



Comparative Investigation of the Effect of Pulverized Egg Shell and Potato Peel Powder as Additives on Rheological Properties of Water-Based Drilling Fluid

*Teniola O. S., Alarape M. A., Odekanle E. L. and Madehin M. B.

Department of Chemical and Petroleum Engineering, Abiola Ajimobi Technical University, Ibadan.

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Corresponding Author:

oluwasanmi.teniola@tec

h-u.edu.ng

+2348062450597

ABSTRACT

The typical additives applied in mud preparation for oil well drilling usually have detrimental effects on the environment and crew safety. However, additives of biodegradable origin have the capacity to eliminate these effects. This study employed a mixture of two food wastes (egg shell and potato peel powders), which were dried and pulverized as alternative drilling fluid additives. A variety of muds prepared with different quantities of the additives (potato peel powder (PPP) and egg shell powder (ESP)) were subjected to rheological and filtration testing. According to the results obtained, ESP lowers the yield point and filtrate loss by an average of 65 % and 2.2 %, respectively, while increasing plastic viscosity and mud density by 50% and 0.75%, respectively, at higher concentrations. Additionally, the additions were able to lower the pH by one unit. In contrast, PPP demonstrated a decrease of about 50% in each of plastic and apparent viscosities, yield point, and pH, while boosting mud density and filtrate reduction at higher doses. When coupled, ESP and PPP indicated a 25 % drop in plastic viscosity and yield point but enhanced mud density, lowered filtrate, and enhanced mudcake formation at lower concentrations. These findings suggest that while ESP and PPP can change a range of fluid properties, their careful combination in drilling mud formulation has great potential to improve all desirable rheological and filtration features when compared to traditional additives like sodium carbonate and xanthan gum.

INTRODUCTION

Drilling fluids play a critical role in oil well drilling by facilitating wellbore stability, cuttings transport, lubrication, and pressure control (Agwu and Akpabio, 2018; Nyeche *et al.*, 2015). They are typically formulated from base fluids—water, oil, or synthetic—with various chemical additives to achieve desired rheological, filtration, and density properties (Gamal *et al.*, 2019). However, conventional additives such as sodium carbonate, xanthan gum, and other synthetic materials can be costly, environmentally harmful, and pose risks to personnel safety, which has motivated the search for safer and more sustainable alternatives (Al-Hameedi *et al.*, 2019).

Recent studies have explored biodegradable and agro-waste materials as potential drilling fluid additives. For example, eggshell powder has been investigated for its ability to increase mud density and pH while maintaining acceptable rheological properties (Onyejekwe, 2023; Medved *et al.*, 2023). Potato peel powder has been shown to improve filtration control, enhance mudcake quality, and modify rheology, including reducing yield point and gel strength (Al-Hameedi *et al.*, 2020; AlBajalan *et al.*, 2025). Similarly, bio-composites such as plantain peel–snail shell (Mamukuyomi, 2021) and palm kernel shell powder (Akintola *et al.*, 2024) demonstrated improvements in fluid loss and rheology. Despite these promising results, previous

studies have largely focused on individual additives, with limited exploration of combined bio-additive systems, and in some cases, inconsistencies exist in their reported effects on plastic viscosity, yield point, and filtration performance (Asad *et al.*, 2024; Teniola *et al.*, 2025).

This study addresses these limitations by investigating both individual and combined effects of eggshell powder (ESP) and potato peel powder (PPP) on the rheological, filtration, and density properties of water-based drilling fluids. Combining these two agro-waste materials is scientifically justified because they offer complementary functional properties: ESP can enhance density and viscosity, while PPP contributes to filtration control and mudcake formation. Evaluating their combined performance may reveal synergistic effects that improve drilling fluid efficiency while maintaining environmental sustainability.

The specific research questions addressed in this study are:

How do varying concentrations of ESP and PPP individually affect the rheological, filtration, density, and pH properties of water-based drilling fluid?

Does combining ESP and PPP provide superior or complementary improvements compared to individual additives?

How do ESP, PPP, and their combination compare with conventional additives such as sodium carbonate and xanthan gum in terms of drilling fluid performance?

By answering these questions, this study seeks to provide practical guidance for the use of biodegradable agro-waste additives in water-based drilling fluids and to advance knowledge on eco-friendly drilling fluid formulations.

MATERIAL AND METHODS

Materials

The materials used in this study were potato peel powder (PPP) and eggshell powder (ESP), as shown in Figures 1 and 2. Other reagents included distilled water, bentonite, sodium carbonate, and xanthan gum. Distilled water served as the base fluid for conditioning bentonite and other additives. Sodium carbonate was used as a pH control additive, while xanthan gum was used for fluid-loss control.

Preparation of ESP and PPP:

- Eggshells were washed, oven-dried at 105 °C for 24 h, and ground to a particle size range of 75–150 µm using a laboratory grinder.
- Potato peels were washed, oven-dried at 60 °C for 48 h, and ground to a particle size range of 100–200 µm.
- Both powders were sieved to ensure uniform particle distribution.

