Received: 21 April 2022, Accepted: 27 June 2022, Published: 30 June 2022, Publisher: UTP Press, Creative Commons: CC BY 4.0

EXPERIMENTAL STUDY OF SOLANUM TUBEROSUM WASTE AS DRILLING FLUID ADDITIVES

Shazriana binti Suaib[1], Muhammad Aslam Bin Md Yusof[1*], M Arif Bin Ibrahim[2]

[1]Department of Petroleum Engineering, Universiti Teknologi PETRONAS, Malaysia
[2]School of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Malaysia

*Email: aslam.myusof@utp.edu.my

ABSTRACT

Environmental consideration is essential during the drilling process in oil and gas development. However, the existing additives used in Water-Based Mud (WBM) are unable to create an efficient, entirely eco-friendly drilling fluid system. At the same time, Solanum Tuberosum Russet Burbank Waste (STRBW) which ranks as the second most produced food waste, shows a potential to be used as an environmentally friendly additive. In this experimental work, full-set rheological measurements under fresh and aged conditions and the filtration properties of STRBW were investigated in different concentrations; 1.2 wt%, 1.4 wt%, 1.8 wt% and 2.2 wt%. The analysis was conducted according to American Petroleum Institute RP-13B-1 Standard. The result was compared with a commercial WBM additive, Polyanionic Cellulose Low Viscosity (PAC-LV). The characterisation of STRBW was performed through Thermogravimetry Analysis (TGA), Field Emission Scanning Electron Microscopy with Energy dispersive X-ray (FESEM-EDX) and X-ray Diffraction (XRD) analysis. The results showed that the microscopic appearance of STRBW was irregular and had rough. STRBW was degraded at 287°C, and it consisted of Carbon (C), Oxygen (O), Potassium (K), Calcium (Ca) and Magnesium (Mg). From XRD spectra, the existence of B-type starch was identified in STRBW. To sum up, PAC-LV showed better rheological and filtration performance than STRBW at the same concentration. However, the performance of STRBW was enhanced as the concentration of STRBW increased up to 1.8 wt%. Other than decreasing the quantity of non-biodegradable waste thrown to the environment, these findings indicated that STRBW has the potential to be utilised as a substitute for several standard chemical additives in the industry, such as polymers and fluid loss agents.

Keywords: *Drilling fluid, Solanum Tuberosum, Russet Potato, Environmental friendly additive*

INTRODUCTION

Drilling mud, a key component of the drilling process, must be formulated thoroughly to achieve itsthe function in the well. Drilling fluid serves various functions, including transferring cuttings from beneath the rotary bit to the annulus and separating them at the surface [1]-[3]. Also, mud is used to clean and keep the rotary bit cool when operating. It decreases the amount of friction between the drill string and the borehole's sidewalls [4]. Additionally, drilling mud executes the following purposes; seals permeable formations, reduces mud filtrate, reduces the permeability filter cake, which seals pores and other openings in the formations penetrated by the drill bit, minimises reservoir damage, and ensures adequate formation evaluation by forming a thin, and lower the loss of drilling and maintains the stability of uncased sections of the borehole fluids through the permeable formations [5]-[7].

In earlier days, the drilling fluids comprised only bare clay and water and thus had minimum environmental effects. However, as the drilling conditions became more challenging, many problems started with basic drilling fluid properties. Therefore, complex chemicals or additives must be added to prepare the base mud to meet its best functions[8],[9]. Additives that are used in the formulation of drilling mud is essential to achieve a few respective reasons, such as viscosity control, weighting control, rheology control, emulsifier, pH control additive also filtration control [10]-[11]. Some of the additives mentioned are hazardous to public health and threaten aquatic life. Due to high environmental demands to prevent marine resource destruction, innovative environmentally friendly drilling fluid is highly preferable. This has made the investigation of the alternative for mud additives from waste material is needed in the industry. Various researchers have experimented with various substance including waste materials in order to improve the characteristics of drilling mud in a cost-effective and environmentally friendly way [11]-[12].

Waste is a growing worldwide concern in modern civilisation because it may have a variety of unintended repercussions that harm people's health and the environment [13]-[14]. However, not all waste products may be utilised for petroleum-related projects. One of the ordinary wastes that is popular in the oil and gas industry is food waste [15]. The Food and Agriculture Organization (FAO) estimated the worldwide cost of food waste to be close to 2.6 trillion dollars of losses per year [16]. Waste products can be used in various petroleum applications, including improved oil recovery, stimulation fluid and more. This includes mandarin peels and durian rind as a rheological modifier [17]-[18].Bisphenol A as a fluid loss control agent [19] and saffron purple petals as corrosion inhibitors [20]. STRBW, a common food waste generated from potato-based food production, is potentially an eco-friendly WBM additive. During the preparation of potato-based food, about 35-46% of potato's recycled mass becomes waste that results in 162.8 MT of potato waste in 2019 [21]-[23]. Other than that, Solanum Tuberosum contains a high amount of starch that helps control mud filtration properties [23].

Based on the literature, the latest study on Potato Peel Powder (PPP) shows that PPP has the potential to be invested as a filtration control additive and also improve the thickness of filter cake [17]. However, limited research has been done in investigating the ability of waste from Russet Burbank as a drilling fluid additive. Therefore, this experimental study examines the characterisation of STRBW using TGA, FESEM-EDX and XRD analysis. This is followed by the investigation of the performance of different concentrations of STRBW and PAC-LV on rheological and filtration properties. This paper ends with a summarised conclusion of the research and several recommendations.

METHODOLOGY

This section describes the method that has been used in this research work. The materials used in the mud formulation are freshwater, potassium hydroxide, xanthan gum, potassium chloride, PAC-LV, shale inhibitor and barite. All additive of mud and equipment was provided and available at Block 12, Drilling Fluid Laboratory of Universiti Teknologi Petronas.

Raw materials

Freshwater acts as the base fluid to condition the other additives into the mud. The brine of potassium chloride was used to providing salinity, potassium hydroxide was used to increase the pH of the mud, shale inhibitor was added to provide inhibition control, and Xanthan Gum was used as a primary viscosifier. PAC-LV and STRBW were tested as fluid loss agents and secondary viscosifier in the mud. Barite is the weighting agent contributing to the mud weight of drilling fluid**.**

Equipment

Electronic balance is sutilised to weigh all the additives used in the formulation. Then, drilling mud is mixed thoroughly to ensure the additives are entirely mixed together using FANN Five Spindle Multimixer Model 9B. The rheological property of mud is determined by using FANN Model 35 Viscometer. A hot roller oven is used to simulate the drilling process at 200°F for 16 hours. The filtration test is conducted using the OFITE LPLT filter press.

STRBW Preparation

The preparation method is closely based on a research paper studied by[14]. Collected STRBW was chopped into small pieces and then placed into a drying oven at 90°C for 3 hours. After that, dried STRBW was left in dry space for five days to remove the moisture completely. Next, it was ground into a very fine pieces using the food processor and sieved for a maximum particle size of 60 μm.

