



**BUSITEMA
UNIVERSITY**
Pursuing Excellence

**INVESTIGATION OF PECTIN-BASED ADHESIVE FROM SWEET
POTATO RESIDUES FOR ENHANCED BINDING OF NONWOVEN
FABRICS.**

By

AKELLO WINNIE

REG. NO. BU/UG/2021/0085

SUPERVISORS:

- 1. DOCTOR JANANI LOUM**
- 2. MS. CATHERINE NAMUGA**
- 3. MR. SENDAWUULA CHARLES**

*This report is submitted to the Department of Polymer, Textile and Industrial Engineering in
Partial Fulfilment of the Requirement for the Award of the Degree of Bachelor of Science in
Polymer, Textile and Industrial Engineering of Busitema University.*

MAY 2025

ABSTRACT

The growing demand for sustainable and eco-friendly adhesives in the textile industry has highlighted the need to explore natural alternatives to synthetic, petroleum-based adhesives. This project investigated the effectiveness of pectin-based adhesive from sweet potato residues for binding nonwoven textile materials. Sweet potato peel, an abundant agricultural byproduct in Uganda is under-utilized and yet can be used as a low-cost source of pectin. The study focuses on three main objectives: optimizing the pectin extraction process, characterizing the chemical properties of the extracted pectin and evaluating its adhesive performance in binding nonwoven fibers. The use of Response Surface Methodology to optimize the extraction parameters mainly extraction time and extraction temperatures using Composed Composite design experiment consisting of 32 runs was employed to determine pectin yield as the response with hydrochloric acid as the extraction solvent. The pH of the extraction solvent was kept constant at 1.5. This was followed by modifying the adhesion of the extracted pectin using calcium chloride as a crosslinking agent and glycerol as plasticizer. Both modified and unmodified extracted pectin sample was analyzed on Fourier Transform Infrared Spectroscopy (for functional group and degree of esterification) which are very crucial for adhesive properties. The adhesive's binding strength, thermal stability and water resistance tests were carried out to assess the suitability for textile applications. These properties were conducted on nonwoven cotton fabrics as hygienic nonwoven fabrics. Results from this study demonstrated the potential of sweet potato derived pectin as a renewable, environmentally friendly adhesive contributing to sustainable development in the textile industry.

DECLARATION

I AKELLO WINNIE solely declares that all the information in this report on the title Investigation of Pectin based Adhesive from Sweet Potato Residues for Enhanced Binding of Nonwoven Fabrics is true original findings of my research and has never been presented in any institutions for academic purposes.

Student's Name AKELLO WINNIE

Signature Akello Winnie

Date 20/05/2025

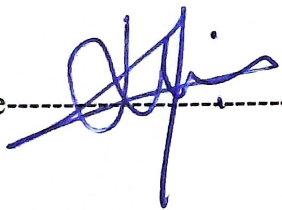
APPROVAL

This is to certify that the project report titled "Investigation of Pectin Based Adhesive from Sweet Potato Residue for Enhanced Binding of Nonwoven Fabrics" submitted by AKELLO WINNIE in partial fulfillment of the requirements for the degree of BACHELOR OF SCIENCE IN POLYMER, TEXTILE AND INDUSTRIAL ENGINEERING in DEPARTMENT OF POLYMER, TEXTILE AND INDUSTRIAL ENGINEERING at BUSITEMA UNIVERSITY, has been reviewed and approved.

The research conducted in this report is original and has been carried out under the supervision of DR. JANANI LOUM, MR. SSENDAWULA CHARLES AND MADAM. CATHERINE NAMUGA. The results presented are authentic to the best of our knowledge, and the project adheres to the academic standards and ethical guidelines of BUSITEMA UNIVERSITY.

Approved by:

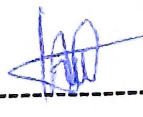
Main Supervisor: Dr. Janani Loum

Signature----- 30-5-2025

Co. Supervisor: Mr. Ssendawuula Charles

Signature-----

Co. Supervisor: Madam Catherine Namuga

Signature-----

DEDICATION

I firstly dedicate this project to my family members whose unwavering support, encouragement, and belief in me have been the foundation of my academic journey, especially my lovely mother Dorine Aloyo, beloved brother Richard Okot and Uncle Stephen Lokoya for their endless love, sacrifices and guidance.

Secondly to all my friends and colleagues, for their constant motivation and encouragement throughout this endeavor and lastly to all educators and mentors who have inspired me to pursue my passions and strive for excellence. Your wisdom and encouragement have been invaluable.

Thank you for believing in me always.

ACKNOWLEDGEMENT

I would like to express my deepest gratitude to all those who have contributed to the completion of this research work.

Firstly, I am immensely grateful to my supervisors, Ms. Catherine Namuga, Mr. Ssendawuula Charles and Dr. Janani Loum, for their invaluable guidance, continuous support, and encouragement throughout the research process. Their insightful feedback and expertise were instrumental in shaping this project and overcoming various challenges. I also acknowledge the guidance and support of the laboratory technicians Mr. Godius and Mr. Sammy, Mr. Collins and Mr. Duncan from Nagongera Chemistry laboratory. Not forgetting the entire staff in the Department of Polymer, Textile and Industrial Engineering for all the guidance, support and encouragement to enable me accomplish this research work. I am also grateful to my family and friends for their unwavering support, patience, and encouragement throughout this endeavor. Their belief in my abilities and constant motivation kept me determined and focused towards the success of my proposal work.

