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Utilizing Rice (Oryza sativa) Hulls as a Sustainable Alternative to Sand in Cookstove (Dalikan) Manufacturing: Social and Environmental Benefits

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Abstract: This study evaluates the acceptability of rice husk (Oryza sativa) as an alternative material to sand in household cookstove production, focusing on usability, durability, and appearance. Employing a descriptive-experimental design, the research involved thirty selected households in Peñarrubia, Abra, distributing respondents evenly across three barangays. Data were collected using an adapted assessment sheet and analyzed through weighted mean and ANOVA at a 0.01 significance level. Results showed Treatment 1 had moderate acceptance (mean=3.22), Treatment 2 achieved high acceptance (mean=3.57), and Treatment 3 comprising 5 kg cement and 5.7 kg rice husk attained the highest acceptance (mean=4.73), indicating very high user approval. Statistical analysis confirmed significant differences among treatments. These findings highlight rice husk's potential as an effective and socially acceptable sand substitute in cookstove manufacturing. Additionally, they underscore its role in promoting environmental responsibility and sustainable resource utilization, contributing to community well-being by offering a practical, eco-friendly cooking technology. This aligns with broader social goals of waste valorization and local economic empowerment through innovation.

Kata kunci:
sekam padi; tungku masak; bahan alternatif; keberlanjutan; tanggung jawab lingkungan; rumah tangga; penerimaan pengguna.

Abstrak: Penelitian ini mengevaluasi tingkat penerimaan sekam padi (Oryza sativa) sebagai bahan alternatif pengganti pasir dalam produksi tungku masak rumah tangga, dengan fokus pada kegunaan, daya tahan, dan penampilan. Menggunakan desain deskriptif-eksperimental, penelitian melibatkan tiga puluh rumah tangga terpilih di Peñarrubia, Abra, dengan distribusi responden yang merata di tiga desa (barangay). Data dikumpulkan menggunakan lembar penilaian yang telah diadaptasi dan dianalisis melalui rata-rata tertimbang serta analisis varians (ANOVA) pada taraf signifikansi 0,01. Hasil menunjukkan bahwa Perlakuan 1 memperoleh tingkat penerimaan sedang (nilai rata-rata=3,22), Perlakuan 2 mencapai tingkat penerimaan tinggi (nilai rata-rata=3,57), dan Perlakuan 3 yang terdiri dari 5 kg semen dan 5,7 kg sekam padi mendapatkan nilai rata-rata tertinggi sebesar 4,73, yang menunjukkan penerimaan pengguna sangat tinggi. Analisis statistik mengonfirmasi adanya perbedaan signifikan di antara perlakuan tersebut. Temuan ini menyoroti potensi sekam padi sebagai substitusi pasir yang efektif dan dapat diterima secara sosial dalam produksi tungku masak. Selain itu, penelitian ini menegaskan peran sekam padi dalam mendorong tanggung jawab lingkungan dan pemanfaatan sumber daya yang berkelanjutan, serta memberikan kontribusi terhadap kesejahteraan masyarakat melalui penyediaan teknologi memasak yang ramah lingkungan dan praktis. Hal ini sejalan dengan tujuan sosial yang lebih luas terkait pengelolaan limbah dan pemberdayaan ekonomi lokal melalui inovasi.

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INTRODUCTION

Agriculture has a significant impact on the economic, social, and environmental landscape of nations around the world (Vishnoi & Goel, 2024). As the backbone of many economies, it provides essential sustenance, employment, and income for billions of people, particularly in developing countries. Beyond its economic contributions, agriculture plays a crucial role in ensuring food security, promoting rural development, and preserving cultural traditions associated with farming practices (Vishnoi & Goel, 2024).

Rice is a staple food source consumed worldwide, and it is produced in substantial quantities every year (Bin Rahman & Zhang, 2023; Samal et al., 2022). China is the world's largest producer of rice, with an average annual production exceeding 200 million tons (Shen et al., 2021). The rice milling process generates a byproduct known as rice hull. The average rice hull coefficient is around 0.18, implying that the rice paddies may produce approximately 36 million tons of rice hull. In developing countries, the most common method of disposing of rice hulls is to burn or dump them in the field, which raises concerns about environmental damage (Lu et al., 2020).