Muds Preparation

The mud was prepared by a procedure described as follows. Firstly, 316 g of freshwater was poured into the cup of FANN Five Spindle Multimixer Model 9B. The pH of the solution was adjusted to 11 by dissolving 3 g of potassium hydroxide in the freshwater and mixed at a mixing speed of 12000 rpm for 5 minutes. Then, 24.6 g of potassium chloride was added and mixed for 10 minutes before adding 1.2 wt% of PAC-LV into the solution for another 10 minutes. 2 g of Xanthan Gum and 3 g of shale inhibitor were added where the mixing time for each additive is 5 minutes. After that, 66.5 g of barite was added and mixed for 15 minutes in order to ensure that it was perfectly dispersed in the mud. The same procedure was followed to prepare mud containing STRBW, where the concentration varies from 1.2 wt% to 2.2 wt%.

Rheology Testing

The mud sample was stirred using FANN Viscometer while heated to 120 °F. Values of each RPM available are recorded to calculate the PV and YP of the mud for the property analysis. Then, mud was left at rest for 10 seconds and 10 minutes to determine the 10′ and 10′ gel strength, respectively. The values of PV and YP were calculated as:

$$PV = \theta_{600} - \theta_{300} \quad (1)$$

$$YP = \theta_{300} - PV \quad (2)$$

Filtration Testing

The filtration properties of mud were measured using an OFITE LPLT filter press under a pressure of 100 psi at ambient temperature. Firstly, 88.9 mm filter paper was placed in the base cup of the filter press. Then, gaskets were set properly before attaching the main part of the cup with the base. Mud was poured into the cell and secured with the upper part of the cup. Then, the cell was set and tightened in the frame, where 100 psi of pressure was applied. After 30 minutes, API filtrate was collected and the filter press was disassembled and the mud cake deposited was measured using a digital caliper.

Characterisation of STRBW

Thermogravimetry Analysis (TGA)

A Thermogravimetric Analyzer with model DTA 60A was used with a Muffle furnace. While running TGA, and the STRBW sample was held for 2.0 min at 29°C and heated to 900°C at a rate of 20°C/min. Then, the result was interpreted using Perkin Elmer Thermal Analysis to obtain the degradation point and cumulative mass loss.

Field Emission Scanning Electron Microscopy (FESEM) with Energy Dispersive X-ray Analysis (EDX)

By rastering a focused electron beam across the surface and detecting secondary or backscattered electron signals, FESEM offers comprehensive high-resolution images of STRBW. Other than that, elemental identification and quantitative compositional information were also provided by EDX.

X-Ray Diffraction (XRD)

An X-ray powder diffraction (XRD) study was carried out at room temperature using a Cu Ka X-ray source that was adjusted to span a 2h range of 10–80. The data has been recorded in 0.04 increments at a speed of 0.004 min^{-1}. XRD was done to identify crystalline phases and phase composition of STRBW.

RESULT AND DISCUSSION

Characterisation of STRBW

TGA

The thermal stability of STRBW was tested using TGA. Figure 1a shows the mass loss (%) of STRBW with respect to temperature, while Figure 1b tells the decomposition of STRBW at a specific temperature during the thermal breakdown. The combination of two curves, TG and DTG, can be seen in Figure 1c. Figure 1c shows two significant decomposition peaks seen in the DTG curve. The first decomposition peak is at 29°C to 120°C which is compatible with the temperature of water evaporation in a substance [24]. The second decomposition peak can be seen at 215°C to 355°C, where the main degradation occurred at 287°C. A weight loss of about 45% was observed at this stage due to the decomposition of hemicellulose and cellulose in STRBW [25].

FESEM-EDX

The structure and micro morphologies of STRBW that were observed using FESEM are shown in Figure 2. As can be seen in Figures 2a and 2b, some interesting morphological variations of the particle can be

