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Extraction and Characterization of Drilling Fluid from Castor Oil

Manase Auta

School of Chemical Engineering,
Engineering Campus, Universiti Sains Malaysia,
14300 Nibong Tebal, Pulau Penang, Malaysia

ABSTRACT: Drilling fluid is an essential component in drilling operations. It is used to prevent blowouts by creating adequate hydrostatic pressure, lubricating the walls of a well and the drill string, flushing to the surface of cuttings, and keeping the drill bit clean and cool. Extraction, characterization and formation of drilling fluid from castor seed oil were investigated. The castor seeds used were obtained from a local market and the extraction of the oil was done mechanically. The extracted oil characteristics such as specific gravity, pH, acid value, iodine value, saponification value, refractive index and viscosity were within the standard range before before formulating it to drilling fluid by the addition of additives. The result of the formulation obtained showed that the formulated drilling fluid had an electrical stability of 222 V, High Pressure/High Temperature of 8.8, mass funnel viscosity at 30 and 50 ^{o}C were 26.5 and 25 s, respectively; chemical alkalinity was 0.3 and excess lime of 0.39 Ib/bbl. The findings in this research have shown that formulated drilling fluid from castor seed oil is safe as drilling fluid and has characteristics close to that of the standard drilling mud equivalent circulating density 99. The formulated drilling fluid can adequately serve as an alternative to the commercial products.

KEYWORDS: Formulation, castor seeds, drilling mud, oil, borehole, lubrication, petroleum.

1 INTRODUCTION

The petroleum industry is a very important sector worldwide as a lot of other industries and activities depend on its products and services. During the extraction of petroleum, an important operation that must be carried out is the drilling of the pathway for laying the pipes through which oil will be returned from the depth of the earth [1]. Depending on the geology of the area, drilling of the ground can be an expensive operation and is often an important consideration in the overall cost of operation [2]. Drilling of wells can be carried out with or without fluid. However, dry boring result in damage of drill head or transmitter and ultimately fail the making of bores. Oil and water based drilling systems are the two major types of fluid drilling methods [3]. The latter often results to collapse of bores due to a fast filter of water, thermal instability and changes in fluid rheology [4]. The most effective option is oil-based drilling which has lots of benefits such as temperature stability, lubricity and bore stability [2]. Drilling fluids are the bloodline of wells and a wise part of the rotary drilling process which plays a major role in completing a well safety and economics. It is a complex mixture of a fluid phase, a solid phase and a chemical phase, and possess some unique characteristics to fulfill its functional behavior during the course of drilling. Horizontal, multilateral, high angle and open hole systems are some of the common methods employed in drilling petroleum from reservoir [5].

Properly designed drilling fluid enables operator to reach the desired geological ore with lower cost, enhanced penetration of bit and drill string, easier penetration, faster cooling of bits, minimal damage of hole beneath the bit, easier transport of cuttings to the surface at the end of the drilling process and meeting environmental pollution regulation standards [6].

Castor plants from which castor beans and castor oil are subsequently derived are found naturally over a wide range of geographical regions and may be cultivated under a variety of physical and climatic regions. Biological degradable non-edible

Corresponding Author: Manase Auta (manaseauta@yahoo.com)

castor oil has several industrial applications such as production of high grade lubricants, manufacture of wax and polishes, crayon, cosmetics, paints and varnish industries application, biodiesel production among others [7] -[8]. The pumice or residue after crushing is used as a fertilizer when the toxin (resin) has been removed. Castor seeds contain averagely 46-55% oil by weight even though there are various species of the seeds. Castor oil contains about 90% (18:1) recinuleic acid (simply unsaturated fatty acids) which is unique among vegetable oils and having the hydroxyl group near the double bond giving it extraordinary viscosity than other oils [9]. The seed contains ricin, ricinine and certain allergens which are protein polysaccharide toxic to man [10]. Neither the resin nor the allergen is carried over to the oil if it is properly extracted, but remains in the meal. However, a method has been found to detoxicate such type of meal [11].