A rice hull is a firm protective shell that separates rice grains during the milling process. Rice hull is a readily available waste material in all rice-producing countries, containing around thirty to fifty percent organic carbon (AboDalam et al., 2022). During a standard milling procedure, the hull is removed from the raw grain, revealing complete brown rice. This is then further milled to remove the bran layer, yielding white rice. Current global rice production is expected to reach 700 million tons (Darko et al., 2025).

Humankind uses a wide range of mineral resources in the production of goods (Jie et al., 2023). The majority of natural resources are limited and cannot be replenished. However, rice waste is an infrequent exception. This waste material contains two kinds of resources. The organic half of rice hulls can be oxidized when exposed to energy. At the same time, the inorganic leftovers, or ash, are composed of amorphous silica, which can be used to manufacture a variety of products (Gaur et al., 2024; Parrillo & Sánchez, 2024). Rice hull ash production is equivalent to the extraction of silica minerals from the ground as a raw material for a variety of products. (Kalapathy et al., 2000)

With a total area of 30 million hectares, of which 47% is used for agriculture, the Philippines is primarily an agricultural country. Thirteen million hectares are allotted to crops, which are divided between food crops, non-food crops, and food grains. Rice, coconuts, and sugarcane are the three main crops that provide the most biomass energy resources. In the Philippines, bagasse, rice hull, rice straw, and coconut hull and shell are the most frequent agricultural wastes (Kharwar et al., 2026). Because rice is grown in one-third of the nation's agricultural area and vast amounts of rice straw and hulls are produced as a result, the country has much potential for biomass power plants (Hiloidhari & Baruah, 2011).

Rice also generates much solid waste. Aside from rice straw, the second significant waste product from rice production is rice hull, a byproduct of the rice milling industry. The country produces approximately 2 million tons of rice hulls annually. The rice hull, which accounts for 20 to 22 percent of the grain weight, serves as a coating for the rice plant's seeds. The hull is comprised of rigid materials to protect the seed while it grows. Humans are unable to digest rice hulls because they are so hard. Rice hulls are classified as waste and are often discarded in open fields, waterways, or burned in landfills (Moraes et al., 2014).

The significance of this study stems from its potential impact on cookstove design and construction by incorporating rice hulls. This study proposes a potential approach to reducing dependency on sand. This resource is becoming increasingly scarce and environmentally damaging due to its extraction practices. By examining the viability of rice hulls as an alternative to sand in the construction of a cookstove, we aim to address this issue. Using rice hulls in cookstove construction provides an opportunity to repurpose agricultural waste, addressing both environmental issues and socioeconomic challenges by adding value to a widely available byproduct.

Furthermore, the study is significant because of its implications for sustainable development. Cookstoves are essential in millions of households worldwide, particularly in areas with low incomes and limited access to clean cooking fuels. Lastly, the widespread adoption of this eco-friendly cookstove has the potential to improve the lives of millions of people by promoting environmental sustainability and economic resilience in communities worldwide.

Several studies have highlighted the potential value of rice hulls due to their unique properties. They contain high organic carbon and amorphous silica, making them useful as insulating materials, additives in construction, and sources of renewable silica for industrial applications (Kalapathy et al., 2000). In the Philippines, where rice production is extensive, the availability of rice hull waste provides an opportunity to convert this byproduct into practical applications. Research has demonstrated that rice hulls can be incorporated into construction materials, thereby reducing dependence on natural resources such as sand and cement, while mitigating the environmental hazards associated with improper disposal (Moraes et al., 2014).

Despite existing literature, limited attention has been given to the direct use of rice hulls in household technologies, particularly cookstoves, which are vital for daily food preparation. Traditional cookstoves in rural communities remain inefficient, consuming large amounts of fuel and producing harmful emissions that pose environmental and health risks (Khan et al., 2012). Improved cookstove designs that integrate alternative materials have been developed in particular contexts; however, the potential of rice hulls as a partial substitute for sand in cookstove construction remains underexplored.

