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Effect of particle size of wheat on the rheological and filtration properties of the drilling fluid

Bachelor thesis

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Anotace:

Vrtná kapalina představuje důležitou součást rotačního vrtání díky její schopnosti odvádět odštěpky hornin na povrch, čímž zabraňuje vnikání formovacích kapalin do vrtu. Obvykle se k optimalizaci souvisejících vlastností vrtných kapalin používaly některé chemikálie a nanomateriály. Tato studie se zaměřuje na formulaci nanobiodegradabilních vrtných kapalin z pšeničného prášku v různých koncentracích (0.5, 1 a 2 % hmot.) a velikostech částic (nano-velikost 75, 150, 300 a 600 mm). Nanobiopolymer z pšenice byl připraven technikou kulového mletí a charakterizován pomocí SEM, FTIR, DLS, TGA a DSC. Vliv pšenice byl zkoumán provedením několika experimentálních testů reologických a filtračních měření za různých teplotních podmínek 25, 50 a 70 °C. Získané výsledky ukázaly, že pšeničný prášek všech různých velikostí má vliv na reologické vlastnosti včetně plastické viskozity, meze kluzu a pevnosti gelu. Tyto vlastnosti se zvyšují s rostoucí velikostí a koncentrací částic pšenice. Tento účinek je dominantnější při vyšších teplotách, např. 50 a 70 °C. Použitá biologicky odbouratelná přísada navíc umožnila snížit tloušťku filtračního koláče o 50 % z 5 na 2.5 mm při použití velikostí 75 a 150 mm a koncentrace 2 % hmot. Vlivem pšenice při velikosti 150 mm a koncentraci 2 % hmot. se také výrazně snížila rychlost filtrace vrtné kapaliny z 19.5 na 11.5 cm3.

Anotation:

Drilling fluid is a crucial part of the rotary drilling operation due to its functions in carrying rock cuttings to the surface and preventing formation fluids to enter the wellbore. Conventionally, several chemicals and nanomaterials were applied to optimize the related properties of the drilling fluids. This study focuses on formulating nano-biodegradable drilling fluids from wheat powder at different concentrations (0.5, 1 and 2 wt.%) and particle sizes (nano-size, 75, 150, 300 and 600 μm). The nano-biopolymer of wheat was prepared using ball milling technique and characterized using SEM, FTIR, DLS, TGA and DSC. The impact of the wheat was investigated conducting several experimental tests of rheological and filtration measurements under different temperature conditions of 25, 50 and 70 °C. The obtained results showed that wheat powder at all different sizes has an impact on the rheological properties including plastic viscosity, yield point and gel strength. These properties are increased with increasing the size and concentration of the wheat particles. This effect is more dominant with higher temperature, such as 50 and 70 °C. In addition, the used biodegradable additive enabled to reduce the thickness of the filter cake by 50% from 5 to 2.5 mm using 75 and 150 μm sizes and 2 wt.% concentrations. The filtration rate of the drilling fluid is also highly reduced from 19.5 to 11.5 cm^3 under the influence of wheat at 150 µm size and 2 wt.% concentration.

Klíčová slova: Filtrační koláč, Ztráta tekutiny, Reologické vlastnosti, Pšenice, Vrtná kapalina.

Keywords: Filter cake, fluid loss, rheological properties, wheat, drilling fluid.

Number of pages: 42
Number of annexes: 0

Declaration

I declare that I have prepared the bachelors thesis myself and that I have stated all the used information resources in the thesis.

In Olomouc, June 26,2023 Dlovan Yaseen Abbas

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AV	Apparent Viscosity
BHA	Bottom Hole Assembly
CMC	Carboxymethyl Cellulose
CNM	Cellulose Nanofibers
DLS	Dynamic Light Scattering
DSC	Differential Scanning Calorimetry
ECD	Equivalent Circulating Density
FTIR	Fourier-Transform Infrared Spectroscopy
LCM	Lost Circulation Material
NPT	Non-Productive Time
PPG	Pounds Per Gallon
PV	Plastic Viscosity
SEM	Scanning Electron Microscopy
TEM	Thermal Scanning Microscopy
TGA	Thermogravemetric Analysis
YP	Yield Point

1. Introduction

The demand for oil and gas has experienced an increase due to the necessity for cost-effective methods of extraction and acquisition. However, it is imperative that the drilling procedure adheres to strict safety protocols, prioritizes environmental sustainability, and remains economically viable. Numerous challenges arise throughout the drilling and production processes within the petroleum industry. In the event of fluid flow within the borehole, such as drilling fluid or completion fluid, there is a possibility of underground loss to the subsurface formation. Fluid loss is widely acknowledged as a significant issue that occurs during the majority of drilling operations. The significance of fluid loss increases as the differential pressure and circulation rate between the flowing fluid and the wellbore escalate.

Nanotechnology possesses significant potential for driving substantial advancements, particularly in addressing various challenges within the oil and gas industry, when applied to drilling technology. The integration of drilling fluid techniques and nanomaterial studies has resulted in the identification of unique properties and functions of nano-additives in drilling fluids. These include enhanced filtration, improved removal of cuttings, reduced friction, increased stability of wellbore formations, and enhanced speed, safety, and quality of drilling operations in challenging environments. Ikram and Vejpravova (2021) claims that the nanomaterials have demonstrated favorable outcomes in the realm of oil and gas exploration. These materials have exhibited enhanced efficiency and increased success rates, while also contributing to the overall safety of drilling operations. According to Al-Yasiri and Al-Sallami (2015), the incorporation of nanomaterials, specifically nanoparticles, into drilling fluids enhances their rheological and filtration properties.

In order to perform the cleaning of a drilled well, it is necessary to introduce a carefully measured combination of a base fluid and additional components into the drilling mud. According to Agwu et al. (2021), some of the drilling-related responsibilities of the system include cuttings conveyance, drill string cooling and lubrication, wellbore wall stability, and formation pressure management. A mud window is employed to determine the pressure differential between the pore pressure and the mud pressure, which is crucial for ensuring mechanical stability of the wellbore, as outlined by Vajargah and Oort (2015). The process of drilling oil and gas wells entails incurring supplementary expenses due to the occurrence of drilling fluid losses and complications arising from lost circulation. Based on the findings of Feng and Gray (2018), it has been observed that lost circulation has a significant impact on approximately 20% to 25% of drilling wells worldwide. In addition, effectively managing and mitigating circulation loss presents a significant challenge for the organization.

Additional consequences that may arise include the loss of drilling time, the occurrence of stuck drill pipe, the potential plugging of formations that could yield productivity, the excessive inflow of water, the excessive caving of formations, and the occurrence of blow-outs. These outcomes contribute to an increase in non-productive time (NPT) and drilling costs. The following references have been cited: Lavrov (2016), Yang et al (2020), Xu et al (2021), and Albattat and Hoteit (2021). Wells are frequently abandoned as a result of their failure to reestablish circulation (Howard and Scott, 1951). According to Naybergs study conducted in 1987, it has b een observed that drilling fluid solids might not be adequate in effectively sealing gaps within fractured or massive void formations. Lost circulation can be encountered during the drilling process or during excursions when there are sudden increases in pressure as the drill pipe or casing is being lowered into the wellbore. The drilling fluid level in the annulus may decrease following lost circulation events, contingent upon the formation pressure, prior to reaching a stable level according to Naybergs study conducted in (1987).

1.1.Research objectives

The primary objective of this report is to enhance the quality of the drilling fluid through the utilization of environmentally friendly and sustainable materials. This will be achieved by pursuing the following objectives:

- The process involves the preparation of wheat powders derived from wheat grains of varying sizes, encompassing five distinct categories.
- Characterization of the wheat nanobiopolymer.
- Assess the impact of the prepared wheat nanobiopolymer on the rheological and filtration properties of the drilling fluid.
- Conduct a study on the effects of synthesized wheat on the functionality of biodegradable drilling fluid.

1.2. Report outlines

The report consists of five chapters. Firstly, chapter one comprises an introduction, research objectives, and report outlines. Additionally, chapter two consists of the background and literature review, which encompasses various aspects such as the drilling process, drilling fluid, properties of drilling fluid, additives, and borehole problems. Furthermore, the third section encompasses the materials and methodology employed in this study. This chapter focuses on the materials, preparation of wheat nano-polymer, the preparation of drilling fluids, the measurement of filtration properties, and the assessment of rheological characteristics. As a result, the fourth chapter will comprise an analysis of the findings and a comprehensive discussion. Lastly, the final section will encompass the conclusion, recommendations, and references.

2. Background and Literature Review

2.1. Drilling process

Drilling is a method employed to fracture different types of rocks and extract underground minerals through the use of a diverse range of tools. It is of utmost importance within the oil, gas, and geothermal industries. Due to the significant expenses associated with drilling operations, it is imperative to optimize drilling efficiency (Gan et al., 2022). In addition, the drilling process commences when a drilling rig penetrates multiple layers of soil and rock, and eventually reaches the oil and gas reservoir where the oil is contained. In order to reduce potential issues, it is necessary to stick to a set of prescribed steps.

The initial phase involves the preparation of the rig site, which involves the organization and arrangement of wells, pads, and roads. Subsequently, the drilling operation commences, applying a drill bit to penetrate the well. This is then followed by the crucial steps of cementing and testing, which are undertaken to guarantee the absence of any oil or gas leakage during the entirety of the process. In addition, the process of well completion involves the careful lowering of perforated guns into the borehole, followed by their activation to create openings in the casing. These openings help the smooth flow of oil and gas to the wellbore. Upon reaching the production phase, we start the extraction of oil. Once the entire oil reservoir has been fully exploited, we proceed to conclude the process by executing the final step of abandonment and land restoration.

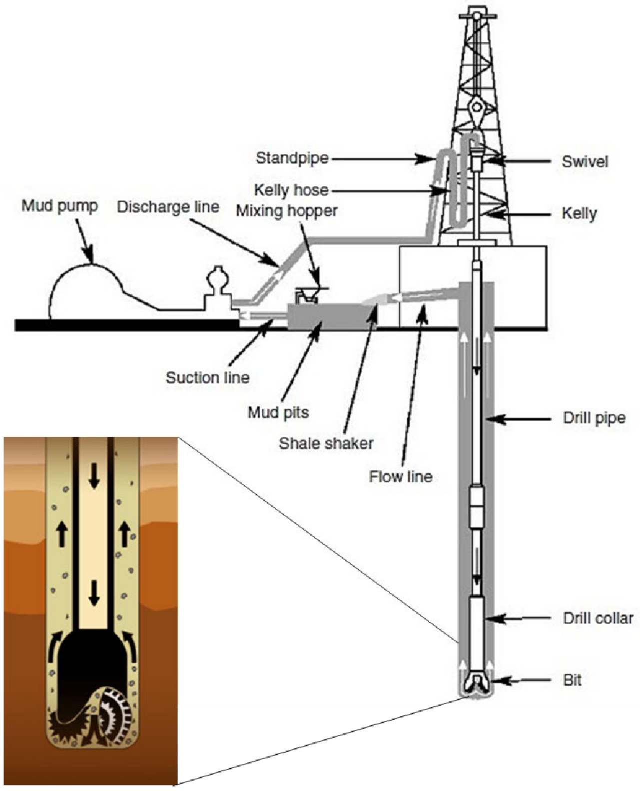

Figure 1 Drilling process circulating system (Eritia, 2015).

2.2. Drilling fluid

According to Davoodi et al. (2023), drilling fluids consist of a combination of water, bentonite, weighing additives, and chemicals. These components are carefully produced and conditioned in surface tanks or pits before being circulated throughout the wellbore during drilling operations. Drilling fluid, commonly referred to as drilling mud, serves seven primary functions. The purpose of this process is to effectively clean the wellbore, ensuring that the bit teeth can efficiently penetrate the formation and remove cuttings. This allows the teeth to achieve an appropriate depth when inserted into the formation. Additionally, the drilling fluid serves the purpose of cooling and lubricating the drill string during the rotation of drilling components, which generates significant heat. This elevated temperature can result in increased wear on the drill string and bit. Furthermore, the process of lubrication occurs when drilling fluid is introduced into the borehole in order to prevent pipe sticking.

Another crucial function of drilling fluid is its ability to remove cuttings from the annulus and transport them to the surface for proper disposal. As a result, the utilization of drilling fluid aids in the preservation of wellbore stability. When the drilling mud encounters a permeable formation under high pressure, it enters the porous spaces within the formation, leaving a residual mud cake. These mud cakes serve to prevent potential breaks and safeguard the integrity of the wellbore walls. In addition, the drilling fluid serves the purpose of regulating formation pressure. This is achieved by the mud generating hydrostatic pressure in the wellbore, which ultimately offsets the existing formation pressure. In the event that the density (mud weight) of the drilling fluid decreases below the standard level, there is a possibility of a kick occurring, which, if left uncontrolled, may result in a blowout. Finally, the drilling fluid serves the purpose of conveying valuable data regarding the formation. This is achieved through the analysis of the cuttings that are extracted to the surface. Additionally, the drilling fluid effectively suspends the cuttings when the pumping process is stopped.

