Corn cob (*zea mays*) and rice (*oryza sativa* l.) Hulls as bio pots an alternative to single-use plastic pots

ABSTRACT

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| --- |
| Global plastic production has surged in recent decades, exacerbating the environmental crisis due to its persistent presence and slow degradation. This parallels the environmental challenge agricultural waste poses, often improperly disposed of. On the other hand, biodegradable pots offer a sustainable alternative to plastic pots by decomposing naturally in the soil, reducing waste, and promoting soil health. Thus, this research investigated the feasibility of repurposing agricultural waste such as corn cob and rice hulls into biodegradable alternatives to conventional plastic pots. This study aimed to determine the mechanical performance of biodegradable pots in terms of tensile strength, compressive strength, and compressive strength (peak force). Additionally, comparing its mechanical properties to commercially available pots in the market. A quantitative research approach was employed, utilizing experimental methodologies and the Kruskal-Wallis test to assess differences between the materials. The analysis revealed that the bio-pots exhibited a tensile strength within the 0.1 MPa to 0.3 MPa range. Furthermore, compressive strength demonstrated an average of 0.4 MPa with a maximum peak force of 2625.2 N. The Kruskal-Wallis test result revealed a *P*-value of (.392), indicating no statistically significant difference in tensile and compressive strength compared to commercially available plant pots. These findings collectively suggest that the fabricated bio-pots possess the potential to be viable alternatives. However, further research and development are necessary to optimize their properties and enhance their performance. Consequently, by utilizing agricultural byproducts, this research contributes to mitigating environmental impact and promoting sustainability in agriculture. |

***Keywords:*** *Corn Cob, Rice Hull, Agricultural Waste, Biodegradable pots, Plastic Pots, Sustainability*

1. INTRODUCTION

Plastic-based pots are widely practised in agriculture since they are affordable, lightweight, and durable (Pilapitiya & Ratnayake, 2024). However, given their strong resistance to microbial destruction, plastic pots are non-biodegradable because they are inert material, prompting a long-lasting carbon footprint for centuries (Mohanan et al., 2020). Similarly, agricultural waste, with over 998 million tonnes produced yearly (Raut et al., 2023), including corn cob and rice hulls, also contributes to carbon emissions. Although it is unavoidable and detrimental to the environment, agricultural waste can be repurposed into various sustainable products that can be an alternative to the use of plastic products in human daily life.

Moreover, the global use of plastic products has doubled production since the beginning of the century to almost 400 million metric tons per year in 2021. In contrast, decomposing can take 500 years (Alves, 2024), mainly when improperly disposed of. Oftentimes, plastics are either burned or abandoned in the open fields, disposed of in landfills, and incinerated, resulting in greenhouse gas emissions and economic loss (Maitlo et al., 2022), comparable to agricultural waste management practices. In this sense, it is harmful to the environment since it leads to land and water pollution, the release of harmful substances and air pollutants, and land degradation (Vanella et al., 2022), which is harmful to the ecosystem and biodiversity. From the agronomical point of view, the use of plastic pots influences the ulterior plant development. Pot walls force roots to grow downward and get encircled among themselves, during their search for water and nutrients. As a consequence, a few long roots are entangled, leading to their choking (Helgeson et al. 2009; Hall et al. 2010; Fuentes et al. 2021).

Biodegradable pots are a greener alternative to plastic pots. Produced from organic material like coconut coir or peat moss, they break down in the soil, causing no waste and fertilizing the soil in which they are planted (Beeks & Evan, 2013). Unlike plastic, which stays intact for centuries in landfills, these pots break down, leaving behind nothing but nutrients in the ground. The use of biodegradable products lowers the use of petroleum-based products and will contribute to making the planet a healthier place. The pots offer a green alternative to growing plants, lowering the environmental impact of plastic waste and promoting a greener way of life worldwide. As the environment becomes a bigger and bigger concern, the demand for biodegradable pots increases, driving the production of green solutions. The use of these green alternatives is significant in a greener future.