ACCRONYMS AND ABBREVIATIONS

FTIR-Fourier Transform Infrared Spectrometry

SEM-Scanning Electron Microscopy

EDANA-European Disposable and Nonwovens Association

HCl-Hydrochloric acid

NaOH- sodium Hydroxide

pH- Potential of Hydrogen

DE- Degree of Esterification

UBOS-Uganda National Bureau of Statistics

FAO-Food and Agriculture Organization

CAGR-Compound Annual Growth Rate

LMP-Low Methoxyl Pectin

HMP-High Methoxyl Pectin

AOAC-Association of Official Agricultural Chemist

ASTM-American Standards of Testing and Machine

UTM-Universal Testing Machine

AATCC-American Association of Textile Chemists and Colorists.

PVA-Polyvinyl acetate

EVA-Ethylene Vinyl acetate

Table of Contents

ABSTRACT.....	i
DECLARATION	ii
APPROVAL.....	iii
DEDICATION	iv
ACKNOWLEDGEMENT.....	v
ACCRONYMS AND ABBREVIATIONS	vi
LIST OF FIGURES.....	x
LIST OF TABLES.....	xi
CHAPTER ONE: INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement.....	3
1.3 Study Objectives	3
1.3.1 Main Objectives	3
1.3.2 Specific Objectives	3
1.3.3 Research Questions.....	4
1.4 Justification	4
1.5 Significance	4
1.6 Scope of the scope	4
1.6.1 Conceptual scope	4
1.6.2 The Geographical Scope	5
1.6.3 Time Scope	5
1.7 Conceptual framework	5
CHAPTER TWO: LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Pectin based adhesives	7
2.3 Sweet potato residues as source of adhesive.....	7
2.4 Background on Pectin	8
2.4.1 Extraction of pectin.....	9
2.5 Role of the crosslinking agent.....	11
2.6 Glycerol as a plasticizer	12
2.7 Nonwovens production.....	12
2.7.1 Fibers used in nonwovens	13

CHAPTER THREE: METHODOLOGY.....	15
3.1.0 Materials and equipment.	15
3.2.0 Objective one: To optimize the extraction parameters of pectin from sweet potato residues using Response Surface Methodology.....	15
3.2.1 Preparation of Materials.....	15
3.2.2 Experimental procedures.....	15
3.2.3 Analysis on the extracted pectin	16
3.3.0 Specific Objective Two: To characterize both the extracted pectin and the improved pectin solution	17
3.3.1 Formulation of pectin-based adhesive	17
3.3.2 Functional group identification.....	17
3.3.3 Degree of Esterification (DE) Analysis	17
3.3.4 Scanning Electron Microscopy (SEM) Analysis	18
3.4.0 Specific Objective Three: To determine the performance of the formulated pectin-based adhesive on nonwoven fabrics.	18
3.4.1 Tensile strength test for adhesive durability	18
3.4.2 Elongation at break	18
3.4.3 Water resistance test.....	18
CHAPTER FOUR: RESULTS AND DISCUSSION	20
4.1.0 Objective One: To optimize the extraction parameters for the extraction of pectin from sweet potato residues using Response Surface Methodology.	20
4.1.1: The yield of pectin result	20
4.1.2: Solubility Test of Pectin.....	26
4.2.0 Objective Two: To characterize the extracted pectin.....	27
4.2.1 Formulation of a 5% w/v pectin based adhesive.....	27
4.2.2 Functional Groups Analysis.....	28
4.2.3 Degree of Esterification Analysis	31
4.2.4 Scanning Electron Microscopy	31
4.3.0. Objective 3: To evaluate the performance of the adhesive in binding nonwoven fabrics.....	33
4.3.1: Tensile Strength	33
4.3.2 Elongation at break	35
4.3.3: Water resistance test	36
CHAPTER FIVE: RECOMMENDATIONS, CHALLENGES AND CONCLUSIONS.....	38
5.1: RECOMMENDATIONS	38

5.2: CHALLENGES FACED.....	38
5.3: CONCLUSION.....	38
APPENDIX.....	39
REFERENCES.....	41

LIST OF FIGURES

Figure 1 showing types of adhesivesINTERVENING VARIABLES	5
Figure 2 shows conceptual framework of the study	5
Figure 3 showing types of adhesives	6
Figure 4 showing comparision of predicted and actual pectin yield	23
Figure 5 showing Main Effects Plot for Pectin Yield	24
Figure 6 showing Surface Plot of Pectin Yield (%)	25
Figure 7 showing Optimization plot of Pectin Yield (%)	26
Figure 8 showing key functional groups of the extracted Pectin	28
Figure 9 showing comparison of the FTIR results for the extracted adhesive and the formulated adhesive	30
Figure 10 showing image (a) of the extracted pectin from SEM	31
Figure 11showing image (b) of the extracted pectin from SEM	32
Figure 12showing the extracted pectin structure	32
Figure 13showing tensile strength comparison.....	35
Figure 14 showing comparisons of elongation at break for pectin and synthetic adhesives.....	36
Figure 15 showing water absorption comparisons for improved pectin and synthetic adhesives	37
Figure 16 showing the formulated adhesive's pH adjustment.	39
Figure 17 showing filtration of unwanted residue during pectin extraction.....	40
Figure 18 showing precipitated pectin filtration	40
Figure 19 Shows centrifuge results.....	40
Figure 20 showing wet extracted pectin sample	40
Figure 21 showing formulated pectin adhesive.....	40

