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Research paper

# A novel bio-based deflocculant for bentonite drilling mud

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ABSTRACT

The physical and chemical properties of bentonite, a widely utilized drilling fluid additive, in the aqueous phase could potentially change when encountering drilling fluids contaminants. Therefore, prior to encountering an excepted contaminant, it is mandatory that one treat the bentonite mud by an appropriate deflocculant. This study assesses for the first time the performance of Oak seed extract (OSE) as a novel bio-based deflocculant in bentonite drilling mud through some extensive experiments. After being exposed to high temperatures and contaminants, the value of rheological parameters and fluid loss of bentonite mud free from any additives changed remarkably. The OSE kept the stability of bentonite in aqueous phase by restraining the capacity of bentonite to form a flocculated structure, decreasing rheological parameters and fluid loss value. From bentonite inhibition tests, the incapacity of OSE to reduce the magnitude of plastic viscosity was fairly clear. Based on particle size measurements, OSE had a significant impact in reducing particle size of contaminated bentonite muds. According to SEM observations, no remarkable difference was seen between the morphological features of modified bentonite with and without OSE, indicating particle delamination in both cases and no inhibitive property of OSE. The findings verify that OSE can act as a superior deflocculant. The deflocculating performance of OSE was more drastic in the case of cement-contaminated mud owing to its acidic nature (pH = 4.58 at 1 mass%). Therefore, this study proposes the pre-treat of the bentonite mud with OSE for encountering ultra-high pH condition generated by cement. The deflocculation mechanism is believed to be a neutralization of the positive edges of montmorillonite (Mt, dominant mineral in bentonite) by tannins (dominant constituent in OSE), destroying the ability of Mt layers to link one another. In addition to high performance, environmentally friendliness and cost effectiveness are characteristics which can be considered as other fascinating aspects of OSE.



## 1. Introduction

Smectite clays are naturally occurring minerals formed by the weathering and decomposition of igneous rocks (Teich-McGoldrick et al., 2015). They are aluminosilicate compounds made of two tetrahedral sheets encompassing an octahedral sheet (Anderson et al., 2010; Paineau et al., 2011; De Jong et al., 2014). The process in which ions occupying the center of tetrahedral and octahedral sheets are replaced by ions of lower charge (for example, $Si^{4+}$ may be replaced by $Al^{3+}$ in tetrahedral sheet and $Al^{3+}$ may be replaced by $Mg^{2+}$ or $Fe^{2+}$ in octahedral sheet) is called isomorphous substitution, resulting in a net negative charge. This positive charge deficiency is balanced by charge-balancing cations (e.g., $Na^+$, $K^+$, $Ca^{2+}$, or $Mg^{2+}$) located in the interlayer region (Salles et al., 2007, Xi et al., 2005). It is generally accepted that smectites have increasingly a lot of attention owing to several properties including rheological, adsorbing capacity, plasticity, high surface area, cation exchange capacity (CEC) and swelling (Konta, 1995; Grim, 1962; Hartwell, 1965; Grim and Guven, 1978; Elzea and Murray, 1990; Luckham and Rossi, 1999; Allo and Murray, 2004; Eisenhour and Brown, 2009; Güven, 2009; Abdel-Motelib et al., 2011; Agha et al., 2012).

The term "bentonite" in drilling industry is the generic name applied to a mixture of minerals that are mainly composed of sodium-based montmorillonite (Mt, a familiar member of smectite groups) (Grim and Guven, 1978; Besq et al., 2003; Boussen et al., 2015). In addition to drilling industry, it is used for a large number of industrial applications including refractory manufacturing, pottery wares, cosmetics, paints, pharmaceutical and animal feed additive (Odom, 1984; Aghamelu and Okogbue, 2015). In drilling operations, bentonite is purposely used to provide viscosity, impermeable filter cake on the wellbore wall in order to limit filtration losses, and prevent loss circulation (Mahto and Sharma, 2004). These specific features are due to its small and plate-like particles, high surface area, and high ability to hydrate and swell in water (Annis and Smith, 1996). The ability of bentonite to carry out the aforementioned functions is strongly linked to the chemical environment in which bentonite is placed. When bentonite is exposed to harsh conditions (e.g., contaminants such as high salinity water formation, calcium chloride, cement, etc), its ability to hydrate, swell and consequently disperse in aqueous solution reduces greatly. In fact, due to the existence of some cations such as calcium or ultra-

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high pH condition, clay layers will associate together and will form an aggregated or flocculated structure, leading to high fluctuation in rheological properties and high amount of fluid loss into the formation (Annis and Smith, 1996). In such cases, certain chemicals referred to as "deflocculant" or "thinner" are added into the drilling mud which neutralize the positive edge of clay layers and prevent particle associations, avoiding the tendency of the mud to flocculate. Nowadays, environmentally friendly and cost effective additives have sparked a lot of interest within the research and field sectors (Nareh'ei et al., 2012; Arabloo et al., 2013; Ahmadi et al., 2015; Moslemizadeh et al., 2015; Shadizadeh et al., 2015). To date, various deflocculants are introduced which include phosphates, extracts from Quebracho and Hemlock trees, lignins, and lignosulphonates (Bourgoyne et al., 1991). In addition to inadequate performance in different conditions, most of the introduced deflocculants, except those of bio-based, are chemical-based which could potentially affect the environment. Therefore, introducing environmentally friendly and cost effective deflocculants with high performance is now interesting within drilling industry. This study assesses for the first time the performance of Oak seed extract (OSE) as a newly bio-based additive for deflocculating bentonite drilling mud. To gain the goal of this study, a number of experiments in different conditions were conducted: rheological measurements, fluid loss measurements, bentonite inhibition, particle size measurements, and scanning electron microscopy (SEM). The results obtained from this study have been presented and discussed in greater details throughout the paper. This study could be instructive for screening special products as deflocculants in bentonite drilling mud.

