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Fabrication of Sustainable Silver-Reinforced Biodegradable Cups from Agro-waste

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Abstract: The growing environmental concerns associated with plastic waste have highlighted the need for sustainable alternatives in food packaging. This study focuses on the development of biodegradable cups using natural agro-waste materials such as onion peel (Allium cepa), orange peel (Citrus sinensis), rice bran (Oryza sativa), reinforced with silver nanoparticles (AgNPs) to enhance antimicrobial properties and improve the overall functionality of the cups. Onion peel extract plays a dual role, acting as a natural reducing and stabilizing agent for the green synthesis of AgNPs while also contributing to the structural integrity and biodegradability of the cups. Orange peel and rice bran are incorporated as reinforcing agents to improve the mechanical strength, thermal stability, and durability of the biopolymer matrix, making the cups more resilient for practical use. The addition of AgNPs further boosts antimicrobial efficacy, ensuring the cups provide an added layer of protection against microbial contamination, thereby enhancing food safety and extending shelf life of the cups. The developed cups are subjected to various analyses to assess their physicochemical properties, biodegradation behavior of the developed cups. The results indicate that the integration of agro-waste materials and silver nanoparticles leads to a robust biodegradable material. This eco-friendly approach not only reduces the valorization of agricultural by-products, aligning with the principles of sustainable development and circular economy. The development of these biodegradable cups contributes to global environmental conservation with promising sustainability.
Keywords: Biodegradable cups, onion peel extract, silver nanoparticles (AgNPs), orange peel, rice bran, biodegradation, eco-friendly, agro-waste, shelf life, sustainable development.

I. INTRODUCTION

Plastic pollutant has become a significant environmental concern, contaminating ecosystems worldwide. These human-derived materials have surpassed planetary boundaries, pushing us beyond the safe limits for sustainable living [Zimmermann et al., 2021]. Environmental issues associated with plastics include their low degradability and limited biodegradability, the decreasing availability of landfill space, the reliance on increasingly scarce petroleum-based fossil resources, and the harmful emissions produced during incineration [Ardanuy et al., 2012]. By 2050, plastics production and processing could represent up to 20% of global petroleum consumption and 15% of the annual carbon emissions budget [Agenda., 2016].

A potential solution for reducing disposable non-biodegradable cups is to replace them with (a) reusable cups, (b) biodegradable non-edible cups, (c) biodegradable edible cups. The polyethylene can be substituted with a biodegradable material, such as natural polymers [Shulga et al., 2023]. Biodegradable packaging serves as a replacement for synthetic plastic packaging [Attri et al., 2021]. While the 3R concept – Reduce, Reuse, Recycle-is widely advocated as a sustainable waste management approach [Yao et al., 2024]. The replacement of petroleum-based plastics with bio-based polymers is essential, as the production of conventional plastics consumes approximately 65% more energy, is environmentally unsustainable, and results in 30-80% higher greenhouse gas emissions compared to bioplastics. Biodegradable polymers are derived from renewable resources, are fully biodegradable, and replicate the properties of conventional plastics such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) [Mangaraj et al., 2019].

Vegetable fibers offer numerous advantages, including widespread availability, renewable nature, low density, low coefficient of thermal expansion, effective thermal and acoustic insulation, and high flexural and tensile modulus, among other benefits [Ardanuy et al., 2012]. It is widely recognized that plants typically contain anti-nutrients, which may result from the use of fertilizers and pesticides, as well as various naturally occurring compounds [Soetan et al., 2009].

Fibers are valued for their distinctive properties, including low density, biodegradability, resistance to corrosion, wide availability, non-toxicity, and minimal carbon emissions [Komal et al., 2020]. Nanomaterials frequently enhance mechanical strength and durability by improving tensile properties. They also increase antibacterial effectiveness, which helps prolong shelf life [Xing et al., 2021]. Red onions, in particular, contain between 415 and 1917 mg of flavonols per kilogram of fresh weight (FW) [Slimestad et al., 2007]. Sweet orange peels are a valuable source of pectin [Pandharipande et al., 2012]. Rice bran typically comprises 12-22% oil, 11-17% protein, 6-14% fiber, 10-15%moisture, and 8-17%ash [Sharif et al., 2014]. These by-products are of natural origin and are likely to decompose fully in nature without causing pollution [Olt et al., 2019].

II. LITERATURE REVIEW

Biodegradable cups are produced by extracting biocomponents from plant-based sources like onion peel, orange peel, and rice bran. To boost antimicrobial effectiveness and prolong shelf life, these cups are reinforced with silver nanoparticles. Polyvinyl alcohol (PVA) coatings provide several advantages, such as improved barrier properties, water solubility, and biodegradability. Furthermore, the cups are enhanced with diverse natural materials, contributing to their overall sustainability.