When the drilling fluid exits the drill bit and returns to the annulus at a different location on the drill string, it creates a new annulus. The drilling process involves two main functions: the removal of drill cuttings from the borehole and the prevention of fluid ingress into the borehole. Given that numerous challenges arise during the drilling of a well, many of which are linked to the fluids used, it is of utmost importance to ensure the appropriate selection or modification of drilling fluids to effectively fulfill their intended purpose in the drilling process. Based on estimations, the expenditure associated with mud purchasing could potentially account for up to 10% of the overall expenses paid in the drilling process. Although it may seem expensive, neglecting to maintain proper mud qualities can lead to drilling challenges that require a substantial amount of time and, consequently, expense to resolve if not addressed correctly, as stated by Azar (2007).

During the drilling process, drilling fluids or muds are employed to aid in the transportation of fluids from the surface to the drill bit, and subsequently back to the surface through the annulus. Due to the significant financial consequences associated with poor mud quality, many operating companies choose to hire a drilling fluid specialist, commonly referred to as a "mud engineer." These professionals are responsible for overseeing the rigs mud operations, including the preparation, monitoring, and treatment of the mud as required.

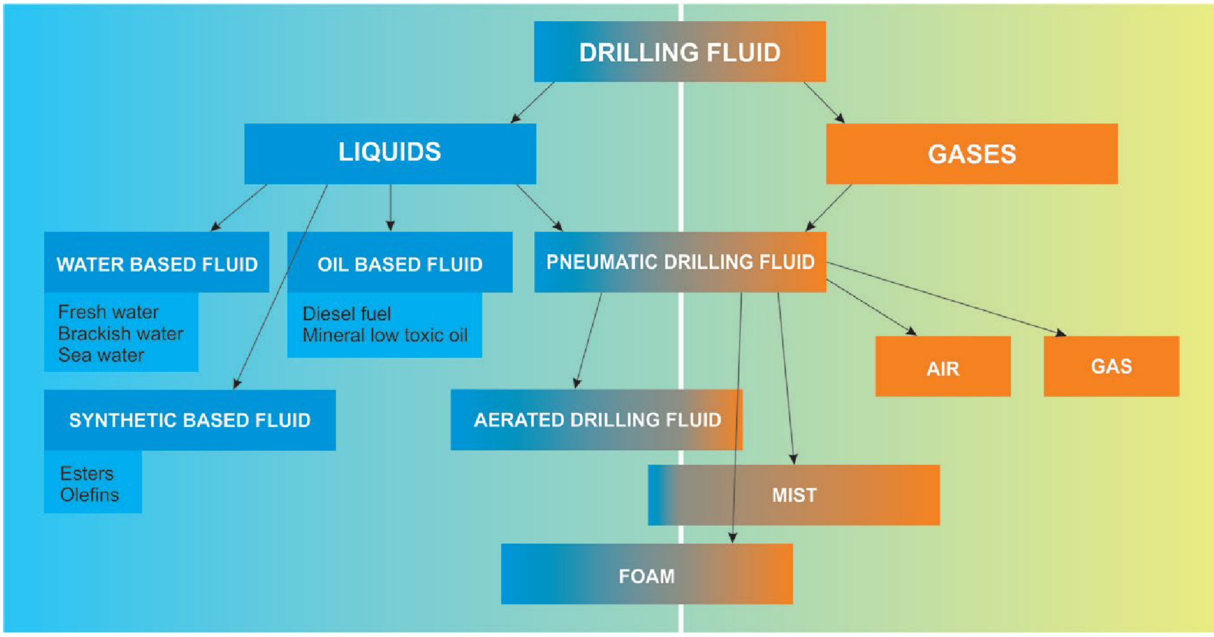

Figure 2 Drilling fluids (Paulauskiene, 2018).

2.3. Properties of drilling fluid

The density of mud is a critical physical and chemical characteristic of drilling fluids, which play a vital role in optimizing the rotary drilling process. It aids in the prevention of formation fluid inflow, preservation of wellbore stability, provision of hydraulic energy, elimination of drilled solids, and the promotion of solids and gas segregation at the surface. The chemical characteristics of drilling fluids encompass various aspects, such as formation damage, changes in rheological properties, and challenges in cuttings transport. The mud density, measured in pounds per gallon (PPG), is utilized in drilling operations to regulate hydrostatic pressure. The resistance encountered by fluid flow within a system is commonly referred to as internal resistance. This internal resistance is primarily determined by the fluids viscosity, which can be further classified into two components: funnel viscosity and plastic viscosity. Having a comprehensive understanding of these factors is crucial for ensuring the success of drilling operations.

- **Rheological properties**

Rheology is an academic discipline that focuses on the analysis of deformation or flow characteristics of substances. In the context of the drilling process, rheology plays a crucial role in evaluating the properties of the drilling fluid. The rheological properties involve plastic and apparent viscosity, yield point, and gel strength. According to Ge et al. (2023), the rheological properties of dough made from wheat flour play a crucial role in determining its processing characteristics, which in turn have a significant influence on the final products.

- **Filtration properties**

Filtration occurs when an operational unbalanced exists between the mud and formation. To be more precise, formation damage occurs when drilling fluid infiltrates the porous formation, thereby reducing permeability in the region of the wellbore. The usage of drilling fluids that possess insufficient filtration properties can result in various challenges. These challenges include the risk of drill-pipe sticking due to the formation of a thick fluid cake on the wellbore wall, high swab and surge pressures, as well as the application of excessive torque and drag on the drill string (Yuxiu et al., 2016; Parizad et al., 2018).

- **Density**

The density of the drilling fluid is mud weight and its measured using a mud scale or mud balance. The unit of density is pounds per gallon (lb/gal) or ppg. Normally a mud can have a density of 22ppg to 23 ppg. Complex difficulties such as lost circulation or well collapse are typically encountered during the deep well drilling process due to the challenging flow of high-density drilling fluid, substantial circulating resistance, and high swabbing pressure according to Wang et al. (2023). Consequently, improving the performance of high-density drilling fluid is critical to ensuring safe and speedy deep-well drilling (Bageri et al., 2022; Mao et al., 2015). Lastly, Equivalent Circulating Density (ECD) is measured by the following equation where d is the mud weight (ppg), P is the pressure drop in the annulus between depth D and the surface (psi), and D is the vertical Depth(feet).

$$ECD = d + \frac{P}{0.052(D)} \quad \text{(Eq.1)}$$

2.4. Additives

Chemicals that are often added to drilling fluids to change their properties are bad for both the environment and the health and safety of workers. Additives that are sold in stores are made of non-biodegradable materials that damage the environment when they are dumped. Al-Hameedi et al. (2019) say that new biodegradable drilling fluid ingredients are urgently required to improve the quality of drilling fluid while lowering risks to the environment and the health of workers. Aboulrous et al. (2016) claim that it is possible to reduce the amount of drilling fluid that gets into porous rocks by using fluid loss fillers made from cellulose. Due to their stickiness, polymeric materials, especially superabsorbent materials and rubber, can help cut down on circulation loss when cutting.

Polymeric cellulose components, such as guar gum and starch, are widely available and cost-effective. Carboxymethyl cellulose (CMC), a cellulose derivative, is formed by the addition of carbonyl groups to the hydroxyl groups of glucopyranose monomers. Guar gum consists of two monosaccharides, namely galactose and mannose. Starch and other anhydro glucose polymers can be found naturally occurring in various sources. It is worth noting that this particular biomass is the second most abundant in nature, following cellulose. Additionally, it consists of two main weight components. According to the analysis, the composition consists of a linear polymer called amylose and a branched polymer known as amylopectin. Simultaneously, the claims possess characteristics of both amorphous and crystalline nature. According to Alsabagh (2014), Food waste byproducts, such as banana peels and potato peels, have the potential to significantly influence the filtration and rheological properties of mud.

According to Al-Hameedi et al. (2019), grass waste can be used to regulate filtration properties and mud rheology. According to Al-Hameedi et al. (2019), it has been observed that the addition of black sunflower seed shell powder does not have any impact on the density of drilling fluid. Therefore, it is possible to use larger quantities of this powder for addressing partial losses. Fluid losses can potentially occur when a fluid substance makes contact with a permeable structure. The fluid loss is determined by the porosity and permeability characteristics of the formation. In certain instances, a notable quantity of oil technology fluids may be lost due to their considerable expense. In addition to environmental conservation, there exist additional justifications for preventing fluid loss.

In most water-based muds, clays are the dominant fluid loss agent (also known as filtrate-reducing agents). This is critical information for drilling and completion fluids, fracturing fluids, and cement slurries. The amount of fluid that can be lost is determined by the formations porosity and permeability. Because of the high cost, a substantial number of oil technology fluids are lost at times. There are additional reasons to avoid fluids from being lost besides saving the environment. Clays are the major fluid loss factor in most water-based muds (also known as filtrate-reducing agents). This will result in a filter cake with low permeability and porosity. It is probable that using centrifuges or cyclones to remove microscopic particles will cause filtering concerns. The starch is manufactured in such a way that it gelatinizes and swells fast as a fluid loss agent. Water-soluble polymers are commonly used as viscosifiers, which reduce fluid loss by acting on the fluid phase. It is a polymerized organic colloid with a long chain structure that may be polymerized into different lengths or grades. Clay particles can be covered with a coating, or long chains can be curled into balls and utilized as plugs. A polyanionic cellulose is utilized as a fluid loss agent in low-solids drilling fluids with high salt contents Faruk (2012).

2.4.1 Conventional materials

There are some essential conventional materials in the drilling process.

- **Alkalinity and pH Control** are designed to control the degree of acidity or alkalinity of the drilling fluid and its most common are lime, caustic soda and bicarbonate of soda (Paulauskiene, 2018).
- **Bactericides** are used to reduce the bacteria count and it's found on paraformaldehyde, caustic soda, lime and starch preservatives are the most common. The combined use of multiple organic bactericides can effectively decrease the quantity of bactericides required, while also enhancing their bacteriostatic performance (Smilanick et al., 2008).
- **Calcium Reducers** are used to prevent, reduce and overcome the contamination effects of calcium sulfates (anhydrite and gypsum) and its most common are caustic, soda, soda ash, bicarbonate of soda and certain polyphosphates.
- **Corrosion Inhibitors** are composed of heteroatoms, such as oxygen, nitrogen, sulfur, and phosphorus, which possess multiple bonds that serve as adsorption centers. These inhibitors have demonstrated remarkable effectiveness in preventing corrosion (Palimi et al. 2023). Corrosion inhibitors are used to control the effects of oxygen and

hydrogen sulfide corrosion and hydrated lime and amine salts are often added to check this type of corrosion and usually oil-based muds have excellent corrosion inhibition properties.

- **Filtrate Reducers** are used to reduce the amount of water lost to the formations and the most common are bentonite clays, CMC (sodium carboxymethylcellulose) and pre-gelatinized starch. The molecular chain of the filtrate reducer is adsorbed on the surface of the bentonite particles through van der Waals forces and hydrogen bonding. This leads to the formation of a weak gel network structure, creating a bridging effect between the particles. As a result, the small bentonite particles are prevented from entering the formation. The rapid formation of a thin and compact filter cake occurs at the borehole as a result of the pressure differential. The application of this technique can efficiently stabilize the wall of the open borehole, thereby minimizing reservoir damage caused by decreasing the filter loss of the drilling fluid according to Luo et al. (2023).
- **Shale-Control Inhibitors** are used to control the hydration, caving and disintegration of clay/shale formations and its commonly used in gypsum, sodium silicate and calcium lignosulfonates (Rana et al., 2019). These shale inhibitors work as anti-swelling agents by reducing dispersion and clay-water interactions according to Muhammed, (2021).
- **Surfactants** are used to reduce the interfacial tension between contacting surfaces (oil/water, water/solids, and water/air). Oil-in-water include emulsification in base fluid formulations; shale-swelling inhibitors to reduce wellbore instabilities; detergency to prevent cuttings clinging to drill bit (clay adherence to metal parts); differential sticking prevention; dispersants to inhibit clay particle flocculation. On the contrary, In water-based drilling fluids, there is a continually-growing variety of applications that include: oil-in-water emulsification in base fluid formulations; hale-swelling inhibitors to prevent wellbore instabilities; detergency to prevent cuttings sticking to drill bit (adhesion of clay to metal parts);prevention of differential sticking; dispersants to inhibit flocculation of clay particles; foaming additives, to generate high gas/water ratio foam used as drilling fluids for low-pressure reservoirs and hard-rock drilling; defoaming additives to eliminate undesirable foam in water-based fluids;

surfactant-polymer complexes for enhanced properties in fluids for low-pressure reservoirs (Quintero, 2002).