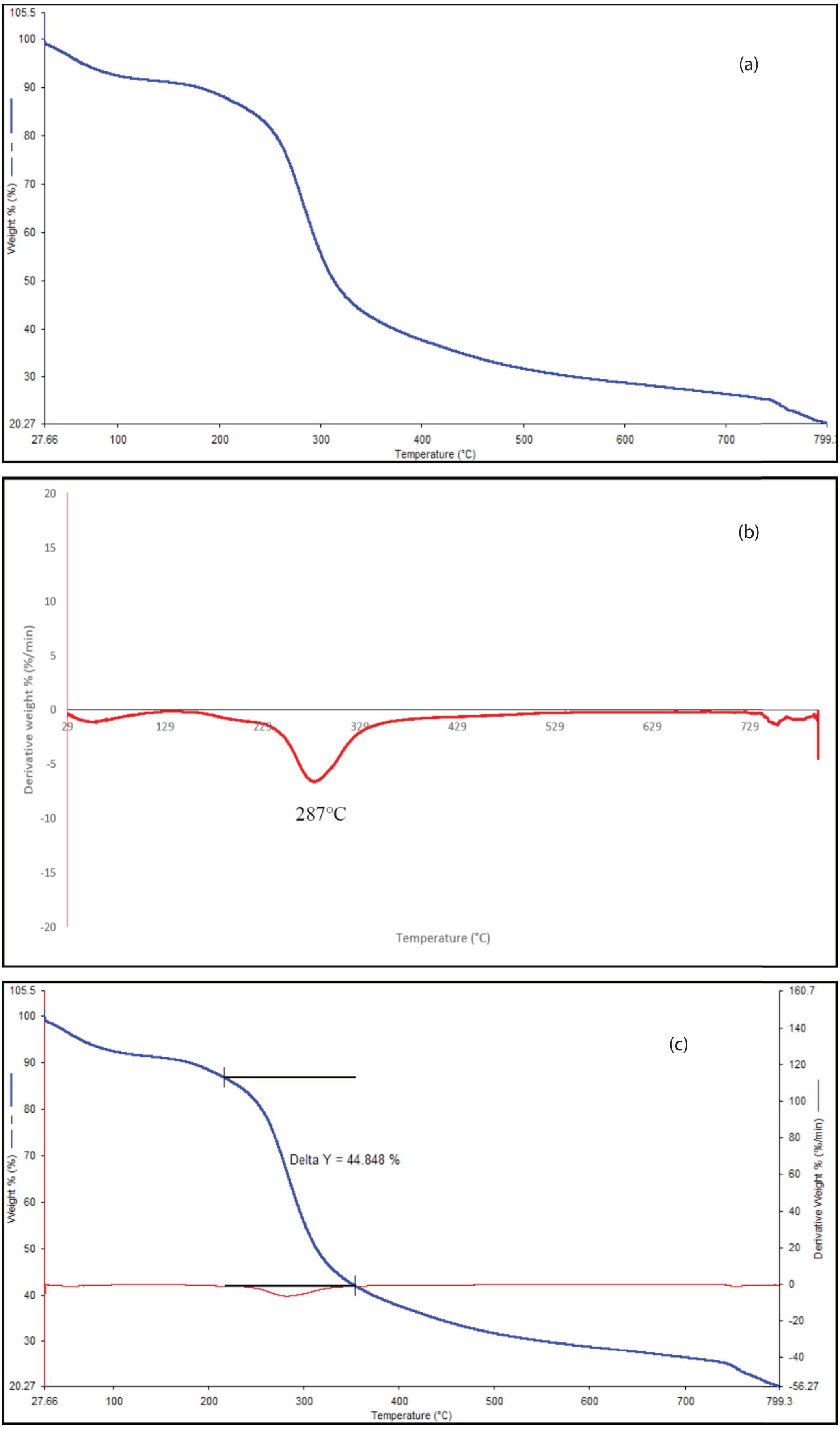

Figure 1 Thermal stability analysis of STRPB using TGA. a) Thermogravimetry, b) Derivation Thermogravimetry and c) DTG Curves

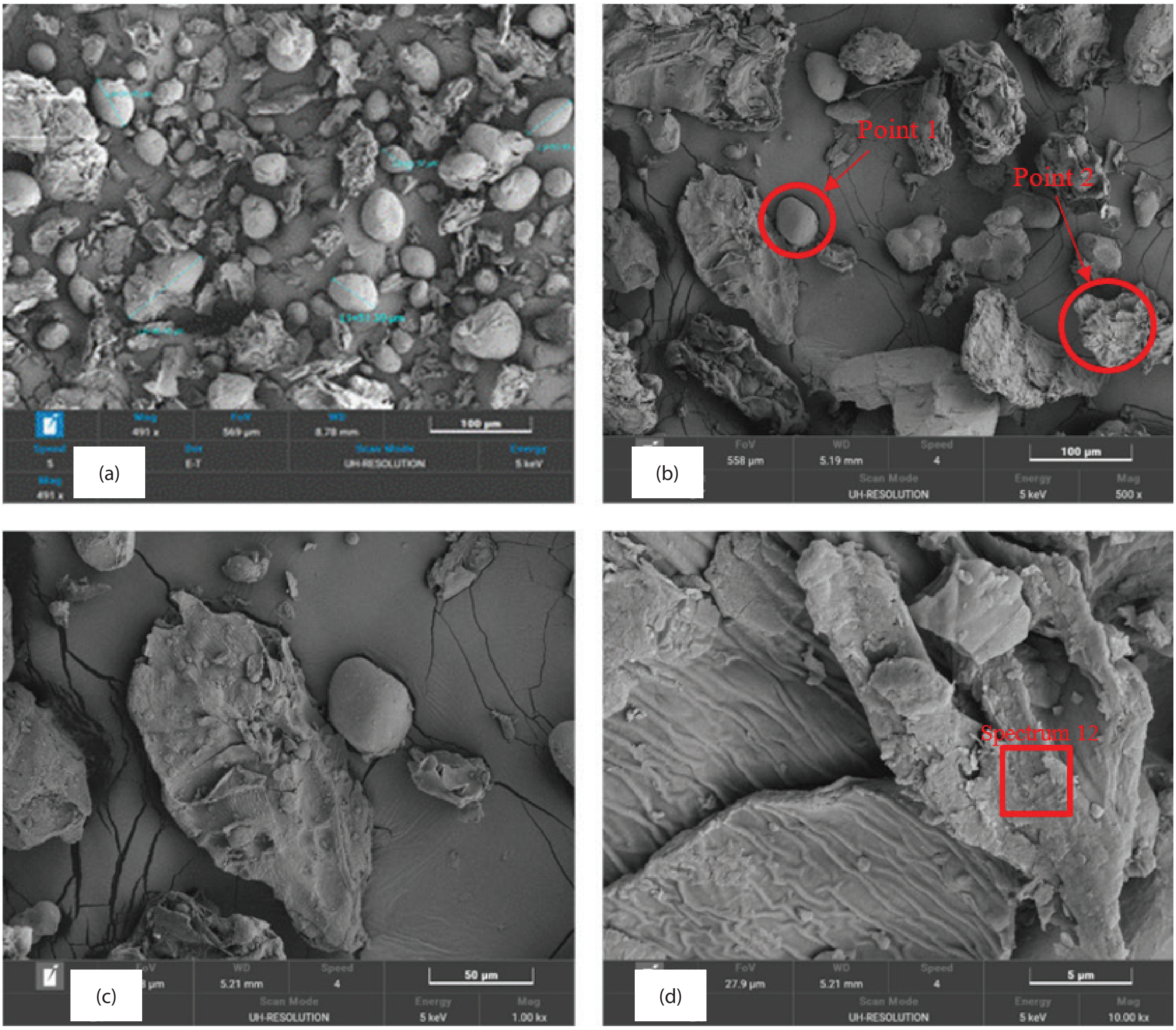

Figure 2 FESEM analysis of STRPB

seen. The two main structures, spherical shapes with smoother textures shown in Point 1 and irregular rough textures seen in Point 2 are clearly observed from the image. The particle differences are due to the presence of solanum tuberosum that is attached to its skin during the peeling process. From Figure 2c, a spherical rounded shape with a smoother texture represents solanum starch's existence. This result was in agreement with the previous study of [16], where the potato starch gives the same appearance as shown in Figure 2c. A closer inspection of 10000x magnification in 5µm resolution, as presented in Figure 2d, shows a threaded-like structure of STRBW. This finding is similar to the current study by [26] that found the morphology of potato peel cells has rough surface.

The EDX analysis clarifies the occupancy of a significant percentage of different elements in STRBW, as shown in Figure 3. Carbon (C), oxygen (O), potassium (K), calcium (Ca) and Magnesium (Mg) are detected where the percentage is 51.8 wt%, 44.5 wt%, 2.8 wt%, 0.5 wt% and 0.4 wt% respectively. Potassium ions are found to be the highest mineral composition in STRBW. Based on the literature, K ion has a stabilising impact on waster-sensitive shale formations, preventing swelling and dispersion [27].

