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Preparation of Bio-Based Polymer from Biomass Using Green Plantain Peel and Rice Husk Blends

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Abstract **Original Research Article**

Biopolymers were prepared from blends of Green Plantain Peel Powder (GPPP) and Rice Husk Powder (RHP) in various ratios (25:75, 60:40, 50:50, 40:60, 75:25, and 100:0) and evaluated for solvent extractability, chemical resistance, water solubility and biodegradability of the biopolymer samples. Hexane extractability was low (2 to 25 %). The solubility in acid (HCl) and acetic acid ranged from 27-36 % and 15 to 34 %, respectively with RHP-rich biopolymers showing enhance chemical stability. Solubility in alkaline (NaOH) varied from 01to 4 %. Water absorption (33-96 %) increased with GPPP content, consisted with its hydrophilic starch-rich matrix. The findings showed that biodegradability was strongly influenced by blend composition. Formulations rich in GPPP exhibited rapid degradation, with 40:60 (GPPP: RHP) blend achieving total degradation (100 % weight loss) by day 15. The 100:0 and 75:25 blends recorded 86 % and 79 % weight loss respectively, while moderate degradation was observed for the 60:40 blend (65.5 %). The RHP-rich blends (50:50, 25:75) showed complete degradation from the 5th day through the 15th day period.

Keywords: Biopolymers, Biodegradability, Plantain Peel, Rice Husk, Solubility, Blend Ratio.

Introduction

The term plastic is derived from the Greek word (plastikos) meaning "able to be shaped or formed and ultimately, from (plastos) meaning moulded." The material consists of wide range of synthetic or semi-synthetic organic compounds that are malleable and so can be moulded into solid form (Noorjahan *et al.*, 2022). Plastics consist of polymers and additives, which are polymeric chains made up of repetitive units or monomers linked together. They rank among the most used versatile materials (Lackner, 2019). Nearly, all plastics in current circulation are synthetically produced and they have much better properties compared to naturally occurring plastics but it takes decades to decompose in the environment (Wahyuningtyas and Suryanto, 2017). Plastics are significant for their versatility, lightweight, flexibility, moisture resistance, strength, and relatively affordability contributing to excessive consumption of plastic products (He *et al.*, 2017). Globally, Plastic are desired the most commonly utilized materials (Singh *et al.*, 2022). Plastic materials are comprised of polymers with relatively high molecular weight. They are commonly produced through chemical synthesis processes. The synthetic polymers are made from monomers through poly-condensation, poly-addition or polymerization, and most of them have a simpler

structure than natural ones. They can be categorised into four primary groups; elastomers, thermosets, thermoplastics and synthetic fibres (Gerardo *et al.,* 2021). Theoretically, all common plastics are generally degradable, but undergo slow disintegration process hence, considered as non-biodegradable. Biodegradation of bio-plastics depends on their physical and chemical structures in terms of polymer chains, functional groups and crystallinity, but also on the natural environment in which they are placed. Biodegradation is an enzymatic reaction catalysed in different ecosystems by microorganisms such as actinobacteria (Amycolatopsis, Streptomyces), bacteria (Paenibacillus, Pseudomonas, Bacillus, Bulkholderia) and fungi (Aspergillus, Fusarium, Penicillium) (Emadian *et al*., 2017).