- **Weighting Agents** Calcium carbonate and barite are essential materials in mud density control additives, such as BaSO4. These materials combine water, clay, and barite to generate mud density ranging from 9 ppg to 19 ppg. API barite is a density-controlling component used in oil-based mud, while calcium carbonate (CaCO3) may be used in some cases. Oil-based mud settles more slowly due to lower gel strengths of barite, making LCM essential for preventing drilling fluid leakage into weak formations or thief zones. The materials fibrous or flaky texture allows it to patch down places where drilling fluid is lost according to Caenn and Gray (2011). LCM must be added to the drilling fluid to fill the thief zones, pores, and gaps that the mud alone cannot. To do this, the fluid must include particles big enough to attach to the largest apertures.
- **Thinners** were initially used to reduce flow resistance and avoid the development of gels. Modern dispersants and thinners, on the other hand, are employed to improve fluid leakage control. Thinners in clay-based drilling fluids include plant tannins, lignitic chemicals, lignosulfonates, and low molecular weight synthetic water-soluble polymers as its stated in Hossain and Al-Majed (2015). The thinners can minimize filtration and cake thickness, as well as the influence of water on drilled formations and oil emulsion stability at high temperatures.
- **Deflocculants** Viscosifying substances form a colloidal suspension in water, increasing viscosity, yield point, and gel strength through inter-surface friction and chemical water binding. These versatile additives can change viscosity, adjust filtering properties, and prevent clay flocculation, ensuring a smooth and efficient suspension. Since bentonite, CMC, PAC, Xanthan gum, and Guar Gum are frequently use in drilling fluid viscosity calculations (Hossain and Wajheeuddin, 2016). Sodium hydroxide (NaOH), a caustic chemical, is the principal element needed to keep the muds pH raised. The prevention of corrosion and hydrogen embrittlement is critical. The pH of most muds ranges between 9.5 and 10.5, however this might vary. Ca(OH)2 and slaked lime, KOH, are more options.

2.4.2 Biodegradable (waste, natural polymer) materials

According to Sami (2016), it is possible to replace various chemical additions in the oil and gas sector, including exploration, biofuels, drilling, and completion, with biodegradable materials such as food and plant wastes. Having an advanced understanding of chemical biodegradability is crucial when making environmental protection decisions related to the extensive range of compounds used in drilling operations. Both anaerobic and aerobic biodegradation processes can take place. However, in the case of contamination that is well dispersed in water, aerobic biodegradation is more probable. The biodegradability of a petroleum product is influenced by the chemical structure of its individual components. The biodegradability of a compound is inversely proportional to its molecular weight.

Petroleum hydrocarbons with higher solubility and lower molecular weight generally exhibit greater biodegradability compared to hydrocarbons that are less soluble and have higher molecular weight. It is widely believed that the viscosity of a substance has a significant impact on its biodegradability. According to Nrior and Alabo (2017), the slow breakdown of highly viscous hydrocarbons can be attributed to the inherent physical challenges in establishing contact between contaminants and the components of microbes, nutrients, and electron acceptors. The use of drilling fluids composed of biodegradable materials is of significant importance due to their capacity to undergo spontaneous and safe decomposition into their constituent molecules when subjected to treatment with water and completion mud. Biodegradable fluids offer numerous advantages compared to petroleum-based fluids, including the one mentioned here. One additional benefit of biobased fluids is their comparable, if not superior, performance to conventional drilling fluids.

There are several strategies available to mitigate the expenses associated with drilling operations. Enhancing the lubricity of biobased fluids can potentially lead to a reduction in drilling time. This improvement allows smoother drilling through rock formations, resulting in increased efficiency. Moreover, the enhanced lubricity helps maintain optimal operating temperatures for the drill bit, enabling extended drilling durations. Furthermore, the enhanced lubricity also presents the advantage of minimizing wear on drilling equipment. Upon completion, a significant volume of drilling fluids is utilized, and an unintentional leakage of stated fluids transpires. This issue is of significant concern. To mitigate the adverse environmental impact resulting from fluid leakage and spillage, it is recommended to employ biobased and biodegradable drill fluids. The release will result in a significantly reduced environmental impact as well as a more expedient post-release cleanup process.

Biobased biodegradable drill fluids may also help with relationships with government agencies because they are biodegradable. Biobased lubricants, hydraulic fluids, and cleansers are allowed because of Federal Purchasing Requirements that require government agencies and their contractors to utilize certified biobased goods whenever possible. Every year, 140 billion metric tons of natural polymers are created as waste from agricultural, household, and industrial processing operations across the world. If this vast amount of materials is used, upstream operations in the oil and gas industries will provide a better and less expensive alternative to waste management and environmental harm Adewole and Muritala (2019).

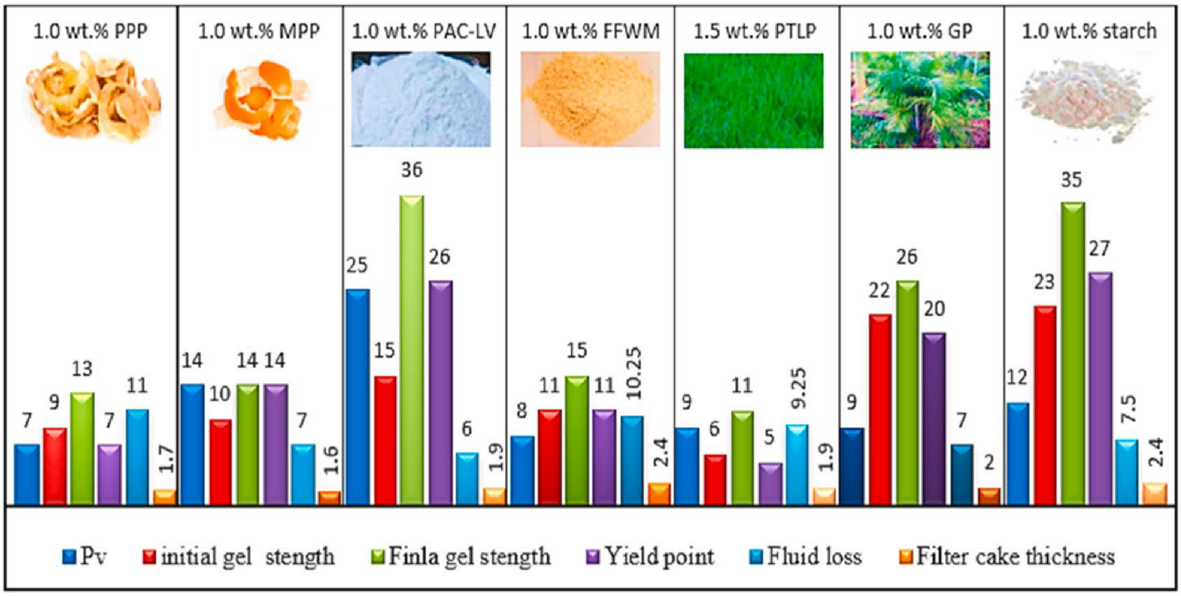

Figure 3 Biodegradable materials images used in previous works and their influences on the rheological and filtration properties (Tahr et al., 2023).

2.4.3 Nanomaterials

There is a growing interest among oil and gas companies in making use of nanomaterials to enhance the performance of drilling fluids. Nanomaterials within the size range of 1 nm to 100 nm have been used to enhance the rheological properties of drilling fluids. The utilization of nanomaterials-based drilling fluid has the potential to significantly reduce friction between the borehole and drill pipe by forming a thin coating on the drill pipe. In order to enhance drilling efficiency, it is possible to apply microscopic spherical nanoparticles in combination with thin lubricating layers to create a barrier between the borehole wall and the pipe. The enhanced mobility of the drill pipe is made possible by using of nano-sized ball-bearing surfaces. According to a study conducted by Ikram and Vejpravova (2021), the addition of nanoparticles has the potential to improve the lubricating and rheological properties of WBDF.

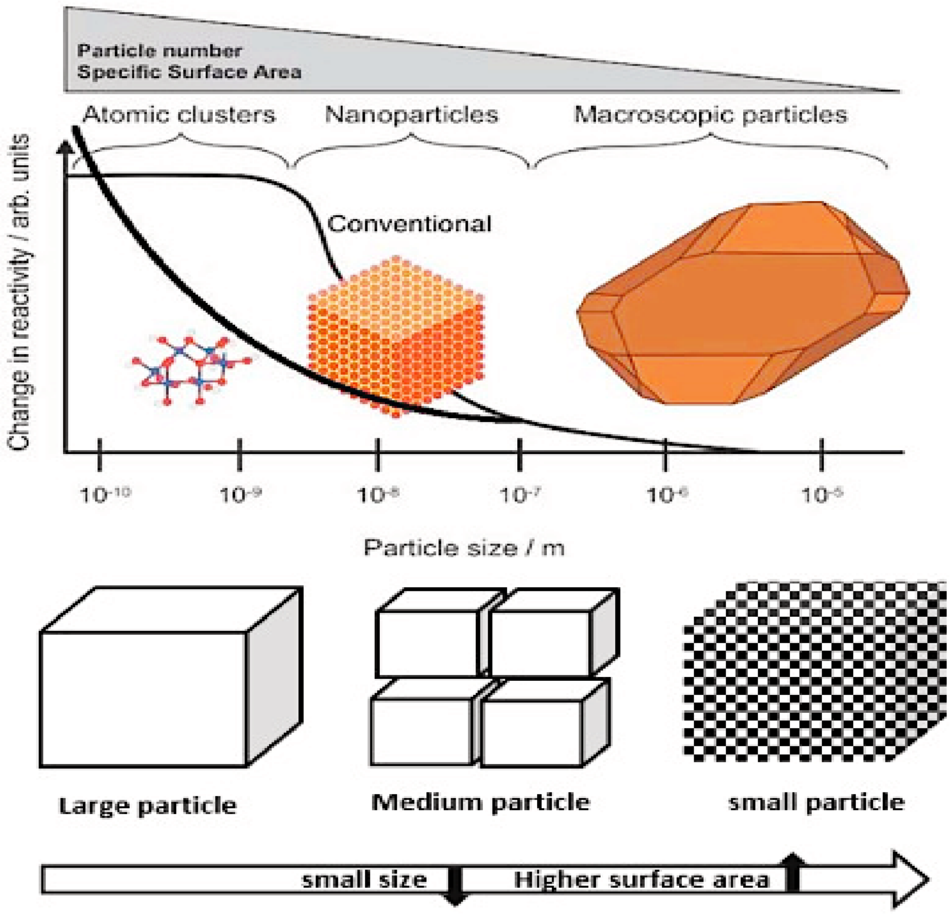

Figure 4 Nanoparticles with a large surface area to volume ratio (Tahr et al., 2023).

- **Carbon black**

In recent experiments, carbon black has been applied to enhance fluid rheology. According to the study conducted by Ikram and Vejpravova (2021), the addition of filler, specifically carbon black, resulted in a notable enhancement in rheological properties when compared to carbon nanotubes. Applying carbon black to enhance the stability and viscosity of polyacrylamide aqueous solutions. The exceptional stability of this drilling method makes it highly suitable for drilling in unconsolidated shales, offering significant advantages under specific conditions.

- **Carbon nanotubes**

Liu et al. (2022) claims that carbon nanotube walls are made up of a carbon hexagonal network structure, comparable to graphite sheets, with each carbon atom next to three surrounding carbon atoms. Graphene sheet, single walled, double walled, and multiwalled carbon nanotubes are all forms of carbon nanotubes based on the number of tube-shaped layers present on an axis. Drilling fluid filtrate loss can be reduced by incorporating a tiny multiwall carbon tube into the water.

- **Graphene oxide nanosheet**

Graphene nanosheets are two-dimensional honeycomb lattices made up of monolayers of densely packed carbon atoms. Graphene nanosheet-based MFC anodes can be made utilizing a variety of ways. Filtration loss volume is reduced, and the thickness of the filter cake is formed (Gudarzifar, 2020).

- **Cellulose Nanofiber**

There has been a significant increase in interest regarding the consumption of Cellulose Nanofibers (CNM) in drilling fluids. Due to the formation of CNMs, bentonite-water-based drilling fluids demonstrate enhanced viscosity even under low shear rates, as well as more pronounced shear thinning behavior. These attributes offer significant advantages to drilling fluid performance. Drilling fluids with a higher viscosity at low shear rates promote the suspension and transportation of cuttings from the wellbore to the surface more effectively. Drilling fluids that demonstrate pronounced shear-thinning behavior have the ability to achieve remarkably low viscosity levels under high shear rates, thereby ensuring optimal pumpability. According to Li (2020), the shape and surface properties of carbon nanomaterials (CNMs) have a significant impact on the performance of drilling fluid.