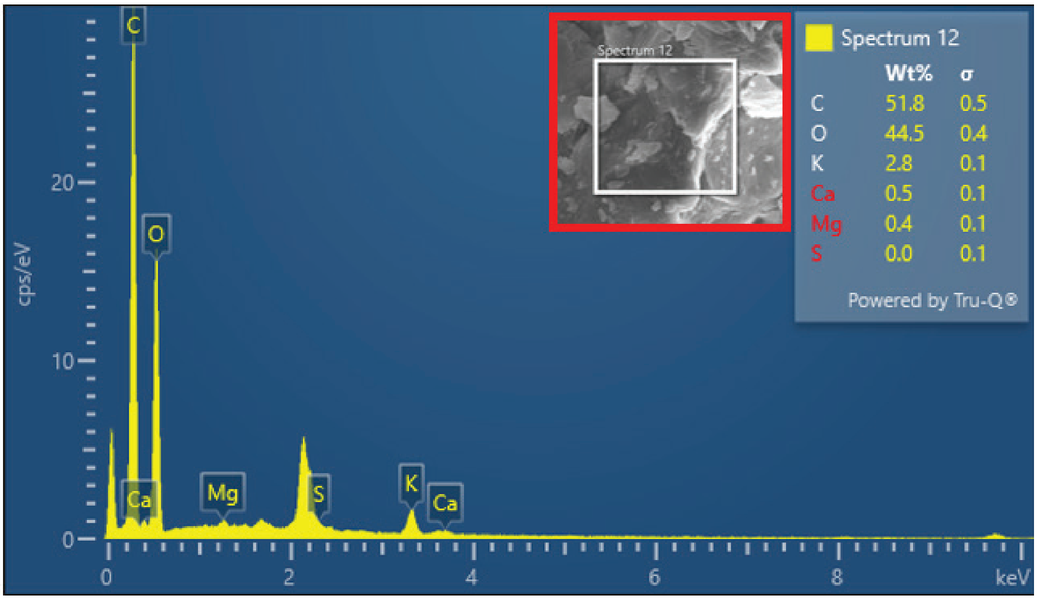

Figure 3 EDX analysis of STRPB

XRD

According to [28], starch can be classified into three types: A, B and C, depending on their crystalline structure. Strong diffraction peaks at 15° and 23° indicate A-type starch. On the other hand, B-type starch showed a strong diffraction peak at 17° also a low-intensity peak at 15°, 20°, 22° and 24°. C-type starch combines both types [29]. The XRD spectra of STRBW is shown in Figure 4. As can be seen, it is apparent that STRBW had a strong intensity peak at 17.1° and low-intensity peaks at 15.1°, 19.8°, 22.0° also at 23.9°. The trend corresponds with the B-type starch. The result obtained agreed with previous work carried out by [30] and [31]. Therefore, the existence of starch in STRBW has been confirmed through the analysis.

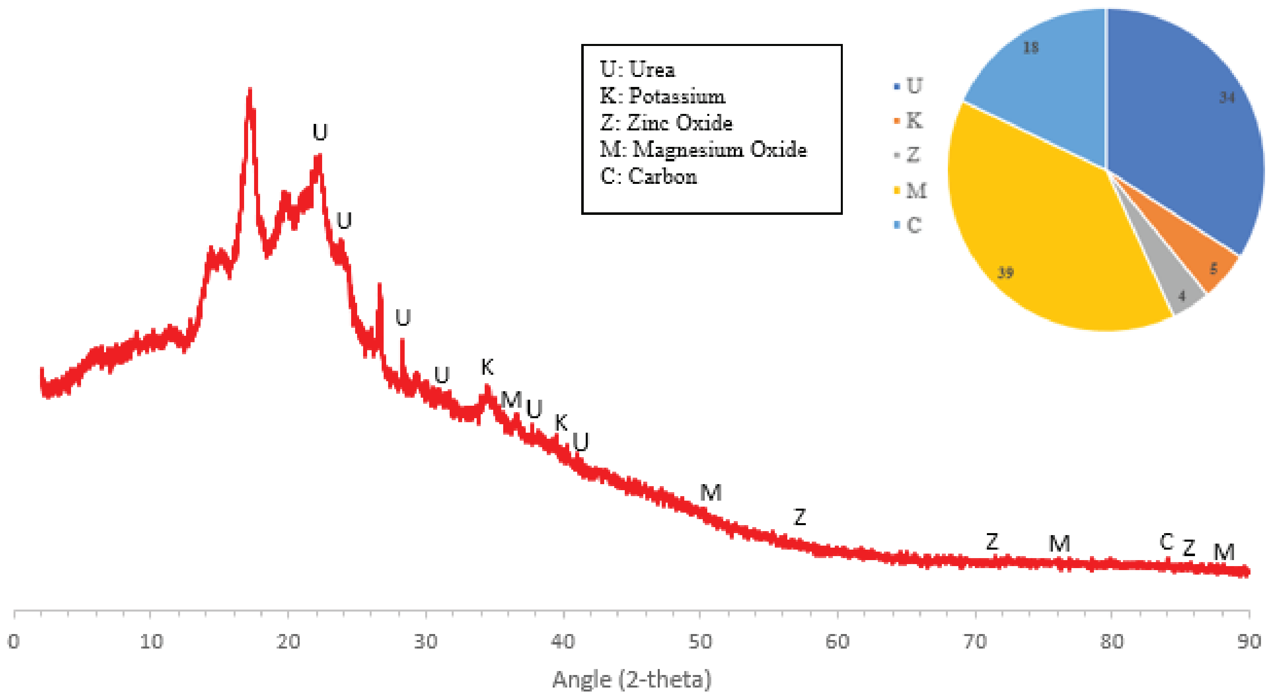

Figure 4 Chemical compound from XRD analysis

Table 1 Chemical compound in STRBW

Reference	Compound Name	Chemical Formula	SemiQuantity (%)	Application in Drilling Fluid
[32]	Potassium	K	5	Lower the hydration energy and swelling of clays, enhancing shales' stability
[33]	Zinc Oxide	ZnO	4	Maintain and stabilise rheological characteristics at high temperatures
[34]	Urea	$C_1H_4N_2O_1$	34	Improve fluid stability and prevent solids sagging
[35]	Magnesium Oxide	MgO	39	Enhanced hole cleaning
[36]	Carbon	C	18	Improved rheological properties

The mineralogy characteristics of STRBW measured by XRD analysis is shown in Table 1. The XRD test revealed that STRBW consists of several compounds, including potassium (K), zinc oxide (ZnO), urea ($C_1H_4N_2O_1$) and magnesium oxide (MgO).

Performance of PAC-LV and STRBW with the same Concentration

Rheological Properties

The properties of both fluid loss agents were tested in two conditions; before a hot roll (BHR) and after a hot roll (AHR). AHR was measured after the mud was kept in a rolling oven at 200°F and 100 psi for 16 hours. The result of AHR will commonly be emphasised in the analysis rather than BHR. This is because the process of hot rolling mud simulates the drilling operation where the mud will be exposed to high temperature and pressure. However, the BHR value is also needed as a comparison to AHR to ensure that the properties of mud after hot rolled was not completely dropped. The rheological properties of 1.2 wt% PAC-LV and 1.2 wt% STRBW measured by the FANN viscometer are shown in Figure 6. As can be seen, the rheological properties of PAC-LV and STRBW were found to be decreased after hot rolled. This decrease could be due to the effect of Xanthan Gum (viscosifier). It is expected that mud containing Xanthan Gum provides less viscosity under elevated temperature and pressure. A similar finding has been observed in a study [37]. However, although the mud has encountered degradation, AHR values showed that it still has a viscosifying ability even though it has been exposed to temperature and pressure. Therefore, the analysis of AHR can be further discussed.

