S. (2002). *Six Sigma for electronics design and manufacturing*. McGraw-Hill, Inc..

Singh, R., Kumar, R., Bishnoi, K. and Bishnoi, N.R. (2009). Optimization of synergistic parameters for thermostable cellulase activity of *Aspergillus heteromorphus* using response surface methodology. *Biochemical Engineering Journal*. 48(1), 28-35.

Singhania, R.R., Sukumaran, R.K., Patel, A.K., Larroche, C. and Pandey, A. (2010). Advancement and comparative profiles in the production technologies using solid-state and submerged fermentation for microbial cellulases. *Enzyme and Microbial Technology*. 46(7), 541-549.

Smaali, M.I., Gargouri, M., Limmam, F., Maugard, T., Legoy, M.D. and Marzouki, N. (2004). A. β.-glucosidase from *Sclerotinia sclerotiorum*: biochemical characterization and use in oligosaccharides synthesis. *Appl Biochem Biotechnol*. 112, 63-78.

Somkuti, G. A. (1974). Synthesis of cellulase by *Mucor pusillus* and *Mucor miehei*. *Microbiology*. 81(1), 1-6.

Somkuti, G.A. and Babel, F.J. (1968). Lipase activity of *Mucor pusillus*. *Applied microbiology*. 16(4), 617-619.

Song, H.T., Gao, Y., Yang, Y.M., Xiao, W.J., Liu, S.H., Xia, W.C., Liu, Z.L., Yi, L. and Jiang, Z.B. (2016). Synergistic effect of cellulase and xylanase during hydrolysis of natural lignocellulosic substrates. *Bioresource Technology*. 219, 710-715.

Srebotnik, E., Messner, K. and Foisner, R. (1988). Penetrability of white rot-degraded pine wood by the lignin peroxidase of *Phanerochaete chrysosporium*. *Applied and environmental microbiology*. 54(11), 2608-2614.

Sreekala, M.S., Kumaran, M.G. and Thomas, S. (1997). Oil palm fibres: Morphology, chemical composition, surface modification, and mechanical properties. *Journal of Applied Polymer Science*. 66(5), 821-835.

Subramaniyan, S. and Prema, P. (2002). Biotechnology of microbial xylanases: enzymology, molecular biology, and application. *Critical reviews in biotechnology*. 22(1), 33-64.

Sukumaran, R. K., Singhania, R. R. and Pandey, A. (2005). Microbial cellulases-production, applications and challenges. *Journal of Scientific and Industrial Research*. 64(11), 832.

Sun, Y. and Cheng, J. (2002). Hydrolysis of lignocellulosic materials for ethanol production: a review. *Bioresource technology*. 83(1), 1-11.

Sun, X.F., Sun, R., Fowler, P. and Baird, M.S. (2005). Extraction and characterization of original lignin and hemicelluloses from wheat straw. *Journal of Agricultural and Food Chemistry*. 53(4), 860-870.

Sun, H., Ge, X., Hao, Z. and Peng, M. (2010). Cellulase production by *Trichoderma* sp. on apple pomace under solid state fermentation. *African Journal of Biotechnology*. 9(2).

Sun, S., Sun, S., Cao, X. and Sun, R. (2016). The role of pretreatment in improving the enzymatic hydrolysis of lignocellulosic materials. *Bioresource technology*. 199, 49-58.

Sukumaran, R.K., Singhania, R.R. and Pandey, A. (2005). Microbial cellulases-production, applications and challenges. *Journal of Scientific and Industrial Research (JSIR)*. 64(11).

Swatloski, R.P., Spear, S.K., Holbrey, J.D. and Rogers, R.D. (2002). Dissolution of cellose with ionic liquids. *Journal of the American chemical society*. 124(18), 4974-4975.

Takii, Y., Ikeda, K., Sato, C., Yano, M., Sato, T. and Konno, H. (2005). Production and characterization of β-glucosidase from *Rhizopus oryzae* MIBA348. International *Journal of Biological Macromolecules*. 5(1), 11-16.

Ten, L.N., Im, W.T., Kim, M.K., Kang, M.S. and Lee, S.T. (2004). Development of a plate technique for screening of polysaccharide-degrading microorganisms by using a mixture of insoluble chromogenic substrates. *Journal of Microbiological Methods*. 56(3), 375-382.

Tengerdy, R.P. and Szakacs, G. (2003). Bioconversion of lignocellulose in solid substrate fermentation. *Biochemical Engineering Journal*. 13(2), 169-179.

Thomas, L., Parameswaran, B. and Pandey, A. (2016). Hydrolysis of pretreated rice straw by an enzyme cocktail comprising acidic xylanase from *Aspergillus* sp. for bioethanol production. *Renewable Energy*. 98, 9-15.

Thota, S.P., Badiya, P.K., Yerram, S., Vadlani, P.V., Pandey, M., Golakoti, N.R., Belliraj, S.K., Dandamudi, R.B. and Ramamurthy, S.S. (2017). Macro-micro fungal cultures synergy for innovative cellulase enzymes production and biomass structural analyses. *Renewable Energy*. 103, 766-773.

