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Evaluation of Coefficient of Static Friction on Two Varieties of Paddy Rice at Various Moisture Contents

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Abstract

The study investigates the coefficient of static friction for two varieties of paddy rice, Jamila and Sipi, at different moisture content levels (12, 14, 16, and 18% d.b.). This property is essential for designing and optimizing handling, transportation, and storage systems for paddy rice. The static coefficient of friction was measured on different surfaces (plywood and glass), and the results indicated that as moisture content increased, the coefficient of static friction also increased for both varieties. This behavior is critical in determining the necessary angles for chute and hopper designs to facilitate material flow and avoid clogging.

Introduction

Paddy rice, a vital staple, is processed under various moisture conditions that influence its physical and mechanical properties. It is cultivated in many countries such as India, Thailand, Argentina, Pakistan, China, Brazil, United State of America, Nigeria, Egypt and Cambodia. China, India, Indonesia and Thailand are the main producers and exporters of rice [1] while Egypt, Nigeria, and Madagascar are the main rice producing nations in Africa [1]. One important property is the static coefficient of friction, which determines the ease with which paddy grains slide on surfaces. This property is crucial in the design of hoppers, conveyors, and storage systems. Understanding how the coefficient of friction varies with moisture content helps in optimizing the processing and handling of rice grains. It was reported that the length, width and thickness of agricultural materials are necessary in determining their sizes while the shape of agricultural materials are expressed in terms of its sphericity index [2]. It has been asserted that nearly all the engineering properties of biomaterial are dependent on moisture content; as the moisture content is being varied, this has a significant effect on the behaviour of the material with respect to each of the properties. These properties include thermal, mechanical, electrical, physical, and optical properties [3 4, 5, 6 and 7].. The objective of this study was to evaluate the coefficient of static friction of two commonly cultivated paddy rice varieties, Jamila and Sipi, in Kura, Kano State, Nigeria, under varying moisture contents, using different surface materials (plywood and glass).

MATERIALS AND METHODS

a. Sample Preparation

Two varieties of paddy rice, Jamila and Sipi, were procured from certified seed dealers in Kura Local Government Area, Kano State. The samples were cleaned manually to remove any foreign matter. The initial moisture content of the rice samples was determined using the oven drying method at 103°C for 6 hours. To achieve desired moisture levels (12, 14, 16, and 18 %), a calculated quantity of distilled water was added to the samples and allowed to equilibrate under controlled conditions.

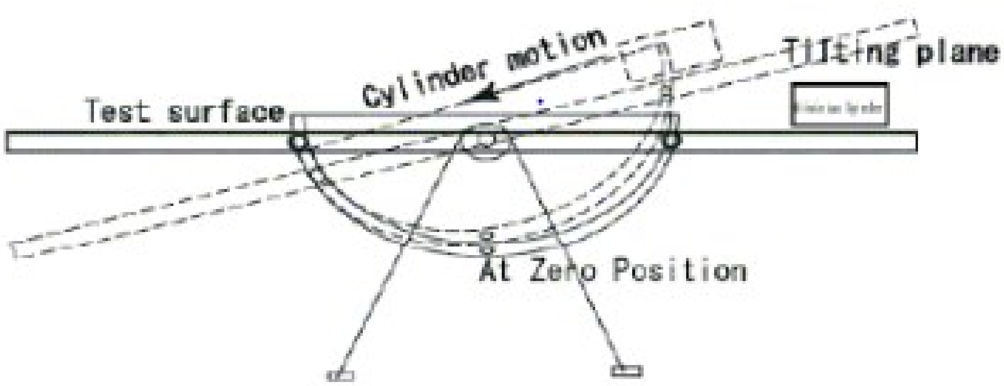

Fig. 1: Apparatus for measuring of static coefficient of friction

b. **Static Coefficient of Friction**

The static coefficient of friction was determined using a test apparatus involving plywood and glass surfaces, following the method described by scholar [8]. The samples were placed on the surfaces, and the force required to initiate motion was measured using a digital dynamometer. The coefficient of static friction (μ) was calculated using the formula:

$$\mu = \frac{F}{W}$$

Where:

μ = Static coefficient of friction

F = Force required to initiate movement, N.