LIST OF TABLES

Table 1 shows the extraction techniques, pectin source and the yield obtained	10
Table 2 shows experimental design	16
Table 3 shows pectin yield results	20
Table 4 showing actual and predicted pectin yield	22
Table 5 shows solubility test results of pectin	26
Table 6 showing tensile strength of synthetic adhesives and the improved pectin.....	34
Table 7 showing elongation at break comparison of improved pectin and synthetic adhesives.....	35
Table 8 showing comparison of water absorption for improved pectin and synthetic adhesives.....	37

REFERENCES

- Arantzazu Valdés, N. B. (2015). Natural Pectin Polysaccharides as Edible Coatings. *Coatings* 2015, 865-874.
- A, M. E. H., & Batabyal, S. K. (2024). Biopolymer pectin with calcium ion crosslinker as biocompatible electrolyte for energy storage applications. *Electrochimica Acta*, 489(144150).
- A, T. S., A, G. F., B, P. J. do A. S., A, R. L. da C., & A, F. C. M. (2019). Biodegradable pressure sensitive adhesives produced from vital wheat gluten: Effect of glycerol as plasticizer. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 560, 42–49.
- Aguirre, A. (2019). *SYSTEMIC*.
- Ahed Almalla, Andreas Hertwig, Daniel Fischer, Ozlem Ozcan, J. W. (2021). Development of layer-by-layer assembled thin coatings on aluminium alloy AA2024-T3 for high resolution studies of local corrosion processes. *Journal of Applied Polymer Science*, 137(48/49826).
- Ahmed, H. B., El-Rafie, M. H., Zahran, M. K., Hussein El-Rafie, M., Kandil, M., & Bactericidal, Z. (2015). Bactericidal Evaluation of Nano-coated Cotton Fabrics. *American Journal of Nano Research and Applications*, 3(6), 105–112. <https://doi.org/10.11648/j.nano.20150306.13>
- Analese Roman-Benna, b, C., D, C. A. C., D, M.-W. L., Lamd, H.-M., Ah-Hena, K., Ulloae, P. E., & María Cristina Ravanal a. (2023). Pectin: An overview of sources, extraction and applications in food products, biomedical, pharmaceutical and environmental issues. *Food Chemistry Advances*, 2.
- Andrew B. Servais, Cristian D. Valenzuela, Arne Kienzle, Alexandra B. Ysasi, Willi L. Wagner, Akira Tsuda, Maximilian Ackermann, and S. J. M. (2018). *Functional Mechanics of a Pectin-Based Pleural Sealant after Lung Injury*. 24(1 May 2018), 9–10.
- Anwar, E. I. M. I. & R. (n.d.). Comparison of Natural and Synthetic Adhesives for Ceramic Conservation. *International Colloquium of Art and Design Education Research (i-CADER 2014)*, 2014, 127–135.
- Babaarslan, N. A. K. and O. (2016). *Fiber Selection for Production of Nonwovens*.
- Cereda, M. P. (2023). Chapter 15 - Starch glues and adhesives. *Starch Industries: Processes and Innovative Products in Food and Non-Food Uses*, 3(24 November 2023), 335–348.
- Chandel, V., Biswas, D., Roy, S., Vaidya, D., Verma, A., & Gupta, A. (2022). *Current Advancements in Pectin : Extraction , Properties and Multifunctional Applications*. 2nd sept 2022, 1–30.
- Chunmeng Han , Xiangying Zhao , Liping Yang, Mingjing Yao, Jiayang Zhang, Q. H., & Liu, J. L. and L. (2024). Extraction and Structural Analysis of Sweet Potato Pectin and Characterization of Its Gel.