Bio plastics are substances that are produced primarily from biomass materials like proteins, lipids, and polysaccharides. (Arifa *et al.,* 2021). The term bio-based specifically refers to the material's manufacturing process. Bio-plastics encompasses those derived from renewable biomass and are readily available in nature (Folino *et al.,* 2020). The biomass typically includes raw materials like vegetable fats and oils, straw, saw dust, wood chips, agricultural waste, food waste etc. among these are plantain and banana peels rich in starch and organic materials with readily available, cost efficient and environmentally friendly making them widely useful for bio-plastic production (Padam *et al.,* 2014). The term does not refer to what happens to it at the end of its existence. Bio-based and biodegradable plastics are increasingly seen as viable alternatives to promote sustainable development within the plastic sector and present a solid substitute for petrochemical plastic in the near future (Steven *et al.,* 2020). Bio-based polymers contribute significantly by decreasing reliance on fossil fuels and offering favourable environmental benefits such as the reduction of carbon dioxide emissions (Ramesh *et al.,* 2013). The first generation of bio-based polymers focused on deriving polymers from agricultural sources like corn, potatoes, and other carbohydrate-rich feedstock. However, the focus has shifted in recent years due to a desire to move away from food-based resources and significant breakthrough in biotechnology. Bio-based polymers similar to conventional plastics are synthesised by bacterial fermentation processes using building blocks (monomers) sourced from renewable materials, including lignocellulose biomass (starch and cellulose), fatty acids, and organic waste. Another categories of bio-based polymers encompasses natural substances found in nature, including proteins, nucleic acids, and polysaccharides (collagen, chitosan, etc) (Ramesh *et al.,* 2013). Plasticizers are essential during the bio-plastics synthesis to enhance flexibility, process ability, workability and dispensability of the polymers by lowering the glass transition temperature (Vieira *et al.,* 2011). In bio-plastics that lack plasticizers, the resulting film tend to be brittle and exhibits poor physical properties (Sirvio *et al.,* 2018). Plasticizers play a vital role in effective plasticization, and improving various parameters, such as polarity, hydrogen bonding, dielectric constant, and solubility (Tyagi and Bhattacharya, 2019). Bio-plastics are comparable to conventional plastics concerning strength and stability thus suitable for applications similar to the later one. Enhanced production and utilization of bio-based plastics would reduce our reliance on conventional fuels and significantly mitigate the environmental hazards associated with them (Nancy *et al.,* 2021). The demand and use of plastics are increasing daily leading to increase in environmental pollution due to non-decomposition of plastics derived from petroleum or natural gas. Petro chemical based plastics like polyethylene terephthalate (PET), polyvinylchloride (PVC), polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyamide (PA) have widespread applications in every field, attributed not only due to their advantageous mechanical and thermal characteristics, but primarily due to their stability, durability, availability and cost effectiveness (Oyedeko *et al.,* 2022). One of the main disadvantage of bio-degradable polymers obtained from renewable sources is their fast degradation rate, due to their dominant hydrophilic character and in some cases, inadequate mechanical properties, particularly in wet environments. Despite their disadvantages, biodegradable polymers offer a wide range of advantages since many plant materials are used to make them. The first is polylactic acid (PLA),

produced by fermenting carbohydrates, and the second important group of biodegradable polymers are polydydroxyalkanoates (PHA), synthesized through bacterially guided fermentation processes. Their products are widely used in different fields (Maja *et al.*, 2020).

This study, therefore presents an innovative approach utilizing a blend of green plantain peel powder and rice husk powder for the production of bio-plastic. While both feedstock have been individually studied in starch based or lignocellulose biopolymers, their combined potential has not been significantly investigated.

Materials and Methods

The fresh, bunch of green plantain were purchased at a local market in Ado Ekiti, Ekiti State.

All other chemicals and reagents including sodium hydroxide (NaOH), hydrochloric acid (HCl), glycerol, and citric acid were purchased from Bisolab Laboratories Ado Ekiti, Ekiti State and they are of analytical grade.

Preparation of Green Plantain Peel Powder (GPPP)

The fresh green plantain fruits were thoroughly washed with distilled water to remove the surface dust and impurities. Green Plantain Peels were carefully removed using a stainless knife and washed with distilled water. The green plantain peels were chopped into small pieces and dried at 70 ^{o}C until constant weight was achieved. The dried samples were ground into fine powder. To attain the desire particle size, the sieves were nested in descending aperture size from top to bottom (300, 250, 200, 150, and 100 µm). The particle size of 100 µm was selected, stored in an air tight container before use and labelled as Green Plantain Peel Powder (GPPP). The same method and procedure were repeated for the preparation of Rice Husk (RH) and labelled as rice husk powder (RHP)