Experimental Design and Formulations

Drilling fluid samples were prepared according to API Standard API 13B-1 (2016) for water-based drilling fluids. The base fluid consisted of 350 mL of distilled water and 17.5 g of bentonite. Additives (ESP, PPP, sodium carbonate, xanthan gum) were added at varying concentrations, as summarized in Table 1. Each formulation was mixed for 15 min using a Hamilton Beach mixer, rested for 24 h, then stirred gently for 5 min before testing to ensure homogeneity.

Measurements and Replicates

- **Rheological properties** (plastic viscosity (PV), apparent viscosity (AV), yield point (YP), initial and final gel strength) were measured using a FANN 35 viscometer at 3–600 rpm.

- **Mud density** was determined using a mud balance, and pH was measured using a calibrated pH meter.
- **Filtration properties** were measured with a filter press following API 13B-1 standard procedures.
- Each measurement was performed in triplicate, and mean values with standard deviations are reported to ensure data reliability

Table 1: Summary of Drilling Fluid Formulations

Sample ID	Additive Type	Concentration (g/350 mL)	Purpose
REF	None	0	Base/reference fluid
ESP1	Eggshell	2	Test effect on rheology & density
ESP2	Eggshell	4	Test effect on rheology & density
ESP3	Eggshell	6	Test effect on rheology & density
PPP1	Potato peel	2	Test effect on rheology & filtration
PPP2	Potato peel	4	Test effect on rheology & filtration
PPP3	Potato peel	6	Test effect on rheology & filtration
COMB1	ESP + PPP	2 + 2	Test combined effect
COMB2	ESP + PPP	4 + 4	Test combined effect
COMB3	ESP + PPP	6 + 6	Test combined effect
SC	Sodium carbonate	2	pH control, conventional additive
XG	Xanthan gum	2	Fluid loss control, conventional additive



(a)



(b)

Figure 1: (a) Dried potato peel (b) Potato peel powder



(a)



(b)

Figure 2: (a) Dried eggshells (b) Eggshell powder

RESULTS AND DISCUSSION

The results from all tests were obtained following API standard methods for water-based drilling fluids. The effects of eggshell powder (ESP), potato peel powder (PPP), and their combination on rheological, filtration, and mudcake properties are analyzed mechanistically, with comparisons to conventional additives (sodium carbonate and xanthan gum).

Rheological properties of different samples

Plastic Viscosity (PV): Plastic viscosity arises from interparticle friction within the mud and reflects its ability to maintain solids in suspension. As shown

in Figure 3, PV generally increased with ESP concentration, attributed to the rigid, high-calcium particle structure, which enhances particle-particle interactions. In contrast, PPP decreased PV at higher concentrations, likely due to its fibrous, organic structure reducing friction between solid particles. The combined ESP + PPP system exhibited a moderate decrease in PV with increasing concentration, indicating that PPP mitigates the frictional effect of ESP particles. Compared with sodium carbonate and xanthan gum, the PV increase from ESP + PPP is modest, highlighting that conventional additives still provide superior viscosity control.