Additionally, in the study of Mohammed and Salih (2021), varying corn cob particle size enhances the mechanical properties of unsaturated polyester resin composites, which is suitable for the improved mechanical performance of the material. Another study by Miller et al. (2019) discusses that rice hulls improve the mechanical properties of rice-based ash in concrete. Moreover, the incorporation of this material led to enhanced mechanical properties. On the other hand, biopots offer sustainability to the environment. For instance, using pineapple waste to produce pots shows higher degradation properties (Jirapornvaree et al., 2017). Furthermore, using biodegradable pots exceeded the sustainability of the products. It helped to maintain the balance of nature better, protect the environment, and provide a better life for future generations (Srisunont et al., 2024; Saha and Hariprasad , 2022).

Furthermore, this study aims to produce biodegradable pots derived from corn cob and rice hulls. The mechanical performance of the biodegradable pots in terms of tensile strength, compressive strength, and compressive strength (peak force) must be determined. Moreover, the mechanical performance of the produced biodegradable pots is compared to that of commercial biodegradable pots sold on the market. In connection, this study aims to create an environmentally friendly alternative approach to minimize plastic and agricultural waste, reduce greenhouse gas emissions, and advance a circular economy in agriculture by using agricultural waste materials. This strategy helps international efforts to lessen the adverse environmental effects of plastic trash and is consistent with sustainable agriculture methods (Kumar et al., 2021).

2. material and methods

**Research Design**

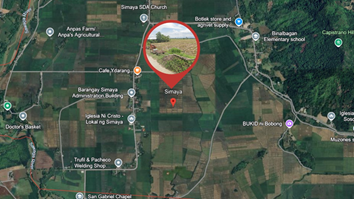
This study employed a Research and Development (R&D) approach, explicitly utilizing a quantitative experimental design, to investigate the feasibility of developing and evaluating biodegradable pots manufactured from agricultural residues, specifically corn cob and rice hulls. The primary focus of this study was to investigate the mechanical performance of these bio-based pots. The experiments involved mechanical tests like tensile strength and compressive strength, which are significant parameters for investigating the pots' structural stability and load-carrying capacity. Additionally, the mechanical properties of developed bio-pots were comparatively investigated with the commercially available biodegradable pots to provide a comparative basis. This comparative analysis aimed to identify potential advantages and limitations of the developed bio-pots in terms of their mechanical performance. Quantitative data was meticulously collected throughout the experimental process. Subsequently, the collected data was subjected to rigorous statistical analysis to identify significant differences in the mechanical properties of the bio-pots. This statistical analysis allowed for a more objective and robust interpretation of the experimental results.

**Entry Protocol**

Prior to commencing the research on corn cobs and rice hulls as bio pots, several formal letters were submitted to ensure ethical and smooth execution. One of the key processes was obtaining formal approval from authorities to carry out the research activities. Also, a letter of assistance was composed to a specialist at the College of Engineering at Central Mindanao University and Allied Material Testing Laboratories - Malaybalay Branch. The letter requested professional guidance and technical support to use the facilities and equipment, such as the laboratory, to aid the research activity. The research team ensured an ethical and smooth research process by securing these required approvals, forming cooperative relationships with the primary stakeholders, and developing valuable connections in the local community and academic institutions.

**Research Locale**

The corn cobs were collected in Cawayan, Lantapan, Bukidnon; while the rice hulls were collected in Basakan District, Barangay Simaya, Malaybalay City, Bukidnon. The raw materials for the biodegradable pots were processed and milled in Valencia City, Bukidnon. Meanwhile, the preparation of materials and the pot-making process were done in the researcher's home. Central Mindanao University in Maramag, Bukidnon, also served as the site for the compressive and tensile strength tests. Moreover, one test was done at Allied Material Testing Laboratories - Malaybalay Branch for the tensile strength of the commercial pots.



