Scientific Contributions Oil & Gas, Vol. 48. No. 4, December: 377 - 390

SCIENTIFIC CONTRIBUTIONS OIL AND GAS

Testing Center for Oil and Gas
LEMIGAS

Journal Homepage:http://www.journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

# Valorization of Tropical Agricultural Waste Into Sustainable Additives for Water-Based Drilling Mud: A Case Study of Orange Peel and Durian Rind

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Manuscript received: October 27th, 2025; Revised: November 17th, 2025
Approved: December 08th, 2025; Available online: December 30th, 2025; Published: December 30th, 2025.

**ABSTRACT** - This study explores the potential of orange peel powder (OPP) and durian rind powder (DRP) as biodegradable additives in water-based drilling mud. These agricultural wastes are processed into fine powders (<45 μm) and are characterized using FTIR, XRD, and SEM to determine their chemical functionality, crystallinity, and morphology. Both additives are incorporated into the base mud at concentrations of 2-8 g per 350 mL, and their rheological and filtration properties are evaluated. Due to its hydrophilic polymer content and microstructure, OPP significantly enhances apparent viscosity, yield point, and gel strength. DRP demonstrates superior performance in filtration control, reducing fluid loss by up to 40.3% and filter cake permeability by 60.2%. Visual and quantitative observations confirm that both additives improve the compactness of the filter cake and sealing efficiency. These results highlight the potential of OPP and DRP as eco-friendly, cost-effective alternatives to conventional chemical additives, supporting waste valorization and sustainable drilling operations.

**Keywords:** drilling mud, biodegradable additive, orange peel, durian rind, fluid loss control, water-based mud



**How to cite this article:**

Le Nguyen Hai Nam, Ly Trung Hieu, Dinh Phuoc Hau2025, Valorization of Tropical Agricultural Waste Into Sustainable Additives for Water-Based Drilling Mud: A Case Study of Orange Peel and Durian Rind, Scientific Contributions Oil and Gas, 48 (4) pp. 377 - 390. DOI org/10.29017/scog.v48i4.1948.

## INTRODUCTION

The increasing global demand for energy has accelerated drilling activities, raising environmental concerns, particularly thóe related to drilling waste generation and disposal. Drilling fluids are essential for efficient and safe drilling operations. They perform several key functions, including reducing friction, cooling the drill bit, facilitating the transport of cuttings to the surface, regulating downhole pressure, and preserving the structural integrity of the wellbore (Wu et al., 2025) (Zhu & Zheng 2021). Drilling muds are typically classified as either water-based muds (WBMs) or oil-based muds (OBMs) (Mahmoud et al., 2024) .WBMs are most commonly used because they are more economical and present fewer environmental risks (Parate 2021).

However, WBMs often rely on chemical additives and synthetic fluid loss control agents. These compounds pose environmental risks and are increasingly subject to regulatory examination. Consequently, there is growing interest in the development of sustainable, biodegradable, and eco -friendly additives derived from agricultural and industrial waste materials (Afdhol et al., 2024; Idress & Hasan, 2020).

Agricultural biomass waste, abundant, inexpensive, and rich in cellulose and lignin, has shown potential as a renewable source of drilling fluid additives. These materials can act as fluid loss control agents by forming mechanically interlocked fiber networks and bridging structures in porous formations, thereby reducing filtrate invasion and improving filter cake quality (Idress & Hasan 2020) (Ikram et al., 2024) (Hallett et al., 2024). Additionally, they can enhance rheological properties such as viscosity, yield point, and gel strength, which are critical for effective cuttings transport and suspension (Ikram et al., n.d.; Qiao et al., 2021).

Recent studies have explored a range of biodegradable additives, including natural rubber latex, rice husk ash, grass powder, mandarin peel, rambutan seed, wild jujube pit, watermelon rind, and coffee ground waste (Al-Hameedi et al., 2020) (Al-hameedi et al., 2019; Al-Hameedi et al., 2020; Madu et al., 2024a; Zhou et al., 2021) (Madu et al., 2024b; Suhascaryo & Dhaffa, 2024). These materials have demonstrated performance improvements in reducing API fluid loss (up to 64%), thinning mud cakes, and enhancing viscosity and thermal stability. Some, such as coffee ground waste, showed dual benefits: improving both rheological and filtration properties, while others, like watermelon rind, were more effective in filtration control alone (Madu et al., 2024b) (Medved et al., 2022) (Fato & Rahmani 2024).

Among these, fruit peels have emerged as promising candidates due to their high content of cellulose, hemicellulose, lignin, and pectin, which are beneficial for viscosity control and filter cake formation. Despite progress, limited studies have been conducted on orange peel and durian rind waste.

Durian, a major agricultural product in Southeast Asia, generated substantial biomass waste. Vietnam alone produced over 1.2 million tons of durian in 2023. Durian rind, often discarded, contains approximately 31-35% cellulose and 10-11% lignin (Madu et al., 2024b). Similarly, orange peel accounts for 50-60% of the fruit's weight during juice processing, leading to over 500 million tons of global waste annually. In Vietnam, orange peel waste is estimated to be 1 million tons annually (Tu et al., 2025). These by-products are underutilized yet highly rich in functional biopolymers, particularly pectin and cellulose, which enhance rheological behavior and filtration control when incorporated into WBMs (Bigi et al., 2023).

This study investigated the use of orange peel powder (OPP) and durian rind powder (DRP) as biodegradable additives to improve the filtration and rheological properties of WBMs. FTIR, XRD, and SEM analyses were performed to characterize the raw biomass powders in terms of functional groups, crystalline structure, and morphology.

