BUSITEMA UNIVERSITY
Pursuing Excellence

P.O. Box 236, Tororo, Uganda
Gen: +256 - 45 444 8838
Fax: +256 - 45 4436517
Email: info@adm.busitema.ac.ug

www.busitema.ac.ug

FACULTY OF ENGINEERING

DEPARTMENT OF POLYMER, TEXTILE AND INDUSTRIAL ENGINEERING

FINAL YEAR PROJECT REPORT.

PROJECT TITLE: DEVELOPMENT OF CASSAVA PEEL STARCH-BASED BIOPLASTIC REINFORCED WITH LIGNIN FROM SUGARCANE BAGASSE FOR LIGHT WEIGHT FOOD PACKAGING APPLICATIONS.

BY

MALOBA EMMY BRIAN

(BU/UP/2019/1794)

TEL 0787637784

Email: malobaemmybrian@gmail.com

AND

TIMANYIRE TEGRAS

(BU/UP/2019/1785)

TEL 0784820173

Email: tegrastima@gmail.com

SUPERVISORS: DR. MUSINGUZI ALEX

MR. TUMUSIIME GODIAS

DR. KAMALHA EDWIN

A final year research project submitted to the department of polymer, textile and industrial engineering as a partial fulfillment for the award of a bachelor of science in polymer, textile, and industrial engineering.

September 2023

ABSTRACT

With the ever-increasing demand of plastics in the world and their consequent disastrous effects on environment, a suitable environmental-friendly substitute like bioplastics/biodegradable plastics is the need time. This study centers on production of a variety of bioplastic samples from cassava peel starch reinforced with lignin using – Glycerol plasticizers. Samples were made using multiple amounts and combinations of the fillers and plasticizers, to test the differences in the physical and chemical characteristics (moisture content, absorption of water, and solubility in water, biodegradation in soil, tensile strength, Light microscope and FT-IR) of the produced samples due to their different compositions. The differences in the properties of the bioplastic samples produced make them suitable for usage in many different applications. The samples produced were synthesized using natural and environmentally safe raw material and showed biodegradation, thus proving to be a good alternative to the conventional plastics.

DECLARATION

We **MALOBA EMMY BRIAN** Reg. No**. BU/UP/2019/1794 and TIMANYIRE TEGRAS** Reg No**. BU/UP/2019/1785** hereby declare that this project work is our original work and that the information contained in this project work is out of our hard work and research except where explicit citation has been made and it has not been presented to any institution of higher learning for any academic award.

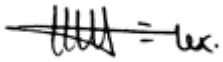
Signature:  **Date: 10th/09/2023.**

Signature:  **Date: 10th/09/2023.**

APPROVAL

This project entitled “development of cassava peel starch-based bioplastic reinforced with lignin from sugarcane bagasse for light weight food packaging applications has been written under the supervision of;

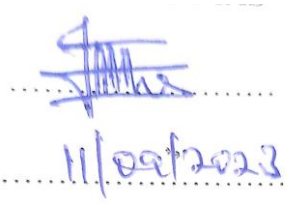
DR MUSINGUZI ALEX

Signature: ……  …….

Date: ……9/09/2023……

MR. TUMUSIIME GODIAS

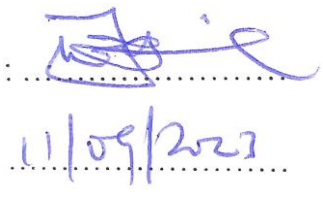
Signature:



Date 11/09/2023

DR. KAMALHA EDWIN

Signature:



Date: 11/09/2023

DEDICATION

We dedicate this report to our lecturers, friends and to our families.

ACKNOWLEGEMENT

We would love to extend our gratitude to a number of people whose efforts and financial support have managed us to progress and put a landmark in our education.

First and foremost, we would like to thank the Almighty God for giving us the strength to carry on with our final year project research.

Sincere thanks go out to Busitema University, department of Polymer, Textile and industrial Engineering and most importantly our supervisors Dr. Musinguzi Alex and Mr. Tumusiime Godias and Dr Kamalha Edwin for the great work done (guidance and consultations).

We also acknowledge the financial support from our families, friends, and well-wishers for all the financial, moral, spiritual, and physical support.