A. Green Synthesis of Silver Nanoparticles (AgNPs)

Green synthesis using plant extracts as natural reducing agents has emerged as an eco-friendly approach. Bioactive compounds like flavonoids, phenolics, and terpenoids in these extracts help reduce silver ions and stabilize nanoparticles [Ortega et al., 2017]. AgNPs showed stronger antibacterial activity, as Gram-positive S. aureus was more vulnerable. The outer membrane of Gram-negative E. coli acts as a barrier, limiting AgNPs penetration and reducing antimicrobial effectiveness [Xing et al., 2021]. Smaller AgNPs have higher diffusivity and antimicrobial activity due to their larger surface area [Senthil et al., 2017]. Key functional groups like hydroxyl (-OH), carboxyl (-COOH), and amide (-NH) were identified for nanoparticle stabilization. AgNPs showed a spherical shape with an average size of 37±29nm [Budhalakoti et al., 2023]. Nanoparticles (NPs) smaller than 100 nm are considered vital components in the field of nanotechnology. Among them, silver nanoparticles (AgNPs) are the most commonly used across various domains, particularly in healthcare, due to their well-known cytotoxic, antibacterial, and antioxidant properties [Suriyakala et al., 2024].

B. Attributes of the Extraction Materials

1) Onion Peel

Onion peel, a by-product of food processing, is abundant in bioactive compounds like quercetin, flavonoids, and polyphenols [Yap et al., 2020]. The primary flavonols detected are: Quercetin 3-glucoside, Quercetin 4'-glucoside, Isorhamnetin derivatives [Celano et al., 2021]. The various anthocyanins, such as: Delphinidin 3,5-diglycosodes, Cyanidin 3,5-diglycosides, Cyanidin 3-glycosides, Cyanidin 3-(6"-malonyl)-glucopyranoside [Zhang et al., 2016]. Additionally, dried onion peel powder has been shown to enhance antioxidant activity [Jokovic et al., 2024]. They are typically discarded as kitchen waste, recent studies have revealed that these peels offer several health benefits for humans [Pirsa et al., 2024].

2) Orange Peel

Orange peel, rich in bioactive compounds like anthocyanins, carotenoids, polyphenols, and vitamin C, is a valuable additive for improving biodegradable cups. It strengthens the polymer matrix, reducing water absorption. It acts as a natural antimicrobial agent, while its lignin and cellulose content improve tensile strength and structural integrity [Tibalia et al., 2023]. The most common method involves treating citrus peels with dilute acids like hydrochloric or citric acid [Tiwari et al., 2017]. Incorporating orange peels into the polymer matrix can enhance recyclability, promote photodegradation, and improve mechanical properties [Fehlberg et al., 2020].

3) Rice Bran and Material Stability Components

Fibre bonding enhances the water resistant and mechanical properties of pulp boards by creating a stronger, more cohesive structure. This improved bonding, reduces moisture absorption, increasing durability and making the boards more resilient to environmental conditions [Gouw et al., 2017]. The effectiveness of natural fibres as reinforcement relies on their chemical composition, thermal stability, and mechanical strength. They offer benefits like low density, biodegradability, renewability, and cost-effectiveness [Manimaran et al., 2018]. Rice bran was incorporated into low-density polyethylene (LDPE) at varying concentrations using a twin-screw extruder, and the resulting blend was processed into uniform films through film blowing [George et al., 2006].

Polyvinyl Alcohol (PVA), a synthetic polymer, has attracted interest for its biodegradable nature and potential use in sustainable packaging. It enhances the moisture resistance and improve structural integrity [Azahari et al., 2011]. Glycerol acts as an effective plasticizer, enhancing the flexibility of materials by reducing intermolecular forces within the polymer structure. This results in increased elasticity and softness, making the material less brittle and more durable [Marichelvam et al., 2019]. Starch is widely regarded as a polymer with significant potential due to its renewable nature. Starch cab be modified or blended with other biopolymers to enhance its mechanical strength, and water resistance. It aids in holding the materials together [Pongracz., 2007].

4) Approaches to Structural and Chemical Evaluation

Biological degradation refers to the breakdown of organic compounds by living organisms, particularly microorganisms. It is a natural process through which microbes utilize these compounds as sources of carbon and energy for their growth. This process plays a vital role in the recycling of materials within natural ecosystems. Organic matter can undergo degradation either aerobically, in the presence of oxygen, or anaerobically, in the absence of oxygen [Priyanka et al., 2011]. The degradation or incineration of starch-based products returns carbon dioxide (CO2) to the atmosphere that was originally absorbed by starch-producing plants, thereby not contributing to potential global warming [Aharinejad et al., 1992]. The scanning electron microscope (SEM) is a highly versatile tool used for analysing and examining microstructural morphology and determining chemical composition characteristics [Berthomieu et al., 2009]. Fourier Transform Infrared (FTIR) spectroscopy is used to investigate the vibrational characteristics of amino acids and cofactors, which are highly sensitive to subtle structural changes. FTIR is a highly effective technique for identifying functional groups in a membrane and detecting potential molecular bonds between chemical compounds [Mohamed et al., 2017].