## METHODOLOGY

### Material

Agricultural waste materials, specifically orange peels and durian rinds, were collected from a local fruit market in Ho Chi Minh City, Vietnam. API-grade bentonite was supplied by the Drilling Mud Company (DMC), Vung Tau City, Vietnam. Xanthan gum was purchased from Xinlong

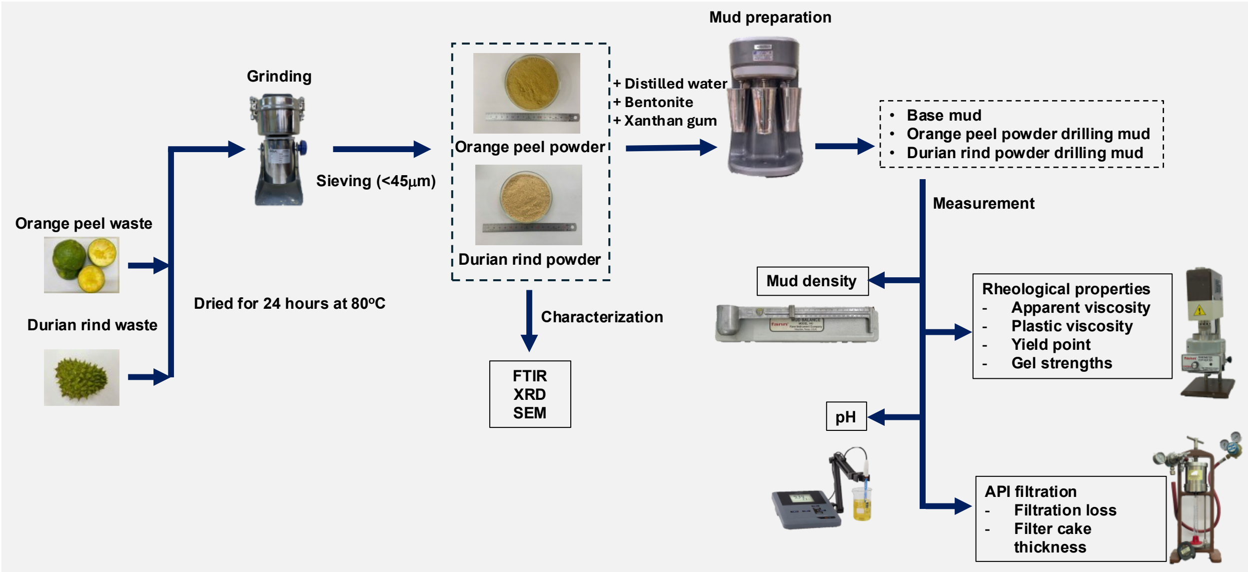


Figure 1. Preparation and experimental procedure for formulating water-based drilling mud using orange peel and durian rind powders.

Company, China, and distilled water was used to prepare all drilling mud samples.

## Preparation of agricultural biomass

The preparation process of agricultural biomass additives involved several steps, as illustrated in Figure 1. Orange peel and durian rind wastes were collected from a local fruit store, thoroughly washed to remove impurities, and oven-dried at 80 °C for 24 hours to eliminate moisture. The dried materials were then ground using a high-speed grinder and sieved to obtain fine powders with particle sizes smaller than 45 μm.

## Characterization of biomass additives

The obtained OPP and DRP were analyzed through multiple characterization techniques. Fourier-transform infrared (FTIR) spectroscopy was employed to identify the functional groups present in the biomass materials, while X-ray diffraction (XRD) was used to assess their crystallinity. The microstructural features of the powders were further examined using scanning electron microscopy (SEM). Following characterization, both additives were incorporated into base drilling mud formulations to investigate their influence on rheological behavior and filtration properties. FTIR analysis was performed using a Shimadzu FT/IR-6X1 typeA spectrometer (Kyoto, Japan) to identify functional groups. Spectra were recorded in the range of 4000-500 cm-1 using a resolution of 2 cm-1. XRD patterns were obtained using a Bruker D8 ADVANCE diffractometer. The instrument operated with Cu Ka radiation (l = 1.5418 Å) under standard conditions. Additionally, surface morphology was evaluated by using a scanning electron microscope (SEM-FE S4800 Hitachi).

## Drilling mud formulation

Base mud was prepared in accordance with API standards by mixing 350mL of distilled water, 20 g of bentonite, and 0.2 g of xanthan gum. The additives were gradually introduced into the water under continuous mixing, and the mixture was homogenized for 30 minutes using a Hamilton Beach high-speed mixer.

OPP and DRP were added separately into the base mud at concentrations of 2g, 4g, 6g, and 8g per 350mL of fluid. Each additive-containing mud sample was blended for 10 minutes using the same mixer. All samples were aged for 24 hours at laboratory temperature to ensure complete hydration.

## Density and pH measurement

Mud density was determined with a FANN mud balance, and the pH of each sample was measured using a Model 7117 digital pH meter.

### Rheological measurements

Rheological testing was conducted following API Recommended Practice 13B-1 (American Petroleum Institute, 2017) using an 8-speed OFITE rotational viscometer. Each sample was stirred at 900 rpm for 10 seconds to ensure uniformity and thermal equilibrium. Dial readings were recorded at 600 and 300 rpm, as well as at 200, 100, 60, 30, 6, and 3 rpm, for rheological modeling. All measurements were performed at 25, 50, and 75 oC, using a FANN heating cup to simulate downhole temperature conditions. The following parameters were calculated:

$$\text{Apparent viscosity (AV - cp)} = \theta_{600}/2 \tag{1}$$

$$\text{Plastic viscosity (PV - cp)} = \theta_{600} - \theta_{300} \tag{2}$$

$$\text{Yield point (YP – lb/100ft}^2\text{)} = \theta_{300} - \text{PV} \tag{3}$$

where 600 and 300 represent the viscometer readings at 600 and 300 rpm, respectively

To determine gel strength, each mud sample was first stirred at the highest speed for 10 seconds. The viscometer was then switched to “GEL” mode and turned off. Once the rotor sleeve stopped rotating, the fluid was allowed to remain static for 10 seconds, and the maximum dial reading at 3 rpm was taken as the 10-second gel strength. For the 10 -minute gel strength measurement, the mud was stirred again and left at rest for 10 minutes before the peak 3 rpm dial reading was recorded.

### Filtration test

The filtration performance was assessed using an OFITE Series 300 LPLT filter press, in accordance with API procedure (American Petroleum Institute, 2017). A measured volume of mud was poured into the filter press chamber, and a constant pressure of 100 psi was applied using a CO2 cartridge. The filtrate volume was collected in a graduated cylinder over 30 minutes at ambient temperature. The thickness of the filter cake deposited on the filter paper was measured in millimeters (mm) using a caliper.