W = Weight of the sample, N.

c. Research variables and method of data analysis

Five replications were performed for each combination of variety and moisture content. To perform a detailed technical analysis using ANOVA

(Analysis of Variance) in SPSS, the following key components must be taken into account:

1. **Independent Variables:**

Variety (V): Categorical variable representing the two paddy varieties (Jamila and Sipi).

Moisture Content (MC): Continuous variable with four levels (12, 14, 16, and 18 %)

Surface Type (ST): Categorical variable representing the two surfaces (Glass and Plywood).

2. **Dependent Variable:**

Static Coefficient of Friction (μ): Continuous outcome, measured for both varieties on different surfaces and at different moisture content levels.

d. Hypothesis for ANOVA

Null Hypothesis (H_0): There is no significant effect of variety, moisture content and surface type on the static coefficient of friction.

Alternative Hypothesis (H_1): There is a significant effect of variety, moisture content and surface type on the static coefficient of friction

Steps for Running ANOVA in SPSS:

e. Model Selection for statistical analysis

A factorial ANOVA was used to analyze the effects of variety, moisture content, and surface type on the static coefficient of friction. This model consist of an interaction terms between the factors and response variable.

RESULTS AND DISCUSSION

The results indicated that the static coefficient of friction for both varieties increased with rising moisture content (Table 1). At all Moisture Content levels (MC), the coefficient of friction was higher on plywood than on glass, this may be due to the smoother surface of glass compared to plywood. The Jamila variety consistently showed a higher coefficient of friction than the Sipi variety across all moisture contents and surfaces. The increase in the static coefficient of friction with moisture content can be attributed to the increased adhesion between the grain surface and the frictional surface due to the moisture layer around the grains. This observation is consistent with the findings of Jouki and Khaza (2012), who reported similar trends in the static coefficient of friction for rice grains on different surfaces.

Table 1: Static coefficient of friction at different MC

	Jamila		Sipi	
MC, %	Glass	Plywood	Glass	Plywood
12	0.3215 ±0.004	0.4350 ±0.008	0.3516 ±0.005	0.4834 ±0.006
14	0.3488 ±0.005	0.4623 ±0.004	0.4046 ±0.09	0.5032 ±0.005
16	0.3918 ±0.01	0.4781 ±0.006	0.4289 ±0.006	0.5190 ±0.006
18	0.4095 ±0.03	0.5032 ±0.006	0.4593 ±0.005	0.5349 ±0.005

Comparison by Moisture Content

At 12% d.b., the static coefficient of friction for Jamila on plywood was 0.4350, while for Sipi, it was 0.4834. At 18% d.b., these values increased to 0.5032 for Jamila and 0.5349 for Sipi. This trend demonstrates that as moisture content increases, more force is required to initiate movement, which has implications for equipment design. Machines handling paddy rice at higher moisture levels need to account for the increased resistance to flow.

Effect of paddy variety, MC and material surface type on Static coefficient of friction

In Table 1, the average static coefficient of friction at 12, 14, 16 and 18 % on glass surface for Jamila were 0.3215±0.004, 0.3488±0.005, 0.3918±0.01 and 0.4095±0.03 respectively. While an average static coefficient of friction of

0.4350 ±0.008, 0.4623 ±0.004, 0.4781 ±0.006 and 0.5032 ±0.006 were observed for plywood surface type at the same moisture contents. This shows that higher static coefficient of friction is possible in plywood than glass surface type for Jamila paddy rice. More so, Table 1 indicated that an average static coefficient of friction of 0.3516 ±0.005, 0.40 46 ±0.09, 0.4289 ±0.006 and 0.4593 ±0.005 were obtained on glass surface type from Sipi paddy rice at 12, 14, 16 and 18 % respectively. While 0.4834 ±0.006, 0.5032 ±0.005, 0.5190 ±0.006 and 0.5349 ±0.005 were observed for plywood surface at 12, 14, 16 and 18 % respectively. This is an indication that static coefficient of friction in Sipi paddy rice was higher in plywood than glass surface type. But the results revealed that between Jamila and Sipi paddy rice, plywood surface has the highest static coefficient of friction.