III. METHODOLOGY

The raw materials required for the development of biodegradable cups – onion peels, orange peels, and rice bran were carefully sourced from local markets and processing units. Onion, orange peels and rice bran were thoroughly washed with distilled water to remove dirt and impurities before being air-dried for further processing, then the peels dried completely in hot air oven until it becomes crispy and brittle. All collected samples were carefully stored in airtight containers to prevent moisture absorption, rancidity, and contamination before further use. The dried peels are then ground into a fine powder. The 25g of measured onion peel powder is soaked in 250ml of distilled water for 12 hours at room temperature in an airtight container. After 12 hours, the extract is filtered, and the filtered solution is stored at room temperature without any damage. The 50g of dried orange peel powder and 100g of rice bran measured and stored separately.

Silver oxide can be synthesized by reacting silver nitrate with a base, such as onion peel extract. The extract contains natural alkaline compounds, including flavonoids, polyphenols, and other reducing agents. The formation of silver oxide is indicated by the appearance of a brown or black precipitate after adding silver nitrate to the onion peel extract. The synthesis of silver nanoparticles (AgNPs) was carried out using silver nitrate ($AgNO_3$) and prepared onion peel extract. A 0.01 M solution of silver nitrate was prepared by dissolving the salt in double-distilled water. The two solutions - onion peel extract and silver nitrate - were combined in varying ratios of 5:5, 6:4, 7:3, 8:2, and 9:1, and kept for 24 hours, with the 7:3 ratio chosen for further experiments, as it yielded the highest production of silver nanoparticles compared to the other ratios. In the chosen 7:3 ratio, the reaction mixture was heated just below its boiling point and continuously stirred at 800 rpm using a magnetic stirrer. Within one hour, the mixture turned brown, a sign of successful nanoparticle formation due to the reduction of silver ions to metallic silver. Following synthesis, the obtained suspension was subjected to centrifugation at 3,500 rpm for 10 minutes to separate the silver nanoparticles from the liquid phase. The resulting pellet, which contained the silver nanoparticles, was washed 3-4 times with 70% ethanol to remove any residual impurities and unreacted materials. Finally, the precipitated nanoparticles were stored in a cool, dry, and dark place to preserve their integrity.

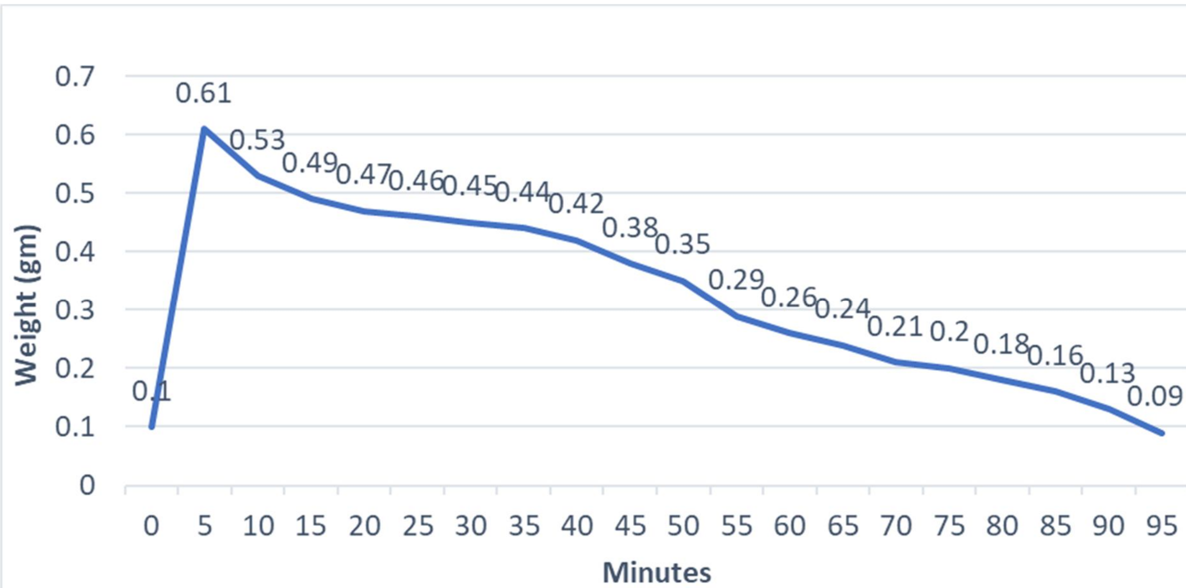
To achieve partial hydrolysis, 50g of dried orange peel powder is treated with approximately 50 mL of 0.1 M HCl, prepared by diluting 0.83 mL of concentrated HCl with 99 mL of distilled water. This mild acidic condition ensures safe mixing while preserving the structural integrity of the peel. After completing the individual processes, all the prepared materials are combined to form a uniform mixture. In a vessel, rice bran, partially hydrolysed orange peel powder, and synthesized silver nanoparticles are mixed with 250 mL of water and heated at 80°C for 30 minutes. Subsequently, polyvinyl alcohol (20g), starch (10g), and glycerol (10g) are added to the mixture and stirred thoroughly. After 30 minutes, the mixture thickens and is then allowed to cool.