Formulation of Bio-based plastic Blends

The formulation ratios were represented as percentage of the total dry powders (GPPP and RHP) while glycerol and citric acid were added at a fixed proportion relative to the total dry powder content. Each bio-plastic formulation was prepared using a total of 30 g of dry powders (GPPP and RHP) expressed as percentage of the total powder. The bio-plastic was prepared using different ratios of plantain peel powder to rice husk powder as follows:

GPPP: RHP 100: 0

GPPP: RHP 75:25

GPPP: RHP 50:50

GPPP: RHP 25:75

GPPP: RHP 60:40

GPPP: RHP 40:60

Preparation of bio-based plastic

Sodium benzoate (0.5 % w/w of the total powder) was dissolved directly in warm distilled water and uniformly dispersed. The required quantity of plantain peel powder (22.5 g) which correspond to 75 % of the total powder was weighed and added to sodium benzoate solution in a 1000 mL beaker. An additional warm distilled water (200 mL) was added and heated at 80 ^{o}C. The mixture was constantly stirred thoroughly for 15 minutes to achieve homogeneous blend, 3 mL of 0.5 M HCl was then added. Glycerol (6 mL) was added to the homogenized mixture and stirred continuously for 5 minutes and 3 mL of 0.5 M NaOH was added in order to neutralize the pH up to 7, stirred continuously for 5 minutes.Then, the pre-weighed quantity of rice husk powder (7.5 g) which correspond to 25 % of the total rice husk powder was added and stirred until the mixture was evenly dispersed for 15 minutes. Citric acid (5 %) was added and the mixture was heated at 80 ^{o}C so that citric acid is evenly distributed. The same procedure was repeated for other selected ratios.

Casting

The viscous bio-plastic paste was poured into casting glass petri dishes and dried at 80 ^{o}C. The dried plastic were carefully and gently scraped off from the petri dish as bio-plastic and prepared for characterization.

Water Absorption Capacity

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL distilled water was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other samples. Water absorption capacity was determined using equation 1

$$\text{Water absorption (\%)} = \frac{W2-W1}{W1} \times 100 \qquad (1)$$

W_1 = initial weight and W_2 = final weight

Solubility in Water

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL distilled water was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other samples. Solubility in water was determined using equation 2 according to Sanyang *et al.,* 2016.

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100 \qquad (2)$$

W_1 = initial weight and W_2 = final weight

Solubility in 0.5 M HCl

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL 0.5 M HCl was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other samples. Solubility in water was determined using equation 3 according to Sanyang *et al.,* 2016.

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100 \qquad (3)$$

W_1 = initial weight and W_2 = final weight

Solubility in 0.5 M NaOH

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL 0.5 M NaOH was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other samples. Solubility in water was determined using equation 4 according to Sanyang *et al.,* 2016.

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100 \qquad (4)$$

W_1 = initial weight and W_2 = final weight

Solubility in 0.5 M Acetic Acid

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL 0.5 M NaOH was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other samples. Solubility in water was determined using equation 5 according to Sanyang *et al.,* 2016.

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100 \qquad (5)$$

W_1 = initial weight and W_2 = final weight

Hexane Extractability

The dried bio-plastic sample (1g, W_1) of 75 % and 25 % bio-plastic was placed in a beaker and 10 mL hexane was added and allowed to stand for 24 hours at room temperature. The mixture was filtered and the weight of the resulting bio-plastic was measured to find its final weight (W_2). The same procedure was repeated for other selected ratios. Solubility in water was determined using equation 6 according to Sanyang *et al.,* 2016.