Lastly, to all our course mates with whom we studied with at Busitema University, thank you for the team cooperation.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

NBP	Non Bioplastic
BP	Bioplastic
SDG	Sustainable Development Goal
NDP	National Development Plan
UIRI	Uganda Industrial Research Institute
HCl	Hydrochloric acid
NaOH	Sodium hydroxide
$C_3H_8O_3$	Glycerol
FTIR	Fourier Transform Infrared Spectrometry
SEM	Scanning Electron Microscopy
UTM	Universal Tensile machine

1.0 CHAPTER ONE

INTRODUCTION.

This chapter includes the background, problem statement, significance of the study, the scope of the study, and justification.

1.1 BACKGROUND OF THE STUDY.

Throughout its history, mankind has explored the earth's natural resources without limits, extracting raw materials for industry. The capacity of the planet to absorb and to transform the wastes that resulted from modern life seemed to be inexhaustible. With the exponential increase in the planet population, the situation has become a matter of great concern(Oates et al., n.d.). The population and economic growth in the majority of the countries has resulted in an enormous increase in waste production. Statistical data show that in Uganda, about 240 to 300 thousand tons of urban solid residues are discharged daily into the environment, of which about 19% are plastics derived from oil. The annual plastic production is approximately 2.2 million tons, of which 40% is destined for the packing industry. To solve these problems, alternatives are being studied, such as the recycling of plastic products and the substitution of conventional plastics for biodegradable ones (Neopaney, Wangchuk, and Tenzin 2012)..

The success of synthetic plastic can be explained by the low cost, easy processing, high applicability and durability. However, it cannot be degraded in the environment by microorganisms in the long term(Sarker et al. 2011).. This problem was recognized back in and ways to recycle these materials by means of initiatives that match practicability and economy are being investigated. It must be considered too, that it is desirable that the decomposition processes of these materials result in inert or biodegradable by-products. (Dominici et al. 2020).

The interest in the use of renewable raw materials in industrial processes is a natural consequence of this panorama and is intensifying (Lodha, P., & Netravali 2005).

Plastics are being used for a plethora of purposes as they are cheap, easily available and perdurable(Narissara K. 2013). In totality around 8.3 billion metric tons of plastics has been created till now, while around 6.3 thousand metric tons of plastic waste has been produced. Only 9% of that waste plastic was recycled, 12% incinerated and the leftover 79% is cumulated in the sanitary landfill or in the environment. It is estimated that by 2050, 12 thousand metric tons of wasted plastics will get cumulated in the sanitary landfill or in open environment (Geyer R.,

REFERENCES.

. Al-Salem S.M., Antelava A., Constantinou A., Manos G., Dutta A. 2017. “A Review on Thermal and Catalytic Pyrolysis of Plastic Solid Waste (PSW) J. Environ. Manage,” 177–198.

. Jones A., Zeller M.A., Sharma S. 2013. “Thermal, Mechanical, and Moisture Absorption Properties of Egg White Protein Bioplastics with Natural Rubber and Glycerol,” PG 2-12.

. Kuo C.C., Liu L.C., Teng W.F., Chang H.Y., Chien F.M., Liao S.J., Kuo W.F., Chen C.M. 2016. “Preparation of Starch/Acrylonitrile-Butadiene_styrene Copolymers (ABS) Biomass Alloys and Their Feasible Evaluation for 3D Printing Applications. Compos. B.” *Compos. B Eng.*, no. 86: 36– 39.

. Pérez S., Bertoft E. 2010. “The Molecular Structures of Starch Components and Their Contribution to the Architecture of Starch Granules.” *Comprehensive Review. Starch/Stärke.*, 389–420.

. Sardon H., Dove A.P. 2018. “Plastics Recycling with a Difference. Scienc,” ;360(6387):380–381.

Abdul Khalil, H. P.S., Y. Davoudpour, Chaturbhuj K. Saurabh, Md S. Hossain, A. S. Adnan, R. Dungani, M. T. Paridah, et al. 2016. “A Review on Nanocellulosic Fibres as New Material for Sustainable Packaging: Process and Applications.” *Renewable and Sustainable Energy Reviews* 64: 823–36. https://doi.org/10.1016/j.rser.2016.06.072.