- Dinu, L., Iordache, O., & Vamanu, E. (2022). *Scanning Electron Microscopy Study on the Biodeterioration of Natural Fiber Materials Compared to Disposable Hygiene and Sanitary Products*. 1–11.
- E. A. Gyunter, A. K. Melekhin, S. V. Popov, E. A. Durnev, E. A. Martinson, S. G. Litvinets, M. A. K. & V. P. V. (2017). Adhesive Properties of Pectin–Chitosan Composite Gels. *Chemistry of Natural Compounds*, 53(27 September 2017), 823–829.
- Ebrahim, S. A., Othman, H. A., Mosaad, M. M., & Hassabo, A. G. (2022). A Valuable Observation on Pectin as an Eco-friendly Material for Valuable Utilisation in Textile Industry. *Egyptian Journal of Chemistry*, 65(4), 555–568. <https://doi.org/10.21608/EJCHEM.2021.96717.4526>
- Evaluation of adhesion properties of blends of cottonseed protein and anionic water-soluble polymers_ Journal of Adhesion Science and Technology_ Vol 33 , No 1 - Get Access.* (n.d.).
- Fatima Abderrahim, Elizabeth Huanatico, Roger Segura, Silvia Arribas, M Carmen Gonzalez, L. C.-H. (2015). Physical features, phenolic compounds, betalains and total antioxidant capacity of coloured seeds (*Chenopodium quinoa* Willd) from Peruvian Altiplano. *Food Chemistry*, 183, 83–90.
- Frederick W.A.Owusu, Mariam E.Boakye-Gyasi Philomena Entsie, Marcel T.Bayor, K. O. K. (2021). *Utilization of Pectin from Okra as Binding Agent in Immediate Release Tablets*.
- Geeske Langejans, Akessandro Aleo, S. F. and P. K. (n.d.). *Archaeological Adhesives*.
- Gendensuren, B., He, C., & Oh, E. S. (2020). Preparation of pectin-based dual-crosslinked network as a binder for high performance Si/C anode for LIBs. *Korean Journal of Chemical Engineering*, 37(2), 366–373. <https://doi.org/10.1007/s11814-019-0438-0>
- Gharibzahedi, S. M. T., Smith, B., & Guo, Y. (2019). Pectin extraction from common fig skin by different methods: The physicochemical, rheological, functional, and structural evaluations. *International Journal of Biological Macromolecules*, 136, 275–283. <https://doi.org/10.1016/j.ijbiomac.2019.06.040>
- GUEVARA, M. M. S., SAUCEDO-RIVALCOBA, V., RIVERA-ARMENTA, J. L., & ELVIRA-TORALES, and L. I. (2022). EVALUATION OF A CROSS-LINKING AGENT IN THE PREPARATION OF FILMS BASED ON CHITOSAN AND PECTIN FOR FOOD PACKAGING APPLICATIONS. *CELLULOSE CHEMISTRY AND TECHNOLOGY*.
- Hamidon, N. H., Norulfairuz, D., & Zaidel, A. (2017). *Effect of Extraction Conditions on Pectin Yield Extracted from Sweet Potato Peels Residues using Hydrochloric Acid*. 56, 979–984.

<https://doi.org/10.3303/CET1756164>

- Han, C., Zhao, X., Yang, L., Yao, M., Zhang, J., & He, Q. (2024). *Extraction and Structural Analysis of Sweet Potato Pectin and Characterization of Its Gel*. July 2024, 1–16.
- Hrabovska, Olena;Pastukh, Hanna;Demenyuk, Oksana;Miroshnyk, Volodymyr;Halatenko, Tetyana;Babii, Alina;Dobrydnuk, A. (2015). Potato pectin: extract methods, physical and chemical properties and structural features. *Ukrainian Food Journal*, 4(1).
- Ilaria Frosi , Anna Balduzzi , Giulia Moretto, R. C. O. and Adele P. (2023). Towards Valorization of Food-Waste-Derived Pectin: Recent Advances on Their Characterization and Application. *Food Chemistry*, 28(17)(1 September 2023, 6390).
- Joanne Yi Hui Tay, Jian wei See, D. H. (2022). *physicochemical and functional characterization of pectin from Margarita sweet potato leaves*. 385(15 August).
- Kashani, A., Hasani, M., Nateghi, L., Asadollahzadeh, M. J., & Kashani, P. (2022). Optimization of the Conditions of Process of Production of Pectin Extracted from the Waste of Potato Peel. *Iranian Journal of Chemistry and Chemical Engineering*, 41(4), 1288–1304. <https://doi.org/10.30492/IJCCE.2021.127121.4115>
- Kumar, A. K. S. and S. S. (2022). Pectin Production from Biowaste (Fruits & Vegetables) by Crosscurrent Solid-Liquid Extraction Technique. *Nature Environment and Pollution Technology*, 21(2), 651–657.
- Kwang Ho Lee, Tridib Kumar Sinha, Kyum Woo Choi, J. S. O. (2020). Ultra-high molecular-weight polyethylene reinforced polypropylene and polyamide composites toward developing low noise automobile interior. *Journal of Applied Polymer Science*, 137(48720).
- Malel Tian, Xin Huang, Ying Cheng, Yunwei Niu, Jiajia Ma, Yi Zhao, Xingran Kou, Q. K. (n.d.). *Applications of adhesives in textiles _ A review - ScienceDirect* (p. 111089).
- Mario Madrid, Jani Turunen, W. S. (2023). 26 - General industrial adhesive applications: Qualification, specification, quality control, and risk mitigation. *Advances in Structural Adhesive Bonding(Second Edition)*, 849–876.
- Marvin Kaufmann, Florian Flaig, Micheal Muller, Holger Fricke, T. V. (n.d.). Optimized adhesive application. *International Journal of Adhesion and Adhesives*, 130(103620).
- Masuelli, M. G. G. and M. A. (2022). Effect of Cross-Linking Agent on Mechanical and Permeation Properties of Criolla Orange Pectin. *Open Access Peer-Reviewed Chapter*.