2.5. Borehole problems related to the drilling fluids (background)

Borehole problems arise when hydrostatic pressure and mud weight are not controlled, leading to kicks and blowouts. Hydrostatic pressure is the only controlled pressure in drilling fluid, while formation and fracture pressures are uncontrollable. To prevent kicks and blowouts, control hydrostatic pressure and maintain a drilling window between formation and fracture pressures. To maintain wellbore pressure, the mud weight should be greater than formation pressure but less than fracture pressure.

$$formation\ pressure < density\ of\ drilling\ fluid < fracture\ pressure$$

- **Fracture**

Fractures occur below casing shoes, causing loss of drilling fluid and circulation. This results in no flow in the borehole. Insufficient constant speed pumps can cause high pump speed and string weight, leading to a loss of bottom hole pressure and potential kick or blowouts. To prevent these issues, casing and cementing should be done during deeper drilling to reinforce weak formations.

- **Lost Circulation**

Lost circulation happens as a result of fracture that happens in borehole below the casing shoe. When the fluid is lost due the entrance of these fluids to the fractured zones then lost circulation occurs. Usually this causes a kick and if it's not controlled then it leads to a blowout Kang et al. (2023).

- **Pipe sticking**

Pipe sticking commonly occurs during pipe jacking operations in rock formations, primarily due to the accumulation of blockages within the annulus gap Liu et al. (2022). This is another issue if the mud cake has a high thickness or the borehole is not well lubricated.

- **Drill Pipe Failure**

This issue happens because of three factors which are human, pipe material, and environmental factors (Peng et al., 2022). The human factors are such as operating errors and mismanagement of drilling tools while the pipe materials factors may include bad quality of the material that will lead to corrosion over time and hence causing the pipe fail to function.

- **Hole deviation**

The weight on bit W, which can be divided into components, is the second force operating on the drilling Bottom Hole Assembly (BHA). The force component W is responsible for hole deviation, and its magnitude grows as the space between the drill collars and the hole increases, as does the weight on the bit. Formation features are the most common cause of natural hole deviation. Hole deviation can occur in laminated constructions made of alternating soft and rigid bands according to Liu (2021). Hole deviation is caused by laminated dipping formations, according to practical experience. The drilling bit tends to drill up dip when the dip angle is less than 45 degrees. When the dip angle exceeds 45 degrees, the drilling bit will want to drill down dip.

- **Borehole instability**

Due to earth stress, rock properties, and drilling mud chemistry there may be instability in the borehole. In order to maintain the stability, mud should be compatible with the formation by maintaining proper mud weight which is so called the density of the drilling fluid according to Liu (2021).

- **Mud contamination**

Due to the overtreatment of solid material or the extract of additives mud will get contaminated. On the contrary, to avoid that then mud properties should be monitored properly pretreatments with treatments should be scheduled as it is claimed by Liu (2021).

- **Formation damage**

Formation damage is a broad phrase that refers to the deterioration of subsurface formation permeability caused by a variety of unfavorable events (Bennion, 2002). Among the well building stages, one of the most crucial conundrums affecting petroleum extraction is drilling-induced formation damage produced by fluid and solid invasion of drilling fluid. Drilling fluid acts as a main well control mechanism in typical overbalanced drilling operations by keeping the hydrostatic pressure of the drilling fluid column higher than the formation pore pressure. The pressure differential between the drilling fluid column and the permeable formation causes a flow of liquid from the wellbore into the formation, generating a layer of impermeable zone known as filter cake. Filter cake development with diverse sizes of colloid particles is critical not only to limit filtrate seepage into the formation, which may cause formation damage, but also to give stability to the drilled wellbore according to Azar and Samuel (2007).

- **Hole cleaning**

Liu (2021) claims that the borehole should be cleaned to maintain annular velocity and viscosity. This cleaning is useful to avoid pipe sticking too.

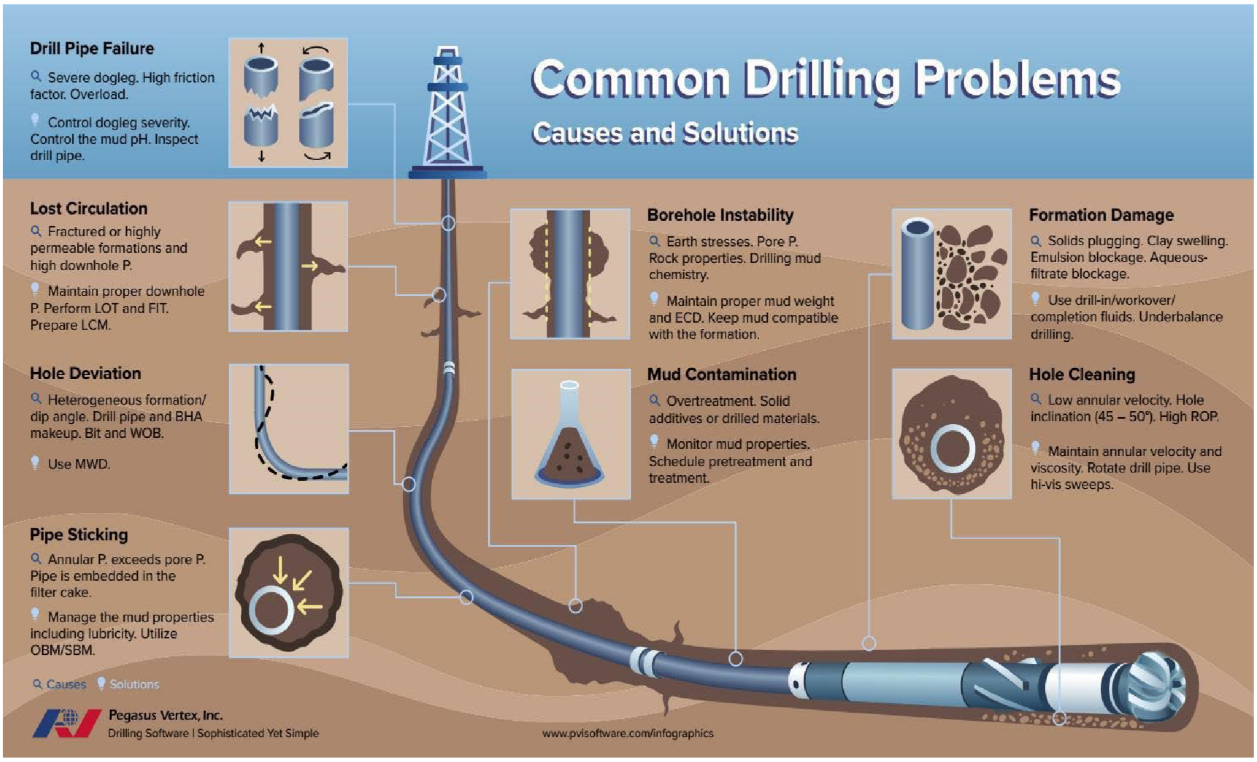

Figure 5 Borehole problems (Liu, 2021).

3. Materials and methodology

3.1. Materials

Purified chemicals, bentonite, soda ash, polymer, and NaOH as well as nanomaterials with sizes ranging between 1 and 100 nm were made in Pulsar Petroleum Company. For base sample bentonite, starch polymer, soda make up the drilling fluid employed in this investigation. The drilling fluid compositions use distilled water as the aqueous phase, coupled with bentonite and other additives. Drilling muds rheological and filtration qualities were boosted with the addi tion of wheat.

3.2. Preparation of wheat nano-biopolymer

This study used natural polymer and ball milling was used to prepare the nano size particle. The ball milling process is a flexible top-down synthesis approach used to create nanomaterials. It is a straight forward, cost-effective, and high-throughput top-down production method for nanocomposites. Consequently, a mill chamber and balls are used in the ball milling procedure and this ball mill has a stainless-steel container and several little iron, hardened steel, silicon carbide, or tungsten carbide balls that revolve within the mill (drum). A natural polymer powder is placed inside a steel container. The natural polymer powder will be converted into nano size by using the ball mining process. The metal balls provide a pulling force to the materials when the milling chamber rotates. These materials carbide balls deliver a huge amount of energy to the material powder that was subsequently crushed. It takes at least 100 to 150 hours to produce fine powder using ball milling because ball milling is a mechanical process where all structural and chemical changes are caused by mechanical energy. Figure 6 shows the procedure of converting wheat into wheat seeds then into powder then into nano size particles.

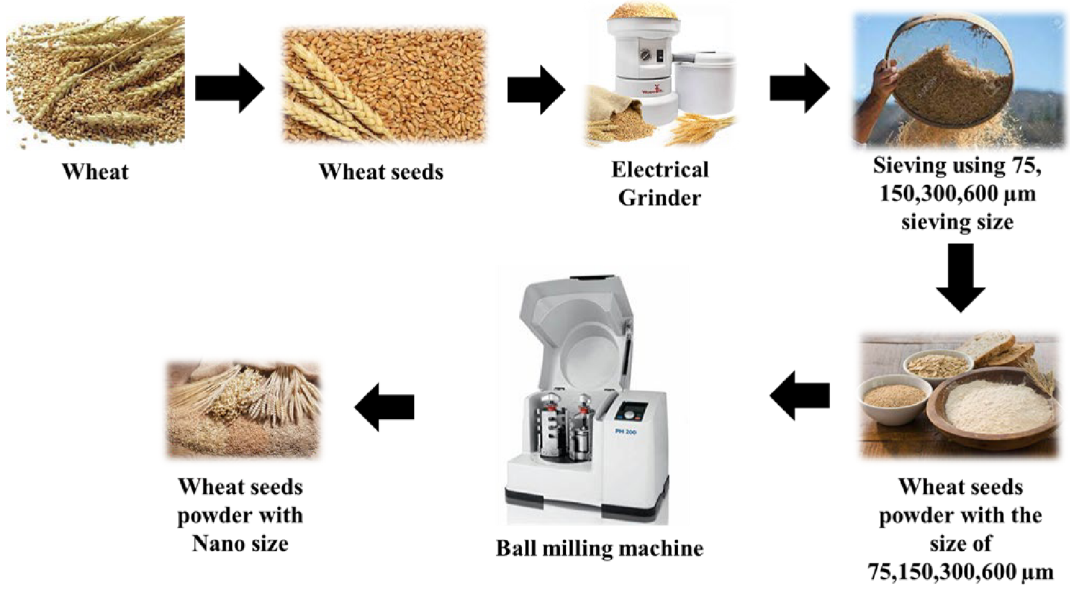

Figure 6 Procedural steps of preparing wheat powder with Nano size.

3.3. Preparation of drilling fluids

The base drilling fluid sample was essentially composed of water (base fluid) and bentonite in addition to other additives, such as caustic soda (NaOH) for controlling alkalinity, soda ash (Na_2CO_3) for preventing reactions with calcium ions, and starch for which is a fluid loss agent. Wheat powder was prepared by grinding the wheat and changing it into powder. Then, sieve was used to get five particle sizes of the wheat which were 75,150,300,600, and nano with three concentrations that were 0.5,1, and 2. API-SPEC-13A-2010.

Table 1 Materials used in this study

`	Bentonite (gm)	Water (mL)	Soda ash (gm)	Polymer (gm)	NaOH (gm)
Concentration	20	350	0.50	0.50	0.10

For this study 20 gm of bentonite was used with 350 mL of water for one barrel. In addition, 0.5g of soda ash and polymer was added with 0.1 gm of caustic soda. To increase density barite is usually added and to increase the viscosity bentonite is added so I this study the viscosity is favored that's why only bentonite is added not barite. Soda ash is inserted to avoid reactions with calcium in polymers. Firstly, in this process water was added then soda ash followed by bentonite then caustic soda (NaOH) and then polymers. Lastly the wheat powder was poured inside in different sizes.