To evaluate the effectiveness of the additives in reducing fluid loss and enhancing filter cake compactness, the filter cake permeability (k) was calculated based on Darcy’s law. The permeability of the filter cake was computed using the following equation:

$$k = \frac{q\mu L}{\Delta PA} \tag{4}$$

Where

k = filter cake permeability (cm2)

q = filtrate flow rate (cm3/s)

m = viscosity of the filtrate (cP)

L = filter cake thickness (cm)

DP = applied differential pressure (Pa)

A = filtration area (cm2)

The percentage reduction in permeability (Rk) was then determined to compare the performance of modified muds relative to the base mud,

$$R_k = \left(\frac{k_{base} - k_{additive}}{k_{base}}\right) \times 100\% \tag{5}$$

Where

kbase = permeability of the filter cake formed by base mud

kadditive = permeability of the filter cake formed by additive-based mud.

## RESULT AND DISCUSSION

### Characterization of OPP and DRP

The FTIR spectrum of OPP (Figure 2a) also reveals a broad peak centered at 3264 cm-1, corresponding to the O-H stretching vibration, indicative of hydroxyl-containing compounds such as cellulose and polysaccharides (Lin et al., 2021; Teng et al., 2022). The peak observed at 2917 cm-1 is attributed to C-H stretching vibrations of aliphatic hydrocarbons.

A more negligible absorption at 2340 cm-1 corresponds to the stretching of carbonyl C=O or nitrile CºN groups, often associated with lignin components or oxidative degradation products. The band at 1602 cm-1 reflects aromatic C=C or N-H

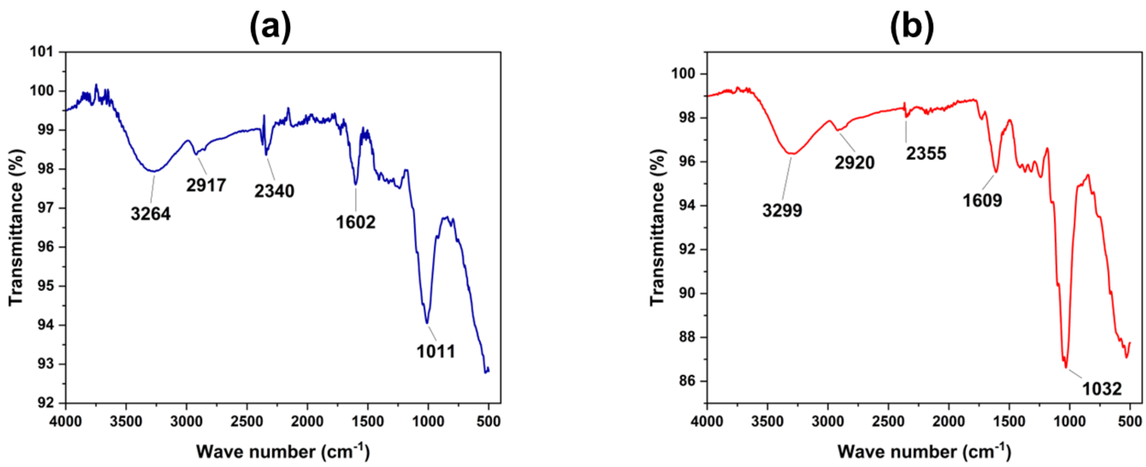


Figure 2. FTIR spectra of agricultural waste additives: (a) Orange Peel Powder (OPP) and (b) Durian Rind Powder (DRP).

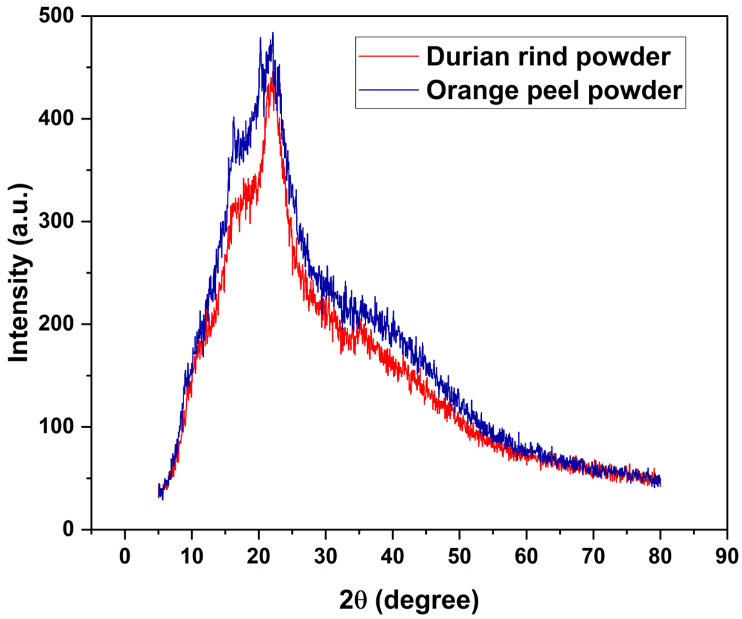


Figure 3. X-ray diffraction patterns of OPP and DRP

bending vibrations. Notably, the C-O stretching vibration at 1011 cm-1 indicates the presence of carbohydrate structures, supporting the existence of polysaccharides in OPP (Kaya et al., 2014; Nandiyanto et al., 2019).

The FTIR spectrum of DRP (Figure 2b) exhibits a broad absorption band at 3299 cm-1, attributed to the O-H stretching vibrations of hydroxyl groups, which are typically found in alcohols, phenols, and carboxylic acids. This band indicates the presence of polysaccharides and supports the high pectin content in durian rind (Zhao et al., 2023) . A sharp peak at 2920 cm-1 corresponds to C-H stretching, indicating the hydrocarbon backbone of natural polymers. The absorption at 1609 cm-1 is likely due to aromatic C=C stretching or N-H bending vibrations from amines. A strong band at 1032 cm-1 is assigned to the asymmetric C-O stretching vibration, confirming the presence of polysaccharide or cellulose structures (Teng et al., 2022).