The scientific novelty of this study lies in evaluating the acceptability of rice hulls as a sustainable substitute for sand in the fabrication of cookstoves. By incorporating rice hulls, this research introduces an innovative approach to reducing reliance on finite natural resources while addressing the dual challenges of waste management and sustainable household energy.

Therefore, this study aims to assess the acceptability of rice hulls in cookstove production in terms of usability, durability, and appearance, and to determine whether significant differences exist in cookstove quality when varying proportions of rice hulls and cement are used.

METHOD

The study employed a descriptive-experimental research design to evaluate the acceptability of rice (Oryza sativa) hull as an alternative to sand in the production of cookstoves, specifically in terms of usability, durability, and appearance. The descriptive component provided an overview of the level of acceptability. At the same time, the experimental method identified the most effective treatment combination of rice hull and cement that yielded the highest evaluation ratings. The participants' responses served as the primary basis for data analysis.

The respondents consisted of thirty (30) selected household representatives from the municipality of Peñarrubia, Abra. These included ten (10) respondents each from Barangay Dumayco, Barangay Poblacion, and Barangay Patiao. Prior to conducting the study, permission was obtained from the Dean and Chairperson of the College of Teacher Education. Upon approval, the researchers distributed score sheets to the selected respondents, who evaluated the cookstoves. The completed instruments were manually reviewed, tallied, and analyzed with the assistance of the adviser and statistician.

The instrument used was a score sheet of sensory evaluation adopted from (Cacciante et al., 2025). It applied a 5-point numerical scale to measure acceptability across the parameters of usability, durability, and appearance. Weighted mean was employed to determine the performance of cookstoves in varying proportions of rice hull and cement. A one-way analysis of variance (ANOVA) was used to test for significant differences among treatments, and a post hoc test was conducted to identify specific variations between treatments when the ANOVA results were significant.

For the experimental phase, rice hulls collected from Peñarrubia, Abra, Philippines, were carbonized and combined with Portland cement in varying ratios: Treatment 1 (100% cement with 5 kg rice hull), Treatment 2 (75% cement with 5 kg rice hull), and Treatment 3 (50% cement with 5.7 kg rice hull). The mixture was prepared by combining cement, carbonized rice hull, and water using a shovel. Used oil was applied to the pail mold, followed by the placement of rectangular styrofoam inside. The mixture was poured into the pail mold, with steel bars and tie wires inserted to reinforce the structure. A smaller 4-liter pail was positioned at the center to form the combustion chamber. Excess mixture was added to level the surface, and four stands were shaped on top. The cookstoves were dried under sunlight for two hours before removing the mold, then cured for seven days on a flat surface.

RESULT AND DISCUSSION

This part focuses on the presentation, analysis, and interpretation of data gathered at Poblacion, Patiao, and Dumayco Peñarrubia, Abra. The results were presented in tabular and textual form.

Problem 1: What is the level of acceptability of Rice Hull as an alternative sand in making cookstoves?

Table 1. Level of Acceptability of the Rice Hull as an Alternative Sand in Making Cookstoves

Product Indicator	Treatment 1 5 kg cement– 11.5kg rice hull 100%		Treatment 2 5 kg cement- 8.6kg rice hull 75%		Treatment 3 5 kg cement- 5.7 kg rice hull 50%	
	X	DR	X	DR	X	DR
Durability	3.42	HLA	3.66	HLA	4.69	VHLA
Appearance	3.13	MLA	3.50	HLA	4.71	VHLA
As a whole	3.00	MLA	3.55	HLA	4.85	VHLA
Durability	**3.22**	**MLA**	**3.57**	**HLA**	**4.73**	**VHLA**

It can be gleaned from Table 1 that Treatment 3, which combined 5 kg of cement and 5.7 kg of rice (Oryza sativa) hull, achieved the highest overall evaluation among all treatments, with a mean rating of 4.73. This score falls within the boundaries of a "Very High Level of Acceptance," indicating that the evaluators strongly recognized and approved the qualities of the cookstove produced under this treatment. The findings suggest that the expected performance requirements of usability, durability, and appearance were successfully met. Respondents further emphasized that cookstoves under Treatment 3 remained durable even after repeated use for cooking and boiling water, as they did not crack easily compared to those made under Treatment 1 and Treatment 2.