The prepared mixture is used to develop biodegradable cups using the necessary moulding and drying facilities. A suitable mould is prepared based on the desired shape and size of the container. This could be done using food-grade or environmentally friendly materials like silicone or metal moulds, depending on the production scale. After the composite, it must be allowed to cure. This can be done in a vacuum oven at a low temperature (around 40-60°C), depending on the specific properties of the biopolymer mixture. The curing process ensures that the PVA and starch binders form a solid matrix around the nanoparticles, giving the container strength and rigidity. Once the composite has solidified after gentle curing 40°C (8-12 hrs) in vacuum oven, the mould is carefully removed to reveal the shaped container. The prepared biodegradable cups are stored at room temperature for 4-5 months. From the date of manufacturing, the shelf life of the cup is 3 months. This cup is designed for single use and can be disposed of after use.

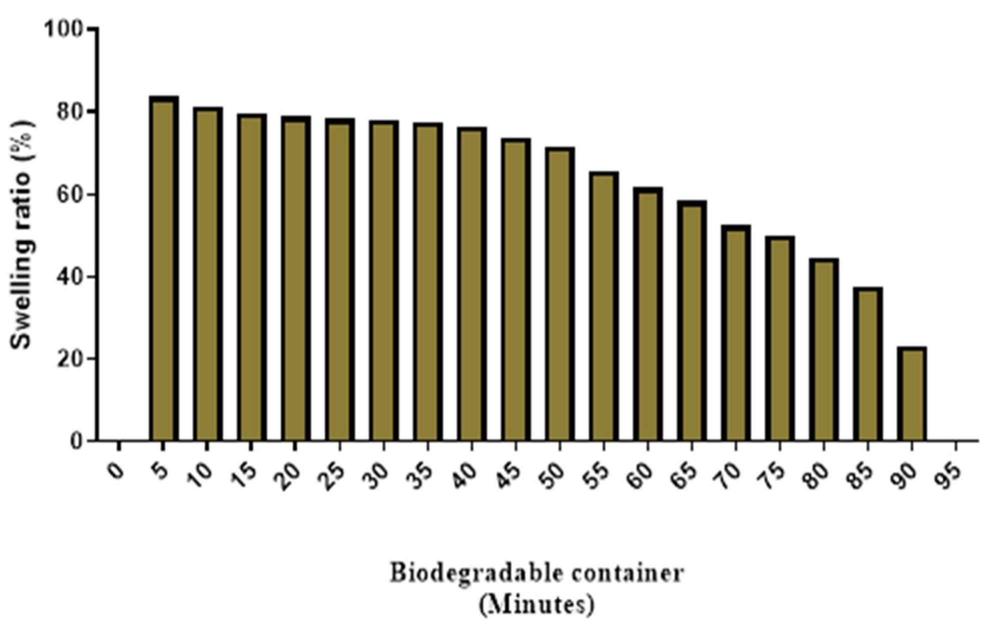
IV. RESULTS

A. Swelling Effect

The swelling effect test is crucial for assessing the water absorption and structural stability of biodegradable materials. Determining the percentage of swelling in biodegradable cups when exposed to water, ensuring their suitability for food packaging applications.



Weight variation of the sample.



Swelling behaviour.

S. No	Time in mins	Weight-Sample
1.	0	0.1
2.	5	0.61
3.	10	0.53
4.	15	0.49
5.	20	0.47
6.	25	0.46
7.	30	0.45
8.	35	0.44
9.	40	0.42
10.	45	0.38
11.	50	0.35
12.	55	0.29
13.	60	0.26
14.	65	0.24
15.	70	0.21
16.	75	0.20
17.	80	0.18
18.	85	0.16
19.	90	0.13
20.	95	0.09

S. No	Time in mins	Percentage of Swelling ratio (%)
1.	0	0
2.	5	83.6065574
3.	10	81.1320755
4.	15	79.5918367
5.	20	78.7234043
6.	25	78.2608696
7.	30	77.7777778
8.	35	77.2727273
9.	40	76.1904762
10.	45	73.6842105
11.	50	71.4285714
12.	55	65.5172414
13.	60	61.5384615
14.	65	58.3333333
15.	70	52.3809524
16.	75	50
17.	80	44.4444444
18.	85	37.5
19.	90	23.0769231
20.	95	0

Table represents the weight of the sample and percentage of swelling ratio of the biodegradable cup.

B. Solubility Test

A solubility test assesses the extent to which a material dissolves or breaks down when subjected to various solvents, including water, acids, and organic liquids. This evaluation is crucial for determining the cup's durability and resistance to moisture, particularly for use in food and beverage applications.

Time in (mins)	Water (10 ml)	Ethanol (10 ml)	Chloroform (10 ml)	Ethyl acetate (10 ml)
15 mins	No change	No change	No change	No change
30 mins	No change	No change	No change	No change
45 mins	Slightly soluble	No change	No change	No change
1 hour	Complete soluble	No change	No change	No change

Changes of the material in different solvents for every 15 minutes.