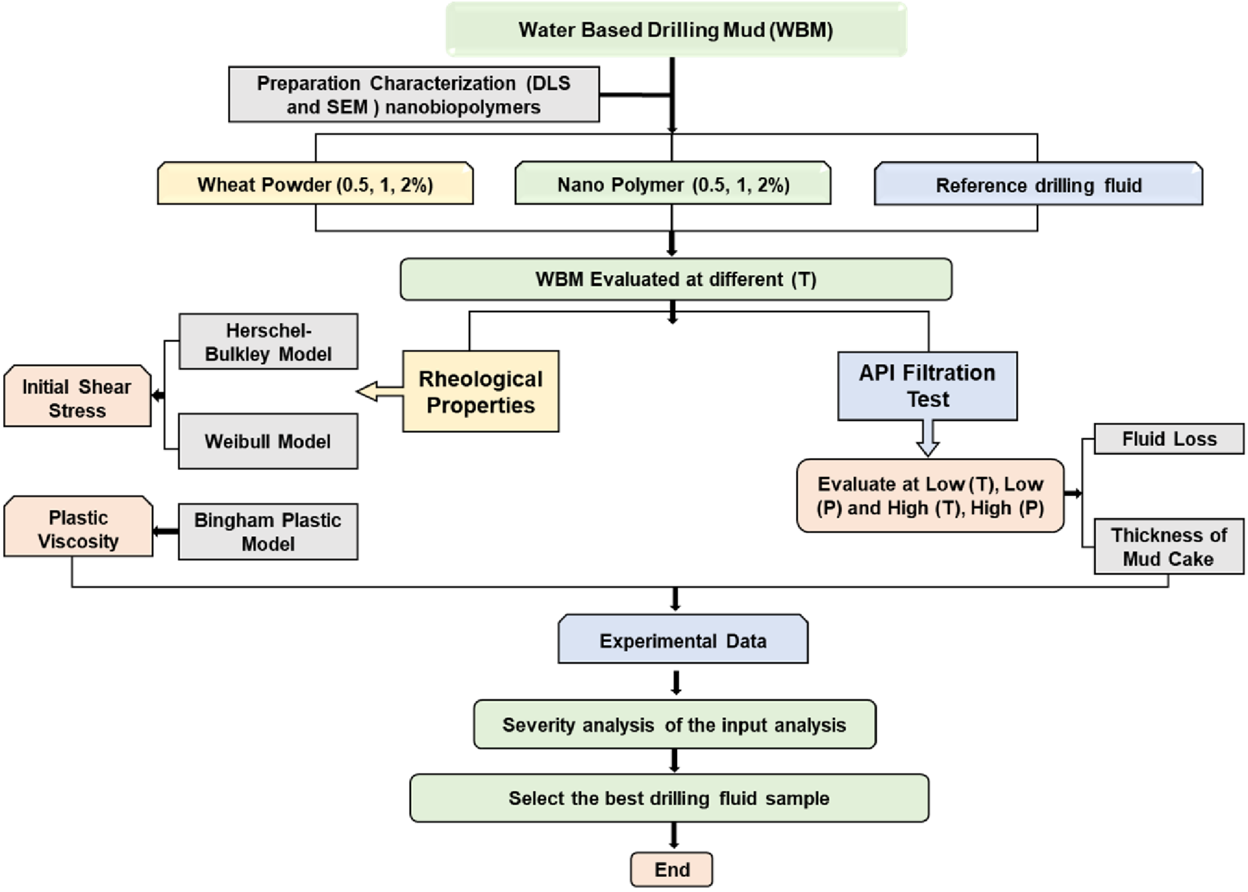

Figure 7 A flowchart that presents the methodology of the work using in this project schematically.

3.4. Filtration measurements

The aim of filtration testing is to have larger hydrostatic pore pressure than the formation fluid pressure during fluid loss that happened via borehole formation. Increased solid content in drilling fluids results in decreased filtrate loss and mud cake thickness so in order to keep track of the drilling fluids performance, it is necessary to measure the filtration rate as well as the cake thickness. This is due to excessive filtrate loss and mud cake thickness that could cause the differential pipe to become stuck. This process includes a high-speed mixer, a high-pressure source, regulators and a stopwatch and graded cylinder in the Filter Press.

Filtration properties includes fluid loss and filter cake that were examined for various concentrations of and time. The thickness of the filter cake and the fluid loss at different periods from 0 to 30 min were measured. A filter paper was placed in the right place in the cell of the

Series 300 LPLT Filter Press correctly, and the drilling fluid was poured into the filter cell. A graduated cylinder was placed under the filtrate tube, and the filter press was set up for the tests. As the apparatus was all set up, timing was initiated and the test was started. The test was allowed to continue for 30 min. The amount of filtrate in the graduated cylinder was read and noted at various periods during the 30 min. The filter cake thickness was then measured. This procedure was repeated for all 16 samples. The high temperature and high pressure (HTHP) environment is an example of an unconventional terrain where oil and gas reserves can be located. While HTHP wells might contain a plethora of resources, they are difficult and costly to construct as its claimed in Aguw et al. (2021) Due to the high temperature and high pressure reservoir conditions, the mud requires excellent thermal stability and density, which is one of the key issues encountered in HTHP well drilling (Fuhua et al., 2012)**.**

3.5. Rheological measurements

Mud flow characteristics such as gel strength, yield point, apparent viscosity, and plastic viscosity can be measured by a rheology test. Rheology is the study of material deformation and flow. An essential rheological quality is the ability of fluids to carry and suspend drilling debris during drilling even when circulation is disrupted. Wheat and base drilling fluid were combined to evaluate the effect of these qualities. Based on the Fann 35 A viscometer, the rheological parameters of each sample were determined (figure 8). Viscometers is used to measure the viscosity of drilling fluid using a rotating coaxial cylinder. In addition, to establish the shear stress (scale reading) it's needed to acknowledge the shear rate (from the rotational speed). Viscosity is measured with a viscometer with dials ranging from 600 to 300 rpm. The test was taken at different temperature 25, 50, and 75 C to understand and evaluate their rheological properties.

$$AV = \frac{\emptyset 600}{2} \qquad \text{(Eq.2)}$$

- **Gel strength**

It is measured by stirring the one of the 15 samples at 600rpm for 10s then getting the concentraion for the initial phase thhen after 10 minutes the concentration should be measured again to know the final phase and after that the values are compared.

- **Plastic Viscosity (PV):**

A Bingham plastic rheological model parameter. The slope of the shear stress-shear rate plot above the yield point is denoted by PV. A viscometer is a piece of equipment used to determine the viscosity of plastic. Plastic viscosity is calculated by subtracting the 600rpm value from the

300rpm data, and PV is measured in centipoises (cp). A low PV implies that the mud can drill quickly due to the low viscosity of the mud exiting the bit. A viscous base fluid and an abundance of colloidal particles create high PV. Dilution can be used to reduce PV by lowering the solids content.

$$PV = \emptyset 600 - \emptyset 300 \quad \text{(Eq. 3)}$$

Figure 8 Digital viscometer.

- **Yield Point:**

The physical meaning of this term is the resistance to initial flow or the tension necessary to initiate fluid movement. In a shear-rate (x-axis) vs shear stress (y-axis) plot, the Bingham plastic fluid displays as a straight line, with YP representing the zero-shear-rate intercept (PV is the slope of the line). YP is determined by subtracting PV from the 300-rpm dial measurement and is expressed as lbf/100 ft2 from 300-rpm and 600-rpm viscometer dial readings. YP is used to assess muds capacity to pull cuttings out of the annulus. A greater YP indicates that the drilling fluid can transport cuttings better than a fluid of comparable density but lower YP.

$$YP = \emptyset 300 - PV \quad \text{(Eq.4)}$$

4. Results and discussion

4.1. Characterization of wheat nanobiopolymer

Non-destructive analytical techniques such as thermal scanning microscopy (TEM), dynamic light scattering (DLS), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) are used. The particle sizing technique known as dynamic light scattering (DLS) is used to determine the size distribution of particles in a solution.

Figure 9 depicts how FTIR examines the absorption of radiation frequencies corresponding to molecular vibrations to detect and assess material chemical composition. This allows the chemical makeup of the sample to be determined. The x-axis of an FTIR plot represents the frequency or wavenumber of infrared radiation, which is commonly measured in cm-1, while the y-axis represents the intensity of absorbed radiation, which is often measured in AU or %T.

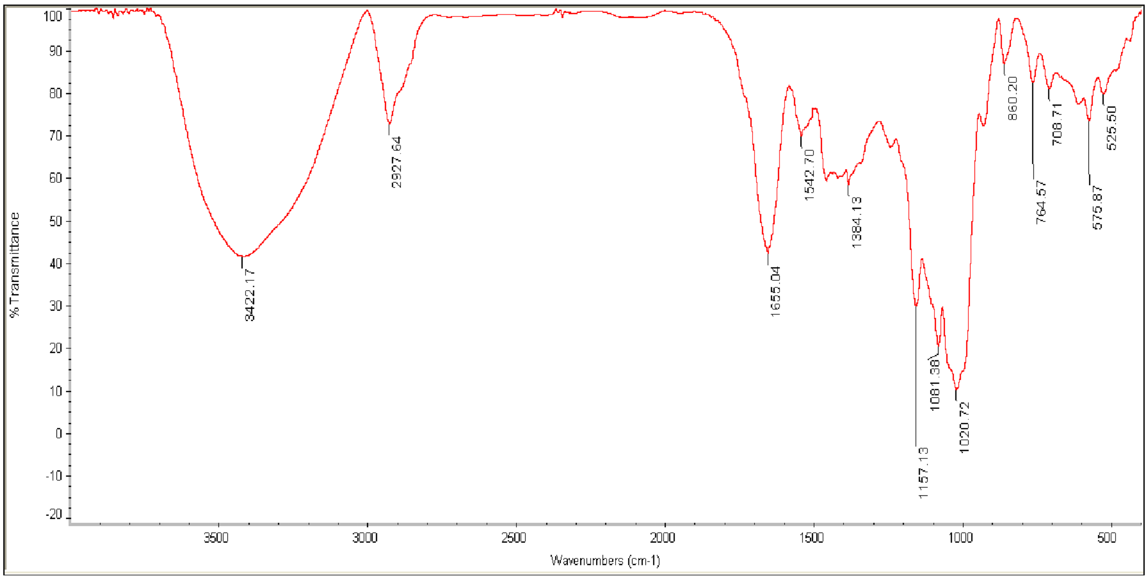

Figure 9 FTIR spectrum of the wheat.

The scanning electron microscope (SEM) was used to study mud cakes of various micron sizes (75, 150, 300, 600, and nano sized) produced by the nano-biodegradable drilling fluid. SEM, or scanning electron microscopy, is a technique that involves scanning the surface of a subject with electrons to generate a detailed picture. High-resolution pictures acquired by SEM show the particle size, shape, distribution, fissures, and other properties of the mud cake. Drilling operations may be enhanced and issues such as lost circulation avoided by using this information.

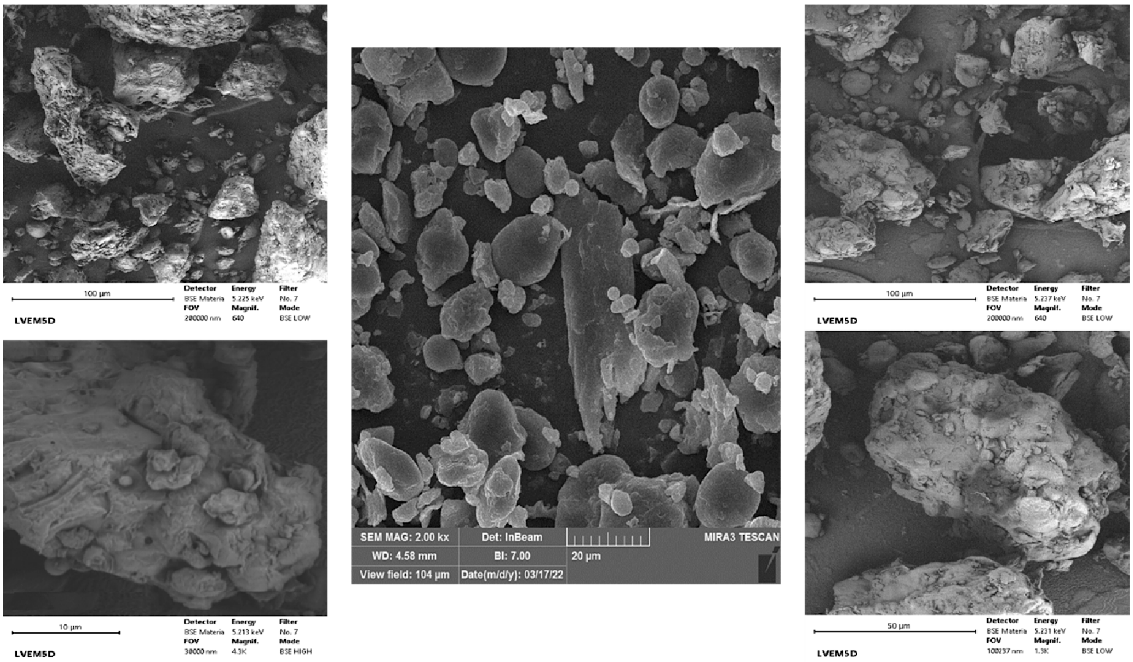

Figure 10 SEM at different sizes characterizing the nanobiopolymer that was created.