Abel, Otache Monday, Stella Chinelo, and Rhoda Chidioka. 2021. “Enhancing Cassava Peels Starch as Feedstock for Biodegradable Plastic.” *J. Mater. Environ. Sci* 12 (02): 169–82.

Abu-Thabit, Nedal, Abbas Saeed Hakeem, Khaled Mezghani, Elaref Ratemi, Mohamed Elzagheid, Yunusa Umar, Adhi Primartomo, et al. 2020. “Preparation of Ph-Indicative and Flame-Retardant Nanocomposite Films for Smart Packaging Applications.” *Sensors (Switzerland)* 20 (19): 1–22. https://doi.org/10.3390/s20195462.

Ahmad, Nor Farah Atiqah, Siti Nooraiin Mohd Razali, Suhaila Sahat, and Masiri Kaamin. 2018.

"PET Concrete as Paver Block." *AIP Conference Proceedings* 2016 (September). https://doi.org/10.1063/1.5055417.

Ano Y., Hours R.A., Akakabe Y., Kataoka N., Yakushi T., Matsushita K., Adachi O. 2017. "Membrane-Bound Glycerol Dehydrogenase Catalyzes Oxidation of D-Pentonates to 4-Keto-D-Pentonates, D-Fructose to 5-Keto-D-Fructose, and D-Psicose to 5-Keto-D." *Biosci. Biotechnol. Biochem*, no. ;81(2): 411–418.

Ant, A Cerqueira. 2015. "Ac Ce p Us Cr T." *Carbohydrate Polymers*. https://doi.org/10.1016/j.carbpol.2015.04.021.

Asim, M, Khalina Abdan, M Jawaid, M Nasir, Zahra Dashtizadeh, M R Ishak, and M Enamul Hoque. 2015. "A Review on Pineapple Leaves Fibre and Its Composites" 2015.

Avérous L., Pollet E. 2012. "Environmental Silicate Nano-Biocomposites, Green Energy and Technology. Springer; London" PG 13-39.

Azahari N.A., Othman N., Ismail H. 2011. "Biodegradation Studies of Polyvinyl Alcohol/Corn Starch Blend Films in Solid and Solution Media." *J. Phys. Sci*, no. 22(2): 15–31.

B. A. Ezgi, H. D. Bilgen. 2019. "Production Ofbioplastic from Potato Peel Waste and Investigation of Its Biodegradability." *International Advanced Researches and Engineering Journa* 03(02): 93–97.

Bilgiç, Seren, Ece Söğüt, and Atıf Can Seydim. 2019. "Turkish Journal of Agriculture - Food Science and Technology Chitosan and Starch Based Intelligent Films with Anthocyanins from Eggplant to Monitor PH Variations #" 7: 61–66.

Brinchi L, Cotana F, Fortunati E, Kenny JM. 2013. "Production of Nanocrystalline Cellulose from Lignocellulosic Biomass: Technology and Applications. Carbohydr Polym," 69–154.

Buléon, A., Colonna, P., Planchot, V. and Ball, S. 1998. "Starch Granules: Structure and Biosynthesis." *International Journal of Biological Macromolecules,* 23(2): 85–112.

Cao X., Chen Y., Chang P.R., Muir A.D., Falk G. 2008. "Starchbased Nanocomposites Reinforced with Flax Cellulose Nanocrystals. EXPRESS." *Polym. Lett*, no. ;2(7): :502–510.

Cazón, Patricia, Gonzalo Velazquez, José A. Ramírez, and Manuel Vázquez. 2017.

"Polysaccharide-Based Films and Coatings for Food Packaging: A Review." *Food Hydrocolloids* 68: 136–48. https://doi.org/10.1016/j.foodhyd.2016.09.009.

Charles, A.L., Chang, Y.H., Ko, W.C., Sriroth, K. and Huang, T.C. 2004. "Some Physical and Chemical Properties of Starch Isolates of Cassava Genotypes." 56(9): 413–18.

Chen, J. and J. Jane. 1994a. "Preparation of Granular Cold–Watersoluble Starches by Alcoholic-Alkanline Treatment." 71(6): 618–622.

———. 1994b. "Preparation of Granular Cold–Watersoluble Starches by Alcoholic- Alkanline Treatment." *CerealChem.,* no. 71(6),: 618–622.