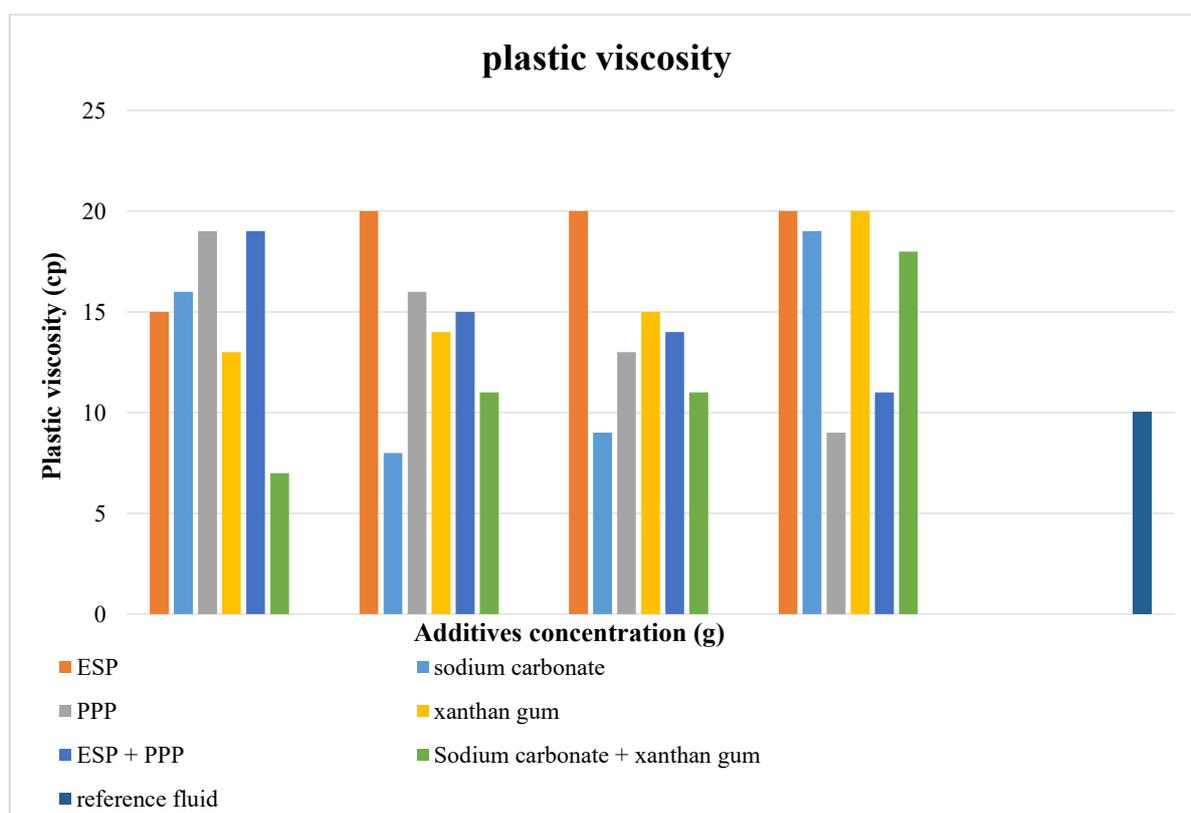


Figure 3: Plastic viscosity of water-based bentonite mud with the additives

Apparent Viscosity (AV): Apparent viscosity influences the fluid's ability to suspend cuttings. Figure 4 shows that ESP increased AV due to solid particle reinforcement of the clay network, while PPP decreased AV at higher concentrations, likely because its fibrous composition disperses clay flocs.

The ESP + PPP mixture resulted in intermediate AV values, suggesting a balance between particle reinforcement and dispersive effects. Compared to xanthan gum, which forms a strong polymeric network, ESP + PPP improves AV only at low to

moderate concentrations (Onolemhemhen et al., 2018).

Yield Point (YP): Yield point reflects the stress required to initiate flow and correlates with the fluid’s carrying capacity. As seen in Figure 5, ESP alone decreased YP with increasing concentration, consistent with Medved et al. (2023), likely because rigid calcium particles reduce clay particle

electrostatic interactions. PPP also reduced YP, as its fibres interfere with the flocculated clay network. Interestingly, the combined ESP + PPP system increased YP at low concentrations but remained below the performance of fluids with sodium carbonate and xanthan gum, indicating that only limited improvement in cuttings-carrying capacity can be achieved.