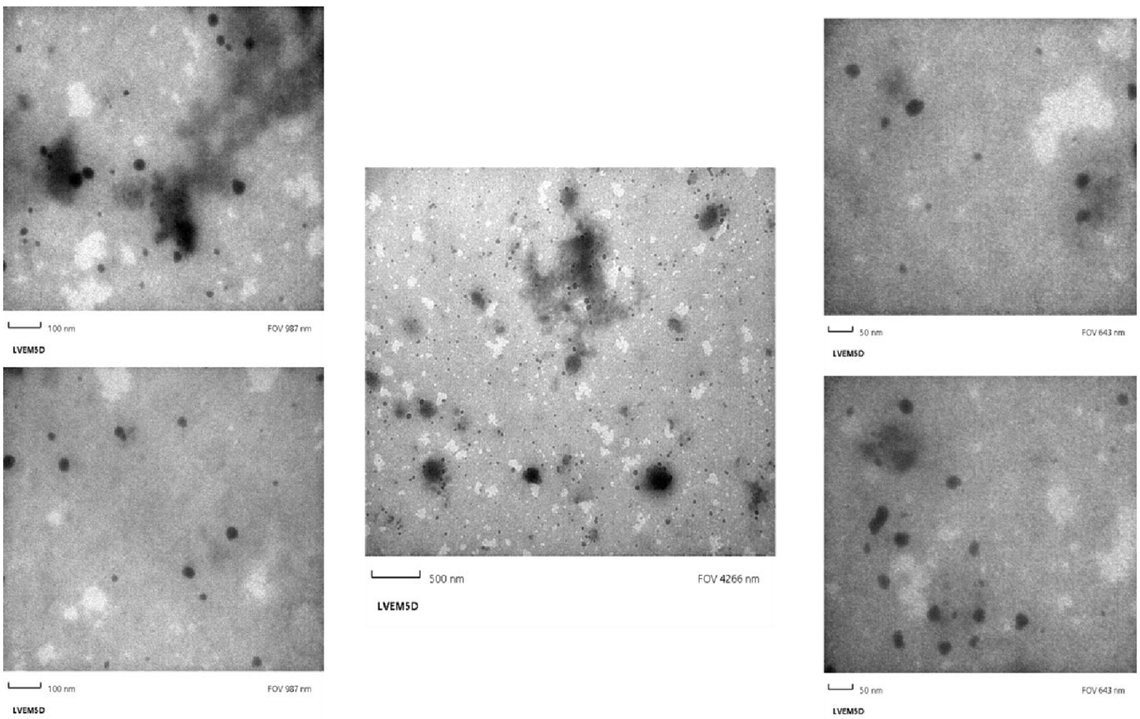

Figure 11 TEM of the wheat nanobiopolymer at different sizes.

TEM (transmission electron microscope) is an electron beam that is passing through the sample to image the nanoparticle. The black ones are the carbon elements making the the nanomaterial to be hidden. Figure 10 shows images in 3 sizes which are 50, 100, and 500 microns. Fore SEM and TEM special device is used as its shown in Figure 12. Figure 13 depicts the DLS analysis of the nano-biodegradable drilling fluid, with the x-axis representing particle size or diameter and the y-axis representing scattered light intensity. To depict the particle size distribution, the intensity (y-axis) as a function of particle size (x-axis) is usually shown.

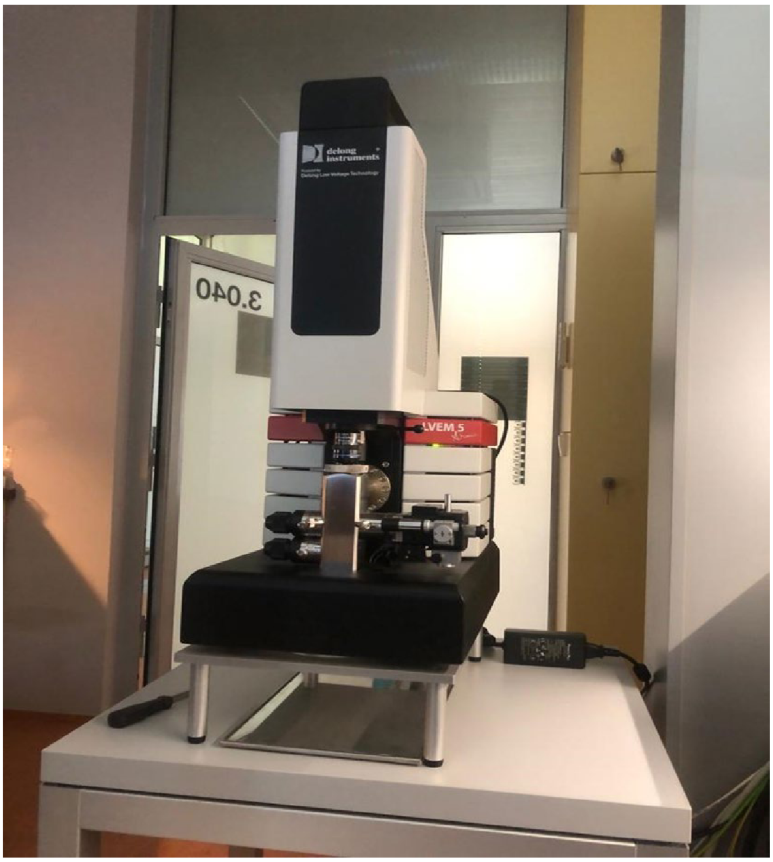

Figure 12 Electron Microscope.

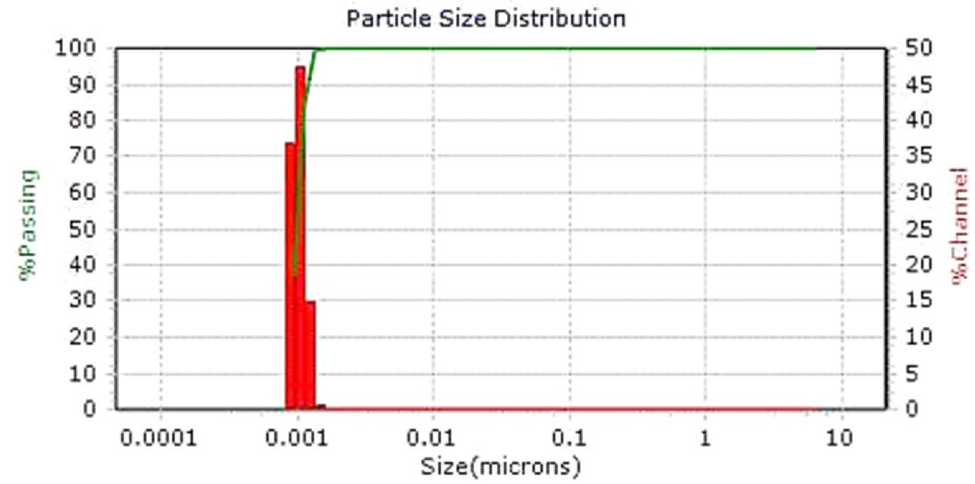

Figure 13 DLS used to characterize naniobiopolyemrs.

To know the thermal stability of the nanobiopolymer that was created, Thermogravemetric Analysis(TGA) and Differential Scanning Calorimetry(DSC) are used. This process is to understand that at which tempreture can the material resist and aviod destruction. In addition, special device is used for that procedure which is shown in figure 14. TGA measures the weight of the sample within increasing tempreture while DSC curve provides information about endothermic and exothermic processes that occur in the material during physical transitions. As seen in figure 12 the weight of the material is significantly decreased between the tempretures of 275C and 325C which went from 80% to 38%. Consequently after that the material's weight decreases more and it turns into ashes in tempreture above 500C. Thermal anaylser was used to get the graph of TGA and DSC as shown in figure 15.

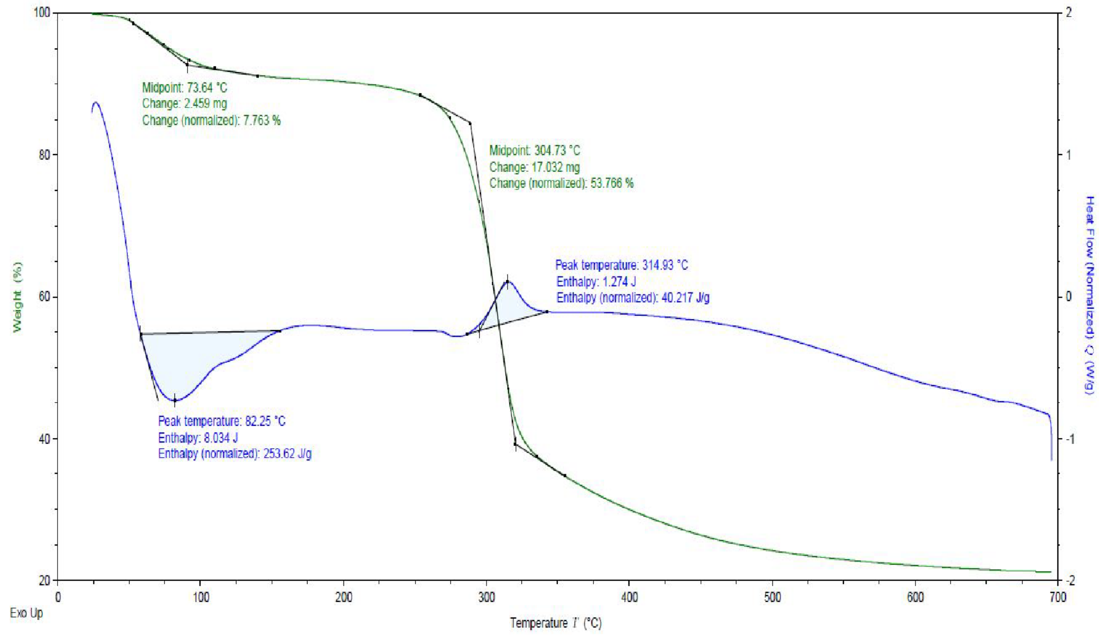

Figure 14 Thermal stability analysis of wheat nanobiopolymers using TGA and DSC techniques.

Figure 15 Thermal analyser

4.2. Rheological properties

Rheology is the study of fluid flow and deformation. During drilling operations, the yield point, gel strength, and viscosity of the drilling mud are measured. As can be observed, the base samples plastic and apparent viscosities were 3 and 8.6 c p, while the yield point was 11.2 lb/100ft2, and the gel strengths at 10 sec and 10 min were 6.8 and 7.7 lb/100ft2 respectively. For rheological property testing, three important temperatures of 25°C, 50°C, and 70°C are utilized to imitate reservoir conditions and boost the impact of wheat powder.

Tables (2, 3, and 4) show the effect of temperature and concentrations change on the rheological characteristics of the base sample, 75 micron, 150 microns and nano microns. Although the effect of temperature increase on plastic viscosity and yield point is not a direct relationship, gel strength and apparent viscosity improved as temperature increased. The gel strength of the base sample is the most impacted by rheological characteristics by temperature, which increased from 7.7 to 29mPa.s when the temperature was raised from 25°C to 70°C.

Table 2 Measured values of the plastic viscosity (μp), apparent viscosity (μa), yield point, and gel strength (10 sec and 10 min) at 75 microns in three concentrations and temperatures.

Samples	**μp (cp)**	**μa (cp)**	**YP**	**Gel strength (Ib/100ft2)**	
			(Ib/100ft2)	**10sec**	**10 min**
BM	3	8.6	11.2	6.8	7.7
BM (50°C)	9.7	13.6	7.8	9.7	25
BM (70°C)	6.3	15.5	18.4	12.7	29
75 0.5%wt.	10.2	14.35	8.3	5.7	18.2
75 0.5%wt. (50°C)	5.5	12.35	13.7	17.5	20.5
75 0.5%wt. (70°C)	6.7	15.1	16.8	18.5	26
75 1%wt.	9	14	10	8.2	16.5
75 1%wt. (50°C)	5.5	13.5	16	15.7	31
75 1%wt. (70°C)	6.3	17	21.4	18.7	24
75 2%wt.	11.5	15.35	7.7	6.5	12.5
75 2%wt. (50°C)	6.8	14.5	15.4	13.5	29
75 2%wt. (70°C)	10	17.5	15	16	21

Table 3 Measured values of the plastic viscosity (μp), apparent viscosity (μa), yield point, and gel strength (10 sec and 10 min) at 150 microns in three concentrations and temperatures.