However, Table 2 revealed that paddy varieties and moisture content has individual significant effect on static coefficient of friction static coefficient of friction at $P < 0.05$. This reveals that the variety of a paddy rice determines the value of static coefficient of friction. This is also an indication that there is a significant different between Jamila and Sipi paddy rice static coefficient of friction. This observation was in line with the results of previous scholars [10] who revealed that the effect of grain moisture content, variety, contact surface and their interactions were significant ($p < 0.01$) on dynamic friction coefficient but they did not consider Jamila and Sipi paddy rice varieties. The surface contact type (plywood and glass) do not have a significant individual effect on static coefficient of friction at $P < 0.05$ as showed in Table 2. Surface Type shows borderline significance ($p = 0.055$), suggesting a slight difference in friction between glass and plywood, though it may not be statistically conclusive in this case. But surface type combined with moisture content has significant effect on static coefficient of friction at $P < 0.05$ as indicated in Table 2. The interaction between variety and moisture content is significant ($p = 0.0041$), suggesting that the effect of moisture content on friction depends on the variety.

Table 2: **paddy variety, MC and material surface type on Static coefficient of friction**

Source of Variation	Sum of Squares	df	Mean Square	F	p-value
Variety	1166.76	1	1166.76	455.63	<0.001*
Moisture Content	455.63	3	151.88	38.77	<0.001*
Surface Type	39.26	1	39.26	0.67	0.055
Variety * Moisture Content	8.18	3	2.73	4.56	0.0041*
Variety * Surface Type	0.67	3	0.67	0.67	0.078
Moisture Content * Surface Type	455.63	3	151.88	38.77	<0.001*
Error	2.62		—	—	—

*Significant at $P < 0.05$

CONCLUSIONS

In this research study, it may be concluded that;

1. The static coefficient of friction of paddy rice is significantly influenced by moisture content and varieties of paddy rice.
2. The Sipi paddy variety exhibited a higher coefficient of friction compared to the Jamila variety, and plywood surfaces showed higher friction values than glass.
3. The findings have practical applications in the design of rice processing and storage equipment, emphasizing the need for careful consideration of moisture content to optimize flow and reduce energy consumption in handling systems.

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Material Recovery and Sustainability in Practice Using Ionic Liquid

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Keywords: Ionic liquid, recycling, reuse, recovery, sustainability.

Abstract

Material recovery is essential to sustainable development and has gained attention over the years. This study investigates the use of 1-butyl-3-methylimidazolium chloride ionic liquid (butylMIMCl-IL) as a mechanism for the recovery of hydrocarbons from simulated contaminated soil. The methodology used in this study are literature review and experimental research to determine the recovery potential of the selected ionic liquids and the adaptability of material recovery mechanisms to businesses to adapt the reusable option to their operation. The findings revealed that the butylMIMCl-IL recovered the target contaminants successfully from the mixture. The study concluded that the adaptability of novel solvents will require a cost-benefit analysis to determine the best approach at what stage of operations the management will need strategic planning to adopt a reuse option.

Introduction

Sustainable development is a lasting solution to environmental impacts. Failure to resolve the usage of natural resources can deplete the resource base. Thus, this emphasises the need to set up structures that can aid the accomplishment of the goal of sustainable use. This requires orientation to technological developments in implementing a mechanism that is beneficial socially, economically and environmentally, and sustained (Tatiya, 2011). Over-extraction and resource exploitation of raw materials can lead to poor sustainability performance hence waste management policies help sectors to meet their environmental responsibilities (National Environmental Commission, 2011).