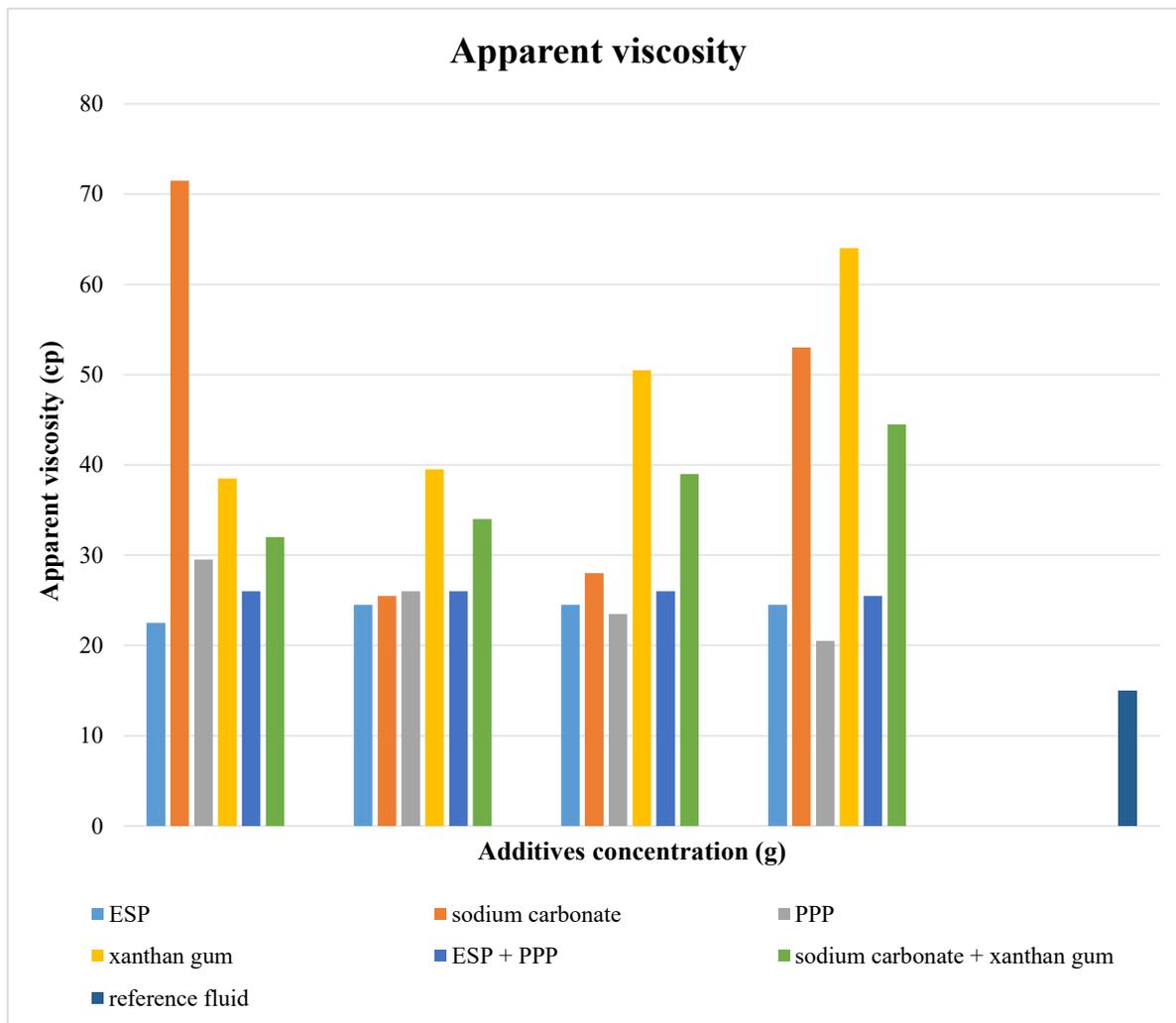


Figure 4: Apparent concentration of ESP, PPP, ESP + PPP, sodium carbonate, xanthan gum and sodium carbonate + xanthan gum

Mud Density Test

Mud Density is a critical parameter of drilling fluid, as it regulates formation pressure and helps prevent blowouts. Figure 6 shows that both ESP and PPP individually increased density with concentration due to the addition of solid mineral and organic matter. The combination of ESP + PPP resulted in a

moderate cumulative density increase, showing that their effects are roughly additive. Compared to sodium carbonate, ESP + PPP achieves similar density enhancement at moderate concentrations, offering a biodegradable alternative to conventional density modifiers.

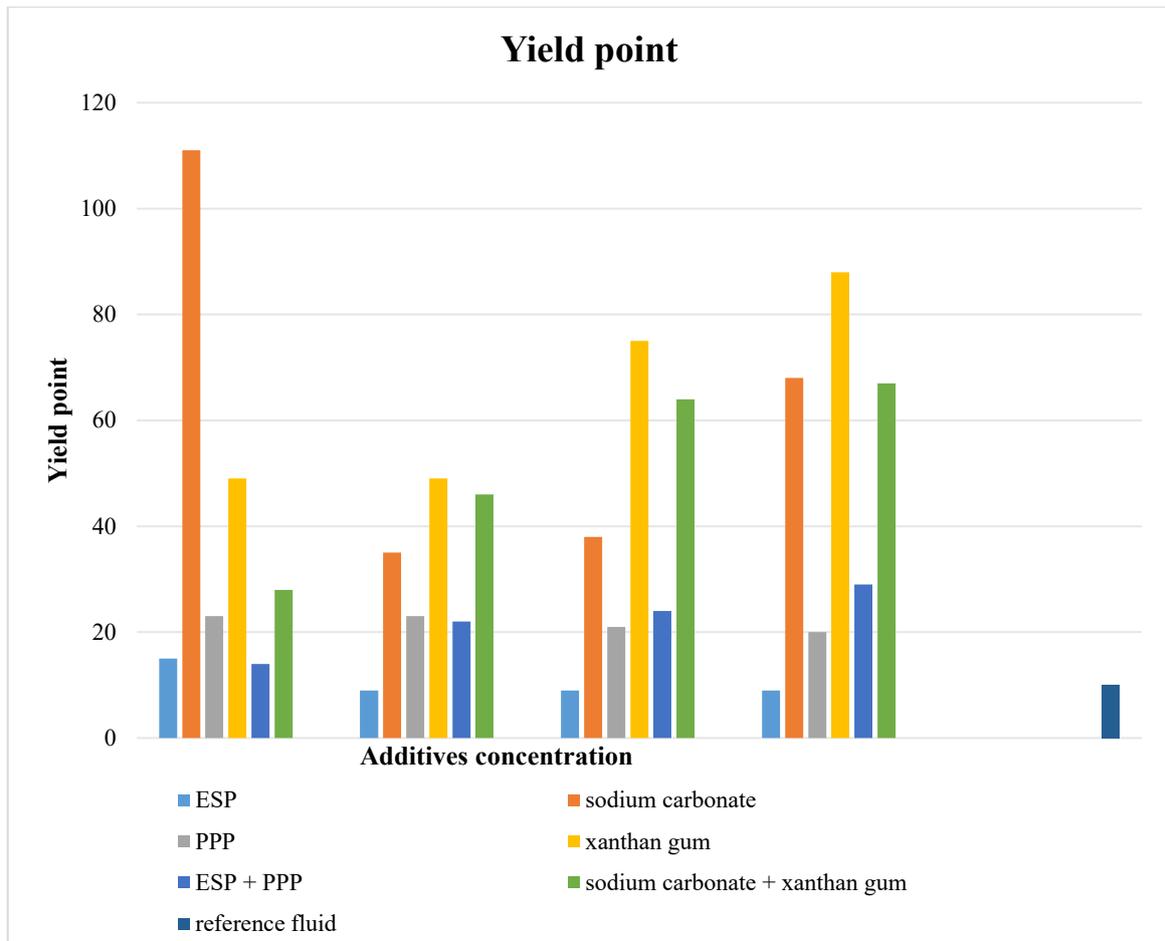


Figure 5: Yield point for different concentration of ESP, PPP and ESP + PPP and reference fluid