$$\text{Solubility in water (\%)} = \frac{W1-W2}{W1} \times 100 \qquad (6)$$

W_1 = initial weight and W_2 = final weight

Biodegradable Test

Biodegradable test was determined using burial degradation test. The bio-plastic was buried in the soil for it to degrade. The dried bio-plastic sample (2.0 g, W_1) of 75 % and 25 % bio-plastic was buried in soil at 5 cm depth for 15 days. The bio-plastic residue was collected from the soil at 5 days interval and weighed (W_2) to measure the rate of degradation of the bio-plastic. The biodegradability was measure using equation 7

Solubility in water (%) = $\frac{W1-W2}{W1} \times 100$ (7)

W_1 = weight before degradation and W_2 = weight after degradation

Results and Discussion

Table 1. Results of solubility Test

Parameters (%)	Plantain Peel-Rice Husk Ratios					
	25:75	60:40	50:50	40:60	75:25	100:0
Water Solubility	17	29	34	30	32	26
Water Absorption	43	78	33	48	77	96
Acid Resistance (HCl)	27	30	35	32	33	36
Alkaline Resistance (NaOH)	13	36	42	19	02	01
Acid Resistance (Acetic Acid)	15	28	22	34	30	27
Hexane Extractability	06	04	11	25	02	03

The solubility test results were presented in table 1.Water solubility was observed to vary between 17 to 34 % with the highest value observed at the 50:50 blend, this outcome suggests a polymer system that is less compact that allows strong interaction with the solvent. Extreme ratios of 25:75 and 100:0 revealed lower solubility, implying that these denser structures resist dissolution. Water absorption increased with plantain peel content from 33 % in the 50:50 blend to 96 % in the 100:0 polymer. The hydrophilic starch and pectin components of plantain peel promote water retention whereas rice husk fibres and silica reduce water uptake, particularly in RH-rich blends (25:75 and 40:60). Formulations with a greater ratio of GPPP (75:25 % and 100:0 %) exhibited relatively higher acid extractability at 33 % and 36 % respectively. This observation is attributed to the abundance of starch and pectin in GPPP. On the other hand, formulations enriched with RHP (25:75 % and 40:60 %) displayed lower acid extractability at 27 % and 32 % respectively. The enhanced acid resistance observed in these ratios may be associated with the presence of cellulose fibres and silica-rich components in RHP which contributing to a more rigid and chemically stable polymer network that inhibits acid penetration and degradation. The 50:50 % blend displayed intermediate behaviour with an acid solubility of 35 %, indicating a partial breakdown of intermolecular interactions within the biopolymer matrix. This suggests that an equal blending of GPPP and RHP does not optimise acid resistance but instead results in a structure that remains susceptible to acid attack. Films rich in GPPP were comparatively more susceptible due to starch hydrolysis under acidic conditions. Mid-level blends and those abundant in GPPP displayed higher extractability with a maximum observed at 40:60 (34 %), likely due to partial plasticization and disruption of hydrogen bonding within the starch-rich matrix by acetic acid. Alkaline resistance (NaOH) varied significantly from 1 to 42 % with intermediate ratios (50:50 and 60:40) exhibiting the most susceptible, indicating partial disruption of the matrix by the base. Extreme compositions (25:75 and 100:0) showed minimal weight loss, reflecting dense and chemically stable network. Hexane extractability was generally low, ranging from 2 to 25 % confirming that the films consist primarily of polar polysaccharide-based, with limited non-

polar extractable fractions. The 40:60 blend showed the highest hexane extractability at 25 %. This behaviour is attributed to the presence of hydrophobic extracts and wax-like substances linked to rice husk (RHP), rather than the dissolution of the polymer itself. Generally, the findings revealed that the blend composition significantly influences the chemical and physical properties of the fibre. GPPP enhances water affinity and solubility while RHP contributes to chemical stability. Intermediate blends (50:50 and 60:40) displayed moderate solubility and alkaline susceptibility highlighting a balance between flexibility and structural integrity.