## 2. Experimental

### 2.1. Materials

#### 2.1.1. Oak tree

Oak (Fig. 1-a) is a deciduous and evergreen tree in the genus Quercus of the beech family, Fagaceae. It is widely distributed in regions from cool temperature to tropical latitudes in the Americas, Asia, Europa, and North Africa. Although there are nearly 600 extant species of Oak which have some differences in term of appearance, all of them are known as Oak. In many species of Oaks, the leaves are spirally with lobate margins. The fruit is called acorn which have a cap-like structure known as cupule (Fig. 1-b). Each acorn contains one seed or in some cases two or tree seeds. It has been reported that the acorn contains high amount of starch and tannin. Based on the species of Oaks, 6 to 18 months needs to mature of acorn (Brenzel, 2001; Williams et al., 2001; Aghamohamadi et al., 2014). In Iran, Oak trees cover a large region (5,785,760 ha) as they are native in Alborz and Zagros Mountains (Yazdian, 2011). Fig. 2 displays general distribution of Oak trees on geological map of Iran.

Four purpose of this study, Oak fruit were obtained from the Zagros Mountain, Chaharmahal and Bakhtiari province, southwestern of Iran. After drying, the seeds were pulverized then a certain amount of that were dispersed into the deionized water. The mixture was filtered and evaporated in soxhlet extractor and resulting powder was dried and pulverized. The pulverized powder, Oak seed extract (OSE), was employed in this study. The general properties of OSE are presented in Table 1.

#### 2.1.2. Bentonite

In this study, typical bentonite containing high amount of montmorillonite (Mt) was utilized for assessing deflocculating property of OSE. The magnitude of bentonite's CEC was 69.5 meq/100 g which was characterized by methylene blue test. The raw sample was characterized by X-ray diffraction (XRD) (Fig. 3). The test analysis revealed that Mt content is about 62%, while other minerals are quartz 13%, feldspar 12.5%, gypsum 0.5%, illite 11%, and calcite 1%. In addition, chemical compositions of bentonite were determined by X-ray fluorescence (XRF) analysis as shown in Table 2.

#### 2.1.3. Other materials

In order to evaluate the performance of OSE as a deflocculant, different contaminants were used including sodium chloride (NaCl, 99.5% Merck), calcium chloride ($CaCl_2$, 99.5% Merck), and cement. In addition, potassium chloride (KCl, 99.5% Merck) was also utilized as commonly clay inhibitor.

### 2.2. Methods

This section describes laboratory methodologies employed in this study. To easily follow the experimental section, the major features of the conducted tests are presented in Table 3.

#### 2.2.1. Rheological properties measurements

In this study, the rheological properties which include apparent viscosity, plastic viscosity, yield point, and gel strength (10 min) were measured by Fann viscometer. The apparent viscosity, plastic viscosity, and yield point were calculated from 600 to 300 rpm dial readings using the following formula according to the API standard procedure for assessment of drilling fluids (API, 1997).

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

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

$$\text{Yield point (YP)} = \varphi_{300} - \text{AV (Pa)} \tag{3}$$

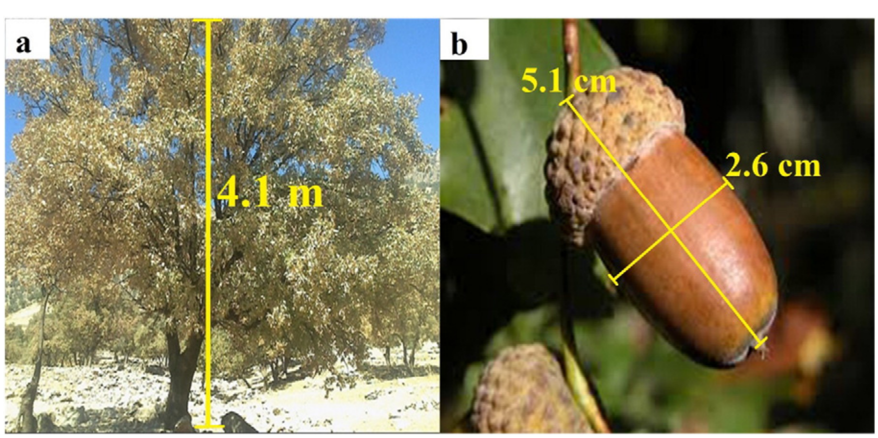


**Fig. 1.** Oak tree (a) and Oak seed (b).