Waste Reduction and Environmental Management

Techniques for waste management, reducing pollution and consumption of natural resources tend to be very specific in nature. These wastes can be transformed into inputs where they are broken down into harmless substances. Waste minimisation comprises disposal with recovery, which is a life-cycle approach. The disposal of waste without treatment or recovery can lead to enormous negative effects on the environment, especially if such waste contains toxic components. Toxics can be ategorized into different groups such as the known and latent. The known group comprises pollutants considered tentatively problematic and are enlisted by regulation, requiring further actions to either prioritise or include them in a watchlist. While the latent comprises wastes yet to be established as toxic due to limited information or studies to justify their long-term effects. In all this, the challenge is how companies can track the hazardous components of their materials, correctly capture their volume and communicate to the regulatory bodies overseeing the management process (Antweiler, 2014).

Adapting to Material Recovery Options

At every level of the life cycle of a product, industries and regulatory agencies are faced with the challenge of how to protect the environmental and social resources at a cost. The regulatory capacity and the established infrastructure to help corporate organizations protect the environment will foster monitoring and compliance. To adapt to material recovery, many industries will require equipment modification to achieve a reduction in waste or reuse, thus this may require new capital investments. Hence, a broad range of possible options for companies to adapt to reuse options that are practicable and economically viable, though desirable will require adequate planning and funding (Hardisty, 2010).

Cost Recovery through Recycling

The recycling of materials can employ the local people. Improving corporate policies and integrating community expectations during environmental management can facilitate sustainable development, especially in developing countries (Barrow, 1999). A cost-benefit analysis of adapting novel innovations that foster reuse or recycling is critical for large-scale infrastructure and requires strategic planning (Petts, 1999). Despite the cost, the environmental sustainability of business operations can be improved and with a series of experimental efforts, the effect of different stages of operations that emit pollutants can be put under control (Aland & Banhazi, 2013).

Recovery Process Using Ionic Liquids

Ionic liquids are molten salts used mainly for extraction, and it’s considered as a solution for recovering and separating hazardous components from a mixed waste stream, for recycling (Inman et al., 2022). The reliability of sustainable principles is at the heart of most business operations as technical and environmental performances are priorities in innovative practices (Christensen & Panoutsou, 2022) and compliance to emission standards across the life cycle of operations (Panoutsou et al., 2020). Recovery and recycling technologies are vital in the removal of organic pollutants from a one-phase or multiple-phase mixture (Khoo et al., 2024).

MATERIALS AND METHOD

To synthesis the butylMIMCl ionic liquid, the reagents, 1-methylimidazole (5.0 g, 0.06mol) and 1-chlorobutane (7.5 g, 0.08 mol) were mixed and heated by microwave for a total duration of 3min 20s at 50, 30, 20, 40, 60-sec intervals at 40, 60, 20,20, 20 % microwave power, respectively. This heating pattern was repeated two more times before washing the reaction mixture (25 mL×5) with ethyl acetate to remove any unreacted starting material. Residual ether was evaporated *in vacuo* and the IL was isolated as a viscous pale yellow liquid in 73% yield.

To test the synthesised ionic liquid for material extraction, treated drill cuttings were obtained from the outlet of a thermal desorption unit of waste management contractors in Port Harcourt Nigeria. Reagents for analysis were purchased from Fisher Scientific UK. To 1g of treated drill cuttings was added 2g separately of the butylMIMCl ionic liquid left for 6 hours without applying heat. A two-phase separation of oil from the cutting residue was observed with clear clean cutting at the base of the conical flask. It was observed that the butylMIMCl ionic liquid separated the oils on the contaminated soil (drill cuttings) in a very clear liquid. The Fourier transform infrared spectroscopy (FTIR) method was adopted to characterise and interpret the reaction.

RESULT

The comparative FTIR for the butylMIMCl ionic liquid and the mixture containing the oil-contaminated soils in **Figure 1** show differences in the peak profile (as circled) around the high wave number regions (3200-3500cm^{-1} and 2800-3100cm^{-1}), and double bond region (1900-2200cm^{-1}) suggesting that some organic contaminant from the oil drill cutting has been extracted into the ionic liquid.