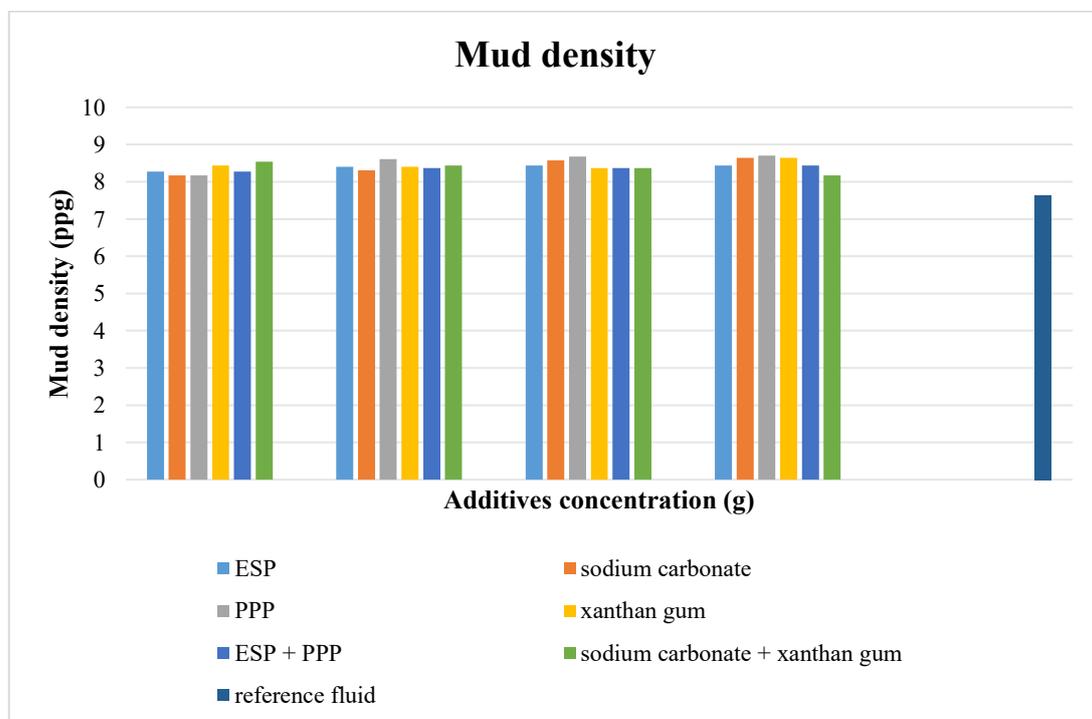


Figure 6: Mud density for different concentration of ESP, PPP and ESP + PPP, reference fluid, sodium carbonate, xanthan gum and sodium carbonate + xanthan gum

pH Determination

pH is defined as the negative logarithm of the hydrogen ion activity in an aqueous solution. Solutions with a pH below 7 are considered acidic, while those with a pH above 7 are classified as basic or alkaline. pH influences drilling fluid stability and clay swelling. Figure 7 shows that ESP slightly

increased pH due to its alkaline calcium carbonate content, whereas PPP reduced pH due to acidic organic residues. The ESP + PPP mixture showed a net pH decrease with increasing PPP fraction, highlighting the need for careful proportioning to maintain optimal mud alkalinity. Compared with sodium carbonate, pH adjustment using ESP + PPP is less pronounced but environmentally friendly.