These results indicate that DRP primarily consists of cellulose, hemicellulose, and pectin, which are hydrophilic and biodegradable. The abundance of hydroxyl and ther groups in DRP facilitates hydrogen bonding, improving biomass dispersion in water-based muds and enhancing its rheological function as an eco-friendly additive.

Both samples display a broad diffraction peak centered around 2q » 22o in Figure 3, characteristic of amorphous cellulose or hemicellulose structures (Nour et al., 2021). The results support the suitability of these agricultural biomass powders as eco-friendly, biodegradable additives in drilling fluids.

The SEM image of orange peel powder, captured at 1000x magnification in Figure 4, reveals heterogeneous plate-like microstructures with irregular edges and rough surfaces. The particles appear fragmented and layered, typical of lignocellulosic biomass materials. Numerous micropores and surface fissures are observed, which could significantly enhance hydration capacity and promote gel formation when used as an additive in drilling fluids.

The particles' disordered morphology and fibrillar surface features are consistent with those previously reported in SEM images of citrus-based biomass additives used in drilling applications (Amanullah et al., 2020; Ezeakacha 2021). The morphological traits support the ability of OPP to form a compact and low-permeability filter cake, which aids in controlling fluid loss and maintaining wellbore stability.

The SEM micrograph of durian rind powder (Figure 5) reveals irregular, layered particles with rough and fractured surfaces, characteristic of heterogeneous lignocellulosic materials. The DRP particles show thin plate-like structures with varying degrees of fragmentation and flake thickness. This morphology suggests a moderate surface area with sufficient edge surface irregularities.

The rough surfaces and layered configuration of DRP provide mechanical interlocking between particles, facilitating hydration and improving suspension capabilities and cuttings-carrying efficiency. These structural features align well with previous studies that investigated the microstructure of fibrous biomass used in drilling fluid (Chatterjee et al 2021; Purnomosidi 2024)

Compared to OPP, the DRP particles appear more compact and less porous, which may explain their slightly lower impact on apparent and plastic viscosity. However, this denser structure likely contributes to a more uniform packing within the filter cake, which helps reduce the permeability of the filter cake, as also observed in the filtration test results.

**Rheological properties**

Apparent viscosity (AV) is a key rheological parameter that reflects a fluid's resistance to flow under dynamic shear conditions. It is influenced by both fluid composition and solid content, especially the concentration and nature of additives. As shown in Figure 6, the base mud exhibited an AV of 13.5 cP. Adding OPP and DRP at concentrations of 2g to 8g per 350 mL resulted in a notable

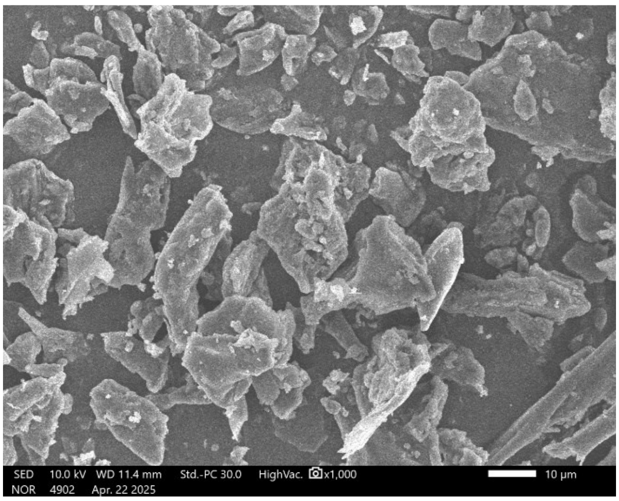


Figure 4. SEM image of OPP at 1000x magnification

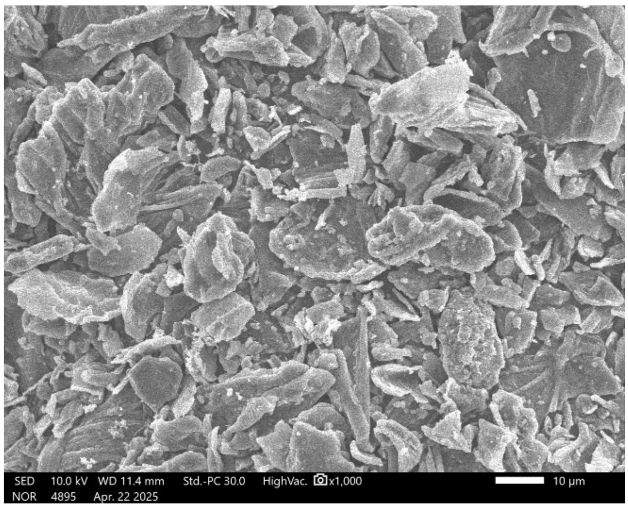


Figure 5. SEM image of DRP at 1000x magnification

increase in AV. The OPP samples exhibited a progressive increase in viscosity, reaching a maximum of 28.5 cP at 8g/350 mL, indicating a strong thickening behavior. Meanwhile, DRP added fluids displayed a more moderate increase, with AV reaching 23 cP at the same concentration. Plastic viscosity (PV) reflects the internal resistance of drilling fluids to flow due to mechanical friction between solid particles, particularly under high shear conditions. A higher PV typically indicates improved solid suspension capacity but may also affect pumpability and circulation efficiency.

As shown in Figure 7, the base mud exhibited a PV of 7 cp. The incorporation of OPP led to a significant increase in PV, reaching a peak of 18 cP at 8 g/ 350 mL. In comparison, DRP enhanced PV more moderately, with a maximum value of 13 cP at the exact dosage. Notably, OPP showed a steeper increase in AV and PV than DRP at the same concentrations. The observed PV rise is likely due to the presence of fibrous cellulose, hemicellulose, and soluble pectin in the biomass additives, which absorb water and swell.