Castor oil has other unique properties such as a great affinity for metal surfaces and highly polar. It is characterized by physical as well as chemical test for an assessment of the quality and purity, and also for identification of the oil. The physical properties include specific gravity, moisture content, refractive index, while the chemical properties include acid value, saponification value, rancidity value and iodine value [8], [10].

2 MATERIALS AND METHOD

The analytical grade reagents used were carbon tetrachloride, potassium hydroxide, DAM's reagent, phenolphthalein, toluene, ethanol, acetone, carbon tetraoxide and starch solution indicator which were products of Merck and Sigma Chemical company purchased from South Africa. Castor seeds were obtained locally from Nigeria market.

The castor seeds were screened and dried in an oven for 12 h at 60 ^{o}C. The dried seeds were winnowed and ground into a paste with the aid of a crusher. The castor paste was fed into a muslin cloth and mechanically pressed while the oil was dripping on a tray. The oil was collected for further use.

2.1 CHARACTERIZATION OF CASTOR OIL

Specific gravity, pH, acid value, iodine value, saponification value, refractive index and viscosity of the oil were determined.

2.1.1 DETERMINATION OF SPECIFIC GRAVITY

Empty specific gravity bottle was weighed (Mc), castor oil was poured into the specific gravity bottle and was weighed to get (Mo). The oil was then substituted with water of the same volume and reweighed to give Mw. The specific gravity was determined by calculation using equation (1):

$$\text{Specific gravity} = \frac{M_O - M_c}{M_W - M_c} \quad (1)$$

2.1.2 DETERMINATION OF PH VALUE

The pH value of oil was determined with the aid of a pH meter (Model Delta 320, Mettler Toledo, China).

2.1.3 DETERMINATION OF ACID VALUE

Using the method specified by International Standard Organization (ISO 279, 1988), the mixture of ethanol and toluene in ratio 1:1 by volume was first neutralized prior to use of ethanolic potassium hydroxide solution in the presence of 0.3 mL of indicator per 40 mL of the mixture.

1.7 g of sample was weighed into a 250 mL conical flask. A few drops of phenolphthalein indicator were added and the content was titrated against 0.1 mg/L solution of ethanolic potassium hydroxide solution until the indicator turned pink. The same procedure was used for the blank. Acid value was determined using equation (2) [7]:

$$\text{Acid value} = \frac{V \times C \times 56.1}{M} \quad (2)$$

where V is volume of the ethanolic hydroxide solution, C is the exact concentration of ethanolic potassium hydroxide solution, M is mass of test sample used and 56.1 g/mol is molar mass of potassium hydroxide.

2.1.4 Determination of Iodine Value

In accordance with International Standard Organization (ISO 3961, 1989), 1.9 g of the sample was weighed into a conical flask and another 2 g of distilled water was weighed into a conical flask or blank. 10 mL of carbon tetrachloride and 20 mL of DAM's reagent was added to both flasks using pipette in a fume chamber. The mixture was corked, held firm and was allowed to stand in a dark cupboard for some minutes, after which 20 mL of freshly prepared 10% potassium iodide solution was added to each, and 70 mL of distilled water was added and the mixture was titrated with 0.1M sodium thiosulphate until a light yellow colored was observed.

About 1 mL (few drops) of 1% starch solution (indicator) was added to the light yellow substance obtained from titration and shaken thoroughly until the solution became colorless. The iodine value was calculated using equation (3):

$$\text{Iodine value} = \frac{12.69 \times C(V_1 \times V_2)}{N} \quad (3)$$

where C is concentration of sodium thiosulphate, V_1 and V_2 are volume of HCL and sodium thiosulphate used for determination, and N is mass of the sample.

2.1.5 Determination of Saponification Value

About 1.9 g of sample was weighed into a conical flask and 25 mL of 0.1 N ethanolic potassium hydroxide was added to it. The mixture of ethanolic potassium hydroxide and the sample was allowed to boil gently for 30 min and refluxed.

Drops of phenolphthalein indicator were added to the warm solution and titrated with 0.5 M HCL acid until the pink color disappeared (end point). A similar procedure was administered to the blank sample solution. The saponification value was determined using equation (4):

$$\text{Saponification value} = \frac{56.1 \times C(V_o - V_{cl})}{M} \quad (4)$$

where Vo is the volume of HCL of blank solution, V_{cl} is the volume of HCl, C is concentration HCl and M is mass of the sample.