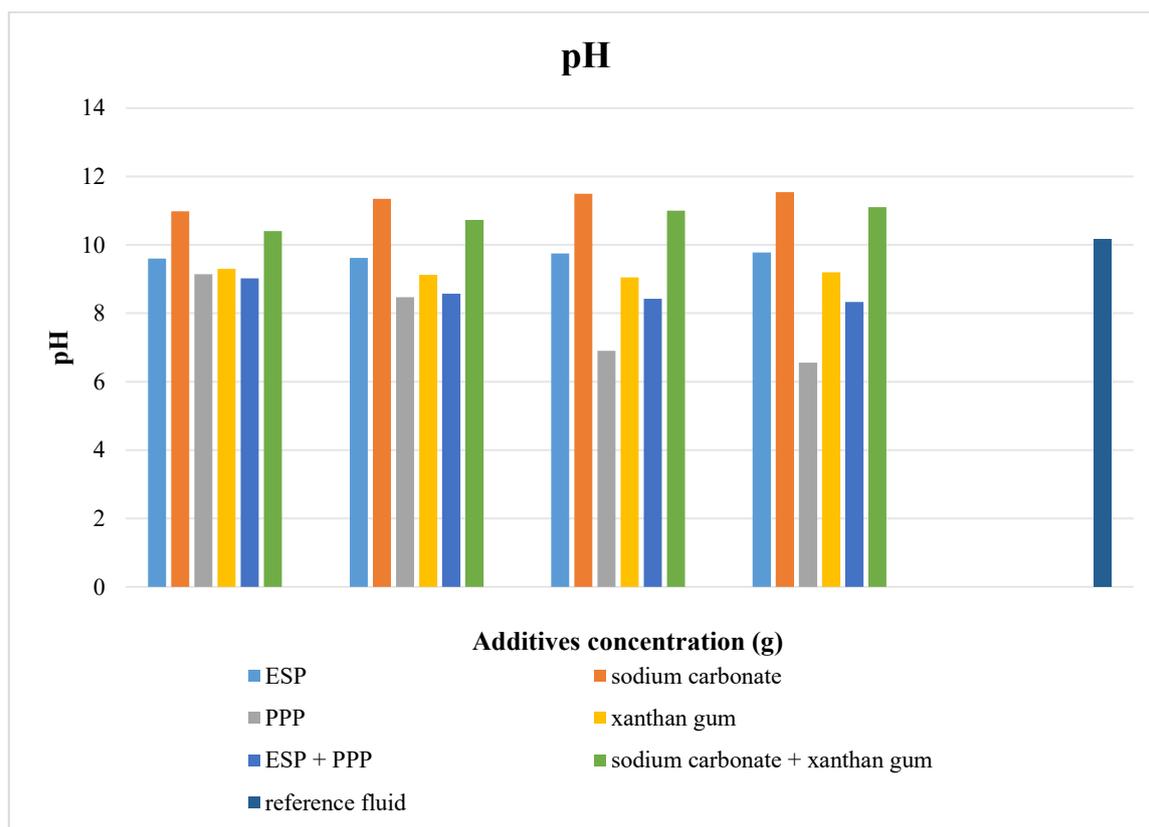


Figure 7: pH for different concentration of ESP, PPP and ESP + PPP, reference fluid, sodium carbonate, xanthan gum and sodium carbonate + xanthan gum

Fluid Loss Test

This section analyzed the fluid loss volume of drilling fluid samples, both with and without different concentrations of eggshell and potato peel powders, comparing them to reference and control samples. Fluid loss refers to the amount of fluid that infiltrates a porous formation due to high mud pressure, and reducing it is crucial to avoid serious and expensive drilling issues such as formation

damage, stuck pipe, lost circulation, and downtime (Yalman et al., 2021).

Figure 8 shows that ESP slightly reduced fluid loss by enhancing particle bridging, while PPP more effectively reduced filtrate through its fine, fibrous structure, which improves pore plugging. The ESP + PPP mixture reduced fluid loss at low concentrations, but at higher concentrations, fluid loss increased, likely due to particle aggregation creating larger voids in the filter cake (Popi and

Alam, 2025). Compared with xanthan gum, which consistently reduces fluid loss via polymer networks, ESP + PPP is effective only at lower additive concentrations.

Mud Cake Thickness

A thin, impermeable mud cake is desired in drilling fluids to prevent lost circulation, stuck pipe, and formation damage. Figure 9 presents the mud cake thickness results for the various drilling fluid systems.

Figure 9 shows that ESP increased mud cake thickness due to its rigid particles, while PPP produced thinner cakes by dispersing clay flocs. The ESP + PPP combination achieved thin mud cakes at low concentrations, which can be advantageous in sensitive formations, but higher concentrations resulted in thicker cakes. The mixture allows tuning of mudcake properties by adjusting relative additive concentrations.