Yield Point (YP) reflects the stress required to initiate flow in a drilling fluid and indicates the fluid's ability to transport drilled cuttings under low shear conditions. As shown in Figure 8, the addition of both OPP and DRP significantly

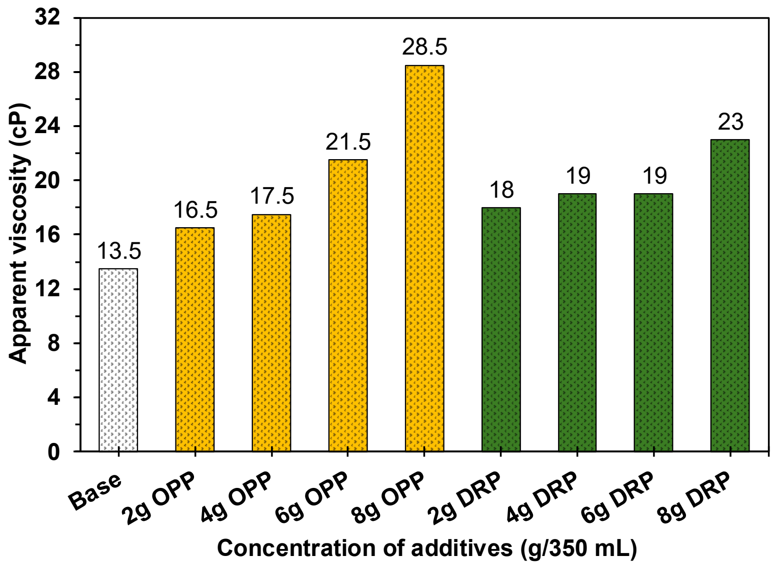


Figure 6. Effect of OPP and DRP concentaration on the apparent viscosity

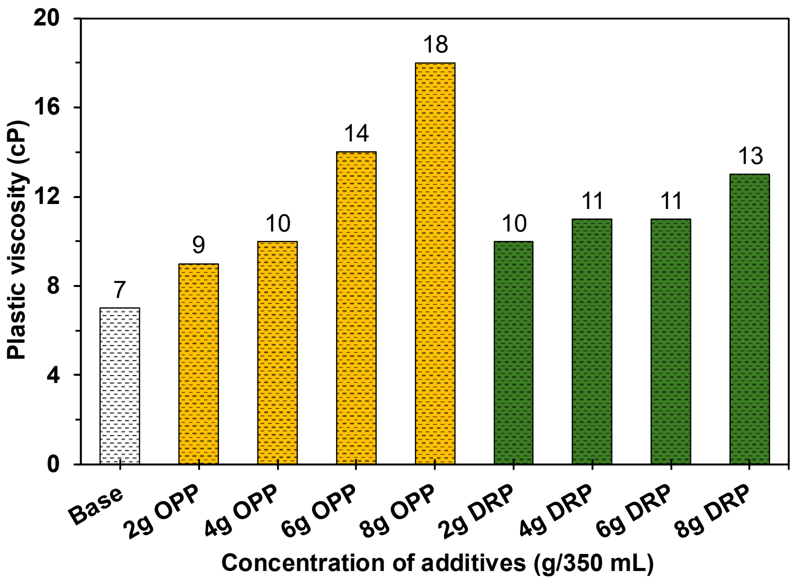


Figure 7. Effect of OPP and DRP concentration on plastic viscosity

improved the YP compared to the base fluid, which had a value of 11 lbf/100ft2. The addition of OPP led to a substantial increase in YP, reaching a maximum of 21 lbf/100ft2 at 8 g/ 350 mL. Notably, the YP remained consistently elevated at 15 lbf/100ft2 for over concentration (2-6g), indicating OPP's ability to enhance interparticle interactions and structural cohesion in the fluid even at low dosages. On the other hand, DRP also enhanced YP from 16 lbf/100ft2 at 2-6g to 20 lbf/100ft2 at 8g/ 350 mL. The gradual increase observed with DRP may be attributed to its coarser particle morphology and lower soluble fiber content compared to OPP, resulting in a slower but stable enhancement of fluid structure. The elevated YP values observed with both additives are likely due to cellulose fibers and hydrophilic biopolymers (pectin, hemicellulose), which increase solid-solid and solid-liquid interactions within the drilling fluid matrix. This leads to stronger internal networks that resist flow under low shear conditions, improving cuttings suspension and transport capacity.

Gel strength (GS) reflects the ability of a drilling fluid to suspend cuttings during non-circulating conditions by measuring the interparticle forces under static conditions. Two time intervals – 10 seconds and 10 minutes are commonly used to assess the structural evolution of the fluid. A controlled difference between short- and long-term GS is essential to prevent excessive gelation, leading to pressure surges or stuck pipe