Table 2: The Biodegradability Test

Blend	Weight loss (g)		
	5^{th} day	10^{th} day	15th day
40:60	1.39	0.25	0.0
100:0	1.82	0.63	0.28
75:25	1.86	1.00	0.42
60:40	1.09	0.90	0.69
25:75	0.00	0.00	0.00
50:50	0.00	0.00	0.00

The recorded weight loss of 0.00 g indicate complete degradation equivalent to 100 % weight loss

Recent researches have indicated that plant waste rich in cellulose and starch can be converted into

Bio-degradable polymers and plastics that decompose rapidly in environmental conditions (Bidari *et al*., 2023; Wali *et al*., 2023). The biodegradation characteristics of the biodegradable polymers derived from combinations of GPPP and RHP was assessed over a 15-day duration using an initial sample weight of 2 g. were presented in table 2. The results demonstrated a strong dependence of degradation rate on blend composition and burial time. In this study, a recorded value of 0.00 g indicates complete degradation with no detectable material remaining at the time of measurement. The 25:75 and 50:50 blends exhibited complete biodegradation by the 5^{th} day as evidenced by total mass loss (0.00 g), their rapid degradation suggests that these compositions possess a loosely packed polymer structures that allows rapid microbial penetration between GPPP and RHP at these ratios likely enhance accessibility of biodegradable compounds to soil microorganisms. The 40:60 blend showed progressive degradation reaching complete biodegradation by the 15^{th} day. This behaviour indicates moderate resistance to microbial attack likely due to partial reinforcement of the matrix by RHP components which delayed but did not prevent degradation. In contrast, blends with higher GPPP content (60:40, 75:25, and 100:0) showed incomplete degradation within 15 days with residual masses of 0.69, 0.42, and 0.28 g respectively. Although, GPPP is rich in biodegradable starch and pectin, the formation of a dense, gelatinized starch network may reduce microbial accessibility, thereby slowing the overall degradation rate. The biodegradation results confirm that complete degradation occurs fastest at intermediate blend ratios, while both GPPP-rich and RHP-rich extremes showed slower degradation under the same conditions. These findings demonstrate that biodegradation rate can be effectively tuned by adjusting the GPPP-RHP ratio, enabling the design of biopolymer films for either rapid

environmental breakdown or extended functional life time.

Figure 1 is the graph of the percentage weight loss over time measured during the biodegradable test using burial method. Weight loss served as a measure of biodegradation, and the findings distinctly indicated that the degradation rate is highly influenced by the mixing proportions of the two biomass components. Biopolymers with a high proportion of GPPP exhibited significant percentage weight loss, confirming their improved biodegradability. The 100:0 (GPPP: RHP) sample exhibited a continuous rise in weight loss from 9.0 % at day 5 to 86.0 % by day 15, indicating ongoing microbial degradation over the duration. This can be attributed to the abundance of starch and cellulose present in GPPP, which are readily hydrolysed and utilized by microorganisms. Likewise, the 75:25 blend recorded a weight loss 79.0 % by day 15, while the 60:40 blend showed a 65.5 % weight loss indicative of moderate biodegradation. The slower degradation rates in these blends are associated with increasing RHP content, which attributes lignin and silica-compounds known to inhibit microbial activity. The 40:60 blend exhibited rapid biodegradation reaching 100 % weight loss by day 15, indicating that an optimal ratio between GPPP and RHP can promote microbial penetration and the breakdown of the polymer structure. RH, an abundant agricultural by-product, has also been investigated in biodegradable polymer structures due to its lignocellulosic composition, although its significant level of lignin and silica content may affect its decomposition properties (Riaz *et al*., 2024). In spite of these advancements, few studies have examined the combined application of GPPP and RHP in biopolymer formulations, regarding their biodegradability and solubility.

