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Prediction of the optimum aqueous phase composition of a triglyceride microemulsion using response surface methodology

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ABSTRACT

This paper presents the application of response surface methodology to predict the optimum aqueous phase composition of a triglyceride microemulsion for enhanced oil recovery. The two models capturing the relationships between interfacial tension and tertiary oil recovery data with the aqueous phase composition were validated prior to optimization. It was predicted that the optimum aqueous phase contains 3 wt% sodium chloride, 0.98 wt% alkyl polyglycosides, and 2.98 wt% glyceryl monooleate. At this composition the corresponding interfacial tension is minimum (0.000229451 mN/m) and the tertiary oil recovery is maximum (71.7865%). The predicted optimum aqueous phase composition using historical-data design is close to the experimental value.

1. Introduction

The potential of microemulsion flooding in enhanced oil recovery (EOR) has been investigated since several decades ago [1–4]. Microemulsion is a chemical formulation, which consists of oil, water, and an amphiphile mixture [5]. In microemulsion flooding, an effective microemulsion formulation is injected to displace the remaining oil in the reservoir post waterflooding by reducing the interfacial tension (IFT) between the remaining oil and water.

The amount and chemical nature of the components in a microemulsion have a considerable effect on IFT, type of microemulsion, and amount of recovered oil [6–8]. The oil-component in pre-prepared microemulsion is usually based on a specific crude oil or a fraction of petroleum such as n-octane [1,3]. However, triglycerides rather than hydrocarbons could be selected as the oil component of the microemulsions. Triglyceride microemulsions have been used in tertiary oil recovery recently [4,9,10] as well as in other applications for decades [6,11–19].

The highest cumulative tertiary oil recovery (TOR) and the lowest IFT between the formulated microemulsion and the model oil are the two essential criteria in determining the optimum aqueous phase composition for EOR. Aligned to our previous experimental studies [9,10], the optimum aqueous phase composition of the microemulsion can be predicted statistically using design of experiments (DOE). DOE, a powerful alternative method in problem solving, statistical modeling and optimization, has successfully been used in estimating the optimum aqueous phase composition of a microemulsion [20]. The optimal mixture DOE was used before to minimize the only one modeling output, which was IFT [20].

The objective of this paper is to estimate the optimum aqueous phase composition of a triglyceride microemulsion using an improved statistical model of DOE. In the triglyceride microemulsion formulation, palm oil was used as the oil phase of the microemulsion. Thus the triglycerides constitute the whole oil-phase of the microemulsion. Alkyl polyglycosides (APG) and glyceryl monooleate (GM) were used as the surfactant and co-surfactant of the triglyceride microemulsion, respectively. The improved statistical model of DOE is the historical data design of response surface methodology (RSM). The model is able to estimate the optimum aqueous phase composition of a triglyceride microemulsion thru simultaneous minimization of IFT and maximization of TOR. Design Expert® software was used to perform the historical data design of the RSM.

2. Experimental tests

2.1. Materials

The surfactant used in this work was Glucopon 650EC, a mixture of alkyl polyglycosides (APGs) having an average alkyl

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