S. No	Name of the sample	RESULTS			
		Water	Ethanol	Chloroform	Ethyl acetate
1.	Biodegradable container	soluble	Insoluble	Insoluble	Insoluble

The result of the sample in different solutions.

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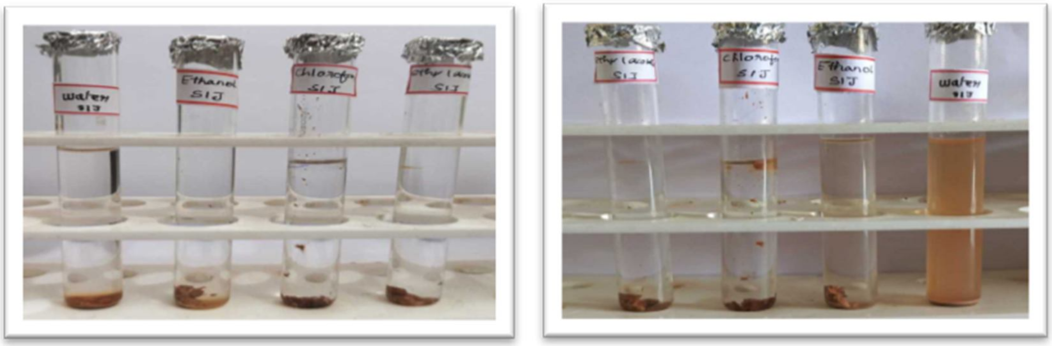


The solubility test – initial time (0) and final time (after 1 hour).

C. Biodegradability Test

Soil burial test measures the degradation of materials in natural soil conditions. It provides a simple and effective way to assess the environmental impact and sustainability of biodegradable materials by simulating real-world disposal conditions.

S. No	Sample	Initial weight of the sample	Final weight of the sample after 15 days
1.	Biodegradable cup	0.68 gram	0.32 gram

Result of biodegradability of the sample.

D. Characterization of the biodegradable cups

A set of biodegradable cups made from a composite material made of rice bran, orange peel, onion peel reinforced with silver nanoparticles was the end result. To create environmentally friendly and solid cups, these ingredients were combined in precise amounts, moulded, and dried.

1) Physical Appearance

The cups exhibit a coarse, grainy texture resulting from the fibrous composition of raw materials like rice bran, orange peel and onion peel. Their outer surface shows a uniform brown colour, reflecting effective blending and drying processes. The absence of visible cracks, shrinkage, or mould indicates strong structural integrity and good resistance to moisture and fungal growth.

2) Dimensions

The accurate measurement of the biodegradable cup measured using an instrument Vernier calliper.
Cup 1, 2, 3, 4.
The Height of the cup: 7.0 cm, 6.8 cm, 7.1 cm, 6.9 cm.
Top Diameter of the cup: 6.5 cm, 6.4 cm, 6.6 cm, 6.3 cm.
Bottom Diameter of the cup: 5.0 cm, 5.1 cm, 5.2 cm, 5.0 cm.
Wall Thickness of the cup: 0.5 cm, 0.4 cm, 0.5 cm, 0.4cm.
The weight of the biodegradable cup measured using an instrument Digital weighing scale. Each cup weighs approximately 25-35 grams, depending on wall thickness and moisture retention. Weight of cup 1: 30.2 gram. Weight of cup 2: 29.7 gram. Weight of cup 3: 31.0 gram. Weight of cup 4: 29.1 gram.

3) Odour and Sensory Characteristics

The cups gave off a faint, earthy aroma attributed to the inclusion of rice bran and orange peel. No offensive or artificial smells were present, confirming their suitability for food packaging applications.

4) Biodegradation Timeline

Initial soil burial analysis indicated that the material began to break down within 10 to 14 days, with full decomposition occurring between 30 and 35 days under typical soil conditions.

5) Shelf Life

Under dry storage conditions, the biodegradable cups remained structurally stable and usable for up to 5-6 months without significant degradation or microbial growth. This shelf life supports their practical application in packaging and short-term storage scenarios.

6) Carrying Capacity

The cups demonstrated the ability to hold to 180-200 ml of liquid without leaking or collapsing. Their strength under this load make them suitable for serving beverages or semi-liquid food items in everyday use.

7) Final Product

V. DISCUSSION

Life Cycle Assessment (LCA) is a standardized method used to evaluate the environmental impacts associated with all stages of a product's life, from raw material extraction through production, usage, and end-of-life disposal. This section presents an LCA of biodegradable cups developed using onion peel reinforced with silver nanoparticles, orange peel, rice bran, polyvinyl alcohol (PVA), glycerol, and rice starch. The environmental impacts of these biodegradable cups are compared with conventional single-use plastic cups to assess their sustainability and eco-friendliness. The swelling test was conducted using various solvents including water, methanol, ethanol, ammonia, acetic acid, chloroform, acetone, sulphuric acid, and orthophosphoric acid, based on the weight change before and after soaking. The material exhibited noticeable swelling in polar solvents, particularly water and ethanol, with the highest swelling observed in water, ethanol, ammonia, and acetic acid. Methanol, however, led to hardening rather than swelling. No dissolution occurred in chloroform, acetone, sulphuric acid, phosphoric acid, or methanol, indicating the material's resistance to these solvents [Yaradoddi et al., 2020]. Complete degradation of the composite cup occurred within 5 weeks in soil, whereas residual traces persisted in moist sand up to 6 weeks. These finding demonstrate that the rate of biodegradation is higher in soil than in sand [Buxoo et al., 2020].