PV was presented in Figure 6 to highlight the properties involved. Given the results obtained, the PV of PAC-LV is higher than STRBW. A possible explanation for the finding might be that PAC-LV contain more solid content in the same concentration than STRBW. The increase in solid content could be attributed to the product's density. PAC-LV has higher specific gravity than STRBW, which is 1.6 and 0.96 g/cc, respectively [38]. Thus, high density contains more solid particles, yielding a high PV in the drilling mud. Figure 6 also presents the same concentration yield point for PAC-LV and STRBW. It is apparent from the result that the YP of PAC-LV is higher than STRBW by 15%. YP indicates the amount of shear stress required to make the fluid move [39]. This result is likely related to the amount of solid content in both additives. As discussed, PAC-LV contains more solid that could affect the viscosity of the mud. Therefore, when the mud is more viscous, more stress required to initiate the fluid moving yields a higher the yield point.

Last but not least, Figure 6 compares the gel strength of mud containing PAC-LV and STRBW. Gel strength was measured at two different times, 10 seconds and 10 minutes. After 10 minutes, the gel strength was increased for both PAC-LV and STRBW. This result may be explained by the fact that the electrically charged particles which link together have created a stronger bonding over time to build a strong structure in the mud. Hence, more shear stress is required to break the bond after the mud is left at rest for a certain period of time.

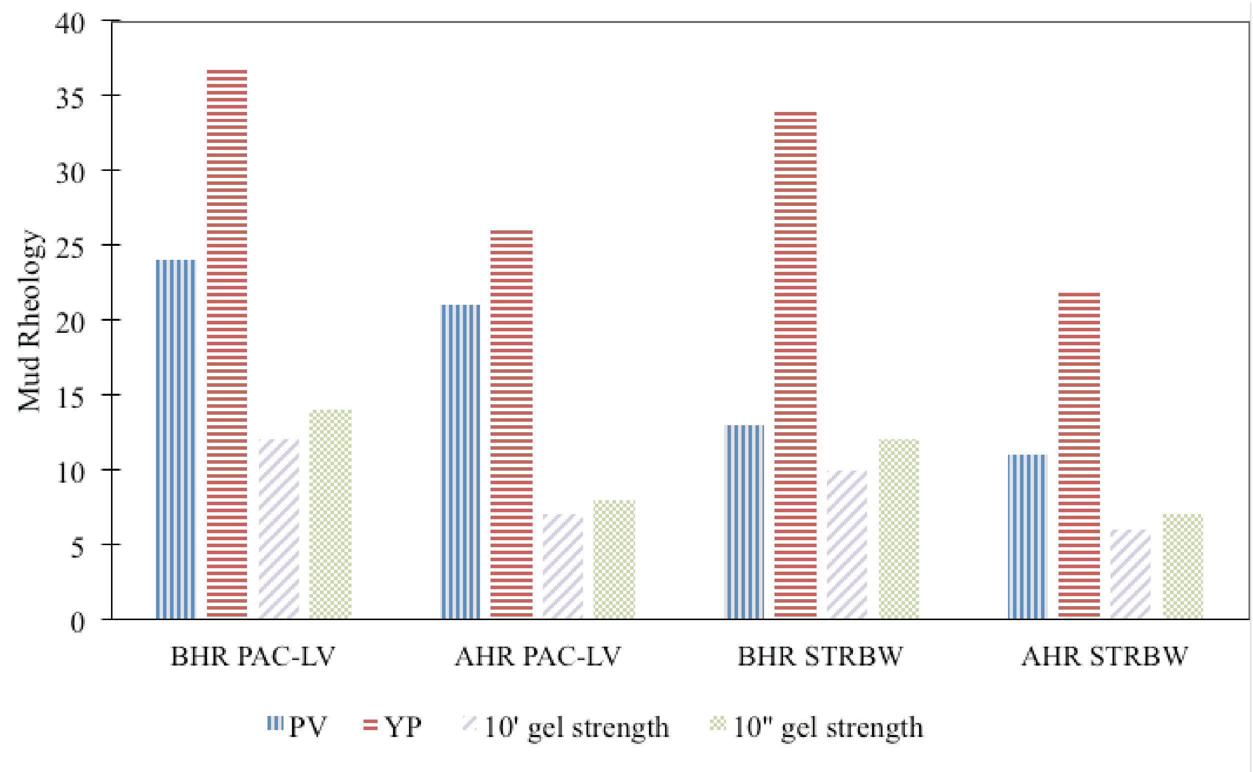

Figure 6 The effect of PAC-LV and STRBW on rheology

Filtration Properties

The API fluid loss and mud cake properties of PAC-LV and STRBW are presented in Table 2. After 30 minutes, 8.8 ml of mud filtrate was measured for mud containing PAC-LV. The fluid loss is increased by 18% when STRBW is used. Both muds have good mud cake properties, as shown in Table 2. Taken together, these results suggest that PAC-LV showed better performance on filtration properties than STRBW with the same product concentration. This result might be because of the effect of PV in the mud. PAC-LV was found to have a higher PV than STRBW, which indicates more solid content. Thus, stronger bonding of the solid particles creates a firm filter cake that could prevent excessive fluid loss [39] .

Table 2 Fluid loss and mud cake thickness of PAC-LV and STRBW

Mud Type	Fluid Loss (ml)	Mud cake thickness (inch)
PAC-LV	8.8	1/32
STRBW	10.4	1/32

Performance of Difference Concentration of STRBW

Rheological Properties

Figure 7 provides the result of PV, YP and gel strengths for different concentrations of STRBW. The result is somewhat surprising, where PV value appeared unaffected and remained unchanged at 11 cP for all muds. This finding was also found in the study that was done by[16], where the PV value was not affected as the product concentration increased. The possible reason that could lead to this result might be because, although the mass of STRBW is increased by magnitude, the amount of particles that could give an impact to the solid content is not adequate. Therefore, no increase in PV was detected. The result of YP was also presented in Figure 8. The increased values of YP from 1.2 to 2.2 wt% of STRBW can be observed. This result gives an indication that STRBW has enhanced the viscosity of mud as the concentration rises. At 2.2 wt%, a significant increase can be seen on YP by 37%.