Chin, Alexander W. 2010. "Polymers for Innovative Food Packaging." *Polymers for Innovative Food Packaging,* no. s.l.

Chiu, C. -W. and D. Solarek. 2009. "Modification of Starches." *Chemistryand Technology* InJ. N. Be (3rd Edition, Academic Press): 629–55.

Darni Y., Dewi F.Y., Lismeri L. 2017. "Modification of Sorghum Starch-Cellulose Bioplastics with Sorghum Stalks Filler." *Jurnal Rekayasa Kimia Dan Lingkungan.*, no. 12(1): 22–30.

Dominici, Franco, Fabrizio Sarasini, Francesca Luzi, Luigi Torre, and Debora Puglia. 2020. "Thermomechanical and Morphological Properties of Poly(Ethylene Terephthalate)/Anhydrous Calcium Terephthalate Nanocomposites." *Polymers* 12 (2). https://doi.org/10.3390/polym12020276.

Ebewele, Robert O. n.d. *POLYMER SCIENCE AND TECHNOLOGY*.

Emadian SM, Onay TT, Demirel B. 2017. "Biodegradation of Bioplastics in Natural Environments." *Waste Management*, no. 59(1): 526–36.

Ezeoha, S L, and J N Ezenwanne. 2013. "Production of Biodegradable Plastic Packaging Film from Cassava Starch" 3 (10): 14–20.

Fabunmi, O., Tabil, L., Panigrahi, S., & Chang, P. 2011. "Effects of Incorporating Polycaprolactone and Flax Fiber into Glycerol-Plasticized Pea Starch." *H. Journal Of Polymers And The Environment, 19(4)*, 841–48.

Gadhave RV, Das A, Mahanwar PA, Gadekar PT. 2018. "Starch Based Bioplastics : The Future of

Sustainable Packaging." *Open Journal of Polymer Chemistry*, no. 8(2): : 21-23.

Gennadios A, Weller CL, Testin RF. 1993. "Property Modification of Edible Wheat, Gluten Based Films." *Transactions of the ASAE.*, no. 36(2): 465-470.

Geyer R., Jambeck J.R., Law K.L. 2017. "Production, Use, and Fate of All Plastics Ever Made. Sci. Adv" 3(7).

GILL., . MUKTI. 2014. "BIOPLASTIC A BETTER ALTERNATIVE TO PLASTICS." *International Journal of Research in Applied, Natural and Social Sciences,* pp. 2-4.

Gregory M. Glenn, William Orts and Syed Imam. 2014. Starch Plastic Packaging and Agriculture Applications.

Groote PH, Devaux J, Godard P De. 2002. "Effect of Benzenesulfonamide Plasticizers on the Glass-Transition Temperature of Semicrytalline Polydodecamide." *Journal of Polymer Science Part B: Polymer Physics.*, no. 40(19): 2208–18.

Gupta, A., Sharma, M., & Kumar. 2008. "). Preparation and Characterization of Potato Starch Based Low Density Polyethylene/Low Density Polyethylene Grafted Maleic Anhydride Biodegradable Polymer Composite." *Polymer-Plastics Technology And Engineering*, no. . doi: 10.1080/03602550802274597: 953–59.

H. D. A. Akbar, P.Sri, K. Myrtha, D. P. Oceu, H. F., and Rani. 2009. ""Fabrication and Characterization of Sweet Potato Starch-Based Bioplastic Plasticized with Glycerol." *Journal of Biological Sciences*, 6 493–500,.

H. Hermansyah, C. Rena, B. F. Merisa, D. Priscilla. 2014. "'Food Grade Bioplastic Based on Corn Starch with Banana Pseudostem Fibre/Bacteria Cellulose Hybrid Filler.'" *Advance Materials Research* Vol 997: 158-168,.

Halley, Ruixiang Zhao Æ Peter Torley Æ Peter J. 2008. . ". Emerging Biodegradable Materials Starch- and Protein-Based Bio-Nan Composite." *International Journal of Engineering and Science,P.*

Hu L, Pan H, Zhou Y, Zhang M. 2011. . ". Methods to Improve Lignin's Reactivity as a Phenol Substitute and as Replacement for Other Phenolic Compounds:" *A Brief Review.*

BioResources, 6(3):3515–25.