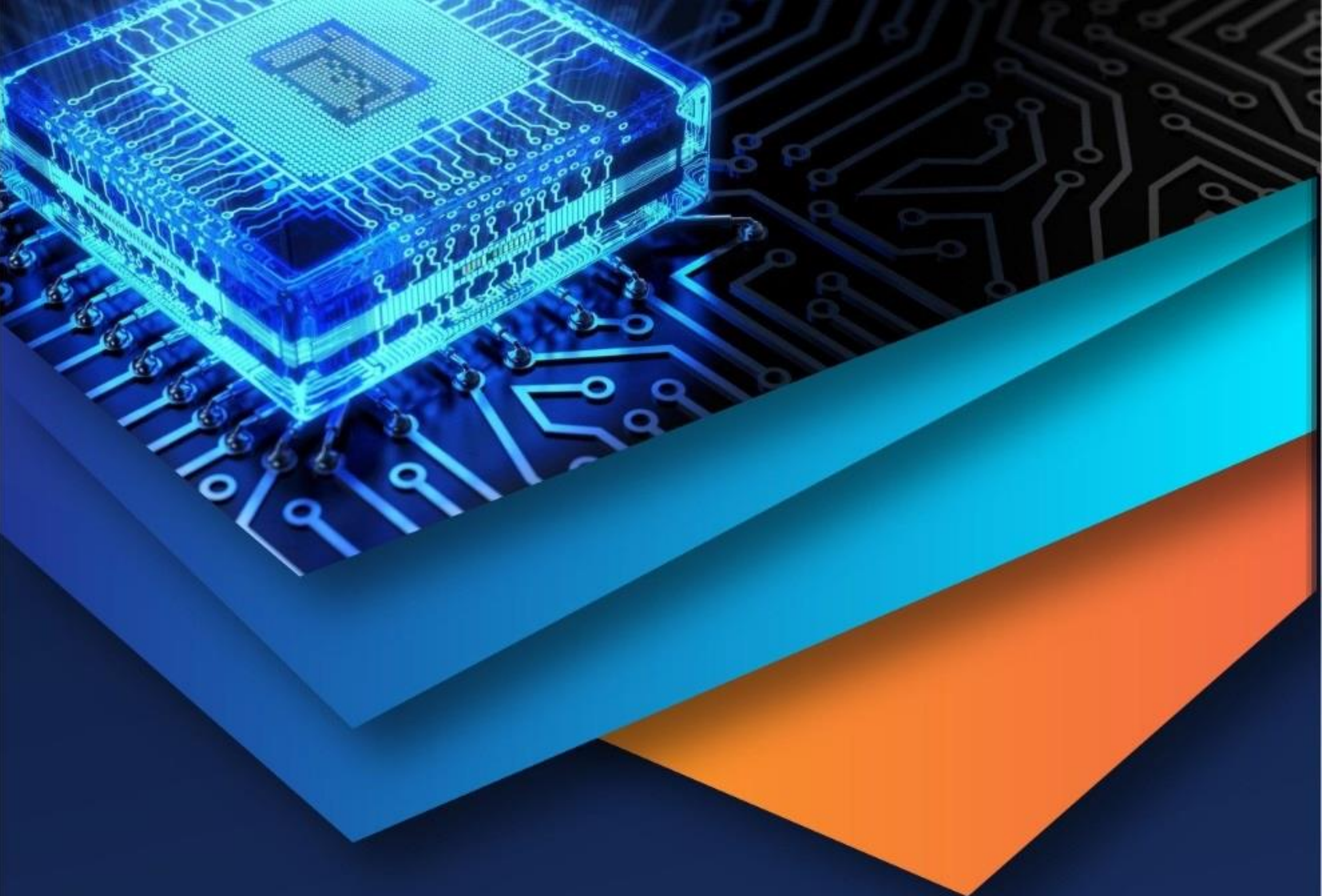
VI. CONCLUSION

The primary objective of this project was to develop sustainable, biodegradable cups using onion peel reinforced with silver nanoparticles, orange peel, and rice bran. The rampant use of disposable cups, particularly in the food and beverage sector, has emerged as a major contributor to the escalating plastic pollution crisis. These single-use items are predominantly manufactured from petroleum-based polymers, which are notoriously resistant to degradation—often persisting in the environment for hundreds of years. As a result, they accumulate in landfills and aquatic ecosystems, causing severe ecological imbalances and posing significant risks to human health. In response to this pressing environmental challenge, the present research explores the development of an innovative, biodegradable alternative crafted from sustainable agricultural by-products—namely onion peel, orange peel, and rice bran. To enhance the structural integrity and performance of the bio-composite material, silver nanoparticles are incorporated as reinforcing agents. Additionally, natural plasticizers and binders such as glycerol, polyvinyl alcohol (PVA), and rice starch are employed to bolster the material's mechanical strength, thermal resistance, and overall functional properties, thereby presenting a viable and eco-conscious solution to the problem of plastic waste. This innovative approach effectively utilizes agricultural waste materials, contributing to waste reduction and sustainable resource management. Moreover, the combination of natural fibers and bio-fillers improves the mechanical strength, thermal resistance, and biodegradability of the cups. These materials not only offer a cost-effective alternative to conventional plastics but also promote eco-friendly manufacturing practices. Overall, this study supports the viability of biodegradable composites in reducing plastic pollution while fostering environmental and economic sustainability.