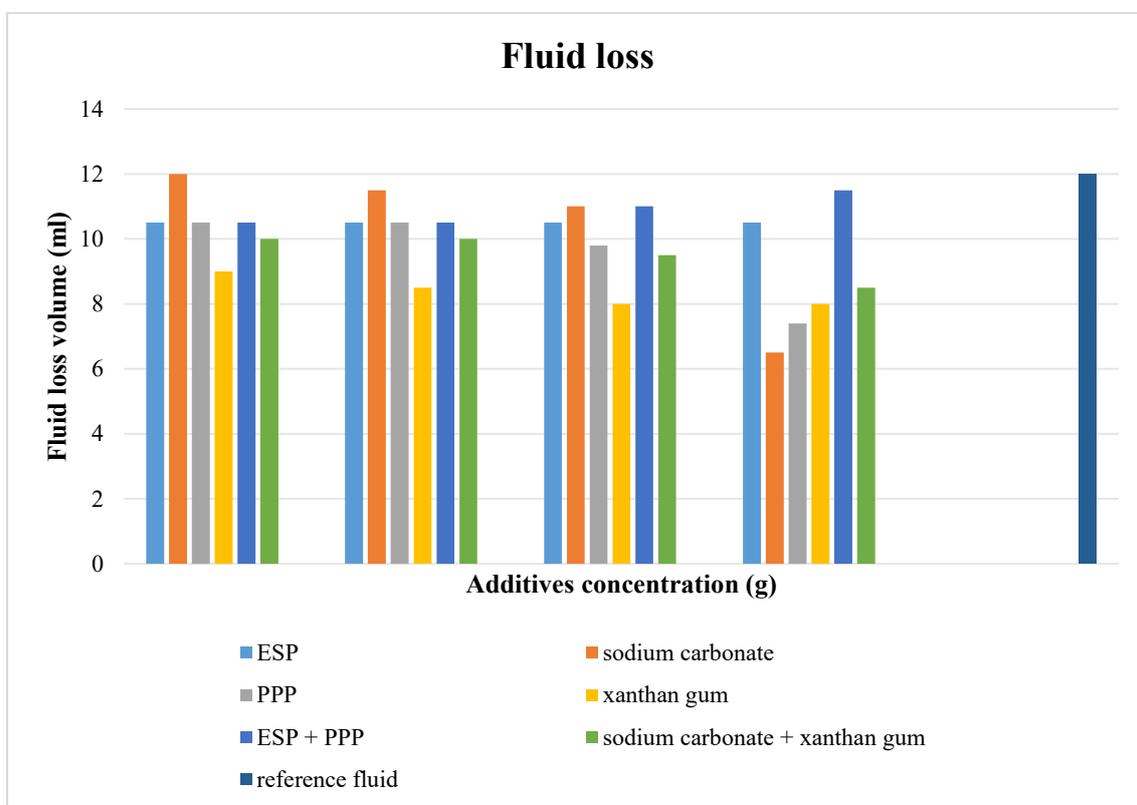


Figure 8: Fluid loss for different concentration of ESP, PPP and ESP + PPP, reference fluid, sodium carbonate, xanthan gum and sodium carbonate + xanthan gum

CONCLUSION

This study demonstrates that eggshell powder (ESP) and potato peel powder (PPP) can serve as environmentally friendly additives for water-based drilling fluids, with distinct and complementary effects on rheological and filtration properties. Key findings include:

ESP improves plastic viscosity and mud density at higher concentrations, enhancing the carrying

capacity of the fluid, but has limited impact on yield point and apparent viscosity.

PPP reduces plastic viscosity and yield point while increasing mud density and reducing filtrate loss at higher concentrations, making it effective for controlling fluid loss and achieving thinner mud cakes.

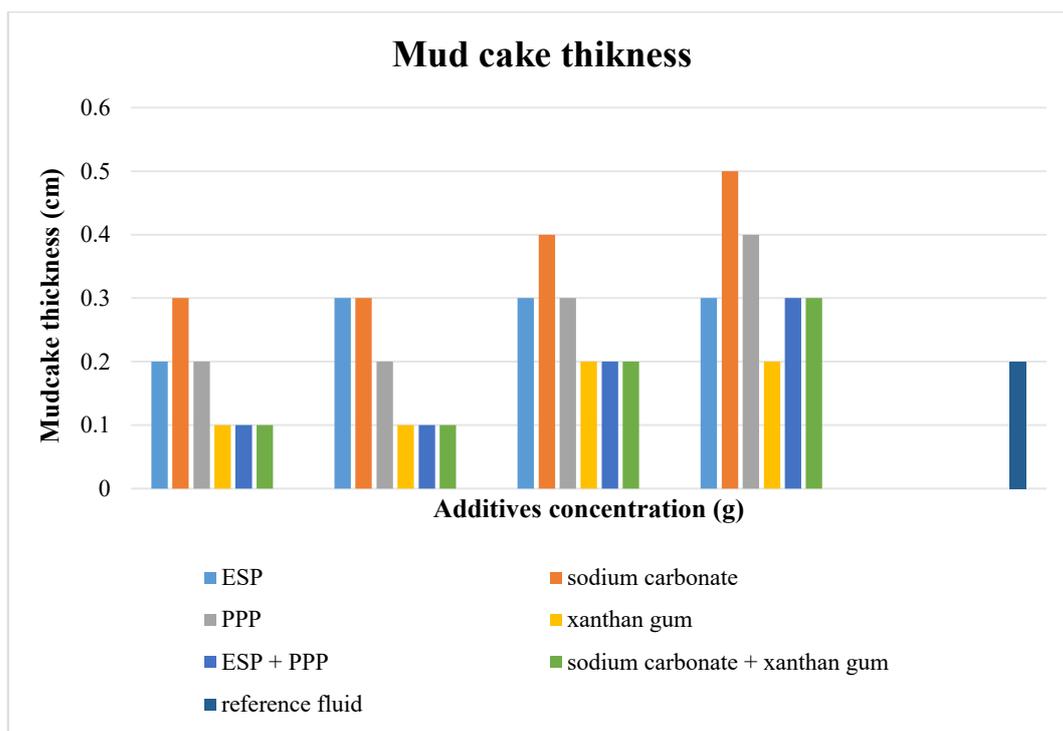


Figure 9: Mud cake thickness for different concentrations of ESP, PPP and ESP + PPP, reference fluid, sodium carbonate, xanthan gum and sodium carbonate + xanthan gum

Combined ESP + PPP can balance rheological and filtration properties, particularly at lower concentrations, though conventional additives like sodium carbonate and xanthan gum still outperform in maximizing apparent viscosity and yield point.

Engineering relevance: The study indicates that ESP and PPP are viable bio-based alternatives for drilling fluids in operations where environmental impact, cost, and moderate performance adjustment are priorities. They are particularly suitable for low-to moderate-pressure wells where fluid loss control and mud density are critical, but extreme rheological enhancement is not required.

Limitations: This investigation was conducted at lab scale, without high-temperature/high-pressure (HTHP) aging tests, and variability in raw material properties (ESP and PPP) may affect field performance.

Future work: Further research should include HTHP testing, long-term stability studies, and field trials to

validate their performance under operational conditions and optimize concentration ranges for specific well requirements.