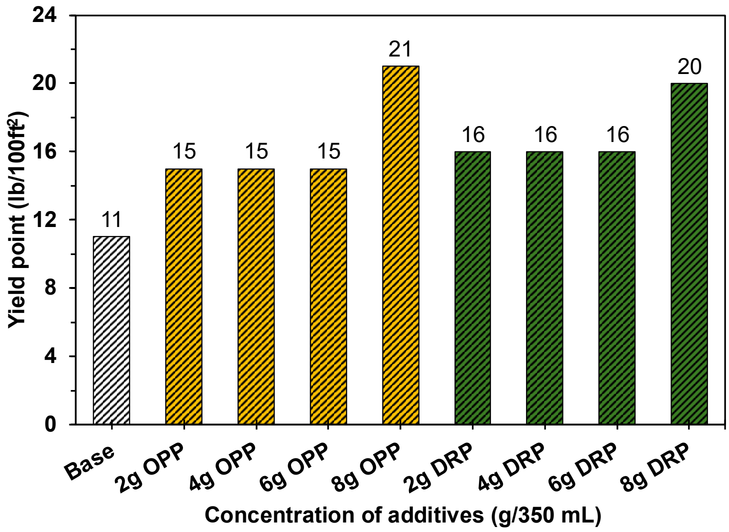


Figure 8. Effect of OPP and DRP concentration on the Yield point

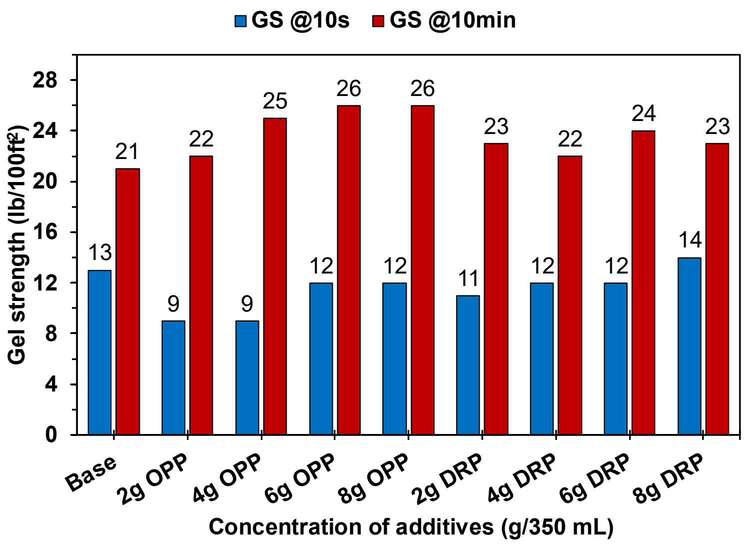


Figure 9. Effect of OPP and DRP concentration on Gel strengths

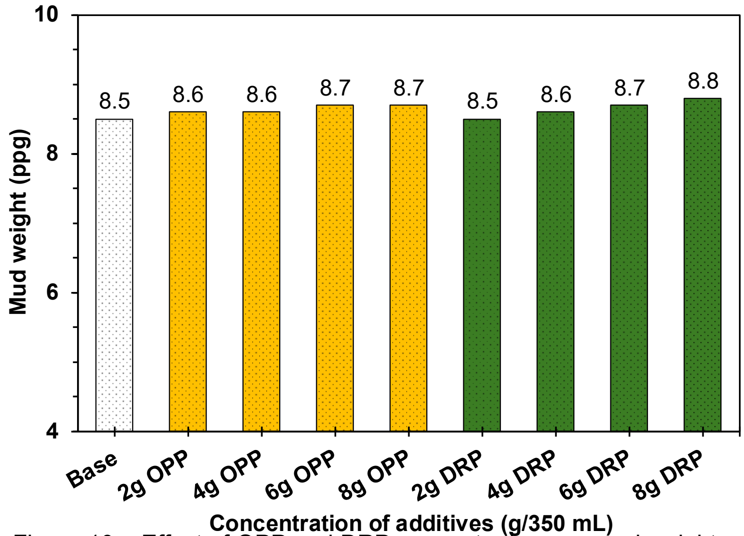


Figure 10. Effect of OPP and DRP concentrations on mud weight

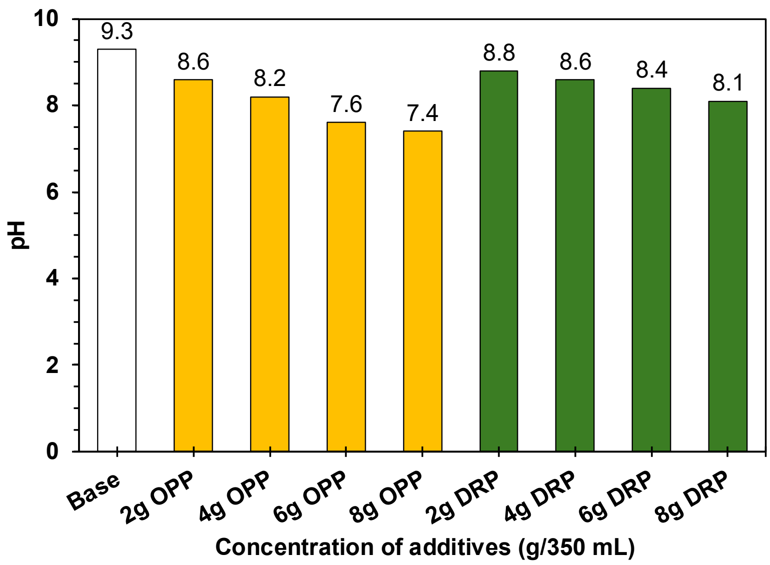


Figure 11. Effect of OPP and DRP concentration on pH value

incidents. Figure 9 illustrates the effect of OPP and DRP additives on the gel strength of WBM. The base fluid exhibited GS values of 13 lbf/100 ft² at 10 seconds and 21 lbf/100 ft² at 10 minutes, indicating a moderate gel development profile. With OPP, the 10s-GS values ranged from 9 to 12 lbf/100ft2, while the 10 min-GS increased steadily, reaching a 26 lbf/100ft2 peak at 6-8 g concentrations. This significant long-term structure build-up suggests that OPP provides robust suspension capability while maintaining initial gelation. With DRP, the fluids exhibited relatively higher initial GS values at 10 seconds (11-14 lbf/100 ft²) and stable 10-minute GS values (23-24 lbf/100 ft²). This behavior may be attributed to the larger particle morphology and more substantial flocculation potential of DRP, which promotes earlier structure formation.

## Mud weight and pH value

Figure 10 shows the effect of increasing concentrations of OPP and DRP on the mud weight of muds. The base mud exhibited a mud weight of 8.5 ppg. With the incremental addition of OPP, the mud weight increased slightly, reaching 8.7 ppg at 6g and 8g concentrations. In comparison, DRP had a slightly more pronounced effect, increasing the mud weight to 8.8 ppg at the highest dosage of 8g.

Figure 11 shows the variation in pH values for muds with increasing concentrations of OPP and DRP. The base mud exhibited a relatively high pH, indicating a strongly alkaline environment due to the natural properties of bentonite and xanthan gum. With the addition of OPP, pH gradually decreased from 8.6 (2g) to 7.4 (8g). This reduction may be attributed to the organic acids and pectin content of the orange peel. In contrast, the addition of DRP resulted in a more stable pH profile, with only a slight decrease from 8.8 to 8.1 across the tested concentration range. The slower pH decline observed with DRP suggests a lower concentration of the acidic component.

### Filtration properties

Figure 12 illustrates the variation in filtrate volume at 7.5 and 30 minutes for muds formulated with OPP at different concentrations (2-8 g per 350 mL). The base mud recorded a filtrate volume of 6.6 mL at 7.5 min and 14.4 mL at 30 min, indicating a high fluid loss rate and limited filtration control. Upon incorporation of OPP, a consistent reduction in filtrate volume was observed. At 2 g and 4g concentrations, the 30 minute fluid loss decreased to 12.6 mL and 11.8 mL, respectively – represent modest improvement, However, more substantial reductions were achieved at higher dosages: at 6 g OPP, 30-min filtrate reduced to 10.4 mL ( decreased by 27.8%), at 8g OPP, 30-min filtrate reduced to 9.2 mL (decreased by 36.1%). Notably, the filtrate volumes at 7.5 minutes plateaued at 5 mL for both 6g and 8g samples, suggesting that OPP effectively forms a low-permeability filter cake that minimizes early-stage fluid invasion.