Iles A, Martin AN. n.d. “Sustainable Business Innovation in the Chemical Industry.” *Journal of Cleaner Production. 2013; 45(1):38-49.*, no. 45(1): 38-49.

Ilyas, R., Sapuan, S., Ishak, M., & Zainudin, E. 2018. “Development and Characterization of Sugar Palm Nanocrystalline Cellulose Reinforced Sugar Palm Starch Bionanocomposites. Carbohydrate Polymers.” . . *Carbohydrate Polymers,* 186–202.

Jafar, Jalal J. 2016. “Utilisation of Waste Plastic in Bituminous Mix for Improved Performance of Roads.” *KSCE Journal of Civil Engineering*. https://doi.org/10.1007/s12205-015-0511-0.

Jaramillo, Natalia, David Hoyos, and Juan F Santa. 2016. “Composites with Pineapple-Leaf Fibers Manufactured by Layered Compression Molding Moldeo Por Compresión Por Capas” 162 (2): 151–62.

Jung, K., Müller, M., & Schmidt, R. 2000. “Intramolecular O-Glycoside Bond Formation,” 4423–42.

K. Norhafezah, S. A. Muhammad. 2018. “Bio-Plastic Using Eggshells and Chitosan on Potato Starch Based”.” *International Journal of Engineering & Technology* 7 (3.32): 110-115,.

Katarzyna Leja, Grażyna Lewandowicz. 2009. “Polymer Biodegradation and Biodegradable Review.”

Kuhad R, Singh A. 2007. “Lignocellulose Biotechnology: Future Prospects.” *International Publishing House*.

Kumar S, Thakur KS. 2017. “Bioplastics – Classification, Production and Their Potential Food Application.” *Journal of Hill Agriculture* 8(2): .: 118–29.

Kumar Y, Shukla P, Singh P, Prabhakaran PP, Tanwar VK. 2014. “A Perfect Tool for Eco-Friendly Food Packaging.” *A Review. Journal of Food Product Development and Packaging*, no. 1(1): 01–06.

Lee SH, Doherty TV, Linhardt RJ, Dordick JS. 2009. . “. Ionic Liquid-Meditated Selective Extraction of Lignin from Wood Leading to Enhanced Enzymatic Cellulose Hydrolysis,” 102(5):1368–76.

Lodha, P., & Netravali, A. 2005. “Thermal and Mechanical Properties of Environment-Friendly ‘Green’ Plastics from Stearic Acid Modified-Soy Protein Isolate” doi: 10.10: 49–64.

M. Hendra S. Ginting, 2M.FauzyRamadhanTarigan, Annisa Maharani, and Singgih. 2015. “Effect of Gelatinization Temperature and Chitosan on Mechanical Properties of Bioplastics from Avocado Seed Starch (Perseaamericana Mill) with Plasticizer Glycerol.” *International Journal Of Engineering And Science*, 3.

M, Lackner. n.d. “Biobased Plastics as Renewable and/or Biodegradable Alternatives to Petroplastics.” *Kirk-Othmer Encyclopedia of Chemical Technology*.

Madhumitha, G, J Fowsiya, S Mohana Roopan, and Vijay Kumar Thakur. 2018. “Recent Advances in Starch-Clay Nanocomposites” 5341. https://doi.org/10.1080/1023666X.2018.1447260.

Mankar SS, Chaudhari AR, Soni I. 2012. “Lignin in Phenol–Formaldehyde Adhesives,” 3(1):116–8.

Mellinas, Cristina, Marina Ramos, and Alfonso Jim. 2020. “Recent Trends in the Use of Pectin from Agro-Waste Residues as a Natural-Based Biopolymer for Food Packaging Applications.”

Mishra, Supriya, Amar K Mohanty, Lawrence T Drzal, Manjusri Misra, and Georg Hinrichsen. 2004. “A Review on Pineapple Leaf Fibers , Sisal Fibers and Their Biocomposites,” 955–74. https://doi.org/10.1002/mame.200400132.

Mohanty AK, Misra M, Drzal LT. 2002. “Sustainable Bio-Composites from Renewable Resources.” *Environment, Journal of Polymers and The*, no. 10(1-2): 19–26.