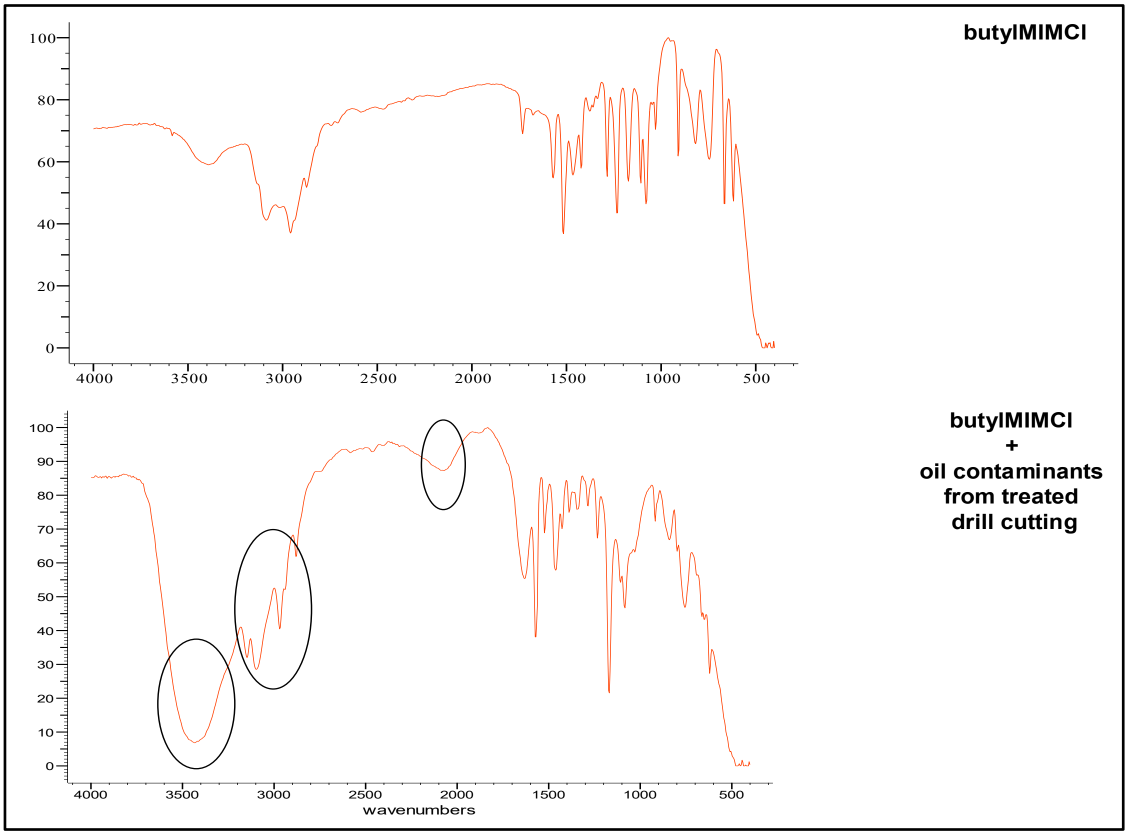

Figure 1: Comparative FTIRs for butylMIMCl and butylMIMCl – treated drill cutting

DISCUSSION

The filtration method is of significance in the recycling of ionic liquids from a mixture. The ionic liquid used in this study, butylMIMCl ionic liquid has been successfully used in other studies, and the membrane filtration method of extraction has been very effective in recovering the target material (Wang et al., 2016). The use of ionic liquid in the extraction of hydrocarbon mixtures is not new (Yu et al., 2024). In this study, the ionic liquid is utilised as a potential green solvent for the management of oily wastes. The scope of ionic liquids as a means of removing contaminated organic materials from soils is an extensive study that requires further investigation with a series of trials to determine the procedures for extraction and protocol for removal.

CONCLUSION

This study highlights the importance of conserving natural resources by adopting sustainable reuse options and mechanisms to reduce the exploitation of natural resources and improve sustainability performance. The novel use of molten salts like ionic liquid is a viable option to address latent toxic components of waste and to protect environmental and social resources. Though this might be difficult due to the cost implication, established protocols such as the membrane filtration method can be easily adapted to recover target materials from complex mixtures for recycling.

RECOMMENDATION

Organic materials can be toxic to the environment. The study recommends improving the separation techniques for oily wastes so that extraction of these organics can become a norm in sustainability practices.

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