Treatment 2, composed of 5 kg of cement and 8.6 kg of rice hull, obtained a total mean rating of 3.57, which corresponds to a "High Level of Acceptance." Respondents noted that this treatment produced relatively durable and usable cookstoves, but minor issues, such as surface appearance, limited their higher evaluation. On the other hand, Treatment 1, which used 5 kg of cement and 11.5 kg of rice hull, recorded the lowest computed mean rating of 3.22, interpreted as a "Moderate Level of Acceptance." Appearance emerged as its weakest aspect, with a mean rating of 3.00, indicating that the excessive rice hull content negatively impacted the structural and aesthetic qualities of the cookstove.

These findings align with (Miah et al., 2009) emphasis that cookstoves utilizing biomass should be designed to maximize thermal and combustion efficiency while minimizing health risks. Improved cookstove technologies, such as those incorporating rice hulls, therefore have the potential to reduce environmental impacts, enhance energy efficiency, and provide safer, more sustainable cooking alternatives.

Problem 2. Are there significant differences in the level of qualities of the cookstove in different proportions of rice (Oryza sativa) hull and cement when grouped according to treatment?

Table 2. ANOVA Summary Table on the differences in the Mean Scores of the Respondents as their Acceptability to the Rice (Oryza sativa) hull as an Alternative Sand in making a Cookstove when Grouped according to Treatment.

Qualities	F-Computed Value	F-Critical Value	F-Probability Value	Decision
Usability	171.081**	3.097	2.17E-31	Significant
Durability	111.044**	3.097	4.99E-25	Significant
Appearance	152.622**	3.097	1.21E-29	Significant
Total	**283. 541****	**3.097**	**1.41E-39**	**Significant**

*Legend: ** - 0.01 level of significance*

The table above shows that the quality of the cookstoves, in terms of usability, durability, and appearance, exhibits significant variation when grouped according to treatments, as evaluated by the respondents. Taken as a whole, the F-computed value of 283. 541, which is greater than the F-critical value of 3.097 and associated with a probability value of 141E-39, lower than the 0.01 level of significance.

The table also reveals the quality of the cookstove in terms of usability, as evidenced by the F-computed value of 171.081 and associated with a probability value of 2.17E-31, which is lower than 0.01, the level of significance. This means that it is safe to claim a significant difference along this property indicator.

For durability, this was evidenced by the F-computed value of 111. 044 and associated with a probability of 4.99E-25, which is lower than 0.01 of the level of significance. This suggests that it is reasonable to conclude that there is a considerable variation in this property indication.

For appearance, this was evidenced by the F-computed value of 152.622, which is less than the F-critical value of 3.097 and associated with a probability of 1.21E-29, which is lower than the 0.01 level of significance. This implies that it is possible to conclude that there is significant variation along this attribute indication.

Generally, significant differences existed in the scores given by the respondents for rice (Oryza sativa) hull as an alternative to sand in making cookstoves, when grouped by treatment. This was confirmed by the F-critical Value of 3.097, associated with a probability of 1.41 × 10^ (-39). This finding is significant at the 0.00 level. This implies that there is a treatment that the respondents to the study most favored.

Comparing the means of Treatment 1 and Treatment 2, a mean difference of 0.35 is not enough to conclude that one of these treatments is more favorable than the other. However, there were significant differences between Treatment 1 and Treatment 3 (mean difference = 1.51), favoring Treatment 3.