Tortora, G.J., Funke, B.R., Case, C.L. and Johnson, T.R. (2004). *Microbiology: an introduction* (Vol. 9). San Francisco: Benjamin Cummings.

Tuor, U., Winterhalter, K. and Fiechter, A. (1995). Enzymes of white-rot fungi involved in lignin degradation and ecological determinants for wood decay. *Journal of Biotechnology*. 41(1), 1-17.

Umikalsom, M.S., Ariff, A.B., Shamsuddin, Z.H., Tong, C.C., Hassan, M.A. and Karim, M.I.A. (1997). Production of cellulase by a wild strain of *Chaetomium globosumusing* delignified oil palm empty-fruit-bunch fibre as substrate. *Applied microbiology and biotechnology*. 47(5), 590-595.

Van Dyk, J.S. and Pletschke, B.I. (2012). A review of lignocellulose bioconversion using enzymatic hydrolysis and synergistic cooperation between enzymes—factors affecting enzymes, conversion and synergy. *Biotechnology advances*. 30(6), 1458-1480.

Vaughn, N.A. and Polnaszek, C. (2007). Design-Expert® software. *Stat-Ease, Inc, Minneapolis, MN*.

Wahid, M.B. and Chan, K.W. (2007). Palm oil: nature's gift to Malaysia and Malaysia's gift to the world. In *2007 Conference on Plantation Commodities, Putra World Trade Centre, Kuala Lumpur (Malaysia), 3-4 Jul 2007*. Malaysian Cocoa Board.

Wahid, Z. and Nadir, N. (2013). Improvement of one factor at a time through design of experiments. *World Applied Sciences Journal*. 21(1), 56-61.

Wang, L., Yan, W., Chen, J., Huang, F. and Gao, P. (2008). Function of the iron-binding chelator produced by Coriolus versicolor in lignin biodegradation. *Science in China Series C: Life Sciences*. 51(3), 214-221.

Whitcomb, P.J. and Anderson, M.J. (2004). *RSM simplified: optimizing processes using response surface methods for design of experiments*. CRC press.

White, T.C., Giroux, G.R. and Wallace, K.E., Iogen Bio-Products Corporation. (2010). *Modified xylanase exhibiting improved expression*. U.S. Patent 7,691,609.

Wingren, A., Galbe, M. and Zacchi, G. (2003). Techno-economic evaluation of producing ethanol from softwood: Comparison of SSF and SHF and identification of bottlenecks. *Biotechnology progress*. 19(4), 1109-1117.

Wood, I.P., Elliston, A., Ryden, P., Bancroft, I., Roberts, I.N. and Waldron, K.W. (2012). Rapid quantification of reducing sugars in biomass hydrolysates: improving the speed and precision of the dinitrosalicylic acid assay. *Biomass and bioenergy*. 44, 117-121.

Wu, T.Y., Mohammad, A.W., Jahim, J.M. and Anuar, N. (2010). Pollution control technologies for the treatment of palm oil mill effluent (POME) through end-of-pipe processes. *Journal of Environmental Management*. 91(7), 1467-1490.

Xiong, H., Nyyssölä, A., Jänis, J., Pastinen, O., von Weymarn, N., Leisola, M. and Turunen, O., 2004. Characterization of the xylanase produced by submerged cultivation of *Thermomyces lanuginosus* DSM 10635. *Enzyme and Microbial Technology*, *35*(1), pp.93-99.

Yacob, S. (2008). Progress and challenges in utilization of palm biomass. *Advanced Agriecological Research*.

Yang, S.Q., Yan, Q.J., Jiang, Z.Q., Li, L.T., Tian, H.M. and Wang, Y.Z., 2006. High-level of xylanase production by the thermophilic Paecilomyces themophila J18 on wheat straw in solid-state fermentation. *Bioresource Technology*, 97(15), pp.1794-1800.

Yang, S.Q., Xiong, H., Yang, H.Y., Yan, Q.J. and Jiang, Z.Q. (2015). High-level production of β-1, 3-1, 4-glucanase by *Rhizomucor miehei* under solid-state fermentation and its potential application in the brewing industry. *Journal of applied microbiology*. 118(1), 84-91.

Yusoff, S. (2006). Renewable energy from palm oil innovation on effective utilization of waste. *Journal of Cleaner Production*.14, 87–93.

Zakaria, M.R., Hirata, S. and Hassan, M.A. (2014). Combined pretreatment using alkaline hydrothermal and ball milling to enhance enzymatic hydrolysis of oil palm mesocarp fibre. *Bioresource technology*. 169, 236-243.

Zhang, Y.H.P. and Lynd, L.R. (2004). Toward an aggregated understanding of enzymatic hydrolysis of cellulose: noncomplexed cellulase systems. *Biotechnology and bioengineering*. 88(7), 797-824.

Zhang, Y.H.P., Himmel, M.E. and Mielenz, J.R. (2006). Outlook for cellulase improvement: screening and selection strategies. *Biotechnology advances*. 24(5), 452-481.

Zhang, J., Tang, M. and Viikari, L. (2012). Xylans inhibit enzymatic hydrolysis of lignocellulosic materials by cellulases. *Bioresource technology*. 121, 8-12.