Samples	μ_p (cp)	μ_a (cp)	YP	Gel strength (Ib/100ft2)	
			(Ib/100ft2)	10sec	10 min
BM	3	8.6	11.2	6.8	7.7
BM (50°C)	9.7	13.6	7.8	9.7	25
BM (70°C)	6.3	15.5	18.4	12.7	29
150 0.5%wt.	9	14	10	8.5	18.2
150 0.5%wt. (50°C)	7	15	16	14	23
150 0.5%wt. (70°C)	6.4	12.8	12.8	17	42
150 1%wt.	9.3	13.75	8.9	7	18.9
150 1%wt. (50°C)	7.2	12.35	10.3	8.5	25.5
150 1%wt. (70°C)	6.3	14.5	16.4	13	20.2
150 2%wt.	9.3	14.5	10.4	12	23.7
150 2%wt. (50°C)	7.7	14.35	13.3	13.2	17.5
150 2%wt. (70°C)	7.5	16.25	17.5	16	29.2

Table 4 Measured values of the plastic viscosity (μp), apparent viscosity (μa), yield point, and gel strength (10 sec and 10 min) at Nano in three concentrations and temperatures.

Samples	μ_p (cp)	μ_a (cp)	YP	Gel strength (Ib/100ft2)	
			(Ib/100ft2)	10sec	10 min
BM	3	8.6	11.2	6.8	7.7
BM (50°C)	9.7	13.6	7.8	9.7	25
BM (70°C)	6.3	15.5	18.4	12.7	29
Nano 0.5%wt.	7	16.5	19	7	10
Nano 0.5%wt. (50°C)	6	14.5	17	20	31

Nano 0.5%wt. (70°C)	5.7	15.35	19.3	14	23
Nano 1%wt.	8	14.85	13.7	10.5	19.3
Nano 1%wt. (50°C)	6.2	16.1	19.8	16	29
Nano 1%wt. (70°C)	8	17.5	19	20	34
Nano 2%wt.	9	14	10	11	20
Nano 2%wt. (50°C)	4	15.5	23	13	19.7
Nano 2%wt. (70°C)	7	17.5	21	17	23

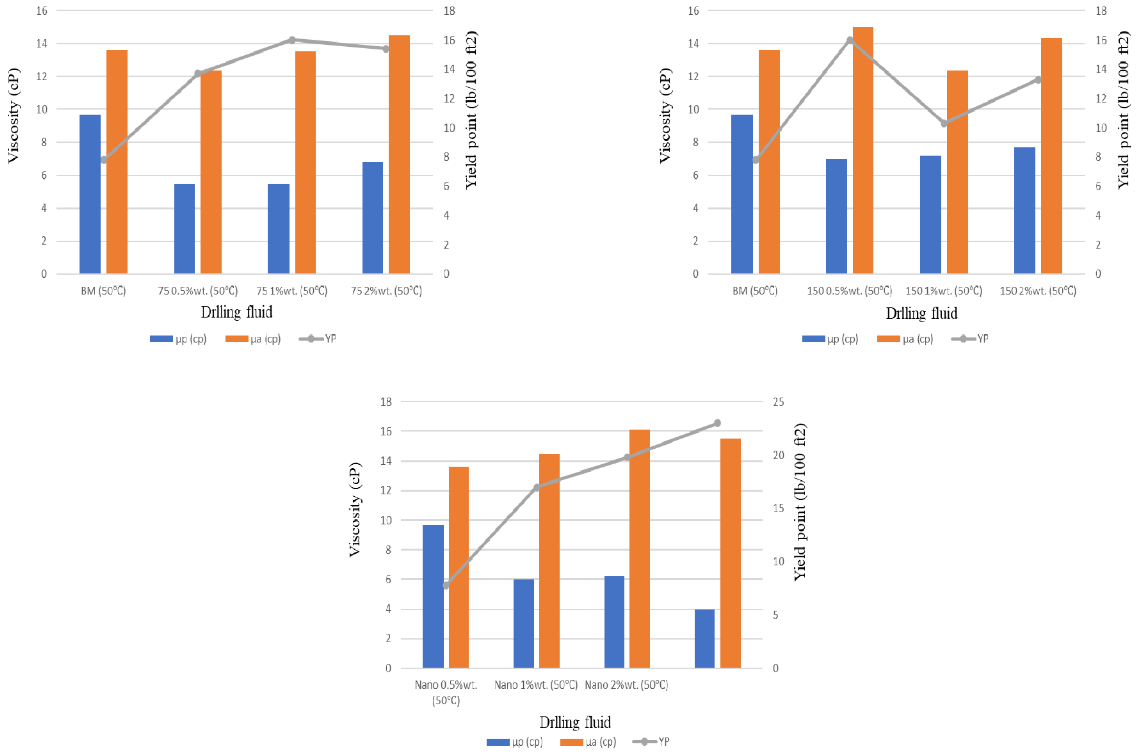

Figure 16 The results of the plastic viscosity (μp), apparent viscosity (μa), and yield point of the biodegradable drilling fluids; 75μ, 150μ, and nano microns at 50C.

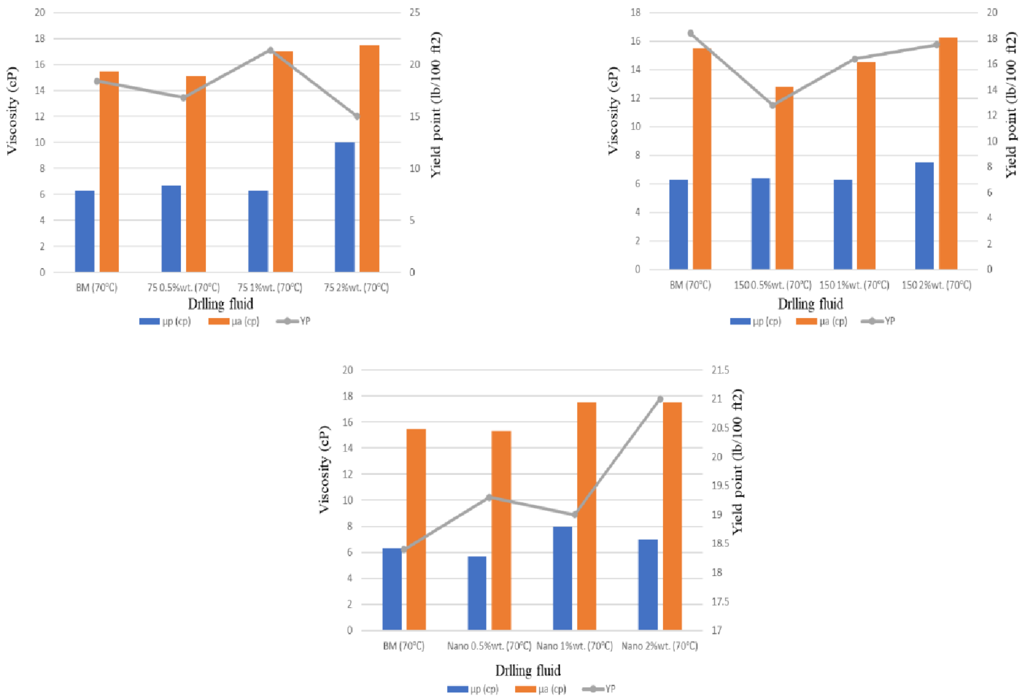

Figure 17 The results of the plastic viscosity (µp), apparent viscosity (µa), and yield point of the biodegradable drilling fluids; 75µ, 150µ, and nano microns at 70C.

From the figures 16 and 17 it is seen that high temperatures affect the rheological properties more. Nano microns with concentrations 1%wt. and 2%wt. at 70C had the highest apparent viscosity which was 17.5cp compared to 75 and 150 microns for (50C and 70C). Consequently, 75 microns with the concentration of 2%wt. at 70C had the high level of plastic viscosity which was 10cp. In addition, nano microns with the concentration of 2%wt. at 50C had the highest yield piont which was 23 Ib/100ft2 and yield point curve for that graph to get to that point increased with increasing concentration of the drilling fluid.

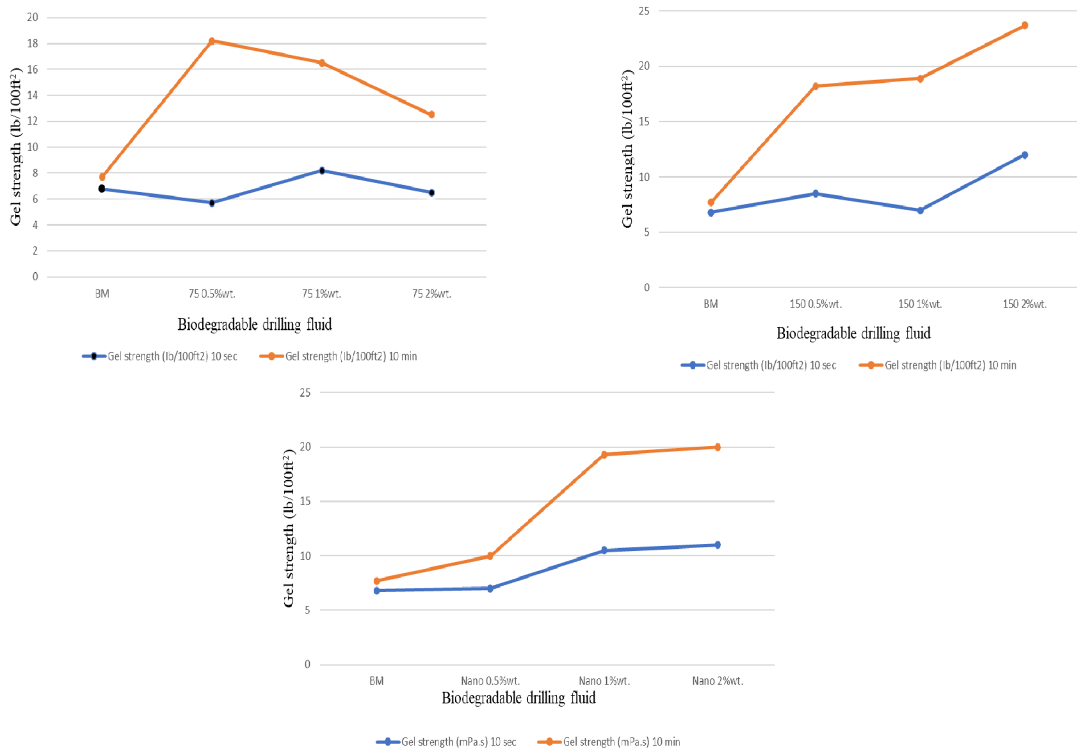

Figure 18 The results of the gel strength at 10 sec and 10 min for 75µ, 150µ, Nano-sized microns, at temperature room (25°C).

For figures 18 and 19 the highest gel strength for 10s was at 75 microns with the concentration of 1%wt. at 70C which was 18.7 Ib/100ft2. On the other hand, highest gel strength for 10min was at nano microns with the concentration of 1%wt. at 70C which was 34 Ib/100ft2. Hence a conclusion can be made that concentration of 1%wt. and temperature of 70C always give the highest gel strength values. Nano micron curves for 25C was in steady state that was directly proportional with the concentration as its gel strength increased within the increase of concentration level for both 10s and 10min. The other curves had all up and downs so no relation with concentration increase or decrease.

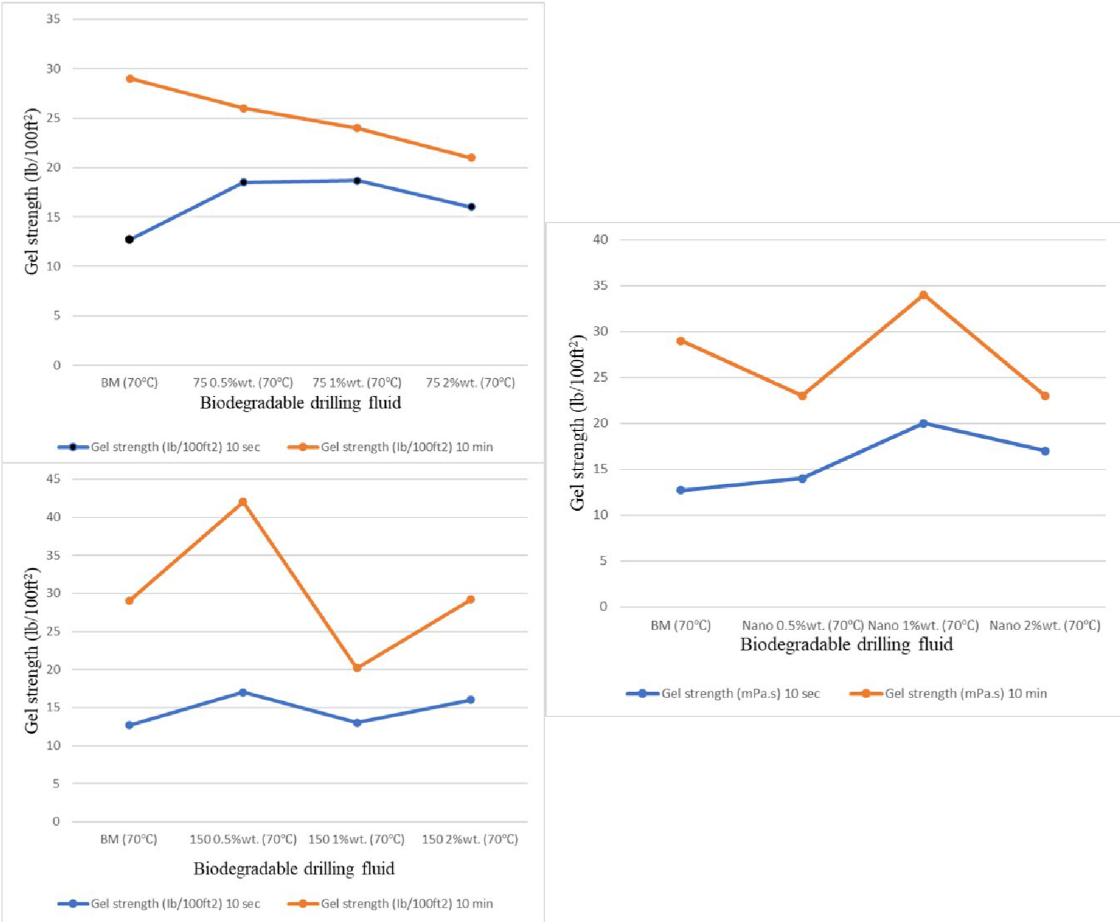

Figure 19 The results of the gel strength at 10 sec and 10 min for 75µ, 150µ, Nano-sized microns, at temperature room (70℃).