Mudambi, Sumati R., Rao, Shalini M., Rajagopal, M.V. 2009. “Food Science.” *New Age International Limited, New Delhi*.

Narissara K., Shabbir H.G. 2013. “Greenhouse Gas Evaluation and Market Opportunity of Bioplastic Bags from Cassava in Thailand. J. Sustain. Energy Environ,” 15–21.

Neopaney, Megnath, Kezang Wangchuk, and Sherub Tenzin. 2012. “Stabilization of Soil by Using Plastic Wastes” 2 (2): 461–66.

Oates, Lucy, Ross Gillard, Peter Kasaija, Andrew Sudmant, and Andy Gouldson. n.d. "Supporting Decent Livelihoods through Sustainable Service Provision : Lessons on Solid Waste Management from Kampala , Uganda Summary," 1–20.

Olagundoye, Adetuyi Abayomi, and Adejuwon Olorunsola Morayo. 2022. "Characterization of Potato Peel Starch-Based Bioplastic Reinforced with Banana Pseudostem Cellulose for Packaging Applications." *International Journal of Innovative Science and Research Technology* 7 (4). www.ijisrt.com.

Pereira, Valdir Aniceto, Iza Natália Queiroz de Arruda, and Ricardo Stefani. 2015. "Active Chitosan/PVA Films with Anthocyanins from Brassica Oleraceae (Red Cabbage) as Time-Temperature Indicators for Application in Intelligent Food Packaging." *Food Hydrocolloids* 43: 180–88. https://doi.org/10.1016/j.foodhyd.2014.05.014.

Pérez S., Bertoft E. n.d. "The Molecular Structures of Starch Components and Their Contribution to the Architecture of Starch Granules," 62:389–420.

Qin, Yan, Yunpeng Liu, Limin Yuan, Huimin Yong, and Jun Liu. 2019. "Food Hydrocolloids Preparation and Characterization of Antioxidant , Antimicrobial and PH- Sensitive Films Based on Chitosan , Silver Nanoparticles and Purple Corn Extract." *Food Hydrocolloids* 96 (May): 102–11. https://doi.org/10.1016/j.foodhyd.2019.05.017.

Rafiqah, A, K Abdan, M Nasir, and M Asim. 2020. "Effect of Extraction on the Mechanical , Physical and Biological Properties of Effect of Extraction on the Mechanical , Physical and Biological Properties," no. February. https://doi.org/10.1007/978-981-15-1416-6.

Ren, Jiawei, Khanh Minh Dang, and Eric Pollet. n.d. "Preparation and Characterization of Thermoplastic Potato Starch / Halloysite Nano-Biocomposites : Effect of Plasticizer Nature and Nanoclay Content." https://doi.org/10.3390/polym10080808.

Roy, Swarup, and Jong Whan Rhim. 2020. "Anthocyanin Food Colorant and Its Application in PH-Responsive Color Change Indicator Films." *Critical Reviews in Food Science and Nutrition* 0 (0): 1–29. https://doi.org/10.1080/10408398.2020.1776211.

S. Maulida, M, Siagian, and P, Tarigan. 2016. "'Production of Starch Based Bioplastic from Cassava Peel Reinforced with Microcrystalline Celllulose Avicel PH101 Using Sorbitol as

Plasticizer'." *Journal of Physics*.

Sanyang M.L., Sapuan S.M., Jawaid M., Ishak M.R., Sahari J. 2016. "Effect of Plasticizer Type and Concentration on Physical Properties of Biodegradable Films Based on Sugar Palm (Arenga Pinnata) Starch for Food Packaging. J. Food Sci. Techno," ;53(1):326– 336.

Sarker, Moinuddin, Aminul Kabir, Mohammad Mamunor Rashid, Mohammed Molla, and A. S. M. Din Mohammad. 2011. "Waste Polyethylene Terephthalate (PETE-1) Conversion into Liquid Fuel." *Journal of Fundamentals of Renewable Energy and Applications* 1: 1–5. https://doi.org/10.4303/jfrea/r101202.

Silva, Francisco A G S, Fernando Dourado, and Miguel Gama. 2020. "Nanocellulose Bio-Based Composites for Food Packaging," 1–29.