- Mirza Mohammad Omar Khyum, S. R. (2024). Innovations in nonwoven textiles. *Sustainable Innovations in the Textile Industry, The Textile Institute Book Series*, 187–215.
- Muhammad Awais Imran, Muhammad Qamar Khan, A. S. and A. A. (2020). *Cotton in Nonwoven Products*.
- Narimane Mati-Baouche, Helene de Baynast, Philippe Michaud, Pierre-Henri Elchinger, Guillaume Pierre, C. D. (2014). *Chitosan as an adhesive*. 60(November 2014), 198–212.
- Nateghi, Leila, Zarei, Fatemeh, Zarei, M. (2022). Optimize the Extraction Conditions of Pectin Extracted from Saveh Pomegranate Peels. *Iran.J. Chem. Chem. Eng.*, 41(11), 3835–3850.
- Nesic, A., Meseldzija, S., Onjia, A., & Cabrera-Barjas, G. (2022). Impact of Crosslinking on the Characteristics of Pectin Monolith Cryogels. *Polymers*, 14(23). <https://doi.org/10.3390/polym14235252>
- Norulfairuz, D., Zaidel, A., Maslina, Y., Jusoh, M., & Muhamad, I. I. (2015). *Extraction and characterisation of pectin from sweet potato (Ipomoea batatas) pulp*. July 2017.
- Ortiz-Fernández, A., Ríos-Soberanis, C. R., Chim-Chi, Y. A., Moo-Huchin, V. M., Estrada-León, R. J., & Pérez-Pacheco, E. (2021). Optimization of biodegradable starch adhesives using response surface methodology. *Polymer Bulletin*, 78(7), 3729–3749. <https://doi.org/10.1007/s00289-020-03297-y>
- Rushikesh Handibag, Dorcus Masih, Chitra Sonkar, P. V. and R. J. (2022). Microwave-assisted extraction and quality evaluation of pectin from sweet lemon peel. *International Journal of Advanced Chemistry Research*, 4(2 (Part C)), 203–206.
- Salleh, K. M., Hashim, R., Sulaiman, O., Hiziroglu, S., Noor, W., Wan, A., Karim, N. A., Jumhuri, N., Mohd, K., Hashim, R., & Sulaiman, O. (2015). Evaluation of properties of starch-based adhesives and particleboard manufactured from them. *Journal of Adhesion Science and Technology*, 4243, 1–17. <https://doi.org/10.1080/01694243.2014.987362>
- Samuel de la Hoz Vega¹, Bernardo Vásquez Jaraba¹, José Pérez Mendoza¹, A. A. A. O. Q. (2018). Effect of Precipitating Solventson the Extraction of Pectin from the Pomelo Albedo by Acid Hydrolysis. *Contemporary Engineering Sciences*, 11(78), 3849–333855.
- Sayed, A. (2014). *Non-woven Fabric: Raw Materials, Characteristics and End Uses*. updated on September, 7th 2024.
- Sergey Popov ORCID, Nikita Paderin, E. C. andDmitry P. (2023). Serosal Adhesion Ex Vivo of Hydrogels Prepared from Apple Pectin Cross-Linked with Fe³⁺ Ions. *International Journal of Molecular*

Sciences, 24(2).

- Seyed Mohammad Taghi Gharibzadeh, B. S. and Y. G. (2019). Pectin extraction from fig skin by different methods: The physicochemical, rheological, functional and structural Evaluations. *International Journal of Biological Macromolecules*, 136(1 September 2019), 275–283.
- Sheyla Moreira Goncalves, Daiane Cardial dos Santos, Joyce Fagundes Gomes Motta, Regiane Ribeiro dos Santos, Davy William Hidalgo Chavez, N. R. de M. (2019). structure and functional properties of cellulose acetate films incorporated with glycerol. *Carbohydrate Polymers*, 209, 190–197.
- Shuai Xu, Shujie Xu, Xiaoli Ge, Liping Tan, T. L. (2022). Low-cost and highly efficient production of bacterial cellulose from sweet potato residues: Optimization, Characterization, and Application. *International Journal of Biological Macromolecules*, 196(31 Jan 2022), 172–179.
- Sylvester, E. D. and B. (2017). Adhesives: Applications and Recent Advances. *Applied Adhesive Bonding in Science and Technology*.
- Sylvester, E. D. and B. (2018). *Adhesives: Application and Recent Advances*.
- T.Karthik, P. K. C. and R. R. (2016). Non-woven-Process, Structure, Properties and Applications. *WOODHEAD PUBLISHING INDIA IN TEXTILES*.
- T.Maloney, A. . S. P. J. T. F. (2021). *bio-based materials for nonwovens*. 31 July 2021.
- Tapanee Chuenkaek, T. K. (2024). Citrus Waste Upcycling toward Pectin Moisturizer Films Plasticized with Glycerol and Polyethylene GlycolClick to copy article link. *ACS Sustainable Resource Management*, 1(2).
- Vilas, R., Gadhave, I., & Gadhave, C. R. (2022). Adhesives for the Paper Packaging Industry : An Overview. *Open Journal of Polymer Chemistry*, 55–79. <https://doi.org/10.4236/ojpchem.2022.122004>
- Williams, James MD; Prey, Beau MD; Francis, Andrew MD; Weykamp, Michael MD; Liu, Betty MD; Parsons, Michael MD; Vu, Michael MD; Franko, Jace MD; Roedel, Erik MD; Lallemand, Michael MD; Bingham, Jason MD; Mentzer, Steven MD; Kuckelman, J. DO. (2023). Pectin based biologic Velcro effectively seals traumatic solid organ and small bowel injuries. *Journal of Trauma and Acute Care Surgery*, 95(1), 55–61.
- Yongping Lu, Xinyuan Xu, J. L. (2023). Recent advances in adhesive materials used in the biomedical field: adhesive properties, mechanism, and applications. *Journals of Material Chemistry B*,

11(15,2023), 3338–3355.