2.1.6 Determination of Refractive Index

The refractive index of the oil extracted was determined with the aid of a refractometer. Some drops of the fluid were put into a glass slide and water at 30 ^{o}C enveloping it to maintain its temperature. At no parallax position the refractive index pointer scale was viewed through the eyepiece and recorded. An average of three repeated readings was taken as the refractive index of the oil.

2.1.7 Determination of Viscosity

The sample was filtered through a sintered glass (five meshes to eliminate solid materials in the liquid oil). This viscometer was charged with the oil by inverting the tube's thinner arm into the oil and suction force was drawn up to the timing mark of viscometer, later the instrument was turned to normal vertical position.

The viscometer was placed into a holder and inserted to constant temperature both set at 27 ^{o}C and allowed for 5 minutes for temperature to attained same value (27 ^{o}C). Suction pressure was applied to the thinner arm to draw the liquid little above the upper timing mark. Readings of afflux time of the flow of the oil as it flows freely from the upper timing mark to the lower timing mark were recorded.

2.2 Formulation of Drilling Fluid

Calcium chloride (brine) was premixed with water before addition of the castor oil in a base mixer. Primary and secondary emulsifiers, Benton 38, Soltex and Bore plate were chronologically added as well. Graphite wetting agent $CaCO_3$ and Barite were also added. The resulting mixture was characterized.

2.2.1 CHARACTERIZATION OF THE FORMULATED DRILLING FLUID

The formulated drilling fluid's viscosity, electric stability, high pressure/high temperature (HPHT) and chemical analysis were carried out.

2.2.2 DETERMINATION OF VISCOSITY

Sample of drilling mud was poured into a funnel with the orifice for Marsh funnel viscosity was determination. A viscosity cup was placed beneath the funnel tip and the blockage was removed. Viscosity was measured when mud level reached liquid mark on the viscosity cup. Stop watch was used to record number of seconds required to outflow liquid of mud.

2.2.3 DETERMINATION OF ELECTRIC STABILITY

Electric stability (ES) test utilizes a probe with a pair of electrode which is placed in the fluid. Sample was put into a thermal cup and stirred with the ES probe for 30 s. It was heated to 50 ^{o}C and electric stability was adjusted to zero. Electric stability was immersed into the fluid and held firm. Result was obtained by turning voltage knob clockwise until the red light illuminated.

2.2.4 DETERMINATION OF HIGH PRESSURE/HIGH TEMPERATURE (HPHT)

This is run at bottom-hole temperatures under static conditions to determine the condition of emulsion, the filtrate volume and filter cake quality. Some sample of drilling fluid was poured in a high speed mixer; stirred mud was poured into a cell and a filter paper on the top of cell. After that, cell was inverted (cell lid) and carefully placed in a cell heating jacked with thermometer on top of HPHT cell body. With two valves on cell body values A and B tightly closed, valve A was opened to maintain desired temperature of about 50 ^{o}C, then pressure of cell regulator was increased to 600 psi by turning handle clockwise. Filtrate was collected from valve C while maintaining test temperature and pressure drop to 0 psi. Test and thickness of cake was taken after cell was cooled down.

2.2.5 CHEMICAL ANALYSIS

The formulated drilling fluid chemical analysis was carried out by determining the mud alkalinity and lime content and oil/water/solids ratios.

DETERMINATION OF MUD ALKALINITY AND LIME CONTENT

Xylene and isopropanol were mixed in a ratio of 1:1 in a flask. Then 2 mL of mud was added to the mixture and shaken thoroughly until it became homogeneous. 200 ml of distilled water and 10-15 drops of phenolphthalein indicator were added. It was stirred thoroughly and titrated with 0.1M H_2SO_4 until pink the color disappeared.