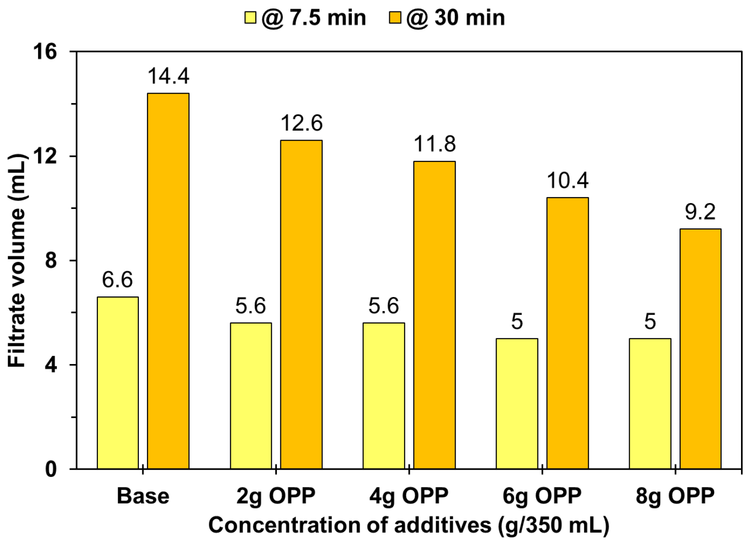


Figure 12. Effect of OPP concentration on filtration volume at 7.5 min and 30 min

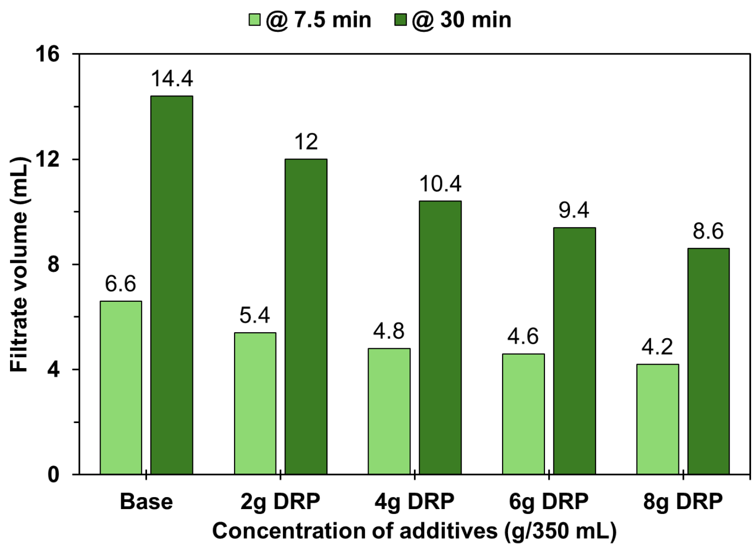


Figure 13. Effect of DRP concentration on filtration volume at 7.5 min and 30 min

Figure 13 presents the effect of DRP concentration on filtrate volume at both 7.5 and 30 minutes. With the DRP addition, a clear decreasing trend in filtrate volume was observed as the additive concentration increased. At 2 g DRP, the filtrate volume reduced to 12.0 mL after 30 min (16.7 %), at 4 g DRP: reduced to 10.4 mL (27.8%), at 6 g DRP: reduced to 9.4 mL (34.7%), and at 8g DRP: reduced to 8.6 mL (40.3%). The 7.5-minute filtrate volumes also showed a reduction from 5.4 mL at 2 g to 4.2 mL at 8g per 350 mL, supporting the idea of early-stage filtration control.

Figure 14 presents the reduction in filter cake permeability (%) as a function of additive concentration (2-8g/ 350 mL) for both OPP and DRP. This parameter reflects the sealing capability of the filter cake and its ability to inhibit filtrate invasion into the formation. Both OPP and DRP significantly reduced the permeability of the filter cake compared to the base mud, with performance improving as the dosage increased. At a concentration of 2g, OPP and DRP achieved 41.7% and 44.4% reductions in permeability, respectively. At 4g, reduction values increased to 45.4% for OPP and 51.9% for DRP. At 6g, OPP and DRP reached 51.9% and 56.5%, respectively. At 8g, maximum reductions were recorded at 57.4% (OPP) and 60.2% (DRP).

OPP exhibited excellent sealing characteristics, particularly at higher concentrations, likely due to its high pectin and cellulose content, which enhances mud cake compaction. The superior performance of DRP across all concentrations may be attributed to its fibrous and more compact structure, which promotes tighter pore bridging and more effective sealing of the filter cake.

The image visually compares the texture, compactness, and surface uniformity of the filter cake, as presented in Figure 15. It is evident that the base mud (a) resulted in a thicker, more porous

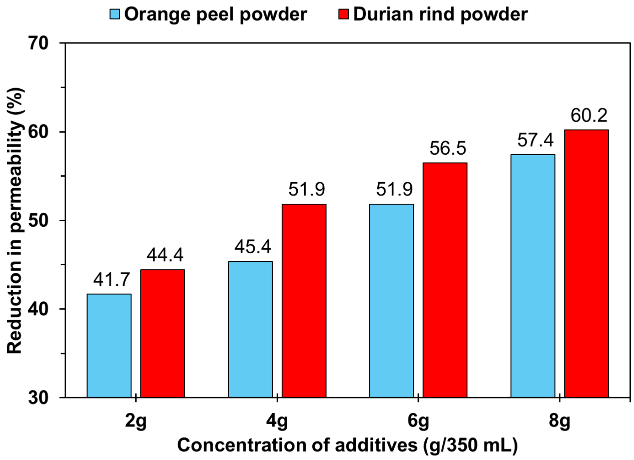


FIGURE 14. Reduction in filter cake permeability (%) of water-based drilling mud with increasing concentrations of OPP and DRP.