- You, Q., & Wan, M. (n.d.). *Optimization of sweet potato pectin extraction using hydrochloric acid*. *Optimization of sweet potato pectin extraction using hydrochloric acid*. <https://doi.org/10.1088/1757-899X/736/2/022042>
- Zhang, W., Cao, J., & Jiang, W. (2022). Effect of different cation in situ cross-linking on the properties of pectin-thymol active film. *Food Hydrocolloids*, 128(107594).
- A, M. E. H., & Batabyal, S. K. (2024). Biopolymer pectin with calcium ion crosslinker as biocompatible electrolyte for energy storage applications. *Electrochimica Acta*, 489(144150).
- A, T. S., A, G. F., B, P. J. do A. S., A, R. L. da C., & A, F. C. M. (2019). Biodegradable pressure sensitive adhesives produced from vital wheat gluten: Effect of glycerol as plasticizer. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 560, 42–49.
- Aguirre, A. (2019). *SYSTEMIC*.
- Ahed Almalla, Andreas Hertwig, Daniel Fischer, Ozlem Ozcan, J. W. (2021). Development of layer-by-layer assembled thin coatings on aluminium alloy AA2024-T3 for high resolution studies of local corrosion processes. *Journal of Applied Polymer Science*, 137(48/49826).
- Ahmed, H. B., El-Rafie, M. H., Zahran, M. K., Hussein El-Rafie, M., Kandil, M., & Bactericidal, Z. (2015). Bactericidal Evaluation of Nano-coated Cotton Fabrics. *American Journal of Nano Research and Applications*, 3(6), 105–112. <https://doi.org/10.11648/j.nano.20150306.13>
- Analese Roman-Benna, b, C., D, C. A. C., D, M.-W. L., Lamd, H.-M., Ah-Hena, K., Ulloae, P. E., & María Cristina Ravanal a. (2023). Pectin: An overview of sources, extraction and applications in food products, biomedical, pharmaceutical and environmental issues. *Food Chemistry Advances*, 2.
- Andrew B. Servais, Cristian D. Valenzuela, Arne Kienzle, Alexandra B. Ysasi, Willi L. Wagner, Akira Tsuda, Maximilian Ackermann, and S. J. M. (2018). *Functional Mechanics of a Pectin-Based Pleural Sealant after Lung Injury*. 24(1 May 2018), 9–10.
- Anwar, E. I. M. I. & R. (n.d.). Comparison of Natural and Synthetic Adhesives for Ceramic Conservation. *International Colloquium of Art and Design Education Research (i-CADER 2014)*, 2014, 127–135.
- Babaarslan, N. A. K. and O. (2016). *Fiber Selection for Production of Nonwovens*.
- Cereda, M. P. (2023). Chapter 15 - Starch glues and adhesives. *Starch Industries: Processes and Innovative Products in Food and Non-Food Uses*, 3(24 November 2023), 335–348.

- Chandel, V., Biswas, D., Roy, S., Vaidya, D., Verma, A., & Gupta, A. (2022). *Current Advancements in Pectin : Extraction , Properties and Multifunctional Applications. 2nd sept 2022*, 1–30.
- Chunmeng Han , Xiangying Zhao , Liping Yang, Mingjing Yao, Jiayang Zhang, Q. H., & Liu, J. L. and L. (2024). Extraction and Structural Analysis of Sweet Potato Pectin and Characterization of Its Gel. *Polymers*, 10,July 2024.
- Dinu, L., Iordache, O., & Vamanu, E. (2022). *Scanning Electron Microscopy Study on the Biodeterioration of Natural Fiber Materials Compared to Disposable Hygiene and Sanitary Products*. 1–11.
- E. A. Gyunter, A. K. Melekhin, S. V. Popov, E. A. Durnev, E. A. Martinson, S. G. Litvinets, M. A. K. & V. P. V. (2017). Adhesive Properties of Pectin–Chitosan Composite Gels. *Chemistry of Natural Compounds*, 53(27 September 2017), 823–829.
- Ebrahim, S. A., Othman, H. A., Mosaad, M. M., & Hassabo, A. G. (2022). A Valuable Observation on Pectin as an Eco-friendly Material for Valuable Utilisation in Textile Industry. *Egyptian Journal of Chemistry*, 65(4), 555–568. <https://doi.org/10.21608/EJCHEM.2021.96717.4526>
- Evaluation of adhesion properties of blends of cottonseed protein and anionic water-soluble polymers_ Journal of Adhesion Science and Technology_ Vol 33 , No 1 - Get Access.* (n.d.).
- Fatima Abderrahim, Elizabeth Huanatico, Roger Segura, Silvia Arribas, M Carmen Gonzalez, L. C.-H. (2015). Physical features, phenolic compounds, betalains and total antioxidant capacity of coloured seeds (*Chenopodium quinoa* Willd) from Peruvian Altiplano. *Food Chemistry*, 183, 83–90.
- Frederick W.A.Owusu, Mariam E.Boakye-Gyasi Philomena Entsie, Marcel T.Bayor, K. O. K. (2021). *Utilization of Pectin from Okra as Binding Agent in Immediate Release Tablets*.
- Geeske Langejans, Akessandro Aleo, S. F. and P. K. (n.d.). *Archaeological Adhesives*.
- Gendensuren, B., He, C., & Oh, E. S. (2020). Preparation of pectin-based dual-crosslinked network as a binder for high performance Si/C anode for LIBs. *Korean Journal of Chemical Engineering*, 37(2), 366–373. <https://doi.org/10.1007/s11814-019-0438-0>
- Gharibzahedi, S. M. T., Smith, B., & Guo, Y. (2019). Pectin extraction from common fig skin by different methods: The physicochemical, rheological, functional, and structural evaluations. *International Journal of Biological Macromolecules*, 136, 275–283. <https://doi.org/10.1016/j.ijbiomac.2019.06.040>
- GUEVARA, M. M. S., SAUCEDO-RIVALCOBA, V., RIVERA-ARMENTA, J. L., & ELVIRA-TORALES, and L. I. (2022). EVALUATION OF A CROSS-LINKING AGENT IN THE