REFERENCES

[1] Agenda, I. (2016, January). The new plastics economy rethinking the future of plastics. In World Economic Forum (Vol. 36).
[2] Aharinejad, S. H., Lametschwandtner, A., Aharinejad, S. H., & Lametschwandtner, A. (1992). Fundamentals of scanning electron microscopy. Microvascular Corrosion Casting in Scanning Electron Microscopy: Techniques and Applications, 44-51.
[3] Ardanuy, M., Antunes, M., & Velasco, J. I. (2012). Vegetable fibres from agricultural residues as thermo-mechanical reinforcement in recycled polypropylene-based green foams. Waste Management, 32(2), 256-263.
[4] Attri, S., Talwar, G., Kumar, N., Chawla, R., & Wakchaure, N. (2021). Effect of different concentrations of corn starch and whey protein on the characteristics of biodegradable cup. Environment Conservation Journal, 22(SE), 21-31.
[5] Azahari, N. A., Othman, N., & Ismail, H. (2011). Biodegradation studies of polyvinyl alcohol/corn starch blend films in solid and solution media. Journal of Physical Science, 22(2), 15-31.
[6] Berthomieu, C., & Hienerwadel, R. (2009). Fourier transform infrared (FTIR) spectroscopy. Photosynthesis research, 101, 157-170.
[7] Budhalakoti, N. (2023). Synthesis of silver nanoparticles using onion peel polyphenols and their antimicrobial effect. BioNanoScience, 13(2), 718-729
[8] Buxoo, S., & Jeetah, P. (2020). Feasibility of producing biodegradable disposable paper cup from pineapple peels, orange peels and Mauritian hemp leaves with beeswax coating. SN Applied Sciences, 2, 1-15.
[9] Celano, R., Docimo, T., Piccinelli, A. L., Gazzerro, P., Tucci, M., Di Sanzo, R., ... & Rastrelli, L. (2021). Onion peel: Turning a food waste into a resource. Antioxidants, 10(2), 304.
[10] Fehlberg, J., Lee, C. L., Matuana, L. M., & Almenar, E. (2020). Orange peel waste from juicing as raw material for plastic composites intended for use in food packaging. Journal of Applied Polymer Science, 137(26), 48841.
[11] George, J., Kumar, R., Jayaprahash, C., Ramakrishna, A., Sabapathy, S. N., & Bawa, A. S. (2006). Rice bran-filled biodegradable low-density polyethylene films: Development and characterization for packaging applications. Journal of applied polymer science, 102(5), 4514-4522.
[12] Gouw, V. P., Jung, J., Simonsen, J., & Zhao, Y. (2017). Fruit pomace as a source of alternative fibers and cellulose nanofiber as reinforcement agent to create molded pulp packaging boards. Composites Part A: Applied Science and Manufacturing, 99, 48-57.
[13] Joković, N., Matejić, J., Zvezdanović, J., Stojanović-Radić, Z., Stanković, N., Mihajilov-Krstev, T., & Bernstein, N. (2024). Onion peel as a potential source of antioxidants and antimicrobial agents. Agronomy, 14(3), 453.
[14] Komal, U. K., Lila, M. K., & Singh, I. (2020). PLA/banana fiber based sustainable biocomposites: A manufacturing perspective. Composites Part B: Engineering, 180, 107535.
[15] Mangaraj, S., Yadav, A., Bal, L. M., Dash, S. K., & Mahanti, N. K. (2019). Application of biodegradable polymers in food packaging industry: A comprehensive review. Journal of Packaging Technology and Research, 3, 77-96.
[16] Manimaran, P., Senthamaraikannan, P., Sanjay, M. R., Marichelvam, M. K., & Jawaid, M. (2018). Study on characterization of Furcraea foetida new natural fiber as composite reinforcement for lightweight applications. Carbohydrate polymers, 181, 650-658.
[17] Marichelvam, M. K., Jawaid, M., & Asim, M. (2019). Corn and rice starch-based bio-plastics as alternative packaging materials. Fibers, 7(4), 32.
[18] Mohamed, M. A., Jaafar, J., Ismail, A. F., Othman, M. H. D., & Rahman, M. A. (2017). Fourier transform infrared (FTIR) spectroscopy. In Membrane characterization (pp. 3-29). elsevier.
[19] Olt, J., Soots, K., Olt, A., & Rooni, V. (2019). Exploration of the possibilities for the production of tableware from the bran of various cereals. In Rural Development: Proceedings of the International Scientific Conference (pp. 188-193).
[20] Ortega, F., Giannuzzi, L., Arce, V. B., & García, M. A. (2017). Active composite starch films containing green synthetized silver nanoparticles. Food Hydrocolloids, 70, 152-162.
[21] Pandharipande, S., & Makode, H. (2012). Separation of oil and pectin from orange peel and study of effect of pH of extracting medium on the yield of pectin. Journal of Engineering Research and Studies, 3(2), 6-9
[22] Pirsa, S., Bener, M., & Şen, F. B. (2024). Biodegradable film of carboxymethyl cellulose modified with red onion peel powder waste and boron nitride nanoparticles: Investigation of physicochemical properties and release of active substances. Food Chemistry, 445, 138721.
[23] Pongrácz, E. (2007). The environmental impacts of packaging. Environmentally conscious materials and chemicals processing, 237-278.
[24] Priyanka, N., & Archana, T. (2011). Biodegradability of polythene and plastic by the help of microorganism: a way for brighter future. J Environ Anal Toxicol, 1(4), 1000111.
[25] Senthil, B., Devasena, T., Prakash, B., & Rajasekar, A. (2017). Non-cytotoxic effect of green synthesized silver nanoparticles and its antibacterial activity. Journal of Photochemistry and Photobiology B: Biology, 177, 1-7.
[26] Sharif, M. K., Butt, M. S., Anjum, F. M., & Khan, S. H. (2014). Rice bran: a novel functional ingredient. Critical reviews in food science and nutrition, 54(6), 807-816.
[27] Shulga, O., Koretska, I., Chorna, A., Shulga, S., & Lin, Y. (2023). Consumer properties of biodegradable edible cups for hot drinks.
[28] Slimestad, R., Fossen, T., & Vågen, I. M. (2007). Onions: a source of unique dietary flavonoids. Journal of agricultural and food chemistry, 55(25), 10067-10080.
[29] Soetan, K. O., & Oyewole, O. E. (2009). The need for adequate processing to reduce the anti-nutritional factors in plants used as human foods and animal feeds: A review. African Journal of food science, 3(9), 223-232.
[30] Suriyakala, G., Sathiyaraj, S., Paranthaman, U. G., Velmurugan, R., Jayashan, S. S., Babujanarthanam, R., ... & Sukrong, S. (2024). Agro-waste mediated silver nanoparticles from Pithecellobium dulce (Roxb.) Benth fruit peel and their multifaceted biomedical applications. Nano-Structures & Nano-Objects, 38, 101189.
[31] Tibalia, E. M. S. E., Wintoko, J., & Purnomo, C. W. (2023, November). Biodegradable Food Container from Rice Straw and Sugarcane Bagasse with Orange Peel Addition. In IOP Conference Series: Earth and Environmental Science (Vol. 1275, No. 1, p. 012012). IOP Publishing.
[32] Tiwari, A. K., Saha, S. N., Yadav, V. P., Upadhyay, U. K., Katiyar, D., & Mishra, T. (2017). Extraction and characterization of pectin from orange peels. International Journal of Biotechnology and Biochemistry, 13(1), 39-47.
[33] Xing, Y., Liao, X., Liu, X., Li, W., Huang, R., Tang, J., ... & Yu, J. (2021). Characterization and antimicrobial activity of silver nanoparticles synthesized with the peel extract of mango. Materials, 14(19), 5878.