DETERMINATION OF OIL/WATER/SOLIDS RATIO

The ratio of oil to mud was determined at 650 ^{off}. The ratio Oil/Water/Solid was obtained from equations (5-7):

$$\text{Oil percentage in oil and water ratio} = \frac{100(V_o)}{V_o+V_w} \quad (5)$$

$$\text{Water percentage in oil and water ratio} = \frac{100(V_w)}{V_o+V_w} \quad (6)$$

$$\text{Oil and water ratio} = \frac{\text{oil \%}}{\text{water \%}} \quad (7)$$

Where V_o is volume of oil and V_w is volume of water.

3 RESULTS AND DISCUSSIONS

The results obtained for the characterization of extracted castor oil and formulated drilling fluid is presented in Table 1 and 2, respectively.

Table 1. Comparison of the Physical and Chemical Properties of Extracted Castor Oil with American Society for Testing and Materials (ASTM) Standard Value [12]-[13]

Property	Extracted Oil	Standard Value
Specific gravity	0.9502	0.958-0.968
pH	6.29	6.11-6.29
Acid	2.31 mg KOH/g	0.4-4 mg KOH/g
Iodine value	92.30	81-93
Saponification value	194.1 mg KOH/g	176-187 mg KOH/g
Refractive index	1.468	1.473-1.477
Viscosity	6.5847 st	6.3-6.8 st

Table 2. Comparison of Formulated Drilling Mud with equivalent circulating density (ECD) 99 Drilling Mud [14]

Property	Extracted oil	Standard value
Funnel marsh viscosity at 30^{o}C	26.5	22
Funnel marsh viscosity at 50^{o}C	25	-
Electric stability	222 V	210 V
HPHT	8.8	9.98
Alkalinity	0.30	0.50
Excess lime	0.39 Ib/bbl	0.65 Ib/bbl

The physical and chemical properties of castor oil extracted shown in Table 1 can be compared with ASTM castor oil values.

The specific gravity of extracted castor oil (comparison of the density of the oil with that of water) was found to be 0.9502, which is slightly out of the ASTM standard but above that of dehydrated castor oil [10]. The difference was attributed to non usage of the standard density bottle. Saponification value and refractive index obtained were slightly out range of standard values. Increased in alkalinity in the course of determining the end point of saponification value may have caused the variation. Probable presence of impurities in the oil was attributed to refractive index changes however; it is still within acceptable limits. Variable refractive index of castor oil has been reported by previous researchers [13], [15].

The acid value, iodine value, pH and viscosity fell within the ASTM standards. Acid value of 2.31 mg KOH/g, iodine value of 92.30, pH 6.29 and viscosity of 6.5847 st were obtained. Previous researchers have reported similar finding [9], [15]-[16]. This justified the use of the castor oil extracted for formulation.

Properties of formulated drilling mud mud from castor oil were comparable with standard drilling mud ECD 99 of Arkleen oil and Gas limited, Shell Nigeria. Funnel marsh viscosity at 30 ^{o}C was 26.5 s which is close to 22 s of ECD 99. A difference of 4.5 s was attributed to the higher viscosity of the formulated mud. High Pressure/ High Temperature (HPHT) of formulated drilling fluid is run at bottom hole temperatures under static conditions to determine the condition of emulsion, the filtrate volume and filter cake quality. The HPHT value was found to be 8.8 while the standard ECD 99 is 9.98. High HPHT is commonly associated with a risk of formation damage, stuck in pipes due to excessive filtrate loss, low penetration and compliance with safety and environmental regulations [17]. The alkalinity value was 0.30 as compared with the ECD 99 which is 0.50. The excess lime values for both the formulated drilling mud and ECD 99 were within acceptable limits.

Oil/water is the ratio of the volume percent oil to the volume percent water in an oil mud, where each is a percent of the total liquid in the mud. The results obtained from the formulated drilling mud was of good standard, this is because formulated drilling mud should always have more oil as much as three times greater than water in the liquid content of the mud. This gives excellent lubricity and stability [2].

4 CONCLUSION

The results of the research showed that castor oil can be used to formulate a drilling fluid that has comparable characteristics with ECD 99. These include electrical stability, funnel marsh, viscosity, HPHT, and the chemical analysis. However, some variation of properties observed which was attributed to difference in composition of the castor oil used as compared with the base of ECD 99 were still with tolerance and acceptable standard of formulation of drilling fluid.

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