PREPARATION OF FILMS BASED ON CHITOSAN AND PECTIN FOR FOOD PACKAGING APPLICATIONS. *CELLULOSE CHEMISTRY AND TECHNOLOGY*.

- Hamidon, N. H., Norulfairuz, D., & Zaidel, A. (2017). *Effect of Extraction Conditions on Pectin Yield Extracted from Sweet Potato Peels Residues using Hydrochloric Acid*. 56, 979–984. <https://doi.org/10.3303/CET1756164>
- Han, C., Zhao, X., Yang, L., Yao, M., Zhang, J., & He, Q. (2024). *Extraction and Structural Analysis of Sweet Potato Pectin and Characterization of Its Gel*. *July 2024*, 1–16.
- Hrabovska, Olena;Pastukh, Hanna;Demenyuk, Oksana;Miroshnyk, Volodymyr;Halatenko, Tetyana;Babii, Alina;Dobrydnuk, A. (2015). Potato pectin: extract methods, physical and chemical properties and structural features. *Ukrainian Food Journal*, 4(1).
- Ilaria Frosi , Anna Balduzzi , Giulia Moretto, R. C. O. and Adele P. (2023). Towards Valorization of Food-Waste-Derived Pectin: Recent Advances on Their Characterization and Application. *Food Chemistry*, 28(17)(1 September 2023, 6390).
- Joanne Yi Hui Tay, Jian wei See, D. H. (2022). *physicochemical and functional characterization of pectin from Margarita sweet potato leaves*. 385(15 August).
- Kashani, A., Hasani, M., Nateghi, L., Asadollahzadeh, M. J., & Kashani, P. (2022). Optimization of the Conditions of Process of Production of Pectin Extracted from the Waste of Potato Peel. *Iranian Journal of Chemistry and Chemical Engineering*, 41(4), 1288–1304. <https://doi.org/10.30492/IJCCE.2021.127121.4115>
- Kumar, A. K. S. and S. S. (2022). Pectin Production from Biowaste (Fruits & Vegetables) by Crosscurrent Solid-Liquid Extraction Technique. *Nature Environment and Pollution Technology*, 21(2), 651–657.
- Kwang Ho Lee, Tridib Kumar Sinha, Kyum Woo Choi, J. S. O. (2020). Ultra-high molecular-weight polyethylene reinforced polypropylene and polyamide composites toward developing low noise automobile interior. *Journal of Applied Polymer Science*, 137(48720).
- Malel Tian, Xin Huang, Ying Cheng, Yunwei Niu, Jiajia Ma, Yi Zhao, Xingran Kou, Q. K. (n.d.). *Applications of adhesives in textiles _ A review - ScienceDirect* (p. 111089).
- Mario Madrid, Jani Turunen, W. S. (2023). 26 - General industrial adhesive applications: Qualification, specification, quality control, and risk mitigation. *Advances in Structural Adhesive Bonding(Second Edition)*, 849–876.