[34] Yao, K. C., Hsieh, H. H., Li, K. Y., Xu, J. R., Ho, W. S., Huang, W. L., ... & Tseng, Y. J. (2024). Sustainable Packaging Solutions: Food Engineering and Biodegradable Materials. Designs, 8(6), 133.
[35] Yap, Y. H., Azmi, A. A., Mohd, N. K., Yong, F. S. J., Kan, S. Y., Thirmizir, M. Z. A., & Chia, P. W. (2020). Green synthesis of silver nanoparticle using water extract of onion peel and application in the acetylation reaction. Arabian Journal for Science and Engineering, 45, 4797-4807.
[36] Yaradoddi, J. S., Banapurmath, N. R., Ganachari, S. V., Soudagar, M. E. M., Mubarak, N. M., Hallad, S., ... & Fayaz, H. (2020). Biodegradable carboxymethyl cellulose based material for sustainable packaging application. Scientific reports, 10(1), 21960.
[37] Zhang, S. L., Peng, D. E. N. G., Xu, Y. C., Lü, S. W., & Wang, J. J. (2016). Quantification and analysis of anthocyanin and flavonoids compositions, and antioxidant activities in onions with three different colors. Journal of integrative agriculture, 15(9), 2175-2181.
[38] Zimmermann, L., Bartosova, Z., Braun, K., Oehlmann, J., Völker, C., & Wagner, M. (2021). Plastic products leach chemicals that induce in vitro toxicity under realistic use conditions. Environmental science & technology, 55(17), 11814-11823.



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