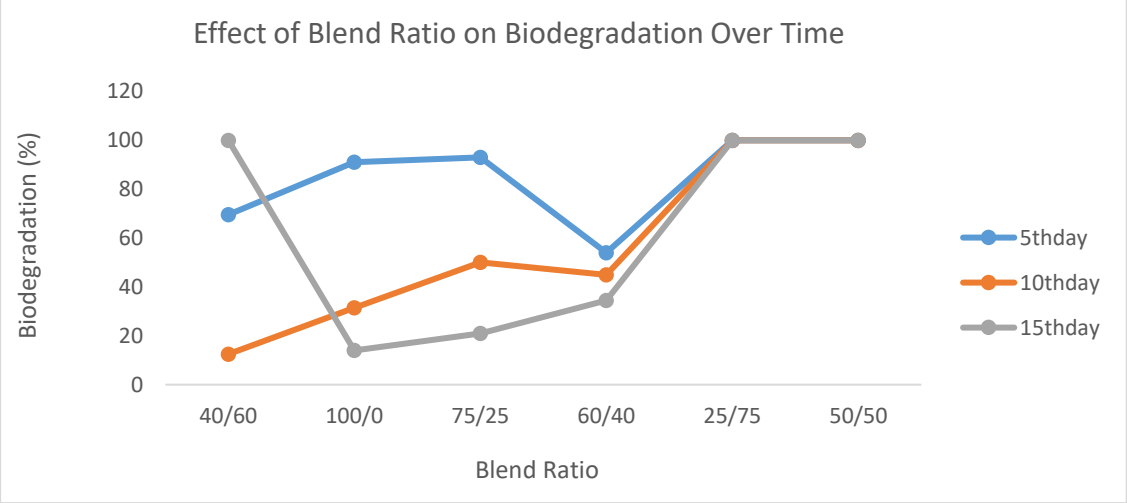

Figure 1. The Graph of Percentage Weight Loss

Conclusion

Bio-based polymers formulated from GPPP and RHP blends exhibited biodegradation behaviour-independent on their composition. Formulations with higher GPPP content showed rapid and significant degradation while RHP-rich blends demonstrated considerable resistance to biodegradation during the 15-day test period. Complete degradation was achieved for the 40:60 (GPPP: RHP) blend, indicating its suitability for short-lived, environmentally friendly applications. Solubility tests in selected solvents provided preliminary insights into the chemical stability of the prepared biopolymers. Further chemical and mechanical characterization will be carried out to support

these findings and expand potential applications of the biopolymers.

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References

Arifa Shafgat, Arifa Tahir, Waheed Ullah Khan, Adeel Malmood, Ghulam Hassan Abbasi (2021). Production and Characterization of Rice Starch and Corn Starch-Based Biodegradable Bioplastic Using Various Plasticizers and Natural Reinforcing Fillers. *Cellulose chem. Technol*, 55(7-8): 867-890.

Bidari, R., Abdillah, A.A., Ponce, R. A, Charles, A..L (2023). Characterization of Biodegradable Films Made from Taro Peel (*Colocasia esculenta*) starch. *Polymers* (15(2), 338

Eka Yulli Kartika and ENDANG Saepudin (2020). Synthesis of Crosslinked Cellulose/PVA Bioplastic Strengthened With Chitosan as an Alternative to Conventional Plastics. *Proceeding of The 2nd International Conference on Science, Technology and Environment (CoSTE)* ISBN: 978-558-545-6. 17-24.

Di Bartolo, G, Infurna, N. T Dintcheva (2021). A Review of Bioplastic and their Adoption in the Circular Economy, Polymer (Base) 13: 1229.

Emadian, S. M, Onay T. T, Demirel B (2017). Biodegradation of Bioplastics in Natural Environments. *Waste maneg.* 59: 526-536.

Folino, A, Karageorgiou, A, Calabro, P. S, Komilis, D (2020). Biodegradation of Wasted Bioplastics in Natural and Industrial Environments: A review. *Sustainability* (Switzerland), 12 (15): 1-37.

Gerardo Coppola, Maria Teresa Gaudio, Catia Giovanna Lopresto, Vincenza Calabro, Stefano Curcio, Sudip Chakraborty (2021). Bioplastic from Renewable Biomass: A Facile Solution for a Greener Environmental Earth Systems and Environment. (5): 231-251

He M, Wang X, Wang Z, Chenl, Luy, Zhangx, Li Me, Liu Z, Zhang Y (2017). Biocompatible and Biodegradable Bioplastics Constructed from Chitin via a Green Pathway for Bone Repair, *ACS Sustain, Chem. Eng.* 5(10): 9126-9135.