Although high yield point improves drilling fluid's solids-carrying properties however, high YP also increased pressure drop in the well-bore, which could lead to greater ECD. Hence, taken together,

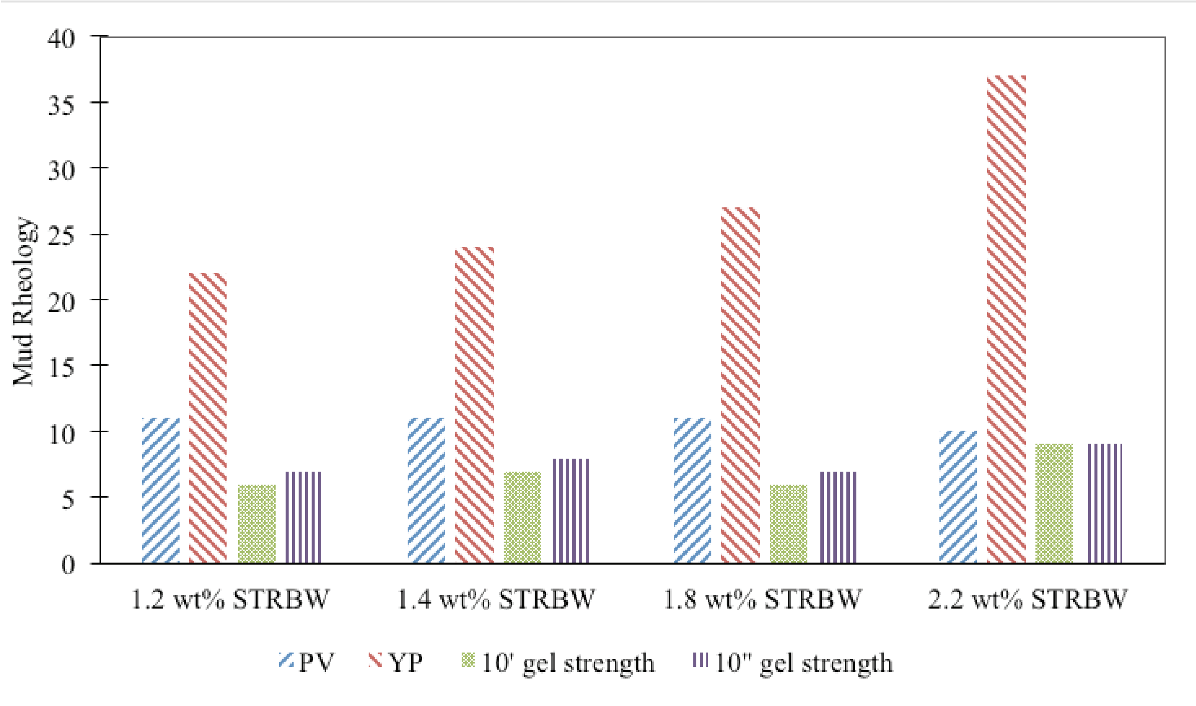

Figure 7 Effect of different concentrations of STRBW on rheology

1.8 wt% STRBW gives a better YP that reduces the possibility of well-bore damage. Figure 8 provides the gel strength values obtained from the FANN viscometer. It can be seen that all muds showed a flat gel property which is desirable in drilling fluid characteristics. The highest gel strength can be seen in 2.2 wt% STRBW, which is 9 lb/100ft^2. This is thought to be due to more particles of STRBW in the mud joined together to form a strong bond in the mud. Therefore, the higher pressure needed to break the structure shows a higher gel strength value.

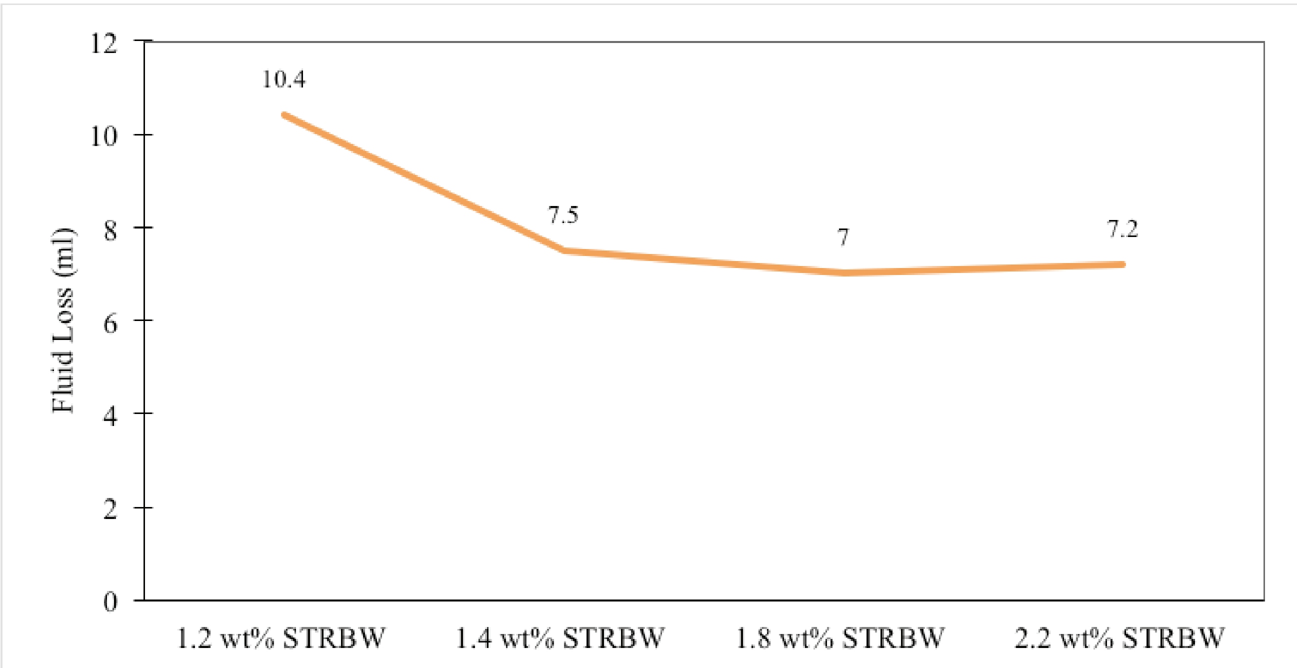

Figure 8 Effect of STRBW with different concentration on fluid loss

Filtration Properties

Generally, the mud samples produced lesser mud filtrate as the concentration of fluid loss additives was added. The trends for fluid loss volume of different STRBW concentrations are shown in Figure 8. According to these data, we can infer that the increment of STRBW up to 1.8 wt% gives better fluid loss volume. Filtration volume decreased by 28% in 1.4 wt% of STRBW, followed by 34% in 1.8 wt% of STRBW. At 2.2 wt% STRBW, the filtration volume is slightly increased by 4%. This outcome is contrary to previous studies, which have suggested that a higher concentration of potato peels yields lower filtration volume [40]. Thus, further work would be needed to confirm this result. The result collected the lowest volume of fluid loss from 1.8 wt% STRBW. This is believed to occur that a higher concentration (before saturation point) will yield a high accumulation of solid particles at the bottom of the equipment, which can prevent higher filtrate produced through filter paper. Once the additive saturation point is achieved, and no fluid loss reduction can be seen.