***Figure 1****. Cawayan, Lantapan, Bukidnon Figure 2. Simaya, Malaybalay City, Bukidnon Figure 3. Farmer’s Market, Valencia City, Bukidnon*



*Figure 4. Central Mindanao University, Maramag, Bukidnon Figure 5. Allied Material Testing Laboratories, Malaybalay City, Bukidnon*

**Identification Of Mechanical Performance**

Mechanical property evaluations, specifically tensile and compressive strength, were conducted on bio-pot samples at two accredited laboratories: the College of Engineering laboratory at Central Mindanao University and Allied Material Testing Laboratories – Malaybalay Branch. Adhering to established sampling and manufacturing protocols, specimens were subjected to rigorous testing procedures to assess their mechanical behaviour. Tensile strength, the maximum amount of tensile stress a product can endure before fracture, was measured on a Universal Testing Machine (UTM).

The Compression Testing Machine (CTM) was used to test compressive strength, which is the ability of a material or structure to withstand loads that try to shrink it. The tests were conducted under conditions that were controlled such that there were correctly prepared samples to ensure the quality and reliability of the ensuing data. These critical strength parameters are essential for informed material selection, optimized design, and effective quality control within the broader context of various engineering applications.

**Sample Collection and Preparation**

This study utilized corn cobs (Zea mays) collected from Cawayan, Lantapan, Bukidnon, and rice hulls (Oryza sativa L.) collected as waste from harvested rice in Basakan District, Barangay Simaya, Malaybalay City, Bukidnon, as the primary materials for producing biodegradable plant pots. Other materials used included cornstarch, white vinegar, water, and various equipment such as a grinding machine, stove, casserole, digital weighing scale, containers, spatulas, measuring cups, basins, moulds, and surgical gloves. The collected corn cobs and rice hulls were sun-dried for 3-5 days before ground using a grinding machine in Valencia City, Bukidnon. An adhesive mixture was prepared by heating 1.5 cups of water to boiling and then adding 2 cups of cornstarch and 50 ml of white vinegar, following the procedure outlined by Minay (2023). This mixture was stirred continuously until a homogenous gel was formed. For each pot, 50 grams of ground corn cob and 50 grams of ground rice hull (1:1 ratio) were mixed with the adhesive. The mixture was then poured into moulds, removed after setting, and left to air-dry for 2-3 days.

**Statistical Analysis**

A Kruskal-Wallis test was conducted to determine the mechanical strength of the biodegradable pots produced from rice hulls and corn cobs compared to the commercial bio-pot. The test is a non-parametric test applied to compare three or more independent groups whose data do not necessarily have a normal distribution. The test was conducted to determine if there were statistically significant differences in the pot strength.

**Ethical Consideration**

This study was conducted with the highest ethical and professional integrity. Researchers maintain data integrity to ensure correct and credible data collection and analysis. This study has rigorous safety protocols to minimize potential risks to researchers. Researchers have no conflict of interest that may bias the research outcome or influence the result of the study. The researchers recognize that they personally and solely bear responsibility for what they do and the conduct of this research, including the application of ethical principles and compliance with all relevant regulations. The institution cannot be held accountable for any action or outcome of this study. This study was conducted with respect to all parties concerned and with responsible and ethical research practices.

**Data Documentation**

Throughout the research, all procedures and experimentation were meticulously documented. Detailed written records were maintained, and photographs were captured using the researcher's smartphone to provide visual documentation. These measures ensured the accuracy, integrity, and reliability of the data pertaining to the production of biodegradable pots from corn cob and rice hulls. Comprehensive data documentation practices were implemented, encompassing detailed recording of all experimental procedures, observations, and measurements. Photographs were taken throughout the research process, including during the collection of variables, to complement and support the written records.