Conflicts of Interest

The authors declare no conflicts of interest

Authors' Contributions

Oluwasanmi Samuel TENIOLA – Conception and design of the work, Manuscript drafting, Maryam Ayomide ALARAPE – Investigation and acquisition of data, Ebenezer Leke ODEKANLE – editing and revising of manuscript, Marydiah Bukola MADEHIN - Investigation and acquisition of data,

Data Availability

Needed data are made available on request

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Ethics, Consent to Participate and Consent to Publish Declaration

Not applicable

REFERENCES

- Agwu, O.E. and Akpabio, J.U., 2018. Using agro-waste materials as possible filter loss control agents in drilling muds: A review. *Journal of Petroleum Science and Engineering*, 163, pp.185–198. <https://doi.org/10.1016/j.petrol.2018.01.009>
- Akintola, S.A., James, O.T. and Fatai, O.A., 2024. Investigating the effect of palm kernel shell powder on the rheological and filtration properties of water-based mud. *American Journal of Science, Engineering and Technology*, 9(1), pp.32–41.
- ALBajalan, A.R., Rasol, A.A. and Ameen, H.F.M., 2025. Enhanced performance of nanocomposite drilling fluids with synthesized TiO₂ Quillaja saponin Cr nanoparticles and their impact on rheology and filtration. *Scientific Reports*, 15, 27667. <https://doi.org/10.1038/s41598-025-13459-5> (*Nature*)
- Al-Hameedi, A.T., Alkinani, H.H., Dunn-Norman, S. and Hamoud, Z.A., 2020. Investigation study of the effectiveness of eggshell powder as a multifunctional eco-friendly additive in water-based fluid. *Proceedings of the 54th US Rock Mechanics/Geomechanics Symposium*, Golden, Colorado, USA, 28 June–1 July.
- Al-Hameedi, A.T., Alkinani, H.H., Dunn-Norman, S., Alshammari, A.F., Albazzaz, H.W., Alkhamis, M.M. and Mutar, R.A., 2019. Insights into the application of a new eco-friendly drilling fluid additive to improve the fluid properties in water-based drilling fluid systems. *Journal of Petroleum Science and Engineering*, 183, pp.106424. <https://doi.org/10.1016/j.petrol.2019.106424>
- Asad, M.S., Jaafar, M.T., Rashid, F.L., Togun, H., Rasheed, M.K., Al-Obaidi, M.A. and Sarris, I.E., 2024. Sustainable drilling fluids: A review of nano-additives for improved performance and reduced environmental impact. *Processes*, 12(10), 2180. <https://doi.org/10.3390/pr12102180> (*MDPI*)
- Odekanle E. L., Teniola O. S., Odewale S. A., Olaoye I. O. and Soliu M. A. (2025). Application of Oil Palm Fruit Waste and Saw Dust as Filtration Loss Control Agents in a Water-Based Drilling Mud. *LAUTECH Journal of Engineering and Technology* 19 (1) 2025: 177-186. DOI:10.36108/laujet/5202.91.0161
- Gamal, H., Elkatatny, S., Basfar, S. and Al-Majed, A., 2019. Effect of pH on rheological and filtration properties of water-based drilling fluid based on bentonite. *Sustainability*, 11(23), p.6714. <https://doi.org/10.3390/su11236714>
- Mamukuyomi, J., 2021. Evaluation of the rheological and pH control performance of plantain peel-snail shell biocomposite additive in water-based drilling fluid. *LAUTECH Journal of Engineering and Technology*, 15(1), pp.1-10.
- Medved, I., Gaurina-Medimurec, N., Novak Mavar, K. and Mijić, P., 2022. Waste mandarin peel as an eco-friendly water-based drilling fluid additive. *Energies*, 15(7), 2591. <https://doi.org/10.3390/en15072591>
- Nyeche, W.E., Nmegbu, C.G.J. and Ifeoma, P.J., 2015. Drilling mud formulation using potato starch (*Ipomoea batatas*). *International Journal of Engineering Research and Applications*, 5(9), pp.48–54.
- Onolemhemen, R.U., Olamigoke, O. and Kaka, A.O., 2018. The suitability of eggshell and snail shell waste for pH and mud weight enhancement of water-based drilling mud. *Department of Chemical and Petroleum Engineering, University of Lagos, Nigeria*.
- Onyejekwe, I.F., 2023. Experimental study on the suitability of local eggshell and snail shell as additives for drilling mud pH control. *International Journal of Oil, Gas and Coal Engineering*, 11(2), pp.37–46. <https://doi.org/10.11648/j.ogce.20231102.12>
- Popi, K. and Alam, M.S., 2025. Biodegradable materials for lubricity enhancement of drilling fluids: A review. *Engineering*, 3(10), pp.1-13. <https://doi.org/10.38032/scse.2025.3.10> (*SciEn Publishing Group*)

Teniola, O.S., Bello, S.O., Odekanle, E.L. and Iyala, F.A., 2025. Comparative studies of the effects of date plant seed and palm kernel shell powder with metal oxide particles on the rheological properties of water-based mud. *Egyptian Journal of Petroleum*, 34, pp.249–259. <https://doi.org/10.62593/2090-2468.1080>

Yalman, E., Depci, T., Federer-Kovacs, G. and Al-Khalaf, H., 2021. A new eco-friendly and low cost additive in water-based drilling fluids. *Regional Journal of Geosciences*, 5(1), pp.1–10. <https://doi.org/10.17794/rjn.2021.5.1>