Lastly, there were significant differences between Treatment 2 and Treatment 3 (mean difference = 1.16), favoring Treatment 3. However, the mean difference alone cannot be used to determine which of these treatments is preferred. According to (Sedighi & Salarian, 2017), the energy performance of an improved cookstove is assessed and compared to that of a charcoal stove and a three-stone fire utilizing two biomass fuels: rice husk and sawdust briquettes. The performance of the cookstoves is tested using a standard water boiling test technique in three phases: cold start, hot start, and simmer. The cookstoves' energy performance is compared using ANOVA. The study found that the ICS functioned better in cold and hot beginnings than in the simmering phase.

Table 2.a. Tukey Test Showing the Significant Difference in the Level of Usability of the Rice (Oryza sativa) hull as an Alternative Sand in making Cookstoves

Treatments	T2	T3
T1	0.24*	1.27*
T2	0	1.03*

S*=0.18

In terms of overall differences in the level of usability of rice (Oryza sativa) hull as an alternative to sand in making cookstoves, the Tukey Test Table above reveals that Treatment 2 is favored over Treatment 1. In contrast, Treatment 3 is more favored than Treatment 2. Overall, Treatment 3 is significantly better than Treatments 1 and 2 when considered collectively.

The results of the comparison made in this study showed that Treatment 3 performed better than Treatment 1 (100% rice hull) and Treatment 2 (75% rice hull). This was verified by the computed mean differences of 0.24 and 1.27, respectively, where their absolute values were discovered to be higher than the 0.18 Post hoc value. This indicates that a higher Rice Hull percentage mixed in the cement is less durable. Hence, more Rice Hull is not advisable because it will make the cookstove perform poorly.

This finding is supported by previous studies, which have shown that higher rice hull content in cement mixtures decreases structural integrity due to reduced binding strength (Obi et al., 2020) Similarly, experiments conducted on biomass waste as aggregate substitutes indicate that optimal performance occurs at lower substitution ratios, as excessive organic components weaken the durability of the final product (Muthukrishnan et al., 2019). Furthermore, practical applications of rice hull ash in cement-based products demonstrate that controlled incorporation enhances sustainability without compromising usability, provided that substitution levels are carefully maintained (Thomas et al., 2021).

Table 2.b. Tukey Test Showing the Significant Difference in the Level of Durability of the Rice (Oryza sativa) Hull as an Alternative Sand in making a Cookstove

Treatments	T2	T3
T1	0.37*	1.58*
T2	0	1.21*

S*=0.273

In terms of overall differences in the durability of Rice (Oryza sativa) hull as an alternative sand for making cookstoves, the Tukey Test Table above revealed that the only significant difference was found between Treatment 1 and Treatment 3 of the cookstove.

The results of the comparison made in this study revealed that Treatment 3 showed better performance compared to Treatment 1 (100% rice hull) and Treatment 2 (75% rice hull). This was verified by the computed mean differences of 0.37 and 1.58, respectively, where their absolute values were discovered to be higher than the 0.273 Post hoc value. This indicates that a lower Rice hull percentage mixed in the cement is Durable. Hence, less Rice hull is advisable because it will enable the cookstove to meet its performance requirements.

This finding is consistent with the study by (Thomas et al., 2021), who reported that partial replacement of cement with agricultural by-products, such as rice husk ash, enhances the strength and durability of concrete when used in controlled amounts. Similarly, (Indumathi et al., 2024) emphasized that an excessive proportion of agro-waste materials tends to compromise durability and mechanical integrity. In addition, (Jittin & Bahurudeen, 2024) observed that incorporating rice husk ash at lower replacement levels improves compressive strength while maintaining durability standards.

Table 2.c. Tukey Test Showing the Significant Difference in the Level of Durability of the Rice (Oryza sativa) Hull as an Alternative Sand in making a Cookstove

Treatments	T2	T3
T1	0.23*	1.53*
T2	0	1.3*

S*=0.233

In terms of the overall differences in the appearance of Rice (Oryza sativa) hull as an alternative sand for making cookstoves, the Tukey Test Table above revealed that the only difference found was between Treatment 1 and Treatment 3 of the cookstove.