3. results and discussion

*Table 1. Results of the Mechanical Property Obtained from the Samples*

|  |  |  |  |
| --- | --- | --- | --- |
| ***Property*** | **Tensile Strength**  **(MPa)** | **Compressive Strength**  **(MPa)** | **Compressive Strength**  ***(Peak Force)***  **(N)** |
| Alternative Biopots | 0.2 | 0. 4 | 2021.5 |
| Commercial Pots | 61 | 6.3 | 644.8 |

Table 1 presents the mechanical performance results of biodegradable pots produced from corn cob and rice hulls, compared to commercial biodegradable pots. Three biodegradable pot samples with a 1:1 ratio of corn cob and rice hulls were subjected to tensile and compressive strength tests.

Tensile strength is the maximum tensile stress a material can withstand before failure. In simpler terms, it's the resistance of a material to breaking under tension (Otutu, 2020). In this study, the tensile strength results revealed an inverse relationship between thickness and strength. The thinnest sample exhibited the highest tensile strength (0.3 MPa), peak force (68.2 N), and deformation (5.8 mm). Conversely, the thickest sample demonstrated the lowest strength and peak force. This aligns with the study of Iannucci et al. (2018) which reveals a clear inverse relationship between specimen thickness and tensile strength, with thicker samples significantly exhibiting reduced tensile strength. This phenomenon is attributed to structural and manufacturing factors. However, while sample thickness can influence tensile strength and compressive strength, it is primarily determined by the constituent materials and the moulding temperature. Acknowledging that thickness is not the sole determinant of tensile strength is crucial. This is supported by the study of (Zhao & Liu, 2018), which states that the material composition significantly impacts mechanical properties. Furthermore, the average tensile strength of the biodegradable pots (0.2 MPa) was lower than that of the commercial biodegradable pots (61 MPa). This finding is consistent with the study by Castro et al. (2022), which reported tensile strengths ranging from (0.0024 MPa) to (0.00526 MPa) for biodegradable pots produced from Apple Pomace (Malus domestica), Banana Peel (Musa acuminata), Coconut fibre (Cocos nucifera), all of which were lower than commercially available options.

Compressive strength or compression strength is the capacity of a material or Compressive strength or compression strength is the capacity of a material or structure to withstand loads (Sabhadiya, 2024). The compressive strength test results indicated significant variations in the performance of the three tested samples, with Sample 1 exhibiting the lowest peak force (1213.8 N) and compressive strength (0.2 MPa), while Sample 2 demonstrated the highest performance with a peak force of (2625.2 N) and a compressive strength of (0.5 MPa). Sample 3 displayed intermediate performance, aligning with its deformation value, and recorded a peak force of (2225.6 N) and a compressive strength of (0.4 MPa). The average compressive strength across all samples was calculated to be (0.4 MPa). The observed variations in compressive strength among the bio-pot samples, ranging from 1213.8 N to 2225.6 N, can be attributed to several interacting factors. Firstly, the manual molding process likely introduced dimensional inconsistencies, as noted by Gyurkó & Nemes (2020), which can significantly influence peak force. Subtle variations in size and wall thickness can lead to differing stress concentrations under compression. Secondly, the hollow geometry of the bio-pots contributed to non-uniform stress distribution. Unlike a solid cube, which facilitates even stress application, the hollow structure may have resulted in localized stress peaks, leading to the observed variability in peak force. This aligns with the established practice of utilizing cube-shaped specimens for compressive strength testing, as they ensure a more uniform stress field, yielding more consistent and reliable results. Therefore, both the inherent inconsistencies of manual molding and the non-ideal hollow geometry of the bio-pots likely contributed to the observed range of compressive strengths. Furthermore, as highlighted by Anum and Job (2021), the significant impact of material property variations on compressive strength emphasizes the critical role of optimal material selection in achieving desired mechanical performance. Furthermore, a study by Younis and Pilakoutas (2013) established that the specific gravity and water absorption of aggregates play critical roles in determining the compressive strength of concrete, which may explain the performance discrepancies observed among samples. Additionally, Zhang et al. (2018) presented a model incorporating various factors affecting concrete strength, including aggregate size and composition, further supporting the findings that different materials yield varying mechanical properties.