Lackner, M (2019). Bioplastics, Kirk-othme. John Willey and Sons, Inc.

Maja Cŏlnik, Maša Knez HRNČIČ, MojcA, Škerget, Željko Knez (2020). Biodegradable Polymers, Current Trends of Research and their Applications. A Review. *Chem. Ind.chem. Eng. Q.* 26 (4): 401-418.

Nancy George, Abhrajit Debroy, Shilpa Bhat, Shivani Singh, Shikha Bindal (2021). Biowaste to Bioplastics. An Eco Friendly Approach for A sustainable Future. *J. Appl. Biotecnol Rep.* 8(3): 221-233.

Noorjahan, C, M; Nishra, S. Subhashree, V (2022). Bioplastic Synthesis Using Banana Peels and its Characterization. *Journal of Phamaceutical Negative Results*, 13 (7): 2855-2863.

Oyedeko, K.F, Afamefine, E. I, Oshinga, O. T, Bakare, L (2022). Comparative Study of Biodegradable Plastic from Corn and Cassava Starch. *American Journal of Engineering Research* (AJER), 11(05): 58-64.

Padam, B. S, Tin, H. S, Chye, F. Y, Abdullah, M. I (2014). Banana By-Products: An Under-Utilized Renewable Food Biomass with Great Potential. *Journal of Food Science and Technology*. 51(12): 3527-3545.

Ramesh P. Babu, Kevin O'Connor, Ramakrishna Seeram (2013). Current Progress on Biobased Polymers and their Future trends. *Progress in biomaterials*, 2(8): 1-19.

Riaz, S., Maan, A. A., Butt, M. S., Khan, M. K. J (2024). Valorization of Agricultural Residues

in the Development of Biodegradable Active Packaging Films. Industrial crops and products, 215, 118587

Sirviö, J. A, Visinko, M, Ukkola, J, Liimatainen, H (2018). Effect of Plasticizers on the Mechanical and Thermochemical Properties of Cellulose-Based Biocomposite Films Industrial Crops and Products. 122: 513-521.

Singh, Salam Suresh, Thakur, Abhinay, Sandilya, Saumya (2020). Recent Advances in Bioplastics: Synthesis and Engineering Perspective. *Iran J. Chem. Chem. Eng.* Vol 41, No 8, 2704-2748.

Steven, S, Octiano, I, Mardiyati, Y (2020). Cladophora Algae Cellulose and Starch-Based Bio-Composite As An Alternative for Environmentally Friendly Packaging Materials, In: *AIP Conf. Proc.* AIP Publishing LLC. P. 40006.

Tyagi, V; Bhattaacharya, B (2019). Role of Plasticizers in Bioplastics. *MOJ Food Processing Technology*, 7(4): 128-130.

Vieira, M. G. A, da Silva, M. A, dos Santos, L. O, Beppu, M. M (2011). Natural-based plasticizers and biopolymer films: A review. *European Polymer Journal*, 47(3): 254-263.

Yitong Xie, Shishuai Gao, Daihui Zhang, Chunpeng Wang, Fuxlang Chu (2023). Biobased Polymeric Materials Synthesized from Renewable Resources: A mini review. *Resources chemicals and materials* 2: 223-230.

Wahyuningtyas, N, Suryanto (2017). Analysis of Biodegradation of bioplastics Made of Cassava Starch. *J. Mech. Eng. Sci Technos.* 1(1): 24-31.

Wali, F. H., Abubakar, H. S., Birnin-Yauri, A. U., Haruna, S. Y (2023). Development and Characterization of Starch Based Bio-plastics Using Banana Peels. *American Journal of Polymer Science and Technology*. 9(2), 21-25.