The results of the comparison made in this study revealed that Treatment 3 showed better performance compared to Treatment 1 (100% rice hull) and Treatment 2 (75% rice hull). This was verified by the computed mean differences of 0.23 and 1.53, respectively, where their absolute values were discovered to be higher than the 0.233 Post hoc value. This indicates that Treatment 1 with 0.23 is significantly different from Treatment 3 with 1.53, implying that the use of Rice hull was in a different proportion.

These findings corroborate the studies of (Ben & Olubambi, 2024), who emphasized that rice husk-based materials, when mixed in proper proportions, enhance both structural and aesthetic properties of fabricated products. Similarly, (Chao-Lung et al., 2011) found that varying proportions of agro-waste materials influence the texture, strength, and overall appearance of composite products, aligning with the current study's result that a balanced proportion yields better quality. Furthermore, (Hu et al., 2020) highlight that optimal utilization of rice husk ash in construction materials contributes to improved finish and durability, validating that Treatment 3's proportion was more effective in producing a better appearance.

This research demonstrates that using rice husks (Oryza sativa) as a substitute for sand in household cooking stove production offers significant social benefits. Firstly, the very high user acceptance rate observed for the optimized composition (Treatment 3) reflects the community's readiness to adopt innovative, environmentally friendly technology. This is important because social acceptance is a key factor for the successful implementation of new technology, especially in rural communities where access to conventional resources may be limited. Thus, these results support the development of technical solutions that take into account local social and cultural aspects.

Beyond social aspects, this study clearly emphasizes its important contribution to environmental sustainability. The use of rice husks as an alternative material reduces agricultural waste that is typically burned and causes air pollution, while also decreasing dependence on sand as a building material, whose sources are increasingly depleted.

Consequently, this innovation not only offers a more affordable and easily accessible economic alternative for the community but also collectively supports environmental responsibility. The integration of social and environmental values reflects a sustainable development model oriented toward community welfare and the conservation of natural resources.

Finally, the use of rice husks in the production of cooking stoves directly improves the community's quality of life. Durable, efficient stoves can reduce reliance on traditional fossil fuels and potentially lower health risks from smoke pollution. This is particularly relevant for areas with high poverty levels and limited healthcare access, where simple, affordable technology can improve household well-being. Therefore, the findings of this study provide a strong scientific basis for policymaking that supports the adoption of green technology while sustainably empowering the local economy.

This research contributes significantly to society by introducing a sustainable and socially acceptable alternative material—rice husks—to replace sand in household cooking stove production. The high user acceptance rate indicates that the community is ready and willing to adopt innovative, environmentally friendly technologies. This readiness is crucial, especially in rural areas, where conventional resources are limited, ensuring that such innovations can be successfully implemented and benefit local populations.

Environmentally, the research helps reduce air pollution caused by the common practice of burning agricultural waste, thereby improving the quality of life. Economically, it offers an affordable, accessible material option that eases household financial burdens and supports local economic empowerment. The use of durable, efficient cooking stoves also reduces reliance on traditional fossil fuels, thereby lowering the health risks associated with smoke pollution.

Overall, this study supports sustainable development by combining social acceptance, environmental conservation, and economic practicality. It encourages policymakers to consider and promote green technologies that empower communities while responsibly managing natural resources. Such integration fosters improvements in welfare and a healthier living environment for society.

CONSLUSION

The findings of this study reveal that rice (Oryza sativa) hull is a highly acceptable alternative to sand in making cookstoves, with Treatment 3 emerging as the most preferred design due to its superior usability, durability, and appearance compared to Treatments 1 and 2. Statistical analysis confirmed that significant differences exist among the treatments, thereby validating the research hypothesis that varying proportions of rice hull influence the cookstove's overall performance. The study highlights the potential of carbonized rice hull as a sustainable and practical material for producing efficient cookstoves, supporting both functionality and environmental responsibility. In light of these findings, it is recommended that rice hull be considered as an eco-friendly substitute for sand in cookstove production to promote waste utilization and environmental conservation. Furthermore, carbonized rice hull should be optimized in cookstove development to enhance usability and durability. Future researchers are encouraged to build upon this study by exploring other innovative variables and material combinations to improve cookstove performance further and broaden the application of agricultural by-products in sustainable technologies.

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