*Table 2. Results of the significant difference between the biodegradable pots produced and commercial pots*.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Dependent Variable** | **H (χ²)** | **df** | ***P*-value** | **Decision** |
| Tensile Strength | 3.00 | 3 | .392 | Retain the null hypothesis |
| Compressive Strength | 3.00 | 3 | .392 | Retain the null hypothesis |
| Compressive Strength  *(Peak force)* | 3.00 | 3 | .392 | Retain the null hypothesis |

Legend: (*P* = .05), reject the null hypothesis. (*P* = .05), retain the null hypothesis.

The table shows the results of a hypothesis test summary using the Kruskal-Wallis Test; the hypothesis test summary table provides the results of statistical tests conducted to determine if there are significant differences in the distributions of three variables: Tensile Strength, Compressive Strength, and Compressive Strength (Peak Force).

The results indicated no statistically significant difference among the three groups. In this table, the result of the distribution of tensile strength, compressive strength, and compressive strength (peak force) revealed a *P*-value of *P* = .392. The significance level (*P* = .05) is a standard threshold for rejecting the null hypothesis. However, since the *P* = .392 is more significant than the significance level of (*P* = .05) for all three tests, it retains the null hypothesis for each variable. Moreover, it was concluded that there are no significant differences in the distributions of tensile strength, compressive strength, and compressive strength (peak force) across the different categories. Lastly, the results suggest that the treatment categories do not significantly impact these three variables statistically.

The mechanical performance of bio-pot varies significantly depending on the composition and the processing techniques employed. For instance, the study of Jaya et al. (2024) explores the mechanical characteristics of biodegradable pots made from sodium alginate combined with oil palm empty fruit bunches. The tensile tests revealed that incorporating sodium alginate as a polymeric matrix enhances the mechanical performance of the bio-pot. These findings emphasize the critical need for optimized processing methodologies and material compositions to improve the mechanical and practical performance of bio-pots.

This optimization is paramount for ensuring superior product quality and achieving widespread consumer acceptance. Similarly, the study of Fuentes et al. (2021) explores the mechanical properties of biodegradable pots made from sodium alginate combined with various agro-industrial byproducts. The findings indicate that optimizing the composition and processing techniques can lead to improved tensile strength and overall mechanical performance of the bio-pots, emphasizing the role of sodium alginate in enhancing material properties.

4. Conclusion

In conclusion, this research successfully demonstrated the feasibility of creating biodegradable plant pots from agricultural waste, specifically corn cobs and rice hulls, achieving comparable mechanical performance to commercially available options with a notable strength advantage in peak force. The result of the statistical analysis revealed no statistical difference between the mechanical performance of the biodegradable pots in terms of their Tensile Strength, Compressive Strength, and Compressive strength (Peak force), which indicated that the fabricated pots are viable alternatives. Although statistical analysis showed no significant difference, observed performance variations suggest further research is warranted to optimize material formulations and processing techniques, ultimately enhancing the strength and durability of these sustainable alternatives. Specifically, this study recommends the incorporation of methods and chemicals that enhance the fabrication of biodegradable pots. It includes the incorporation of sodium alginate that according to other studies, improves the mechanical performance of the pots. Moreover, acquiring a thermo-pressing machine or hydraulic press is highly advisable to achieve a significantly stronger material bond, substantially enhancing the final product's strength and long-term durability. Future studies should also investigate different ratios of raw materials used in pot production. By varying these ratios, researchers can identify ideal combinations that maximize the perfect property of the material. Consequently, the environmental benefits of utilizing biodegradable pots manufactured from agricultural waste are substantial. This approach minimizes landfill burden by effectively repurposing materials that would otherwise contribute to environmental pollution. It significantly reduces the carbon footprint of producing and disposing of conventional plastic pots. This sustainable practice aligns perfectly with the escalating global emphasis on environmentally conscious agricultural practices. Furthermore, it actively supports the transition towards a circular economy, a model that prioritizes waste minimization and the efficient utilization of resources.

**Ethical Approval:**

Authors are obtaining formal approval from authorities to carry out the research activities.

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