Singh, J., L. Kaur and N. Singh. 2004. "Effect of Acetylation Onsome Properties of Corn and Potato Starche," no. Starch, 56: 586–601.

Singh, J. and N. Singh. 2001. . ". Studies on the Morphological,Thermal and Rheological Properties of Starch Separated FromIndian Potato Cultivars." *Food Chem*, no. 75(1),: 67–77.

smail N.A., Tahir S.M., AbdulWahid M.F., Khairuddin N.E., Hashim I., Rosli N., Abdullah M.A. 2016. "Synthesis and Characterization of Biodegradable Starch-Based Bioplastics. Mater. Sci. Forum," ;846:673–678.

Suderman N, Isa M I N, Sarbon N M. 2016. "6 Effect of Drying Temperature on the Functional Properties of Biodegradable CMC-Based Film for Potential Food Packaging Int." *Food Res. J*, no. 23 3: 1075–84.

Sujuthi R.A.F., Liew K.C. 2016. . ". Properties of Bioplastic Sheets Made from Different Types of Starch Incorporated With Recycled Newspaper Pulp." *Trans. Sci. Technol.*, no. 3(1–2): 257–64.

Suryati, Meriatna, Marlina. 2016. "Optimization of Bioplastic Manufacturing Processes from Cassava Peel Waste Starch)," no. J. Tek. K. Unima.l 5 1: 78–91.

Swaminathan, M. 1985. "Essentials of Food and Nutrition" Vol.I&II,.

Talegaonkar, Sushama, Harshita Sharma, Shweta Pandey, Pawan Kumar Mishra, and Rupert Wimmer. 2017. *3 - Bionanocomposites: Smart Biodegradable Packaging Material for Food Preservation*. *Food Packaging*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-804302-8/00003-0.

Verma D, Gope PC, Maheshwari MK, Sharma RK. 2012. "Bagasse Fiber Composites." - *A Review. J. Mater. Environm. Sci.*, no. 3(6): 1079-1092.

Vo, Thuy Vi, Tan Hiep Dang, and Bing Hung Chen. 2019. "Synthesis of Intelligent PH Indicative Films from Chitosan/Poly(Vinyl Alcohol)/Anthocyanin Extracted from Red Cabbage." *Polymers* 11 (7): 1–12. https://doi.org/10.3390/polym11071088.

Wang M, Leitch M, Xu. 2009. "Synthesis of Phenol–Formaldehyde Resol Resins Using Organosolv Pine Lignins," ;45:3380–8.

Wiwoho, Mudjanarko Sri, Mayestino Machicky, and Rasidi Nawir. 2017. "Bamboo Waste as Part of The Aggregate Pavement The Way Green Infrastructure in The Future" 03013. https://doi.org/10.1051/matecconf/201713803013.

Wróblewska-krepsztul, Jolanta, Tomasz Rydzkowski, Gabriel Borowski, Mieczysław Szczypiński, Tomasz Klepka, and Vijay Kumar Thakur. 2018. "International Journal of Polymer Analysis and Recent Progress in Biodegradable Polymers and Nanocomposite-Based Packaging Materials for Sustainable Environment ABSTRACT." *International Journal of Polymer Analysis and Characterization* 23 (4): 383–95. https://doi.org/10.1080/1023666X.2018.1455382.

Y, amshidi K. Hyon SH and Ikada. 1998. "Thermal Characterization of Polylactides. Polymer" ; (29(12):): 2229–34.

Y, Chisti. 2014. "How Renewable Are the Bioplastics?. Biotechnology Advance," no. 32(7): 1361.

Yin Y., Li J., Liu Y., Li Z. 2005. "Byun H.S., Yoon S.D. Biodegradability of Chemically Modified Starch." *Appl. Polym. Sci.*, 1394–97.

YJ, Chen. 2014. "Bioplastic and Their Role in Achieving Global Sustainability." *Y. Journal of Chemical and Pharmaceutical Research*, no. 6(1): 226–31.

Yogesh, M, and A N Hari Rao. 2018. “Fabrication , Mechanical Characterization of Pineapple Leaf Fiber (PALF) Reinforced Vinylester Hybrid Composites” 020062. https://doi.org/10.1063/1.5029638.