4.3 Filtration Properties

The filtering characteristics of base drilling fluids modified with biodegradable wheat powder and nano-sized wheat powder materials were examined and evaluated, including fluid loss volume and filter cake thickness. As shown in figure 20, the mud thickness (mm) of 75 microns, 150 microns, 300 microns, 600 microns, and nano microns were determined in three different concentrations (0.5% wt., 1% wt., and 2% wt.). In each concentration, each micron has different values. In Bm, it was 9.3 mm, and after that, in 75 microns, the concentration of 0.5% wt. had 5.6 mm after increasing concentration to 1% wt. it became the same 5.6 mm after increasing concentration to 2% wt. the mud cake thickness then decreased to 4.6 mm. Same values applies for 150 microns and hence the two lowest sizes are 75 and 150 microns which has a mud cake thickness value of 4.6mm.

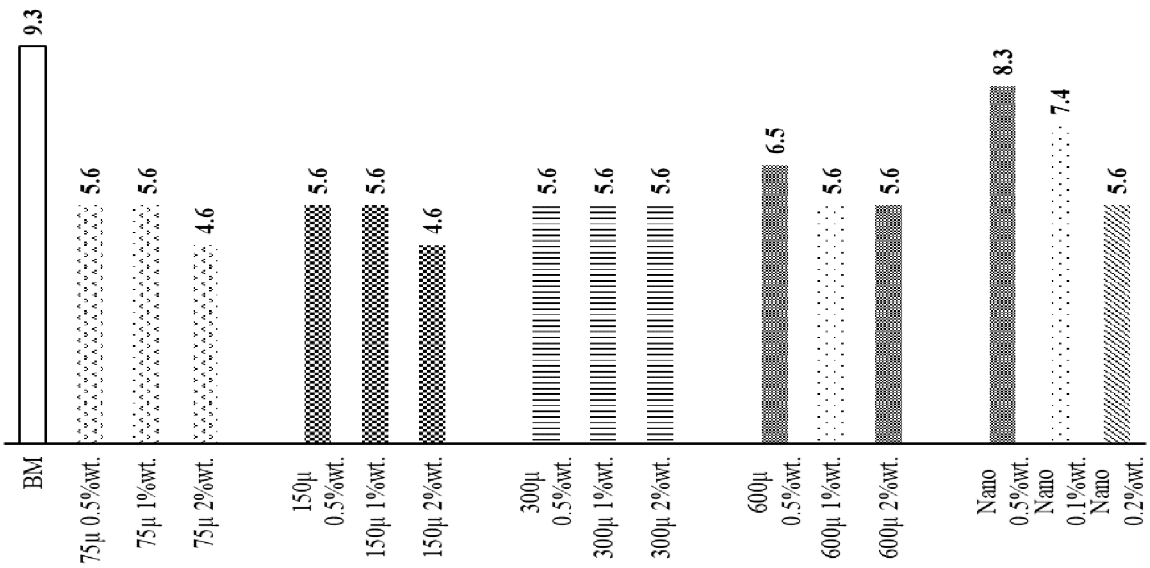

Figure 20 Mud cake thickness

During the examination of the optimal concentration of nanoparticles combined with base drilling fluids. Figure 21 depicts the filtration rates of the base drilling fluid with its five different sizes. The addition of 0.5%wt. 75-Micron wheat powder to the base drilling fluid decreased fluid loss by 33.3% when compared to the base drilling fluid. Furthermore, adding 2%wt. 75 microns wheat powder to the base drilling fluid reduced fluid loss by 38.4% as compared to the base drilling fluid. The combination of nano-wheat powder and base drilling fluid is then investigated. The addition of 0.5%wt. nano-wheat powder to base drilling fluid reduced fluid loss by 7.7% as compared to the base drilling fluid. The most efficient outcome with nano-wheat powder was utilizing 2%wt. nano-wheat powder to base drill, which reduced fluid loss by 28.2%. The best filtration rate was for 150 microns when 2%wt. was added which was 11.5cc and it reduced the fluid loss by 41%.

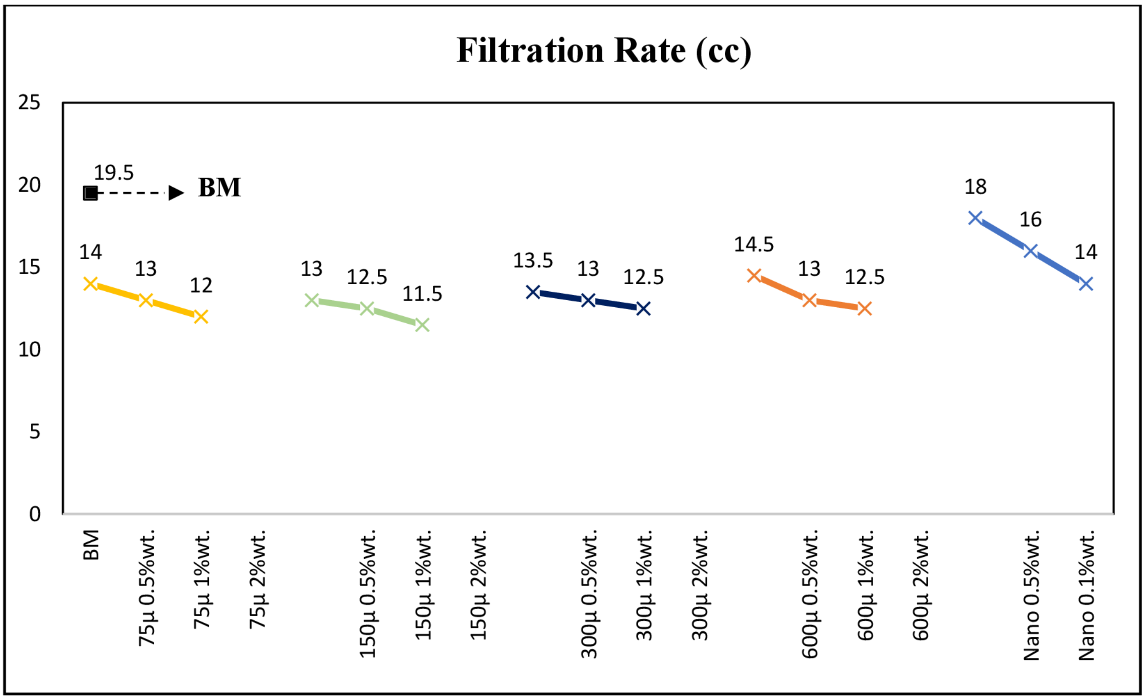

Figure 21 Filtration Plot

The thickness of the filter cake, as the second important factor of filtration, was also evaluated for all produced samples of drilling fluids, including base drilling fluid, biodegradable drilling fluids, and nano-biodegradable drilling fluids at various concentrations (all mud cake samples shown in Figure 22).

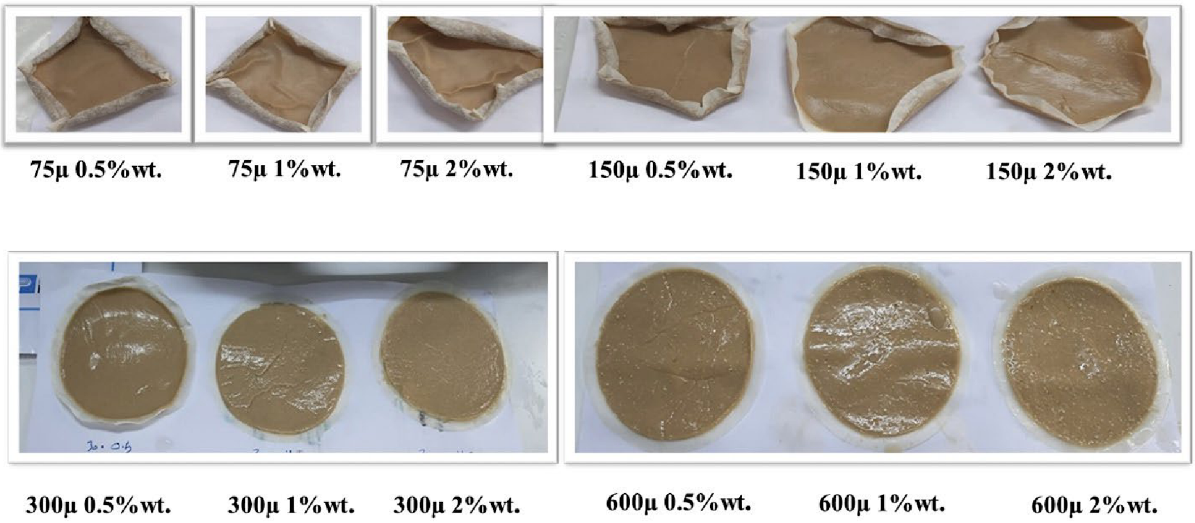

Figure 22 Mud Cake Filtrates

5. Conclusion and recommendation

5.1 Conclusion

Finally, rheological and filtration studies were done on each sample to find the most efficient drilling fluid that had the best fluid loss.

- The main objective in this experiment was to choose the best sample that lowers the fluid loss based on rheological and filtration measurements. Wheat powder is used in 5 size particles such as (75-micron, 150-micron, 300-micron, 600 microns, and nano sized) and for each concentration which is 0.5%, 1%, and 2% we need to evaluate plastic viscosity, apparent viscosity, yield point, and gel strength based on 3 different temperatures which are standard room temperature (25C^o), 50 C^o, and 70 C^o to know the effect on rheological properties. On the other hand, for the filtration measurement only different concentrations are favored not the temperatures.

- Wheat powder, in both biodegradable and nanoparticle forms, increased the rheological qualities of the base drilling fluid. Because to the better mixing with the drilling fluid, their reduced size leads in superior rheological and filtration qualities. The greatest results were obtained by including wheat powder with a particle size of 150 micrometers, which significantly improved the fluids rheological characteristics.

- The filtration test results show that integrating (1 or 2) wt.% of 150-micron wheat powder into the basic drilling fluid to generate a biodegradable drilling fluid resulted in the lowest filtration rate. Furthermore, the nano-biodegradable drilling fluids generated intriguing filter cakes, which successfully sealed the permeable filters that served as the borehole wall.

5.2 Recommendation

The use of drilling fluids in oil and gas drilling plays a crucial role in determining the efficiency and safety of drilling operations. Our research indicates that the inclusion of wheat powder in drilling fluid yields substantial enhancements in its filtration properties. Unfortunately, there is a lack of available data regarding the impact of biopolymer nanoparticles, specifically wheat powder, on the characteristics and performance of drilling fluid. The investigation into the impact of nano-sized materials on drilling fluids is not as widespread as the examination of the effects of micro-sized materials on drilling fluids.

Based on the positive results obtained from the application of nano-sized biopolymer wheat powder in enhancing the filtration properties of drilling fluids, it is highly recommended that researchers and companies undertake further scientific investigations to explore the impact of nano-sized biopolymers. Conducting a study with similar objectives can enhance our comprehension of drilling fluid properties while allowing the advancement of novel and enhanced drilling fluid additives, thereby enhancing drilling operations. By implementing these measures, we can enhance the efficiency, safety, and sustainability of drilling operations within the oil and gas industry.

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