- Marvin Kaufmann, Florian Flaig, Micheal Muller, Holger Fricke, T. V. (n.d.). Optimized adhesive application. *International Journal of Adhesion and Adhesives*, 130(103620).
- Masuelli, M. G. G. and M. A. (2022). Effect of Cross-Linking Agent on Mechanical and Permeation Properties of Criolla Orange Pectin. *Open Access Peer-Reviewed Chapter*.
- Mirza Mohammad Omar Khyum, S. R. (2024). Innovations in nonwoven textiles. *Sustainable Innovations in the Textile Industry, The Textile Institute Book Series*, 187–215.
- Muhammad Awais Imran, Muhammad Qamar Khan, A. S. and A. A. (2020). *Cotton in Nonwoven Products*.
- Narimane Mati-Baouche, Helene de Baynast, Philippe Michaud, Pierre-Henri Elchinger, Gullaume Pierre, C. D. (2014). *Chitosan as an adhesive*. 60(November 2014), 198–212.
- Nateghi, Leila, Zarei, Fatemeh, Zarei, M. (2022). Optimize the Extraction Conditions of Pectin Extracted from Saveh Pomegranate Peels. *Iran.J. Chem. Chem. Eng.*, 41(11), 3835–3850.
- Nesic, A., Meseldzija, S., Onjia, A., & Cabrera-Barjas, G. (2022). Impact of Crosslinking on the Characteristics of Pectin Monolith Cryogels. *Polymers*, 14(23). <https://doi.org/10.3390/polym14235252>
- Norulfairuz, D., Zaidel, A., Maslina, Y., Jusoh, M., & Muhamad, I. I. (2015). *Extraction and characterisation of pectin from sweet potato (Ipomoea batatas) pulp*. July 2017.
- Ortiz-Fernández, A., Ríos-Soberanis, C. R., Chim-Chi, Y. A., Moo-Huchin, V. M., Estrada-León, R. J., & Pérez-Pacheco, E. (2021). Optimization of biodegradable starch adhesives using response surface methodology. *Polymer Bulletin*, 78(7), 3729–3749. <https://doi.org/10.1007/s00289-020-03297-y>
- Rushikesh Handibag, Dorcus Masih, Chitra Sonkar, P. V. and R. J. (2022). Microwave-assisted extraction and quality evaluation of pectin from sweet lemon peel. *International Journal of Advanced Chemistry Research*, 4(2 (Part C)), 203–206.
- Salleh, K. M., Hashim, R., Sulaiman, O., Hiziroglu, S., Noor, W., Wan, A., Karim, N. A., Jumhuri, N., Mohd, K., Hashim, R., & Sulaiman, O. (2015). Evaluation of properties of starch-based adhesives and particleboard manufactured from them. *Journal of Adhesion Science and Technology*, 4243, 1–17. <https://doi.org/10.1080/01694243.2014.987362>
- Samuel de la Hoz Vega¹, Bernardo Vásquez Jaraba¹, José Pérez Mendoza¹, A. A. A. O. Q. (2018). Effect of Precipitating Solventson the Extraction of Pectin from the Pomelo Albedo by Acid Hydrolysis. *Contemporary Engineering Sciences*, 11(78), 3849–333855.

- Sayed, A. (2014). *Non-woven Fabric: Raw Materials, Characteristics and End Uses*. updated on September, 7th 2024.
- Sergey Popov ORCID, Nikita Paderin, E. C. and Dmitry P. (2023). Serosal Adhesion Ex Vivo of Hydrogels Prepared from Apple Pectin Cross-Linked with Fe³⁺ Ions. *International Journal of Molecular Sciences*, 24(2).
- Seyed Mohammad Taghi Gharibzadeh, B. S. and Y. G. (2019). Pectin extraction from fig skin by different methods: The physicochemical, rheological, functional and structural Evaluations. *International Journal of Biological Macromolecules*, 136(1 September 2019), 275–283.
- Sheyla Moreira Goncalves, Daiane Cardial dos Santos, Joyce Fagundes Gomes Motta, Regiane Ribeiro dos Santos, Davy William Hidalgo Chavez, N. R. de M. (2019). structure and functional properties of cellulose acetate films incorporated with glycerol. *Carbohydrate Polymers*, 209, 190–197.
- Shuai Xu, Shujie Xu, Xiaoli Ge, Liping Tan, T. L. (2022). Low-cost and highly efficient production of bacterial cellulose from sweet potato residues: Optimization, Characterization, and Application. *International Journal of Biological Macromolecules*, 196(31 Jan 2022), 172–179.
- Sylvester, E. D. and B. (2017). Adhesives: Applications and Recent Advances. *Applied Adhesive Bonding in Science and Technology*.
- Sylvester, E. D. and B. (2018). *Adhesives: Application and Recent Advances*.
- T.Karthik, P. K. C. and R. R. (2016). Non-woven-Process, Structure, Properties and Applications. *WOODHEAD PUBLISHING INDIA IN TEXTILES*.
- T.Maloney, A. . S. P. J. T. F. (2021). *bio-based materials for nonwovens*. 31 July 2021.
- Tapanee Chuenkaek, T. K. (2024). Citrus Waste Upcycling toward Pectin Moisturizer Films Plasticized with Glycerol and Polyethylene Glycol Click to copy article link. *ACS Sustainable Resource Management*, 1(2).
- Vilas, R., Gadhave, I., & Gadhave, C. R. (2022). Adhesives for the Paper Packaging Industry : An Overview. *Open Journal of Polymer Chemistry*, 55–79. <https://doi.org/10.4236/ojpchem.2022.122004>
- Williams, James MD; Prey, Beau MD; Francis, Andrew MD; Weykamp, Michael MD; Liu, Betty MD; Parsons, Michael MD; Vu, Michael MD; Franko, Jace MD; Roedel, Erik MD; Lallemand, Michael MD; Bingham, Jason MD; Mentzer, Steven MD; Kuckelman, J. DO. (2023). Pectin based biologic

Velcro effectively seals traumatic solid organ and small bowel injuries. *Journal of Trauma and Acute Care Surgery*, 95(1), 55–61.

Yongping Lu, Xinyuan Xu, J. L. (2023). Recent advances in adhesive materials used in the biomedical field: adhesive properties, mechanism, and applications. *Journals of Material Chemistry B*, 11(15,2023), 3338–3355.

You, Q., & Wan, M. (n.d.). *Optimization of sweet potato pectin extraction using hydrochloric acid*. *Optimization of sweet potato pectin extraction using hydrochloric acid*. <https://doi.org/10.1088/1757-899X/736/2/022042>

Zhang, W., Cao, J., & Jiang, W. (2022). Effect of different cation in situ cross-linking on the properties of pectin-thymol active film. *Food Hydrocolloids*, 128(107594).