On the other hand, no changes of filter cake thickness can be seen when increasing the STRPB concentration from 1.2 wt% to 1.8 wt% STRBW. However, a slight increment of 2/32 was detected at 2.2 wt% STRBW. A similar finding has been observed [40], where a higher concentration of date-pit showed more minor improvement in filtration properties. The result in this section indicates that 1.8 wt% of STRBW shows an outstanding performance on filtration properties. It produced the lowest filtration volume and deposited a thin mud cake on filter paper that would cause less formation damage in the wellbore.

CONCLUSION AND RECOMMENDATIONS

This work was devoted to assessing the capability of STRBW to be used as environmentally friendly additive for water-based mud. STRBW presents several structural types, such as irregular, rough texture and smooth spherical surface. The temperature tolerance of STRBW was 287°C and it consists of C, O, K, Ca and Mg. From XRD spectra, the existence of B-type starch has been identified. This study showed that PAC-LV had a better performance on rheology and filtration properties than STRBW with the same concentration. Then, STRBW was experimented with in several concentrations, up to 2.2 wt%. An increased in yield point was obtained as the concentration of STRBW increased through the rheological testing. However, a minor effect was seen on plastic viscosity and gel strength, which could be due to the amount of solid particles in STRBW was insufficient to affect the solid content in the mud. It was found that the filtration properties could give a better result with a maximum of 1.8 wt% STRBW but could not be processed at higher STRBW content due to its saturation point. It is believed that the research objectives stated in the introduction have been met with the completion of this study. However, more detailed works need to be carried out to obtain more accurate results on the rheological and filtration properties. Some recommendations for future work are proposed as follows:

1. The chemistry of the mud compositions and their impact on reactive shale rocks might be the focus of future research.
2. Contamination with cations, oil, gases, water, and drilled solids are not tolerated by WBM-containing biopolymers. Further research is needed to identify the impact of mud contamination at various concentrations on mud compositions.
3. The effect of water-based mud containing STRBW on lubricity needs further investigation

ABBREVIATION AND NOMENCLATURES

AHR	After Hot Roll
BHR	Before Hot Roll
C	Carbon
Ca	Calcium
DTG	Derivation Thermogravimetry
EDX	Energy dispersive X-ray
FESEM	Field Emission Scanning Electron Microscopy
K	Potassium
Mg	Magnesium
O	Oxygen
PPP	Potato peels powder
TG	Thermogravimetry
XRD	X-ray Diffraction

REFERENCES

[1] A. S. Apaleke, A. Al-Majed and M. E. Hossain, "State of the art and future trend of drilling fluid: an experimental study", presented at the SPE Latin America and Caribbean petroleum engineering conference, 2012.

[2] M. F. Jamaludeen and M. A. M. Yusof, "MULTIPHASE DRILLING KICK ANNULAR FLOW BEHAVIOUR IN VERTICAL AND INCLINED WELL PROFILES", *Platform: A Journal of Engineering,* 5, 3, pp. 23-37, 2021.

[3] J. Nasser , A. Jesil, T. Mohiuddin, M. Al Ruqeshi, G. Devi, and S. Mohataram, "Experimental investigation of drilling fluid performance as nanoparticles", *World Journal of Nano Science and Engineering,* 2013.

[4] M. A. Md Yusof, N. Wahid, and N. H. Hanafi, "Usage of Nano Silica in Synthetic Based Mud: A Comparison Study for High Temperature High Pressure Well", presented at the Applied Mechanics and Materials, 2015.

[5] A. T. Bourgoyne, K. K. Millheim, M. E. Chenevert, and F. S. Young, "Applied drilling engineering", *Society of Petroleum Engineers Richardson*, 2, 1986.

[6] M. A. Md Yusof, and N. A. Mahadzir, "Development of mathematical model for hydraulic fracturing design", *Journal of Petroleum Exploration and Production Technology,* 5, 3, pp. 269-276, 2015.

[7] Y. A. Sokama-Neuyam, M. A., Yusof, and S. K. Owusu, "CO2 Injectivity in Deep Saline Formations: The Impact of Salt Precipitation and Fines Mobilization", *Carbon Sequestration,* 2022.

[8] M. Al-Saba, K. Amadi, K. Al-Hadramy, M. Dushaishi, A. Al-Hameedi, and H. Alkinani, "Experimental investigation of bio-degradable environmental friendly drilling fluid additives generated from waste", presented at the SPE International Conference and Exhibition on Health, Safety, Security, *Environment, and Social Responsibility*, 2018.

[9] S. Elkatatny, "Enhancing the rheological properties of water-based drilling fluid using micronised starch", *Arabian Journal for Science and Engineering,* 44, 6, pp. 5433-5442, 2019.

[10] M. Murtaza, S. A. Alarifi, M. S. Kamal, S. A. Onaizi, M. Al-Ajmi, and M. Mahmoud, "Experimental investigation of the rheological behavior of an oil-based drilling fluid with rheology modifier and oil wetter additives", *Molecules,* 26, 16, pp. 4877, 2021.

[11] N. Wahid, M. A. Yusof, and N. H. Hanafi, "Optimum nanosilica concentration in synthetic based mud (SBM) for high temperature high pressure well", presented at the SPE/IATMI Asia Pacific Oil & Gas Conference and Exhibition, 2015.

[12] A. T. T. Al-Hameedi, H. H. Alkinani, H. W. Albazzaz, S. Dunn-Norman, and M. M. Alkhamis, "Insights into the applications of waste materials in the oil and gas industry: state of the art review, availability, cost analysis, and classification", *Journal of Petroleum Exploration and Production Technology,* 10, 5, pp. 2137-2151, 2020. doi:10.1007/s13202-020-00865-w

[13] D.Hoornweg, P. Bhada-Tata, and C. Kennedy, "Environment: Waste production must peak this century", *Nature News,* 502, 7473, pp. 615, 2013.