Zahidah, Nur, Rozaki Seng-neon Gan, and Desmond Teck-chye Ang. 2016. “Environmentally Friendly Oil-Modified Polyesters as Polymeric Plasticizers for Poly (Vinyl Chloride).” *Journal of Polymers and the Environment*. https://doi.org/10.1007/s10924-016-0810-7.

Zulkifli, Rozli, and Isaac Nongwe Beas. n.d. “Environmental Impact of Food Packaging Materials : A Review of Contemporary Development from Conventional Plastics to Polylactic Acid Based Materials.”

Lourdin, D.; Della Valle, G. and Collona, P. (1995), Influence of amylose content on starch films and foams. Carbohydrate Polymers, 27, 261-270.

Lourdin, D.; Bizot, H. and Colonna P. (1997), Antiplasticization in starch-glycerol films? Journal of Applied Polymer Science, 63, 1047-1053.

Mali, S.; Grossmann, M. V. E.; Garcia, M. A; Martino, M. N. and Zaritzky, N. E. (2002), Microstrucural characterization of yam starch films. Carbohydrate Polymers, 50, 379-386.

Morais, L. C.; Carvalho, A. J. F.; Da Róz, A. L. and Curvelo, A. A. S. (2001), Preparação e caracterização de termoplásticos a partir de lignossulfato e amido. In: 6. Congresso Brasileiro de Polímeros / 9. International Macromolecular Colloquium. Anais… Gramado/RS.

Myllärinen, P.; Partanen, R.; Seppälä, J. and Forssell, P. (2002), Effect of glycerol on behaviour of amylose and amylopectin films. Carbohydrate Polymers, 50, 355-361.

Narayan, R.; Bloembergen, S. and Lathia, A. (1999), Method of preparing biodegradable modified-starch moldable products and films. USA Patent n° 5,869,647.

Rindlav, A.; Hulleman, S. H. D. and Gatenholm, P. (1997), Formation of starch films varying crystallinity. Carbohydrate Polymers, 34, 25-30.

Rosa, D. V.; Franco, B. L. M. and Calil, M. R. (2001), Biodegradabilidade e propriedades mecânicas de novas misturas poliméricas: polímeros. Ciência e Tecnologia, 11 : (2), 82-88.

Shogren, R. L.; Fanta, G. F. and Doane, W. M. (1993), Development of starch-based plastics - A reexamination of selected polymer systems in historical perspective. Starch/Stärke, 8, 276.

My Organic Chemistry [home page on the internet]. Available from: https://myorganicchemistry.wikispaces.com/Cellulose [cited 04.01.14]

Brinchi L, Cotana F, Fortunati E, Kenny JM. Production of nanocrystalline cellulose from lignocellulosic biomass: technology and applications. Carbohydr Polym 2013;94:154–69.

Hu L, Pan H, Zhou Y, Zhang M. Methods to improve lignin's reactivity as a phenol substitute and as replacement for other phenolic compounds: a brief review. BioResources 2011;6(3):3515–25.

Min D, Smith SW, Chang H, Jameel H. Influence of isolation condition on structure of milled wood lignin characterized by quantitative 13 ◦C nuclear magnetic resonance spectroscopy. BioResources 2013;8(2):1790–800.

Kuhad R, Singh A. Lignocellulose biotechnology: future prospects. I.K. International Publishing House; 2007.

Lee SH, Doherty TV, Linhardt RJ, Dordick JS. Ionic liquid-meditated selective extraction of lignin from wood leading to enhanced enzymatic cellulose hydrolysis. Biotecnol Bioeng 2009;102(5):1368–76.

Brosse N, Ibrahim MNM, Rahim AA. Biomass to bioethanol: initiatives of the future for lignin. ISRN Mater Sci 2011;2011:1–10

Barton F. Chemistry of lignocellulose: methods of analysis. Animal Feed Sci Technol 1988;21:279–86.

Wang M, Leitch M, Xu C. Synthesis of phenol–formaldehyde resol resins using organosolv pine lignins. Eur Polym J 2009;45:3380–8.

Mankar SS, Chaudhari AR, Soni I. Lignin in phenol–formaldehyde adhesives. Int J Knowl Eng 2012;3(1):116–8