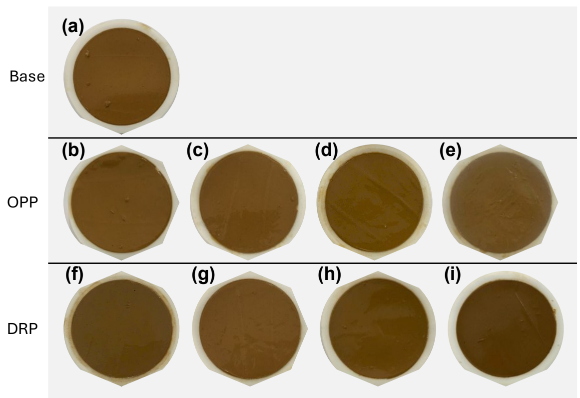


FIGURE 15. Photographs of filter cakes formed with different concentrations of agricultural additives: (a) base mud; (b-e) Orange peel powder at 2, 4, 6, and 8 g/350mL, respectively; (f-i) durian rind powder at 2, 4, 6, and 8 g/350mL, respectively.

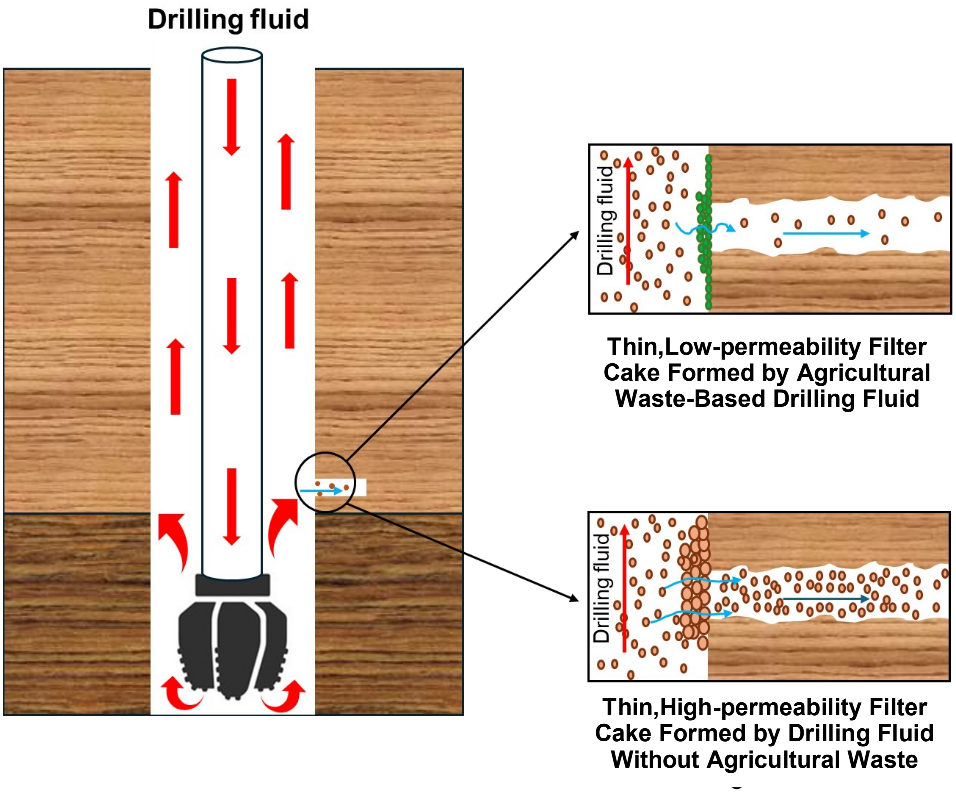


Figure 16. Improved filter cake formation and filtration control by OPP and DRP

cake. As the OPP (Figure 15 b-e) concentration increased, the cakes became denser and smoother, indicating improved sealing properties. Similarly, DRP (Figure 15 f-i) produced relatively thin and uniform cakes at higher concentrations, with (Figure 15 i) showing the most compact structure. These visual results align with quantitative data on reduced filtrate loss and mud cake permeability, supporting the conclusion that OPP and DRP enhance filter cake quality. FTIR analysis confirmed the presence of hydroxyl, aliphatic, and polysaccharide functional groups, while XRD patterns indicated a predominantly amorphous lignocellulosic structure in both materials. SEM observation supported the structural roles of OPP and DRP in improving the filtercake microstructure.

The schematic in Figure 16 illustrates the fluid invasion process and filter cake formation during drilling operations, emphasizing the critical role of drilling fluid additives in mitigating filtration invasion. The mud system exhibits enhanced sealing performance upon incorporating biodegradable additives such as OPP and DRP. The additives contribute to forming a denser, more compact filter cake that reduces the permeability of the invaded zone and impedes fluid penetration into the formation.

## CONCLUSION

This study evaluated the feasibility of utilizing orange peel powder and durian rind powder as biodegradable additives for water-based muds. Both agricultural waste materials significantly enhanced the rheological and filtration properties of the mud. OPP exhibited superior performance in improving apparent and plastic viscosity, yield point, and gel strength, attributed to its fibrous morphology and semi-crystalline cellulose domains. In contrast, DRP was more effective in filtration control, reducing filtrate volume and filter cake permeability due to its denser particle packing and lower crystallinity. The findings suggest that OPP and DRP are viable, eco-friendly alternatives to conventional additives, contributing to developing sustainable drilling fluids aligned with environmental waste valorization goals.

## ACKNOWLEDGEMENT

This research is funded by Vietnam National University HoChiMinh City (VNU-HCM) under grant number C2024-20-28. We also acknowledge Ho Chi Minh City University of Technology, VNU -HCM for supporting this study.

## GLOSSARY OF TERMS AND SYMBOLS

| Symbol | Definition | Unit |
|---|---|---|
| API | American Petroleum Institute | |
| OPP | Orange Peel Powder | |
| DRP | Durian Rind powder | |
| AV | Apparent Viscosity | cP |
| PV | Plastic Viscosity | cP |
| YP | Yield Point | $Lb/100ft^2$ |
| GS | Gel Strenght | (gram) |

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