[14] J. M. Links, "Municipal, industrial, and hazardous waste", 2006. [Online]. Available: https://silo.tips/download/municipal-industrial-and-hazardous-waste-jonathan-m-links-phd-johns-hopkins-univ

[15] A. T. Al-Hameedi, H. H. Alkinani, S. Dunn-Norman, M. M. Alkhamis, M. A. Al-Alwani, R. A. Mutar, & E. Salem, "Proposing a new biodegradable thinner and fluid loss control agent for water-based drilling fluid applications", *International Journal of Environmental Science and Technology,* 17, 8, pp. 3621-3632, 2020. doi:10.1007/s13762-020-02650-y

[16] M. Lins, R.Puppin Zandonadi, A. Raposo, and V. C. Ginani, "Food Waste on Foodservice: An Overview through the Perspective of Sustainable Dimensions", *Foods,* 10, 6, 2021. doi:10.3390/foods10061175

[17] A. T. T. Al-Hameedi, H. H. Alkinani, S. Dunn-Norman, A. M. M.lkhamis, and J. D. Feliz, "Full-set measurements dataset for a water-based drilling fluid utilising biodegradable environmentally friendly drilling fluid additives generated from waste", *Data Brief,* 28, pp. 104945, 2020. doi:10.1016/j.dib.2019.104945

[18] N. F. Fatihah Majid, A. Katende, I. Ismail, F. Sagala, N. M. Sharif, and M. A. Che Yunus, A comprehensive investigation on the performance of durian rind as a lost circulation material in water based drilling mud. *Petroleum,* 5, 3, pp. 285-294, 2019. doi:10.1016/j.petlm.2018.10.004

[19] Z.-L. Zhang, F.-S. Zhou, Y.-H. Zhang, H.-W. Huang, J.-W. Shang, L. Yu, W.-S. Tong, "A Promising Material by Using Residue Waste from Bisphenol A Manufacturing to Prepare Fluid-Loss-Control Additive in Oil Well Drilling Fluid", *Journal of Spectroscopy,* pp. 1-10, 2013. doi:10.1155/2013/370325

[20] S. Ghaderi, S. A. Haddadi, S. Davoodi, and M. Arjmand, "Application of sustainable saffron purple petals as an eco-friendly green additive for drilling fluids: A rheological, filtration, morphological, and corrosion inhibition study", *Journal of Molecular Liquids,* 315, 2020. doi:10.1016/j.molliq.2020.113707

[21] S. Liang, and A. G. McDonald, "Chemical and thermal characterisation of potato peel waste and its fermentation residue as potential resources for biofuel and bioproducts production", *Journal Agric Food Chem,* 62, 33, pp. 8421-8429, 2014. doi:10.1021/jf5019406

[22] A. Minajeva, A. Jasinskas, R. Domeika, E. Vaiciukevičius, E. Lemanas, and S. Bielski, "The Study of the Faba Bean Waste and Potato Peels Recycling for Pellet Production and Usage for Energy Conversion", *Energies,* 14, 10, 2021. doi:10.3390/en14102954

[23] R. Wing, "Non-chemically modified cornstarch serves as an entrapment agent", *Paper presented at the Proceedings of Corn Utilization Conference II, National Corn Growers Association*, 1988.

[24] E. F. Lessa, M. L. Nunes, and A. R. Fajardo, "Chitosan/waste coffee-grounds composite: An efficient and eco-friendly adsorbent for removal of pharmaceutical contaminants from water", *Carbohydrate Polymers,* 189, pp. 257-266, 2018.

[25] M. Poletto, J. Dettenborn, V. Pistor, M. Zeni, and A. J. Zattera,. Materials produced from plant biomass: Part I: evaluation of thermal stability and pyrolysis of wood. *Materials Research,* 13, 3, pp. 375-379, 2010.

[26] S. Wang, A. H.-M. Lin, Q. Han, and Q. Xu, "Evaluation of direct ultrasound-assisted extraction of phenolic compounds from potato peels", *Processes,* 8, 12, pp. 1665, 2020.

[27] K. Gillenwater, and C. Ray, "Potassium acetate adds flexibility to drilling muds", *Oil Gas journal, (United States),* 87, 12, 1989.

[28] R. Kong, J. Wang, M. Cheng, W. Lu, M. Chen, R. Zhang, and X. Wang, "Development and characterisation of corn starch/PVA active films incorporated with carvacrol nanoemulsions", *International Journal of Biological Macromolecules,* 164, pp. 1631-1639, 2020.

[29] J. Guo, L. Liu, X. Lian, L. Li, and H. Wu, "The properties of different cultivars of Jinhai sweet potato starches in China", *International Journal of Biological Macromolecules,* 67, pp. 1-6, 2014.

[30] L. Chuang, N. Panyoyai, L. Katopo, R. Shanks, and S. Kasapis, "Calcium chloride effects on the glass transition of condensed s ystems of potato starch", *Food Chemistry,* 199, pp. 791-798, 2016.

[31] Y. Ma, H. Zhao, Q. Ma, D. Cheng, , Y. Zhang, , W. Wang, J. Sun, "Development of chitosan/potato peel polyphenols nanoparticles driven extended-release antioxidant films based on potato starch", *Food Packaging and Shelf Life,* 31, pp. 100793, 2022.

[32] T. Al-Bazali, "Insight on the inhibitive property of potassium ion on the stability of shale: a diffuse double-layer thickness (κ−1) perspective", *Journal of Petroleum Exploration and Production Technology,* 11, 6, pp. 2709-2723, 2021.

[33] S. Medhi, D. Gupta, and J. S. Sangwai, "Impact of zinc oxide nanoparticles on the rheological and fluid-loss properties, and the hydraulic performance of non-damaging drilling fluid", *Journal of Natural Gas Science and Engineering,* 88, pp. 103834, 2021.

[34] A. Mohamed, S. Al-Afnan, S. Elkatatny, and I. Hussein, "Prevention of barite sag in water-based drilling fluids by a urea-based additive for drilling deep formations", *Sustainability,* 12, 7, pp. 2719, 2020.

[35] M. T. Alsaba, M. F. Al Dushaishi, and A. K. Abbas, "Application of nano water-based drilling fluid in improving hole cleaning. *SN Applied Sciences,* 2, 5, pp. 1-7, 2020.

[36] X. Meng, Y. Zhang, F. Zhou, and P. K. Chu, "Effects of carbon ash on rheological properties of water-based drilling fluids", *Journal of Petroleum Science and Engineering,* 100, pp. 1-8, 2012.

[37] C.Kim, and B. Yoo, Rheological properties of rice starch–xanthan gum mixtures. *Journal of Food Engineering,* 75, 1, pp. 120-128, 2006.

[38] K. B. Jeddou, F. Bouaziz, S. Zouari-Ellouzi, F. Chaari, S. Ellouz-Chaabouni, R. Ellouz-Ghorbel, and O. Nouri-Ellouz, "Improvement of texture and sensory properties of cakes by addition of potato peel powder with high level of dietary fiber and protein", *Food Chemistry,* 217, pp. 668-677, 2017.

[39] M. Wajheeuddin and M. E. Hossain, "Development of an environmentally-friendly water-based mud system using natural materials", *Arabian Journal for Science and Engineering,* 43, 5, pp. 2501-2513, 2018.

[40] J. Flsk, S.Shaffer, and S. Helmy, "The Use of Filtration Theory in Developing a Mechanism for Filter-Cake Deposition by Drilling Fluids in Laminar Flow", *SPE Drilling Engineering,* 6, 03, pp. 196-202, 1991.

[41] J. K. Adewole and M. O. Najimu, "A study on the effects of date pit-based additive on the performance of water-based drilling fluid", *Journal of Energy Resources Technology,* 140, 5, 2018.